JYVÄSKYLÄ STUDIES IN COMPUTING
274

Kashif Naveed

Transformative Direction of Innovation and Measurement of Uncaptured GDP in the Digital Economy

JYVÄSKYLÄN YLIOPISTO

JYVÄSKYLÄ STUDIES IN COMPUTING 274

Kashif Naveed

Transformative Direction of Innovation and Measurement of Uncaptured GDP in the Digital Economy

Esitetään Jyväskylän yliopiston informaatioteknologian tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston Agora-rakennuksen auditoriossa 2
joulukuun 20. päivänä 2017 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Information Technology of the University of Jyväskylä,
in building Agora, auditorium 2, on December 20, 2017 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Transformative Direction of Innovation and Measurement of Uncaptured GDP in the Digital Economy

JYVÄSKYLÄ STUDIES IN COMPUTING 274

Kashif Naveed

Transformative Direction of Innovation and Measurement of Uncaptured GDP in the Digital Economy

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Editors
Timo Männikkö
Faculty of Information Technology, University of Jyväskylä
Pekka Olsbo, Ville Korkiakangas
Publishing Unit, University Library of Jyväskylä

Permanent link to this publication: http://urn.fi/URN:ISBN:978-951-39-7296-7

URN:ISBN:978-951-39-7296-7
ISBN 978-951-39-7296-7 (PDF)

ISBN 978-951-39-7295-0 (nid.)
ISSN 1456-5390

Jyväskylä University Printing House, Jyväskylä 2017

ABSTRACT

Naveed, Kashif
Transformative Direction of Innovation and Measurement of Uncaptured GDP in the Digital Economy
Jyväskylä: University of Jyväskylä, 2017, 102 p. (+ included articles)
(Jyväskylä Studies in Computing
ISSN 1456-5390; 274)
ISBN 978-951-39-7295-0 (nid.)
ISBN 978-951-39-7296-7 (PDF)
Finnish summary
Diss.

The Internet has dramatically changed business dynamics and our daily lives by providing extraordinary services and welfare never anticipated before. However, productivity in industrialized countries has confronted an apparent decline. The ICT advanced firms and countries are suffering with low marginal productivity of their ICT investments. This reveals the two-faced nature of ICT and productivity paradox in the digital economy.

With the progression of technology and transition from commodity-oriented to information society, the consumers' preferences are believed to be shifted beyond economic value. The digitization has promoted the free and un-monetized consumption of digital goods and services that provides utility and happiness to consumers, but it cannot necessarily be captured through GDP (gross domestic product) statistics. This research conceptualizes it as "uncaptured GDP" and develops a new method for its measurement. The comparison of two ICT advanced countries reveals their contrary ICT-driven development trajectories, "happiness-oriented" in Finland versus "growth-oriented" in Singapore. It signifies how nations and industries use technology differently to create their unique competitiveness.

The digitization of taxi and music industries is studied to analyze the impact of ICT-driven disruptive innovations on traditional industries and their consolidation challenges with institutions. The national level analyses explore useful insights for developing ICT-driven competitiveness through higher education (20 countries) and gender equality (44 countries) in the digital economy. These results reveals, how industries and countries are harnessing the potential of untapped and non-economic resources so-called "soft value innovation" to create unique competitiveness in the digital economy. With the analyses of transformative direction of innovation (by 500 ICT firms), it is anticipated that the role of soft value innovation will further increase in addressing the challenges of digital economy such as declining marginal productivity of technology, increasing role of uncaptured GDP and intense competition.

Keywords: Digital economy, productivity paradox, two-faced nature of ICT, uncaptured GDP, soft value innovation, transformative strategy

Author's address	Kashif Naveed Faculty of Information Technology University of Jyväskylä, Finland kashif.k.naveed@jyu.fi
Supervisors	Professor, Dean Pekka Neittaanmäki Faculty of Information Technology University of Jyväskylä, Finland
	Professor, Chihiro Watanabe Research Professor, University of Jyväskylä Research Scholar, Intl. Institute for Applied Systems Analysis (IIASA), Vienna, Austria
	Professor, Pasi Tyrväinen Faculty of Information Technology University of Jyväskylä, Finland
Reviewers	Professor, Yoshiaki Nakamura Department of Economics, School of Economics, Senshu University, Tokyo, Japan
	Associate Professor, Noritomo Ouchi Department of Industrial and Systems Engineering, College of Science and Engineering Aoyama Gaukin University, Tokyo, Japan
Opponent	Dr. Leena Ilmola Senior Research Scholar Advanced System Analysis The International Institute for Applied Systems Analysis, Vienna, Austria

ACKNOWLEDGEMENTS

First of all I would like to thanks, Almighty for His blessings upon me and my family for giving me the strength, courage and wisdom to finally complete this dissertation.

I am highly obliged to express my deepest gratitude and appreciation to my supervisors and mentors Prof. Pekka Neittaanmäki, Prof. Chihiro Watanabe and Prof. Pasi Tyrväinen for their kind interest and support throughout the due process. Prof. Watanabe's excellent understanding of research topic has provided me the best possible guidance from beginning until the completion. Without his dedication and persistent help this dissertation would not have been a reality, he deserves very special gratitude.

I would like to thanks the critical and constructive feedback of Prof. Yoshiaki Nakamura (Senshu University, Tokyo Japan) and Prof. Noritomo Ouchi (Aoyama Gaukin University, Tokyo Japan) in the capacity of dissertation examiners. I would also like to highly appreciate Dr. Leena Ilmola (International Institute of Applied System Analysis (IIASA), Vienna Austria) for her consent to act as an opponent at public defense.

During this research I had a unique experience to collaborate with culturally diverse and international team of researchers. I highly appreciate my coauthors, Prof. Yuji Tou (Tokyo institute of technology, Japan), Dr. Weilin Zhao (Fujitsu research institute, Japan), and Ms. Brenda Fox (Global Connexus, Silicon Valley, USA) for their valuable contributions. I would like to thanks the "Platform Value Now" project team members for their valuable discussions and feedback. I would also appreciate Prof. Charla Griffy Brown (Pepperdine University, Malibu, United States) for her valuable advice and feedback.

I would like to thanks Faculty of Information Technology, University of Jyväskylä, for providing consistent financial support. I also appreciate Ellen ja Artturi Nyyssösen foundation for their financial support in beginning of my research.

I would like to thanks all amazing staff members and colleagues at the University of Jyväskylä for creating an innovative and supportive working environment. I would like to thanks Mr. Timo, Männikkö for his editorial advice and Ms. Jaana Räisänen for her contribution in the Finnish summary section of dissertation.

Finally, I would like to dedicate this dissertation to my parents who have provided me the best possible education and support in all ups and downs of my life. I am also very grateful to all my siblings and their families for encouraging and supporting me, particularly my brother Nasir Naveed who has supported me in many different ways throughout this process.

I would also like to pay gratitude to my wife and lots of love to my very special little daughter Aynoor. Thank you, Aynoor! Your love is always a great blessing and your beautiful artwork displayed next to my work desk has been a great source of inspiration and creativity.

Lastly, I am extremely happy to be able to complete this ambitious piece of work after a challenging and hardworking journey of numerous long working days and sleepless nights. I hope it would be a step forward in my career. Thanks to everybody who have contributed in any way to make it happen.

I hope this dissertation will have a valuable scientific and social contribution and you will enjoy reading through it.

Jyväskylä 11.12.2017
Kashif Naveed

LIST OF FIGURES

LIST OF TABLES

CONTENTS

LIST OF ORIGINAL ARTICLES

PI Watanabe, C., Naveed, K., Zhao, W., 2014. Institutional sources of resilience in global ICT leaders: Harness the vigor of emerging power. *Journal of Technology Management for Growing Economies* 5(1), 7–34. DOI 10.15415/jtmge.2014.51001

PII Watanabe, C., Naveed, K., Zhao, W., 2014. Structural Source of the trap of ICT advancement: Lessons from world ICT top Leaders. *Journal of Technology Management for Growing Economies* 5(2), 49-71. DOI 10.15415/jtmge.2014.52008

PIII Watanabe, C., Naveed, K., Zhao, W., 2015*a*. New paradigm of ICT productivity: Increasing role of uncaptured GDP and growing anger of consumers. *Technology in Society* 41, 21–44. http://dx.doi.org/10.1016/j.techsoc.2014.10.006

PIV Watanabe, C., Naveed, K., Neittaanmäki, P., 2015*b*. Dependency on uncaptured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore. *Technology in Society* 42, 104–122. http://dx.doi.org/10.1016/j.techsoc.2015.04.003

PV Watanabe, C., Naveed, K., Neittaanmäki, P., Tou, Y., 2016a. Operationalization of uncaptured GDP: The innovation stream under new global mega-trends. *Technology in Society* 45, 58–77. http://dx.doi.org/10.1016/j.techsoc.2016.02.008

PVI Naveed, K., Watanabe, C., Neittaanmäki, P., 2017a. Co-evolution between streaming and live music leads a way to the sustainable growth of music industry: Lessons from the US experiences. *Technology in Society* 50, 1–19. http://dx.doi.org/10.1016/j.techsoc.2017.03.005

PVII Watanabe, C., Naveed, K., Neittaanmäki, P., 2016b. Co-evolution of three mega-trends nurtures uncaptured GDP: Uber's ride-sharing revolution. *Technology in Society* 46, 164–185. http://dx.doi.org/10.1016/j.techsoc.2016.06.004

PVIII Watanabe, C., Naveed, K., Neittaanmäki, P., 2017a. Consolidated challenge to social demand for resilient platforms: Lessons from Uber's global expansion. *Technology in Society* 48, 33–53. http://dx.doi.org/10.1016/j.techsoc.2016.10.006

PIX Watanabe, C., Naveed, K., Neittaanmäki, P., 2017b. Co-evolution between trust in teachers and higher education toward digitally-rich learning environments. *Technology in Society* 48, 70–96. http://dx.doi.org/10.1016/j.techsoc.2016.11.001

PX Watanabe, C., Naveed, K., Neittaanmäki, P., 2017c. ICT-driven disruptive innovation nurtures uncaptured GDP: Harnessing women's potential as untapped resources. *Technology in Society* 51, 81–101. http://dx.doi.org/10.1016/j.techsoc.2017.07.007

PXI Naveed, K., Watanabe, C., Neittaanmäki, P., 2017b. The transformative direction of innovation toward an IoT-based society – Increasing dependency on uncaptured GDP in global ICT firms. *Technology in Society* 52. https://doi.org/10.1016/j.techsoc.2017.11.003

PXII Watanabe, C., Naveed, K., Neittaanmäki, P., 2017d. Measuring GDP in the digital economy: Increasing dependency on uncaptured GDP. *Technological Forecasting and Social Change (under review).*

AUTHOR'S CONTRIBUTION IN ARTICLES

Naveed, as an author of this dissertation, I would like to fully appreciate the joint and collaborative effort and supportive working environment throughout the research process.

Conception and Design

I was fully involved in the conception and design of research along with my supervisors.

Data collection and management

Our research work is based on intensive quantitative and qualitative data analysis. All data collection, integration, transformation and data management was done by me. I have developed a large Ms. Access database to facilitate storage and retrieval of data. The remaining data was stored in MS. Excel spread sheets.

Data analysis and interpretation

I have conducted the substantial part of data analysis and also actively contributed to the interpretation of results together with my co-authors. For analyses the SPSS, MATLAB and R were used.

Drafting the articles

I have substantially contributed in drafting all of the articles together with my co-authors. Most of the figures and tables in each article were drafted by me. I have fully drafted the Article PVI and Article PXI with the assistance of my co-authors.

Final approval or revision of the article

I was actively involved in finalizing, submitting and revising all articles.

1 INTRODUCTION

In today's digital world, the technology has become the vital part of our social, business and institutional culture and the source of competitiveness among countries. However, the dramatic advancement of ICT particularly the Internet seems to have two faces, positive that brings opportunities and negative that leads to economic stagnation and unemployment. Similar to many other developed countries, Finland also faces challenges like slow economic growth and unemployment, as number of public and private institutions have laid-off their employees. Generally, the innovation opportunities seems to have slowed down and to survive businesses are turning toward activities with highest returns, cutting costs by automating processes and eliminating the need to hire extra workers to produce more output (Ogden, 2012). Another important factor for companies to rapidly adopt digital technologies is to minimize the risk of being disrupted by emerging digital technologies and platforms as it is observed in case of digitization of music industry and disruption of taxi industry by Uber and several others.

Undoubtedly the Internet and the digital economy have profound impacts on our daily lives and the way we conduct businesses (Tapscott, 1994). The rapid progression in digitized innovation has further augmented this change by providing extraordinary services and welfare never anticipated before. The online intermediaries (e.g., search engines, social networks, online market places, ecommerce, sharing economy platforms etc.) provide platforms to facilitate exchange of goods, services and information and play a core role in the digital economy (The Copenhagen Economics, 2013).

Clearly the online intermediaries are at the heart of the today's economic progress, but as pointed out by Brynjolfsson et al. (Revised 2017), this realization is only the beginning of an understanding of the economics of new goods and services. Contrary to all accomplishments, unprecedented services and convenience offered by online intermediaries, this is also a harsh fact that with the introduction and widespread of new types of goods and services such activities have increased, which are difficult to monetize and capture by gross domestic product (GDP) statistics. Consequently the productivity in industrialized countries has confronted a structural decline (OECD, 2016, US Council of Competitiveness, 2016) and this decline raises the questions of a "productivity paradox" in the digital economy and the GDP myth.

Other big issue that propagates with the advancement of the Internet is the increasingly invisible and non-monetary consumption of digital products and services. This can be the consequence of a free culture that emerged parallel to the commercialization of the Internet in 1990s, as pointed out by Lowery (2011), the consumption of free contents and services provide utility and happiness to people but cannot necessarily be captured through GDP statistics that measure revenue. One of its typical examples is the digitization of traditional recording music industry and its declining revenues. Brynjolfsson and McAfee (2011) explained it as "Because you and I stopped buying CDs, the music industry has shrunk according to revenues and GDP. But we're not listening to less music. There's more music consumed than before." They postulated it as the limitation of GDP statistics in reflecting the true picture of digital consumption and argued that rather than growth, the yardstick (GDP) could be the one that is deficient (Brynjolfsson et al., 2014).

Doubting the positive contribution of the Internet to the economy, Cowen (2011) stressed that, historically the technological progress brought a large and predictable stream of growth across most of the economy, however these assumptions turned out to be wrong or misleading in terms of the Internet, and suggested it as the two-faced nature of ICT.

By realizing the two faced nature of ICT, author postulates it as a possible trap in ICT advancement. Generally, the advancement of ICT contributes to increase prices through new functionality development (as typically demonstrated by the increasing price of iPhone[1] series smartphone with newer model). However, contrary to traditional ICT, with the dramatic advancement of the Internet, prices of ICT have declined. Possibly because of the massive digitization of physical products, emergence of new digital platforms, increasing competition and large availability of digital products and services as freebies that are easy to copy, replicate and deliver over the Internet (Publication PI).

Consequently the decline in ICT prices leads to the low marginal productivity of technology at industry and national level. Therefore, the economic growth engine particularly in ICT advanced economies seems to have disappeared resulting in a great stagnation (Cowen, 2011).

However, there exist different views regarding the contribution of ICT in recent slowdown in growth and high unemployment problem. Brynjolfsson and McAfee (2011) in their famous research exploring, whether the advancing ICT might be an important contributor to the current unemployment disaster, concluded that the root cause was not a decline in innovation but an acceleration of innovation. Technological advancement had moved so fast that many people were losing the race against the machine. Their argument signifies the importance of highly educated workforce in the digital economy. This is also

[1] Price of Apple's smartphone has demonstrated increase as functionality advances as follows: iPhone8 (US$ 699), iPhone8 plus (US$ 795), and iPhoneX (US$ 999).

one of the case studies in this research, that how different countries have managed to create competitiveness in education despite their slow economic growth.

Cowen (2011) analyzed similar problem at macro level. He argued that, contrary to the dramatic advancement of the Internet and subsequent ICT advancement, we were living through the consequences of a dramatic decrease in the rate of innovation that resulted in fewer new industries and less creative destruction, hence less new jobs.

Exploring the potential of "Third Industrial Revolution" Rifkin (2011) explains how new era of distributed capitalism is coming through the "energy internet" where hundreds of millions of people will produce and share energy with each other alike how we share information online. Rifkin (2014) describes how the emerging Internet of Things (IoT) is speeding us to an era of nearly free goods and services. This argument inspires this research to analyze the transformative direction of innovation towards the IoT based society.

Claiming the lack of capacity of GDP statistics to measure the digital economy, the famous Nobel Prize winning economist Joseph Stiglitz pointed that, GDP is not a good measure of economic performance, it's not a good measure of well-being. In order to keep with the challenges of "Fourth Industrial Revolution" we need to find a new measure to assess the health of our economies (Ross, 2016). The limitations of the GDP in measuring advancement of the digital economy have become an important subject (Brynjolfsson et al., 2014; Economist, 2016). The Organization for Economic Cooperation and Development (OECD) has raised the question "Are GDP and productivity measures up to the challenges of the digital economy?" A large number of research papers have attempted to understand issues concerning the capability of GDP as a measurement tool in representing the true picture of a digital economy (e.g., Feldstein, 2017; Syverson, 2017; Groshen et al., 2017; US Council on Competitiveness, 2016; Byrne et al., 2016). However, none has provided rational answers to this fundamental question (IMF, 2017*b*).

This question is very crucial because GDP is considered to be a fundamental yardstick in determining the competitiveness and economic health of any country and devising economic policies. If large part of economic activities and developments are invisible and not being captured by the GDP statistics, then decision making and policy implementation can become biased and misleading.

By realizing importance of the issue this research conceptualizes the term "uncaptured GDP", elucidates its structural sources and develops a new method to measure its magnitude. To analyze its operationalization the magnitude of uncaptured GDP for two ICT advanced countries: Finland and Singapore is compared, together with their ICT-driven development trajectories. This analysis helps to understand that, how different countries are using technology to create their unique competitiveness, while trying to achieve an optimal balance between economic development and social wellbeing.

Undoubtedly, the new digital technologies are reshaping business models, organizational structures, required skills, nature of jobs (turning full-time into on-demand jobs) and employment relationships. Due to the complexity of the situation, governments are facing "decision maker's dilemma" in terms of devising ICT strategies, economic and social policies.

The next phase of this research focuses on understanding the transformative direction of innovation at industry and national level. For that the digitization of music and taxi industry is studied to analyze the impact of ICT-driven disruptive innovations on traditional industries and consolidation challenges with public and private institutions. The national level analyses explore useful insights for developing ICT-driven competitiveness through higher education (20 countries) and gender equality (44 countries) in the digital economy. To further analyze the transformative direction of innovation and the unique soft value innovation strategies, the detailed empirical analyses of top 500 global ICT firms and in-depth analyses of selected top six ICT firms is conducted.

Undoubtedly, the dramatic advancement of the Internet and digital technologies, new business models, changing organizational structures and employment issues have inevitably complicated the global business environment. However, the technological advancement is also an important driver for economic and social development.

By better understanding the phenomenon of digitization, measuring it's positive and negative impacts, understanding the changing organizational structures and by devising responsive ICT strategies, economic and social policies, we can turn the crisis into a springboard for innovation and future opportunities.

As a part of the bigger research efforts, the objective of this research is bring useful empirical insights and global experiences for Finland and for other countries for learning strengths and weaknesses of their institutional systems and assist in making better decisions in future.

1.1 Research phases

In the first phase of research an extensive literature review is conducted to understand the phenomenon of productivity paradox in the digital economy. By detailed empirical analyses a bi-polarization trend is realized at national as well as at industrial level. It is found that the ICT advanced countries and high R&D intensive firms are trapped in a vicious cycle of ICT advancement and its marginal productivity decline, while ICT growing countries and relatively low R&D intensive firms enjoy virtuous cycle between ICT advancement and its marginal productivity growth. On the basis of the empirical findings, the two-faced nature of ICT is elucidated. To further approve the two-faced nature of ICT, its prices in world leading ICT countries Finland and Singapore is estimated and ICT prices declining trend in both countries is realized.

In second phase of research, by empirically recognizing the people's preferences shift (from economic value to beyond economic value) and increasing trend of un-monetized consumption, the concept of uncaptured GDP is postulated. A new method to measure uncaptured GDP is developed and magnitude of uncaptured GDP for two ICT advanced countries Finland and Singapore is measured. Their comparison provides interesting insights toward the contrary development trajectories in Finland (Happiness seeking despite low economic growth) and Singapore (High economic growth while low welfare and choking society). This reflects how different countries are using technology to create unique competitiveness in terms of economic growth or social welfare.

With the dramatic advancement of the digital economy and massive digitization, new types of innovative businesses are emerging that are challenging traditional businesses and national level institutions. Therefore intuitive innovation strategies are indispensable to successfully deal with current and future challenges of technology advancement as well as for creating ICT-driven competitiveness.

In the third phase of research the case study method was used to analyze the new stream of innovation at industrial and national level. For the industrial level case studies, the music industry and the taxi industry were selected as both are facing the consequences of digitization and disruption. At national level, higher education and gender equality is selected as case studies. As highly educated workforce is a key to compete in the digital economy and the gender equality is essential not only as a matter of fairness and inclusive growth but also as a strategic tool to cope with increasing demographics of ageing societies. By analyzing industrial and national level business strategies it is learned that, how few ICT firms and ICT countries are harnessing the potential of untapped and non-economic resources denoted as “soft value innovation” to cope with the challenges of two-faced nature of ICT and to gain competitiveness in the digital economy.

In the fourth phase, on the basis of lessons learned in previous phases, a detailed empirical and qualitative analysis of 500 global ICT firms is conducted to explore the transformative direction of innovation towards an IoT-based society. In next step the top six high R&D intensive firms are selected and their business strategies are analyzed with special attention to their features of soft value innovation.

It is anticipated that in future the role of soft value innovation at industrial and national level will further increase in addressing the challenges of digital economy such as declining marginal productivity of technology, increasing role of uncaptured GDP and intense competition.

1.2 Research framework and relationship of the articles

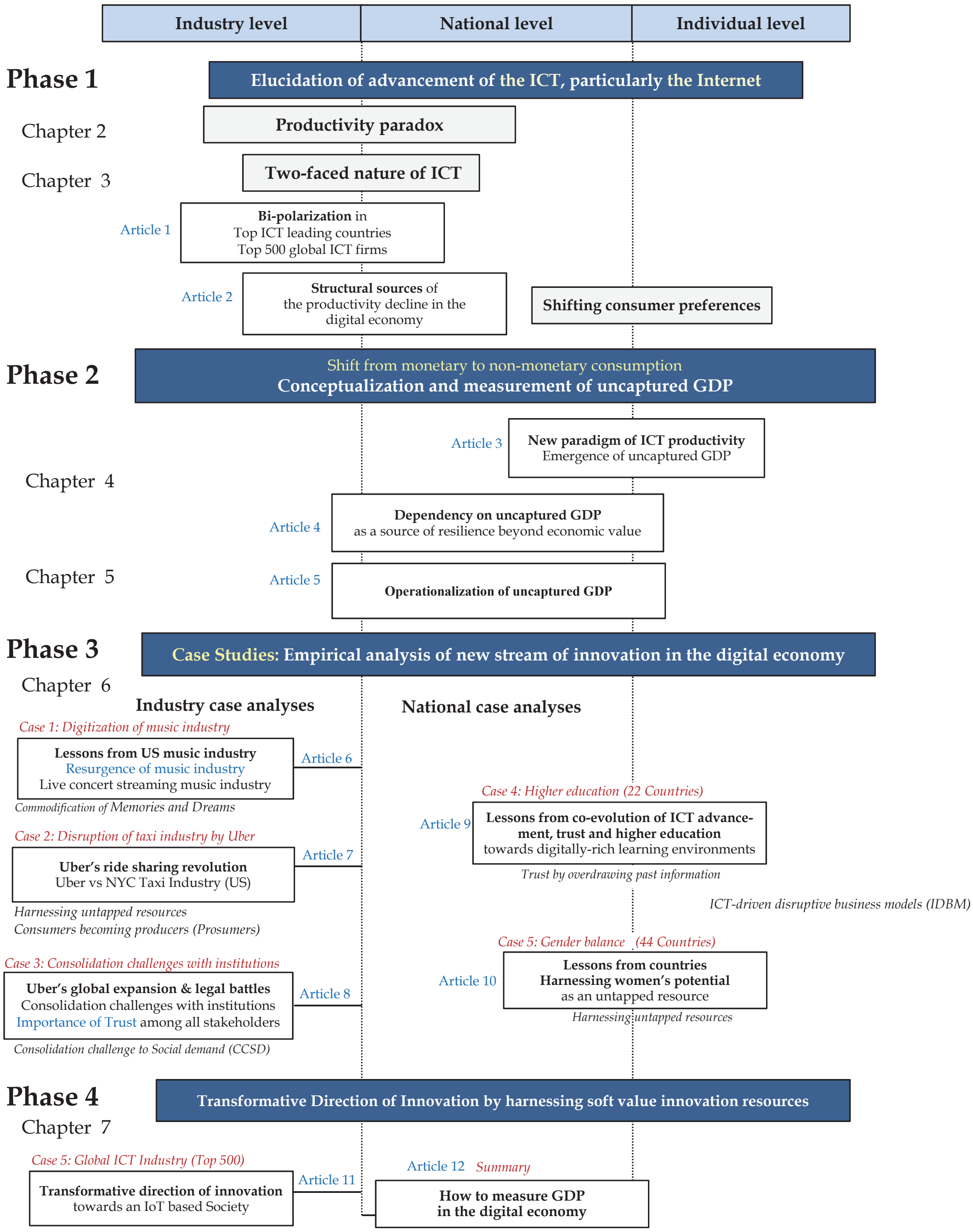


FIGURE 1 Research framework and relationship between articles

1.3 Structure of the dissertation

Chapter 2 reviews the productivity paradox in the digital economy. Chapter 3 analyzes the two-faced nature of ICT. The shift to non-monetary consumption is analyzed in Chapter 4. The measurement of uncaptured GDP is demonstrated in Chapter 5. Chapter 6 presents the case analyses for the new stream of innovation. Chapter 7 discusses the transformative direction of innovation towards an IoT-based society. Chapter 8 presents the research methodology. The overview of articles is discussed in Chapter 9, and Chapter 10 summarizes the conclusion, noteworthy findings, policy suggestions, and future research.

2 PRODUCTIVITY PARADOX AND LIMITATIONS OF GDP

The Productivity Paradox is defined as a "*perceived discrepancy between measures of investment in information technology and measures of output at the national level*" (Triplett, 1999). This concept is sometimes associated with famous quip of Nobel Laureate Robert Solow's in 1987, and referred to as the Solow's computer paradox. Several authors used different explanations for the concept of productivity paradox. Brynjolfsson (1993) splits these explanations into four different categories, mismeasurement of outputs and inputs, lags due to learning and adjustment, redistribution of dissipation of profits and mismanagement of information technology.

As reviewed earlier that the advancement of ICT, particularly the Internet, online intermediaries and progression of digitized innovation provides us extraordinary services and welfare never anticipated before. However, contrary to such accomplishments productivity in industrialized countries experiences an apparent decline as demonstrated by the comparison of average real GDP growth rates in three different periods in Figure 2. The countries are ordered by their word ICT ranking in 2014 (WEF, 2014a).

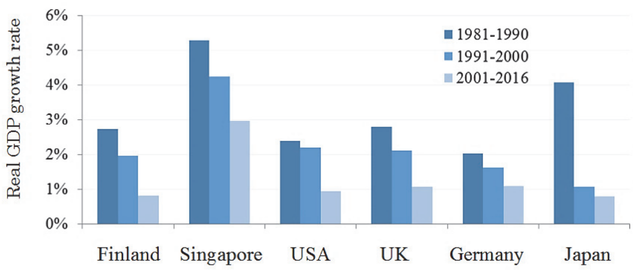


FIGURE 2 Productivity decline in six ICT advanced countries

Source: World Economic Outlook Database (IMF, 2017a).

Figure 2 clearly demonstrates productivity decline over time in six ICT leading countries, and following section briefly discusses the different debates around productivity paradox.

2.1 Productivity paradox in the digital economy

2.1.1 Computer-initiated productivity paradox

Following the "Productivity Paradox" postulated by Nobel Laureate Solow (Solow, 1987), a significant number of studies has discussed the social and economic effects of ICT advancement. Following the response to the productivity paradox by Brynjolfsson (1993), several other analyses attempted to understand the relationship between ICT and its productivity (Kraemer and Dedrick, 1994; Lichtenberg, 1995; Brynjolfsson and Hitt, 1996).

Brynjolfsson et al. (1996) disproved the productivity paradox and attributed it to the problems in productivity measurement and a long lag between technology investments and productivity gains. Later, Brynjolfsson et al. found a significant positive relationship between ICT investments and productivity (Brynjolfsson and Hitt, 1998; Brynjolfsson and Yang, 1999). In the late 1990s, some signs emerged that productivity in the workplace had improved, particularly in the United States, thus encouraging the popular consideration that there was no paradox (Triplett, 1999).

2.1.2 Internet-initiated productivity paradox

A new paradox appeared in last years of the first decade of this century, and it was largely attributed to the third industrial revolution initiated by the dramatic advancement of the Internet (Rifkin, 2011). The Internet within two decades became the day-to-day reality of billions of people from merely a network of researchers (McKinsey, 2011). Undoubtedly, the Internet has significantly changed our way of living, working and socializing, by transforming the computer-initiated ICT world into more integrated, seamless and interconnected.

However, Cowen (2011) argued that, "contrary to the dramatic advancement of the Internet and subsequent ICT advancement, we were living through the consequence of a dramatic decrease in the rate of innovation." He claimed that the consequence of reduced innovation is fewer new industries and lesser creative destruction, thus fewer new jobs. He stressed that historically, the technological progress brought a large and predictable stream of growth across most of the economy. However, these assumptions turned out to be wrong or misleading in terms of the Internet and then suggested it as the possible consequence of the two-faced nature of ICT.

Brynjolfsson, who earlier reacted to Solow's production paradox in 1993, later raised the following question, "Could technology be destroying jobs?" (Brynjolfsson and McAfee, 2011). By giving the example of music industry, he contended that "Because you and I stopped buying CDs, the music industry has shrunk according to revenues and GDP. But we're not listening to less music. There's more music consumed than before." He further mentioned that rather than growth, the yardstick could be deficient and postulated the limitations of GDP statistics in reflecting true picture of digital consumption (Brynjolfsson et al., 2014).

2.1.3 IoT-initiated productivity paradox

With the rapid advancement of the Internet and the Internet of things (IoT), our world is transforming into an IoT-based society (Bharadwaj et al., 2013; Internet Society, 2016). The IoT[2] has the potential to change the base of competition and drive new business models (McKinsey Global Institute, 2015), thus propelling the next phase of digitization of our society (EU, 2017). The IoT is changing the traditional meaning of word "product". In IoT era, a product can be a technology, device, service (powered by software), and flow of data, software application, or any combination of the above. The transformation from the traditional Internet, in which data are "created by people," into the IoT, in which data are "created by things" (Madakam et al., 2015) generates data at a much larger scale. To capitalize on the highly promising business opportunities of the IoT, global ICT firms need to restructure their business models and embrace sophisticated digital solutions (Bharadwaj et al., 2013).

Aside from discussing the opportunities, some studies also indicate the possibility of another productivity paradox. According to McKinsey (2015), the economic effect of IoT would reach US$ 3.9-11.1 trillion per year, which will be roughly equivalent to 11% of the global GDP by 2025. However, this report also notifies the possibility of another productivity paradox in context of IoT, because of a possible lag between technology investments and productivity gains to be reflected at the macroeconomic level.

2.2 Limitations of GDP in measuring the digital economy

2.2.1 Emergence of free culture

As reviewed earlier, the Internet has integrated into our everyday lives and changed lot of things. Some effects of the Internet are rather technological but others, such as the radical changes in our traditions and cultures may have way deeper consequences. Lowrey (2011) postulated that the Internet promotes a free culture, the consumption of which provides utility and happiness to people,

[2] Internet Society (2015) defines IoT as scenarios in which network connectivity and computing capability extend to objects, sensors, and everyday items not normally considered by computers, allowing these devices to generate exchanges and consume data with minimal human intervention.

but it could not accurately be captured through the GDP data, which measure revenue.

Traditionally, so called "free" or noncommercial culture existed since centuries as a part of our daily lives e.g. people telling stories to kids, playing songs on street's corners. These types of activities and their consumption generate no monetary value and represent the non-monetary economy. Similarly, the commercial culture is also existed since centuries in a form of products or services produced to be sold for monetary value. The consumption of commercial culture has positive economic contributions. An optimal balance between the noncommercial and commercial culture is vital for our economy and society to function in harmony.

Nevertheless, the Internet seems to have shifted this balance by inducing much bigger impacts on noncommercial culture relative to the commercial culture. The Internet gave the ability to an ordinary person to create contents at his own computer and distribute it to the global audience in matter of seconds for almost free at a scale never anticipated before. With the progression of technology the possibilities of promoting noncommercial culture are unlimited. One of its examples is the peer-to-peer (p2p) file sharing technology meant to facilitate the sharing and distribution of contents among peers but it has been vastly misused by distributing the enormous amount of copyrighted contents for free. Other examples of copyright infringements include incorporating contents from the Internet to your own work "copy paste culture", mixing audio tracks, images and video clips from online archives to create new music, video films, movies and so on.

Piracy has also enabled the free and illegal distribution of contents meant to be created for commercial use. The enormous availability of free and noncommercial contents has become the primary source of consumer's utility and happiness. Consequently the free contents start to distort the revenues of commercial cultural products and the declining revenues of recording music industry are one of its typical example. The massive substitution of commercial products by noncommercial products may have its serious negative consequences because an optimal balance between "free" and "paid" products is crucial for sustainable functioning of our economy and society.

2.2.2 Consumer surplus

The consumer surplus is the difference between the highest price a consumer is willing to pay and the actual market price of the good. In light of the increasing economic gain by consumer surplus, Brynjolfsson et al. (Revised 2017) analyzed online booksellers and found that the increased product variety available through electronic markets could be the significantly larger source of consumer surplus compared to efficiency gains through increased competition and low average prices. Their analysis indicated that the increased product variety of online bookstores enhanced consumer welfare by US$731 million to US$1.03 billion in the year 2000. This value is 7-10 times larger than the consumer welfare gain from increased competition and lower prices in this market.

Brynjolfsson et al. (Revised 2017) also pointed out the possibility of large welfare gains in other Stock Keeping Unit (SKU)-intensive consumer goods, such as music, movies, consumer electronics, and computers. The white paper of Japan's Ministry of Internal Affairs and Communication (2016) demonstrated similar results by analyzing consumer surplus in music and audio-visual services. Analyzing the economics of the Internet of Things (IoT), McKinsey (2015) estimated that consumer surplus derived from the IoT could be more than 10 % of the global economy by 2025.

2.2.3 New goods and services derived from online intermediaries

There is no clear definition of online intermediaries despite few common factors such as, *online intermediaries provide digital platforms to bring users and service providers together and facilitate the exchange of goods, services and information online* (Copenhagen Economics, 2015). The online intermediaries include ecommerce platforms, social networks, search providers, entertainment platforms and comparison service platforms. In the digital economy the online intermediaries play a core role and provide extraordinary services and convenience to consumers.

The search engines such as Google and Yahoo have significantly reduced the time and cost of information search. The e-commerce platforms such as Amazon, Alibaba and Rakuten offer inexpensive products and services to consumers. The open source software platforms such as Wikipedia, Linux and R, provides free information search and distribution services. Social networks such as twitter, Facebook, LinkedIn and YouTube provide efficient services of social interaction and exchange of information. The cloud computing platforms such as Amazon, Apple, Cisco, IBM, Google, Microsoft etc. provides cost effective solutions for businesses to acquire technology as an alternative to costly investments for indigenous infrastructure. New P2P services such as Uber, Airbnb, eBay, and crowd funding etc. have developed digital platforms that enable consumers to become producers (prosumers) and offer their services or assets online and blurring the production boundaries.

There is an increasing trend of services provided by households e.g., digital marketing, freelancer services etc. The technology has also enabled producer's to shift their burden to consumers by introducing services e.g., self-service, self-check-ins, online hotel or flight bookings etc. The individuals are contributing enormous amount of digital contents in blogs, social networks, video sharing websites (e.g., Facebook, Twitter, and YouTube), open source software platforms and webpages (e.g., Wikipedia, R, Linux etc.). The other issues include online piracy, unlicensed software, illegal file sharing etc.

Most of the services discussed above are provided to consumers for totally free, partially free, or at least up to a certain limit e.g. free package with basic services. Some services are free for consumers but generate revenues through online advertising, some services are available at marginal costs that provide substantial cost and time savings. The efficiency gains, cost and time savings, low average selling prices and free digital products and services increase consumer's surplus. The economic gain through free goods and increasing consumer surplus are the major sources of uncaptured GDP. As reviewed earlier that the Internet promotes a free culture, the consumption of which provides utility and happiness to people, but it cannot accurately be captured through the current GDP statistics, which measure revenue (Lowrey, 2011). Authors denoted it as "*uncaptured GDP*" and defined it as "*the added value that provides people with utility and happiness beyond economic value, however it cannot be measured by traditional GDP accounting that measures economic value*".

2.3 Emergence and increasing role of uncaptured GDP

As indicated by Brynjolfsson et al. (Revised 2017) that clearly new goods are at the heart of economic progress, but this realization is only the beginning of an understanding of the economics of new goods.

The new type of business activities and services are posing huge challenges for governments and statistical offices to accurately record their transactions. The lacking capacity of statistical offices are contributing to the increasing role of uncaptured GDP in the digital economy.

US Council on Competitiveness (2016) pointed out that the apparent slowdown in productivity in industrialized countries could simply be due to the lack of capacity in statistical offices to accurately measure the massive quality gains and hard-to-measure benefits of relatively new goods and services (e.g., Google, Facebook, and Twitter), which are radical breaks with previous products or in some cases are provided for free to users. According to this report, some evidence suggests that statistical agencies can now better understand the economics of new goods and services. However, adjustment issues related to previous gains still remain a problem in accurately measuring productivity growth.

The current estimates for the non-market benefits of free goods and services (e.g. Google, Wikipedia, and Facebook etc.) do not make up for the shortfall in productivity growth (The US Council on Competitiveness, 2016). Moreover, these estimates may understate the non-market benefits but knowing so would be difficult. The Economist (2016) also raised similar concerns by claiming that "GDP is a bad gauge of material well-being and it is a time for fresh approach." Copenhagen Economics (2013) examined the contribution of online intermediaries on the GDP of EU27 countries in 2012 as demonstrated in Figure 3.

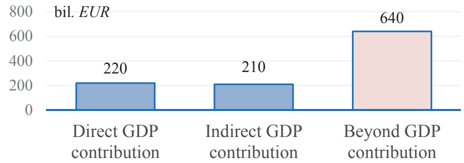


FIGURE 3 Online intermediaries contribution to the GDP of EU27 countries
Source: (Copenhagen Economics, 2013)

The report estimated that the online intermediaries have *direct GDP contribution* of EUR 220 billion (1.7% of the GDP) through consumption, *indirect GDP contribution* of EUR 210 billion (1.65% of the GDP) through productivity increase, and *beyond GDP* contribution of EUR 640 billion (5.0% of the GDP) derived from B2B platforms, e-commerce, online advertising and consumer benefits of free services such as Google search among others.

This report also pointed out that these estimates are understated because they did not include the direct contribution of investments and the socio-cultural value created by social development, which are hard to measure. The beyond measurement GDP contribution of EUR 640 billion is 5.0% of the EU27 GDP and it seems high but according to author's estimates the actual magnitude of uncaptured GDP can be much higher.

As reviewed earlier, the GDP is considered as the most fundamental yardstick in devising economic policy, the identification of the loop-holes of GDP measurement and the extent of the resultant bias has become a crucial subject under the digital economy. The OECD has been taking a leading role in this identification.

Although we expect people to enjoy the well-being enabled by the digital economy, however such gains are excluded from GDP accounting as it is considered at odds with the conceptual basis of measuring GDP. Claiming the lack of capacity of GDP statistics to measure the digital economy, famous Nobel Prize winning economist Joseph Stiglitz pointed out that, GDP is not a good measure of economic performance, it's not a good measure of well-being. In order to keep with the challenges of "Fourth Industrial Revolution" we need to find a new measure to assess the health of our economies (Ross, 2016).

2.4 Transformation into a GDP diminishing structure

The diminishing GDP structure in digital economy can be another source of increasing role of uncaptured GDP. Analyzing the economic effect of advancement of technology in the digital economy (Watanabe et al., 2015a) discusses the two-faced nature of ICT and the emergence of uncaptured GDP (Watanabe et al., 2015*a*, 2015*b*, 2016*a*, 2016*b*). The authors pointed out that, although the advancement of ICT generally contributes to enhance prices of technology through new functionality development, the dramatic advancement of the Internet contributes to decrease prices of technology because of its unique inherent characteristics of freebies, easy copying, and mass standardization.

The first factor contributing to diminishing GDP is derived from the misleading ICT prices due to the pseudo calculation of ICT deflator in evaluating the real value of ICT-driven digital economy (see chapter 3).

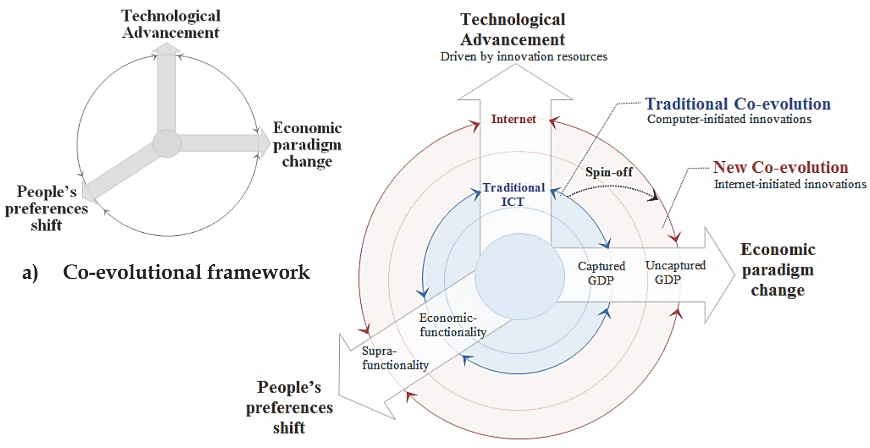
Another factor contributing to the GDP diminishing structure and emergence of uncaptured GDP can be the increasing trend in non-monetary consumption of consumers (due to the availability of free goods and services and new business models) that contributes no value to the GDP (see details in chapter 4) hence resulting in increase of consumer surplus. It is believed that with the progression of technology the consumer's preferences are also steadily shifting from economic value to beyond economic value which is denoted as "supra-functionality" (see details in chapter 4). It means that while making their buying decisions, consumers increasingly tend to focus more on the social, cultural and emotional relevance of the product rather than functional value. So the shifting consumer preferences are contributing to non-monetary transactions thus increase in free consumption and consumer surplus.

Ahmad et al., (2016) points out seven productivity loop holes derived from the advancement of the digital economy as: new forms of intermediation of peer-to-peer services, blurring production boundaries leading consumers to become producers, consumer durables and investment, free and subsidized consumer products, free assets produced by households, vague transactions through e-commerce, and mismeasurement of ICT prices.

2.5 Co-evolution of three mega-trends and spinoff dynamism

Author uses the concept of co-evolution to explain the advancement of technology. Although the co-evolution is an ecological concept, however researchers have applied this concept by analogy to many different fields. *Co-evolution occurs when two or more species exert selective pressure and reciprocally affect each other's evolution.*

Any technological invention turns to innovation when it becomes commercially successful and consumers choose to buy it, which in turn generates financial benefits for businesses and economies. The author postulates that the evolution of the advancement of technology, social preferences and economic outcomes impacts each other in a co-evolutional manner, and developed a co-evolutional framework as demonstrated in Figure 4a.



a) Co-evolutional framework

b) Spin-off dynamism

FIGURE 4 Co-evolutional framework and its spin-off dynamism

Traditionally, new innovation introduces technologies or products, and consumers choose products by considering its functional features and pay a certain price that generate revenues for businesses and also contributes to the GDP of country, authors called it "*Traditional co-evolution*". This relationship has benefited everyone involved and has been working successfully through the computer-initiated innovations.

However, with the emergence of new stream of internet-initiated innovation, the consumer's preferences started shifting from economic functionality to supra-functionality beyond economic value. The economic impact of technology gradually started shifting from increasingly monetary (*captured GDP*) to increasingly non-monetary (increasing *uncaptured GDP*) consumption (due to the digital nature of the products that are increasingly available for free, easy to replicate and transfer over the Internet). Author denoted this new phenomenon as "*New co-evolution*". The shifting trend from traditional to new co-evolution is denoted as "*spin-off dynamism*" demonstrated in Figure 4b.

The concepts of co-evolution and its spin-off dynamism is supportive to understand the two-faced nature of ICT, shifting trend of consumer preferences and emergence of uncaptured GDP. It can also help to determine and compare the transitioning state of different countries from traditional to new co-evolution.

The above overview reveals that the two-faced nature of ICT (which leads to ICT price decline) and the shift from monetary to non-monetary consumption are critical sources of the productivity decline and emergence of uncaptured GDP in the digital economy. The succeeding sections focus on the analysis of these issues.

3 TWO FACED NATURE OF ICT

This chapter presents the conceptual framework of two-faced nature, its empirical evidences at industry and national level and finally discusses another important issue, the miscalculation of ICT deflators that may contribute to the mismeasurement of productivity, growth and inflation in the digital economy.

As reviewed earlier, Cowen (2011) argued that, "Contrary to the dramatic advancement of the Internet and subsequent ICT advancement, we were living through the consequences of a dramatic decrease in the rate of innovation". He also claimed that historically the technological progress brought a large and predictable stream of growth across most of the economy; however these assumptions turned out to be wrong or misleading in terms of the Internet. He then suggested it as the consequence of two-faced nature of ICT.

In light of the two faced nature of ICT, the author postulated it as a trap in ICT advancement. Generally, the advancement of ICT contributes to enhance prices through new functionality development, (as typically demonstrated by the increasing price of iPhone[3] series). However, with the dramatic advancement and diffusion of the Internet the prices of ICT declined, due to the massive digitization and abundant online availability of digital resources as freebies, easy to copy, replicate, share and deliver over the Internet.

Based on the empirical findings (Publications PI, PII) related to bipolarization trend observed at industrial and national level, and inspired by the preceding reviews on productivity decline by the rapid advancement of the Internet, emergence of online intermediaries, decrease in technology prices and consequent emergence of uncaptured GDP, the conceptual framework of two-faced nature of ICT is developed as demonstrated in Figure 5.

[3] Price of Apple's smartphone has demonstrated increase as functionality advances as follows: iPhone8 (US$ 699), iPhone8 plus (US$ 795), and iPhoneX (US$ 999).

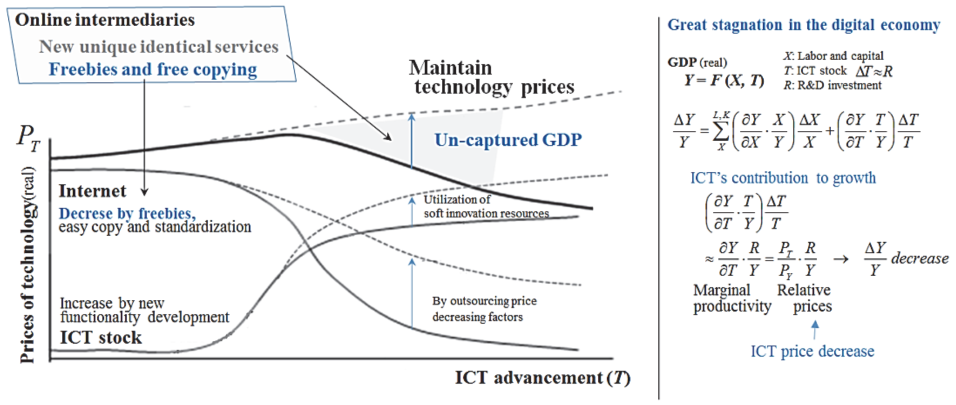


FIGURE 5 Conceptual framework of two-faced nature of ICT

Original source: (Watanabe et al., 2015a)

3.1 Two faces of ICT in global ICT leading countries

To further demonstrate the supposition of the two-faced nature of ICT, the trends in ICT prices based on the ICT stock and Internet dependency in two ICT leading countries, Finland and Singapore, were computed as demonstrated in **Figure 6** (See details in Publication PIII).

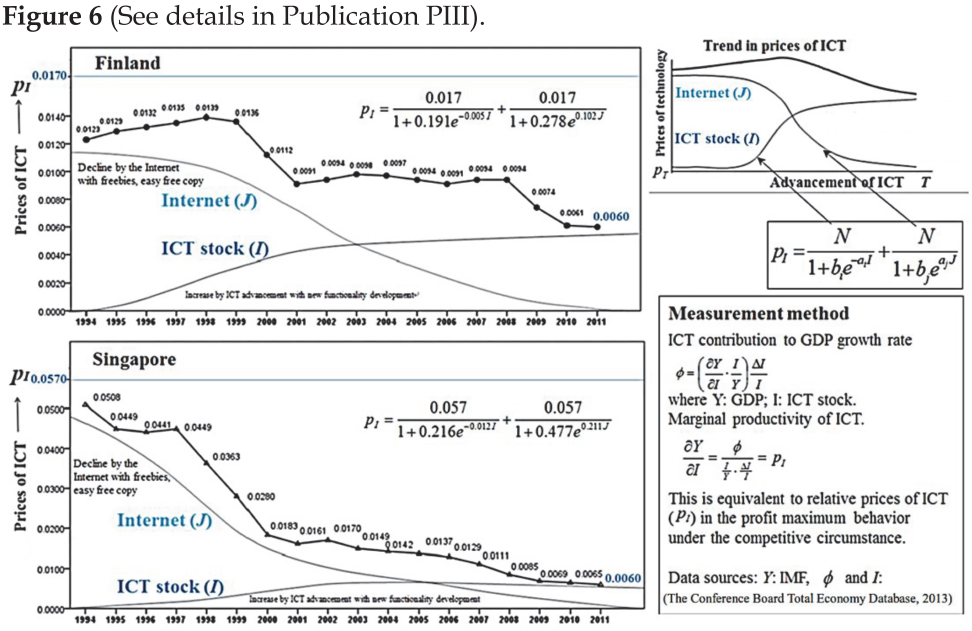


FIGURE 6 Prices of ICT in Finland and Singapore (1994-2011)

Original source: (Publication PIII)

The declining trend in prices of ICT in both countries Finland and Singapore is evident through Figure 6 and it supports the hypothesis of two-faced nature of ICT as a structural source for the trap of ICT advancement. Recent technological advancements can largely be attributed to the Internet and it can be considered as a source of declining prices of technology in ICT advanced countries.

3.2 Two faces of ICT in top 500 global ICT firms

The preceding analysis demonstrates clear evidence of the two-faced nature of ICT, but it depended on the national-level macro analysis using aggregated data. To confirm this result at industry level that represents the actual competitive behavior in the digital market, the prices of ICT in 500 global ICT firms by using micro data is estimated. Figure 7 compares the trends in ICT prices decrease with the advancement of ICT among 500 global ICT firms in 2005 and 2016 (see details in Publication XI.

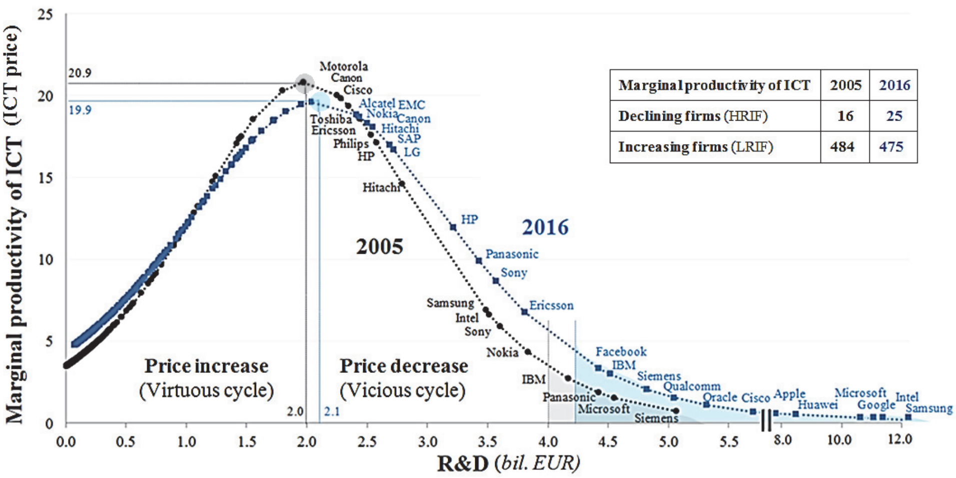


FIGURE 7 Bi-polarization of ICT prices in 500 global ICT firms (2005-2016)

Original source: (Publication PXI)

Given that the global ICT firms seek profit maximum strategy in competitive global market, their ICT prices are represented by the marginal productivity of ICT, and ICT advancement efforts are represented by gross ICT stock (incorporating all ICT advancement facilities including the Internet related facilities) proportional to their broad R&D investments.

Figure 7 presents the bi-polarization trend between high R&D-intensive firms (HRIF) and relatively low R&D-intensive firms (LRIF). While relatively low R&D intensive ICT firms enjoy virtuous cycle between R&D investment and productivity increase, the most of high R&D-intensive ICT firms suffered vicious cycle between R&D investment and productivity decline.

It can be observed in Figure 7 that at the inflection point, the level of R&D investment has shifted from EUR 2.0 billion in 2005 to EUR 2.1 billion in 2016 that means the R&D investments has increased during that period. However, the maximum level of marginal productivity of ICT at the inflection point has decreased in 2016 compared to 2005, which reflects decline in marginal productivity.

It can also be observed that the number of ICT firms trapped in vicious cycle has increased from 16 firms in 2005 to 25 firms in 2016. It demonstrates that the negative consequences of two-faced nature of ICT have increased over time parallel to the progression in the digital economy.

3.3 Calculation of the pseudo ICT deflator

The Internet has undoubtedly provided new ways of transactions that have boosted economic activities, but the emergence and growth of new type of business activities and business models (that cannot be captured through GDP) have also contributed to the deflationary pressures. The miscalculation of ICT deflators may contribute to the mismeasurement of productivity, growth and inflation. Figure 8 clarifies the confusion in miscalculation of ICT deflator.

$$ICT\ prices = \frac{Cost\ for\ ICT}{Utility\ of\ ICT} = \frac{Cost\ for\ ICT\ (nominal)}{Gross\ utility\ (real)}$$

(**Deflator**)

$$\nearrow\ Pseudo\ deflator = \frac{Cost\ for\ ICT}{Captured\ GDP} \rightarrow$$ Increase as un-captured GDP increase

$$\searrow\ Actual\ deflator = \frac{Cost\ for\ ICT}{Gross\ utility} \rightarrow$$ Decrease as ICT advances and subsequent un-captured GDP increase

(Captured GDP + Un-captured GDP)

FIGURE 8 Calculating the pseudo ICT deflator

Original source: (Publication PXII)

The calculation of ICT prices (ICT deflator) without considering the magnitude of uncaptured GDP leads to a pseudo deflator because its value increases as uncaptured GDP increases, resulting in devaluating the actual (real) value of digital economy.

Instead the actual deflator should be calculated by using the gross utility, which considers both captured and uncaptured GDP. By considering gross utility the value of deflator decreases as ICT advances and the subsequent magnitude of uncaptured GDP increases, that results in appreciating the actual (real) value of digital economy.

4 SHIFT FROM MONETARY TO NON-MONETARY CONSUMPTION

4.1 Shifting consumer preferences

In light of discussions in Chapter 2, related to the significance of shift from monetary to non-monetary consumption as one of the sources of GDP diminishing structure in the digital economy, Chapter 3 further explores the phenomenon of non-monetary consumption in terms of shifting consumer preferences, consumption behavior, consumer utility and finally develops a method to measure the elasticity of utility to consumption.

The progressing of technology and shift from commodity-oriented society to service and information-oriented society has significantly improved efficiency and convenience for conducting business transactions. It has also provided consumers with much more choices and raises their level of expectation.

It is believed that with the advancement of ICT the consumer preferences have been steadily shifting from economic functionality to supra-functionality. Here, supra-functionality beyond economic value encompasses social, cultural, aspirational, tribal and emotional values as illustrated in Figure 9.

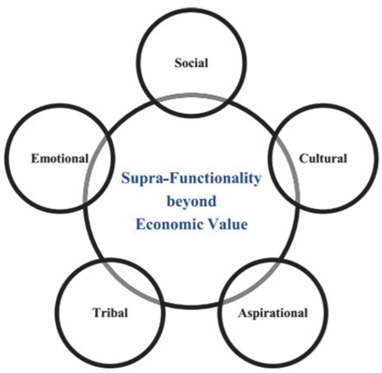


FIGURE 9 Basic concept of supra-functionality beyond economic value

Due to the shifting consumer preferences, the integration of supra-functionality in design become very crucial, and providing satisfactory functionality alone doesn't guarantee the acceptance or use of product or service (Watson et al., 2004). So the firms put extra efforts to maximize the consumer's experience by fulfilling their supra-functional needs but these efforts are not necessarily be monetized and captured by the GDP (McDonagh, 2008). This shift seems to have a significant relevance in increasing level of consumer surplus and consumer welfare that is one of the sources of increasing role of uncaptured GDP as reviewed in earlier section.

Figure 10 illustrates the results of Japan's *Public Opinion Survey Concerning People's Lifestyles*[4] conducted annually by Japan's Cabinet Office.

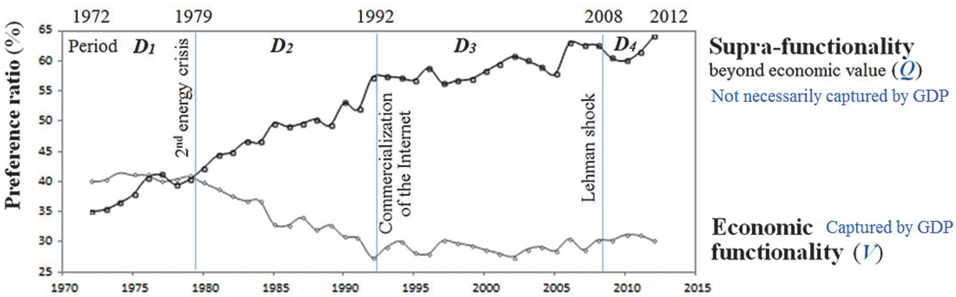


FIGURE 10 Trends in shift of people preferences in Japan (1972-2012)
Original source: (Publication PIV)

The shift of consumer preferences can clearly be observed in Japan, which is extremely sensitive to institutional innovation against external shocks and crises (Hofstede, 1991, Watanabe, 2009). The period demonstrating the shifting trend from economic functionality (V) to supra-functionality (Q) can be classified into four phases: *Phase 1* (1972-1979), *Phase 2* (1980-1992), *Phase 3* (1993-2008), and *Phase 4* (2009-2012) as indicated D_1 - D_4 in Figure 10 respectively.

Contrary to the steady decline in people's preference in V, Q steadily increases and exceeds V in 1979, the year of the second energy crisis. Whereas Q continues to increase steadily, V declines to its lowest level in 1992, the year immediately after the commercialization of the Internet in 1991. It has remained at the same level since then. A decline in Q due to the Lehman shock in 2008 is followed by a sharp recovery.

With the shift in consumer preferences from economic functionality (*captured GDP*) to supra-functionality (*uncaptured GDP*) (Watanabe et al., 2011), supported by the advancement of the Internet (facilitated consumers the access to freebies and digital contents), there emerges a free culture, that gives happiness and utility to consumer but cannot necessarily be captured through GDP

[4] In this survey, personal preference for future life is chosen from three options: (i) Richness of the heart-spiritual happiness (*Since a reasonable level of material affluence has been achieved, future emphasis should be put on spiritual happiness and a comfortable life.*), (ii) Wealth of things – material affluence (*Emphasis should still be put on material affluence for future life.*), or (iii) Cannot identify explicitly. While the second option corresponds to a preference for economic functionality, the first option corresponds to that of supra-functionality beyond economic value (Watanabe et al., 2011).

statistics (Lowery, 2011) and free consumption has become the major source of consumer's utility and general happiness (JCO, 2012).

Since the consumption shares the larger part of the GDP (approx. 60%), so its sustainability is very crucial for sustainable GDP growth. By considering its importance an empirical analysis of marginal propensity to consume[5] in six leading ICT countries for the period before and after the financial crisis of 2008 was conducted, and results are demonstrated in Table 1.

TABLE 1 Marginal propensity to consume in six selected countries

	1990-2007*	2008-2012**
Finland	0.42	0.23
Singapore	0.32	0.21
Japan	0.59	0.34
USA	0.74	0.64
Germany	0.55	0.44
UK	0.70	0.37

* 1990-2006 in US and Germany
** 2007-2012 in US and Germany
Original source: (Publication PIV)

The results of analysis suggest that, in all selected countries the marginal propensity to consume has declined concurrent to the global financial crisis in 2008. This declining trend has led to sluggish consumption and subsequent economic stagnation. Such trend together with the shifting consumer preferences from economic functionality to supra-functionality suggested a possibility of an emergence of post-excessive consumption society.

4.2 Utility enhancement under great stagnation

The structure of utility under great stagnation is illustrated in Figure 11.

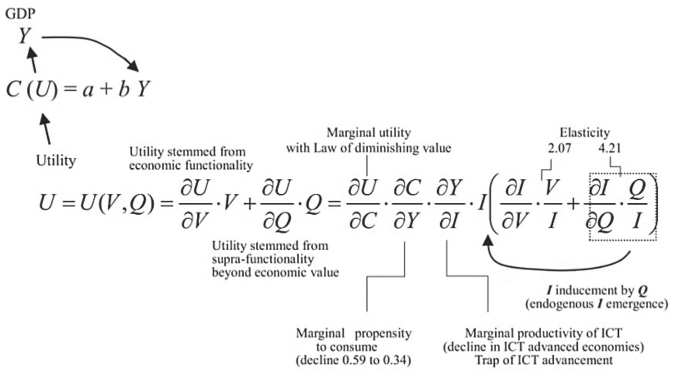


FIGURE 11 Structure of utility under great stagnation
V: economic functionality, Q: supra-functionality beyond economic value, I: ICT stock, and J: Internet. Figures demonstrate a comparison of Japan between 1997-2007 and 2008-2012. Original source: (Publication PII).

[5] The marginal propensity to consume (MPC) is the proportion of an aggregate raise in pay that a consumer spends on the consumption of goods and services, as opposed to saving it.

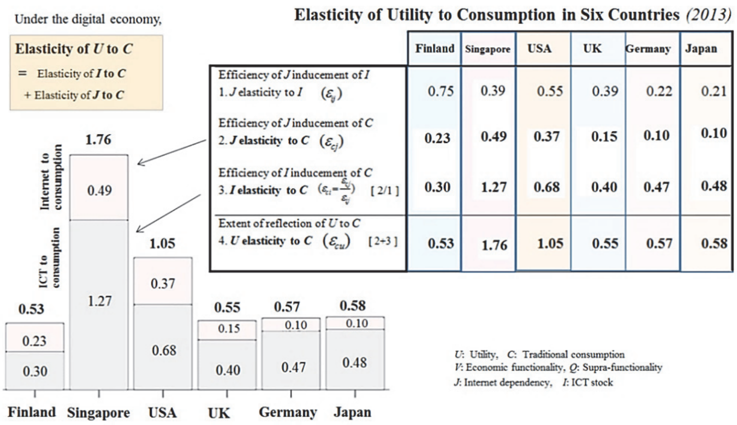
Given the great stagnation, due to the decline in marginal utility, marginal propensity to consume, and marginal productivity of ICT (due to the trap in ICT advancement), the only option for sustainable growth comes from enhancing consumer utility (satisfaction of consumption) through the Internet and ICT stock (Publication PIII - Appendix 1).

Consequently, the effective enhancement of utility as a function of the Internet and ICT stock can be the key for sustainable growth under great stagnation by reconstructing a virtuous cycle between consumption and GDP growth.

As reviewed earlier that the consumption shares major part of GDP, so how effectively the enhancement of utility contributes to increase in consumption would be a key measure to assess the state of uncaptured GDP dependency[6] in any country.

4.3 Measuring elasticity of utility to consumption

As reviewed earlier, in the digital economy the utility is governed by ICT stock and Internet dependency. The elasticity of utility to consumption[7] can be measured by the sum of elasticity of ICT stock to consumption and Internet dependency to consumption (see details in Publication PIV). Figure 12 compares the elasticity of consumption[8] in six countries in 2013.



Elasticity of Utility to Consumption in Six Countries *(2013)*

	Finland	Singapore	USA	UK	Germany	Japan
Efficiency of J inducement of I 1. J elasticity to I (ε_{ij})	0.75	0.39	0.55	0.39	0.22	0.21
Efficiency of J inducement of C 2. J elasticity to C (ε_{cj})	0.23	0.49	0.37	0.15	0.10	0.10
Efficiency of I inducement of C 3. I elasticity to C ($\varepsilon_{ci}=\frac{\varepsilon_{cj}}{\varepsilon_{ij}}$) [2/1]	0.30	1.27	0.68	0.40	0.47	0.48
Extent of reflection of U to C 4. U elasticity to C (ε_{cu}) [2+3]	0.53	1.76	1.05	0.55	0.57	0.58

FIGURE 12 Elasticity of utility to consumption in six countries (2013)
Original source: (Publication PIV)

---

[6] Lower level of utility reflection to consumption suggests higher level of uncaptured GDP dependency.

[7] Elasticity is the measurement of how responsive an economic variable (X) is to a change in another (W). The elasticity of X to W (X elasticity to W) ε_{WX} implies a 1% increase in X increases ε_{WX} % increase in W and represents the efficiency of X inducement of W.

[8] This elasticity is computed by using a consumption function governed by I and J as follows:

$C = C(I,J) =$ Taylor expansion to the secondary term. $\ln C = a + b\ln I + c\ln J + d\ln I.\ln J$

$$\varepsilon_{cj} = \frac{\partial \ln C}{\partial \ln J} = c + d\ln I + (b + d\ln J)\cdot\frac{\partial \ln I}{\partial \ln J} = c + d\ln I + (b + d\ln J)\cdot\varepsilon_{ji}$$ where a - d: coefficients.

original source: (Publication PIV)

It is observed that Singapore demonstrates conspicuously high elasticity, while Finland demonstrates lowest elasticity among six countries compared.

Figure 13 illustrates contrasting development trajectories between Finland and Singapore. Finland effectively utilizes the Internet in inducing ICT stock but its induced ICT stock significantly contributes to satisfy supra-functional preferences of consumers rather than economic value. Consequently Finland's high ICT stock doesn't contribute to increase in consumption, results in low GDP growth rate (0.57 %, average 2006-2013).

Although Singapore's Internet's inducement to ICT stock is smaller than Finland, its ICT stock largely contributes to satisfy its consumers' preferences for economic functionality, which is captured by the GDP through consumption, thus leading to a high GDP growth rate (5.85 %, average 2006-2013).

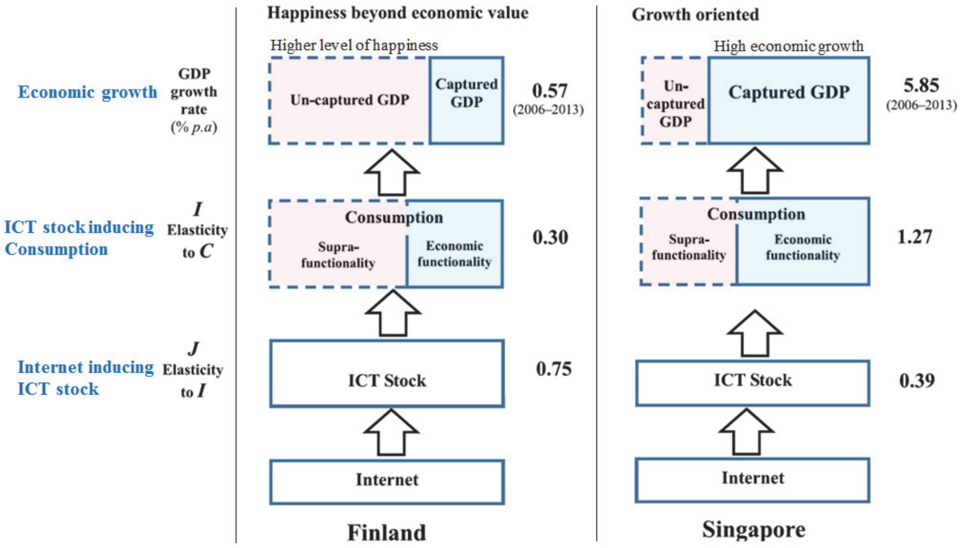


FIGURE 13 Contrasting trajectories of Finland and Singapore (2013)

J: Internet dependency, *I*: ICT stock, *C*: Consumption. GDP growth rate is an average between 2006 and 2013. Original source: (Publication PIV)

5 MEASURING UNCAPTURED GDP

As reviewed earlier, the authors defined *uncaptured GDP* as *"the added value that provides people with utility and happiness beyond economic value, however it cannot be measured by traditional GDP accounting that measures economic value"*.

To date, several attempts have been made to measure uncaptured GDP in the context of beyond GDP, which includes "true wealth and the well-being of nations" (Wesselink et al., 2007), "quality of human life while living within the carrying capacity of the supporting ecosystems" (Costanza et al., 2009), "quest for a measure of social welfare" (Fleurbaey, 2009), "well-being, economic welfare and sustainability" (Bleys, 2012), and "global genuine progress" (Kubiszewski et al., 2013). However, no-one has so far attempted to measure the magnitude of uncaptured GDP in digital economy and derived from the dramatic advancement of the Internet. In order to link this issue to uncaptured GDP problem driven by digital innovation, Brynjolfsson and McAfee (2014) have pointed out that" the rise in digital innovation means we need innovation in our economic metrics." Prompted by this understanding, a practical method to measure uncaptured GDP is developed.

5.1 Hypothetical view

The contrasting ICT-driven resilience and competitiveness strategies in Finland (happiness/welfare under the great stagnation) and Singapore (economic growth orientation with low welfare and "choking society") inspire us a hypothetical view, that such contrast can be derived from their state in shifting from traditional to new co-evolution of three mega-trends (Figure 14) and uncaptured GDP explicitly demonstrates this state.

This study attempts to demonstrate the above hypothetical view by measuring uncaptured GDP of the two world's ICT leading countries: Finland and Singapore, over the period of last two decades.

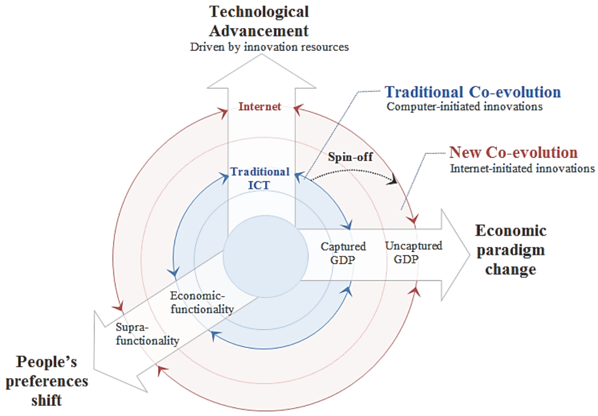


FIGURE 14 Co-evolution of three mega trends

5.2 Emergence of uncaptured GDP

5.2.1 Trap in ICT advancement due to its two-face nature

As reviewed in (Publication PV), while advancement of ICT generally contributes in enhancing prices of technology by new functionality development, the dramatic advancement of the Internet tends to decrease prices of technology due to its nature (incl. freebies, easy copying and mass standardization) as demonstrated in Figure 15.

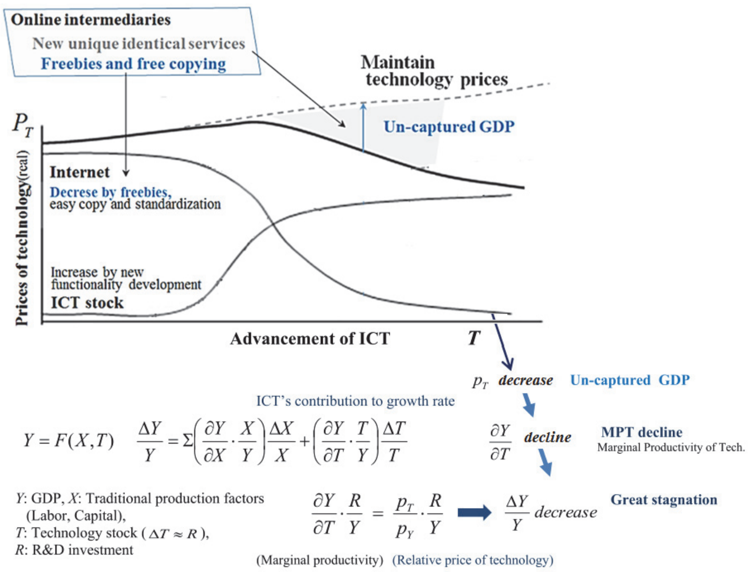


FIGURE 15 Two faced nature of ICT advancement
Original source: (Publication PV)

Consequently, the prices of technology in ICT advanced economies may start experiencing a decreasing trend. This decrease in prices corresponds to the decline in marginal productivity of technology given the maximum profit behavior under the competitive circumstances, resulting in decreasing growth rate as reviewed earlier and also outlined in the lower part of the Figure 15. This can be the structural source of the trap in ICT advancement for ICT-advanced nations/firms facing a vicious cycle between advancement of ICT and its declining marginal productivity. The above decrease in prices can be considered as an economic representation of uncaptured GDP.

As reviewed earlier, with the advancement of the Internet and emergence of online intermediaries and digitization such activities have increased which are difficult to be captured through GDP. There is an argument that the Internet creates significant value for B2B businesses through ecommerce and online advertisings platforms. But this does not represent final consumption but rather an input to final products so it is not directly captured by GDP statistics. While consumers get great benefits by using free services e.g. Google search etc., but because consumers do not pay directly to search engines so these transactions are also not being captured by GDP so as the huge socio-cultural value created by social networks.

The research by Copenhagen Economics (2013) estimated that the online intermediaries have beyond GDP contribution of approx. 640 billion EUR in EU27's GDP in 2012. This is induced by B2B related ecommerce, online advertising platforms, consumer benefits through free consumption and socio-cultural value created by the use of social networks. If the socio-cultural value derived from shifting consumer preferences and subsequent non-monetary consumption is considered, then the estimated value would be much higher than 5%. In addition, unlicensed software, online piracy among other illegal or unauthorized ways are other sources of uncaptured GDP.

5.2.2 Shifting consumer preferences

As reviewed earlier, the consumer's preferences are shifting from economic functionality to supra-functionality beyond economic value and free consumption has become the source of utility and satisfaction for consumers. Such utility depending on uncaptured GDP does not increase consumption as measured by traditional GDP data.

5.3 Trajectories impacting uncaptured GDP

In this section the GDP growth trajectory, ICT-driven development trajectory and consumption trajectories between Finland and Singapore are compared as they are used to measure uncaptured GDP.

5.3.1 Captured GDP trajectory

The comparison of GDP growth trajectories for the period of 1960-2015 in Figure 16 demonstrates that Finland and Singapore have similar trends for both GDP per capita and GDP except the period after 2010 Singapore slightly surpasses Finland.

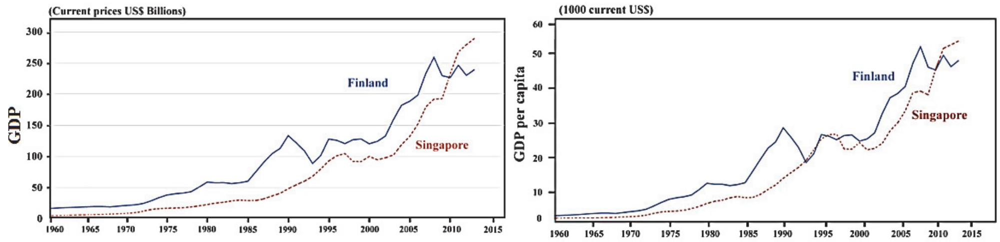


FIGURE 16 Trends of GDP in Finland and Singapore
Original source: (Publication PV)

5.3.2 ICT and internet development trajectory

The ICT development trajectories of ICT stock and Internet dependency are compared in Figure 17. Over the last two decades, Finland has maintained higher growth of ICT stock than Singapore. In 1990s both countries maintained almost a similar level of Internet dependency, however since the start of new millennium, Finland has constantly maintained a significantly higher level than Singapore that might have significant impacts on the emergence of Internet-driven uncaptured GDP in Finland.

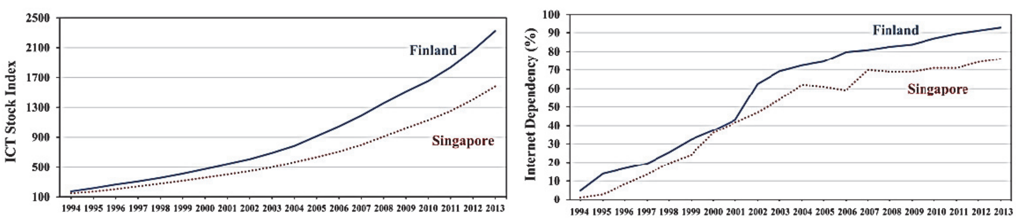


FIGURE 17 ICT-driven development trajectories in Finland and Singapore
Original source: (Publication PV)

The trend in ICT usage of any country can also impact the shift of consumer preferences toward supra-functionality as it is observed that the countries steering toward a new co-evolution encourages the usage of Internet not only by their governments but also individuals and businesses.

TABLE 2 Trends in ICT usage in Finland and Singapore (2010-2014)

		2010	2011	2012	2013	2014
Individual Usage	Finland	2	5	6	6	5
	Singapore	7	10	11	10	11
Business Usage	Finland	8	5	3	2	4
	Singapore	10	14	14	15	14
Government Usage	Finland	24	17	10	8	17
	Singapore	3	2	1	1	1

Sources: The Global Information Technology Report (WEF, annual issues).

Table 2 compares trends in ICT usage by individuals, businesses and governments in Finland and Singapore over the period of 2010-2014. It is observed that Finland has much higher level of individual and business ICT usage, while in Singapore there is a conspicuously higher ICT usage by government. This observation suggests that Finland's shift to new co-evolution trajectory has been more extensive than Singapore.

5.3.3 Consumption behavior trajectory

Household consumption

In order to examine the volume of consumption measured by captured GDP, the trends in household consumption in both countries are illustrated in Figure 18. It is observed that, notwithstanding the similar level of incomes (Figure 17), Singapore demonstrates much higher level of consumption compared to Finland. This contrast suggests the different consumption behaviors by the consumers of two countries: High level of monetized consumption resulting higher captured GDP in Singapore, while high level of non-monetary consumption suggests the high level of uncaptured GDP in Finland.

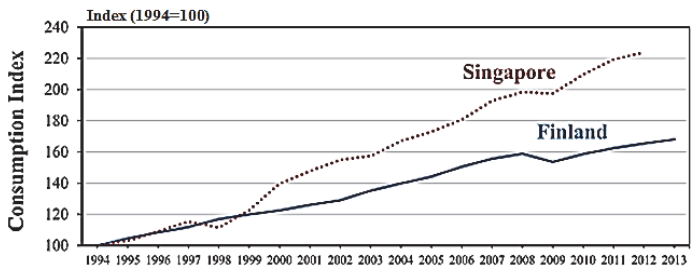


FIGURE 18 Trends of household consumption in Finland and Singapore
Original source: (Publication PV)

Elasticity of utility to consumption

The elasticity of utility to consumption represents the percentage increase in consumption in response to 1% increase in utility. So the degree at which the enhancement of utility drives consumption can be a key measure to assess the state of uncaptured GDP dependency in any country. The method to measure the elasticity of utility to consumption is developed (see details in Publication PV) and Figure 19 compares its trend between Finland and Singapore for the period of 1994-2013.

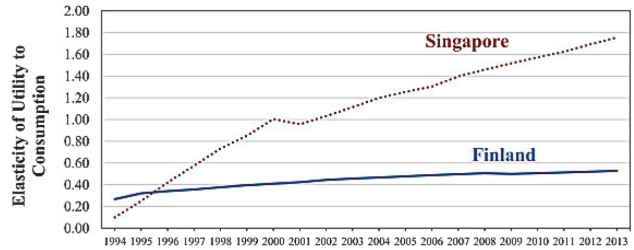


FIGURE 19 Trends in elasticity of utility to consumption in Finland and Singapore
Original source: (Publication PV)

These trends also support above hypothesis of higher monetary consumption related to captured GDP in Singapore and higher non-monetary consumption related to uncaptured GDP in Finland.

5.4 Measurement of uncaptured GDP

5.4.1 Conceptual framework based on factual observations

Notwithstanding similar levels of GDP but significantly different levels of consumption can be attributed to the magnitude of non-monetary consumption between Finland and Singapore. Based on the foregoing factual observations the conceptual framework is developed for measuring uncaptured GDP as illustrated in Figure 20.

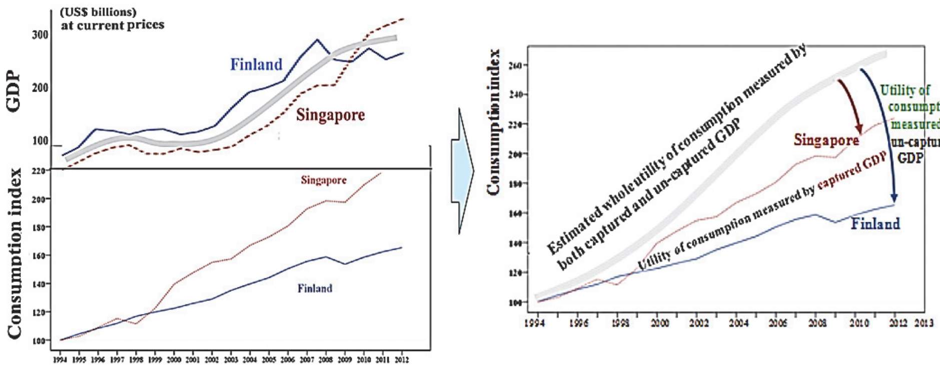


FIGURE 20 Utility to consumption measured by uncaptured GDP
Original source: (Publication PV)

The locomotive for spin-off and increasing uncaptured GDP is driven by its stimulation from the Internet advancement and shifting people's preferences so uncaptured GDP can be traced from both sides. The equilibrium of both lifting powers further increase the level of uncaptured GDP as demonstrated in Figure 21.

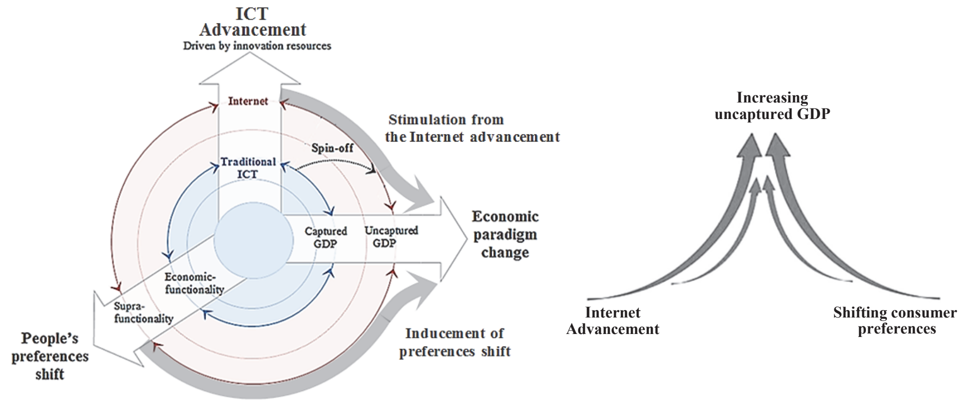


FIGURE 21 The locomotive for the spinoff impacting uncaptured GDP
Original source: (Publication PV)

5.4.2 Stepwise estimation of uncaptured GDP

On the basis of the foregoing suggestions and conceptual frameworks in Figure 20 and Figure 21, an equation to measure Internet-driven uncaptured GDP is developed (see details in Appendix of Publication PV). By utilizing this equation the governing factors of uncaptured GDP in Finland and Singapore is identified by an empirical analysis over the period of 1994-2013 (see detailed results in Tables A1 and A2 in the Appendix of Publication PV). Based on the results of the analysis, the magnitude of uncaptured GDP is estimated.

On the basis of trends in captured GDP and estimated uncaptured GDP, the uncaptured GDP ratio (uncaptured GDP/captured GDP) is calculated and Figure 22 demonstrates its trend in Finland and Singapore over the period of 1994-2013 with the highest and lowest possible estimates.

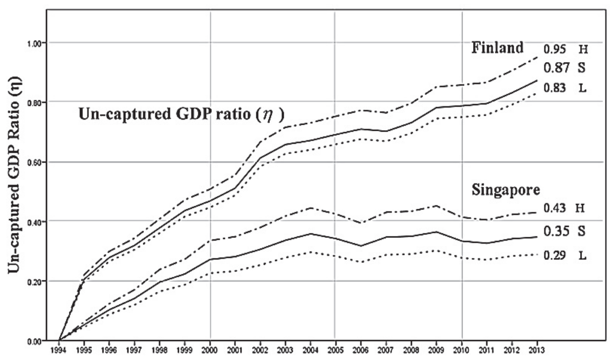


FIGURE 22 Trends in uncaptured GDP ratio in Finland and Singapore
Original source: (Publication PV)

Based on the above results, the Figure 23 shows trends in captured GDP and estimated uncaptured GDP in Finland and Singapore.

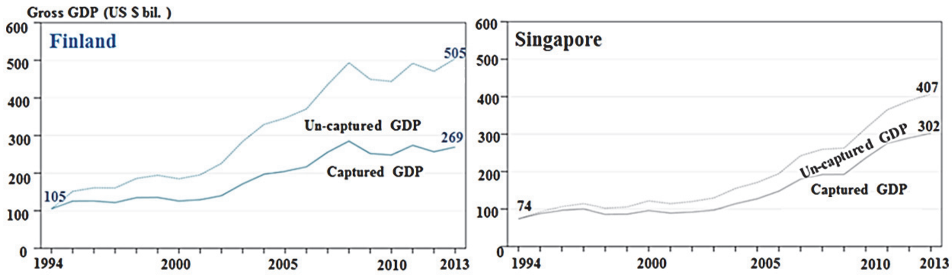


FIGURE 23 Comparison of captured and uncaptured GDP between Finland
Original source: (Publication PV)

Figures 23 presents that since 2010, in Finland the level of captured GDP is lower than Singapore, however its level of gross GDP (the sum of captured and uncaptured GDP) is much higher, that reflects higher magnitude of uncaptured GDP in Finland compared to Singapore. These estimates are aligned with trends in elasticity of utility to consumption (Figures 18, 19) and suggest that Finland has largely shifted to uncaptured GDP dependency while Singapore has retained its dependency on captured GDP.

5.5 Significance of a shift to new co-evolution

The review of development trajectories in both countries realizes substantial differences between its institutional systems. Whilst Finland experiences high level of happiness and well-being amidst the great stagnation, Singapore manages to achieve higher level of economic growth amidst its choking society suffering low level of happiness, higher level of inequality as demonstrated in Table 3.

TABLE 3 Difference in institutional systems between Finland and Singapore (2013)

	Finland	Singapore	References
Population (million)	5.5	5.4	The Global Competitiveness Report 2014 (WEF, 2014)
ICT (Rank out of 148)	1	2	The Global Information and Technology Report 2014 (WEF, 2014)
Global competitiveness (Rank out of 148)	3	2	The Global Competitiveness Report 2014 (WEF, 2014)
GDP per capita (US$1000)	47.1	54.8	The Global Competitiveness Report 2014 (WEF, 2014)
GDP growth rate (2006-2013) (% p.a. at fixed price)	0.57	5.85	World Economic Outlook Database (IMF, 2014))
Happiness (rank out of 156)	7	30	World Happiness Report 2013 (The Earth Institute et al., 2013)
Inequality (GINI index) 2010	19	45	Distribution of Household Income by Source (ILO, 2012)
Gender parity (Rank out of 136)	2	58	The Global Gender Gap Report 2013 (WEF, 2013)

It is postulated that these differences between Finland and Singapore can be explained by their contrasting level of uncaptured GDP and transitioning state from traditional to new co-evolution. To examine their shifting state, the correlation between the Internet productivity of ICT (as a proxy for Internet advancement in ICT-driven economy) and uncaptured GDP ratio over the period of 1996-2013 is analyzed and results are demonstrated in Figure 24.

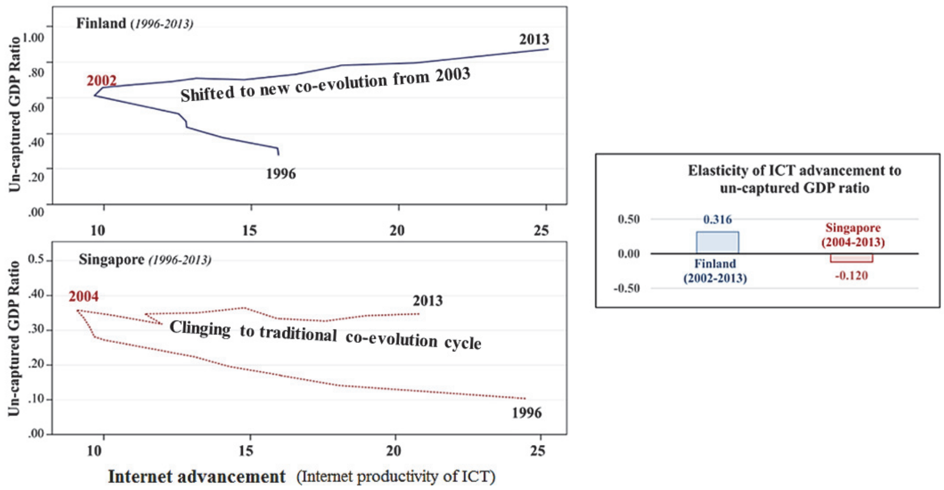


FIGURE 24 Correlation between Internet advancement and uncaptured GDP shift in Finland and Singapore
Note: Internet advancement is measured by the Internet productivity of ICT
Original source: (Publication PV)

It is observed that Finland's inflection towards new co-evolution occurs around 2002 (after the net bubble burst in 2000). Since then its elasticity of ICT advancement to uncaptured GDP ratio is increasing which suggests their active co-evolution. Contrarily, Singapore demonstrates its inflection to co-evolution fairly late in around 2004, two years behind Finland but since then it elasticity of Internet productivity of ICT to uncaptured GDP ratio is slightly negative.

This demonstrates that, while Finland has shifted to a new co-evolution between advancement of the Internet, shifting consumer preferences to supra-functionality and uncaptured GDP, while Singapore is still clinging to the traditional co-evolution.

Figure 25 demonstrates the state of co-evolution of Finland and Singapore with corresponding correlation graphs over the period of 1996-2013. It shows that the stimulations from Internet dependency and shifting consumer preferences have contributed to increase the level of uncaptured GDP in both countries, but the level of uncaptured GDP in Finland is much higher compared to Singapore.

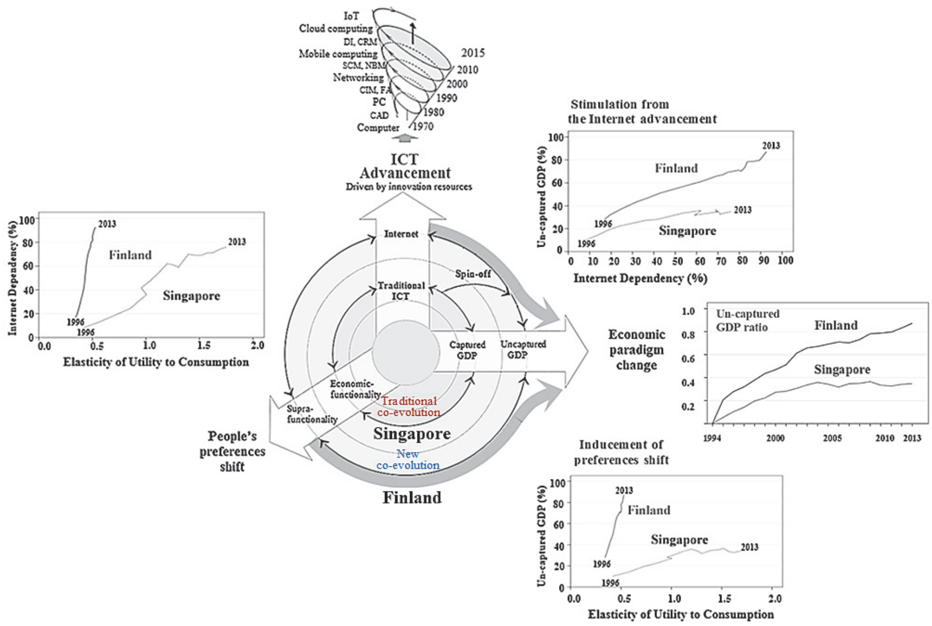


FIGURE 25 Co-evolution of internet, uncaptured GDP and people's preferences in Finland and Singapore (1996-2013)
Original source: (Publication PV)

By considering the development trajectories in of both countries in Table 3, "Happiness seeking" despite low GDP growth in Finland supports the following view that "The well-being of the Finnish people has developed in a more positive direction than one might conclude on the basis of the economic development of recent years indicated by GDP data" (Ylhainen, 2017). It also reminds the limitations of the GDP for measuring the digital economy.

The next chapter demonstrates the significance of uncaptured GDP dependency and new stream of innovation at industrial and national level by conducting several case studies.

6 CASE ANALYSES: NEW STREAM OF INNOVATION

Chapter 6 presents case studies to analyze the new innovation trends at industrial and national level. Three case studies analyze innovations at industrial level and two case studies at national level.

6.1 Case analyses: Industrial level

This section analyzes the industry level case studies. Digitization is all over the place and new digital platforms are emerging and challenging traditional industries by effectively using digital technologies and by introducing new innovative business models. Cohen et al. (2014) reminded that in recent years, new and different type of businesses have emerged that challenges the traditional thinking about how resources can or should be offered and consumed. This supports the arguments that incremental improvements in our existing production and consumption systems are insufficient to transform our global economy toward sustainability (Lovins et al., 2011, Stead et al., 2013).

The selection criteria for selecting case studies were based on the major in the digital economy. The first major trend at industry level is the digitization of physical products and music industry is one of its typical examples as declining music industry revenues raises serious concerns regarding its potential collapse.

The second major trend is the emergence of new sharing economy digital platforms (e.g. sharing economy). The ridesharing platform company, Uber is has successfully disrupted the traditional taxi industry, and expanded globally at very rapid pace. The second case study analyzes the impact of Uber at New York taxi industry and the emergence of uncaptured GDP. The third case study analyzes Uber's global expansion and its legal battles in different countries or cities around the world to demonstrate the consolidation challenges of new disruptive innovations with our existing private and public institutions.

6.1.1 Case 1: Digitization and potential resurgence of music industry

This section analyses the digitization of music industry. The music industry of US is the biggest globally and plays a pivotal role in the development and consumption of digital music, as evident by Figure 26 comparing revenues of digital and physical music industry in different countries representing the major input share of global music industry. By considering its size, the US music industry was selected for this analysis.

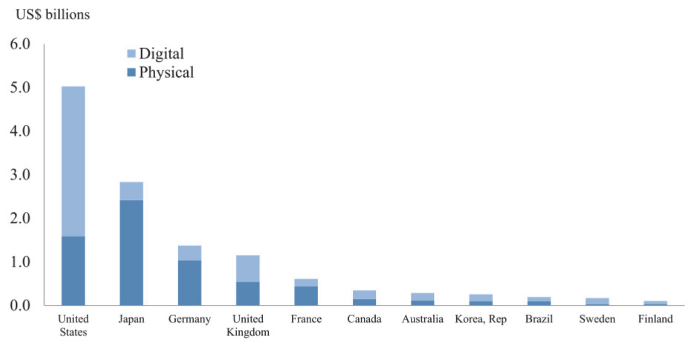


FIGURE 26 International comparison of music industry by revenues (2014)
Original source: (Publication PVI)

The music industry has undergone significant changes recently. Despite the popularity of digital and streaming music, the revenues of the overall recording music industry have steadily declined. The digitization of music industry has caused strong concerns regarding its potential collapse similar to print media, newspaper and book publishing industries.

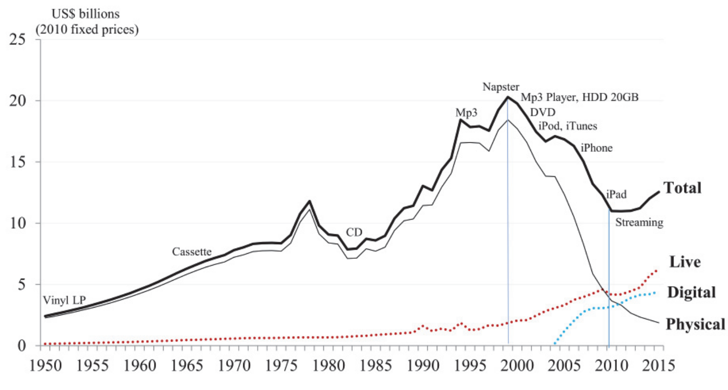


FIGURE 27 US music industry revenues (1950 - 2015)
Original source: (Publication PVI)

Figure 27 shows that the US music industry has been continuously developing from 1950s to 1999s except during the period of economic recession in the early 1980s. This increase finally reached at its peak in 1999 and after the expansion of the Internet it started to decline sharply. The direct relationship between the widespread access of the Internet and decline in record music sales can be observed. Digital music emerged in 2004 but it also seemingly unable to become the savior of declining revenues of music industry. In 2010, the continued decline in music industry revenues suddenly changed and turned upward largely due to the renaissance of live music industry. In recent years, the live shows and music festivals have become increasingly popular and valuable because live music is something fans cannot experience merely by listening to recorded or online music.

Although it seems quite unlikely that live concerts could serve as the sole revenue stream for a viable music industry model, however its rapid growth offers new valuable opportunities for the music industry (Gamal, 2012).

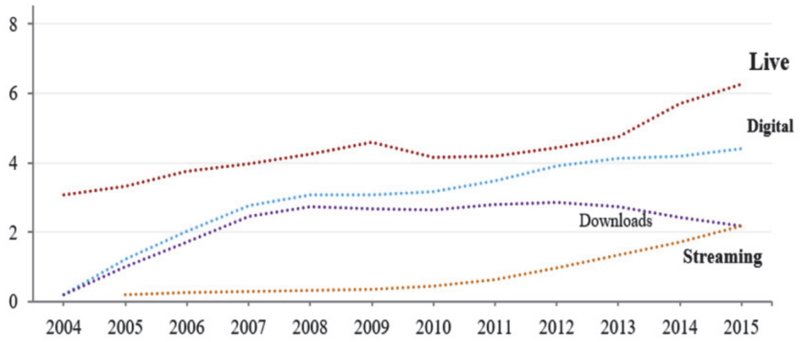


FIGURE 28 US digital and live music industry revenues (2004 - 2015)
Original source: (Publication PVI)

Figure 28 suggests that the streaming music has been gaining popularity and demonstrate the sustainable growth by substituting music downloads. There has been observed a clear shift in the number of consumers who select streaming as a primary source of their music consumption contrary to all other formats of recorded music. With every other format of recorded music industry declining, it seems that the streaming music could be the potential driving force behind the growth of the live music industry. This pattern suggests that there could be parallel paths of sustainable growth in a co-evolutional way.

In addition, the resurgence of live music can largely be attributed to its dependency on similar advanced digital innovations. The popularity of the streaming music can also be attributed to the assimilation of its preceding digital innovations.

This led us to our hypothesis that the notable resurgence in live music can largely be attributed to its assimilation of digital innovations incorporated in digital music and this assimilation has been enabled by the co-evolution between streaming and live music industries.

Co-evolutionary development of the streaming and live music industries

In order to test the hypothesis developed in preceding section, the correlational dynamism between the increasing popularity of streaming services and the boom of live music was analyzed, focusing the period after the economic recession in September 2008, also called as Lehman Shock.

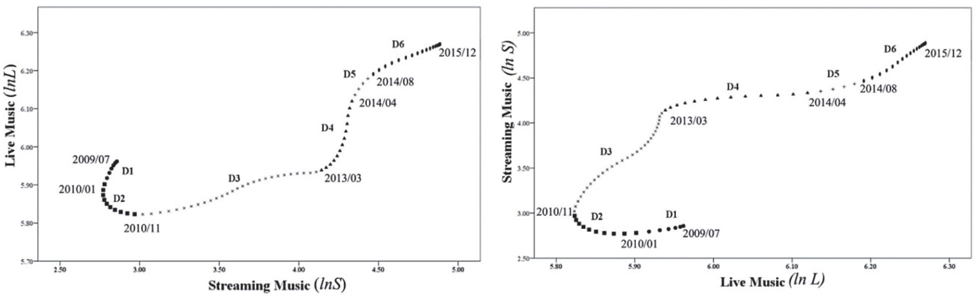


FIGURE 29 Inducement between streaming and live music in the US (2009 - 2015)
Original source: (Publication PVI)

The co-evolutionary dynamism presented in Figure 29 clearly demonstrates that after the initial vicious cycle, in late 2010, the co-evolutional relationship between streaming and live music emerged and further accelerated from the early 2013. This provides the reasonable explanation for the parallel paths of the increasing popularity of streaming and conspicuous growth of live music after 2010 and onwards.

Self-propagating function incorporated in live music industry

With the hypothesis that the possible resurgence of live music can be the result of its successful assimilation of preceding digital innovation accumulated in streaming music. This set of innovation also assimilated the preceding innovation from downloading music. We expect to see that this assimilation would be a driving force for the resurgence of live music industry (see detailed mathematical development of the assimilation dynamism in Publication PVI).

The trends in the assimilation capacity and gross assets of live music in the US over the period of 2006-2015 were measured as demonstrated in Figure 30. With the dramatic increase in live music's assimilation capacity of its preceding digital innovations particularly after Jun. 2013, the share of assimilated assets in live music has significantly increased, reached up to 50% of its indigenous assets in 2015. The significant assimilation of digital innovation (through the co-evolution with streaming music) enabled live music to incorporate a self-propagating function which enhances the functionality of live music. Higher functionality prolongs the lifetime of live music and lowers its obsolescence rate that contributes to increase its revenues and assets.

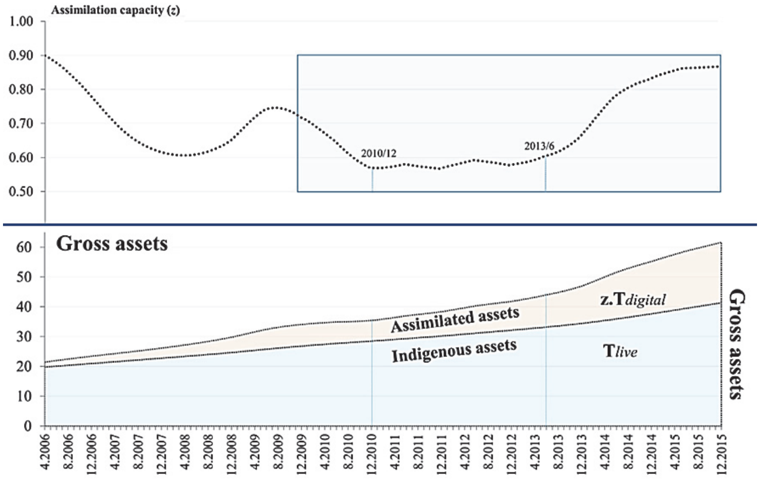


FIGURE 30 Trends in assimilation capacity and gross assets in the US live music industry
Original source: (Publication PVI)

Transformation into a "live concert streaming music industry"

After the above analyses of successful co-evolution between streaming and live music and their assimilation of preceding innovations, authors concern goes to analyze, whether the resurgence of music industry is based on sustainable structure or a transient phenomenon. To answer this question, this research analyzes the structure governing the future trends in the respective music industries and the tasks to be carried out to maintain the co-evolution of live and digital music initiated by streaming music.

By utilizing the hybrid logistic growth model (HLG Watanabe Naveed model, see details in Publication PVII), monthly trend in revenues of physical, digital and live music over the period of 1985 to 2015 were estimated and its fitness with the actual trends were evaluated. With the confirmation of the reliability of results, the future prospects of revenues towards 2030 were forecasted as illustrated in Figure 31.

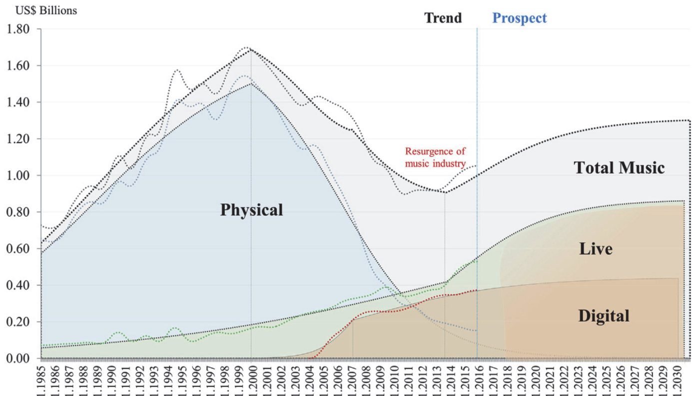


FIGURE 31 Trends and future prospects of the US music industry
Original source: (Publication PVI)

The Figure 31 illustrates that the improving trends in revenues of live and digital music suggest a possible resurgence of music industry as a whole, from its lowest point in early 2010. These trends of prospect resurgence is based on the co-evolution of streaming and live music, therefore it should be noted that the co-existence of two sectors in same industry does not necessarily means co-evolvement as sometimes they substitute and diminish each other (as we observed in case of downloading and streaming music) and this phenomenon is beyond the objectives of this analysis. Figure 32 presents the detailed evolution and direction of music industry toward a live concert streaming industry (see details in Publication PVI). It is intelligently developing the business models for the "C*ommodification of Memory and Dream*" of consumers by incorporating latest digital technologies (e.g. M-Learning, S-recognition, MIR, VR, AR etc.).

FIGURE 32 Evolution of music industry towards live concert streaming music industry
Original source: (Publication PVI)

6.1.2 Case 2: Uber's ride sharing revolution

This section analyses the digitization of New York City taxi industry by rides-haring platform company Uber.

The dramatic advancement of ICT has brought a new reality in recent years, in which information, people, organization, logistics, and finance are constantly connected globally and influence each other. This interaction allows the creation of new type of industries and businesses never possible before. Avital et al. (2014) stressed that an economy (sharing economy) based on the exchange of capital, assets and services between individuals has grown significantly, spurred by the proliferation of Internet-based platforms that allow people to share underutilized resources and trade with reasonable transaction costs. The sharing economy platforms such as Uber, Airbnb etc. has facilitated the exchange of goods and services between individuals. There is also a growing trend of renting a product or service rather than owning it. The success of Uber also witnessed this shifting consumer preference towards mobility as a service rather than vehicle as a product.

This emerging paradigm is disruptive to the conventional company-driven economic paradigm as evident by a large number of peer-to-peer based services (Avital et al., 2014), and Uber is one of the example. Isaac et al. (2014) considered Uber as one of the most disruptive, successful tech-startup company which has severely disrupted the taxi service industry by efficient and innovative use of digital technologies. Horpedahl (2015) highlighted that smartphone apps allow consumers to bypass traditional taxicabs.

Ride-sharing company Uber is a high-tech company founded in March 2009. It is seen as the jewel of ICT as it brilliantly connects the transportation industry with ICT via its ride-sharing application. Uber leverages the sharing economy revolution (Belk, 2014), leading to the transformation of the market for taxi cabs and limousines.

As of June 2016, Uber offers its service in over 479 cities worldwide as demonstrated in Figure 33.

FIGURE 33 Uber's worldwide expansion in 479 cities (as of June 2016)
Original source: (Publication PVIII)

Uber is regarded as the highest-valued venture supported company and one of the fastest growing startups worldwide.

Uber is perceived by passengers as a better service with cost and time savings in reaching a location. Its system is also convenient for drivers as they can work in flexible hours and have a choice to reject unwanted clients. Through their cashless system based on credit cards, Uber can trace and choose highly rated drivers. Reliance on digital technology provides passengers with a transparent view of quality and prices. Similarly, drivers can give feedback on passenger's behavior. Thus, Uber has established a mutual rating system among the company, drivers, and passengers.

Medallion prices as a proxy for the trend in taxi demand

Every New York City (NYC) yellow taxi needs a medallion which is like a license to operate legally. Drivers can lease or buy them. NYC announces limited number of medallions and scarcity made medallions seemingly a safe investment (Rossel, 2017).

The medallion system is in place since 1937 that sets an upper limit of the number of those cabs with licenses. As the demand grew, medallions became more and more valuable, resulting in higher medallions prices. Therefore, the trend in medallion prices can be considered as a proxy for a trend in taxi demand and given its sustainable increase, taxi medallions were considered the best investment compared to gold in the US (Badger, 2014). Thus, this continuously increasing trend led to a sharp hike in medallion prices from 250 thousand US$ in January 2004 to a peak of 1.3 million US$ (for the corporate sector) in June 2013, as demonstrated in Figure 35A.

However, starting in May 2011, Uber added more and more drivers, the medallion prices started to stagnate after a peak in June 2013. The prices then fell precipitously from May 2014, corresponding to the time when Uber's prices reached the level of taxi's prices as demonstrated in Figure 35B.

Trend in the substitution for taxi

Figure 34 demonstrates trends in taxi trips, revenues, and prices in NYC over the period of Jun-2013 to Sep-2015. As a consequence of Uber's astounding rise the number of taxi trips rapidly declined (Figure 34A), which resulted in their revenue decline (Figure 34B), and subsequent increase in their prices (Figure 34C).

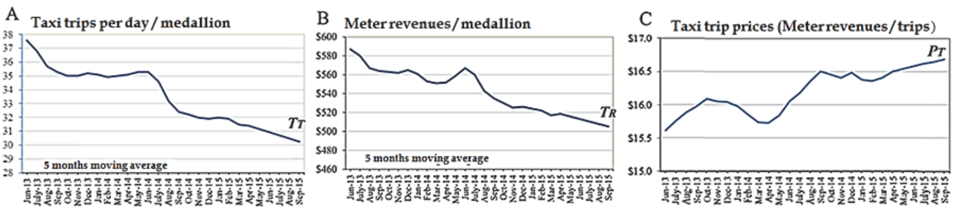


FIGURE 34 Trend in taxi trips, meter revenues and taxi prices in NYC
Original source: (Publication PVII)

Comparison of trips and prices between Uber and Taxi

Figure 35B compare the trends in average number of trips and Figure 35C compares the trends in average price per trip between Uber and taxi in NYC over the period of May-2011 to Sep-2015.

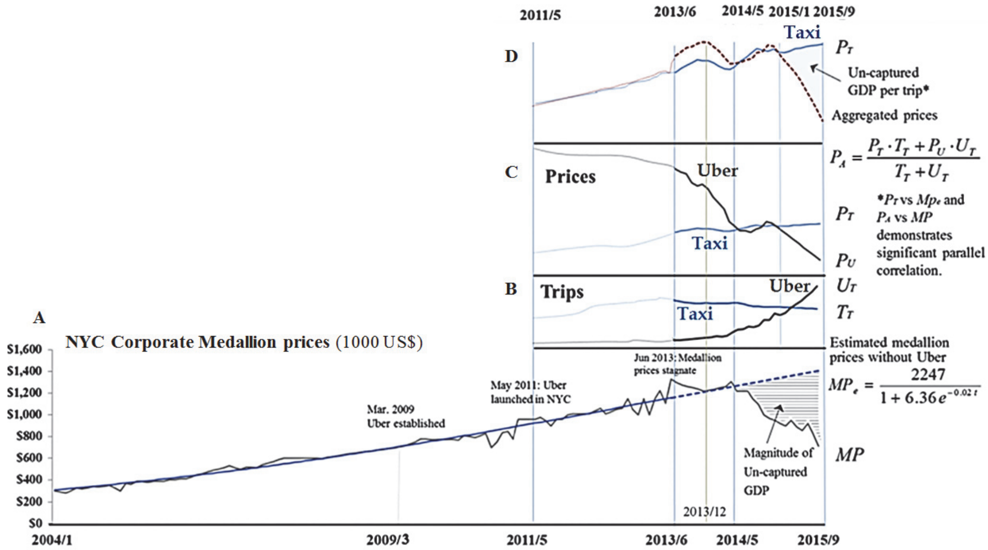


FIGURE 35 Trends in medallion prices, trips, prices and aggregated prices and measurement of uncaptured GDP in NYC (Jun 2013 – Sep 2015)
Original source: (Publication PVII)

Correlation between dependency on Uber and medallion prices

More trips are booked through Uber, the less money taxi drivers make and worse the taxi medallions look like as an investment. Medallion prices started to drop continuously after Uber's prices declined to the level below the traditional taxi prices in May 2014.

Figure 36 illustrates the correlation between dependency on Uber (share of Uber trips out of sum of Uber and taxi trips) and medallion prices (as a proxy of taxi demand) in NYC over the period of Jun-2013 – Sep-2015. The declining medallion prices and increasing dependency on Uber can be the structural sources of astounding rise of Uber.

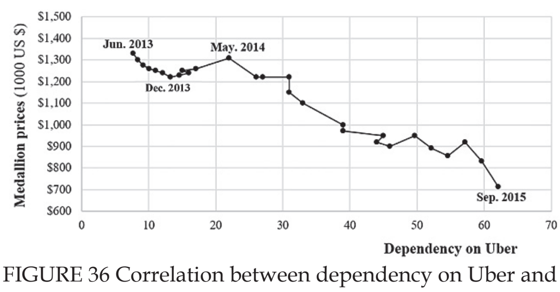


FIGURE 36 Correlation between dependency on Uber and medallion prices in NYC
Original source: (Publication PVII)

Magnitude of emergence of uncaptured GDP

The discrepancy between actual medallion prices and estimated medallion prices without Uber can be considered as uncaptured GDP as demonstrated in

Figure 35A. The uncaptured GDP emerged by Uber can be captured by measuring the discrepancy between taxi prices and magnitude of their decline effect derived from Uber as illustrated in Figure 35D. So the magnitude of declining effect can be measured by the balance of taxi prices and aggregated prices of taxi and Uber with respective share of trips. Figure 37A demonstrates the trends in emerging uncaptured GDP and Figure 37B presents uncaptured GDP per trip induced by Uber, and since the beginning of 2015 it has been increasing significantly.

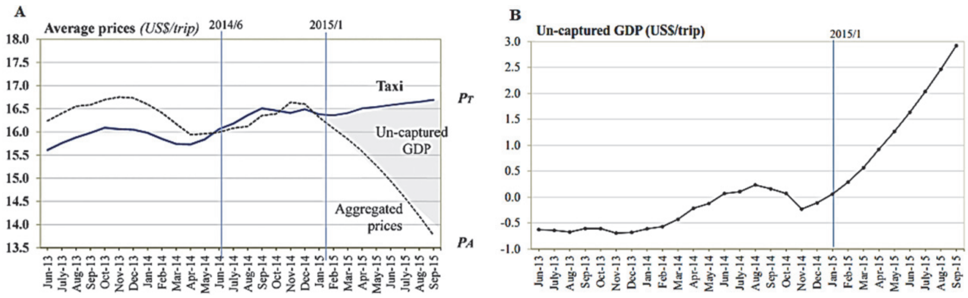


FIGURE 37 Comparison between taxi and aggregated prices, and emergence of uncaptured GDP due to Uber in NYC (Jun.2013 - Sep. 2015)
Original source: (Publication PVII)

Spinoff from Taxi (traditional) to Uber (Sharing economy)

Uber's conspicuous virtuous cycle between prices decline and increased trips can largely be attributed to its self-propagating function incorporating new functionality development during its diffusion process. Diffusion trajectory of innovative goods can be depicted by the simple logistic growth function (SLG) and the level of carrying capacity is assumed to be constant. However in particular innovations the interaction between innovation and institutions displays a systematic change in the process of growth and maturity that leads to the creation of a new carrying capacity. Such innovations can be depicted by logistic growth within a dynamic carrying capacity (LGDCC) function that demonstrates the level of carrying capacity enhancement as the diffusion proceeds (Meyer et al., 1999).

So authors have compared the self-propagating function in taxi and Uber by examining their adaptability to LGDCC (See details in Table 6, Publication PVIII). It's observed that the diffusion of taxi is better explained by the SLG and Uber demonstrated higher statistical significance for LGDCC. This demonstrates that the Uber has developed the self-propagating functionality that dynamically increasing its carrying capacity.

The self-propagating function plays a vital role in spinning off from traditional to more sophisticated co-evolutional dynamism as demonstrated between taxi and Uber. The sharing economy platform company: Uber have managed to pull costs down and improve the quality of service by the innovative utilization of modern technologies and untapped resources (drivers, cars in case of Uber).

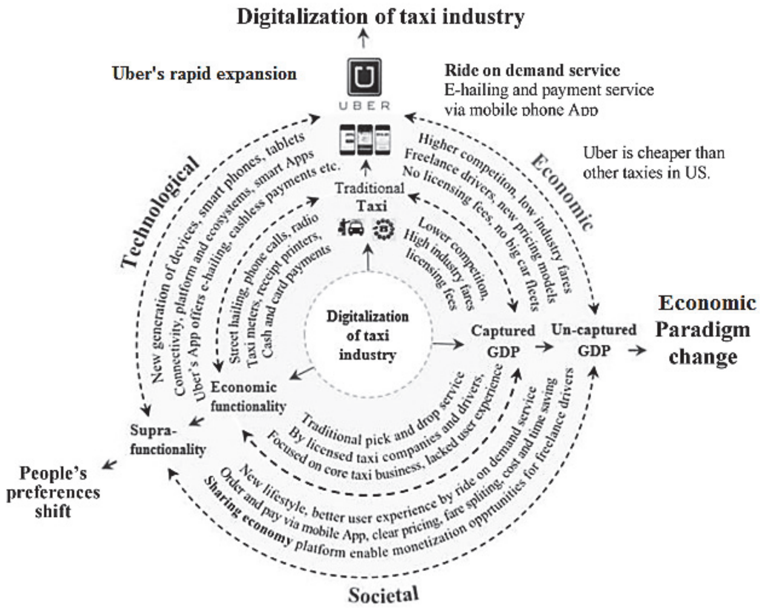


FIGURE 38 Co-evolutional spinoff dynamism from taxi to Uber
Original source: (Publication PVII)

Uber's ICT-driven disruptive business model can be appreciated as a fore-runner in the transformation of a new business design. Figure 38 by using the co-evolutional framework compares some noteworthy features of the taxi and Uber.

6.1.3 Case 3: Uber's consolidation challenges with institutions

This section analyses the legal battles faced by Uber in its global expansion, to demonstrate the consolidation and integration challenges faced by new disruptive innovations with existing private and public institutions.

Uber is currently one of the fastest growing start-ups worldwide. However, this rapid global expansion has resulted in the emergence of legal battles in some cities around the world (Arvind et al., 2014). In several countries the taxi drivers and labor unions protested against Uber and called it as unethical, illegal and unfair and demanded governments to ban Uber. They questioned about the legality of hiring private citizens as drivers because unlike licensed taxi drivers, private citizens providing ride-sharing services do not necessarily carry driver licenses, take license exams, purchase commercial insurances or even honor all ride requests. The licensed taxi drivers complained Uber as unfair competition as they are saddled with greater costs that hamper their ability to compete with ride sharing services (Arvind et al., 2014). Some people called Uber as tax confusion or exploiting the loop holes in the existing system and legal laws. Nowadays sharing economy platforms such as Uber are on the rise. The numbers of researchers have discussed issues in the rationale of sharing economy or Uber's ridesharing service in particular. Some discussed its negative impacts (Cannon et al. 2015; Arvind et al., 2014; Cheng, 2014; Mastrorillo, 2016), while others have positive thoughts (Rogers, 2015), and few of the researchers have different point of view about the whole issue (Cusumano, 2015).

As reviewed in previous section that every NYC yellow taxi needs an expensive medallion license and they usually buy it on credit or lease. With increasing substitution of taxi by Uber, their demand decreases so as their revenues, and it became difficult to pay their fixed costs. On the other hand, Uber has lower fixed costs because their service is provided by private drivers using their own cars, so Uber kept lowering their prices that further increased their demand. Thus it became very difficult for traditional NYC taxi industry using traditional business model to compete with new and innovative ICT-driven disruptive business model (IDBM) incorporated by Uber.

This unique feature of Uber's IDBM and innovative use of technology enabled them to offer higher functionality at lower price that further increased its demand. Uber's virtuous cycle can be attributed to ICT's self-propagating function that enhances the level of functionality as its diffusion proceeds. By comparing development trajectories between taxis and Uber in NYC (see details in Table 2, Publication PVIII), we noted that, while the development of taxis depended on simple logistic growth (*SLG*) with constant carrying capacity through its development process, Uber's development depended on *LGDCC* thereby it enjoyed self-propagating functionality development.

Uber's rapid global expansion and legal battles

The digital platforms have the ability to scale and expand very quickly.
The rapid expansion of Uber can be attributed to its innovative ICT-driven disruptive business model and its indigenous nature of self-propagating functionality development.

During rapid global expansion to over 479 cities as of June 2016, Uber faced legal battles in several cities and countries as demonstrated in Figure 39.

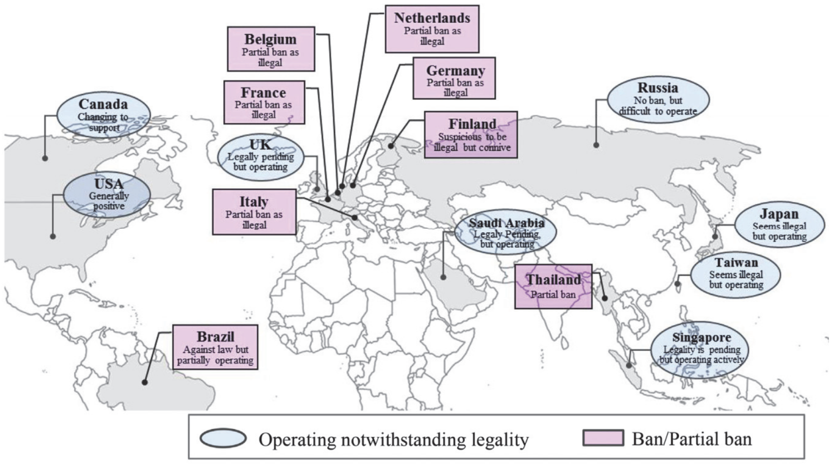


FIGURE 39 Contrasting features of Uber's global expansion in 16 countries (as of June 2016). Original source: (Publication PVIII)

Typical cases include: Thailand, which has completely banned Uber as illegal. Germany banned certain services same as France, Italy, Belgium, Netherland, Finland and Brazil. In some countries the Uber continues to operate notwithstanding its legal issues such as in USA, Singapore, Saudi Arabia, London, Tokyo, Taiwan, Canada and Russia etc. The success and failure of Uber also remind us another indigenous function of ICT development that is bi-polarization. Bi-polarization demonstrates that ICT incorporates two-faced nature and ICT-driven development can be split into virtuous or vicious cycles.

Adaption to institutional systems

This research has conducted detailed analysis of Uber’s expansion and their legal battles in 16 countries. The empirical analysis found that the legal conflict of Uber can be attributed to its co-evolution or dis-engagement with institutions depending on the velocity of Uber’s expansion (its growth rate) and institutional elasticity of the host city or country.

While the rapid growth of technological development, significantly enhances its functionality level but it does not give sufficient time for the host to develop necessary routinization. It can restrict the necessary interaction with institutions that should be developed in self-propagating manner, and it is a necessary condition for the successful adaption of ICT-driven innovations similar to Uber, so the optimal velocity of growth is very crucial.

The other important factor is the institutional elasticity of the host because non-elastic institutions apt to internal regulations and protect vested interests of incumbent organizations. With an understanding that there exists a certain threshold resisting innovation (Oreg et al., 2015), Figure 40 illustrates the scheme of adaption of Uber in institutional systems in different host cities or countries.

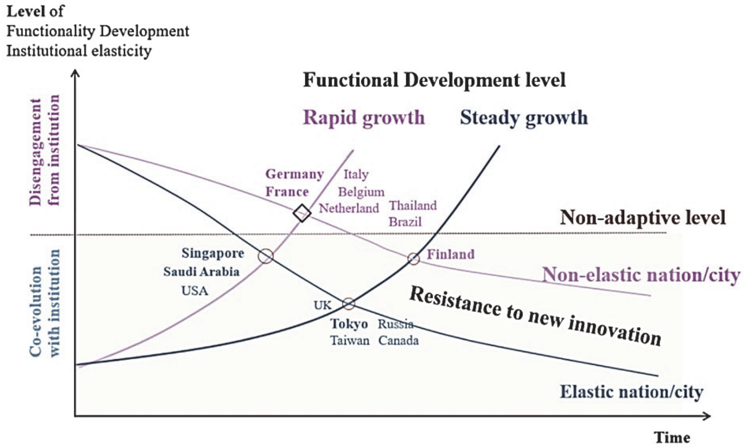


FIGURE 40 Adaption of Uber in institutional systems
Original source: (Publication PVIII)

For example, the legal battles in Germany and France can be attributed to rapid growth in their non-elastic institutions, while relatively mild state in Finland notwithstanding its non-elastic institutions can be attributed to Uber's steady growth. Active operation in Singapore and Saudi Arabia notwithstanding legality can be attributed to a co-evolution with their elastic institutions which induces Uber's rapid growth in these countries. Tokyo's steady operation notwithstanding possible illegality can be attributed to its institutional elasticity with demanding nature in matured competitive environment and Uber's steady growth.

ICT-driven disruptive business model with consolidated challenge to social demand (CCSD)

Nowadays a key factor in obtaining a business opportunity is the ability to solve a social problem and by fulfilling a social demand. Uber has developed a digital platform supported by an innovative business model and managed to disrupt the traditional taxi industry by creating a social demand by providing better user experience on comparatively affordable prices, and denoted as "ICT-driven disruptive business model". Uber has managed to create a social demand successfully but as it is evident through the analysis of Uber's global expansion that they faced lot of challenges and legal battles. And through our empirical analyses we found that the diffusion velocity and institutional elasticity of host determined the adaption of Uber.

Notably those countries or cities without legal battles have constructed co-evolutionary acclimatization system by starting a consolidation dialogue with broader stakeholders to develop mutual trust. One of its successful examples is the tri-partism framework introduced by Singapore. The objective of this forum is forging consensus in developing strategies for the development of benefits for employers, workers and society and take action to achieve sustainable national growth. Such frameworks facilitate the consolidation dialogue between broader stakeholders including companies, employers, users and governments to discuss their concerns and challenges in solving a social problem or in fulfilling a social demand as demonstrated in Figure 41.

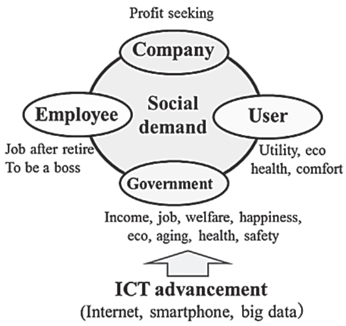


FIGURE 41 Consolidated challenge to social demand dialogue framework
Original source: (Publication PVIII)

Such initiatives help to develop mutual trust among stakeholders and to find a better solution of the social problem. Authors denoted it as "Consolidated challenges to social demand (CCSD)" necessary dialogue for the successful integration of ICT-driven disruptive innovations with institutions by developing systems that addresses demands of different stakeholders' in society as a whole that can allow these disparate groups to successfully function together.

The contrast between countries or cities with and without legal battles can be attributed to with or without CCSD as demonstrated in Figure 42.

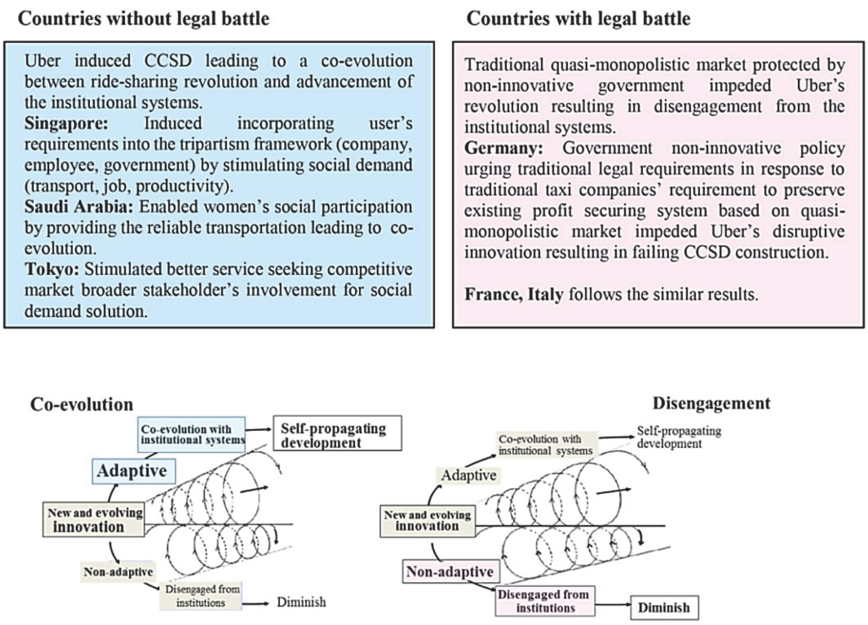


FIGURE 42 Uber's co-evolution and disengagement with host institutions
Original source: (Publication PVIII)

Preceding analysis suggests that ICT-driven disruptive business models with a consolidated challenge to social demand (IDBM - CCSD) would be decisive for resilient IDBM co-evolving with the institutional systems of the host. Uber is encouraging vertical and horizontal integration in the car-hire sector reducing vertical fragmentation within taxi companies, employers and drivers relationship and integrating the sector horizontally. Uber is compiling a massive database of driver and rider behavior essential to price setting and market-making functions thereby reducing horizontal fragmentation of the sector (Rogers, 2015) Thus, Uber can be recognized as incorporating the inherent potential of IDBM with CCSD.

Given such inherent potential, Uber's success in its global expansion depends on the optimization of timing, pace, and selection of the hosts with different social demands suitable enough to constructing co-evolutionary acclimatization.

6.2 Case analyses: National level

By considering the importance of education in the digital economy and demographics of ageing societies particularly in developed countries, higher education and gender equality were selected as case studies for national level analyses.

6.2.1 Case 4: Trust based higher-education towards digitally-rich learning environments

The quality of higher education is crucial for innovation in digital economy and particularly for those countries aiming to move up the value chain beyond simple production processes and products (World Economic Forum, 2013a). Since such quality is subject to trust in teachers for delivering good education (OECD, 2014, Sahlberg, 2010, Stehlik, 2016, Varkey Gems Foundation, 2014) and advancement of ICT leading to digital learning environments (UNESCO, 2003), co-evolution between higher-education, trust in teachers and advancement of ICT have been gaining increasing significance.

This case study aims to explore a new approach for constructing the above mentioned co-evolution in a systematic way. An empirical analysis of twenty countries is conducted by using a unique dataset representing the rate of trust in teachers providing good education (in the context of quality of education and their social status), level of higher education and state of the ICT development. Based on the level of ICT advancement, these countries were classified as ICT advanced countries (IAC), semi-advanced countries (ISC) and growing countries (IGC) based on their level of ICT advancement as demonstrated in Figure 43.

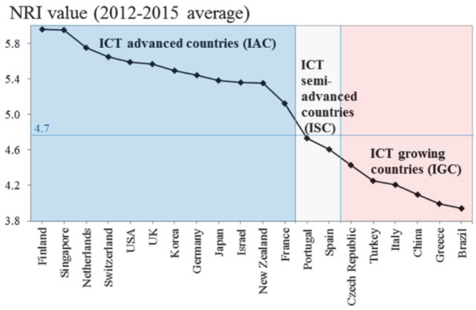


FIGURE 43 The stage of ICT advancement in 20 countries (2012-2015 average)
Original source: (Publication PIX)

Figure 44 presents the level of higher education and level of trust in teachers for delivering good education.

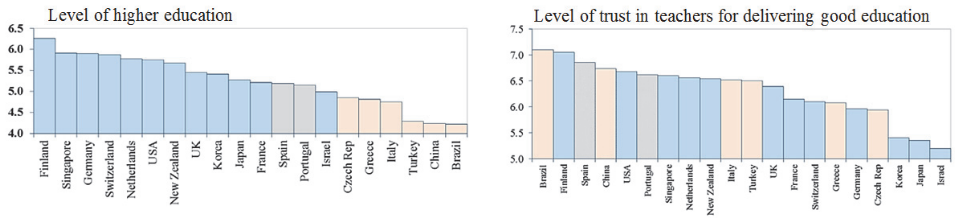


FIGURE 44 The level of higher education, and trust in teachers in 20 countries (2013)
Original source: (Publication PIX)

Co-evolutionary advancement between ICT, trust in teachers and higher education

By utilizing the above data, comparative co-evolution analyses between ICT advancement, trust in teachers and higher education for three different groups of countries as IAC, ISC and IGC, were conducted. On the basis of the empirical analyses results, authors found co-evolution and disengagement as demonstrated by Figure 45.

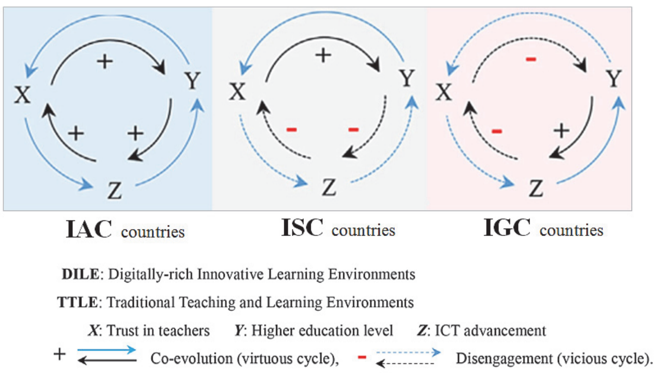


FIGURE 45 Co-evolution and dis-engagement between ICT, education and trust
Original source: (Publication PIX)

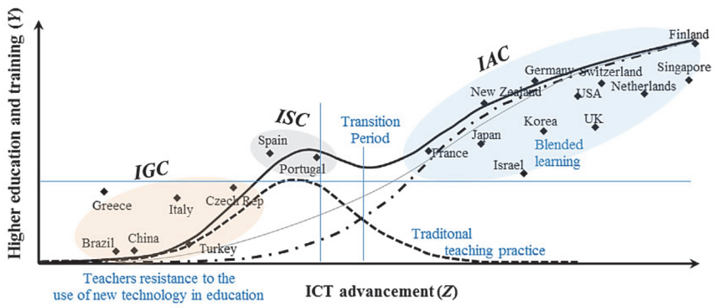


FIGURE 46 State of hybrid development in 20 countries
Original source: (Publication PIX)

Figure 46 presents the hybrid development of education in transition from (traditional teaching learning environment (TTLE) to digitally-rich learning environments (DILE).

Based on the above results, it was observed that the ICT-driven trust-based higher education is becoming crucial for national competitiveness in the digital economy. In Digitally-rich learning environments (DILE), ICT advancement, higher education and trust in teachers are closely interweaved with each other. The developed countries are shifting from traditional teaching and learning environments (TTLE) to modern (DILE). Given the significant shift from traditional teaching practice to blended learning towards DILE, the performance of education in each country depends on the stage of their shift between TTLE to DILE. The detailed findings and suggestions for each group are as follows:

IAC countries – shifted to DILE

According to our analysis, IAC countries have shifted to DILE by successfully constructing the co-evolutionary dynamism between ICT, higher education and trust. IAC countries should maintain their innovation efforts to further improve the level of DILE by leveraging ICT.

The transfer of knowledge and experiences of IAC countries can be a huge support for ISC and IGC countries for their successful transition from TTLE to DILE.

While IAC countries have high level of knowledge in DILE, but they are facing the problem of low economic growth, the IGC countries have high growth potential but they are striving to improve their education systems, so by collaborating and harnessing the potential of each other should be another priority.

ISC countries – In transition from TTLE to DILE

ISC countries are in transition phase from TTLE to DILE and their bigger challenge is to effectively utilize the ICT resources for raising the standard of their higher education level. ISC countries should capitalize their successful co-evolution between trust and education and by further leveraging ICT resources in education would be helpful for them to transform TTLE to DILE.

IGC countries – Remained in TTLE

IGC countries remained in TTLE, because of their disengagement due to the mismatch between ICT advancement and trust in teachers. This means that with the advancement in ICT in IGC counties, the trust on teachers is decreasing. One of the possible reasons could be the low standard of teachers' knowledge stock and their resistance to adopt new technologies. As the students are getting access to online learning resources, their trust on teachers is decreasing. The IGC countries should encourage teachers to use digital technologies in their teaching practices. Introduction of teachers training programs related to the teacher's own topic (pedagogy) and for using digital learning technologies and resources (technology) can be very helpful. IGC countries should leverage ICT for the systematic and stepwise transformation (introduction, absorption, application, diffusion and transformation) of traditional (TTLE) toward digitally-rich learning environments. The collaborations with ISC and IAC countries should be encouraged to learn from their experiences of transition from TTLE to DILE. Consistent effort for a steady shift to DILE should be made in a systematic way while maintaining an optimal balance with TTLE.

6.2.2 Case 5: Harnessing women's potential

To deal with the future challenges of digital economy, harnessing untapped resources has become essential for inclusive growth particularly in developed countries due to their rapidly growing demographics of ageing. Harnessing women's economic potential is one of the urgent subjects in this context and successive initiatives have been taken in many countries.

However, given the institutional complexity of the issue, as well as considerable variety across nations, uniformed non-systematic approaches are hardly satisfactory in achieving timely solution. Using a unique dataset representing the state of gender balance improvement, an empirical analysis of 44 countries was attempted.

Pathways to gender-balanced organizational leadership

The growing participation of women in the labor market has been a major engine for global growth and competitiveness (International Labour Organization, 2015) at national and enterprise levels. Bridging gender divide is not only a matter of fairness but also one of the effective governance and inclusive growth strategies (OECD, 2016). Gender balance improvement can be monitored using the Gender Balance Index (GBI) demonstrating the share of women on boards, which represents the state of gender parity as demonstrated in Figure 47.

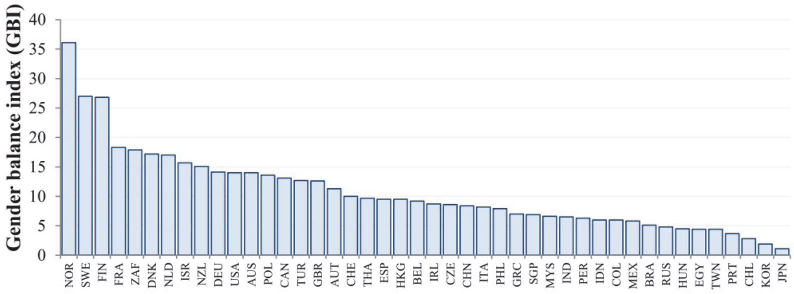


FIGURE 47 Gender balance index (GBI) in 44 countries (2013)
Original source: (Publication PX)

Since gender balance improvement is influenced by income level, gender balance intensity (GBI/GDP per capita) can be an effective supportive tool in identifying the state of gender balance improvement. Furthermore, gender balance improvement is subject not only to income level but also to cultural dimensions, particularly to "muscularity" and "individualism."

Taking these dimensions into account, the gender balance intensity level in 44 countries can be classified into three clusters, emerging countries (EMC), industrialized countries (INC), and countries with a specific culture based on their traditions of a male-dominated society (CSC) as demonstrated by Figure 48.

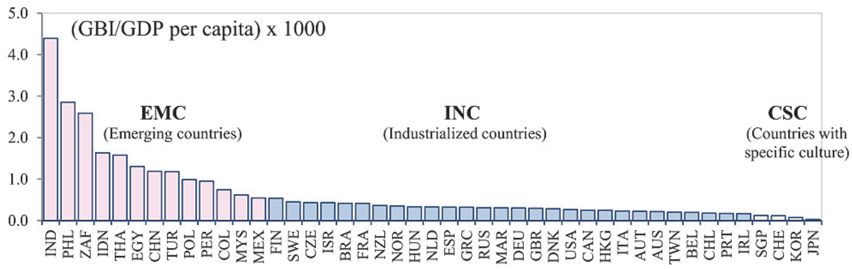


FIGURE 48 Gender balance intensity in 44 countries by 3 clusters (2013)
Original source: (Publication PX)

Gender balanced leadership in the digital economy

Based on the understanding that harnessing women's potential by improving gender balance is essential for inclusive growth in the digital economy and that this issue is subject not only to income level but also to the cultural dimensions. The tri-lateral co-evolution (Figure 49) between "econo-cultural development", gender balance improvement and ICT advancement was analyzed by taking the "econo-cultural position" of respective countries into account (see details in Publication PX).

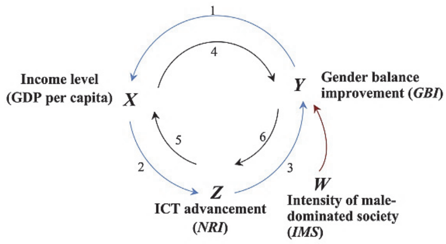


FIGURE 49 Co-evolutionary dynamism for gender balanced leadership
Original source: (Publication PX)

The Figure 50 presents the correlation graphs and Table 4 demonstrates the results of the detailed tri-lateral co-evolution analyses.

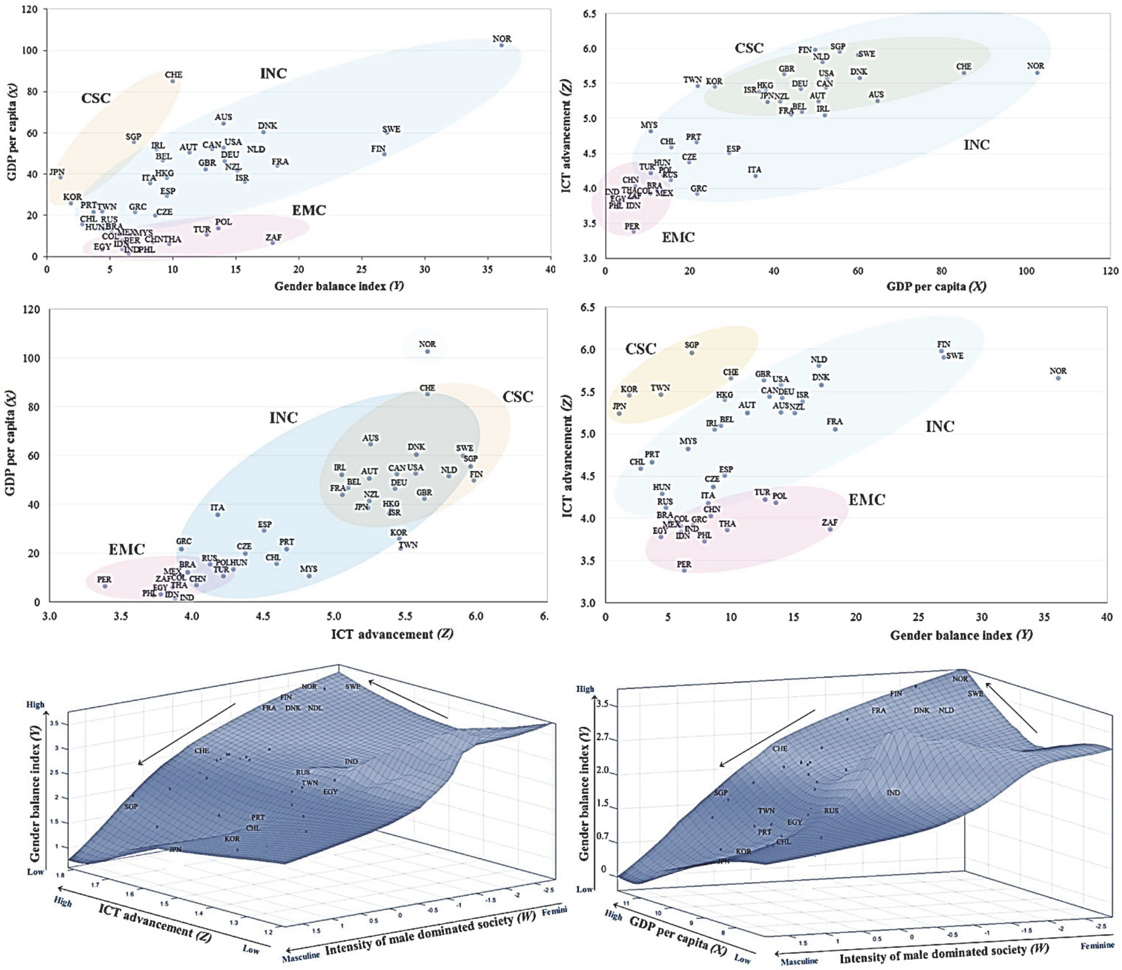


FIGURE 50 Correlation analyses between GBI, income level, ICT advancement and intensity of male dominated society
Original source: (Publication PX)

TABLE 4 Elasticities of co-evolution in 44 countries (2013)

	Emerging countries (EMC)	Industrialized countries (INC)	Countries with specific culture (CSC)
1 $Y \rightarrow X$	0.21	0.86	1.26
2 $X \rightarrow Z$	0.12	0.12	0.13
3 $Z \rightarrow Y$	2.63	2.12	2.05
$W \rightarrow Y$	−0.41	−0.37	−2.49
4 $X \rightarrow Y$	0.56	0.44	0.41
$W \rightarrow Y$	−0.48	−0.32	−0.89
5 $Z \rightarrow X$	3.03	3.58	3.56
6 $Y \rightarrow Z$	0.06	0.16	0.09

X: Income level (GDP per capita), *Y*: Gender balance improvement (*GBI*).
Z: ICT advancement (*NRI*), *W*: Intensity of male-dominated society (*IMS*).

Original source: (Publication PX)

According to our analyses, the INCs demonstrate explicit performance in trilateral co-evolution between "econo-cultural development," gender balance improvement and ICT advancement. This explicit performance can be attributed to their high level of elasticity of gender balance improvement to ICT advancement. EMCs demonstrate the lowest performance in trilateral co-evolution, notwithstanding the highest elasticity of growth to gender balance improvement. However, it is anticipated that once sufficient ICT advancement prevails, a virtuous cycle leading to income growth and gender balance improvement can be expected. Notwithstanding their high level of income and ICT advancement, CSCs remain at the lowest level of gender balance intensity, which can be attributed to their traditional high intensity of male-dominated society.

Strategies for emerging countries – ICT-driven economic growth

Based on the following understandings that
ICT advancement ⟶ income growth ⟶ gender balance improvement
and that the ICT advancement incorporates a potential that enables all nations to attain a similar income level, the possible ICT-driven income growth trajectories in EMCs, INCs and CSCs are estimated. The estimation was conducted by using the hybrid logistic growth model (see details in Publication PVI) depicting identical development trajectories depending on countries' respective econo-cultural positions.

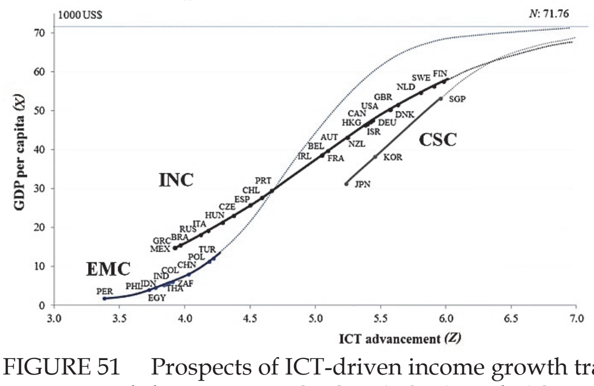


FIGURE 51 Prospects of ICT-driven income growth trajectories
39 countries excluding 5 countries NOR, CHE, AUS, TWN and MYS.
Original source: (Publication PX)

The results of the analysis in Figure 51 suggests that given the sufficient ICT advancement, the EMCs countries have a rapid growth potential in their ICT-driven income trajectory because of their "early minority stage", this provide them the opportunity to accelerate its diffusion velocity (Rogers, 1962). From these observations it's estimated that the EMCs have extremely high growth potential (3 times higher than INCs and CSCs).

This research suggests that the key sustainable strategy for EMCs is to first improve their income level through enhancing ICT facilities that will help to further improve their gender balance. Given the lack of indigenous capacity to achieve ICT advancement, the EMCs can collaborate with INCs and CSCs to extend their ICT advancement facilities in exchange to get benefits from the growth potential of EMCs, thereby harnessing the strengths of each other.

Strategies for countries with a specific culture – IMS and the improvement of ICT advancement

An explicit contrast between INCs and CSCs regarding their gender balance improvement notwithstanding their similarities in ICT advancement and income levels is observed. The comparative analysis of INCs and CSCs countries can provide insightful suggestions for CSCs regarding the gender balance improvements. In this context the contrasting development trajectories of Finland (the leading INC) and Japan (typical CSC) was analyzed by comparing their trends in share of women directors in both countries for the period of 2001-2016.

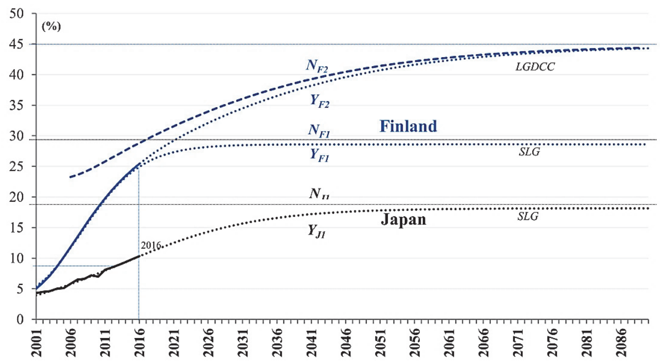


FIGURE 52 Trends and prospects of women directors share in Finland and Japan (%)
Y_1: Trajectory without self-propagating function. Y_2: Trajectory with self-propagating function.
N_1: Carrying capacity in SLG. N_2: Carrying capacity in LGDCC.
Original source: (Publication PX)

The Figure 52 presents the trends and prospects for Finland and Japan based on our analysis results (See details in Table 9, Watanabe et al., 2017c). It suggests that the potential prospect for maximum share of women directors' in Japan (Y_{J1}) remains at 18%, while Finland can increase it up to 45% (Y_{F2}). This higher level in Finland is subjected to the incorporation of the self-propagating function, without which the maximum level would remain at 29% (Y_{F1}). This it suggests the significance of self-propagating function for sustainable gender balance improvement in the digital economy. Among INCs, Finland has demonstrated high performance in trilateral co-evolution by incorporating a self-propagating function in the gender balance improvement trajectory, while Japan (which lags significantly behind among 44 countries) was unable to incorporate this function primarily due to its male- dominated culture.

Based on the findings of all preceding analyses, lessons from industrialized countries for both emerging countries and countries with specific culture were analyzed. It was suggested that ICT should be strategically advanced depending on the state of what we are calling "econo-cultural development" for constructing co-evolution of gender balance improvement along with techno-economic development.

7 TRANSFORMATIVE DIRECTION OF INNOVATION

This chapter analyzes the transformative direction of innovation in global ICT firms. With the Internet of Things (IoT), the physical world is becoming an ecosystem composed of digital objects embedded with sensors and actuators connected to applications and services through a wide range of networks. IoT has the potential to drive next steps toward the digitization of our society and economy (EU, 2017) and wide adoption of IoT is expected to generate significant revenues to the providers of its applications and services (Mazhelis et al., 2012). Firms that use the IoT in novel ways to develop their new business models or discover new ways to monetize IoT data are likely to enjoy more sustainable benefits. (McKinsey Global Institute, 2011, 2015). To capitalize the future opportunities of digitization, the global ICT firms are quickly embracing digital solutions, restructuring their business model and business strategies.

This research analyzes the transformative direction of innovation by conducting an empirical analysis of top 500 global ICT firms over the period of 2005-2016 with emphasis on their special features of soft value innovation.

It was identified that high R&D-intensive firms have fallen into a trap of ICT advancement, resulting in a decline of their marginal productivity of ICT that could be due to increasing dependency on uncaptured GDP. As a result, these firms are harnessing soft innovation resources by activating a self-propagating function that induces functionality development by incorporating more sophisticated business models and business strategies as demonstrated by the following section.

7.1 Transformative direction of high R&D intensive firms

The dynamism of functionality development reflecting the transformative efforts initiated by the global ICT firms in competitive environment is presented in Figure 53**.** This dynamism corresponds to the increase in supra-functionality beyond economic value and is induced by the self-propagating function, which can be activated by harnessing the vigor of the following soft innovation resources:

- People's preference shift to supra-functionality beyond economic value
- Sleeping resources as the ridesharing revolution
- Trust by overdrawing past information
- Utmost gratification ever experienced
- Memory and dream
- Untapped resources and vision

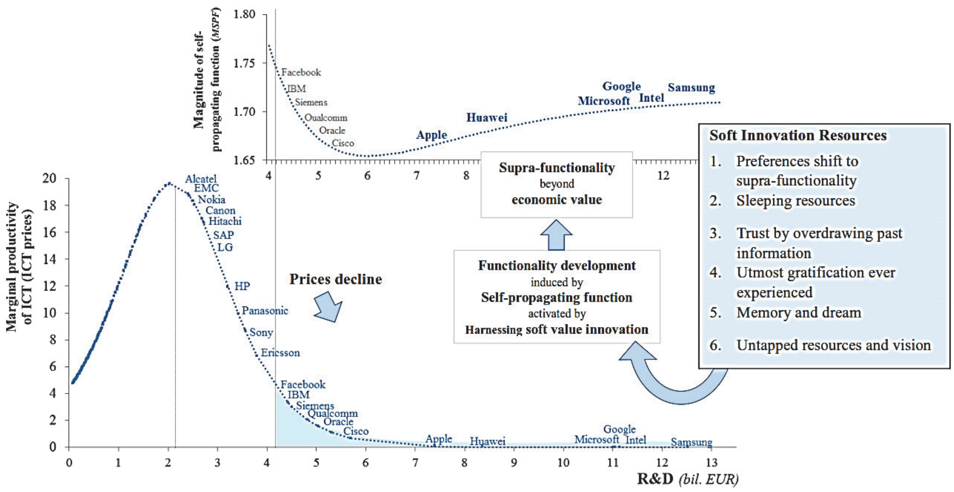


FIGURE 53 Transformative direction of high R&D-intensive global ICT firms (2016)
Original source: (Publication PXI)

Figure 54 presents the soft value innovation initiatives and transformative direction of high R&D intensive ICT firms.

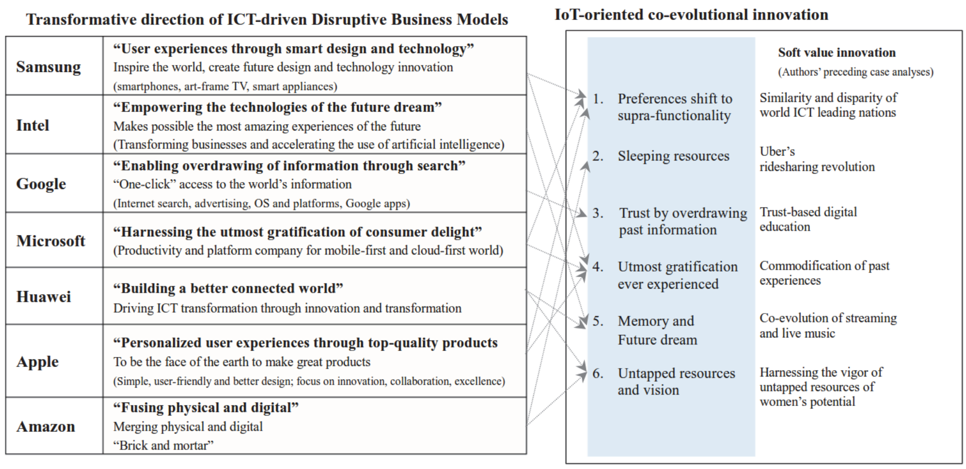


FIGURE 54 Transformative directions of ICT-driven disruptive business models
Original source: (Publication PXI)

Harnessing soft innovation resources corresponds to maintaining sustainable growth by means of the gross GDP, including uncaptured GDP satisfies people's preference shift to supra-functionality beyond economic value.

7.2 Spin-off dynamism of increasing dependency on uncaptured GDP

Based on the preceding confidence, Figure 55 illustrates a platform which demonstrates spin-off dynamism to increase dependency on uncaptured GDP that leads to a new trajectory to sustainable growth in the digital economy.

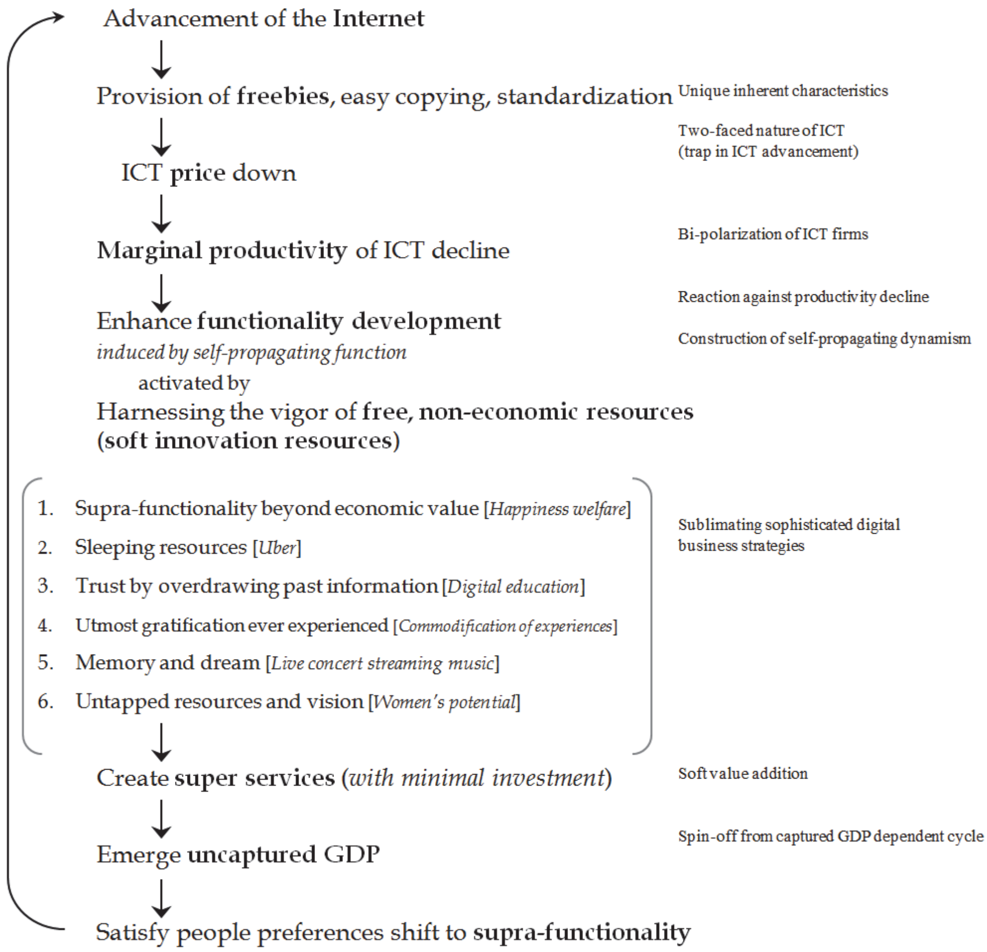


FIGURE 55 Spin-off dynamism stimulating uncaptured GDP
Original source: (Publication PXI)

8 RESEARCH METHODOLOGY

8.1 Basic methodology

Research methodologies used are primarily based on techno-economics analysis and its standard steps are as follows:

1) Intensive comprehensive observations from
   a. Own experiences
   b. Symposium, conference, workshop and seminar
   c. Existing literature, publications and news
2) Formulation of hypothetical views
3) Overview prior demonstration by pioneer studies through literature reviews
4) Identify focal hypothesis which no one has demonstrated
5) Construction of numerical analysis framework

8.2 Numerical analysis

The following numerical methods have been used for the analysis:

1) Production function for the analysis of
   i. Growth
   ii. Contribution to growth
   iii. Productivity
   iv. Substitution of production factors
   v. Profit maximization condition

2) Diffusion function for the analysis of
   i. Diffusion trajectory
   ii. Functionality development
   iii. Substitution of consumer preference

3) Consumption function for the analysis of
   i. Consumption trend
   ii. Utility of consumption

iii. Uncaptured GDP

4) Learning and spillover theory for the analysis of

i. Effects of learning

ii. Absorption and assimilation capacity

iii. Open innovation

5) Investment return method for the analysis of

i. Internal rate of return to R&D investment

ii. Marginal productivity

iii. Optimal allocation of investment

iv. Optimal time for R&D undertaken

Collection of empirical evidences

1) Expert interviews
2) Survey questionnaires
3) Literature review
4) On-site investigation

Cross evaluation

Cross evaluation between empirical results and empirical evidences

8.3 Mathematical development of analytical framework

The analytical framework used for the analyses is summarized as follows:

$$V = F(X, I_g), \tag{1}$$

where $I_g = I + J$,

and I_g : gross stock, I : ICT stock, and J : Ineternet dependency.

Taylor expansion on the first term:

$$\ln V = p + q \ln X + r \ln I_g, \tag{2}$$

where $p, q,$ and r are coefficients.

I_g embodies into X in the IoT society a

I_g embodies into X in the IoT society as follows:

$$X = F(I_g) \qquad \ln X = p_x + r_x \ln I_g, \tag{3}$$

where p_x, r_x are coefficients.

Synchronizing equations (2) and (3):

$$\ln V = p + q(p_x + r_x \ln I_g) + r \ln I_g = (p + q \cdot p_x) + (q \cdot r_x + r) \ln I_g \equiv \alpha + \beta \ln I_g, \tag{4}$$

where $\alpha = p + q \cdot p_x, \ \beta = q \cdot r_x + r.$

V is governed by I_g under the above circumstances.
As Internet permeates into ICT general, I_g increases proportional to gross R & D (see Note 1).

$$I_g = I + J \approx \frac{R_i}{\rho_i + g_i} + \frac{R_j}{\rho_j + g_j} \approx \frac{R_i}{\rho + g} + \frac{R_j}{\rho + g} = \frac{R_i + R_j}{\rho + g} = \frac{R}{\rho + g}, \tag{5}$$

where R_j : R & D related to Internet, and R_i : R & D related to other ICT;
ρ : rate of obsolescence of ICT, and g : R & D growth rate at the initial stage.

Substituting equation (5) for I_g in equation (4):

$$\ln V = \alpha + \beta \ln \frac{R}{\rho + g} = \alpha - \beta \ln (\rho + g) + \beta \ln R \equiv \alpha' + \beta \ln R, \tag{6}$$

where $\alpha' = \alpha - \beta \ln (\rho + g)$.

Thus, digital value is governed by gross R & D in the global ICT firms in an IoT society.

Given the logistic growth nature of ICT, V can be developed by an R - driven logistic growth function.

$$V \approx F(R), \ \frac{dV}{dR} = \frac{\partial V}{\partial R} \cdot \frac{dR}{dR} = \frac{\partial V}{\partial R} = aV\left(1 - \frac{V}{N}\right), \tag{7}$$

where N : carrying capacity, and a : velocity of diffusion.
Equation (7) develops the following simple logisitc growth function (SLG):

$$V_s(R) = \frac{N}{1 + be^{-aR}}, \tag{8}$$

where b is coefficient indicating the initial level of diffusion.

This leads to bipolarization as follows:

$$be^{-aR} \equiv \frac{1}{x} \quad \frac{\partial V}{\partial R} = aV\left(1 - \frac{V}{N}\right) = aN \cdot \frac{1}{1 + \frac{1}{x}}\left(1 - \frac{1}{1 + \frac{1}{x}}\right) = \frac{aN \cdot x}{(1 + x)^2}. \tag{9}$$

$$\frac{d\frac{\partial V}{\partial R}}{dx} = \frac{d\frac{\partial V}{\partial R}}{dR} \cdot \frac{dR}{dx} = \frac{d\frac{\partial V}{\partial R}}{dR} \cdot \frac{1}{ax} = \frac{1 - x}{(1 + x)^3} \qquad \frac{1}{ax} = \frac{b}{a} e^{-aR} > 0. \tag{10}$$

Digitalization exceeding certain R & D level *(R > ln b/a)* results in productivity decline.

$$\frac{d\,\frac{\partial V}{\partial R}}{dR}=0 \Leftrightarrow x=1 \Leftrightarrow R=\frac{\ln b}{a} \;\;\rightarrow\;\; R>\frac{\ln b}{a} \;\;\Rightarrow \frac{d\,\frac{\partial V}{\partial R}}{dR}<0\,. \tag{11}$$

This decline can be compensated by activating ICTindigenous self - propagating function. This can be enabled by creating new carrying capacity $N(R)$ during the process of diffusion.

$$\frac{dV(R)}{dR}=aV(R)\left(1-\frac{V(R)}{N(R)}\right). \tag{12}$$

Equation (12) develops the following logistic growth within a dynamic carrying capacity ($LGDCC$) function :

$$V_k(R)=\frac{N_k}{1+be^{-aR}+\frac{b_k}{1-a_k/a}e^{-a_kR}}, \tag{13}$$

where N_k : ultimate carrying capacity; a_k and b_k are coefficients indicating self - propagation.

Dynamic carrying can be depicted as follows :

$$N_k(R)=V_k(R)\left(\frac{1}{1-\frac{1}{a}\cdot\frac{\Delta V_k(R)}{V_k(R)}}\right), \tag{14}$$

where $\Delta V_k(R)=\frac{dV_k(R)}{dR}$.

Since functionality devleopment (FD) can be expressed by the ratio of carrying capacity and diffusion level (Watanabe et al., 2003), functionality with self - propagating effect can be depicted as follows :

$$FD=\frac{N_k(R)}{V_k(R)}=\frac{1}{1-\frac{1}{a}\cdot\frac{\Delta V_k(R)}{V_k(R)}}\,. \tag{15}$$

Magnitude of self - propagating function ($MSPF$) can be expressed by means of the ratio of upper limit of the diffusion (dynamic carrying capacity) and diffusion level without self - propagating function (diffusion level by SLF) as follows (Watanabe et al., 2017*c*)

$$MSPF=\frac{N_k(R)}{V_s(R)}=\frac{V_k(R)}{V_s(R)}\cdot\left(\frac{1}{1-\frac{1}{a}\cdot\frac{\Delta V_k(R)}{V_k(R)}}\right)\,. \tag{16}$$

8.4 Data construction for numerical analysis

The data collection from different resources, filtration, conversion and integration of data required lot of working hours, skill and hard work. To produce the high quality research results, all possible efforts were made to assure the quality and integrity of data. In case of doubt, alternative sources were consulted to check the validity of data.

Global institutional performance indicators database

Author has developed a huge database named "global institutional performance indicators database" at the server of University of Jyväskylä. That contains more than 300 institutional and economic indicators for more than 140 countries for several years as demonstrated in Figure 56.

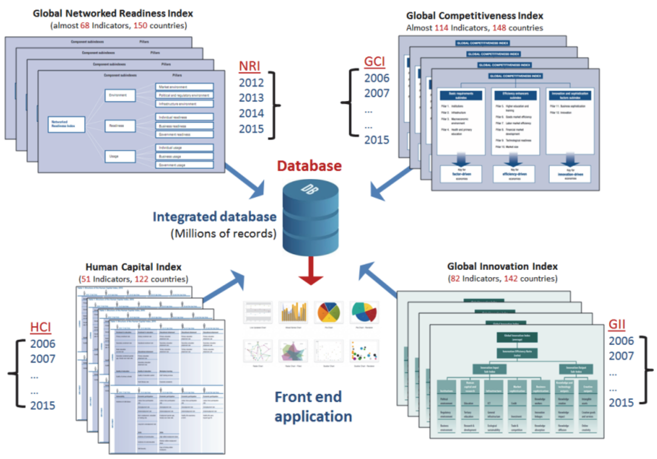


FIGURE 56 Structure of institutional indicators database

The Data sources used in each article

PI – Institutional sources of resilience in global ICT leaders

- The EU Industrial R&D Investment Scoreboard, EU (2004-2013)
- The Networked Readiness Index, World Economic Forum (WEF) (annual issues)
- World Economic Outlook Database, IMF (annual issues)
- Annual reports of ICT firms (1990-2013)

PII – Structural source of the trap of ICT advancement

- The Conference Board - Total Economy database (1950-2015)
- ITU's World Telecommunication Union/ICT indicators database, ITU (1990-2014)
- Japan's Cabinet Office (JCO), (annual issues, 1972-2012)
- The EU Industrial R&D Investment Scoreboard, EU (2004-2013)
- The Networked Readiness Index, WEF(annual issues)

PIII - New paradigm of ICT productivity

- The Conference Board, Total Economy database (1950-2015)
- The Global Information Technology Report, WEF(annual issues)

- Economics of Industrial Research and Innovation, EU (2004-2013)
- World Economic Outlook Database, IMF (annual issues)
- World Telecommunication/ICT Indicators, ITU (1990-2014)
- National Survey of Lifestyles, JCO (1972-2012)
- Annual reports of ICT firms (annual issues)

PIV - Dependency on uncaptured GDP
- The Global Information Technology Reports, WEF (2012- 2014)
- The Global Competitiveness Reports, WEF (2011-2014)
- World Economic Outlook Database, IMF (annual issues)
- The Global Innovation Report, INSEAD, et al. (annual issues)
- World Telecommunication/ICT Indicators, ITU(annual issues)
- World Development Indicators, World Bank (annual issues)
- Finnish and Singapore government official websites
- Statistics Finland (annual issues)

PV – Operationalization of uncaptured GDP
- The Global Information Technology Report, WEF (2012-2014)
- The Global Competitiveness Report, WEF (2011-2014)
- World Economic Outlook Database, IMF (annual issues)
- The Global Innovation Report, INSEAD, et al. (annual issues)
- World Telecommunication/ICT Indicators, ITU (annual issues)
- World Development Indicators, World Bank (annual issues)
- Finnish and Singapore government official websites
- Statistics Finland (annual issues)

PVI - Music industry analysis
- Recording Industry Association of America (RIIA) (1973-2016)
- Pollstar (1960-2016)
- International Federation of Phonography Industry (IFPI) (annual issues)
- Global Music Sales Statistics, Music Ally Data Map (annual issues)

PVII – Disruption of taxi industry by Uber
- NYC Taxi and Limousine Commission (annual issues)
- Uber.com
- Certify, 2015
- ComScore Monthly Reports (monthly issues)
- Online articles, reports, blogs.

PVIII – Uber's legal battles
- NYC Taxi and Limousine Commission (annual issues)
- Uber.com
- NY times, Huffington post, Reuters, WSI, CNN, local news reports
- Global competitiveness report, WEF (2015-2016)
- Online articles, reports, blogs.

PIX – Higher education towards digitally-rich learning environments
- The Global Information Technology Reports, WEF (2012-2015)
- The Global Competitiveness Reports, WEF (2013-2014)
- Global Teachers Status Index, Varkey Gems Foundation (2013)
- World Economic Outlook Database (IMF) (annual issues)
- UNESCO Institute of Statistics (2013)

PX – Harnessing women's potential as untapped resources
- Gender Statistics Database, European Commission (annual issues)
- Global Gender Gap Report, WEF (annual issues)
- GMI Ratings (annual issues)
- Women's Access to Leadership, OECD (annual issues)
- Hofstede's Cultural Dimensions

- Global Information Technology Report, WEF (annual issues)
- Ministry of Health, Labor and Welfare Japan
- FINNCHAM
- Catalyst census

PXI – Transformative direction of Innovation

- The EU Industrial R&D Investment Scoreboard, EU (2004-2016)
- Forbes Global 2000 statistics, Forbes (2005 – 2016)
- Annual reports of ICT firms (annual issues)
- ICT Firms websites, Wikipedia, Google search, research reports etc.

9 OVERVIEW OF THE ARTICLES

9.1 PI - Institutional sources of resilience in global ICT leaders: Harness the vigor of emerging power

Watanabe, C., Naveed, K., Zhao, W., 2014. Institutional sources of resilience in global ICT leaders: Harness the vigor of emerging power. *Journal of Technology Management for Growing Economies* 5(1), 7–34. DOI 10.15415/jtmge.2014.51001

In light of the significant impacts on global economy, both nations and firms witnessed a dramatic advancement of information and communication technology (ICT). The bi-polarization is observed between ICT advanced and ICT growing economies on the basis of their marginal productivity of ICT investments.

In this paper, the institutional sources of resilience were analyzed. On the basis of an empirical analysis comparing techno-preneurial performance in world top 500 ICT firms by market value, sales and profit over the last decade, resilient firms maintaining world top 100 positions by all three values over the whole period were identified. The governing factors of market value in selected 10 resilient ICT firms were analyzed and their noteworthy characteristics of resilience were summarized.

9.2 PII - Structural Source of the trap of ICT advancement: Lessons from world ICT top Leaders

Watanabe, C., Naveed, K., Zhao, W., 2014. Structural Source of the trap of ICT advancement: Lessons from world ICT top Leaders. *Journal of Technology Management for Growing Economies* 5(2), 49-71. DOI 10.15415/jtmge.2014.52008

In this paper the structural sources of declining marginal productivity in two ICT advanced economies Finland and Singapore were empirically analyzed.

Based on their trend in marginal productivity of ICT and its subsequent prices, two faced nature of ICT advancement was identified.

It was demonstrated that the country's success is attributed to the effective utilization of external innovation resources and by outsourcing price decreasing factors. The significance of innovation-consumption co-emergence for harnessing the vigor of counterparts was also discussed.

9.3 PIII - New paradigm of ICT productivity: Increasing role of uncaptured GDP and growing anger of consumers

Watanabe, C., Naveed, K., Zhao, W., 2015*a*. New paradigm of ICT productivity: Increasing role of uncaptured GDP and growing anger of consumers. *Technology in Society* 41, 21–44. http://dx.doi.org/10.1016/j.techsoc.2014.10.006

This paper identified that the trap in ICT advancement can be attributed to the two-faced nature of ICT in which advancement of ICT contributes to price increase due to functionality development while dramatic advancement of the Internet has resulted in price decrease because of its inherent characteristics of freebies, easy copying and standardization.

Based on an empirical analysis of a customer preferences shift from economic functionality to supra-functionality beyond economic value, this paper unveils increasing conflict between captured and uncaptured GDP derived from the Internet advancement. The Internet promotes free culture that provides utility and happiness to consumers which cannot necessarily be captured through GDP data that measures revenue.

It is demonstrated that this conflict has resulted in growing anger of consumers which can be transformed into a springboard for new innovation by activating the innovation-consumption co-emergence.

9.4 PIV - Dependency on uncaptured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore

Watanabe, C., Naveed, K., Neittaanmäki, P., 2015*b*. Dependency on uncaptured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore. *Technology in Society* 42, 104–122. http://dx.doi.org/10.1016/j.techsoc.2015.04.003

The majority of countries with advanced information and communication technology (ICT) infrastructure have been experiencing extended stagnation due to an “embedded” trap in ICT advancement. However, certain countries have been able to sustain a high level of ICT-driven global competitiveness.

This suggests that in these contexts there is resilience beyond economic value. Finland and Singapore can be considered as resilient countries with respect to ICT-driven global competitiveness. While both countries share significant similarities including institutional strength in ICT, they demonstrate noteworthy disparities in their development trajectories: Singapore is growth-oriented based on captured GDP while Finland seeks happiness by shifting to uncaptured GDP.

Given the increasing significance of uncaptured GDP derived from the dramatic advancement of the Internet, this paper conducted a comparative analysis of ICT-driven development trajectories in six leading countries over last two decades. This analysis revealed the different options for maintaining economic resilience.

A new method for measuring uncaptured GDP was developed to assess the consequences and state of uncaptured GDP in any country. Institutional sources leading to this state were analyzed and a source of resilience beyond economic value was conceptualized and articulated.

9.5 PV - Operationalization of uncaptured GDP – Innovation stream under new global mega trends

Watanabe, C., Naveed, K., Neittaanmäki, P., Tou, Y., 2016a. Operationalization of uncaptured GDP: The innovation stream under new global mega-trends. *Technology in Society* 45, 58–77. http://dx.doi.org/10.1016/j.techsoc.2016.02.008

Based on the learning of previous paper, the following hypothetical view was postulated: The disparity between the world's ICT leading countries with respect to happiness or welfare amidst great stagnation (Finland) or conspicuous economic growth (Singapore) can be attributed to their different state in shifting from traditional to new co-evolution.

An empirical analysis was conducted to measure the dependency on uncaptured GDP which is a key factor in identifying the shifting trends. Noteworthy findings were obtained and significant policy suggestions about the role of government and businesses in the context of new innovation streams were discussed.

9.6 PVI - Co-evolution of streaming and live music leads a way to the sustainable growth of music industry: Lessons from the US experiences

Naveed, K., Watanabe, C., Neittaanmäki, P., 2017a. Co-evolution between streaming and live music leads a way to the sustainable growth of music industry: Lessons from the US experiences. *Technology in Society* 50, 1–19. http://dx.doi.org/10.1016/j.techsoc.2017.03.005

The digital music particularly streaming music has gained popularity however, revenues of recording music industry has steadily declined. This is causing strong fear of the possible collapse of recording music industry similar to other industries such as print media, newspaper and book publishing etc. However, recent changes in the music industry with the resurgence of live music are giving some hopes for the survival and growth of music industry.

This paper attempted to elucidate the co-evolutionary dynamism between the increasing popularity of streaming music and the resurgence of live music. An empirical analysis of monthly trends over the period of the last three decades in the US music industry by its sectors revealed that (i) the co-evolution between streaming and live music industries has functioned well over the last few years, (ii) the live music industry has incorporated a self-propagating function by assimilating innovations previously initiated by digital music, (iii) given the above co-evolution, the recent resurging trend in the music industry can be sustained, (iv) the advancement of digital innovations such as artificial intelligence, machine learning, fintech, virtual reality, big data, and social media by enabling such co-evolution have transformed the live music industry into a "live-concert-streaming music industry" (LCSMI) that further enabling the participative creativity of its stakeholders. For these collaborative and cultural industries to function in harmony, trust between its participating stakeholders is very crucial.

9.7 PVII - Co-evolution of three mega-trends nurtures uncaptured GDP: Uber's ride-sharing revolution

Watanabe, C., Naveed, K., Neittaanmäki, P., 2016b. Co-evolution of three mega-trends nurtures uncaptured GDP: Uber's ride-sharing revolution. *Technology in Society* 46, 164–185. http://dx.doi.org/10.1016/j.techsoc.2016.06.004

Uber is a ridesharing digital platform company. It has disrupted the traditional taxi industry by effectively utilizing digital technologies and an innovative business model. Uber is regarded as one of the fastest growing startup.

This paper analyzed the impact of Uber on the New York City (NYC) taxi industry by comparing the co-existing development trajectories of Uber and taxis. It further analyzed the institutional factors contributed to the success of

Uber. It is found that the substitution from traditional taxi to Uber was due to the Uber's ability to decrease prices lower than taxi, and subsequently Uber managed to increase its market share. This paper compares the trips and prices between Uber and taxi, correlation of dependency on Uber and medallion prices, and magnitude of uncaptured GDP per trip.

The Uber have successfully managed to pull costs down and improve the quality of service by innovative utilization of modern digital technologies and untapped resources.

9.8 PVIII - Consolidated challenge to social demand for resilient platforms - Lessons from Uber's global expansion

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017a. Consolidated challenge to social demand for resilient platforms: Lessons from Uber's global expansion. *Technology in Society* 48, 33–53. http://dx.doi.org/10.1016/j.techsoc.2016.10.006

Uber has succeeded in its global expansion to over 479 cities in more than 75 countries by Jun. 2016. Such rapid expansion provides constructive insights regarding the significance of ICT-driven disruptive business model (IDBM), not only in transportation but also in other business fields. While at the same time Uber's legal battles in some cities around the world raised a serious question regarding the rationale of IDBM.

In light of such a question, this paper examined the institutional sources contrasting success and failure in Uber's global expansion. By the comparative empirical analysis, it was identified that the contrast could be attributed to a bipolarization nature of ICT-driven logistic growth, and the success can be attributed to a co-evolutionary acclimatization that harnesses the vigor of counterparts.

This analysis suggested the significance of IDBM with a consolidated challenge to social demand (CCSD); it demonstrates that a co-evolutionary acclimatization plays a transformative role in this accomplishment.

9.9 PIX - Co-evolution between trust in teachers and higher education toward digitally-rich learning environments

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017b. Co-evolution between trust in teachers and higher education toward digitally-rich learning environments. *Technology in Society* 48, 70–96. http://dx.doi.org/10.1016/j.techsoc.2016.11.001

Based on a powerful notion that the quality of higher education is crucial for innovation in digital economy and it is subject to a conception of trust in teachers to deliver good education and advancement of ICT, the dynamism of co-evolution between them was analyzed.

An empirical analysis of 22 countries is conducted by using a unique dataset representing the rate of trust in teachers providing good education (in the context of quality of education and their social status), level of higher education and state of the ICT development. These countries were classified as advanced, semi-advanced and growing.

It was found that while ICT advanced countries have embarked on co-evolution of ICT, higher education and trust, ICT growing countries have not been successful in this due to a vicious cycle between ICT and trust.

The paradox of education productivity in ICT growing countries can be attributed to mismatch between ICT advancement and trust in teachers. It was suggested that steady ICT advancement by fully utilizing external resources in digitally-rich learning environments may be essential for ICT growing countries in achieving higher education. On the other hand, ICT advanced countries should continue persistent innovation efforts to further improve the digitally-rich learning environments. A new approach for systematically constructing the co-evolution among ICT advancement, higher education and trust in teachers was explored.

9.10 PX - ICT-driven disruptive innovations nurtures uncaptured GDP – harnessing women's potential as untapped resources

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017c. ICT-driven disruptive innovation nurtures uncaptured GDP: Harnessing women's potential as untapped resources. *Technology in Society* 51, 81–101. http://dx.doi.org/10.1016/j.techsoc.2017.07.007

The harnessing of untapped resources has become essential for inclusive growth in digital economies particularly, developed economies continue to age demographically. The harnessing of women's potential is an urgent subject in this context, and successive initiatives have been flourishing in many countries. However, given the institutional complexity of the issue, as well as considerable variety across nations, uniformed non-systematic approaches are hardly satisfactory in achieving a timely solution. Against this back drop, this paper analyzed a new information communication technology (ICT)-driven disruptive innovation that may nurture uncaptured GDP by harnessing untapped resources such as women's economic potential.

Using a unique dataset representing the state of gender balance improvement, an empirical numerical analysis of 44 countries was attempted. These countries were classified as emerging, industrialized, and with a specific culture based on traditions of a male-dominant society.

It was found that industrialized countries, typically Finland have achieved high performance in co-evolution between "econo-cultural development," ICT advancement, and gender balance improvement, while emerging countries have been constrained by low ICT advancement. In addition, notwithstanding high economic level, countries with a specific culture have been constrained by a traditional male-dominant culture, Japan being a typical case.

Based on these findings, lessons from industrialized countries for both emerging countries and countries with a specific culture were analyzed. It was suggested that ICT should be strategically advanced depending on the state of what we are calling "econo-cultural development" for constructing co-evolution of gender balance improvement along with techno-economic development. A new practical approach for harnessing untapped resources for sustainable growth was thus explored.

9.11 PXI - Transformative direction of Innovation toward an IoT-based Society – Increasing dependency on uncaptured GDP in global ICT firms

Naveed, K., Watanabe, C., Neittaanmäki, P., 2017b. The transformative direction of innovation toward an IoT-based society – Increasing dependency on uncaptured GDP in global ICT firms. *Technology in Society* 52. https://doi.org/10.1016/j.techsoc.2017.11.003

Driven by the possibilities of the Internet of Things (IoT), global ICT firms have taken significant steps forward in recent years. The Internet provides extraordinary services to people while promoting a free culture. However, such services cannot be captured through gross domestic product (GDP) data that measure revenue. Consequently, advancement of the Internet leads to increasing dependency on uncaptured GDP (added value providing people utility and happiness beyond economic value) and ICT price decreases.

Against such circumstances, global ICT firms are quickly embracing digital solutions for new competitiveness that urge them to restructure their business model toward digital business strategies. Aiming at demonstrating this hypothetical view, this paper attempted to explore new approach for analyzing such dynamism and examines some optimal solutions that are co-evolving with it.

An empirical analysis of digital business solutions in 500 global ICT firms over the period 2005–2016 was conducted with special attention to their specific features. It was identified that research and development–intensive firms have fallen into a trap of ICT advancement, resulting in a decline in their marginal productivity of ICT that could be due to increasing dependency on uncaptured GDP. As a result, these firms are endeavoring to harness soft innovation resources and activate a self-propagating function that induces functionality development sublimating sophisticated digital business strategies, such as:

- Shifting from software to network (e.g., Apple and Google),
- Merging network and real (e.g., Amazon's merging of e-commerce and brick-and-mortar retail),
- Shifting from commodity to culture (e.g., Facebook and Samsung).

All can be considered as soft value addition in response to uncaptured GDP. This analysis explored new insights for ICT firms in their transformative strategies toward an IoT-based society.

9.12 PXII - Measuring GDP in the digital economy: Increasing dependency on uncaptured GDP

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017d. Measuring GDP in the digital economy: Increasing dependency on uncaptured GDP. Journal of *Technological Forecasting and Social Change (under review).*

The Internet has dramatically changed the way of conducting business and our daily lives. The further advancement of digitized innovation, including cloud, mobile services, and artificial intelligence, has augmented this change significantly and provided us with extraordinary services and welfare never anticipated before. However, contrary to such accomplishments, productivity in industrialized countries has been confronted with an apparent decline, and it has raised the question of a possible productivity paradox in the digital economy. These limitations of the GDP statistics in measuring the advancement of the digital economy have become an important subject.

Based on the intensive empirical analyses of national, industrial and individual behaviors in the digital economy, a solution to this critical issue was investigated. As the two-faced nature of ICT and people's preferences go beyond economic value, the concept of uncaptured GDP was postulated and its measurement was attempted. By analyzing the transformative direction of leading global ICT firms, the significance of uncaptured GDP dependency was demonstrated. Overall, this analysis explored new insights for measuring the digital economy.

10 CONCLUSION

In light of the concerns related to productivity paradox, increasing role of uncaptured GDP and the limitations of GDP in measuring the digital economy, a new practical solution was examined based on intensive empirical analyses at individual, industrial and national level.

Given the two-faced nature of ICT and people's preference shift beyond economic value, the concept of uncaptured GDP was postulated and its measurement was attempted. The significance of uncaptured GDP dependency and new stream of innovation was demonstrated at industrial and national level by conducting several case studies. Finally the transformative direction of innovation in the digital economy was discussed.

The following findings are noteworthy:

- It was found that the ICT advanced countries and high R&D intensive firms are trapped in a vicious cycle of ICT advancement and its declining marginal productivity.
- ICT prices have continued to decline due to the trap in ICT advancement derived from the two-faced nature of ICT.
- The emergence and growth of new types of business activities and business models have increased deflationary pressures. The pseudo ICT deflators may contribute in the mismeasurement of productivity, growth and inflation.
- The shifting consumer preferences and increasing un-monetized consumption of free digital goods and services provide higher utility and happiness to consumers but it cannot accurately be captured through GDP statistics, which intensified the emergence of uncaptured GDP.
- A new method to measure uncaptured GDP was developed. It emphasizes the need for a comprehensive approach to measure gross GDP (including captured and uncaptured GDP) and importance of corresponding taxation system to deal with tax avoidance strategies.
- The comparison of two ICT advanced countries reveals their contrary ICT-driven development trajectories, "happiness-oriented" in Finland versus

"growth-oriented" in Singapore. This reflects how different countries are using technology to create unique ICT-driven competitiveness.

- Emerging digital platforms are posing unique challenges for traditional businesses and national level institutions. The policy makers are trapped in a "decision maker's dilemma", therefore well-informed innovation strategies at industrial and national level are indispensable.
- In light of the above, the industry level case study of digitization of taxi industry revealed that how the sharing economy platforms similar to Uber are disrupting traditional industries by the intelligent use of technology, innovative business models and by harnessing untapped assets and human resources.
- The music industry analysis revealed that the co-evolution of streaming and live music industry supported by latest digital technologies provide some hopes for the potential resurgence of declining trend in music industry revenues.
- In light of the consolidation issues, the case analysis of Uber's expansion and legal battles revealed that the success and failure of Uber depends on its expansion rate, adaptability and institutional elasticity of the host country or city.
- The above co-evolution or disengagement with institutions emphasizes the need of consolidation frameworks to develop trust by facilitating dialogue among broader stakeholders by discussing each other's concerns and challenges in solving a social problem or fulfilling a social demand, e.g. tripartism framework in Singapore.
- The analysis of 22 countries by considering their level of higher education, ICT advancement and trust revealed useful insights that can be helpful for constructing ICT-driven competitiveness.
- The analyses of gender equality in 44 countries revealed that few countries are harnessing the participation of women in workforce, not only as a matter of fairness and inclusive growth but also as a strategic tool to cope with challenges of the digital economy and ageing societies.
- These results revealed that how industries and countries are developing strategies to harness the potential of untapped and non-economic resources so-called "soft value innovation" to create unique competitiveness and to deal with the economic challenges in the digital economy.
- In the light of the analyses of transformative direction of innovation (by 500 ICT firms), it was anticipated that the role of soft value innovation will further increase in future to address the challenges of digital economy such as declining marginal productivity of technology, increasing role of uncaptured GDP and intense competition.

This dissertation explored new insights for measuring the digital economy and provides corresponding policy suggestions to develop GDP accounting system by considering gross GDP. Future works should focus on international and historical reviews of success stories of gross GDP management both at the national and industrial levels. The development of public policies based on the gross GDP concept should be prioritized. The insights from the case studies provide constructive suggestions about the transformative direction of innovation and consolidation challenges. The soft-value innovation is another phenomenon that is anticipated to increase in future, so its supplementary detailed analysis should be encouraged.

YHTEENVETO (FINNISH SUMMARY)

Innovaatiotoiminnan muutos ja mittaamatta jäävän bruttokansantuotteen arvo digitaalisessa taloudessa.

Internet on dramaattisesti muuttanut tapaa harjoittaa liiketoimintaa ja elää jokapäiväistä elämäämme tarjoamalla parempia palveluita ja hyvinvointia kuin on edes osattu ennakoida. Kuitenkin tuottavuus on teollisuusmaissa heikentymään päin. Edistyneet ICT-yritykset ja maat kärsivät ICT investointien heikosta marginaalisesta tuotosta. Tämä paljastaa ICT:n kahdet kasvot ja tuottavuusparadoksin digitaalisessa taloudessa.

Teknologian kehitys ja muutos kulutusorientoituneesta yhteiskunnasta informaatioyhteiskuntaan ovat vaikuttaneet siihen, että kuluttajien mieltymysten on uskottu muuttuvan taloudellisista arvoista muihin arvoihin. Digitalisaatio mahdollistaa ilmaiset digitaaliset hyödykkeet, palvelut ja ei-rahallisen kuluttamisen ja tuottaa sitä kautta hyödyllisyyttä ja onnellisuutta kuluttajille. Tällaista kuluttamista ei kuitenkaan välttämättä voida arvioida bruttokansantuotteen (BKT) avulla. Tässä tutkimuksessa tämä käsitteellistetään mittaamatta jääväksi BKT:ksi ja tässä tutkimuksessa luodaan uusi menetelmä sen mittaamiseksi. Kahden edistyneen ICT-maan vertailu paljastaa niiden vastakkaiset ICT-johtoiset kehitysstrategiat: Suomi on onnellisuusorientoitunut kun taas Singapore on kasvuorientoitunut. Tutkimus selvittää kuinka maat ja teollisuudenalat käyttävät teknologiaa luodakseen ainutlaatuista kilpailuetua.

Taksi- ja musiikkialan digitalisoitumista tutkitaan, jotta saadaan analysoitua ICT:hen perustuvien häiritsevien innovaatioiden vaikutusta perinteisiin aloihin ja niiden yhteensovittamisen haasteita instituutioissa. Kansallisen tason analyysissa tarkastellaan hyödyllisiä näkemyksiä ICT:hen perustuvan kilpailuedun saavuttamisesta digitaalisessa taloudessa korkeakouluopetuksen (20 maata) ja sukupuolten välisen tasa-arvon (44 maata) avulla. Tutkimustulokset paljastavat kuinka teollisuudenalat ja maat hyödyntävät käyttämättömiä ja ei-taloudellisia resursseja, niin kutsuttaja pehmeiden arvojen innovaatioita, luodakseen ainutlaatuista kilpailuetua digitaalisessa taloudessa. Analysoimalla innovaatioiden suuntamuutosta (500 ICT yritystä) voidaan pitää todennäköisenä, että pehmeiden arvojen innovaatioiden rooli vastauksena digitaalisen talouden haasteisiin - kuten teknologioiden pienentyviin tuottomarginaaleihin - tulee lisääntymään, kasvattaen mittaamatta jäävän BKT:n roolia ja intensiivistä kilpailua.

REFERENCES

Ahmad, N., Schreyer, P. 2016. Are GDP and productivity measures up to the challenges of the digital economy? International Productivity Monitor 30, Spring, 4-27.

Arvind, M., Marshall, V.A. 2014. The dark side of the sharing economy and how to lighten it. Commun. ACM Assoc. Comput. Mach. 57 (11), 24-27.

Badger. E, Taxi Medallions Have Been the Best Investment in America for Years: Now Uber May Be Changing that, The Washington Post, 2014, 20 Jun.2014.

Belk, R. 2014. You are what you can access: sharing the collaborative consumption online, J. Bus. Res. 67, 1595-1600.

Bharadwaj, A., Sawy, O.A.E., Pavloyu, P.A., Venkatraman, N. 2013. Digital business strategy: Toward a next generation of insights. MIS Quarterly 37(2), 471–482.

Bleys, B. 2012. Beyond GDP: Classifying alternative measures for progress, Soc. Indic. Res. 109 (3), 355-376.

Brynjolfsson, E. 1993. Productivity paradox of information technology. Communications of the Association for Computing Machinery 36(12), 66–77.

Brynjolfsson, E., Hitt, L. 1996. Paradox lost? Firm-level evidence on the returns to information systems spending. Management Science 42, 541–558.

Brynjolfsson, E., Hitt, L. 1998. Beyond the productivity paradox. Communications of the ACM 41(8), 49–55.

Brynjolfsson, E., Yang, S. 1999. The intangible costs and benefits of computer investments: Evidence from financial markets. Atlanta, Georgia. Proceedings of the International Conference on Information Systems.

Brynjolfsson, E., McAfee, A. 2011. Race against the Machine. Digital Frontier, Lexington, MA.

Brynjolfsson, E., McAfee, A. 2014. The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. W.W. Norton & Company, New York.

Brynjolfsson, E., Hu, Y., Smith, M. revised 2017. Consumer surplus in the digital economy: Estimating the value of increased product variety at online booksellers. Management Science, Forthcoming. http://dx.doi.org/10.2139/ssrn.400940

Byrne, D., Corrado, C. 2016. ICT Prices and ICT Services: What do They Tell about Productivity and Technology? Economic Program Working Paper Series, EPWP #16-05, The Conference Board, New York.

Cannon, B., Chung, H. 2015. A framework for designing co-regulation models well-adapted to technology-facilitated sharing economies, St. Clara High. Tech. L.J 31, 23-97.

Cheng, D. 2014. Is sharing really Caring? A nuanced introduction to the peereconomy. Policy Primer. 1-28. October 2014.

Cohen, B., Kietzmann, J. 2014. Ride on! mobility business models for the sharing economy. Organ. Environ. 27 (3), 279-296.

Copenhagen Economics (CE). 2013. The Impact of Online Intermediaries on the EU Economy. CE, Copenhagen.

Copenhagen Economics (CE). 2015. The Impact of Online Intermediaries on the EU Economy, CE, Copenhagen.

Costanza, R., Hart, M., Posner, S., Talberth, J. 2009. Beyond GDP: the Need for New Measures of Progress. Pardee Paper 4, Pardee Center for the Study of the Longer-Range Future, Boston.

Cowen, T. 2011. The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better. A Penguin eSpecial from Dutton, Penguin, New York.

Cusumano, M.A. 2015. How traditional firms must compete in the sharing economy? Commun. ACM 58 (1), 32-34.

Economist. 2016. How to measure prosperity. https://www.economist.com/news/leaders/21697834-gdp-bad-gauge-material-well-being-time-fresh-approach-how-measure-prosperity (accessed 30.04.2016).

EU. 2017. The Internet of Things: Digital Single Market. EU, Brussels.

European Union (EU). 2017. Economics of Industrial Research and Innovation. EU, Brussels.

Feldstein, M. 2017. Understanding the real growth of GDP, personal income, and productivity. Journal of Economic Perspectives 31 (2), 145-164.

Fleurbaey, M. 2009. Beyond GDP: The quest for a measure of social welfare, J. Econ. Literature 47 (4), 1029-1075.

Gamal, A. El. 2012. The Evolution of the Music Industry in the Post-Internet Era, CMC Senior Thesis, Claremont College, p. 532.

Groshen, E.L., Moyer, B.C., Aizcorbe, A.M., Bradley, R., Friedman, D.M. 2017. How government statistics adjust for potential biases from quality change and new goods in an age of digital technologies: A view from the trenches. Journal of Economic Perspectives 31 (2), 187-210.

Horpedahl, J. 2015. Ideology Uber alles?: Economics bloggers on Uber, Lyft, and other transportation network companies, Econ. J. Watch 12 (3), 360-374.

Hofstede, G. 1991. Cultures and Organizations. McGraw-Hill International, London.

International Telecommunication Union (ITU), 2013. Measuring the Information Society 2013. http://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2013.aspx (accessed 27.07.2017).

International Labor Organization (ILO). 2012. Distribution of Household Income by Source. ILO, Geneva.

International Labour Organization (ILO). 2015. Women in Businesses and Management: Gaining Momentum, ILO, Geneva.

International Monetary Fund (IMF). 2014. World Economic Outlook Database, IMF, Washington, D.C.

International Monetary Fund (IMF). 2017a. World Economic Outlook Database, IMF, Washington, D.C.

International Monetary Fund (IMF). 2017b. Measuring the Digital Economy: IMF Statistical Forum. IMF, Washington D.C.

International Telecommunication Union (ITU). 2014. World Telecommunication/ ICT Indicators Database, 2014, ITU, Geneva.

Internet Society. 2015. The Internet of Things: An Overview. Internet Society, https://www.internetsociety.org/doc/iot-overview (accessed 05.08.2017).

Internet Society. Global Internet Report 2016, 2016. https://www.internetsociety.org/globalinternetreport/2016/wp-content/uploads/2016/11/ISOC_GIR_2016-v1.pdf (accessed 05.08.2017).

Isaac, E. 2014. Davis, Disruptive innovation: risk-shifting and precarity in the age of Uber, BRIE Work. Pap. 2014-2017.

Japan Cabinet Office (JCO). 2012. National Survey of Lifestyle Preferences. JCO, Tokyo.

Japan Ministry of Internal Affairs and Communication (MIC). 2016. White Paper of Japan's ICT.

Kahre, C., Hoffmann, D., Ahlemann, F. 2017. Beyond business-IT alignment-digital business strategies as a paradigmatic shift: A review and research agenda. Proceedings of the 50th Hawaii International Conference on System Sciences, 4706–4715.

Kraemer, K.L., Dedrick, J. 1994. Payoffs from investment in information technology: Lessons from the Asia-Pacific region. World Development 22(12), 1921–1931.

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Aylmer, C. 2013. Beyond GDP: Measuring and achieving global genuine progress, Ecol. Econ. 93 (2), 57-68.

Lichtenberg, F.R. 1995. The output contributions of computer equipment and personnel: A firm-level analysis. Economic Innovations and New Technology 3, 201–217.

Lovins, H., Cohen, B. 2011. Climate Capitalism in the Age of Climate Change, Hill & Wang, New York.

Lowrey. A. 2011. Freaks, Geeks, and GDP. Slate. http://www.slate.com/articles/business/moneybox/2011/03/freaks_geeks_and_gdp.html (accessed 20.06.17).

McDonagh, D. 2008. Satisfying needs beyond the functional: The changing needs of the silver market consumer. Proceedings of the International Symposium on the Silver Market Phenomenon - Business Opportunities and Responsibilities in the Aging Society, Tokyo.

Madakam, S., Ramaswamy, R., Tripathi, S. 2015. Internet of Things (IoT): A literature review. Journal of Computer and Communications 3(5), 164–173.

Mastrorillo, E. 2016. Getting taken for a ride by Uber technologies incirporated, Sociol. Imagin. 5 (1), 1-9.

Mazhelis, O., Luoma, E., Warma, H. 2012. Defining an Internet of things ecosystem, in: A. Andreev, S. Balandin, Y. Koucheryavy (Eds.), Internet of Things, Smart Spaces and Next Generation Networking, Lecture Notes in Computer Science (Book 7469), Springer, Heidelberg, pp. 1-14.

McKinsey Global Institute. 2011. Internet matters: The Net's Sweeping Impact on Growth, Jobs, and Prosperity. San Francisco: McKinsey & Company.

McKinsey Global Institute. 2015. The Internet of Things: Mapping the Value Beyond the Hype. San Francisco: McKinsey & Company.

Meyer, P.S., Ausbel, J.H. 1999. Carrying capacity: a model with logistically varying limits, Technological Forecasting and Social Change 61 (3), 209-214.

Naveed, K., Watanabe, C., Neittaanmäki, P., 2017a. Co-evolution between streaming and live music leads a way to the sustainable growth of music industry: Lessons from the US experiences. *Technology in Society* 50, 1–19. http://dx.doi.org/10.1016/j.techsoc.2017.03.005

Naveed, K., Watanabe, C., Neittaanmäki, P., 2017b. The transformative direction of innovation toward an IoT-based Society: Increasing dependency on uncaptured GDP in global ICT firms. Technology in Society 51, 1–24. https://doi.org/10.1016/j.techsoc.2017.11.003

OECD. 2010. The Economic and Social Role of Internet Intermediaries. OECD, Paris.

OECD. 2014. Trust: What it Is and Why it Matters for Governance and Education?, OECD, Paris.

OECD. 2016. Background Report: Conference on Improving Women's Access to Leadership, OECD, Paris.

OECD. 2016. Tax Challenges in the Digital Economy. OECD, Paris.

Ogden, T. 2012. The race vs. the stagnation. Stanford Social Innovation Rev 2012; (Spring).

Oreg, S., Goldenberg, J. 2015. Resistance to Innovation e Its Sources and Manifestations, The University of Chicago Press, Chicago and London.

Rifkin, J. 2011. The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World. Macmillan, New York.

Rifkin, J. 2014. The Zero Marginal Cost Society: The Internet of things, the collaborative commons, and the eclipse of capitalism, New York.

Rogers, B. 2015. The Social Costs of Uber, 2015 vol.28, The University of Chicago Law Review Dialogue, 2015, pp. 85-102.

Rogers, E. 1962. Diffusion of Innovations, Simon and Schuster, New York.

Ross, C. 2016. Beyond GDP – is it time to rethink the way we measure growth?, https://www.weforum.org/agenda/2016/04/beyond-gdp-is-it-time-to-rethink-the-way-we-measure-growth/. Retrieved Jun 10 2016.

Rossel, C. 2017. Uber losers – NYC taxi medallion owners are screwed, https://news.vice.com/story/uber-losers-nyc-taxi-medallion-owners-are-screwed. Retrieved Aug 20 2017.

Sahlberg, P. 2010. The Secret to Finland's Success: Educating Teachers, September 2010, Stanford Center for Opportunity Policy in Education. pp. 1-8.

Singapore Department of Statistics (SDS). 2015. Household Expenditure Survey. SDS, Singapore.

Solow, R. 1987. We'd better watch out, review of S.S. Cohen and J. Zysman, Manufacturing matters: The myth of the post-industrial economy. New York Times Book Review 36.

Statistics Finland. 2015. Statistical Yearbook of Finland. Statistics Finland, Helsinki.

Stead, J., Stead, W. 2013. The co-evolution of sustainable strategic management in the global marketplace, Organ. Environ. 26 (2), 162-183.

Stehlik, T. 2016. Is "Pedagogical Love" the Secret to Finland's Educational Success?, http://www.aare.edu.au/blog/?p=1578. Retrieved 30 May 2016.

Syverson, C. 2017. Challenges to mismeasurement explanations for the US productivity slowdown. Journal of Economic Perspectives 31 (2), 165-186.

Tapscott, D. 1994. The Digital Economy: Promise and Peril in the Age of Networked Intelligence. McGraw-Hill, New York.

The Conference Board Total Economy Database. 2013. http://www.conference-board.org/data/economydatabase (accessed 10.01.14).

The Earth Institute, Colombia University. 2013. World Happiness Report 2013. The Earth Institute, Colombia University, New York.

Triplett, J. 1999. "The Solow productivity paradox: What do computers do to productivity?" Canadian Journal of Economics 32(2), 309-334.

UNESCO. 2003. Towards Policies for Integrating Information and Communication Technologies into Education, UNESCO, Paris.

US Council on Competitiveness. 2016. No recovery: An analysis on long-term U.S. productivity decline. Washington, D.C.

Varkey Gems Foundation (VGF). 2014. 2013 Global Teacher Status Index, VGF, London.

Watanabe, C., Takayama, M., Nagamatsu, A., Tagami, T., Griffy-Brown, C. 2002. Technology spillover as a complement for high-level R&D intensity in the pharmaceutical industry, Technovation 22 (4), 245-258.

Watanabe, C., Kondo, R., Ouchi, N., Wei, H., Griffy-Brown, C. 2004. Institutional elasticity as a significant driver of IT functionality development. Technological Forecasting and Social Change 71(7), 730–750.

Watanabe, C. 2009. Managing Innovation in Japan: The Role Institutions Play in Helping or Hindering How Companies Develop Technology. Springer Science & Business Media, Berlin.

Watanabe, C., Lei, S., Ouchi, N. 2009. Fusing indigenous technology development and market learning for greater functionality development: An empirical analysis of the growth trajectory of Canon printers. Technovation 29(4), 265–283.

Watanabe, C., Nasuno, M., Shin, J. H. 2011. Utmost gratification of consumption by means of supra-functionality leads a way to overcoming global economic stagnation. Journal of Services Research 11(2), 31-58.

Watanabe, C., Zhao, W., Nasuno, M. 2012. Resonance between innovation and consumers: Suggestions for emerging market customers. Journal of Technology Management for Growing Economies 3(1), 17–31.

Watanabe, C., Naveed, K., Zhao, W., 2014*a*. Institutional sources of resilience in global ICT leaders: Harness the vigor of emerging power. Journal of Technology Management for Growing Economies 5(1), 7–34. DOI 10.15415/jtmge.2014.51001

Watanabe, C., Naveed, K., Zhao, W., 2014*b*. Structural Source of the Trap of ICT Advancement: Lessons from World ICT Top Leaders. Journal of Technology Management for Growing Economies 5(2), 49-71. DOI 10.15415/jtmge.2014.52008

Watanabe, C., Naveed, K**.,** Zhao, W., 2015*a*. New paradigm of ICT productivity: Increasing role of uncaptured GDP and growing anger of consumers. *Technology in Society* 41, 21–44. http://dx.doi.org/10.1016/j.techsoc.2014.10.006

Watanabe, C., Naveed, K., Neittaanmäki, P., 2015*b*. Dependency on uncaptured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore. *Technology in Society* 42, 104–122. http://dx.doi.org/10.1016/j.techsoc.2015.04.003

Watanabe, C., Naveed, K., Neittaanmäki, P., Tou, Y., 2016*a*. Operationalization of uncaptured GDP: The innovation stream under new global mega-trends. Technology in Society 45, 58–77. http://dx.doi.org/10.1016/j.techsoc.2016.02.008

Watanabe, C., Naveed, K., Neittaanmäki, P., 2016*b*. Co-evolution of three mega-trends nurtures uncaptured GDP: Uber's ride-sharing revolution. Technology in Society 46, 164–185. http://dx.doi.org/10.1016/j.techsoc.2016.06.004

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017*a*. Consolidated challenge to social demand for resilient platforms: Lessons from Uber's global expansion. Technology in Society 48, 33–53. http://dx.doi.org/10.1016/j.techsoc.2016.10.006

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017*b*. Co-evolution between trust in teachers and higher education toward digitally-rich learning environments. Technology in Society 48, 70–96. http://dx.doi.org/10.1016/j.techsoc.2016.11.001

Watanabe, C., Naveed, K., Neittaanmäki, P., 2017*c*. ICT-driven disruptive innovation nurtures uncaptured GDP: Harnessing women's potential as untapped resources. Technology in Society 51, 81–101. http://dx.doi.org/10.1016/j.techsoc.2017.07.007

Watson, B., McDonagh, D. 2004. Responding to users needs beyond the functional. The Journal of the Institution of Engineering Designers September/October.

Wesselink, B., Bakkes, J., Hinterberger, F., Brink, P. 2007. Measurement beyond GDP, in: Background Paper for the International Conference beyond GDP: Measuring Progress, True Wealth, and the Well-being of Nations, Bruddels.

World Economic Forum (WEF). 2013. The Global Competitiveness Report 2013-2014, WEF, Geneva, 2013a
World Economic Forum (WEF). 2013b. The Global Gender Gap Report, 2013. WEF, Geneva.
World Economic Forum (WEF). 2014a. The Global Information Technology Report, 2014. WEF, Geneva.
World Economic Forum (WEF). 2014b. The Global Competitiveness Report, 2014. WEF, Geneva.
World Economic Forum (WEF). 2016, White Paper Digital Transformation of Industries: In collaboration with Accenture, WEF, Geneva.
Ylhainen, I. 2017. Challenges of Measuring the Digital Economy. https://www.sitra.fi/en/articles/challenges-measuring-digital-economy/

ORIGINAL PAPERS

PI

INSTITUTIONAL SOURCES OF RESILIENCE IN GLOBAL ICT LEADERS - HARNESS THE VIGOR OF EMERGING POWER

by

Chihiro Watanabe, Kashif Naveed and Weilin Zhao, 2014

Journal of Technology Management for Growing Economies, vol. 5(1), pp. 7-34

Institutional Sources of Resilience in Global ICT Leaders - Harness the Vigor of Emerging Power

Chihiro Watanabe
National University of Singapore, Singapore & University of Jyvaskyla, Finland

Kashif Naveed
University of Jyvaskyla, Finland

Weilin Zhao
Fujitsu Research Institute, Japan

Abstract

In light of the significant impacts on global economy both nations and firms witnessed a dramatic advancement of information and communication technology (ICT). There was particularly bi-polarization between ICT advanced and growing economies compelling a vicious cycle between ICT advancement and its productivity decline in these economies. The institutional sources of resilience were analyzed. On the basis of an empirical analysis comparing technopreneurial performance in world top 500 ICT firms by market value, sales and profit over the last decade, resilient firms maintaining world top 100 position by all three values over the whole period were identified. Institutional sources enabling resilient firms maintain leading position can largely be attributed to co-evolutionary acclimatization ability, which harnesses the vigor of emerging power of counterparts both in home countries and in advanced countries as well as growing economies in a co-evolutional way. Such ability maximizes synergy between efficiency and resilience in their technopreneurial management. Contrasting business model in global ICT firms with and without resilience structure suggests the sources of emerging trap due to ICT advancement and endorsed the significance of co-evolutionary acclimatization. This suggests the significance of institutional co-evolution between ICT advanced and growing economies that enables both economies to harness the vigor of partners for global sustainability.

Keywords: *Resilience, Institutional Source, ICT Leaders, Co-evolutionary Acclimatisation, Emerging Power.*

Journal of Technology Management for Growing Economies
Vol. 5 No. 1
April 2014
pp. 7-34

INTRODUCTION

Nowadays "sudden death" is becoming popular on the forefront of competitiveness race in high-technology firms. Contrary to notable profits in Japan's leading automobile firms such as Toyota, Nissan and Honda, majority of its electric machinery firms (which are global ICT firms) such as Panasonic, Sony and Sharp suffered significant deficits. Similar bi-polarization can be observed in the global competitive race between ICT advanced economies and ICT growing economies. Contrary to a conspicuous economic growth in the latter, the former suffers from greater stagnation (Cowen, 2011) except Singapore (Zhao et al., 2013, Watanabe, 2013).

Such a bi-polarization and subsequent "sudden death" can be attributed to misunderstanding the new stream beyond anticipation and unable to adapt to new environment as a consequence of clinging to efficiency oriented traditional business model. While looking at the current global socio-economy, we can clearly observe that it is in the midst of a stage beyond anticipation due to such events viz., the US sub-prime mortgage crisis, the Lehman shock, a Euro currency crisis, Japan's March 11 disaster, flooding in Thailand, Hurricane Sandy's and powerful typhoon's damage to New York and Philippines. Digitalization of manufacturing processes, a third industrial revolution initiated by the maker movement and also dramatic advancement of the Internet represent another stream of beyond anticipation that has shaken up the business model of firms. Trends in aging and a declining birthrate may also lead to a beyond anticipation world once they exceed a certain threshold.

In order to correspond to such new stream, optimal balance between efficiency and resilience in the whole perspective of innovation value chain encompassing emergence, diffusion and utilization would be essential.

To date, only a few studies have pointed the significance of resilience for sustainability. Resilience generally means ability to recover from some shock or disturbance and this concept is popular particularly in ecology, physics, network and psychology. In materials, for example, resilience can be defined as the ability of a material to absorb energy when its elasticity is deformed, and release that energy upon unloading (Campbell, 2008). Grimm and Wissel (1997) postulated (i) stability, (ii) constancy, (iii) persistence, (iv) resistance, (v) elasticity, and (vi) domain of attraction as necessary requirements to resilience. These concepts have been applying broadly in economic and business as well as industrial and organizational safety and exploring new perspectives in assessing the performance of technoprenerial strategy of global ICT firms. Watanabe et al. (2003) postulated a concept of resilience as a source of survival strategy for high-technology firms. Focusing on this dimension they realized resilience is the ability of an ecosystem to continue functioning despite occasional and severe disturbance as Marten (2001) defined, and more generally, the capacity of a sustained body to recover from, or adjust smoothly to external changes, shocks or crises. Primentel et al. (2000) stressed that resilience plays a significant role in maintaining ecological integrity. Ulanowicz (1995) identifies the role of resilience, in terms of this integrity, as a core function of a system consisting of vigor, organization and resilience. Based on this resilience role as a core function for maintaining system integrity, Watanabe et al. (2003) postulated that it is essential for high-technology firms to set a resilient structure, thereby maintaining an operating income to sales while minimizing elasticity of factors with uncertainty. This concept could be supportive in envisioning a sustainable strategy for high-technology firms in global competition. Neely and Hii (1998) posited that the innovation capacity of a firm regards three important and interrelated perspectives viz., (i) culture, (ii) internal processes, and (iii) external environment. Ilmola and Casti (2013) defined resilience as a concept consisting of three elements viz., (i) adaptability (the capability to absorb an extreme event or shock), (ii) agility (the capacity to benefit from the new situation which the shock generates, and (iii) assimilation (the capacity for using a shock as a trigger for renewal and improvement). This concept prompts us the significance of transforming crises or shocks into a springboard for new innovation as demonstrated by Japan against the energy crises in the 1970s, Finland against disruption of the USSR in the beginning of the 1990s and Korea against Asian financial crisis in 1997 (Watanabe, 2009a).

Notwithstanding the foregoing postulates, none has ever taken in-depth analysis of the institutional sources of resilience, which should be the basis of business model for global competition in the midst of beyond anticipation.

Prompted by the foregoing observation, this paper analyzes the forefront of the new stream in global Information and Communication Technology (ICT) competition race. Empirical analyses focusing on the ICT driven developing trajectory in 100 nations and also 500 global ICT firms are undertaken. Based on the comparative analysis between resilient and no-resilient trajectories, suggestions for resilient business model are extracted.

The paper reviews transnational pan-global bi-polarization phenomena in nations as well as global ICT firms. The study analyzes consequence of the bi-polarization both in nations and global ICT firms. Technopreneurial structure between resilient and non-resilient firms are compared. Structural source of the trap of ICT advancement is analyzed in the subsequent section. The study demonstrates lessons from resilient model both by country and firm. Section 6 briefly summarizes noteworthy findings, policy implications supportive to resilient business and also the points for future works.

Trans National Pan-global Bi-polarization

Dramatic advancement of ICT has led ICT driven logistic growth in both nations and global ICT firms as demonstrated in Figs. 1[1] and 2 (Zhao et al., 2013).

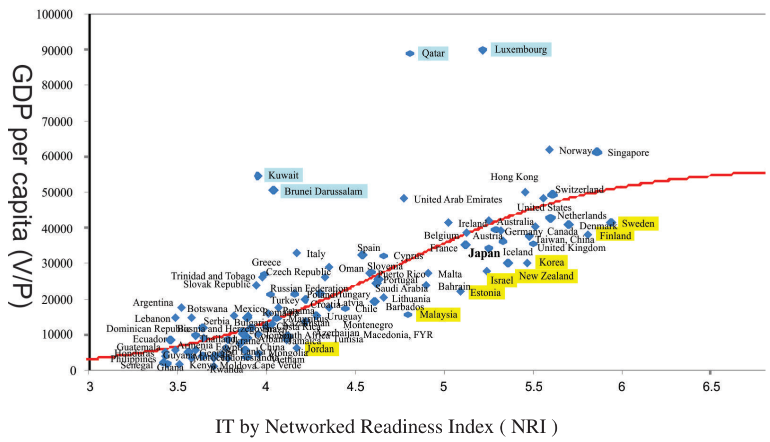


Figure1: ICT Driven Economic Development Trajectory in 100 Countries (2011)

Sources: The Global Information Technology Report 2012 (World Economic Forum, 2012), World Economic Outlook Database (IMF, 2012).

V/P: GDP per capita, *N*: carrying capacity, *NRI*: Networked readiness index, D_1, D_2: dummy variables, and *a*, *b*, *c*, *d*: coefficients.

$$\frac{V}{P} = \frac{N}{1+e^{-aNRI+b}} + cD_1 + dD_2$$

N	*a*	*b*	*c*	*d*	
57239	1.68	-7.90	46434	-12913	adj R^2 0.885
(9.62)	(7.58)	(-9.80)	(14.54)	(-5.25)	

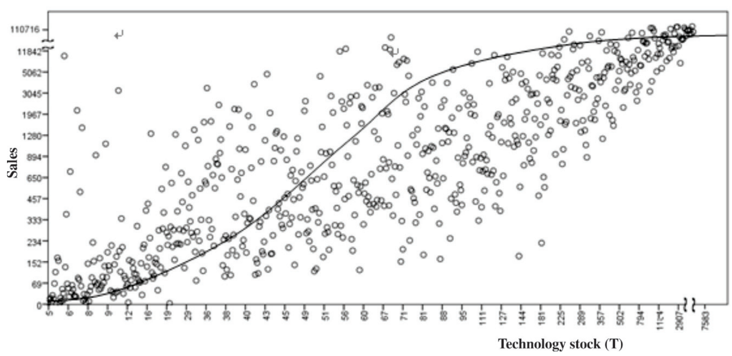


Figure 2 : ICT Driven Development Trajectory in 500 Global ICT Firms (2010)

Source: Economics of Industrial Research and Innovation (EU, 2011).

$$S = \frac{N}{1+be^{-af}} + cD$$

S: sales, N: carrying capacity, T: technology stoc
D: dummy variables, and a, b, c: coefficients.

N	*a*	*b*	*c*	
42668	0.002	22.61	45184	*adj.*R^2 0.885
(28.31)	(26.02)	(10.23)	(30.32)	

Such a logistic growth inevitably results in bi-polarization[2] among nations as well as global ICT firms as demonstrated in Figs. 3 and 4 where x and y signify ICT (or R&D) and marginal productivity of technology increase toward the origin of the coordinate axes (Watanabe, 2013, Zhao et al., 2013) .

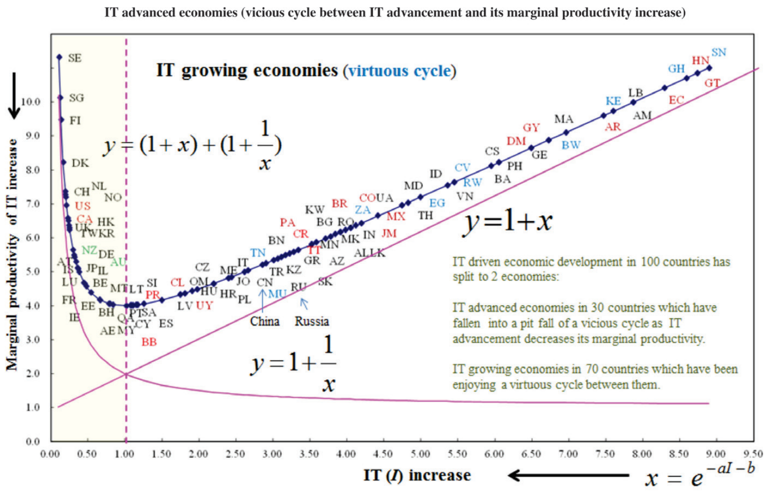


Figure 3: Bi-polarization of ICT Driven Economic Development Trajectory in 100 Nations (2011)

Sources: The Global Information Technology Report 2012 (World Economic Forum, 2012), World Economic Outlook Database (IMF, 2012).

Consequently, 100 nations have split to two economies as demonstrated in Table 1. While ICT growing 70 nations (nations with *NRI* ranking 31 to 100 in Table 1) have been enjoying a virtuous cycle between ICT advancement and its marginal productivity increase as generally anticipated, ICT advanced 30 nations (*NRI* ranking 1 to 30) have fallen into a pit of a vicious cycle as IT advancement decreases its marginal productivity against anticipation.

Table 1: Bi-polarization of Development Trajectories by Networked Readiness Index in 100 Nations (2011) – 1-30: ICT advanced economies (vicious cycle)

1 SE Sweden 5.94	26 MT Malta 4.91	51 CN China 4.11	76 MX Mexico 3.82
2 SG Singapore 5.86	27 BH Bahrain 4.90	52 TR Turkey 4.07	77 TH Thailand 3.78
3 FI Finland 5.81	28 QA Qatar 4.81	53 MU Mauritius 4.06	78 MD Moldova 3.78
4 DK Denmark 5.70	29 MY Malaysia 4.80	54 BN Brunei Darussalam 4.04	79 EG Egypt 3.77
5 CH Switzerland 5.61	30 AE United Arab Emirates 4.77	55 KZ Kazakhstan 4.03	80 ID Indonesia 3.75
6 NL Netherlands 5.60	31 LT Lithuania 4.66	56 RU Russian Federation 4.02	81 CV Cape Verde 3.71
7 NO Norway 5.59	32 CY Cyprus 4.66	57 PA Panama 4.01	82 RW Rwanda 3.70
8 US United States 5.56	33 PT Portugal 4.63	58 CR Costa Rica 4.00	83 VN Vietnam 3.70
9 CA Canada 5.51	34 SA Saudi Arabia 4.62	59 GR Greece 3.99	84 BA Bosnia and Herzegovina 3.65
10 UK United Kingdom 5.50	35 BB Barbados 4.61	60 TT Trinidad and Tobago 3.98	85 CS Serbia 3.64
11 TW Taiwan, China 5.48	36 PR Puerto Rico 4.59	61 AZ Azerbaijan 3.95	86 PH Philippines 3.64
12 KR Korea, Rep. 5.47	37 SI Slovenia 4.58	62 KW Kuwait 3.95	87 DM Dominican Republic 3.60
13 HK Hong Kong SAR 5.46	38 ES Spain 4.54	63 MN Mongolia 3.95	88 GE Georgia 3.60
14 NZ New Zealand 5.36	39 CL Chile 4.44	64 SK Slovak Republic 3.94	89 BW Botswana 3.58
15 IS Iceland 5.33	40 OM Oman 4.35	65 BR Brazil 3.92	90 GY Guyana 3.58
16 DE Germany 5.32	41 LV Latvia 4.35	66 MK Macedonia, FYR 3.91	91 MA Morocco 3.56
17 AU Australia 5.29	42 CZ Czech Republic 4.33	67 RO Romania 3.90	92 AR Argentina 3.52
18 JP Japan 5.25	43 HU Hungary 4.30	68 AL Albania 3.89	93 KE Kenya 3.51
19 AT Austria 5.25	44 UY Uruguay 4.28	69 IN India 3.89	94 AM Armenia 3.49
20 IL Israel 5.24	45 HR Croatia 4.22	70 BG Bulgaria 3.89	95 LB Lebanon 3.49
21 LU Luxembourg 5.22	46 ME Montenegro 4.22	71 LK Sri Lanka 3.88	96 EC Ecuador 3.46
22 BE Belgium 5.13	47 JO Jordan 4.17	72 ZA South Africa 3.87	97 GH Ghana 3.44
23 FR France 5.12	48 IT Italy 4.17	73 CO Colombia 3.87	98 GT Guatemala 3.43
24 EE Estonia 5.09	49 PL Poland 4.16	74 JM Jamaica 3.86	99 HN Honduras 3.43
25 IE Ireland 5.02	50 TN Tunisia 4.12	75 UA Ukraine 3.85	100 SN Senegal 3.42

a Color of the country indicates: N: Eurasian, N: Oceania, N: America, N: Africa

Source: The Global Information Technology Report 2012 (World Economic Forum, 2012)

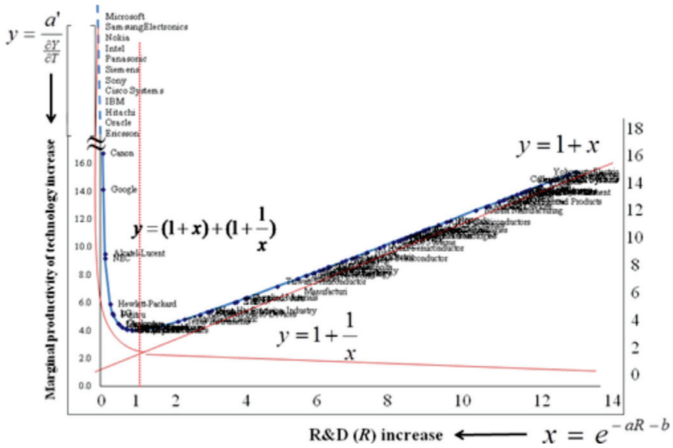


Figure 4: Bi-polarization of ICT Driven Development Trajectory in 500 Global ICT Firms (2010)

Source: Economics of Industrial Research and Innovation (EU, 2011).

Similarly, highly R&D intensive firms among 500 global ICT firms (R&D matured ICT firms: 19 in 2007 and 21 in 2010) have fallen in a pit of a vicious cycle between R&D investment centered by ICT and its marginal productivity as increase in former results in decline for the later. The remaining firms (R&D increasing ICT firms) have been enjoying a virtuous cycle between them as R&D increase leads to productivity increase.

Table 2 demonstrates such a contrast. Top 19 and 21 global ICT firms with respect to R&D investment in 2007 and 2010, respectively led by ICT giant such as Microsoft, Samsung and Nokia have fallen in a pit of a vicious cycle between their R&D investment increase and marginal productivity of technology decline.

Table 2: Bi-polarization in 500 Global ICT Firms in 2007 and 2010 (by R&D level order)

2007	**2010**
1. Microsoft	1. Microsoft
2. Nokia	2. Samsung Electronics
3. Samsung Electronics	3. Nokia
4. Intel	4. Intel
5. IBM	5. Panasonic
6. Panasonic	6. Siemens
7. Alcatel Lucent	7. Sony
8. Siemens	8. Cisco Systems
9. Sony	9. IBM
10. Cisco Systems	10. Hitachi
11. Motorola	11. Oracle
12. Ericsson	12. Ericsson
13. Hitachi	13. Canon
14. Hewlett-Packard	14. Google
15. Toshiba	15. Alcatel-Lucent
16. Canon	16. NEC
17. NEC	17. Hewlett-Packard
18. Oracle	18. LG
19. Philips Electronics	19. Fujitsu
	20. Qualcomm
20. Fujitsu	21. Motorola
21. Texas Instruments	
22. SAP	22. Huawei Technologies
23. Google	23. SAP
24. San Microsystems	24. EMC
25. Advanced Micro Devices	25. Philips Electronics
26. Qualcomm	26. STMicrolectronics
27. LG Electronics	27. Fuji Film
28. EMC	28. Sharp
29. Nortel Networks	29. *Apple*
30. Infineon Technologies	30. Broadcom
32. Sharp	
48. *Apple*	

Firms in blue indicate R&D matured ICT firms (19 in 2007 and 21 in 2010) which suffer a vicious cycle between R&D and marginal productivity of technology while firms in black indicate R&D increasing firms which enjoy a virtuous cycle between them.

Undermined 17 firms indicates firms categorized in matured ICT firms in both 2007 and 2010.

Source: Industrial R&D Investment Scoreboard (EU, annual issues).

CONSEQUENCE OF THE BI-POLARIZATION

Great Stagnation in ICT Matured Economies

While a dramatic advancement in ICT provides strong anticipation in significant economic growth in ICT advanced economies, contrary to such anticipation, their economic growth engine has disappeared except in Singapore which ranks second in the world by NRI in 2011. Fig. 5 traces trends in real GDP increase rate in countries among ICT advanced economies by comparing those in ICT growing economies such as BRIC over the last half century encompassing industrial society (1961-1990), information society (1991-2000) and after net bubble bursting (2001-2010).

Looking at the Fig. 5 we clearly note that contrary to conspicuous economic growth in ICT growing economies, GDP growth rates in countries among ICT advanced economies in this century, particularly during the latter half of the first decade of this century have demonstrated the great stagnation (Cowen, 2011) except Singapore.

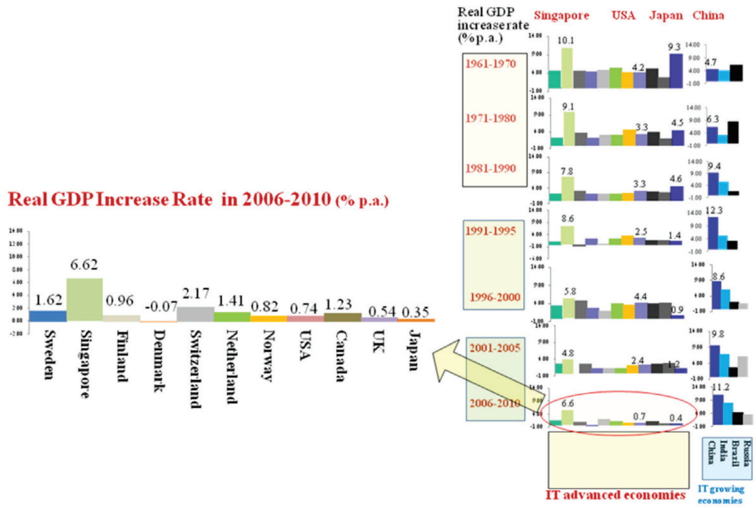


Figure 5: Stagnation in Economic Growth in ICT Advanced Economies (2006-2010)

Source: World Economic Outlook Database (IMF, annual issues).

Such a contrast is not only present in the great stagnation in national level but also in the market competition in global ICT firms. Fig. 6 compares net income of Japan's leading high-technology firms in 2011, which demonstrates a conspicuous bi-polarization between firms maintaining profits and those suffering serious deficits. Contrary to profits in automobile firms such as Nissan, Toyota and Honda, majority of electric machinery firms (they are global ICT firms) such as Panasonic, Sony and Sharp suffered significant deficits. Under such circumstances, only Canon maintained conspicuous profits. Hitachi's profits can be attributed to shifting to social infrastructure field not due to indigenous electric machinery innovation efforts.

Significant deficits in world leading electric machinery firms (global ICT firms) as Panasonic, Sony and Sharp can largely be attributed to overlooking new beyond anticipation streams such as (i) dramatic advancement of the Internet, (ii) digitalization of manufacturing, (iii) new stream of emerging economies, and (iv) subsequent growing anger of consumers (Watanabe, 2013).

This can be a consequence of clinging to traditional efficiency oriented business model without paying careful attention to resilience against new stream that led to foregoing bi-polarization (Watanabe, 2013).

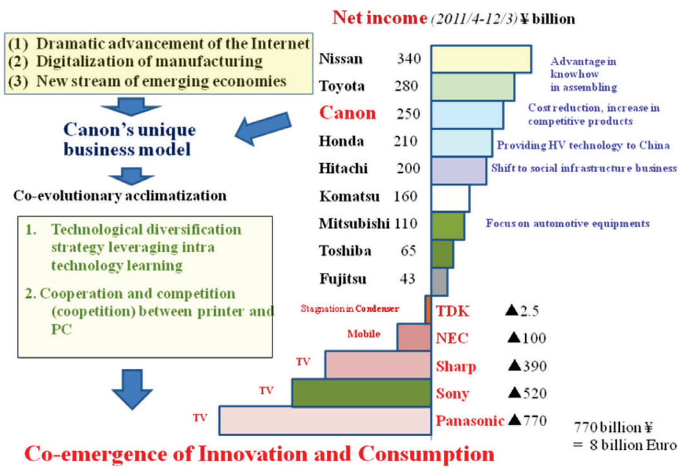


Figure 6: Bi-polarization of Leading High-technology Firms in Japan (2011)

Sources: Annual report of respective firms.

ASSESSMENT OF RESILIENCE IN GLOBAL ICT FIRMS

Struck by these shocking observations, Fig. 7 assesses sustainability of high-performance in high R&D intensive 18 firms[3] which demonstrated R&D among matured ICT firms both in 2007 and 2010 (see Table 2) by examining sales, operating income and market capitalisation (market value of equity) over the period 2003-2010 among firms sustaining their top 100 position in the world.

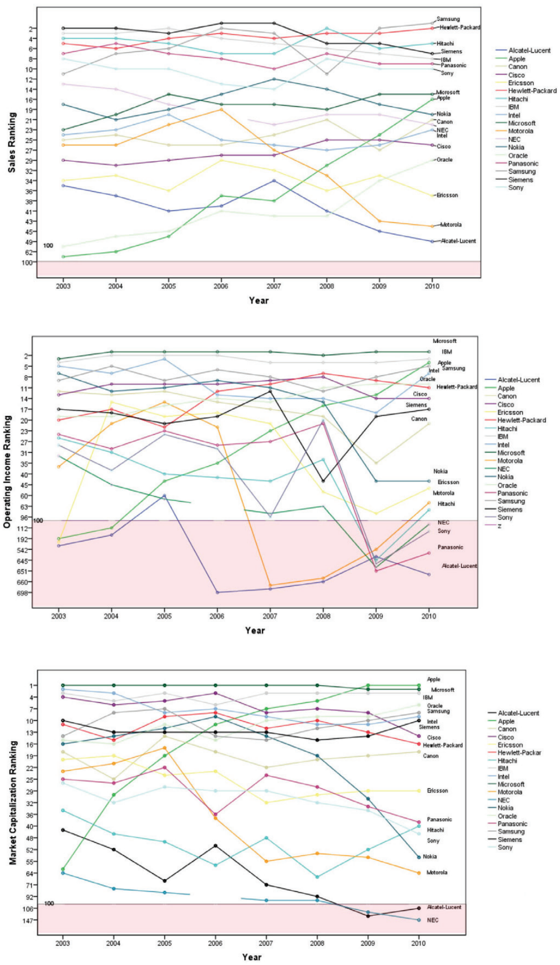


Figure 7: Sustainability of High-performance in High R&D Intensive 18 Firms (2003-2010)

Source: Economics of Industrial Research and Innovation (EU, 2011)

Lessons from significant deficit beyond anticipation that Japan's leading global ICT firms experienced as a consequence of clinging to traditional efficiency oriented business model without paying careful attention to resilience against new stream suggest a significance of the assessment of sustainability from the view point of resilience (Watanabe, 2013).

Here resilience can be defined as "*ability to transform external shocks into a springboard for further advancement by recovering from and adjusting smoothly through prompt and agile reaction*" (Watanabe et al., 2003, Watanabe, 2009b, Ilmola et al., 2013). This concept prompts us with a significance of stability which is a function of constancy, persistence, resistance, elasticity and domain of attraction (Grimm and Wissel, 1997) leading to measuring the resilience of global ICT firms by means of frequency (FQ). In this case, frequency can be measured by counting the years when examinee firms sustain their top 100 position based on all factors of sales, operating income and market capitalization over the period 2003-2010. Firms, which satisfy this requirement for all 8 years can be appreciated based on FQ 8 while those, which failed to sustain any one factor for n years should be appraised as FQ (8-n). Since Panasonic and Sony lost their 100 position based on operating income in 2009 and 2010 due to Lehman shock in 2008, their FQ can be counted as 6 while Ericsson's FQ can be 7 as it lost operating income in 2003. Firms with FQ 8 can be classified as resilient firms while those with lower than FQ 7 should be classified as non-resilient firms.

Fig. 8 illustrates scheme in classifying resilient firms out of high R&D intensive global ICT firms (R&D matured ICT firms) and the result of the classification based on Fig. 7. 12 firms viz., as Microsoft, Samsung Electronics, Nokia, Intel, Siemens, Cisco Systems, IBM, Hitachi, Oracle, Canon, Hewlett-Packard and Apple can be classified under resilient firms while other 6 firms as Panasonic, Sony, Ericsson, Alcatel-Lucent, NEC and Motorola should be classified under non-resilient firms.

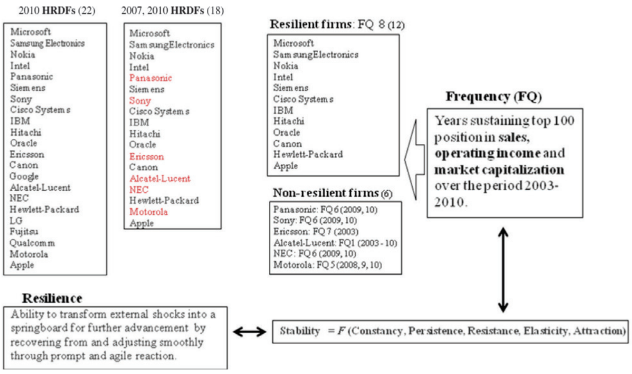


Figure 8: Scheme in Classifying Resilient Firms out of High R&D Intensive Global ICT Firms (HRDFs).

Source: Industrial R&D Investment Scoreboard (EU, annual issues).

a Figures in parenthesis in non-resilient firms indicate years when loosing top 100 firms position either R&D, operating income or market capitalization.

Watanabe, C.
Naveed, K.
Zhao, W.

RESILIENT TECHNOPRENEURIAL STRUCTURE IN RESILIENT GLOBAL ICT FIRMS

Based on the foregoing assessment, resilient technopreneurial structure in resilient global ICT firms are analyzed by comparing them with non-resilient firms.

Analytical Framework

Since market value of global ICT firms is subjected to its technology intensity, its profitability, market exploration power, global economic condition and external happening, provided that it is governed by technology intensity, profitability of R&D, sales volume, market situation, and irregular factors, following equation can be depicted:

$$\ln MC = a + b \ln \frac{T}{S} + c \ln \frac{OI}{R} + d \ln S + e \ln PMI + fD \tag{1}$$

where MC: market value of equity (market capitalization), T: gross technology stock, S: sales, OI: operating income, R: R&D expenditure, PMI: Purchasing Manager's Index[4], D: dummy variables corresponding to the irregular external happenings, and a, b, c, d, e, f: coefficients.

$$\text{Since } T \approx \frac{R}{\rho + g}, \quad T = T_i + zT_s = T_i(1 + z\frac{T_s}{T_i}) \tag{2}$$

where Ti: indigenous technology stock, Ts: technology knowledge stock, z: assimilation capacity, : rate of obsolescence of technology, and g: increasing rate of R&D expenditure at the initial state of technology stock formation.

Direct contribution of technology stock to MC can be depicted as follows:

$$b \ln \frac{T}{S} \approx b(\ln T - \ln S) = b\left[\ln T_i(1 + z\frac{T_s}{T_s}) - \ln S\right] \approx b \ln \frac{T_i}{S} + bz\frac{T_s}{T_i} \approx b \ln \frac{R}{S} + bz\frac{T_s}{T_i} - b\ln(\rho + g) \tag{3}$$

Provided that $\rho + g$ is stable, integration of equations (1) and (2) leads to the following equation:

$$\ln MC = a' + b \ln \frac{R}{S} + b_2 \frac{T_s}{T_i} + c \ln \frac{OI}{R} + d \ln S + e \ln PMI + fD \tag{4}$$

where $a' = a - b\ln(\rho + g)$ coefficient, and $b_2 = bz$

Assimilation capacity can be measured by the following equation

$$z = \frac{b_2}{b} \tag{5}$$

Empirical Analysis

Based on the foregoing analytical framework, an empirical analysis was conducted by taking 10 selected firms, both with & without resilient structure, out of 18 high R&D intensive ICT firms. There are categorized in R&D matured ICT firms both in 2007 and 2010.

Data are constructed by utilizing statistics from EU Industrial R&D Investment Scoreboard, OECD, World Bank, World Economic Forum and also annual reports of respective firms.

To identify the indigenous technopreneurial structure of the firms which are to be analyzed, Fig. 9 compares R&D intensity (R/S), operating income to sales (OI/S), and operating income to R&D (OI/R) in 18 high R&D intensive ICT firms (R&D matured ICT firms) in 2007 and 2010 (before and after the Lehman shock in 2008).

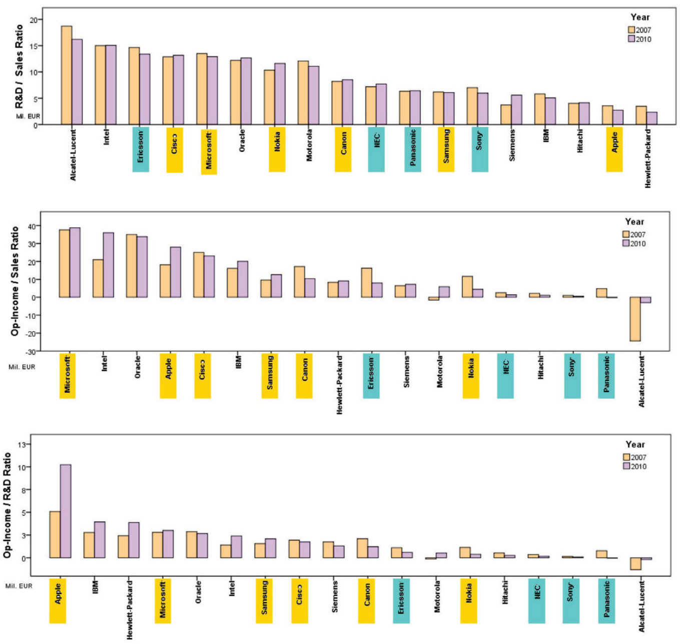


Figure 9: Comparison of R&D Intensity, Operating Income to Sales, and Operating Income to R&D in 18 High R&D Intensive ICT Firms in 2007 and 2010

10 selected firms, which are analyzed include 6 resilient firms viz., Microsoft (US), Canon (Japan), Samsung (Korea), Apple (US), Cisco (US), Nokia

(Finland) and 4 non-resilient firms as Panasonic (Japan), Ericsson (Sweden), NEC (Japan) , Sony (Japan). Results of the analysis are presented in Table 3.

Table 3: Governing Factors of Market Value of Equity in 10 Selected Firms

$$\ln MC = a + b \ln R/S + b_2\, Ts/Ti + c \ln OI/R + d \ln S + e \ln PMI + f D$$

Firm	*a*	*b*	b_2	*c*	*d*		*f*	adj.R^2	$z = b_2/b$	*e*
Microsoft	7.835	6.813	0.008	3.141	0.722	1.755	-0.549	**0.960**	0.12×10^{-2}	(1991,2011, 2000,2010, 1997) = 1 Others = 0
(1991-2011)	2.93($*_1$)	8.71($*_1$)	1.32($*_4$)	7.89($*_1$)	6.35($*_1$)	2.74($*_2$)	-3.70($*_2$)			
Canon	-10.256	1.565	0.095	0.214	1.754	1.037	-0.647	**0.915**	6.07×10^{-2}	(2012) = 1 Others = 0
(1994-2012)	-1.82($*_3$)	2.06($*_2$)	5.60($*_1$)	1.19($*_4$)	4.84($*_1$)	1.74($*_3$)	-3.00($*_1$)			
Samsung	-0.587	3.269	0.076	0.409	1.734	-	-1.328	**0.970**	2.32×10^{-2}	(1998) = 1 Others = 0
(1998-2012)	-0.29($*_5$)	3.64($*_1$)	2.93($*_2$)	3.30($*_1$)	5.70($*_1$)	-	-6.71($*_1$)			
Apple	-10.166	4.877	0.033	0.594	3.346	-	0.726	**0.917**	0.68×10^{-2}	(1991) = 1 Others = 0
(1990-2012)	-3.74($*_1$)	2.59($*_2$)	3.99($*_1$)	2.77($*_2$)	4.68($*_1$)	-	1.22($*_4$)			
Cisco	-0.184	2.673	-	1.148	0.691	2.404	1.095	**0.936**		(1995,1996, 1998, 1999,2000) = 1 Others = 0
(1990-2012)	-0.03($*_5$)	2.17($*_2$)	-	1.87(*3)	5.97($*_1$)	1.72($*_3$)	5.06($*_1$)			
Nokia	7.284	1.884	-	0.914	0.743	-	1.279	**0.961**		(1999,2000, 2001) = 1 Others = 0
(1991-2012)	2.45($*_4$)	3.05($*_2$)	-	8.45($*_1$)	4.62($*_1$)	-	6.86($*_1$)			
Panasonic	2.460	1.456	-	0.451	0.540	1.605	-0.662	**0.536**		(2004,2010, 2012) = 1 Others = 0
(1995-2012)	0.38($*_5$)	1.51($*_4$)	-	3.44($*_1$)	1.14($*_4$)	1.44($*_4$)	-3.26($*_1$)			
Ericsson	13.635	1.381	-	0.271	-0.659	1.600	0.961	**0.597**		(1995,1999, 2000,2012) = 1 Others = 0
(1991-2012)	2.24($*_2$)	1.16($*_4$)	-	1.53($*_4$)	-3.404($*_1$)	1.202($*_4$)	4.51($*_1$)			
NEC	-8.300	-1.630	-0.022	-	1.274	-	-	**0.445**	1.35×10^{-2}	
(1990-2012)	-1.88($*_3$)	-2.32($*_2$)	2.92($*_1$)	-	3.15($*_1$)	-	-			
Sony	-6.648	-1.498	-0.142	-0.18	1.349	-	0.998	**0.733**	9.47×10^{-2}	(1999) = 1 Others = 0
(1990-2012)	-1.93($*_3$)	-1.90($*_3$)	2.62($*_2$)	-1.50($*_4$)	5.21($*_1$)	-	3.15($*_1$)			

Figures in the second line of the respective column indicate t-statistics.$*_1$,$*_2$,$*_3$ and $*_4$ indicate significant at the 1%, 5%, 10% and 20% level, respectively. $*_5$ indicate more than 20% level only for constant term.

Fig. 10 compares resilient structure in 10 firms examined by highlighting sources of resilience through comparison of elasticity of R/S (R&D intensity), OI/R (operating income to R&D: R&D profitability), S (sales volume) and PMI (Purchasing Manager's Index), and also spillover coefficient.

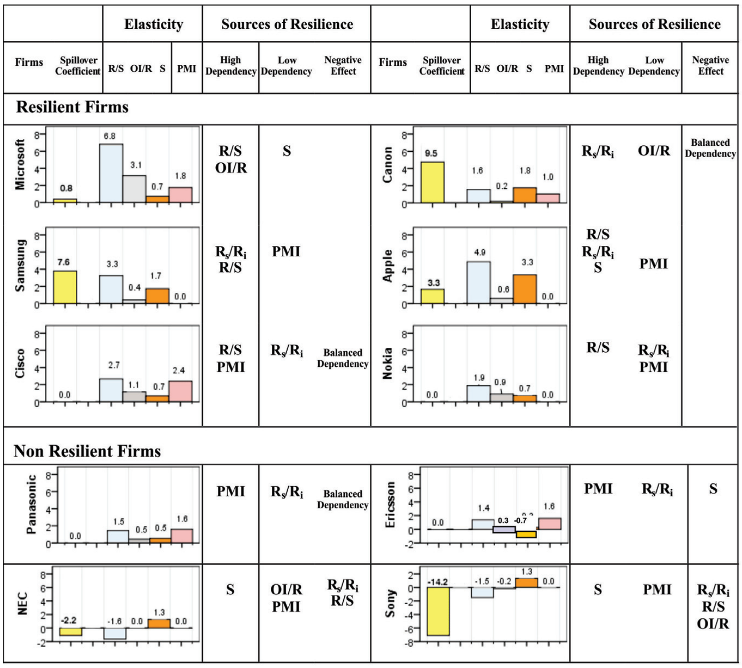


Figure 10: Comparison of Resilient Structure in Selected Firms

Noteworthy structural characteristics leading to resilient and non-resilient firms are summarized as follows:

1) RESILIENT FIRMS

i. **Microsoft** demonstrates high dependency on R&D intensity (R/S) and profitability of R&D (OI/R) while low dependency on sales volume (S). This structure suggests that, as far as high profitable R&D continues that contributes to operating income (OI) increase, market value can be sustained independent of sales.

ii. **Canon** demonstrates extremely high dependency on assimilation of spillover technology, while low dependency on profitability of R&D (OI/R). It also maintains a well balanced dependency on all factors contributing to market value.

This structure suggests that effective utilization of external resources in innovation while minimizing own risk for high profitable R&D can be the source for resilient market value creation. Well balanced structure supports this resilience.

iii. **Samsung** demonstrates high dependency on assimilation of spillover technology and R&D intensity (R/S) while not depending on market situation (PMI). This structure suggests that hybrid management of technology between indigenous R&D and assimilation spillover technology, while not depending on external market situation can also be the source for resilient market value creation.

iv. **Apple** demonstrates similar structure as Samsung, supporting the significance of such structure for resilient market value creation. It demonstrates high dependency on R&D intensity (R/S) and sales volume (S) while low dependency on profitability of R&D (OI/R) and no dependency on market situation (PMI). It depends also on assimilation of spillover technology. Given its high level of profitability of R&D (OI/R) and low level of R&D intensity (R/S) this structure demonstrates efficient and resilient structure as far as its sales volume (S) maintains competence in the market.

v. **Cisco** demonstrates high dependency on R&D intensity (R/S) and market situation (PMI) while not depending on spillover technology as similar to Canon; it also maintains well balanced dependency on all factors contributing to market value. This structure suggests that balanced dependency between internal R&D effort and external market situation can lead to resilient market value creation.

vi. **Nokia** demonstrates high dependency on R&D intensity (R/S), while not depending on spillover technology and market situation (PMI). This structure suggests that sustainable R&D intensity (R/S) with reasonable profitability of R&D (OI/R) function can be a source of resilient market value creation. However, contrary to preceding structures, fragility cannot be removed from this structure.

2) NON RESILIENT FIRMS

i. **Panasonic** demonstrates similar structure as Cisco, while its dependency on profitability of R&D (OI/R) is lower than Cisco. This suggests that resilience of this structure can turn out to be non-resilient upon decreasing dependency on profitability of R&D (OI/R).

ii. **Ericsson** demonstrates negative dependency on sales volume (S: sales increase results in decrease in market value). This implies its products have matured in the market and necessitate new attractive innovation.
iii. **NEC** demonstrates negative dependency on spillover technology and R&D intensity (R/S), while not depending on profitability of R&D (OI/R) and market situation (PMI), It only depends on sales volume (S). This implies that its R&D does not stimulate market value neither assimilate the spillover technology, which is attractive enough to increase its market value.
iv. **Sony** demonstrates negative dependency not only on spillover technology, and R&D intensity (R/S) but also on profitability of R&D (OI/R) while not depending on market situation (PMI). Similar to NEC, it depends only on sales volume (S). This implies that its R&D has lost attractiveness in the market resulted in loosing the increase in operating income (OI) leading to an increase market value.

(3) IMPLICATIONS FOR RESILIENT MARKET VALUE CREATION

Foregoing analysis suggests the following implications for resilient market value creation.

i. Dependency on high R&D profitability (OI/R)[5] while restraining its elasticity enables efficient functionality development while minimizing risk taking leading to resistant market value creation [Apple model].
ii. Effective utilization of external resources in innovation also enables minimum dependency on high risk R&D while maximizing the benefit of open innovation and leads to resilient market value creation [Canon model].
iii. Hybrid management of technology between indigenous R&D and assimilation of spillover technology can lead to resilient market value creation [Samsung model].
iv. While balanced dependency between internal R&D effort and external market situation can lead to resilient market value creation [Microsoft], it can be turn out to be non-resilient upon decreasing dependency on profitability of R&D (OI/R) [Panasonic].
v. Matured products/services as well as R&D which have lost attractiveness in the market may result in negative dependency and non-resilient market value creation [Ericsson, NEC, Sony].

Drivers for resilience in resilient firms and their mechanism for resilience can be summarized as Table 4.

Table 4 : Drivers for Resilience in Resilient Firms

Resilient firms	**Drivers for resilience**	**Mechanism for resilience**
Apple	Dependency on high R&D profitability while restraining its elasticity	Efficient functionality development while minimizing risk taking
Canon	Effective utilization of external resources in innovation	Minimum dependency on high risk R&D while maximizing the benefit of open innovation
Samsung	Hybrid management of technology between indigenous R&D and assimilation of spillover technology	Synergy effect for efficient functionality development and minimum risk taking
Microsoft	Balanced dependency between internal R&D effort and external market situation	Harness the vigor of market while maintaining indigenous vigor

STRUCTURAL SOURCE OF THE TRAP OF ICT ADVANCEMENT

Analysis in the preceding section demonstrates that certain R&D matured resilient ICT firms manage to maintain sustainable growth while the majority of R&D matured ICT firms suffer "the great stagnation" (Cowen, 2011) because of the trap of ICT advancement as reviewed under the heading 'Great Stagnation in ICT Matured Economics'. Success in resilient ICT firms can largely be attributed to efficient functionality development by maximizing R&D profitability (e.g., Apple) and open innovation (e.g., Canon) while minimizing the possibility of risk taking by restraining elasticity of such profitability (e.g. Apple) and depending on spillover effect (e.g. Canon).

Given that these business model enables resilient firms to maintain sustainable growth despite fatal nature of the great stagnation subsequent to the high dependency on the advancement of ICT centered by the dramatic advancement of the Internet, following two faces as illustrated in Fig. 11 can be postulated as a possible source of the trap of ICT advancement.

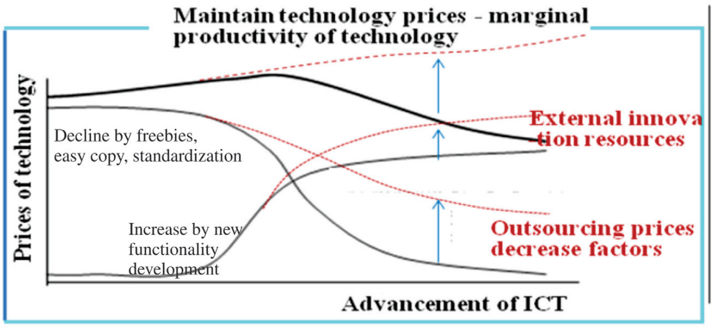


Figure 11: ICT's Identical Two Faces

Fig. 11 illustrates ICT's identical two faces. Advancement of ICT generally contributes to enhanced price of technology by increasing new functionality development. However, the dramatic advancement of the Internet reacts to decline price of technology due to its nature by freebies, easy copy and mass standardization. Consequently, price of technology in highly R&D intensive economies may change to declining trend resulting in decreasing their growth rate as outlined in Fig. 12. This can be the structural source of the trap of ICT advancement compelling ICT advanced nations/firms suffering a vicious cycle between advancement of ICT and its marginal productivity[6] decrease as reviewed in section 2.

Production function and growth rate of ICT firms can be depicted as follows:

$$S = F(X,T) \qquad \frac{\Delta S}{S} = \underbrace{\Sigma\left(\frac{\partial S}{\partial X}\cdot\frac{X}{S}\right)\frac{\Delta X}{X}}_{\text{Contribution by traditional factors}} + \underbrace{\left(\frac{\partial S}{\partial T}\cdot\frac{T}{S}\right)\frac{\Delta T}{T}}_{\text{technology (TFP)}}$$

S: sales, X: traditional production factors (labor, capital, materials and energy), T: technology ($\Delta T \approx R$), R: R&D investment. P_T, P_S: price of technology and products

$$Since \ \frac{\partial S}{\partial T} = \frac{P_T}{P_S}, \ TFP = \frac{P_T}{P_S}\cdot\frac{R}{S}$$

$$\frac{P_T}{P_S}\cdot\frac{R}{S} \rightarrow p_T \ decrease \rightarrow \frac{\Delta S}{S} \ decrease$$

Figure 12: Scheme of the Great Stagnation due to the Decrease in Technology Price

Given the foregoing circumstances, ICT firms endeavor should focus on accelerating price increase by means of successive efficient new functionality development while minimizing price decrease factors by outsourcing them to other parties.

Noteworthy accomplishments demonstrated by resilient global ICT firms as analyzed in the preceding section support this postulate and provide us constructive suggestions supportive to constructing new business model satisfying both efficiency and resilience in a global competitive market.

These accomplishments suggest the following co-evolutionary acclimatization system that enables both ICT advanced and growing economies to harness the vigor of counterparts. While R&D matured ICT firms enable further advancement of ICT, it results in declining its productivity. Thus, such advancement should be addressed with the advancement of R&D increasing ICT firms which enjoy a virtuous cycle between its advancement and productivity increase leading to sustainable growth as reviewed in Fig. 5 if its ICT advancement turns out to enabling position.

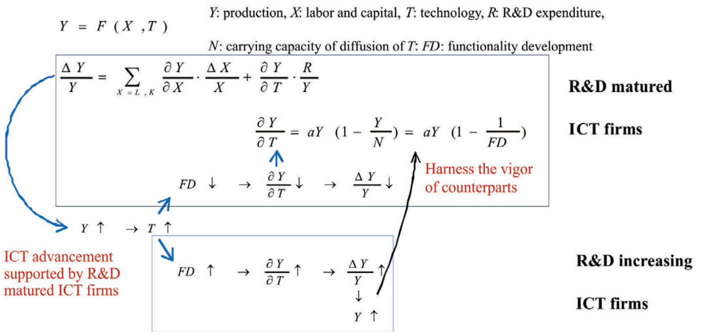


Figure 13: Scheme of Co-evolutionary Acclimatization in Global ICT Firms

LESSONS FROM RESILIENT MODEL

ICT Advanced Economies: A case of Singapore

As reviewed in section 3, contrary to conspicuous economic growth in ICT growing economies, GDP growth rates in countries among ICT advanced economies have demonstrated the great stagnation except for Singapore.

Sources of Singapore's resilient development trajectory can be observed in its NEWater (recycled water) development dynamism as illustrated in Fig. 14. Securing water is a crucial survival strategy for Singapore (Chew et al., 2010). In order to accomplish this survival strategy, Singapore endeavored to explore technology driven water starting from importing advanced membrane technology from USA and Japan (Phase 1). Then it endeavored to transit from learning to indigenous technology development (Phase 2). It further endeavored to accelerate exporting developed indigenous technology (Phase 3) and co-evolutionary acclimatization of global best practices through exporting activities (Phase 4).

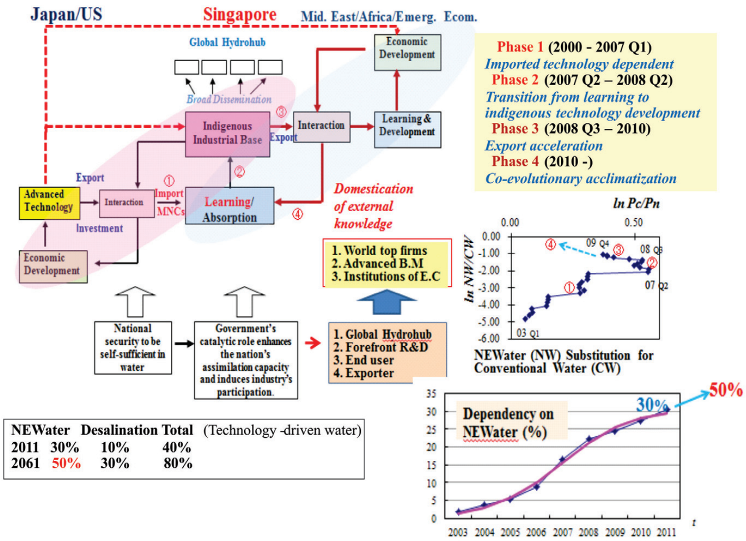


Figure 14: NEWater Development Dynamism in Singapore

Source: Chew et al (2010)

Based on such a stepwise endeavor Singapore succeeded in sourcing 40% of water through technology driven water (30% on NEWater and 10% on desalination). It attempts to increase such dependency to double by 2061 (50% on NEWater and 30% on desalination).

Through the course of accomplishing such survival strategy Singapore has created dual innovation-consumption co-emergence structure which can be considered the source enabling it as exceptional sustainable growth despite bi-polarization structure resulting in stagnating sustainable growth in ICT advanced economies as reviewed in Fig. 5.

Global ICT Firms

(1) Apple

As reviewed in section 3, Apple depends largely on high R&D profitability

(OI/R) while restraining its elasticity. This structure enables acceleration of price increase by means of successive efficient new functionality development while minimizing price decrease factors by outsourcing them to other parties as postulated in the preceding section as effective strategy in overcoming the trap of ICT advancement.

Fig. 15 illustrates this business model. Apple focuses its own resources on high value added business such as design, planning, marketing and after-service while entrusting manufacturing which is relatively adds lower value and higher risk to Japan and EMS thereby maximizing the merit of international division and learning and absorption effects. Based on this strategy it has succeeded to construct co-evolutionary acclimatization dynamism between comparative advantage in its indigenous strength and that of external resources leading to harness the vigor of ICT growing economies.

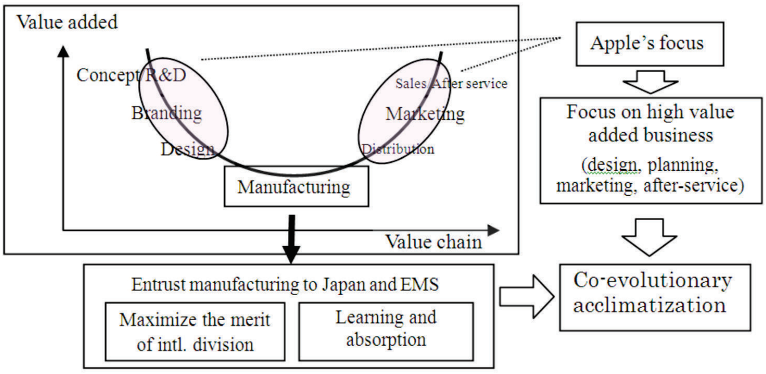


Figure 15: Apple's Business Model in Overcoming the Trap of ICT Advancement

(2) Canon

As compared in Fig. 6, notwithstanding new beyond anticipation stream as dramatic advancement of the Internet, digitalization of manufacturing, new stream of emerging economies, and growing anger of consumers that impacted its rival firms as Panasonic, Sony and Sharp resulting in suffering them significant deficits, Canon has maintained sufficient profits. This can be attributed to its unique business model based on co-evolutionary acclimatization strategy.

Canon's identical business model starts from its technological diversification strategy as illustrated in Fig. 16 (Watanabe, Lei and Ouchi, 2009).

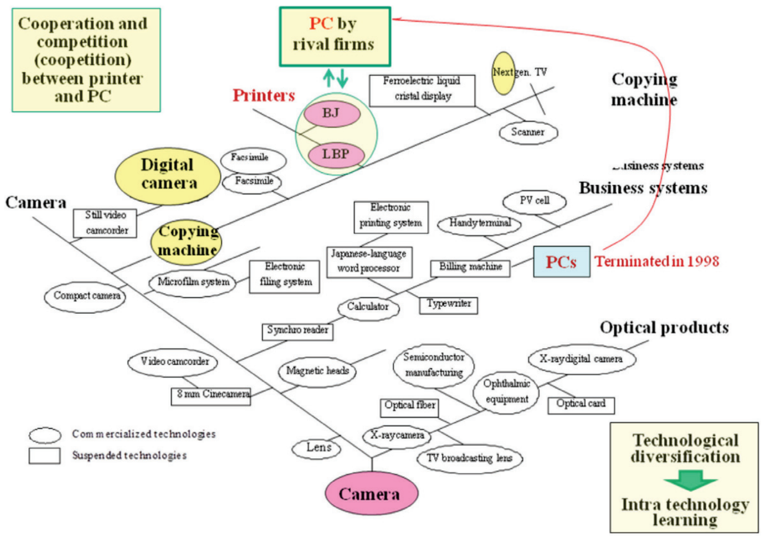


Figure 16: Canon's Technological Diversification Strategy

Starting from camera, Canon endeavored technological diversification strategy inducing intra technology learning such as coping machine, printers and digital camera.

Another noteworthy strategy is coopetition - cooperation and competition strategy. While Canon succeeded to develop market leading printers, it terminated PCs production in 1998 and provides opportunity to utilize attractive printers essential for the advancement of PCs to rival firms as NEC, Fujitsu, Sony and Toshiba. Through such cooperation and competition: coopetition strategy by means of attractive printers, crystal of intra technology learning, Canon has been able to obtain external learning, crystal of PCs technology developed by rival firms thereby constructed a virtuous cycle between its printers and rival firms PCs as illustrated in Fig. 17.

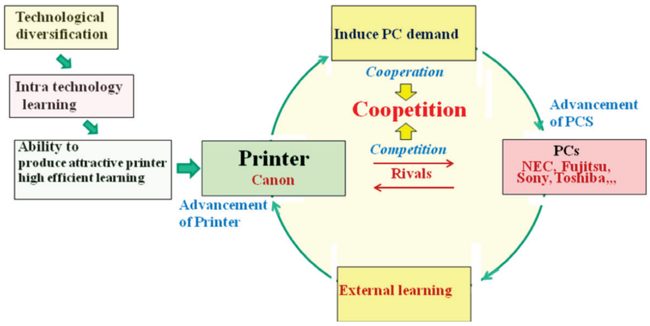


Figure 17; Virtuous Cycle between Canon Printers and PCs

In addition to such a virtuous cycle, Canon endeavored to harness the vigor of mobile phones development in consumers market. While Canon has never involved in mobile phones handset development, it can harness the vigor in the market activated by its attractive digital camera. In response to activated demand in the market rival firms (majority of them are PC producers and users of Canon's printers) endeavors development of advanced handsets which can be learned by Canon through coopetition between printers and PCs. Fig. 18 demonstrates this dynamism in co-emerging innovation and consumption through "in-vitro fertilization."

Based on the foregoing stepwise endeavor as individual technology, intra-technology learning, coopetition and in-vitro fertilization, Canon established unique business model in co-emerging innovation and consumption as demonstrated in Fig. 19. This is similar to Singapore's innovation-consumption co-emergence structure and can be considered the source of its resilience against beyond anticipation issues as demonstrated in Fig. 6.

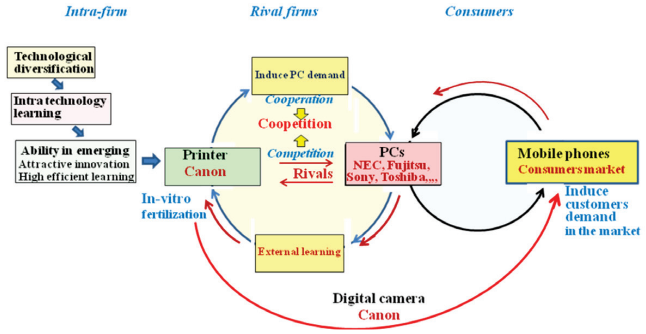


Figure 18: Dynamism in Co-emerging Innovation and Consumption
– In-vitro Fertilization

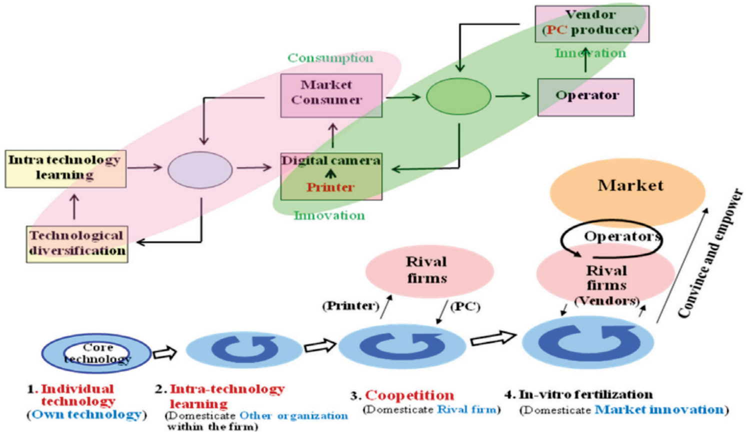


Figure 19: Canon's Business Model in Co-emerging Innovation and Consumption

CONCLUSION

In light of the significant impacts on global economy both nations and firms derived from the dramatic advancement of information and communication technology (ICT), particularly bi-polarization between ICT advanced and growing economies compelling a vicious cycle between ICT advancement and its productivity decline in the former economies, its institutional sources of resilience were analyzed.

Based on an empirical analysis comparing technopreneurial performance in world top 500 ICT firms by market value, sales and profit over the last decade, resilient firms maintaining top 100 position in the world based on all three factors over the period under study were identified.

An empirical analysis identifying governing factors to resilient market creation was conducted focusing on 10 selected high R&D intensive ICT firms both with resilient and non-resilient structure.

Based on this analysis, structural sources of ICT trap was elucidated.

Noteworthy findings include

(i) Dependency on high R&D profitability (OI/R) while restraining its elasticity enables efficient functionality development while minimizing risk taking leading to resilient market value creation .

(ii) Effective utilization of external resources in innovation also enables minimum dependency on high risk R&D while maximizing the benefit of open innovation and leads to resilient market value creation.

(iii) Hybrid management of technology between indigenous R&D and assimilation of spillover technology can lead to resilient market value creation.

(iv) While balanced dependency between internal R&D effort and external market situation can lead to resilient market value creation, it can be turned out to be non-resilient one upon decreasing dependency on OI/R.

(v) Matured products/services as well as R&D, which have lost attractiveness in the market may result in negative dependency and non-resilient market value creation.

(vi) ICT firms endeavor should focus on accelerating price increase by means of successive efficient new functionality development while minimizing price decrease factors by outsourcing them to other parties.

(vii) Noteworthy accomplishments demonstrated by resilient global ICT firms support this postulate and provide us with constructive suggestions supportive to constructing new business model satisfying both efficiency and resilience in a global competitive market.

These findings provide the following policy suggestions:

(i) R&D investment strategy should be carefully examined taking special attention of the two-sided nature of ICT with its prices decrease possibility.

(ii) Given the bi-polarization between R&D matured and R&D increasing ICT firms, policy facilities should be carefully provided by paying balanced attention to both economies.

(iii) Institutional facilities leveraging the construction of co-evolutionary acclimatization structure in global ICT firms should be provided on priority basis.

(iv) Technopreneurial strategy endeavoring harness the vigor of counter parts in the global ICT market should be encouraged, thus co-evolutional acclimatization should be leveraged.

(v) Platform creating hybrid management of technology fusing indigenous R&D and assimilated spillover technology should be facilitated.

(vi) Policy systems removing organizational inertia clinging to matured products/services as well as R&D that have lost attractiveness in the market should be accelerated.

Points of future works are summarized as follows

(i) In order to generalize these suggestions, analyses of other high-technology sectors and firms should be conducted.

(ii) A comparative analysis of institutional factors influencing the resilience of firms should be conducted.

(iii) Further study should be focused on the resilience assessment of innovation value chain.

ENDNOTES

1. Fig. 1 demonstrated by NRI as a proxy of nation's ICT advancement which consists of Environment (Political and regulatory environment, Business and innovation environment), Readiness (Infrastructure and digital content, Affordability), Usage (Individual usage, Business usage, Government usage), and Impact (Economic impact, Social impact).

2. $\frac{\partial S}{\partial T} = aS(1-\frac{S}{N})$, $T \approx \frac{R}{\rho + g}$, $S = \frac{N}{1+be^{-aR}}$, $\frac{aN}{\frac{\partial S}{\partial T}} = 2 + be^{-aR} + \frac{1}{be^{-aR}}$. *Given that* $y \equiv \frac{aN}{\frac{\partial S}{\partial T}}$ *and* $x \equiv be^{-aR}$,

   this can be transformed to $y = (1+x)+(1+\frac{1}{x})$.

   where S: sales, N: carrying capacity, T: technology stock, R: R&D expenditure, : rate of obsolescence of technology, g: R&D increasing rate at the initial stage, and a, b: coefficients.

3. As far as the years 2007 and 2010 concerned, while Apple was not R&D matured firms, given its high R&D performance in recent years exceeding R&D matured firms, it is included in this assessment.

4. PMI is an indicator of economic health of manufacturing sector based on five major indicators: new orders, inventory levels, production, supplier deliveries, and the employment environment.

5. Apple demonstrates conspicuously high OI/R as illustrated in Fig. 9.

   It dramatically increased this ratio after 2008.

6. Given that the firms seek to profit maximum in the competitive market, marginal productivity of technology corresponds to relative price of technology (ratio of technology price and price of products).

REFERENCES

Campbell, F. (2008) *Elements of Metallurgy and Engineering Alloys*, Almere, Netherlands, ASM International.

Chew, M., Watanabe, C. and You, Y. (2010) 'Technology Leapfrogging: Findings from Singapore's Water Industry', *Journal of Technology Management for Growing Economies* 1:2, pp. 29-47.

Cowen, T. (2011) *The Great Stagnation*, New York, Dutton.

EU (2011) Economics of Industrial Research and Innovation, Brussels, EU.

EU, annual issues. Industrial R&D Investment Scoreboard. EU, Brussels.

Grimm, V. and Wissel, C. (1997) 'Babel, or the Ecological Stability Discussions: An Inventory and Analysis of Terminology and Guide for Avoiding Confusion', *Oecologia*, 109:3, pp. 323-334.

Ilmola, L. and Casti, J. (2013) 'Seven Shocks and Finland', *Innovation and Supply Chain*

Management, 7:3, pp. in print.
IMF (2012) World Economic Outlook Database, Washington, IMF.
Marten, G. (2001) *Human Ecology – Basic Concepts for Sustainable Development*, London, Earthscan Publishers Ltd.
Neely, Y.A. and Hii, J. (1998) Innovation and Business Performance: A Literature Review, *The Judge Institute of Management Studies*, University of Cambridge, Cambridge.
Pimentel, D., Westra, L. and Noss, R. (2000) *Ecology Integrity – Integrating Environment, Conservation and Health*, Washington DC, Island Press.
Ulanowicz, R.E. (1995) 'Ecosystem Integrity: A Casual Necessity' in Westra, L. and Lemons, J. (eds), *Perspectives on Ecological Integrity,* Dordrecht, Kluwer Academic Publishers, pp. 77-87.
Watanabe, C. Kishioka, M. and Nagamatsu, A. (2003) 'Resilience as a Source of Survival Strategy for High-technology Firms Experiencing Mega-competition' *Technovation*, 24:2, pp. 139-152.
Watanabe, C. (2009a) *Managing Innovation in Japan: The Role Institutions Play in Helping or Hindering How Companies Develop Technology*, Berlin, Springer.
Watanabe, C. (2009b) 'Co-evolutionary Dynamism between Innovation and Institutional Systems: The Rise and Fall of the Japanese System of Management of Technology', in *The Science of Institutional Management of Technology: Elucidation of Japan's Indigenous Co-evolutionary Dynamism and Its Accrual to Global Assets*, Tokyo, Tokyo Institute of Technology, pp. 21-34.
Watanabe, C., Lei, S. and Ouchi, N. (2009) 'Fusing Indigenous Technology Development and Market Learning for Higher Functionality Development: An Empirical Analysis of the Growth Trajectory of Canon Printers', *Technovation* 29:2, pp. 265-283.
Watanabe, C. (2013) 'Innovation-consumption Co-emergence Leads a Resilience Business' *Innovation and Supply Chain Management*, 7:3, pp. in print.
World Economic Forum (WEF), 2012. The Global Information Technology Report 2012, WEF, Geneva.
Zhao, W., Watanabe, C. and Tou, Y. (2013) 'Co-emergence of Institutional Inoovation Navigates the New Normal in Growing Economies; *Journal of Technology Management for Growing Economies*, 4:1, pp. 69-81.

Chihiro Watanabe, National University of Singapore and University of Jyvaskyla, Finland. Email: watanabe.c.pqr@gmail.com.

Kashif Naveed, University of Jyvaskyla, Finland.
Email: kashif.naveed80@yahoo.com.

Weilin Zhao, Fujitsu Research Institute, Japan.
Email: weilinzhao.chen@gmail.com.

PII

STRUCTURAL SOURCE OF THE TRAP OF ICT ADVANCEMENT- LESSONS FROM WORLD ICT TOP LEADERS

by

Chihiro Watanabe, Kashif Naveed and Weilin Zhao, 2014

Journal of Technology Management for Growing Economies, vol. 5(2), pp. 49-71

Structural Source of the Trap of ICT Advancement - Lessons from World ICT Top Leaders

Chihiro Watanabe
Tokyo Seitoku University, Japan and University of Jyvaskyla, Finland.

Kashif Naveed
University of Jyväskylä, Finland.

Weilin Zhao
Fujitsu Research Institute, Japan.

Abstract

In light of the significant consequence of the trap of dramatic advancement of information and communication technology (ICT) in the global economy, both nations and firms that have been compelling their productivity decline. This resulted in great stagnation of ICT advanced economies and therefore its structural sources were analyzed.

Based on an empirical analysis tracing, the trend in marginal productivity of ICT and its subsequent prices among the top ICT leaders in the world over the last two decades correlating with the effects of ICT, two faces of ICT advancement were identified.

On one side, advancement of ICT contributes to its prices increase by new functionality development, its dramatic advancement particularly centered by internet results in the decline of its prices through freebies, easy copying, and standardization.

It was demonstrated that the success of ICT leaders could largely be attributed to the way in which the two faces of ICT advancement were managed by maximizing the positive face of ICT advancement. This is done by means of the effective utilization of external resources in innovation while minimizing the negative face by outsourcing price decreasing factors.

All of the aforementioned points can be invaluable lessons for global sustainability in both ICT advanced and growing economies in the midst of the advancement of ICT. The significance of innovation-consumption co-emergence for harnessing the vigor of counterparts is discussed.

Keywords: *Trap of ICT advancement, Two Faces of ICT, ICT Leaders, Anger of Consumer.*

INTRODUCTION

While a dramatic advancement of information and communication technology (ICT) provides strong anticipation in significant economic growth, contrary to such anticipation, economic growth engine, particularly in ICT advanced economies has disappeared (except for Singapore) resulting in great stagnation (Cowen, 2011). This can be attributed to the two faced nature of ICT. While advancement of ICT contributes to increase its marginal productivity and subsequently its price by increasing new functionality development (Watanabe et al., 2003), the dramatic advancement of the Internet results in declining prices of ICT by freebies, easy copying and standardization (Watanabe et al., 2014).

Journal of Technology Management for Growing Economies
Vol. 5 No. 2
October 2014
pp. 49-71

To date, significant numbers of analyses have demonstrated the impact of ICT advancement on socio-economic factors. Triggered by Nobel laureate Solow's "Productivity Paradox", which pointed out the discrepancy between measures of investment in ICT and measures of output at the national level by remarking "*You can see the computer age everywhere but in the productivity statistics*" (Solow, 1987), reactions demonstrating the significant role of ICT for the advancement of socio-economy were very few.

The first reaction to the production paradox was to try to explain why it might exist. These explanations were summarized by Brynjolfsson (1993) into four categories- (i) measurement errors of information technology (IT) capital due to rapid price and quality changes, and failure of economic statistics to measure qualitative improvements in the output of service industries; (ii) time lags, an argument made by David (1990) postulating that IT would not have a measureable impact on productivity until it reached a critical mass of diffusion and experience; (iii) management practices, which had not yet evolved to take advantage of the potential of the technology; and (iv) productivity in the whole economy.

The second reaction to the production paradox was to develop more sophisticated models to ease out the relationship between IT and productivity. Studies in 1990s by Brynjolfsson and Hitt (1996), and by Lichtenberg (1995) found evidence that refuted the productivity paradox at the firm level, showing that IT investment was strongly correlated with higher levels of output. In addition, at the country level, a study by Kraemer and Dedrick (1994) of Asia-Pacific countries showed a significant relationship between IT spending and GDP growth. These studies were followed by additional studies at the firm and country level (Dedrick and Kraemer, 2001).

By the late 1990s there were some signs that productivity in the workplace had been improved by the introduction of IT, especially in the US. Brynjolfsson and Hitt (1998) found a significant positive relationship between IT investments and productivity, at least when these investments were made to complement organizational changes (Brynjolfsson and Hitt, 1998). It was considered that there was no paradox (Triplett, 1999).

Near to the end of the first decade of this century, a new paradox appeared to have emerged. IT industry executives astonished as to why business executives did not invest much more in IT than they usually did, given that IT returns were so large. This can largely be attributed to the third industrial revolution initiated by the dramatic advancement of the internet (Rifkin, 2011). Dramatic advancement of the internet has changed computer initiated IT world significantly. The Internet promotes more free culture, the consumption of which provides utility and happiness to people, but cannot be captured through

GDP figures that measure revenue (Lowrey, 2011). The democratization of manufacturing is being accompanied by the tumbling cost of marketing. Due of the centralized nature of the communication technologies of the first and second industrial revolutions initiated by newspapers, magazines, radio and TV marketing costs, it were high and favored giant firms, who could afford to devote substantial funds to market their products and services. The internet has transformed marketing from a significant expense to a negligible cost, allowing start-ups and small and medium size enterprises to market their goods and services on the internet sites that stretch over virtual space, enabling them to compete and even surpass many of the giant business enterprises of the 21st century. Connecting multitudes of sellers and buyers in virtual space is almost free. By replacing all of the middlemen, from wholesalers to retailers, with a distributed virtual network of sellers and buyers and eliminating transaction costs that are marked up at every stage in the marketing process, US e-market place Etsy, for example, has created a new global craft bazaar that scales laterally rather than hierarchically, and markets goods collaboratively rather than top-down. Etsy brings another dimension to the market, the personalization of relationship between seller and buyer.

Dramatic advancement of the internet has changed the entire system interactive, integrated and seamless. This interconnectedness is creating completely new opportunities for cross-industry relationships. The third industrial revolution brings with it a new era of distributed capitalism in which millions of existing and new businesses and homeowners become energy players (Rifkin, 2011).

Such a dramatic advancement of the internet and subsequent third industrial revolution inevitably emerged as new paradox of the advancement of ICT. Brynjolfsson, who first reacted to Solow's production paradox in 1993 (Brynjolfsson, 1993) asked the question: "Could technology be destroying jobs?" (Brynjolfsson and McAfee, 2011). They then expanded further to explore whether advancing ICT might be an important contributor to the current unemployment disaster. They concluded that the root cause was not a decline in innovation but an acceleration of innovation. Technological advancement had moved so fast that many people were losing the race against the machine.

Cowen (2011) analyzed the similar problem. He argued that contrary to the dramatic advancement of the internet and subsequent ICT advancement, we were living through the consequence of a dramatic decrease in the rate of innovation. He argued that the consequence of slowing innovation was a fewer number of new industries and less creative destruction, hence new jobs.

These opposite beliefs can be reconciled more easily than is immediately apparent. Brynjolfsson and McAfee (2011) focus on the technology sector, where it appears that innovation is happening more rapidly than ever. While Cowen (2011) looks at the entire economy and sees stagnation, or regression, in large sectors, such as health care, education, and government, indeed any sector that deals more with managing people than with managing things, the former being more complex and less conductive to innovation and job creation. As general innovation opportunities have slowed, business turn to the next activity with the highest return. Cutting costs by using technology advances to automate processes and eliminating the need to hire more workers to produce more output (Ogden, 2012). He suggested a possibility of the consequence of the two faced nature of ICT.

Notwithstanding such stimulating pioneering debates, particularly noteworthy suggestion of the two faced nature of ICT, none has ever demonstrated the impacts of the two faced nature of ICT in current great stagnation, particularly in ICT advanced economies (Watanabe et al., 2014).

In light of the significant consequence of the trap of the dramatic advancement of ICT in global economy both nations and firms that have been compelling their productivity decline resulting in the great stagnation in ICT advanced economies and therefore its structural sources were analyzed.

Based on an empirical analysis tracing the trend in marginal productivity of ICT and subsequently its prices in world ICT top leaders over the last two decades correlating with the effects of ICT, two faces of its advancement were identified.

The next section reviews trap of ICT advancement and its possible source. After this, the analytical framework is explained. Empirical analysis encompassing the source of the trap and its impacts is demonstrated in the section thereafter. Lastly, a brief summary of the noteworthy findings, policy implications supportive to resilient business and direction for future works are provided.

TRAP OF ICT ADVANCEMENT AND ITS POSSIBLE SOURCE

The advancement of ICT led ICT driven global economy resulted in bi-polarization between ICT advanced economy and ICT growing economy in both nations and global ICT firms (Watanabe et al., 2014). Under such circumstances, certain R&D matured resilient ICT firms manage to maintain sustainable growth while the majority of R&D matured ICT firms suffer "the great stagnation" (Cowen, 2011) because of the trap of ICT advancement. Success in resilient ICT firms can largely be attributed to efficient functionality development by maximizing R&D profitability (e.g., Apple) and open innovation (e.g., Canon) while minimizing the possibility of risk taking by restraining elasticity of such profitability (e.g., Apple) and depending on spillover effect (e.g., Canon) (Watanabe et al., 2014).

Given that these business models enable resilient firms to maintain sustainable growth despite the fatal nature of the great stagnation subsequent to the high dependency on the dramatic advancement of the Internet with "freebies and easy copying" nature, following two faces as illustrated in Figure 1 can be postulated as a possible source of the trap of ICT advancement (Watanabe et al., 2014).

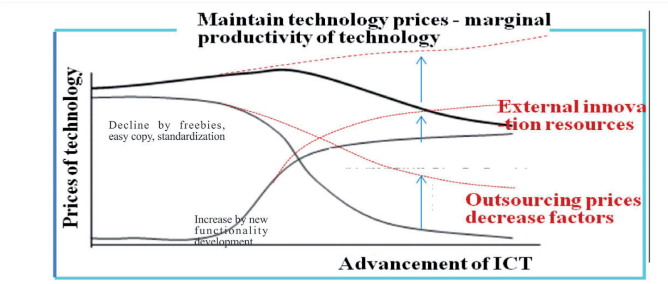


Figure 1: ICT's Identical Two Faces
Source: Author's Original.

Figure 1 illustrates ICT's identical two faces. Advancement of ICT generally contributes to enhanced prices of technology by increasing new functionality development. However, the dramatic advancement of the internet reacts to decline in the prices of technology due to its nature by freebies, easy copying and mass standardization. Consequently, prices of technology in highly R&D intensive economies may move towards a declining trend resulting in a decreasing in their growth rate as outlined in Figure 2. This can be the structural source of the trap of ICT advancement compelling ICT advanced nations/firms suffering a vicious cycle between advancement of ICT and its marginal productivity[1] decrease.

Production function and growth rate of ICT firms can be depicted as follows:

Contribution by traditional factors technology (TFP) TFP

$$Y = F(X,T) \qquad \frac{\Delta Y}{Y} = \Sigma\left(\frac{\partial Y}{\partial X}\cdot\frac{X}{Y}\right)\frac{\Delta X}{X} + \left(\frac{\partial Y}{\partial T}\cdot\frac{T}{Y}\right)\frac{\Delta T}{T} \approx \Sigma\left(\frac{\partial Y}{\partial X}\cdot\frac{X}{Y}\right)\frac{\Delta X}{X} + \frac{\partial Y}{\partial T}\cdot\frac{R}{Y}$$

$$Since\ \frac{\partial Y}{\partial T} = \frac{p_T}{p_Y},\ TFP = \frac{p_T}{p_Y}\cdot\frac{R}{Y}$$

$$\frac{p_T}{p_Y}\cdot\frac{R}{Y} \to p_T\ decrease \to \frac{\Delta Y}{Y}\ decrease$$

Y: production, X: traditional production factors (labor, capital, materials and energy), T: technology stock ($\Delta T \approx R$), R: R&D investment, p_T, p_S : prices of technology and products

Figure 2: Scheme of the Great Stagnation due to the Decrease in Technology Prices.

Given the foregoing circumstances, ICT firms endeavor should focus on accelerating price increase by means of successive efficient new functionality development while minimizing price decrease factors by outsourcing them to other parties.

Noteworthy accomplishments demonstrated by resilient global ICT firms (Watanabe et al., 2014) support this postulate and provide us constructive suggestions supportive to constructing a new business model satisfying both efficiency and resilience in a global competitive market.

These accomplishments suggest the following co-evolutionary acclimatization system that enables both ICT advanced and growing economies harness the vigor of counterparts. While R&D matured ICT firms enable further advancement of ICT, it results in declining its productivity. Thus, such advancement should be addressed to the advancement of R&D increasing ICT firms, which enjoy a virtuous cycle between its advancement and productivity increase leading to sustainable growth as reviewed in Figure 3 if its ICT advancement turns out to as an enabling position.

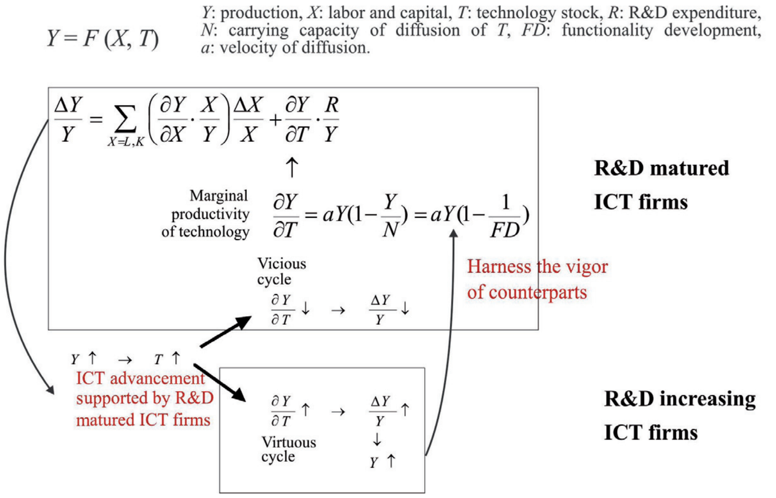


Figure 3: Scheme of Co-evolutionary Acclimatization in Global ICT Firms

ANALYTICAL FRAMEWORK

ICT Prices

Production function encompassing production factors contributing to GDP (Y) as labor (L), non-ICT capital services (n-ICT), ICT capital services

(*ICT*), and other factors contributing to growth (T_r) can be depicted as follows[2]:

$$Y = F(L, n\text{-}ICT, ICT, T_r) \qquad (1)$$

where *ICT* encompasses capital services provided by assets derived from the advancement of ICT and embodying into computer hardware and equipment, telecommunication equipment, and computer software and services, while T_r accounts for the changes in output not caused by changes in other production factors[3].

Contribution of ICT to GDP growth ϕ can be depicted as follows:

$$\phi = \left(\frac{\partial Y}{\partial I} \cdot \frac{I}{Y} \right) \frac{\Delta I}{I} \qquad (2)$$

where I denotes ICT and $\Delta I = \dfrac{dI}{dt}$

From equation (2), marginal productivity of ICT can be depicted as follows:

$$\frac{\partial Y}{\partial I} = \frac{\phi}{\frac{I}{Y} \cdot \frac{\Delta I}{I}} \qquad (3)$$

This is equivalent to relative prices of ICT in the profit maximum behavior under the competitive circumstance as follows:

$$\frac{\partial Y}{\partial I} = p_I = \frac{p_{ICT}}{p_Y} \qquad (4)$$

Therefore, prices of ICT can be measured by equations (3) and (4). All data consisting of these equations are available in the database indicated in the footnote 2.

Effects of ICT Advancement in Its Prices Change

Given the ICT's identical two faces as illustrated in Figure 1, and prices increase by new functionality development is governed by ICT advancement as a whole in a logistic growth way. Price decline is initiated by the increase in the Internet dependency in a reverse logistic growth way (Watanabe et al., 2001), trajectory of ICT prices can be depicted by the following equation:

$$p_I = \frac{N}{1+b_i e^{-a_i I}} + \frac{N}{1+b_j e^{a_j J}} \tag{5}$$

where J: dependency on the Internet, N: carrying capacity[4], a_i, a_j *and* b_i, b_j :diffusion velocity of I and J, and initial stage of diffusion of I and J, respectively.

Equation (5) can be developed as follows:

$$\frac{p_I}{N} = \frac{1+b_j e^{a_j J} + 1 + b_i e^{-a_i I}}{(1+b_i e^{-a_i I})(1+b_j e^{a_j J})} = \frac{2+b_j e^{a_j J} + b_i e^{-a_i I}}{1+b_j e^{a_j J} + b_i e^{-a_i I} + b_i b_j e^{-a_i I} e^{a_j J}}$$

$$\approx \frac{2+b_j e^{a_j J} + b_i e^{-a_i I}}{1+b_i b_j + b_j e^{a_j J} + b_i e^{-a_i I}} = 1 + \frac{1-b_i b_j}{1+b_i b_j + b_j e^{a_j J} + b_i e^{-a_i I}}$$

$$\frac{p_I}{N} - 1 = \frac{1-b_i b_j}{1+b_i b_j + b_j e^{a_j J} + b_i e^{-a_i I}}$$

$$\frac{N}{N-p_I} = \frac{1}{1-\frac{p_I}{N}} = -\frac{1+b_i b_j}{1-b_i b_j} - \frac{b_j e^{a_j J}}{1-b_i b_j} - \frac{b_i e^{-a_i I}}{1-b_i b_j} \approx -\frac{1+b_i b_j}{1-b_i b_j} - \frac{b_j}{1-b_i b_j}(1+a_j J) - \frac{b_i}{1-b_i b_j}(1-a_i I)$$

$$= -\frac{1+b_i b_j + b_i + b_j}{1-b_i b_j} - \frac{a_j b_j}{1-b_i b_j} J + \frac{a_i b_i}{1-b_i b_j} I$$

$$\equiv \alpha + \beta J + \gamma I$$

$$\textit{where} \quad \alpha = -\frac{1+b_i b_j + b_i + b_j}{1-b_i b_j} = -\frac{(1+b_i)(1+b_j)}{1-b_i b_j}, \quad \beta = -\frac{a_j b_j}{1-b_i b_j}, \quad \gamma = \frac{a_i b_i}{1-b_i b_j} \tag{6}$$

EMPIRICAL ANALYSIS

Two Faces of ICT Advancement

Factors Governing Prices of ICT

Aiming at demonstrating the significant effects of two faced nature of ICT advancement which can be considered the main source declining the marginal productivity of ICT and subsequently its price decrease resulting in greater stagnation particularly in ICT advanced economies (Watanabe et al., 2014), an empirical analysis was attempted taking the world's ICT top leaders - Finland and Singapore.

Table 1 tabulates global ICT ranking in 2012 based on the state of the Networked Readiness Index (NRI)[5] published annually by the World Economic Forum.

Table 1: Ranking of the Networked Readiness in 2012 (top 50 out of 144 countries)

1 Finland 5.98 (3)	16 Luxembourg 5.37 (21)	31 Saudi Arabia 4.82 (34)	46 Panama 4.22 (57)
2 Singapore 5.96 (2)	17 Iceland 5.31 (15)	32 Lithuania 4.72 (31)	47 Jordan 4.20 (47)
3 Sweden 5.91 (1)	18 Australia 5.26 (17)	33 Portugal 4.67 (33)	48 Montenegro 4.20 (46)
4 Netherlands 5.81 (6)	19 Austria 5.25 (19)	34 Chile 4.59 (39)	49 Poland 4.19 (49)
5 Norway 5.66 (7)	20 New Zealand 5.25 (14)	35 Cyprus 4.59 (32)	50 Italy 4.18 (48)
6 Switzerland 5.66 (5)	21 Japan 5.24 (18)	36 Puerto Rico 4.55 (36)	
7 United Kingdom 5.64 (10)	22 Estonia 5.12 (24)	37 Slovenia 4.53 (37)	
8 Denmark 5.58 (4)	23 Qatar 5.10 (28)	38 Spain 4.51 (38)	
9 United States 5.57 (8)	24 Belgium 5.10 (22)	39 Barbados 4.49 (35)	
10 Taiwan, China 5.47 (11)	25 UAE 5.07 (30)	40 Oman 4.48 (40)	
11 Korea, Rep. 5.46 (12)	26 France 5.06 (23)	41 Latvia 4.43 (41)	
12 Canada 5.44 (9)	27 Ireland 5.05 (25)	42 Czech Republic 4.38 (42)	
13 Germany 5.43 (16)	28 Malta 4.90 (26)	43 Kazakhstan 4.32 (55)	
14 Hong Kong SAR 5.40 (13)	29 Bahrain 4.83 (27)	44 Hungary 4.29 (43)	
15 Israel 5.39 (20)	30 Malaysia 4.82 (29)	45 Turkey 4.22 (52)	

Source: The Global Information Technology Report 2013 (World Economic Forum, 2013).

[a] Ranking indicates the state in 2012 while the state in 2011 is indicated in parenthesis.
[b] Figure demonstrates the score of the Networked Readiness Index 2013 (the level in 2012).

Table 1 demonstrates that Finland and Singapore play leading role in the state of the advancement (development and effective utilization) of ICT and are the world's ICT top leaders.

Focusing on the ICT driven development trajectory in Finland and Singapore over the period 1994 and 2011, trends in prices of ICT were computed by utilizing equations (3) and (4).

Figure 4 demonstrates the result of the computation through index (1990 = 100) based ICT intensity (*I/Y*). Looking at the figure, we note that while prices of Finland steadily increased during 1994-1999, they turned out to declining trend from 2000. While they maintained a plateau state with slight up and down during 2001-2008, they changed to dramatic decline after the Lehman shock in 2008. While prices of ICT in Singapore demonstrated conspicuously high level in 1994-1997 with slight up and down as a general nature of the "Asian Tiger" (newly emerged economy), they changed to dramatic decline after the Asian financial crisis in 1997. Such a dramatic decline calmed down in 2001 and changed to slightly decreasing trend with certain up and down accessing to the similar level in Finland.

Dramatic declining trend in Singapore in the late 1990s can be considered as a consequence of the transition from newly emerged economy to developed economy together with the Asian financial crisis in 1997. A notable decline in the latter part of the first decade of this century to the beginning of the second decade can be considered as a consequence of "the great stagnation" postulated by Cowen (2011).

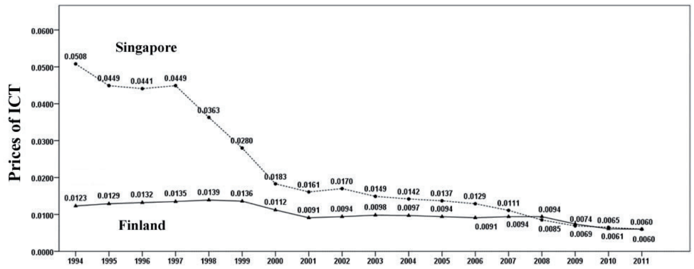


Figure 4: Trends in the Prices of ICT in ICT Top Leaders: Finland and Singapore (1994-2011).

[a] Prices of ICT (relative prices of ICT) are computed by the following equation:

$p_I = \dfrac{\phi}{\frac{I}{Y}\cdot\frac{\Delta I}{I}}$ where ϕ : contribution of ICT to GDP growth (%: equation (2)), $\dfrac{\Delta I}{I}$: growth rate of ICT capital services (%), and $\dfrac{I}{Y}$: ICT intensity (ratio of ICT and GDP) using index (1990 = 100).

In order to demonstrate Cohen's hypothetical view, particularly two-faced nature of ICT resulting in declining the prices of ICT, effects of ICT advancement both of general increase in ICT stock as a whole and increase in the dependency on the Internet on the ICT prices change were next analyzed.

Figure 5 illustrates trends in ICT stock in Finland and Singapore over the period 1990-2011. Looking at the figure we note that ICT stock in both countries demonstrated steady increase with higher increase rate in Finland.

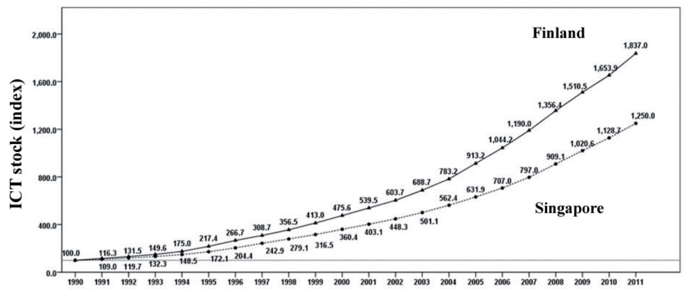


Figure 5: Trends in ICT Stock in ICT Top Leaders: Finland and Singapore (1990-2011) Index: 1990 = 100.

Source: The Conference Board Total Economy Database™, January 2013, http://www.conference-board.org/data/economydatabase/

Similarly, Figure 6 illustrates trends in the Internet dependency in Finland and Singapore over the period 1990-2011.

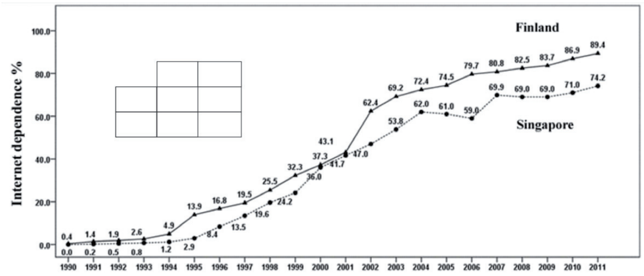


Figure 6: Trends in the Internet Dependency in ICT Top Leaders: Finland and Singapore (1990-2011).

Source: World Telecommunication/ICT Indicators Database (UN, 2013).

Figure 6 demonstrates consequently high increase rate in the Internet dependency in ICT top leaders in 1994-2000 particularly in Singapore while it changed to low increase rate in 2001-2011.

Two Faced Nature of ICT

Based on the foregoing analyses and observations and equation (6), effects of ICT stock and dependency on the internet on the changes in ICT prices in ICT top leaders were analyzed. **Figs. 7** and **8** together with the regression results demonstrate the results of the analyses in decomposing the trends in the prices of ICT into ICT driven logistic growth trajectory (*I*) and the dependency on internet is attributable to reverse logistic growth trajectory (*J*).

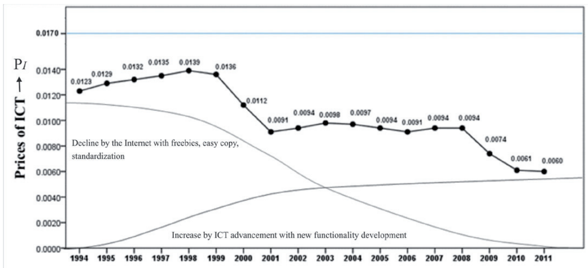


Figure 7: Trends in the Effects of ICT Advancement and Increase in the Internet Dependency to ICT Prices in Finland (1994-2011).

$$\frac{1}{1-\frac{P_I}{N}} = 3.060 + 0.081 D_1 J - 0.026 D_2 J - 0.070 D_3 J + 0.001 I + 0.632 D_2 + 3.747 D_3 - 0.797 D \quad adj.R^2\ 0.992$$

(23.67*) (11.92*) (-4.82*) (-2.12**) (1.89**) (2.28**) (1.40***) (-6.89*) DW 24.43

P_I: prices of ICT, N: carrying capacity ($N = 0.017$), J: Internet dependency, I: ICT advancement

D *indicates dummy* var*iables*

$D_1: 1994-1999=1$, *other years* $=0$; $D_2: 2000-2008=1$; $D_3: 2009-2011=1$; $D: 1999, 2001=1$

Figures in parenthesis indicate t-statistics (significant at the *1%, **5%, ***10% level, respectively).

Looking at Figure 7 together with the regression results, we note that the steady increase in ICT prices in Finland in 1994-1999 can be attributed to the advancement of ICT with new functionality development, while their declining trend from 2000 can largely be attributed to the dramatic advancement of the internet and subsequent increasing popularity of freebies, easy copy and standardization nature. Notwithstanding such effects, Finland maintained its ICT prices in plateau state with slight ups and downs during 2001-2008. This can be attributed to the consistent increase in its ICT stock as demonstrated in Figure 5 and subsequent increase in new functionality development. Dramatic decline in the ICT prices after 2008 can be attributed to the stagnation of the increased efforts ICT under the global simultaneous stagnation due to the Lehman shock in 2008. Dramatic increase in price declining feature of the internet corresponding to this period accelerated to such a decline.

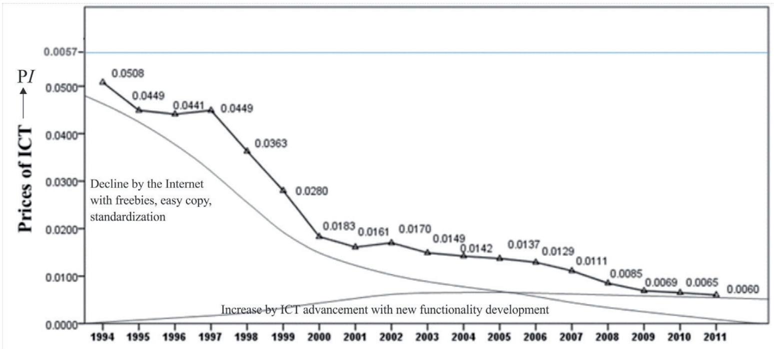


Figure 8: Trends in the Effects of ICT Advancement and Increase in the Internet Dependency to ICT Prices in Singapore (1994-2011).

$$\frac{1}{1-\frac{P_I}{N}} = 36.454 - 0.448\,D_1 J - 1.081\,D_2 J + 0.167\,I - 43.797\,D_1 + 15.056\,D \quad adj.R^2\ 0.$$

$$(2.42^{**})\ \ (-1.92^{***})\ \ (-2.81^{**})\ \ (11.73^{*})\ \ (-2.573^{**})\ \ (2.88^{**})\ \ DW\ 1.51$$

P_I: prices of ICT, N: carrying capacity ($N = 0.057$), J: Internet dependency, I: ICT advancement

D *indicates dummy variables*

$D_1: 1994-2000 = 1, \textit{other years} = 0;\ D_2: 2001-2011 = 1;\ D: 2000, 2009 = 1$

Figures in parenthesis indicate t-statistics (significant at the *1%, **5%, ***10% level, respectively).

Similarly, looking at Figure 8 together with the regression results we note that while advancement of ICT maintained steady increase in ICT prices in Singapore, increase in the internet dependency changed due to decline in the prices. As reviewed earlier, dramatic decline in conspicuously high level of Singapore's ICT prices in the late 1990s can be considered as a consequence of the transition from newly emerged economy to developed economy together with the Asian financial crisis in 1997. While such a dramatic decline calmed down in 2001 and changed to slightly decreasing trend with certain ups and downs. This can be attributed to the balance between the positive effects of ICT advancement and the negative effects of the internet dependency. Notable decline in the latter part of the first decade of this century to the beginning of the second decade can be attributed to the similar sources as Finland: global simultaneous stagnation and dramatic increase in price declining feature of the internet.

New Paradox of Productivity

Increasing Trend in Un-captured GDP

These results support the hypothesis that ICT's identical two faces would be the structural source of the trap of ICT advancement emerging new paradox of productivity as in the reviewed earlier sections. Advances in ICT can largely be attributed to dramatic advancement of the internet, which has significantly changed the computer initiated IT world. The internet promotes a more free culture, the consumption of which provides utility and happiness to people but cannot be captured through GDP figures that measures revenue (Lowrey, 2011).

This un-captured GDP has become the major source of consumer's utility (happiness in consumption) and general happiness (JCO, 2012). This trend corresponds to a general shift in consumers preference from economic functionality (captured by GDP) to supra-functionality beyond economic value encompassing social, cultural, aspirational, tribal and emotional values (not necessarily captured by GDP) (Watanabe et al., 2011). The discrepancy between "captured GDP" and "un-captured GDP" incorporates significant implications, which are as follows-.

(i) First, there exists a possible hypothetical view that a decrease in ICT prices could be in line with a consumer preference shift from economic functionality to supra-functionality beyond economic value.

(ii) Second, shifting from "captured GDP" to "un-captured GDP" could correspond to the transfer of production efforts. Traditionally, all production efforts have been attributed to producer motivation as they can in turn obtain a compensating return. However, certain production efforts, particularly in cerebration, idealization and learning extraction efforts have been transferred from producers to consumers, which justify freebies to both producers and consumers[6].

(iii) Third, under such shifting and transferring circumstances, conflict emerges in the transition leading to growing anger of consumers (Watanabe, 2013).

Figure 9 illustrates this transition dynamism. Elucidation of this transition in dynamism will be a crucial subject for resilience, which inevitably highlights the significance of analysis of consumer anger, which leads to innovation-consumption co-emergence.

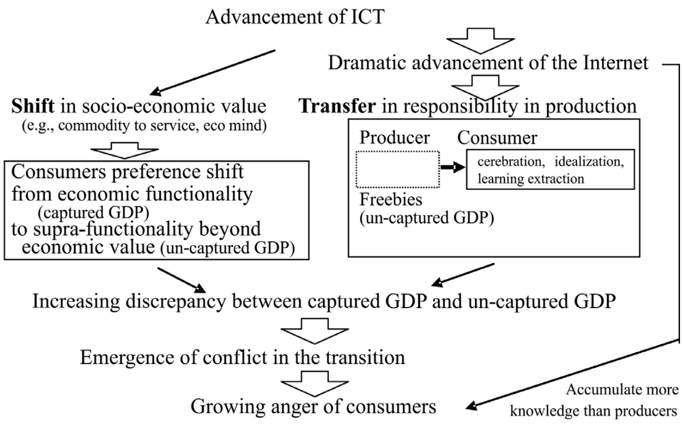


Figure 9: Transition Dynamism in New Paradox of Productivity and its Impact on Consumers

Growing anger of consumers

Since consumption shares more than 60% of GDP, its sustainable growth beyond anticipation issues would be crucial. However, contrary to such anticipation, it has been strongly warned that the increasing consumption haters among Japanese consumers, particularly among young generations have been increasingdue to non-existence of goods and services corresponding to their sincere requirement (Matsuda, 2010, 2012, Watanabe et al., 2012). This demonstrates protest to producers, which cannot satisfy their requirement in the foregoing transition. At the same time, they are irritating themselves being unable to produce their desiring goods and services by themselves. Accumulation of more knowledge than producers depending on the advancement of the internet accelerates such protest resulting in growing anger of consumers.

Given that, resilience incorporates assimilation, the capacity for using a shock as a trigger for renewal and improvement (Ilmola et al., 2013), this consumer's anger can be transformed into a springboard for new innovation. This anticipation prompts us a significance of innovation-consumption co-emergence, which corresponds to co-evolutionary acclimatization as illustrated in Figure 3 suggesting to harness the vigor of hidden counterparts i.e., consumers.

Foregoing emerging conflict in the transition revealed explicitly through decline in marginal productivity of ICT and subsequently its price decrease provides significant impacts on its users by growing their angers to producers and also to themselves as being 'remained consumers' as illustrated in Figure 10 (Watanabe, 2013).

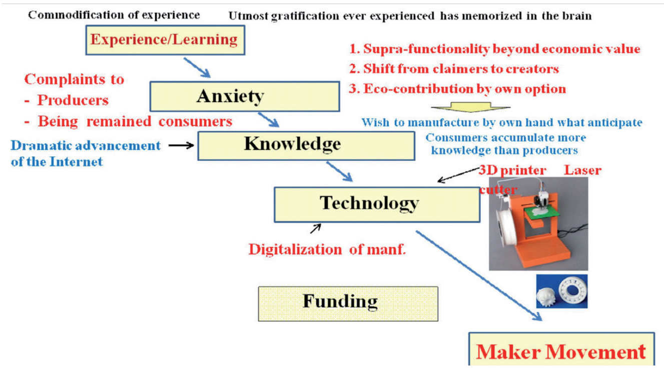


Figure 10: Growing Anger of Consumers

Shift to a Post-excessive Consumption Society

Declining Trend in Marginal Propensity to Consume

Global simultaneous stagnation triggered by the US oriented sub-prime loan issues in 2007 and subsequent Lehman shock in 2008 has reminded us of a possibility of a post-excessive consumption society. Table 2 summarizes correlation between GDP (Y) and household final consumption expenditure (C) in 6 countries including ICT top leaders, Finland and Singapore over the period 1990-2012. Looking at the table we note that their coefficients have changed to declining trend from 2007 (US and Germany) or 2008 (Finland, Singapore, Japan and UK) corresponding to sub-prime loan issue and subsequent Lehman shock. Since this coefficient depicts marginal propensity of consume ($\frac{\partial C}{\partial V}$), Table 2 suggests that marginal propensity of consumption in these countries changed to a declining trend after the global simultaneous stagnation which is demonstrated in Table 3.

Foregoing observation supports a possibility of the emergence of post-excessive consumption society (Matsuda, 2010, 2012) in which consumer's increasing initiative in innovation game is anticipated (McDonagh, 2008, Watanabe, 2009, Watanabe et al., 2011). Such an increasing initiative by the consumers accelerates a shift of their preference from economic functionality to supra-functionality beyond economic value encompassing social, cultural, aspirational, tribal and emotional value (Watson and McDonagh, 2004; McDonagh, 2008; Watanabe, 2009).

Table 2: Correlation between GDP and Final Consumption in Selected 6 Countries (1990-2012)

Finland

$$C = 9718.980 + 0.416 D_1 Y_1 + 0.226 D_2 Y_2 + 35484.176 D_2 + 2263.987 D \quad adj.R^2 \ 0.990$$
$$(6.068^{*}) \quad (32.808^{*}) \quad (2.097^{**}) \quad (2.056^{**}) \quad (3.165^{*}) \quad DW \ 1.32$$

D *indicates dummy* variables

$D_1: 1990-2007 = 1,\ other\ years = 0;\ D_2: 2008-2012 = 1;\ D: 1991, 2006, 2012 = 1$

Singapore

$$C = 42293.395 + 0.317 D_1 Y_1 + 0.213 D_2 Y_2 - 37093.567 D_1 + 6700.379 D \quad adj.R^2 \ 0.986$$
$$(2.939^{*}) \quad (26.082^{*}) \quad (4.138^{*}) \quad (-2.547^{**}) \quad (2.359^{**}) \quad DW \ 1.05$$

D *indicates dummy* variables

$D_1: 1990-2007 = 1,\ other\ years = 0;\ D_2: 2008-2012 = 1;\ D: 2002 = 1$

Japan

$$C = 120152469.362 + 0.591 D_1 Y_1 + 0.340 D_2 Y_2 - 131023751.720 D_1 - 7145417.823 D \quad adj.R^2 \ 0.978$$
$$(1.87^{**}) \quad (25.12^{*}) \quad (2.68^{**}) \quad (-2.02^{***}) \quad (-4.12^{*}) \quad DW \ 1.41$$

D *indicates dummy* variables

$D_1: 1990-2007 = 1,\ other\ years = 0;\ D_2: 2008-2011 = 1;\ D: 1991, 2007, 2008 = 1$

USA

$$C = -656297.750 + 0.735 D_1 Y_1 + 0.641 D_2 Y_2 + 1253670.120 D_2 - 138390.806 D \quad adj.R^2 \ 0.999$$
$$(-11.45^{*}) \quad (132.12^{*}) \quad (7.21^{*}) \quad (1.08^{***}) \quad (-6.52^{*}) \quad DW \ 1.34$$

D *indicates dummy* variables

$D_1: 1990-2006 = 1,\ other\ years = 0;\ D_2: 2007-2011 = 1;\ D: 1997, 1998, 1999, 2000 = 1$

Germany

$$C = 48320.565 + 0.549 D_1 Y_1 + 0.442 D_2 Y_2 + 200373.730 D_2 - 33538.105 D \quad adj.R^2 \ 0.990$$
$$(1.50^{***}) \quad (33.44^{*}) \quad (12.01^{*}) \quad (2.14^{**}) \quad (-4.91^{*}) \quad DW \ 1.56$$

D *indicates dummy* variables

$D_1: 1990-2006 = 1,\ other\ years = 0;\ D_2: 2007-2012 = 1;\ D: 2006, 2007, 2008 = 1$

U K

$$C = -121860.377 + 0.706 D_1 Y_1 + 0.372 D_2 Y_2 + 458633.357 D_2 \quad adj.R^2 \ 0.995$$
$$(-8.63^{*}) \quad (58.05^{*}) \quad (1.70^{***}) \quad (1.46^{***}) \quad DW \ 1.00$$

D *indicates dummy* variables

$D_1: 1990-2007 = 1,\ other\ years = 0;\ D_2: 2008-2012 = 1;$

C: Household final consumption expenditure, *Y*: GDP

(Finland: Euro, Million, base year 2000; Singapore: Singapore Dollars, Million, base year 2005; Japan: Yen, Million, base year 2005; USA: US Dollars Million, base year 2005; Germany: Euro Million, base year 2000; UK: Pound Sterling Million, base year 2009)

Figures in parenthesis indicate t-statistics (significant at the *1%, **5%, ***10% level, respectively).

Source: National Accounts Official Country Data (United Nations Statistics Division, annual issues).

Table 3: Marginal Propensity to Consume in Selected 6 Countries

	1990-2007*	2008-2012**
Finland	0.42	0.23
Singapore	0.32	0.21
Japan	0.59	0.34
USA	0.74	0.64
Germany	0.55	0.44
UK	0.70	0.37

* 1990-2006 in US and Germany

** 2007-2012 in US and Germany

Shift of Consumers Preferences

As postulated by Nobel laureate in Economics, Modigliani, people never forget utmost gratification of consumption ever experienced that has memorized in the brain and affects consumer's preference in consumption (Modigliani, 1965). Such experience can be subject to socio-economic paradigm. As a consequence of historical change in nation's experiences, in line with the general shift in commodity oriented society to service and information oriented society, it is generally postulated that consumer's preference has been steadily shifting from economic functionality driven preference to supra-functionality beyond economic value driven preference (McDonagh, 2008; JCO, 2012). Here supra-functionality beyond economic value encompasses social, cultural, aspirational, tribal and emotional values. Such a shift can be observed clearly by "Public Opinion Survey Concerning People's Lifestyles," conducted annually by Japan's Cabinet Office (JCO) as illustrated in Figure. 11.

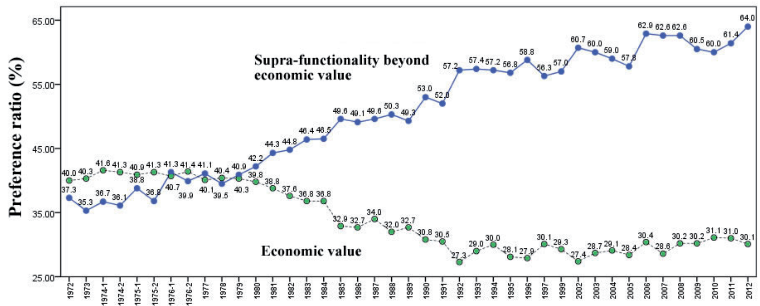


Figure 11: Trend in the Shift in Japanese Nation's Preferences (1972-2012).

* Not necessarily recorded every year and for few years it's recorded more than once.
Source: National Survey of Lifestyle Preferences (Japan Cabinet Office, annual issues).

Under such circumstances consumers desires have been shifting (i) from economic value to supra-functionality beyond economic value, (ii) from claimers to creators, and (iii) to eco-contribution by own option. Consequently, consumers complain to producers and also to themselves as being remained consumers have been growing. In parallel with such increase, consumers wish to manufacture by own hand what they anticipate has dramatically increased. Dramatic advancement of the internet has enabled consumer accumulate more knowledge than producers. Their consumption mode has changed to *AISCEAS*:

Attention → *Interest* → *Search* → *Comparison* → *Examination* → *Action* → *Share*

Maker movement enabled by digitalization of manufacturing, advancement of 3D printers and laser cutter has accelerated the foregoing change in consumer's preference and subsequent consuming style and behavior. New stream of emerging economies also affecting consumer's growing anger by realizing them the beauty of frugality and also suppliers simultaneously start up in new sales. Furthermore, increasing publicity of crowd funding enables consumer's start-up for manufacturing by themselves.

Foregoing observation supports a possibility of the emergence of a post-excessive consumption society (Matsuda, 2010, 2012) in which consumer's increasing initiative in innovation game is anticipated (McDonagh, 2008; Watanabe, 2009; Watanabe et al., 2011). Such an increasing consumer's initiative accelerates a shift of their preference from economic functionality to supra-functionality beyond economic value encompassing social, cultural, aspirational, tribal and emotional value (Watson and McDonagh, 2004;

McDonagh, 2008; Watanabe, 2009).

CONCLUSION

In light of the significant consequence of the trap of the dramatic advancement of information and communication technology (ICT) in global economy both nations and firms that have been compelling their productivity decline resulting in the great stagnation in ICT advanced economies, its structural sources were analyzed.

On the basis of an empirical analysis tracing the trend in marginal productivity of ICT and subsequently its prices in world ICT top leaders viz., Finland and Singapore over the last two decades correlating with the advancement of ICT and dependency of the internet. Two faces of ICT advancement were identified and their impacts on ICT users were analyzed.

Noteworthy findings include:

(i) Marginal productivity of ICT and subsequently its prices in world ICT top leaders viz., Finland and Singapore demonstrated a declining trend from this century.

(ii) While they were maintaining relatively plateaued state with slight ups and downs in this century, they changed to notable decline in the latter part of the first decade of this century.

(iii) While advancement of ICT contributes to its price increase by new functionality development, its dramatic advancement particularly centered by the internet resulted in its price decline by freebies, easy copying and standardization.

(iv) Sources of the recent notable decline can be attributed to the stagnation of ICT increase efforts under the global simultaneous stagnation due to the Lehman shock in 2008 as well as dramatic increase in price declining feature of the internet corresponding to this period.

(v) These decline in marginal productivity of ICT and subsequently its price decrease have provided significant impacts on its users by growing their angers to producers and also to themselves as being remained consumers.

(vi) Declining trend in marginal propensity to consume has led to sluggish consumption and subsequent economic stagnation resulting in a vicious cycle between them.

(vii) Such a trend together with general shift in consumer's preference from economic functionality to supra-functionality beyond economic value suggested a possibility of the emergence of post-excessive consumption society.

These findings provide the following policy suggestions:

(i) Two faced nature of ICT, particularly the price decreasing feature of the advancement of the internet should be seriously taken into account for resilient business.

(ii) Given that freebies, easy copying and standardization are possible sources compelling the price decrease by depending on the internet, transferring dynamism of corresponding values should be traced.

(iii) Provided that supra-functionality beyond economic value plays a governing role for consumers, similar transferring dynamism of encompassed values should be traced.

(iv) Relationship between foregoing two noting stream should be analyzed.

(v) ICT's new face, which is elastic enough to correspond to supra-functionality beyond economic value, should be analyzed.

(vi) In this context, strategy for innovation-consumption co-emergence should be developed on a priority basis.

(vii) While a way to appease consumers growing anger may provide a constructive suggestion to this co-emergence, given that this anger remains intangible, the way to conceptualize voiceless voice of consumer's anger should be taken seriously.

Points of future works are summarized as follows:

(i) In order to generalize the foregoing findings and policy suggestions, analyses of additional countries are expected to be conducted.

(ii) Comparative analysis of institutional factors governing the ICT price trajectory and their attributing ICT advancement and dependency on the internet should be conducted.

(iii) Interdisciplinary approach exploring a way to analyze innovation-consumption co-emergence should be attempted by integrating economics, psychophysiology and engineering.

ENDNOTES

1. Given that the firms seek to profit maximum in the competitive market, marginal productivity of technology corresponds to relative price of technology (ratio of technology prices and prices of product).
2. This production function concept and subsequent data for the analysis are

based on “The Conference Board Total Economy DatabaseTM, *January 2013*, http://www.conference-board.org/data/economydatabase/

3. While in the production function in Figs. 2 and 3 all stock of technological advancement including ICT capital services (excluding those services by obsolescent ICT) are treated by technology stock *T*, in the production function depicted by equation (1), with the aim to identify the identical contribution of ICT, ICT is treated independently by extracting from T in Figs. 2 and 3. Technology stock T_r in equation (1) accounts for the changes in output not caused by changes in other production factors including ICT and obsolescent ICT is categorized in *n*-ICT.
4. Since the Internet has been playing a leading role in the whole ICT and providing significant impacts on the diffusion trajectory of ICT, carrying capacity of logistic growth in *I* and reverse logistic growth in *J* as well as their diffusion tempo ($a_i I \text{ and } a_i J$) were treated as behaved in the similar way.
5. NRI can be used as a proxy of nation’s ICT advancement which consists of Environment (Political and regulatory environment, Business and innovation environment), Readiness (Infrastructure and digital content, Affordability), Usage (Individual usage, Business usage, Government usage), and Impact (Economic impact, Social impact).
6. This is natural to producers as they depend certain due efforts on consumers efforts while consumers have not explicitly realized their contribution.

REFERENCES

Brynjolfsson, E. (1993) ‘Productivity Paradox of Information Technology.’, *Communications of the Association for Computing Machinery*, 36:12, pp. 66-77.

Brynjolfsson, E. and Hitt, L. (1996) ‘Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending’ ,*Management Science,* 42:4, pp. 541-558.

Brynjolfsson, E. and Hitt, L. (1998) ‘Beyond the Productivity Paradox: Computers are the Catalyst for Bigger Changes’, *Communications of the Association for Computing Machinery,* 41:8, pp. 49-55.

Brynjolfsson, E. and McAfee, A. (2011) *‘Race against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and Economy*’, New York. Digital Frontier Press.

Cowen, T. (2011) ‘*The Great Stagnation*’, New York. Dutton.

David, P.A. (1990) ‘The Dynamo and the Computer: A Historical Perspective on the Productivity Paradox.’, *American Economic Review, Papers and Proceedings,* 80:2, pp. 355-361.

Dedric, J. and Kraemer, K. (2001) ‘The Productivity Paradox: Is It Rosolved? Is There a New One? What Does It All Mean for Managers?’, *CRITO Consortium Advisory Board Panel: The End of the Productivity Paradox?,* pp. 2-12.

Ilmola, L. and Casti, J. (2013) ‘Seven Shocks and Finland’, *Innovation and Supply Chain Management*, 7:3, pp. 112-124.

Japan’s Cabinet Office (JCO) (2012) *National Survey of Lifestyle Preferences*, JCO, Tokyo.

Kraemer, K.L. and Dedrick, J. (1994) 'Payoffs from Investment in Information Technology: Lessons from the Asia-Pacific Region', *World Development*, 22: 12, pp. 1921-1931.
Lichtenberg, F.R. (1995) 'The Output Contributions of Computer Equipment and Personnel: A Firm Level Analysis.' *Economic Innovations and New Technology*, 3:3-4, pp. 201-218.
Lowrey, A.(2011) *Impacts of the Great Stagnation*, New York Times.
Matsuda, H. (2010) '*Why not Buy, How to Purchase'*, Tokyo, Asahi-shimbun.
Matsuda, H. (2012) '*Extricating from Stagnation as a Consequence of Consumption Hating*', Tokyo, PHP Institute.
McDonagh, D. (2008) 'Satisfying Needs beyond the Functional: The Changing Needs of the Silver Market Consumer', *Proceedings of the International Symposium on the Silver Market Phenomenon - Business Opportunities and Responsibilities in the Aging Society*, Tokyo.
Ministry of Internal Affairs and Communication (MIC) (2012)*White Paper on Japan's Information and Communication Technology*. MIC, Tokyo.
Modigliami, T .(1965) 'Life Cycle Hypothesis of Savings, the Demand for Wealth and Supply of Capital'Paper Presented at *the Rome Congress of Econometric Society.*
National Accounts Official Country Data (United Nations Statistics Division, annual issues).
Ogden, T.(2012) '*The Race vs. the Stagnation*', *Stanford Social Innovation Review*, Spring.
Rifkin, J. (2011) '*The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World*', New York, Palgrave Macmillan.
Rifkin, J. (2013) 'The Third Industrial Revolution: How the Internet, Green Electricity, and 3-D Printing are Ushering in a Sustainable Era of a Distributed Capitalism', *The World Financial Review.*
Solow, R. (1987) 'We'd better Watch Out: The Myth of the Post-industrial Economy', *New York Times Book Review* 36.
The Conference Board Total Economy DatabaseT (2013) (online) (Available from) <URL:http://www.conference-board.org/data/economydatabase/>.
Triplett, J.E. (1999) 'The Solow Productivity Paradox: What do Computers do Productivity?', *Canadian Journal of Economics,* 32:2, pp. 309-334.
Watanabe, C., Zhu, B. and Miyazawa, T. (2001) 'Hierarchical Impacts of the Length of Technology Waves: An Analysis of Technolabor Homeostasis', *Technological Forecasting and Social Change,* 68:1, pp. 81-104.
Watanabe, C., Asgari, B. and Nagamatsu, A. (2003) 'Virtuous Cycle between R&D Functionality Development and Assimilation Capacity for Competitive Strategy in Japan's High-technology Industry' *Technovation,* 23:11, pp. 879-900.
Watanabe, C. (2009) Co-evolutionary Dynamism between Innovation and Institutional Systems: The Rise and Fall of the Japanese System of Management of Technology, in: Tokyo Institute of Technology, *The Science of Institutional Management of Technology: Elucidation of Japan's Indigenous Co-evolutionary Dynamism and Its Accrual to Global Assets.* Tokyo Institute of Technology, Tokyo, pp. 21-34.
Watanabe, C., Nasuno, M. and Shin, J.H. (2011) 'Utmost Gratification of Consumption by means of Supra-functionality Leads a Way to Overcoming Global Economic Stagnation', *Journal of Services Research,* 11:2, pp. 31-58.
Watanabe, C., Zhao, W. and Nasuno, M. (2012) 'Resonance between Innovation and Consumers: Suggestions to Emerging Market Customers', *Journal of Technology Management for Growing Economies,* 3:1, pp. 7-31.
Watanabe, C. (2013) 'Innovation-consumption Co-emergence Leads a Resilience Business', *Innovation and Supply Chain Management,* 7:3, pp. 92-104.
Watanabe, C., Naveed, K. and Zhao, W. (2014) 'Institutional Sources of Resilience in Global ICT Leaders – Harness the Vigor of Emerging Power', *Journal of Technology Management in Growing Economies,* 5:1*,* pp. 7-34.
Watson, B. and McDonagh, D. (2004) 'Supra-functionality: Responding to Users Needs beyond

the Functional', *Engineering Designer,* 30 :5, pp. 8-11.
World Economic Forum (WEF) (2012) *The Global Information Technology Report*, WEF, Geneva.
World Economic Forum (WEF) (2013) *The Global Information Technology Report,* WEF, Geneva
World Telecommunication/ICT Indicators Database (2013) United Nations.

Chihiro Watanabe, National University of Singapore and University of Jyvaskyla, Finland. Email: watanabe.c.pqr@gmail.com.

Kashif Naveed, University of Jyväskylä, Finland. Email: kashif.naveed80@yahoo.com

Weilin Zhao, Fujitsu Research Institute, Japan. Email: weilinzhao.chen@gmail.com.

PIII

NEW PARADIGM OF ICT PRODUCTIVITY - INCREASING ROLE OF UNCAPTURED GDP AND GROWING ANGER OF CONSUMERS

by

Chihiro Watanabe, Kashif Naveed and Weilin Zhao, 2015

Technology in Society, vol. 41, pp. 21-44

Technology in Society 41 (2015) 21–44

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

New paradigm of ICT productivity — Increasing role of un-captured GDP and growing anger of consumers

Chihiro Watanabe [a, b, *], Kashif Naveed [c], Weilin Zhao [d]

[a] National University of Singapore, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria
[c] University of Jyväskylä, Finland
[d] Fujitsu Research Institute, Japan

ARTICLE INFO

Article history:
Received 10 August 2014
Received in revised form 23 October 2014
Accepted 27 October 2014
Available online 4 December 2014

Keywords:
New productivity paradox
ICT trap
Un-captured GDP
Supra-functionality
Consumers anger

ABSTRACT

The dramatic advancement of the Internet has led all nations to an information communication technology (ICT) driven development trajectory. This trajectory has resulted in bi-polarization between ICT growing economies and ICT advanced economies. While the former enjoys a virtuous cycle between ICT advancement and productivity increase, the later has fallen into a trap of a vicious cycle between ICT advancement and productivity decrease.

This paper identifies that this trap can be attributed to the two-faced nature of ICT in which advancement of ICT contributes to price increases due to functionality development while dramatic advancement of the Internet has resulted in price decreases due to freebies, easy copying and standardization.

Based on an empirical analysis of a customer preference shift from economic functionality to supra-functionality beyond economic value, this paper unveils the increasing conflict between captured GDP and un-captured GDP derived from the Internet advancement which promotes a freer culture, the consumption of which provides utility and happiness but cannot be captured through GDP data that measures revenue.

It was demonstrated that this conflict has led to an emerging growing anger of consumers which can be transformed into a springboard for new innovation leading to a trigger of innovation-consumption co-emergence.

1. Introduction

Dramatic advancement of the Internet beyond anticipation in terms of its diffusion speed and scope has led all nations of the world information communication technology (ICT) driven economic development trajectory (UNDP, 2007 [30]; McKinsey, 2011 [22]; WEF, 2012 [39]; MIC, 2012 [23]).

This trajectory has resulted in bi-polarization between ICT growing economies and ICT advanced economies (Zhao et al., 2013 [41], Watanabe et al., 2014a [36]). While the former economies enjoy a virtuous cycle between the advancement of ICT and increases in marginal productivity, the later economies have fallen into a trap of a vicious cycle between advances in ICT and decreases in marginal productivity.

* Corresponding author. 2-4-2 Kitasenzoku Ota-ku, Tokyo 145-0062 Japan. Tel.: +81 3 6426 2577.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

http://dx.doi.org/10.1016/j.techsoc.2014.10.006
0160-791X/

While a dramatic advancement of ICT provides strong anticipation of significant economic growth, contrary to such anticipation, economic growth engine, particularly in ICT advanced economies has disappeared resulting in the great stagnation (Cowen, 2011 [7]). This can be attributed to the two-faced nature of ICT in which advancement of ICT contributes to increase its marginal productivity and subsequent price increases due to new functionality development while dramatic advancement of the Internet has resulted in price decreases due to freebies, easy copying and mass standardization (Watanabe et al., 2014b [37]).

To date, significant numbers of analyses demonstrated the impacts of ICT advancement on socio-economy triggered by Nobel laurite Solow's "Productivity Paradox" (Solow, 1987 [27]) and reaction to it by Brynjolfsson (1993) [1]. This reaction was followed by more sophisticated models to tease out the relationship between ICT and productivity (Brynjolfsson and Hitt, 1996 [2], Lichtenberg, 1995 [16], Kraemer and Dedrick, 1994 [15], Dedrick and Kraemer, 2001 [8]).

By the late 1990s there were some signs that productivity in the workplace had been improved by the introduction of ICT, especially in the US. Brynjolfsson et al. found a significant positive relationship between ICT investments and productivity (Brymjolfsson and Hitt, 1998 [3], Brynlolfsson and Yang, 1999 [4]) prevailing popular consideration that there was no paradox (Triplett, 1999 [29]).

It was in the late of the first decade of this century a new paradox appeared to have emerged. This can largely be attributed to the third industrial revolution initiated by the dramatic advancement of the Internet (Rifkin, 2011 [26]). The Internet has transformed the way of peoples living, working, socializing and meeting, countries develop and grow. It has changed from a network for researchers to a day-to-day reality for billions people in two decades (McKinsey, 2011 [22]). Consequently, dramatic advancement of the Internet has changed computer initiated ICT world significantly. It has changed the entire system interactive, integrated and seamless. This interconnectedness is creating whole new opportunities for cross-industry relationships. The Internet promotes more free culture, the consumption of which provides utility and happiness to people but cannot be captured through GDP data that measure revenue (Lowrey, 2011 [17]).

Such a beyond anticipation issue derived from a dramatic advancement of the Internet and subsequence third industrial revolution inevitably emerged a new paradox of the advancement of ICT. Brynjolfsson, who first reacted to Solow's production paradox in 1993 (Brynjolfsson, 1993 [1]) raised the question: "Could technology be destroying jobs?" (Brynjolfsson and MaAfee, 2011 [5]). They then expanded to explore whether advancing ICT might be an important contributor to the current unemployment disaster. They concluded that the root cause was not a decline in innovation but an acceleration of innovation. Technological advancement had moved so fast that many people were loosing the race against the machine.

Cowen (2011) [7] analyzed similar problem. He argued that: "Contrary to the dramatic advancement of the Internet and subsequent ICT advancement, we were living through the consequence of a dramatic decrease in the rate of innovation." He argued that the consequence of slowing innovation was fewer new industries and less creative destruction, hence new jobs. He then suggested a possibility of the consequence of the two faced nature of ICT.

Notwithstanding such stimulating pioneering debates, particularly noteworthy suggestion of the two-faced nature of ICT, none has ever unveiled such nature and its impacts on the current great stagnation, particularly in ICT advanced economies (Ogden, 2012 [25], Watanabe et al., 2014b [37]).

Furthermore, while the sources of increasing discrepancy between captured GDP and un-captured GDP can partially be attributed to the shift of people's preferences from an economic functionality-driven preference captured by GDP to supra-functionality beyond economic value-driven functionality which cannot necessarily be captured by GDP (McDonagh, 2008 [21]) and this shift co-evolves with ICT advancement (Watanabe, 2009 [32]), none has ever analyzed this dynamism. Growing anger of consumers derived from increasing discrepancy in the transition (Watanabe, 2013 [35]) and a possibility of its transformation into a springboard for new innovation is another urgent issue to be solved.

In light of the significant consequence of the trap of the dramatic advancement of ICT in global economy both nations and firms that has been compelling their productivity decline resulting in the great stagnation in ICT advanced economies, its structural sources were analyzed first.

On the basis of an empirical analysis tracing the trend in marginal productivity of ICT and subsequent its prices in world ICT top leaders over the last two decades correlating with the effects of ICT, two faces of its advancement were identified.

Second, in light of the increasing role of un-captured GDP in correspond to increasing significance of supra-functionality beyond economic value in sustaining the consumption, substitution trend and its dynamism of supra-functionality beyond economic value for economic functionality as well as its co-evolution with ICT advancement were analyzed.

Since such a substitution and its co-evolution with ICT advancement can be typically observed in Japan which is extremely sensitive to institutional innovation against external shocks and crises (Hofstede, 1991 [11], Watanabe, 2009 [32]), an empirical analysis focusing on the shift in Japan's preferences over the last four decades and its correlation with the advancement of ICT was conducted.

Third, in light of the significance of growing anger of consumers as a consequence of increasing discrepancy between captured GDP and un-captured GDP in transition (Watanabe, 2013 [35]), and a possibility of transforming such anger into a springboard for new innovation, sources of the anger and its mechanism were analyzed.

On the basis of an empirical analysis on the general trend in marginal propensity to consume toward a post-excessive consumption society, possible option for sustaining utility of consumption was identified thereby significance of harness the vigor of hidden counterparts, consumers was demonstrated and significance of innovation-consumption co-emergence was postulated.

This study is thus expected to explore significant insight in elucidating the institutional sources of the resilience in the transition from the paradigm of captured GDP to that of un-captured GDP.

Section 2 reviews global bi-polarization trends both in countries and global ICT firms. Section 3 elucidates trap of ICT advancement and its possible source. Section 4 analyzes new paradox of productivity focusing on the increasing discrepancy between captured GDP and un-captured GDP. Section 5 unveils growing anger of consumers. Section 6 briefly summarizes noteworthy findings, policy implications and also the points for future works.

2. Global bi-polarization

2.1. ICT driven logistic growth trajectory

Dramatic advancement of the Internet beyond anticipation in terms of its diffusion speed and scope has led all nations of the world, both advanced and growing nations, ICT driven economic development trajectory (UNDP, 2007 [30]; McKinsey, 2011 [22]; WEF, 2012 [39]; MIC, 2012 [23]).

McKinsey pointed out the significant feature of such trajectory as follows (Mckinsey, 2011 [22]):

(i) The Internet is big and continues to grow and reach everywhere,
(ii) The Internet is still in its infancy, and the weight of the Internet in GDP varies drastically, even among countries at the same stage of development,
(iii) The Internet is a critical element of growth,
(iv) The maturity of the Internet correlates with rising living standards,
(v) The internet is a powerful catalyst for job creation,
(vi) The Internet drives economic modernization, and
(vii) The impact of the Internet goes beyond GDP, generating astonishing consumer surplus.

Consequently, economic development trajectory of nations as well as global firms can be depicted by the following logistic growth function[1] (Zhao et al., 2013 [41], Watanabe et al., 2014a [36]):

$$W = \frac{N}{1 + be^{-aI}} \tag{1}$$

Table 1
ICT driven economic development trajectory in 100 countries (2011).

N	a	b	c	d	
57,239 (9.62)	1.68 (7.58)	2697.28 (9.80)	46,434 (14.54)	−12913 (−5.25)	adj. R^2 0.885

Y/P: GDP per capita, N: carrying capacity, NRI: Networked readiness index, D_1, D_2: dummy variables (D_1: 8 nations with extreme lower level of *NRI* than V/P (Qatar, Luxemburg, Kuwait, Brunei, UAE, Norway, Italy and Greece) = 1, other nations = 0; D_2: 8 nations with extreme higher level of *NRI* than V/P (Sweden, Israel, New Zealand, Finland, Jordan, Korea, Estonia and Malaysia) = 1, other nations = 0)and a, b, c, d: coefficients.

where W: outcome of economic development (e.g., GDP per capita (Y/P) for countries (Y: GDP and P: population), and sales (S) for global firms), I: proxy of ICT advancement, N: carrying capacity, and a, b: coefficients.

I can be represented by Networked Readiness Index *NRI*[2] for countries (WEF, 2012), and technology stock T[3] for global ICT firms (Watanabe et al., 2014a).

Thus, development trajectories in 100 countries and 500 global ICT firms[4] can be estimated as Table 1, Fig. 1 and Table 2, Fig. 2, respectively.

$$\frac{Y}{P} = \frac{N}{1 + be^{-aNRI}} + cD_1 + dD_2$$

Fig. 1 demonstrates that economic development trajectory of majority of 100 countries follows ICT driven logistic growth initiated by NRI.

$$S = \frac{N}{1 + be^{-aT}} + cD$$

Fig. 2 also demonstrates that development trajectory of majority of 500 global ICT firms follows ICT driven logistic growth initiated by ICT stock.

2.2. Bi-polarization in ICT economy

Since logistic growth trajectory can be developed to a bi-polarization trajectory as follows (Tokumasu and Watanabe, 2008 [28]), foregoing analysis suggests that ICT driven economic development trajectory in 100 nations and also in 500 global ICT firms split into bi-polarization as demonstrated in Figs. 3 and 4.

[1] Outcome of economic development can be depicted by the following logistic growth function initiated by time trend t (Griliches, 1957 [10]; Mansfield, 1958 [18]):$\frac{dW}{dt} = aW\left(1 - \frac{W}{N}\right)$ leading *to* $W = \frac{N}{1+be^{-at}}$Given that I is proportional to t (see Footnote[3]), this logistic growth function can be depicted by equation (1).

[2] Networked Readiness Index (*NRI*) measured by the World Economic Forum (WEF) measures worldwide advancement of ICT by computing following four dimensions:(i) Environment (Political and regulatory environment, business and innovation environment),(ii) Readiness (Infrastructure, digital content, and affordability),(iii) Usage (Individual usage, business usage and government usage), and (iv) Impact (Economic impact and social impact).

[3] Technology stock T at time t can be measured by the following equation:$T_t = R_{t-m} + (1 - \rho)T_{t-1}$ and $T_0 = R_{1-m}/(\rho + g)$, then, $T_t = R_t(1+g)^{1-m}/(\rho+g) \approx R_t(1+(1-m)g)/(\rho+g)$ When $g << 1$, $T_t \approx R_t/(\rho + g)$ and approximated proportional to time trend t (Watanabe, 2009 [32]).where R_t: R&D expenditure at time t, m: lead time between R&D and commercialization, ρ: rate of obsolescence of technology and g: growth rate of R&D expenditure at the initial stage.

[4] World top 500 firms by R&D expenditure in the field of ICT relevant manufacturing and services (not including fixed line and mobile telecommunications and their services).

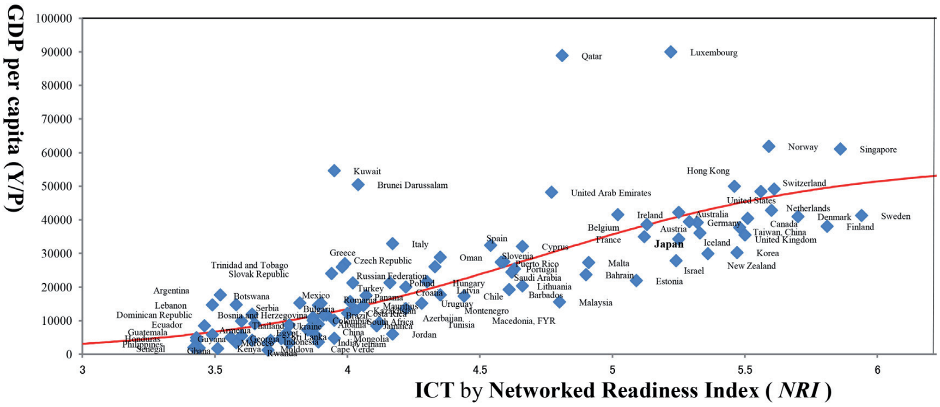


Fig. 1. ICT driven economic development trajectory in 100 countries (2011).
Sources: The Global Information Technology Report 2012 (World Economic Forum, 2012), World Economic Outlook Database (IMF, 2012).

Table 2
ICT driven development trajectory in 500 global ICT firms (2010).

N	a	b	c	
42,668 (28.31)	0.002 (26.02)	22.61 (10.23)	45,184 (30.32)	adj. R^2 0.885

S: sales, N: carrying capacity, T: technology stock, D: dummy variables. (Hon Hai Precision, Hewlett Packard, Samsung Electronics, Dell, Apple, LG Electronics, Hitachi, Quanta Computers, Siemens, IBM = 1 and other 490 firms = 0), and a, b, c: coefficients.

$$\frac{dW}{dt} = aW\left(1-\frac{W}{N}\right) = \frac{aN}{1+be^{-at}}\left(1-\frac{1}{1+be^{-at}}\right)$$
$$= \frac{aN}{(1+be^{-at})}\cdot\frac{be^{-at}}{(1+be^{-at})} = \frac{aN}{(1+be^{-at})}\cdot\frac{1}{(1+be^{at})}$$
$$= \frac{aN}{\left(2+be^{-at}+\dfrac{1}{be^{-at}}\right)} \tag{2}$$

$$\frac{aN}{\dfrac{dW}{dt}} = 2+be^{-at}+\frac{1}{be^{-at}} \tag{3}$$

$$y=(1+x)+\left(1+\frac{1}{x}\right) \quad y\equiv\frac{aN}{\dfrac{dW}{dt}},\quad x\equiv be^{-at} \tag{4}$$

Under ICT driven economy where ICT initiated logistic growth trajectory governs,

$$W=F(t)=F(I) \text{ and } \frac{dW}{dt}=\frac{dW}{dI}=\frac{\partial W}{\partial I}\cdot\frac{dI}{dI}=\frac{\partial W}{\partial I}.$$

Thus,

$$x=be^{-aI},\quad y=\frac{aN}{\dfrac{\partial W}{\partial I}} \tag{5}$$

x and y in Figs. 3 and 4 signify ICT (*NRI* or technology stock) and marginal productivity of technology increase toward the origin of the coordinate axes.

Consequently, 100 nations have split into two economies as demonstrated in Table 3. While ICT growing 70 nations (nations with *NRI* ranking 31 to 100 in Table 3) have been enjoying a virtuous cycle between ICT advancement and its marginal productivity increases as generally anticipated (Zhao et al., 2009 [42]), ICT advanced 30 nations (*NRI* ranking 1–30) have fallen into a pit of a vicious cycle as ICT advancement decreases its marginal productivity against anticipation.

Similarly, high R&D intensive firms out of 500 global ICT firms (21 firms in 2010) have fallen in a pit of a vicious cycle between R&D investment centered by ICT and its marginal productivity as the former increase results in declining the later while remaining firms (479 firms in 2010) have been enjoying a virtuous cycle between them as R&D increase leads to productivity increase.

Table 4 demonstrates such contrast. ICT advanced firms represented by top 21 global ICT firms with respect to R&D investment in 2010 (high R&D intensive firms) including such ICT giant as Microsoft, Samsung and Nokia have fallen in a pit of a vicious cycle between their R&D investment increase and marginal productivity of technology decline.

2.3. Consequence of the bi-polarization

While a dramatic advancement in ICT provides strong anticipation of significant economic growth in ICT advanced economies, contrary to such anticipation, their economic growth engine has disappeared except Singapore (which ranks the world second by NRI in 2011). Fig. 5 traces trends in real GDP increase rate in countries in ICT advanced economies by comparing those in ICT growing economies such as BRIC over the last half century encompassing industrial society (1961–1990), information society (1991–2000) and after net bubble bursting (2001–2010).

Looking at the figure we note clearly that contrary to conspicuous economic growth in ICT growing economies, GDP growth rates in countries in ICT advanced economies in this century, particularly the latter half of the first decade

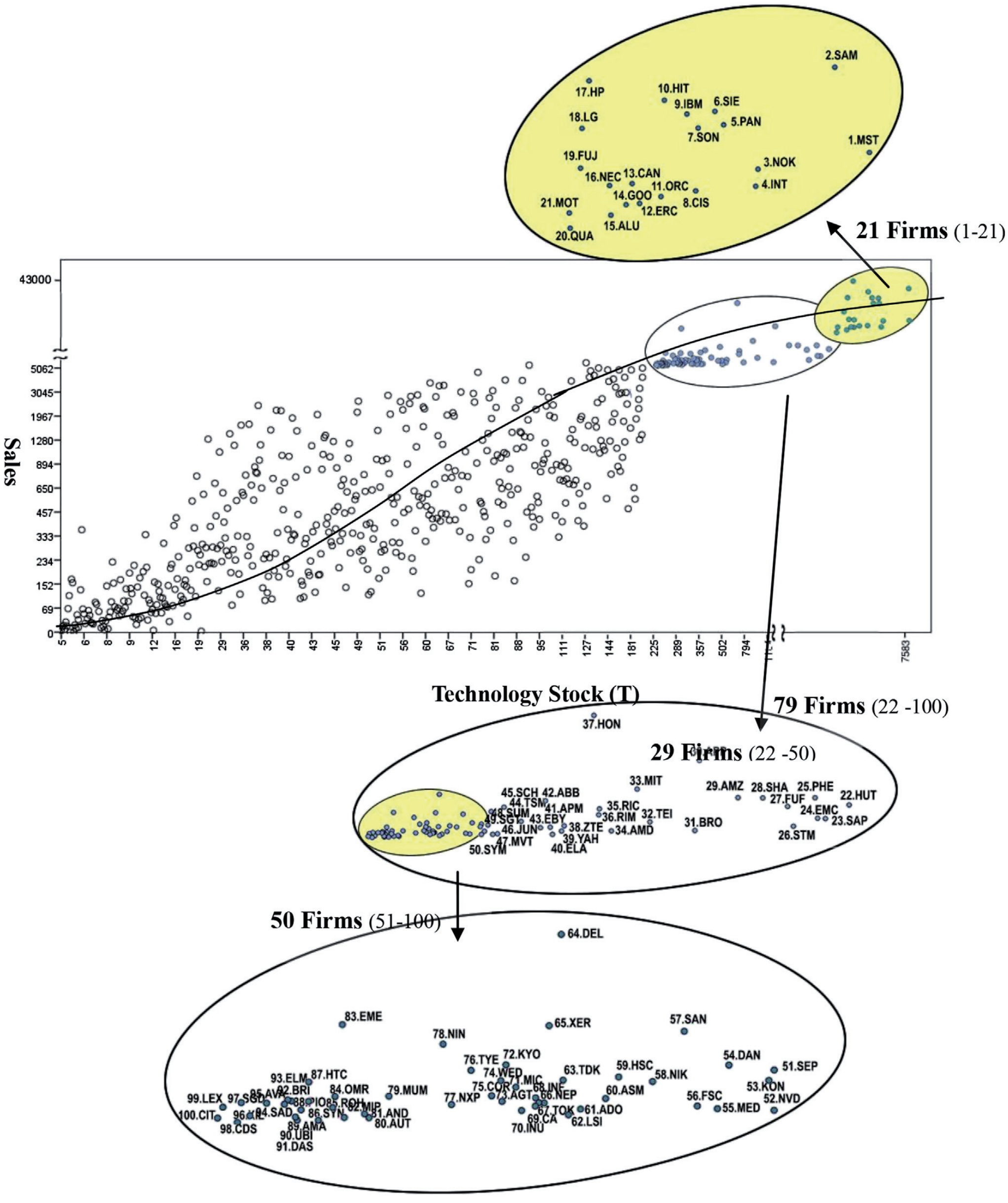


Fig. 2. ICT driven development trajectory in 500 global ICT firms (2010).
Source: Economics of Industrial Research and Innovation (EU, 2011).

of this century have demonstrated the great stagnation (Cowen, 2011 [7]) except Singapore.

Such a contrast is not only the great stagnation in national level but also in the competition market in global ICT firms. Fig. 6 demonstrates average growth rate of sales in top 100 R&D intensive firms over the period 2009–2011 (after the Lehman shock). Looking at the figure we note that while 62 firms out of top 100 R&D intensive firms maintained higher than 5% sales growth rate, only 10 out of 21 ICT advanced firms represented by high R&D intensive firms (HRIFs) maintained this level (ratio of HRIFs is 16.1%). 17 firms demonstrated between 5 and 0% sales growth rate

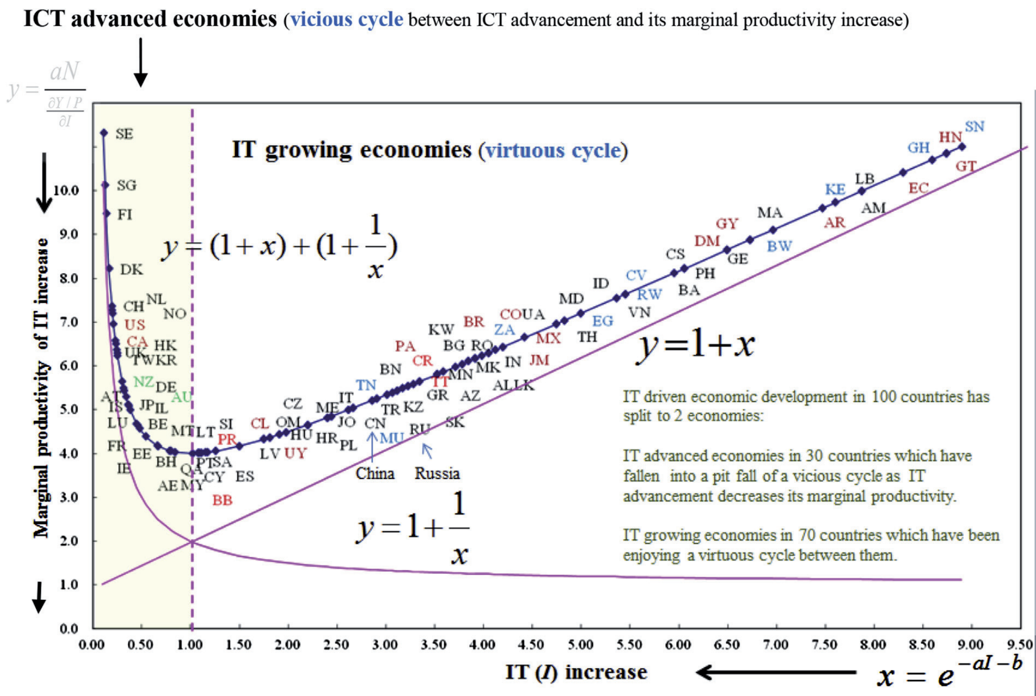


Fig. 3. Bi-Polarization of ICT driven economic development trajectory in 100 nations (2011).
Sources: Same as Fig. 1.

in which 4 firms are HRIF (ratio of HRIFs is 23.5%). 21 firms suffered negative growth including 7 HRIFs as Sony, Alcatel-Lucent, Siemens, NEC, Nokia, LG and Motorola (ratio of HRIFs is 33.3%).

This demonstrates that ICT advanced firms suffer more serious stagnation than ICT growing firms and also demonstrates great stagnation in ICT advanced firms as a consequence of bi-polarization.

3. Trap of ICT advancement and its possible source

3.1. Hypothesis

Foregoing analyses prompt us the following hypothetical view with respect to the structural source of the bi-polarization in ICT economy and its possible countermeasure.

3.1.1. Two faces of ICT

As reviewed in the preceding section, while advancement of ICT led ICT driven global economy, it resulted in bi-polarization between ICT advanced economies and ICT growing economies in both nations and global ICT firms. Under such circumstances, certain ICT advanced resilient[5] firms manage to maintain sustainable growth while the majority of ICT advanced firms suffer the great stagnation as a consequence of the trap of ICT advancement. Success in resilient ICT firms can largely be attributed to efficient functionality development by maximizing R&D profitability (e.g., Apple) and open innovation (e.g., Canon) while minimizing the possibility of risk taking by restraining elasticity of such profitability (e.g., Apple) and depending on spillover effect (e.g., Canon) (Watanabe et al., 2014a [36]).

Given that these business models enable resilient firms to maintain sustainable growth despite fatal nature of the great stagnation subsequent to the high dependency on the advancement of ICT centered by the dramatic advancement of the Internet with freebies, easy copying and mass standardization nature, two faces of ICT as illustrated in Fig. 7 can be postulated as a possible source of the trap of ICT advancement (Watanabe et al., 2014b [37]).

Advancement of ICT generally contributes to enhance prices of technology by increasing new functionality development. However, the dramatic advancement of the Internet reacts to decrease prices of technology due to its nature by freebies, easy copying and mass standardization as demonstrated in Figs. 8 and 9.

As demonstrated in Fig. 8, while the advancement of ICT driven by the dramatic advancement of the Internet emerges huge opportunities leading to price increases as typically observed in Amazon's growing empire (Fig. 9), it

5 Here resilience can be defined as "*ability to transform external shocks into a springboard for further advancement by recovering from and adjusting smoothly through prompt and agile reaction*" (Watanabe et al., 2014a [36]).

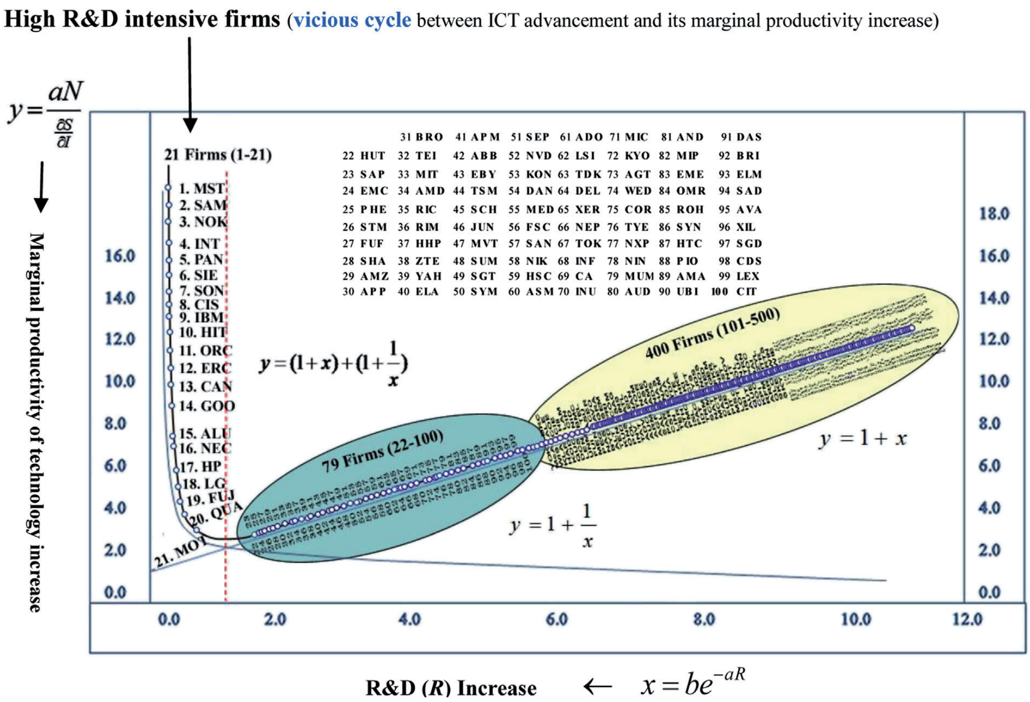


Fig. 4. Bi-polarization of ICT driven development trajectory in 500 global ICT firms (2010).
Source: Same as Fig. 2.

Table 3
Bi-polarization of development trajectories by networked readiness index in 100 nations (2011).

1 SE Sweden 5.94	26 MT Malta 4.91	51 CN China 4.11	76 MX Mexico 3.82
2 SG Singapore 5.86	27 BH Bahrain 4.90	52 TR Turkey 4.07	77 TH Thailand 3.78
3 FI Finland 5.81	28 QA Qatar 4.81	53 MU Mauritius 4.06	78 MD Moldova 3.78
4 DK Denmark 5.70	29 MY Malaysia 4.80	54 BN Brunei Darussalam 4.04	79 EG Egypt 3.77
5 CH Switzerland 5.61	30 AE United Arab Emirates 4.77	55 KZ Kazakhstan 4.03	80 ID Indonesia 3.75
6 NL Netherlands 5.60	31 LT Lithuania 4.66	56 RU Russian Federation 4.02	81 CV Cape Verde 3.71
7 NO Norway 5.59	32 CY Cyprus 4.66	57 PA Panama 4.01	82 RW Rwanda 3.70
8 US United States 5.56	33 PT Portugal 4.63	58 CR Costa Rica 4.00	83 VN Vietnam 3.70
9 CA Canada 5.51	34 SA Saudi Arabia 4.62	59 GR Greece 3.99	84 BA Bosnia and Herzegovina 3.65
10 UK United Kingdom 5.50	35 BB Barbados 4.61	60 TT Trinidad and Tobago 3.98	85 CS Serbia 3.64
11 TW Taiwan, China 5.48	36 PR Puerto Rico 4.59	61 AZ Azerbaijan 3.95	86 PH Philippines 3.64
12 KR Korea, Rep. 5.47	37 SI Slovenia 4.58	62 KW Kuwait 3.95	87 DM Dominican Republic 3.60
13 HK Hong Kong SAR 5.46	38 ES Spain 4.54	63 MN Mongolia 3.95	88 GE Georgia 3.60
14 NZ New Zealand 5.36	39 CL Chile 4.44	64 SK Slovak Republic 3.94	89 BW Botswana 3.58
15 IS Iceland 5.33	40 OM Oman 4.35	65 BR Brazil 3.92	90 GY Guyana 3.58
16 DE Germany 5.32	41 LV Latvia 4.35	66 MK Macedonia, FYR 3.91	91 MA Morocco 3.56
17 AU Australia 5.29	42 CZ Czech Republic 4.33	67 RO Romania 3.90	92 AR Argentina 3.52
18 JP Japan 5.25	43 HU Hungary 4.30	68 AL Albania 3.89	93 KE Kenya 3.51
19 AT Austria 5.25	44 UY Uruguay 4.28	69 IN India 3.89	94 AM Armenia 3.49
20 IL Israel 5.24	45 HR Croatia 4.22	70 BG Bulgaria 3.89	95 LB Lebanon 3.49
21 LU Luxembourg 5.22	46 ME Montenegro 4.22	71 LK Sri Lanka 3.88	96 EC Ecuador 3.46
22 BE Belgium 5.13	47 JO Jordan 4.17	72 ZA South Africa 3.87	97 GH Ghana 3.44
23 FR France 5.12	48 IT Italy 4.17	73 CO Colombia 3.87	98 GT Guatemala 3.43
24 EE Estonia 5.09	49 PL Poland 4.16	74 JM Jamaica 3.86	99 HN Honduras 3.43
25 IE Ireland 5.02	50 TN Tunisia 4.12	75 UA Ukraine 3.85	100 SN Senegal 3.42

1–30: ICT advanced economies (vicious cycle) and 31–100: ICT growing economies (virtuous cycle).
Source: The Global Information Technology Report 2012 (World Economic Forum, 2012).

Table 4
Bi-polarization in 500 global ICT firms in 2010 (Top 100 by R&D level order).

1 **MST** Microsoft	26 **STM**STMicroelectronics	51 **SEP** Seiko Epson	76 **TYE** Tyco Electronics
2 **SAM** Samsung Electronics	27 **FUF** FUJIFILM	52 **NVD** NVIDIA	77 **NXP** NXP Semiconductors
3 **NOK** Nokia	28 **SHA** Sharp	53 **KON** Konica Minolta	78 **NIN** Nintendo
4 **INT** Intel	29 **AMZ** Amazon.com	54 **DAN** Danaher	79 **MUM** Murata Manufacturing
5 **PAN** Panasonic	30 **APP** Apple	55 **MED** MediaTek	80 **AUT** Autodesk
6 **SIE** Siemens	31 **BRO** Broadcom	56 **FSC** Freescale Semiconductor	81 **AND** Analog Devices
7 **SON** Sony	32 **TEI** Texas Instruments	57 **SAN** Sanyo Electric	82 **MIP** Maxim Int. Products*
8 **CIS** Cisco Systems	33 **MIT** Mitsubishi Electric	58 **NIK** Nikon	83 **EME** Emerson Electric
9 **IBM** IBM	34 **AMD** Advanced Micro Devices	59 **HSC** Hynix Semiconductor	84 **OMR** Omron
10 **HIT** Hitachi	35 **RIC** Ricoh	60 **ASM** ASML	85 **ROH** Rohm
11 **ORC** Oracle	36 **RIM** Research In Motion	61 **ADO** Adobe Systems	86 **SYN** Synopsys
12 **ERC** Ericsson	37 **HON** Hon Hai Precisiion Ind.	62 **LSI** LSI	87 **HTC** HTC
13 **CAN** Canon	38 **ZTE** ZTE	63 **TDK** TDK	88 **PIO** Pioneer
14 GOO Google	39 **YAH** Yahoo!	64 **DEL** Dell	89 **AMA** Amadeus
15 **ALU** Alcatel-Lucent	40 **ELA** Electronic Arts	65 **XER** Xerox	90 **UBI** UBIsoft Entertainment
16 **NEC** NEC	41 **APM** Applied Materials	66 **NEP** NetApp	91 **DAS** Dassault Systems
17 **HP** Hewlett-Packard	42 **ABB** ABB	67 **TOK** Tokyo Electron	92 **BRI** Brother Industries
18 **LG** LG	43 **EBY** eBay	68 **INF** Infineon Technologies	93 **ELM** Elpida Memory
19 **FUJ** Fujitsu	44 **TSM** Taiwan Semiconductor	69 **CA** CA	94 **SAD** SanDisk
20 **QUA** Qualcomm	45 **SCH** Schneider	70 **INU** Intuit	95 **AVA** Avaya
21 **MOT** Motorola	46 **JUN** Juniper Networks	71 **MIC** Micron Technology	96 **XIL** Xilinx
22 **HUT** Huawei Technologies	47 **MVT** Marvell Technology	72 **KYO** Kyocera	97 **SGD** SunGard Data Systems
23 **SAP** SAP	48 **SUM** Sumitomo Technology	73 **AGT** Agilent Technologies	98 **CDS** Cadence Design Systems
24 **EMC** EMC	49 **SGT** Seagate Technology	74 **WED** Western Digital	99 **LEX** Lexmark
25 **PHE** Philips Electronics	50 **SYM** Symantec	75 **COR** Corning	100 **CIT** Citrix Systems

Source: Same as Fig. 2.

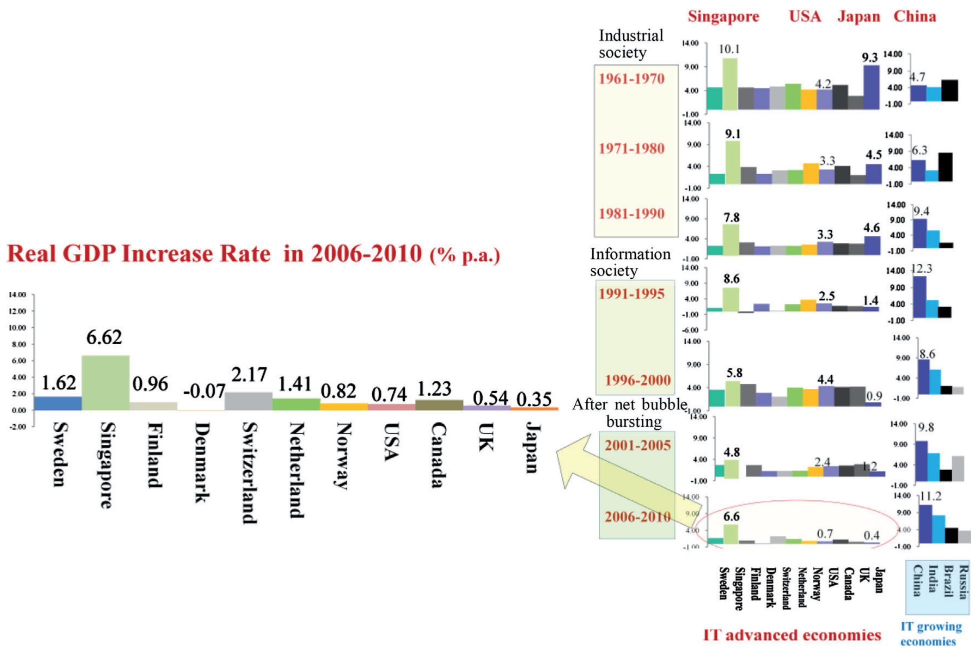


Fig. 5. Stagnation in economic growth in ICT advanced economies (2006–2010).
Source: World Economic Outlook Database (IMF, annual issues).

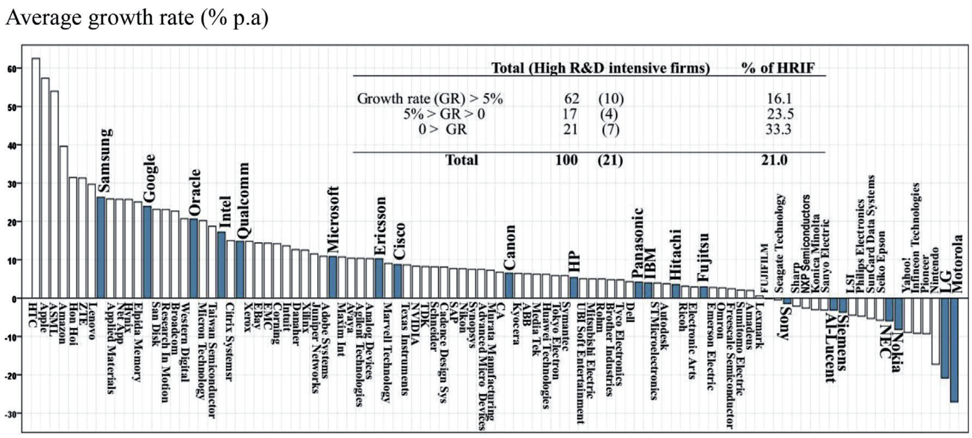


Fig. 6. Stagnation in sales growth in ICT advanced firms – sales growth rate of top 100 R&D intensive firms (2009–2011): average growth rate (% p.a). Source: Same as Fig. 2.

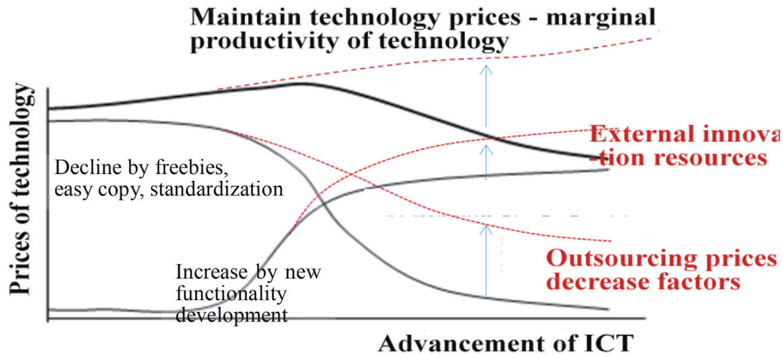


Fig. 7. ICT's identical two faces.

urges significant challenges against price decreases due to marginal productivity decline, innovator's dilemma and consumer preferences shift.

Consequently, prices of technology in highly ICT advanced economies may change to decreasing trend resulting in decreasing their growth rate as outlined in Fig. 10. This can be the structural source of the trap of ICT advancement compelling ICT advanced nations/firms suffering a vicious cycle between advancement of ICT and its marginal productivity[6] decline.

Given the foregoing circumstances, ICT advanced economies endeavor should focus on accelerating prices increase by means of successive efficient new functionality development while minimizing prices decrease factors by outsourcing them to other parties. Noteworthy accomplishments demonstrated by resilient global ICT firms support this postulate and provide us constructive suggestions supportive to constructing a new business model satisfying both efficiency and resilience in a global competitive market.

3.1.2. Co-evolutionary acclimatization

These accomplishments suggest the following co-evolutionary acclimatization system enabling both ICT advanced and growing economies harness the vigor of counterparts as a possible countermeasure to the trap of ICT (Watanabe, 2013). While ICT advanced economies enable further advancement of ICT, it results in declining its marginal productivity. Thus, such advancement should be addressed to the advancement of ICT growing economies which enjoy a virtuous cycle between its advancement and

[6] Given that the firms seek to profit maximum in the competitive market, marginal productivity of technology corresponds to relative price of technology (ratio of technology prices and prices of product).

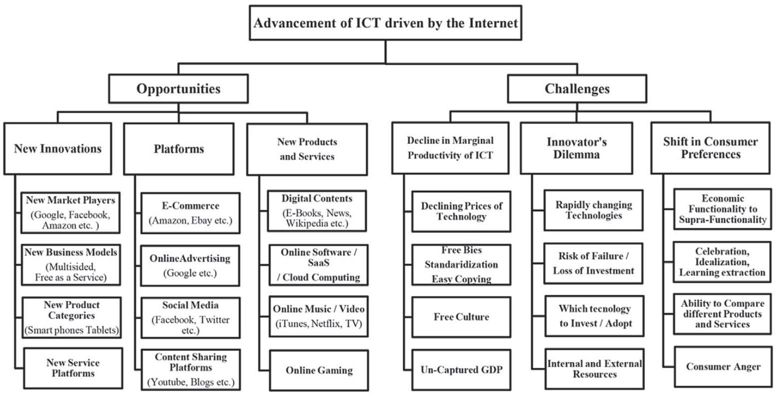


Fig. 8. Structure of the two faces of the advancement of ICT.

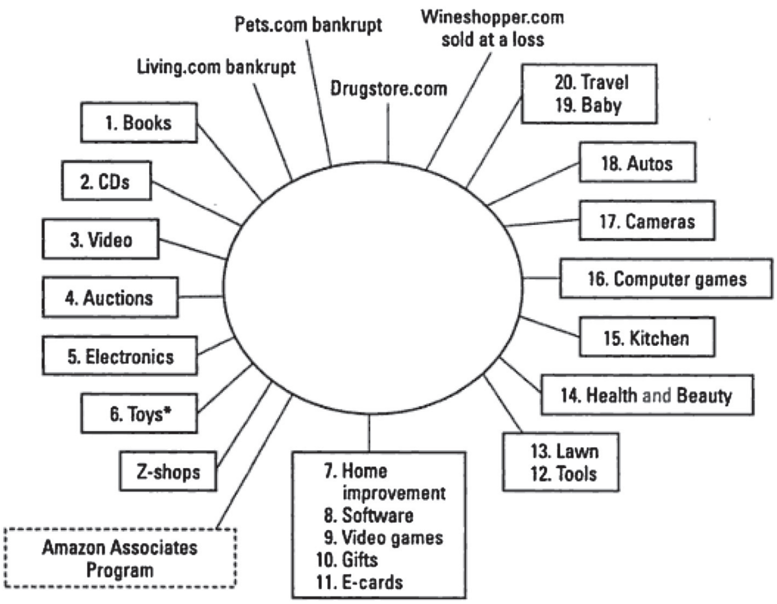


Fig. 9. Amazon's growing empire.
Source: Kenney, The Growth and Development of the Internet in the United States (2003) [14].

marginal productivity increase leading to sustainable growth as reviewed in Fig. 11.

3.2. Demonstration

Aiming at demonstrating the foregoing hypothetical view, an empirical analysis decomposing the prices of ICT was attempted.[7]

[7] This subsection is developed based on Watanabe et al. (2014b) [37].

3.2.1. Measurement of ICT prices

Production function encompassing production factors contributing to GDP (Y) as labor (L), non-ICT capital services (n-ICT), ICT capital services (ICT), and other factors contributing to growth (T_r) can be depicted as follows[8]:

[8] This production function concept and subsequent data for the analysis are based on “The Conference Board Total Economy Database™, *January 2013*, http://www.conference-board.org/data/economydatabase/. Retrieved 5 January 2014.

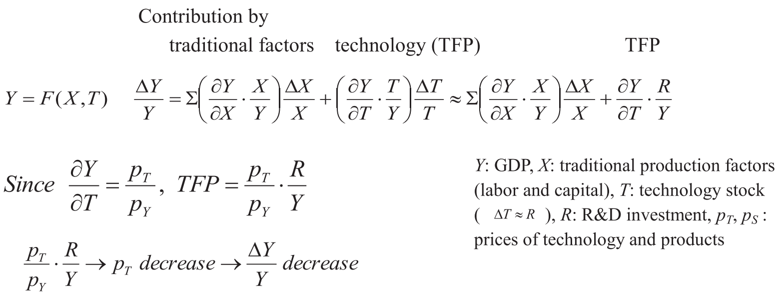


Fig. 10. Scheme of the great stagnation due to the decrease in technology prices.

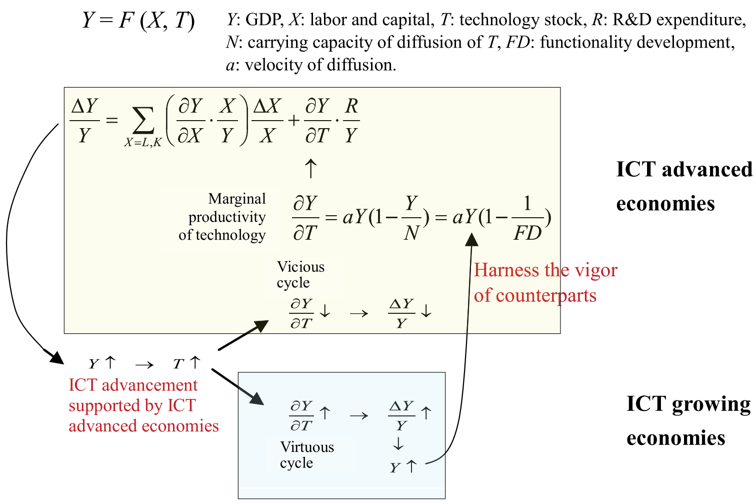


Fig. 11. Scheme of co-evolutionary acclimatization in global ICT firms.

$$Y = F(L,\ n - \mathrm{ICT},\ \mathrm{ICT},\ T_r) \tag{6}$$

where ICT encompasses capital services provided by assets derived from the advancement of ICT and embodying into computer hardware and equipment, telecommunication equipment, and computer software and services, while T_r accounts for the changes in output not caused by changes in other production factors.[9]

Contribution of ICT to GDP growth φ can be depicted as follows:

$$\varphi = \left(\frac{\partial Y}{\partial I}\cdot\frac{I}{Y}\right)\frac{\Delta I}{I} \tag{7}$$

where I denotes ICT and $\Delta I = \mathrm{d}I/\mathrm{d}t$.

From equation (7), marginal productivity of ICT can be depicted as follows:

$$\frac{\partial Y}{\partial I} = \frac{\varphi}{\frac{I}{Y}\cdot\frac{\Delta I}{I}} \tag{8}$$

This is equivalent to relative prices of ICT in the profit maximum behavior under the competitive circumstance as follows:

$$\frac{\partial Y}{\partial I} = p_I = \frac{p_{\mathrm{ICT}}}{p_Y} \tag{9}$$

Therefore, prices of ICT can be measured by equations (8) and (9). All data consisting of these equations are available in the database indicated in the footnote[8].

[9] While in the production function in Figs. 10 and 11 all stock of technological advancement including ICT capital services (excluding those services by obsolescent ICT) are treated by technology stock T, in the production function depicted by equation (6), with the aim to identify the identical contribution of ICT, ICT is treated independently by extracting from T in Figs. 10 and 11. Technology stock T_r in equation (6) accounts for the changes in output not caused by changes in other production factors including ICT and obsolescent ICT is categorized in *n-ICT*.

3.2.2. Decomposition of ICT prices

Given the ICT's identical two faces as illustrated in Fig. 7 and prices increase by new functionality development is governed by ICT advancement as a whole in a logistic growth way while prices decline is initiated by the increase in the Internet dependency in a reverse logistic growth way (Watanabe et al., 2001 [31]), trajectory of ICT prices can be depicted by the following equation:

$$p_I = \frac{N}{1+b_i e^{-a_i I}} + \frac{N}{1+b_j e^{a_j J}} \tag{10}$$

where J: dependency on the Internet, N: carrying capacity[10], a_i, a_j and b_i, b_j: diffusion velocity of I and J, and initial stage of diffusion of I and J, respectively.

Equation (10) can be developed as follows:

$$\begin{aligned}
\frac{p_I}{N} &= \frac{1+b_j e^{a_j J} + 1 + b_i e^{-a_i I}}{\left(1+b_i e^{-a_i I}\right)\left(1+b_j e^{a_j J}\right)} = \frac{2+b_j e^{a_j J}+b_i e^{-a_i I}}{1+b_j e^{a_j J}+b_i e^{-a_i I}+b_i b_j e^{-a_i I} e^{a_j J}} \approx \frac{2+b_j e^{a_j J}+b_i e^{-a_i I}}{1+b_i b_j+b_j e^{a_j J}+b_i e^{-a_i I}} \\
&= 1+\frac{1-b_i b_j}{1+b_i b_j+b_j e^{a_j J}+b_i e^{-a_i I}} \qquad (\because a_i I = a_j J) \\
\frac{p_I}{N} - 1 &= \frac{1-b_i b_j}{1+b_i b_j+b_j e^{a_j J}+b_i e^{-a_i I}} \\
\frac{N}{N-p_I} &= \frac{1}{1-\frac{p_I}{N}} = -\frac{1+b_i b_j}{1-b_i b_j} - \frac{b_j e^{a_j J}}{1-b_i b_j} - \frac{b_i e^{-a_i I}}{1-b_i b_j} \approx -\frac{1+b_i b_j}{1-b_i b_j} - \frac{b_j}{1-b_i b_j}(1+a_j J) - \frac{b_i}{1-b_i b_j}(1-a_i I) \\
&= -\frac{1+b_i b_j+b_i+b_j}{1-b_i b_j} - \frac{a_j b_j}{1-b_i b_j} J + \frac{a_i b_i}{1-b_i b_j} I \equiv \alpha + \beta J + \gamma I
\end{aligned} \tag{11}$$

where

$$\alpha = -\frac{1+b_i b_j+b_i+b_j}{1-b_i b_j} = -\frac{(1+b_i)(1+b_j)}{1-b_i b_j}, \quad \beta = -\frac{a_j b_j}{1-b_i b_j}, \quad \gamma = \frac{a_i b_i}{1-b_i b_j}$$

3.2.3. Significance of two-faced nature of ICT

Since two-faced nature of ICT advancement can be considered the main source declining the marginal productivity of ICT and subsequent its prices decrease resulting in great stagnation particularly in ICT advanced economies, aiming at demonstrating its significant effects, an empirical demonstration of the actual repercussion of the advancement of ICT was attempted taking the world ICT top leaders, Finland and Singapore.

(1) Factors governing prices of ICT

Table 5 tabulates global ICT ranking in 2012 based on the state of the Networked Readiness Index (NRI) published annually by the World Economic Forum (see Footnote[2]).

Table 5 demonstrates that Finland and Singapore play leading role in the state of the advancement (development and effective utilization) of ICT and can be considered the world ICT top leaders.

Focusing on the ICT driven development trajectory in Finland and Singapore over the period 1994 and 2011, trends in prices of ICT were computed by utilizing equations (8) and (9).

Fig. 12 demonstrates the result of the computation using index (1990 = 100) based ICT intensity (I/Y). Looking at the figure we note that while prices of Finland steadily increased in 1994–1999, they turned out to declining trend from 2000. While they maintained plateaus state with slight up and down in 2001–2008, they changed to dramatic decline after the Lehman shock in 2008. While prices of ICT in Singapore demonstrated conspicuously high level in 1994–1997 with slight up and down as a general nature of the “Asian Tiger” (newly emerged economy), they changed to dramatic decline after the Asian financial crisis in 1997. Such a dramatic decline calmed down in 2001 and changed to slightly decreasing trend with certain up and down accessing to the similar level in Finland (Chew et al., 2011 [6]).

While dramatic declining trend in Singapore in the late 1990s can be considered as a consequence of the transition from newly emerged economy to developed economy together with the Asian financial crisis in 1997, notable decline in the latter part of the first decade of this century to the beginning of the second decade can be considered as a consequence of the great stagnation postulated by Cohen (2011) [7].

In order to demonstrate Cohen's hypothetical view, particularly two-faced nature of ICT resulting in declining the prices of ICT, effects of ICT advancement both of general increase in ICT stock as a whole and increase in the dependency on the Internet on the ICT prices change were next analyzed.

Fig. 13 illustrates trends in ICT stock in Finland and Singapore over the period 1990–2011. Looking at the Figure we note that ICT stock in both countries demonstrated steady increase with higher increase rate in Finland.

[10] Since the Internet has been playing a leading role in the whole ICT and providing significant impacts on the diffusion trajectory of ICT, carrying capacity of logistic growth in I and reverse logistic growth in J as well as their diffusion tempo ($a_i I$ and $a_j J$) were treated as behaved in the similar way($a_i I = a_j J$).

Table 5
Ranking of the networked readiness in 2012 (top 50 out of 144 countries).

1 Finland 5.98 (3)	16 Luxembourg 5.37 (21)	31 Saudi Arabia 4.82 (34)	46 Panama 4.22 (57)
2 Singapore 5.96 (2)	17 Iceland 5.31 (15)	32 Lithuania 4.72 (31)	47 Jordan 4.20 (47)
3 Sweden 5.91 (1)	18 Australia 5.26 (17)	33 Portugal 4.67 (33)	48 Montenegro 4.20 (46)
4 Netherlands 5.81 (6)	19 Austria 5.25 (19)	34 Chile 4.59 (39)	49 Poland 4.19 (49)
5 Norway 5.66 (7)	20 New Zealand 5.25 (14)	35 Cyprus 4.59 (32)	50 Italy 4.18 (48)
6 Switzerland 5.66 (5)	21 Japan 5.24 (18)	36 Puerto Rico 4.55 (36)	
7 United Kingdom 5.64 (10)	22 Estonia 5.12 (24)	37 Slovenia 4.53 (37)	
8 Denmark 5.58 (4)	23 Qatar 5.10 (28)	38 Spain 4.51 (38)	
9 United States 5.57 (8)	24 Belgium 5.10 (22)	39 Barbados 4.49 (35)	
10 Taiwan, China 5.47 (11)	25 UAE 5.07 (30)	40 Oman 4.48 (40)	
11 Korea, Rep. 5.46 (12)	26 France 5.06 (23)	41 Latvia 4.43 (41)	
12 Canada 5.44 (9)	27 Ireland 5.05 (25)	42 Czech Republic 4.38 (42)	
13 Germany 5.43 (16)	28 Malta 4.90 (26)	43 Kazakhstan 4.32 (55)	
14 Hong Kong SAR 5.40 (13)	29 Bahrain 4.83 (27)	44 Hungary 4.29 (43)	
15 Israel 5.39 (20)	30 Malaysia 4.82 (29)	45 Turkey 4.22 (52)	

[a]Ranking indicates the state in 2012 while the state in 2011 is indicated in parenthesis.
[b]Figure demonstrates the score of the Networked Readiness Index 2013 (the level in 2012).
Source: The Global Information Technology Report 2013 (World Economic Forum, 2013 [40]).

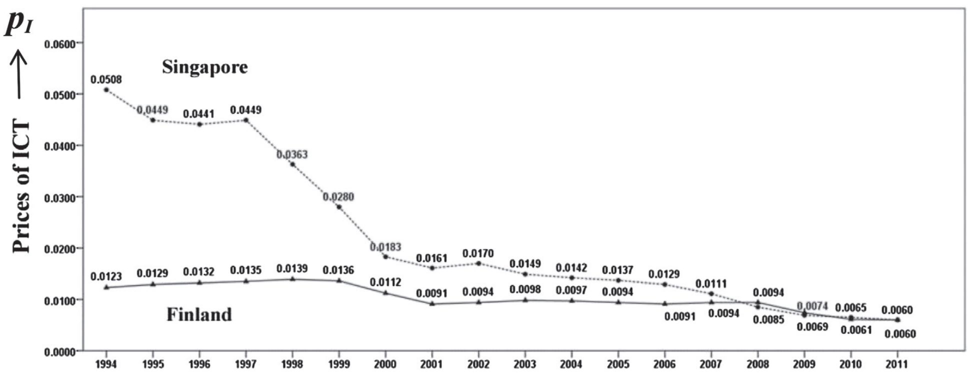


Fig. 12. Trends in the prices of ICT in ICT top leaders: Finland and Singapore (1994–2011). [a] Prices of ICT (relative prices of ICT) are computed by the following equation: $p_I = \frac{\varphi}{\frac{\Delta I}{I}\frac{I}{Y}}$ where φ: contribution of ICT to GDP growth (%: equation (2)), $\Delta I/I$: growth rate of ICT capital services (%), and I/Y: ICT intensity (ratio of ICT and GDP) using index (1990 = 100).

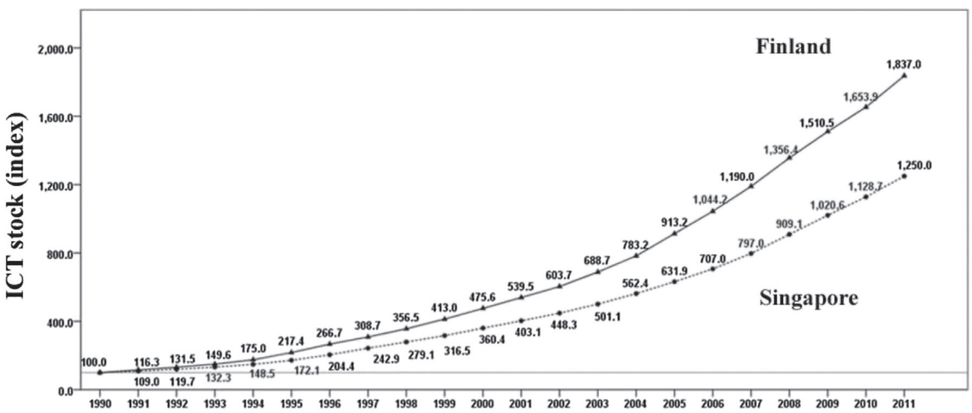


Fig. 13. Trends in ICT stock in ICT top leaders: Finland and Singapore (1990–2011) – index: 1990 = 100.
Source: "The Conference Board Total Economy Database™, January 2013, http://www.conference-board.org/data/economydatabase/. Retrieved 5 January 2014.

Similarly, Fig. 14 illustrates trends in the Internet dependency in Finland and Singapore over the period 1990–2011.

Fig. 14 demonstrates consequently high increase rate in the Internet dependency in ICT top leaders in 1994–2000 particularly in Singapore while it changed to low increase rate in 2001–2011.

(2) Two-faced nature of ICT in world ICT top leaders

On the basis of the foregoing analyses and observations, based on equation (11), effects of ICT stock and dependency on the Internet on the changes in ICT prices in ICT top leaders were analyzed. Figs. 15 and 16 together with the regression results demonstrate the results of the analyses in decomposing the trends in the prices of ICT into ICT driven logistic growth trajectory (I) and the Internet dependency attributable reverse logistic growth trajectory (J).

Looking at Fig. 15 we note that while the steady increase in ICT prices in Finland in 1994–1999 can be attributed to the advancement of ICT with new functionality development, their turning out to declining trend from 2000 can largely be attributed to the dramatic advancement of the Internet and subsequent increasing popularity of freebies, easy copy and standardization nature. Notwithstanding such effects, Finland maintained its ICT prices in plateaus state with slight up and down in 2001–2008. This can be attributed to the consistent increase in its ICT stock as demonstrated in Fig. 13 and subsequent increase in new functionality development. Dramatic decline in the ICT prices after 2008 can be attributed to the stagnation of ICT increase efforts under the global simultaneous stagnation due to the Lehman shock in 2008. Dramatic increase in prices declining feature of the Internet corresponding to this period accelerated to such a decline.

Similarly, looking at Fig. 16 we note that while advancement of ICT maintained steady increase in ICT prices in Singapore, increase in the Internet dependency changed to decline the prices. As reviewed earlier, dramatic decline in conspicuously high level of Singapore's ICT prices in the late 1990s can be considered as a consequence of the transition from newly emerged economy to developed economy together with the Asian financial crisis in 1997. While such a dramatic decline calmed down in 2001 and changed to slightly decreasing trend with certain up and down. This can be attributed to the balance between the positive effects of ICT advancement and the negative effects of the Internet dependency. Noting decline in the latter part of the first decade of this century to the beginning of the second decade can be attributed to the similar sources as Finland: global simultaneous stagnation and dramatic increase in prices declining feature of the Internet.

All these empirical analyses taking world most forefront two-faced nature of ICT advanced circumstances as world ICT top leaders demonstrated the hypothetical view that two-faced nature of ICT advancement has become evident as a consequence of the dramatic advancement of the Internet and this could be the source of bi-polarization between ICT advanced economies and ICT growing economies resulting in the great stagnation in the former economies.

4. New paradox of productivity

4.1. Un-captured GDP

4.1.1. Increasing role of un-captured GDP

The previously noted results demonstrate that the identical two faces of ICT could be the structural source of the trap of ICT advancement leading to new paradox of productivity that appears to have emerged in the latter part of the first decade of this century as reviewed in Section 1. Advances in ICT can largely be attributed to the dramatic advancement of the Internet, which has changed the computer-initiated ICT world significantly. The Internet promotes a freer culture, the consumption of which provides utility and happiness to people but cannot be

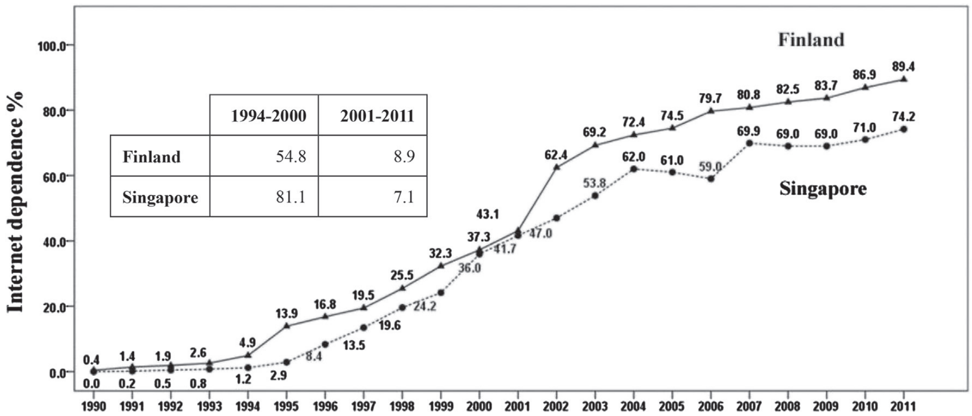


Fig. 14. Trends in the internet dependency in ICT top leaders: Finland and Singapore (1990–2011).
Source: World Telecommunication/ICT Indicators Database (UN, 2013).

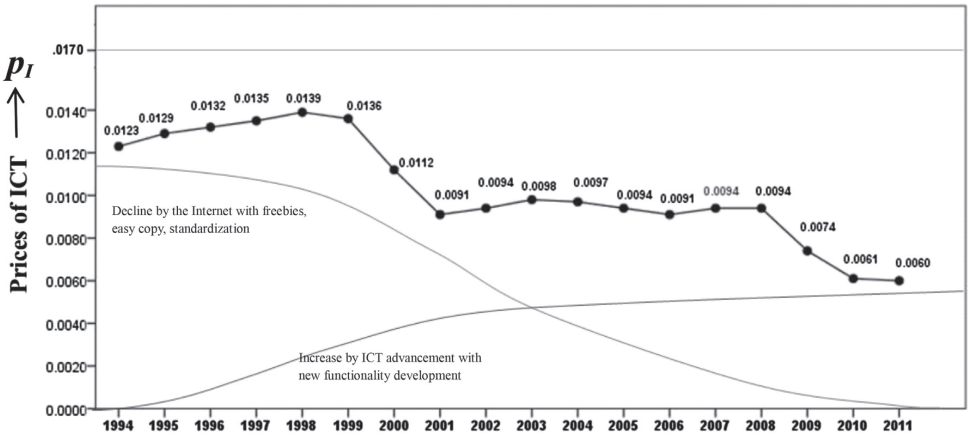


Fig. 15. Trends in the effects of ICT advancement and increase in the internet dependency to ICT prices in Finland (1994–2011).

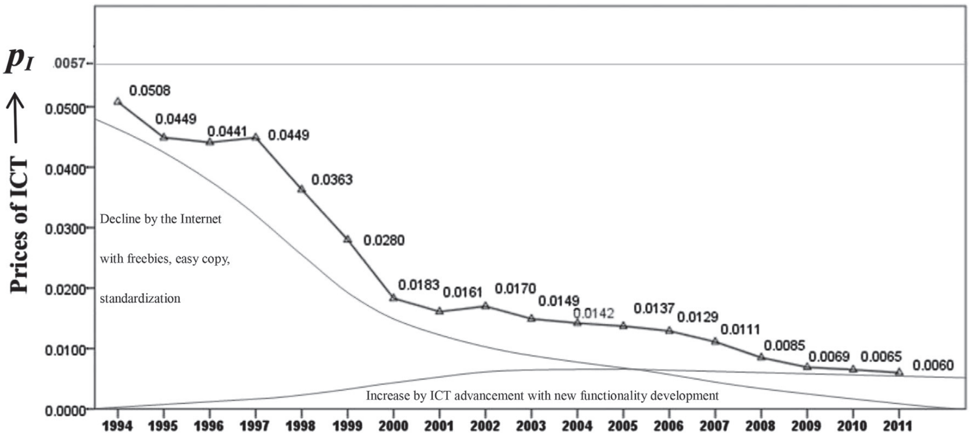


Fig. 16. Trends in the effects of ICT advancement and increase in the internet dependency to ICT prices in Singapore (1994–2011).

captured through GDP data that measure revenue (Lowrey, 2011 [17]).

Un-captured GDP has become the major source of consumers utility (happiness in consumption) and general happiness (JCO, 2012 [13]). As a consequence of historical change in the experience of nations, and in line with the general shift from a commodity-oriented society toward a service and information-oriented society, it is generally postulated that consumer preference has been steadily shifting from an economic functionality-driven preference (captured by GDP) to supra-functionality beyond economic value-driven preference. Here, supra-functionality beyond economic value encompasses social, cultural, aspirational, tribal and emotional values and they are not necessarily captured by GDP (McDonagh, 2008 [21]).[11] Such a shift can be clearly observed in Japan which is extremely sensitive to institutional innovation against external shocks and crises (Hofstede, 1991 [11], Watanabe, 2009 [32]). Fig. 17 illustrates this shift demonstrated by Japan's *Public Opinion Survey Concerning People's Lifestyles*[12] conducted annually by Japan's Cabinet Office (JCO).

Looking at Fig. 17 we note that contrary to a steady decline in people's preference in economic functionality (V),

[11] See Appendix 1 the concept of the supra-functionality beyond economic value.

[12] In this survey, personal preference for future life is chosen from three options: (i) Richness of the heart – spiritual happiness (*Since a reasonable level of material affluence has been achieved, future emphasis should be put on spiritual happiness and a comfortable life.*), (ii) Wealth of things – material affluence (*Emphasis should still be put on material affluence for future life.*), or (iii) Can not identify explicitly. While the second option corresponds to a preference for economic functionality, the first option corresponds to that of supra-functionality beyond economic value (Watanabe et al., 2011 [33]). See the detailed structure of the Survey in the Appendix 2.

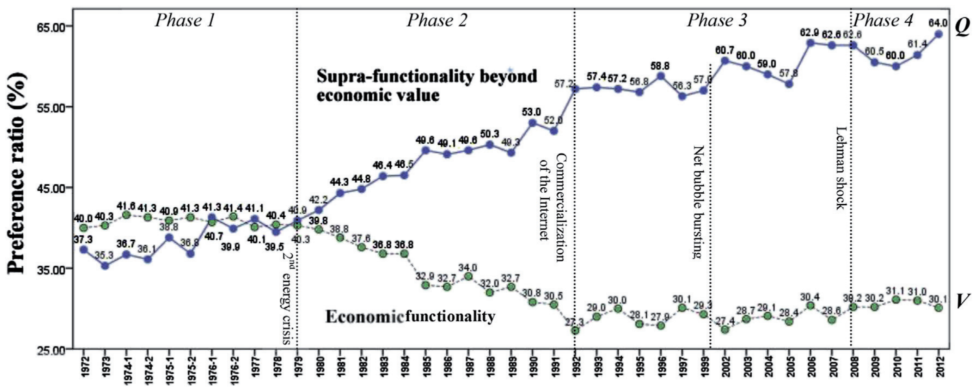


Fig. 17. Trends in the shift of Japan's preferences (1972–2012)[a]. [a]While it has not necessarily been recorded every year, it has been recorded more than once in certain years.
Source: National Survey of Lifestyle Preferences (Japan Cabinet Office, annual issues).

Table 6
Correlation between GDP and the shift of Japan's preferences (1972–2012).

$$\ln V = \underset{(17.36^*)}{6.335} - \underset{(-7.21^*)}{0.555}\, D_1 \ln Y - \underset{(-7.71^*)}{0.549}\, D_2 \ln Y - \underset{(-8.11^*)}{2.959}\, D_3 \quad \text{adj. } R^2\ 0.913 \quad DW\ 1.09$$

$$\ln Q = \underset{(5.29^*)}{1.283} + \underset{(9.76^*)}{0.500}\, D_1 \ln Y + \underset{(10.73^*)}{0.507}\, D_2 \ln Y + \underset{(11.55^*)}{0.515}\, D_3 \ln Y \quad \text{adj. } R^2\ 0.972 \quad DW\ 1.66$$

Y: GDP Index (1972 = 100), V: Economic functionality, Q: Supra-functionality beyond economic value, D: Dummy variables (D_1: 1972–79 (Phase 1) = 1, D_2: 1980–92 (Phase 2) = 1, D_3: 1993–2012 (Phases 3 and 4) = 1, other years = 0).
Figures in parenthesis indicate t-statistics (* means significant at the 1% level).

supra-functionality beyond economic value (Q) steadily increasing and exceeded V in 1979, the year of the 2nd energy crisis. While Q continues steadily increase, V declined to its lowest level in 1992, the year immediately after the commercialization of the Internet in 1991. It has stayed at a similar level since then. A decline in Q due to the Lehman shock in 2008 was followed by a sharp recovery. Consequently, a shifting trend from V to Q can be classified into four phases: *Phase 1* (1972–1979), *Phase 2* (1980–1992), *Phase 3* (1993–2008), and *Phase 4* (2009–2012).

Table 6 demonstrates that while elasticity of supra-functionality beyond economic value Q (which cannot necessarily be captured by GDP) exhibits a slight increasing trend, economic functionality V (which can be captured by GDP by its nature) has changed to stable independent of GDP after Phase 3 (after commercialization of the Internet in the beginning of the 1990s). These results demonstrate that while people's preferences have shifted in line with increased GDP, their inducement has shifted to un-captured GDP suggesting the prelude of the foregoing new paradox due to an Internet initiated ICT world.

4.1.2. Emergence of un-captured GDP substitution for captured-GDP

Aiming at identifying the emergence of un-captured GDP substitution for captured GDP, Table 7 analyzed this substitution by phases by means of the correlation between Q/V and Y[13] over the last four decades with dummy variables corresponding to four phases.

Table 7, first attempted to identify the phase when un-captured GDP effects emerged by comparing 3 models (phase 4, 3 and 2 emergence hypothesis, respectively) and identified that model 2 with phase 3 emergence hypothesis is statistically most significant suggesting that un-captured GDP effects emerged during the period 1993–2008.

Based on this suggestion, identification of the time when un-captured GDP effects substantially activated in shifting from V to Q (Q substitution for V) in Japan was attempted next by comparing 7 models with activation started from 1997 to 2003 (middle of Phase 3), respectively. The result of the comparison demonstrated that model D which hypothesized that un-captured GDP's substantial activation in V to Q shift started from 2000 is statistically most significant. This suggests that a co-evolution between ICT advancement (that increased un-captured GDP effects) and people's preferences shift from V to Q started toward activation from 2000, the year corresponding to the net bubble bursting and earlier than the timing of the emergence of a new ICT paradox which was considered in the late of the first decade of this century (Rifkin, 2011 [26]).

4.2. ICT advancement induced by people's preferences

Given the historical trend in people's preferences in shifting from economic functionality to supra-functionality

[13] Table 6 suggests the following correlation between Y and V and Q: $\ln V = a_1 + b_1 \ln Y$, $\ln Q = a_2 + b_2 \ln Y$ Partial differentiation with respect to $\ln Y$ leads $\frac{\partial \ln V}{\partial \ln Y} = \frac{\partial V}{\partial Y} \cdot \frac{Y}{V} = b_1$, $\quad \frac{\partial \ln Q}{\partial \ln Y} = \frac{\partial Q}{\partial Y} \cdot \frac{Y}{Q} = b_2$ Taking the ratio leadsTaking balance of the first equations $\ln \frac{Q}{V} = (a_2 - a_1) + (b_2 - b_1) \ln Y$ thus, $\ln Y = \frac{1}{b_2 - b_1}\left[(a_1 - a_2) + \ln \frac{b_1}{b_2} + \ln \frac{\frac{\partial V}{\partial Y}}{\frac{\partial Q}{\partial Y}}\right]$ This demonstrates that the correlation between Y and Q/V depicts elasticity of Q substitution for V $\sigma = \frac{\partial \ln \frac{Q}{V}}{\partial \ln \frac{\frac{\partial V}{\partial Y}}{\frac{\partial Q}{\partial Y}}}$

Table 7
Effects of captured and un-captured GDP on the shift in Japan's preferences (1972–2012).

1) *Emergence of un-captured GDP effects by phases*

$$\frac{Q}{V}=\frac{b_1}{b_2}\cdot\frac{\frac{\partial V}{\partial Y}}{\frac{\partial Q}{\partial Y}} \text{ and } \ln\frac{Q}{V}=\ln\frac{b_1}{b_2}+\ln\frac{\frac{\partial V}{\partial Y}}{\frac{\partial Q}{\partial Y}}$$

Model 1 (Emerged in Phase 4)

$$\ln(Q/V)=\underset{(-9.46^{*})}{-4.709}+\underset{(9.35^{*})}{0.983}D_1\ln Y+\underset{(10.19^{*})}{0.989}D_2\ln Y+\underset{(10.88^{*})}{0.998}D_3\ln Y+\underset{(10.84^{*})}{5.407}D_4 \quad \text{adj. } R^2\ 0.964 \quad DW\ 1.36 \quad \text{AIC} \quad -225.93$$

Model 2 (Emerged in Phase 3)

$$\ln(Q/V)=\underset{(-9.63^{*})}{-4.988}+\underset{(9.52^{*})}{1.042}D_1\ln Y+\underset{(10.33^{*})}{1.043}D_2\ln Y+\underset{(11.00^{*})}{5.700}D_3+\underset{(10.96^{*})}{5.685}D_4 \quad \text{adj. } R^2\ 0.964 \quad DW\ 1.52 \quad \text{AIC} \quad -226.61$$

Model 3 (Emerged in Phase 2)

$$\ln(Q/V)=\underset{(-1.06^{***})}{-2.387}+\underset{(1.04^{***})}{0.493}D_1\ln Y+\underset{(1.22^{***})}{2.749}D_2+\underset{(1.38^{***})}{3.099}D_3+\underset{(1.37^{***})}{3.084}D_4 \quad \text{adj. } R^2\ 0.863 \quad DW\ 0.88 \quad \text{AIC} \quad -171.79$$

2) *Time when un-captured GDP effects activated*

$$\ln\frac{Q}{V}=a+b_1D_1\ln Y+b_2D_2$$

Model	**D_1=1 other years = 0**	**D_2=1 other years = 0**	***a***	**b_1**	**b_2**	**adj. R^2**	***DW***	**AIC**
A	1972–1996	1997–2012	−5.353	1.118	6.066	0.964	1.26	−227.74
			(−22.43)	(23.65)	(25.37)			
B	1972–1997	1998–2012	−5.275	1.102	5.994	0.964	1.26	−228.56
			(−23.19)	(24.52)	(26.28)			
C	1972–1998	1999–2012	−5.252	1.097	5.975	0.966	1.33	−230.16
			(−24.22)	(25.68)	(27.49)			
D	**1972–1999**	**2000–2012**	**−5.250**	**1.096**	**5.978**	**0.967**	**1.33**	**−231.35**
			(−25.18)	**(26.75)**	**(28.59)**			
E	1972–2000	2001–2012	−5.277	1.102	6.006	0.966	1.32	−230.96
			(−25.83)	(27.51)	(29.29)			
F	1972–2001	2002–2012	−5.323	1.111	6.048	0.966	1.30	−230.17
			(−26.38)	(28.16)	(29.87)			
G	1972–2002	2003–2012	−5.381	1.123	6.100	0.965	1.30	−229.60
			(−27.03)	(28.90)	(30.51)			

Y: G DP Index (1972 = 100), Q: Supra-Functionality beyond economic value, V: Economic functionality.
D indicates dummy variables.
D_1: 1972–1979 (Phase 1) = 1, other years = 0; D_2: 1980–1992 (Phase 2) = 1; D_3: 1993–2008 (Phase 3) = 1; D_4: 2009–2012 (Phase 4) = 1.
Figures in parenthesis indicate *t*-statistics (*, ***: significant at the 1% and the 10% level, respectively).
(However, we should note that this elasticity is always 1 as is the case of the Cobb–Douglas type production function).
Figures in parenthesis indicate *t*-statistics (all significant at the 1% level).

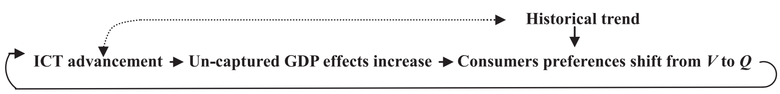


Fig. 18. Co-evolution between ICT advancement and consumers preferences shift.

beyond economic value in correspond to the advancement of ICT, and their co-evolutionary ICT inducement in an information society (Watanabe, 2009 [32]) as demonstrated in Fig. 18 and Table 8, based on the foregoing analyses, Table 9 demonstrates the role of people's preferences in inducing Japan's ICT advancement over the last two decades.

Table 9 demonstrates that people's preference on supra-functionality beyond economic value *Q* (which is not necessary captured by GDP) induces ICT advancement stronger than that of economic value *V* (which can be captured by GDP) with slightly increasing elasticity while *V* elasticity remains stable, just a very small vibration in the last two decades examined.

Table 8
Co-evolution between ICT advancement and consumers preference shift to supra-functionality beyond economic value in Japan (1990–2011).

$$\ln Q=\underset{(46.08^{*})}{3.621}+\underset{(5.77^{*})}{0.085}\ln ICT_{-1} \quad \text{adj.}R^2 0.618 \quad DW\ 1.54$$

$$\ln ICT=\underset{(-4.79^{*})}{-22.413}+\underset{(5.94^{*})}{6.835}\ln Q_{-1} \quad \text{adj.}R^2 0.632 \quad DW\ 0.94$$

Figures in parenthesis indicate t-statistics (*: significant at the 1% level).
ICT_{-1} and Q_{-1} indicate 1 year time-lag, respectively.

With such findings, Table 10 analyzes this correlation applying dynamic elasticity to Qin such a structure as (Watanabe et al., 2012 [34]).

Backward elimination method with 10% significant criteria and mean centric method was used in this correlation analysis. The result of the comparative analysis demonstrated that the second model with power 4 dynamic equation is statistically most significant. Fig. 19 demonstrates trend in this elasticity.

Looking at the figure we note that contrary to stable lower value in *V* elasticity to ICT, *Q* elasticity to ICT demonstrates higher value with dynamic changing trend. It continued to increase up until 2000 corresponding to the year when un-captured GDP effects activated as demonstrated in Table 7. This can be the engine driving *Q* substitution for *V*. However, it changed to decline from 2001 immediately after the bursting of the net bubble. While it continued slight decline up until 2007, it changed to

Table 9
Correlation between functionalities and ICT in Japan (1990–2011).

$$\ln \mathrm{ICT} = \underset{(-2.65^{**})}{-21.473} + \underset{(1.66^{***})}{2.057}\, D_{11} \ln V + \underset{(1.69^{***})}{2.081}\, D_{12} \ln V + \underset{(3.79^{*})}{4.851}\, D_{21} \ln Q + \underset{(3.87^{*})}{4.906}\, D_{22} \ln Q + \underset{(3.91^{*})}{4.913}\, D_{23} \ln Q + \underset{(3.95^{*})}{4.944}\, D_{24} \ln Q - \underset{(-2.53^{**})}{0.281}\, D$$
$$\text{adj.}R^2 \ 0.878 \quad DW\ 0.99 \quad \text{AIC} - 76.54$$

where ICT: ICT stock and D: dummy variables.
D_{11}:1990–2001 = 1;D_{12}:2002–2011 = 1;D_{21}:1990–2000 = 1;D_{22}:2001–2004 = 1;D_{23}:2005–2008 = 1;D_{24}:2009–2011 = 1;D:1993, 1994, 2006 = 1.
Figures in parenthesis indicate t-statistics (significant at the * 1%, ** 5%, and *** 10% level, respectively).

Table 10
Correlation between functionalities and ICT in Japan by dynamic elasticity (1990–2011).

$$\ln \mathrm{ICT} = \underset{(-2.07^{**})}{-14.362} + \underset{(2.08^{**})}{2.307} \ln V + (\underset{(2.58^{**})}{2.957} - \underset{(-1.63^{***})}{4.400 \times 10^{-4}}\, t^2 + \underset{(4.24^{*})}{1.190 \times 10^{-4}} t^3) \ln Q - \underset{(-3.02^{*})}{0.286}\, D_1 \quad \text{adj. } R^2 \ 0.894 \quad DW\ 1.39 \quad \text{AIC} - 80.66$$
$$\ln \mathrm{ICT} = \underset{(-2.80^{*})}{-18.713} + \underset{(2.04^{**})}{2.068} \ln V + (\underset{(3.70^{*})}{4.226} - \underset{(-3.25^{*})}{0.003}\, t^2 + \underset{(2.92^{*})}{9.278 \times 10^{-5}}\, t^3 + \underset{(3.28^{*})}{2.153 \times 10^{-5}}\, t^4) \ln Q + 0.305 D_2 \quad \text{adj. } R^2 \ 0.909 \quad DW\ 1.42 \quad \text{AIC} - 83.47$$
$$\ln \mathrm{ICT} = \underset{(-4.61^{*})}{-30.810} + \underset{(2.65^{**})}{2.982} \ln V + (\underset{(5.51^{*})}{6.438} - \underset{(-2.63^{**})}{2.250 \times 10^{-3}}\, t^2 + \underset{(2.44^{**})}{2.008 \times 10^{-5}}\, t^4 + \underset{(1.98^{**})}{5.599 \times 10^{-7}}\, t^5) \ln Q + \underset{(3.14^{*})}{0.527}\, D_3 \quad \text{adj. } R^2 \ 0.870 \quad DW\ 1.61 \quad \text{AIC} - 75.66$$

D: Dummy variables (D_1: 1993, 1994, 1997=1; D_2: 2005, 2007, 2009 = 1; D_3: 2005 = 1, other years = 0).
Figures in parenthesis indicate t-statistics (significant at the *1%, **5%, and ***10% level, respectively).

increasing trend from 2008. Slight decline can be attributed to the bursting of the net bubble and global simultaneous stagnation derived from the sub-prime loan issues in the US while there existed strong inertia to increasing expectation to Q initiative. This emerged conflict in transition. Change to increasing trend from 2008 can be attributed to the transformation of such conflict into a springboard for new innovation toward a post excessive consumption society.

4.3. Emerging conflict in transition

All support the foregoing hypothetical view emerging new paradox of productivity derived from the two-faced nature of the Internet driven ICT advancement and subsequent increasing discrepancy between captured GDP and un-captured GDP.

This increasing discrepancy reveals the following significant implications:

(i) First, there exists a possible hypothetical view that a decrease in ICT prices could be in line with a consumer preference shift from economic functionality to supra-functionality beyond economic value.
(ii) Second, shifting from captured GDP to un-captured GDP could correspond to the transfer of production efforts. Traditionally, all production efforts have been attributed to producer motivation as they can in turn obtain a compensating return. However, certain production efforts, particularly in cerebration, idealization and learning extraction efforts have been transferred from producers to consumers, which justify freebies to both producers and consumers.[14]
(iii) Third, under such shifting and transferring circumstances, there emerges conflict in the transition leading to an emerging growing anger of consumers (Watanabe, 2013 [35]).
(iv) Fourth, there emerges a possible new innovation transforming such anger into a springboard for new innovation.

Fig. 20 illustrates this transition dynamism.

Elucidation of this transition dynamism, particularly of the emergence of conflict in this transition and a possible transformation of such conflict into a springboard for new innovation, will be a crucial subject for resilience, which inevitably highlights the significance of analysis of consumer anger. This analysis leads to the analysis of innovation-consumption co-emergence.

Since consumption shares more than 60% of GDP in most countries, its sustainable growth despite beyond anticipation issues would be crucial. However, contrary to such anticipation, it has been strongly warned the increasing consumption haters among Japanese consumers, particularly among young generations due to nonexistence of goods and services corresponding to their sincere requirement (Matsuda, 2010 [19], 2012 [20]). This demonstrates protest to producers which cannot satisfy their requirement in the foregoing transition. At the same time they are irritating themselves being remains consumers unable to produce their desiring goods and services by themselves. Accumulation of more knowledge than producers depending on the advancement of the Internet accelerates such protest resulting in growing anger of consumers.

Given that resilience incorporates assimilation, the capacity for using a shock as a trigger for renewal and improvement (Ilmola et al., 2013 [12]), this consumers anger can be transformed into a springboard for new innovation. This anticipation prompts us a significance of innovation-consumption co-emergence which corresponds to co-evolutionary acclimatization as illustrated in Fig. 11 suggesting to harness the vigor of hidden counterparts, consumers.

[14] This is natural to producers as they depend certain due efforts on consumers efforts while consumers have not explicitly realized their contribution.

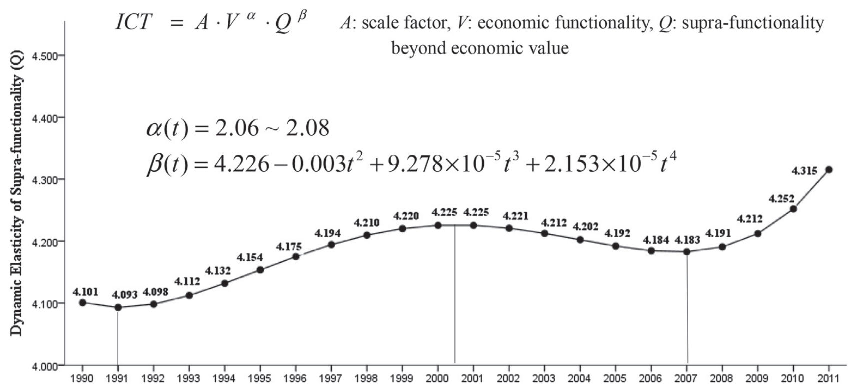


Fig. 19. Trends in elasticity of functionalities to ICT in Japan (1990–2011).

5. Growing anger of consumers

5.1. Shift to a post-excessive consumption society

Foregoing emerging conflict in the transition revealed explicitly by decline of marginal productivity of ICT and subsequent its prices decrease provides significant impacts on its users by growing their angers to producers and also to themselves as being remained consumers as illustrated in Fig. 21 (Watanabe, 2013 [35]).

Global simultaneous stagnation triggered by the US oriented sub-prime loan issues in 2007 and subsequent Lehman shock in 2008 has reminded us a possibility of a post-excessive consumption society. Table 11 summarizes correlation between GDP (Y) and household final consumption expenditure (C) in 6 countries including ICT top leaders, Finland and Singapore over the period 1990–2012. Looking at the Table we note that their coefficients have changed to declining trend from 2007 (US and Germany) or 2008 (Finland, Singapore, Japan and UK) corresponding to the sub-prime loan issue and subsequent Lehman shock in 2008. Since this coefficient depicts marginal propensity of consume ($\partial C/\partial V$), Table 11 suggests that marginal propensity of consume in these countries changed to declining trend after the global simultaneous stagnation as demonstrated in Table 12.

Foregoing observation supports a possibility of the emergence of post-excessive consumption society (Matsuda, 2010 [19], 2012 [20]) in which consumers increasing initiative in innovation game is anticipated (McDonagh, 2008 [21], Watanabe, 2009 [32], Watanabe et al., 2011 [33]). Such an increasing consumers initiative accelerates a

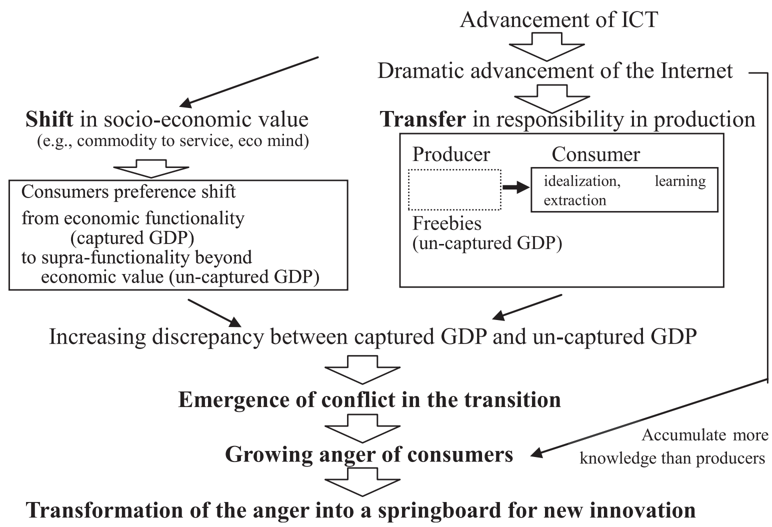


Fig. 20. Transition dynamism in new paradox of productivity and its impact on consumers.

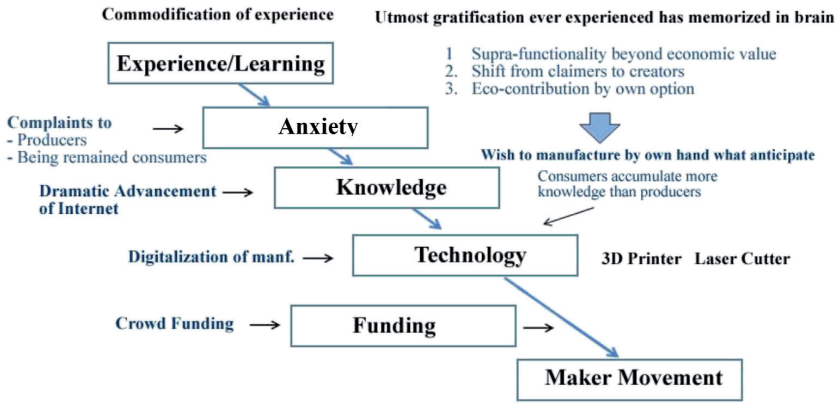


Fig. 21. Growing anger of consumers.

shift of their preference from economic functionality to supra-functionality beyond economic value encompassing social, cultural, aspirational, tribal and emotional value (Watson and McDonagh [38], 2004, McDonagh, 2008 [21], Watanabe, 2009 [32]) as reviewed in the preceding Section.

As postulated by Nobel laurite in Economics Modigliani, people never forget utmost gratification of consumption ever experienced that has memorized in the brain and affects consumers preference in consumption (Modigliani, 1965 [24]). Such experience can be subject to socioeconomic paradigm. As reviewed in the preceding Section, as a consequence of historical change in nations experiences, in line with the general shift in commodity oriented society to service and information oriented society, it is generally postulated that consumers preference has been steadily shifting from economic functionality driven preference to

Table 11
Correlation between GDP and final consumption in selected 6 countries (1990–2012).

Finland

$$C = \underset{(6.068^{*})}{9718.980} + \underset{(32.808^{*})}{0.416}\, D_1Y_1 + \underset{(2.097^{**})}{0.226}\, D_2Y_2 + \underset{(2.056^{**})}{35484.176}\, D_2 + \underset{(3.165^{*})}{2263.987}\, D \quad \underset{DW}{\text{adj.}R^2}\ \underset{1.32}{0.990}$$

D indicates dummy variables

D_1: 1990–2007 = 1, *other year* = 0; D_2: 2008–2012 = 1; D: 1991, 2006, 2012 = 1

Singapore

$$C = \underset{(2.939^{*})}{42293.395} + \underset{(26.082^{*})}{0.317}\, D_1Y_1 + \underset{(4.138^{*})}{0.213}\, D_2Y_2 - \underset{(-2.547^{**})}{37093.567}\, D_1 + \underset{(2.359^{**})}{6700.379}\, D \quad \underset{DW}{adj.R^2}\ \underset{1.05}{0.986}$$

D indicates dummy variables

D_1: 1990–2007 = 1, *other years* = 0; D_2: 2008–2012 = 1; D: 2002 = 1

Japan

$$C = \underset{(1.87^{**})}{120152469.362} + \underset{(25.12^{*})}{0.591}\, D_1Y_1 + \underset{(2.68^{**})}{0.340}\, D_2Y_2 - \underset{(-2.02^{***})}{131023751.720}\, D_1 - \underset{(-4.12^{*})}{7145417.823}\, D \quad \underset{DW}{\text{adj.}R^2}\ \underset{1.41}{0.978}$$

D indicates dummy variables

D_1: 1990–2007 = 1, *other years* = 0; D_2: 2008–2011 = 1; D: 1991, 2007, 2008 = 1

USA

$$C = \underset{(-11.45^{*})}{-656297.750} + \underset{(132.12^{*})}{0.735}\, D_1Y_1 + \underset{(7.21^{*})}{0.641}\, D_2Y_2 + \underset{(1.08^{***})}{1253670.120}\, D_2 - \underset{(-6.52^{*})}{138390.806}\, D \quad \underset{DW}{\text{adj.}R^2}\ \underset{1.34}{0.999}$$

D indicates dummy variables

D_1: 1990–2006 = 1, *other years* = 0; D_2: 2007–2011 = 1; D: 1991, 1998, 1999, 2000 = 1

Germany

$$C = \underset{(1.50^{***})}{48320.565} + \underset{(33.44^{*})}{0.549}\, D_1Y_1 + \underset{(12.01^{*})}{0.442}\, D_2Y_2 + \underset{(2.14^{**})}{200373.730}\, D_2 - \underset{(-4.91^{*})}{33538.105}\, D \quad \underset{DW}{\text{adj.}R^2}\ \underset{1.56}{0.990}$$

D indicates dummy variables

D_1: 1990–2006 = 1, *other years* = 0; D_2: 2007–2012 = 1; D: 2006, 2007, 2008 = 1

UK

$$C = \underset{(-8.63^{*})}{-121860.377} + \underset{(58.05^{*})}{0.706}\, D_1Y_1 + \underset{(1.70^{***})}{0.372}\, D_2Y_2 + \underset{(1.46^{***})}{458633.357}\, D_2 \quad \underset{DW}{\text{adj.}R^2}\ \underset{1.00}{0.995}$$

D indicates dummy variables

D_1: 1990–2007 = 1, *other years* = 0; D_2: 2008–2012 = 1;

C: Household final consumption expenditure, Y: GDP.
(Finland: Euro, Million, base year 2000; Singapore: Singapore Dollars, Million, base year 2005; Japan: Yen, Million, base year 2005; USA: US Dollars Million, base year 2005; Germany: Euro Million, base year 2000; UK: Pound Sterling Million, base year 2009).
Figures in parenthesis indicate t-statistics (significant at the *1%, **5%, ***10% level, respectively).
Source: National Accounts Official Country Data (United Nations Statistics Division, annual issues).

Table 12
Marginal propensity to consume in selected 6 countries.

	1990–2007[a]	2008–2012[b]
Finland	0.42	0.23
Singapore	0.32	0.21
Japan	0.59	0.34
USA	0.74	0.64
Germany	0.55	0.44
UK	0.70	0.37

[a] 1990–2006 in US and Germany.
[b] 2007–2012 in US and Germany.

supra-functionality beyond economic value driven preference (McDonagh, 2008 [21]; JCO, 2012 [13]).

Under such circumstances consumers desires have been shifting (i) from economic value to supra-functionality beyond economic value, (ii) from claimers to creators, and (iii) to eco-contribution by own option. Consequently, consumers complaints to producers and also to themselves as being remained consumers have been growing. In parallel with such increase, consumers wish to manufacture by own hand what they anticipate has dramatically increased. Dramatic advancement of the Internet has enabled consumer accumulate more knowledge than producers. Their consumption mode has changed to *AISCEAS*:

Attention → Interest → Search → Comparison →
Examination → Action → Share

Maker movement enabled by digitalization of manufacturing, advancement of 3D printers and laser cutter has accelerated the foregoing change in consumers preference and subsequent consuming style and behavior. New stream of emerging economies also impacting on consumers growing anger by realizing them the beauty of frugality and also suppliers simultaneous start up in new sales. Furthermore, increasing publicity of crowd funding enables consumers start-up for manufacturing by themselves.

Foregoing observation supports a possibility of the emergence of a post-excessive consumption society (Matsuda, 2010 [19], 2012 [20]) in which consumers increasing initiative in innovation game is anticipated (McDonagh, 2008 [21], Watanabe, 2009 [32], Watanabe et al., 2011 [33]). Such an increasing consumers initiative accelerates a shift of their preference from economic functionality to supra-functionality beyond economic value encompassing social, cultural, aspirational, tribal and emotional value (Watson and McDonagh, 2004 [38], McDonagh, 2008 [21], Watanabe, 2009 [32]).

5.2. Harness the vigor of hidden counterparts

Foregoing consumers growing anger can be transformed into a springboard for new innovation in a resilient system (Watanabe, 2009 [32], Ilmola et al., 2013 [12]). This anticipation prompts us a significance of innovation-consumption co-emergence which corresponds to co-evolutionary acclimatization as illustrated in Fig. 11. This concept suggests us to harness the vigor of counterparts, and in this case, hidden counterparts are consumers.

Given a post-excessive consumption society with the foregoing consumers preference shift, their satisfaction can be measured by the following utility function:

$$U = U(\mathrm{FD}) = U(V, Q) \tag{12}$$

where FD: functionality development, V: economic functionality, Q: supra functionality beyond economic value.

Equation (12) can be developed as follows:

$$U = U(V,Q) = \frac{\partial U}{\partial V}\cdot V + \frac{\partial U}{\partial Q}\cdot Q = \frac{\partial U}{\partial C}\cdot\frac{\partial C}{\partial V}\cdot\frac{\partial V}{\partial I}\cdot I\cdot\left(\frac{\partial I}{\partial V}\cdot\frac{V}{I} + \frac{\partial I}{\partial Q}\cdot\frac{Q}{I}\right) \tag{13}$$

Fig. 22 analyzes the structure of utility: satisfaction of consumers in a post-excessive consumption society.

Fig. 22 demonstrates that (i) marginal utility, (ii) marginal propensity to consume, (iii) marginal productivity of ICT, (iv) ICT stock, and (v) elasticity of economic functionality as well as supra-functionality beyond economic value to ICT govern utility in a post-excessive consumption society.

Since marginal utility incorporates declining nature governed by the Law of diminishing marginal utility, Table 13 summarizes trends in other governing factors before and after the emergence of a post-excessive consumption society in Japan.

Looking at the table we note that, with declining marginal propensity to consume and marginal productivity of ICT, while direct economic growth and exogenous ICT increase may decrease utility by decreasing consumption and growth, endogenous ICT emergence induced by the elasticity of supra-functionality to ICT plays a leading role in

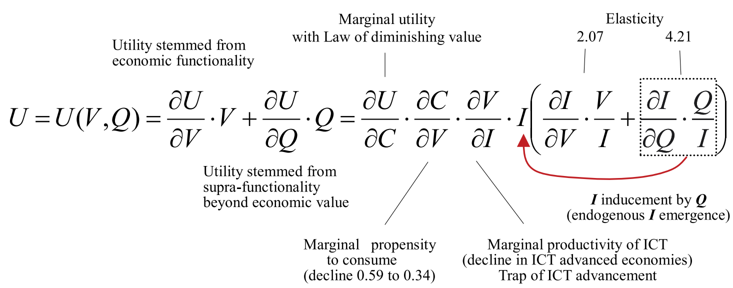


Fig. 22. Structure of utility in a post-excessive consumption society.

Table 13
Comparison of governing factors of utility before and after the emergence of a post-excessive consumption society in Japan.

	1990–2007	2008–2012	
Marginal propensity to consume $\partial C/\partial V$	0.59	0.34	
Marginal productivity of ICT $\partial V/\partial I$	0.025	0.011	Average ICT prices
ICT stock I	7.18	7.77	Average growth rate (% *p.a*)
Economic functionality elasticity $\frac{\partial I}{\partial V}\cdot\frac{V}{I}$	2.06*	2.08**	*1990–2001 **2002–2011
Supra-functionality elasticity $\frac{\partial I}{\partial Q}\cdot\frac{Q}{I}$	4.17	4.24#	#2008–2011

increasing utility notwithstanding such a constrained environment.

Based on the foregoing analyses, Fig. 23 demonstrates dynamism leading to ICT driven resilient development trajectory in overcoming multi-constrained environment with declining marginal propensity to consume and marginal productivity of ICT.

This figure based on the ICT driven production function as depicted in equation (6) analyzes the whole innovation value chain encompassing ICT driven production, diffusion and consumption functions with the understanding that ICT advances proportional to time t, and consumption is subject to utility governed by both economic functionality and supra-functionality beyond economic value.

Triggered by the enhancement of elasticity of supra-functionality to ICT, increased functionality development (FD) induces marginal productivity of ICT increase which contributes to economic growth. Developed economy enables further ICT advancement which increases FD leading to constructing a virtuous cycle between innovation, diffusion and consumption in a way of innovation-consumption co-emergence, and harnessing the vigor of counterparts, "hidden" consumers.

Thus, innovation-consumption co-emergence could lead a resilient business toward a post-excessive consumption society. This co-emergence concept corresponds to a concept of co-evolutionary acclimatization as illustrated in Fig. 11 (Watanabe, 2013 [35]).

6. Conclusion

In light of the significant consequence of the dramatic advancement of information and communication technology (ICT) in global economy both nations and firms that has led to bi-polarization between ICT growing economies and ICT advanced economies and has been compelling productivity decline in ICT advanced economies resulting in the great stagnation, structural sources of the trap of the ICT advancement were analyzed.

Following the empirical analyses of the consequence of the dramatic advancement of ICT in 100 countries as well as 500 global ICT firms, on the basis of an empirical analysis decomposing the prices of ICT in world ICT top leaders, Finland and Singapore, two faces of ICT advancement were identified and their impacts on ICT users were analyzed.

In addition, based on an empirical analysis on customers preference shift from economic functionality to supra-functionality beyond economic value, conflict between captured GDP and un-captured GDP derived from the advancement of the Internet and its consequence of emerging growing anger of consumer was unveiled.

Noteworthy findings include:

(i) Sources of the recent great stagnation in ICT advanced economies both nations and firms can be attributed to a trap of ICT advancement.
(ii) This trap can be attributed to the two-faced nature of ICT advancement incorporating price increases due to functionality development and price decreases due to freebies, easy copying and standardization.

(iii) Two-faced nature of ICT increases discrepancy between captured GDP and un-captured GDP.

(iv) While this can be attributed to a consumer preference shift from economic functionality to supra-

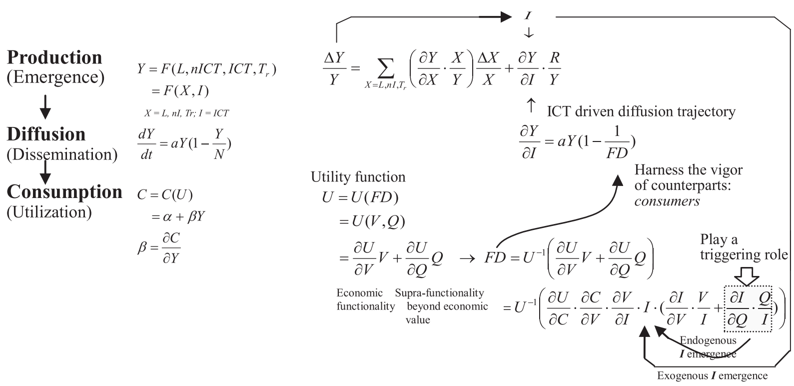


Fig. 23. Dynamism leading to ICT driven resilient development trajectory.

functionality beyond economic value, this shift cannot be captured through GDP.

(v) This conflict has led to an emerging growing anger of consumers demonstrated by declining marginal propensity to consume.

(vi) This anger can be transformed into a springboard for new innovation leading to innovation-consumption co-emergence.

(vii) Enhancing the elasticity of supra-functionality to ICT plays a key role in triggering this co-emergence.

These findings provide the following policy suggestions:

(i) Two-faced nature of ICT, particularly prices decreasing feature of the advancement of the Internet should be seriously taken into account for resilient business.
(ii) Given that freebies, easy copying and standardization are possible sources compelling the prices decrease by depending on the Internet, transferring dynamism of corresponding values should be traced.

(iii) Provided that supra-functionality beyond economic value plays a governing role for consumers, similar transferring dynamism of encompassed values should be traced.

(iv) Relationship between foregoing two noting stream should be analyzed.
(v) ICT's new face elastic enough to supra-functionality beyond economic value should be analyzed.

(vi) In this context, strategy for innovation-consumption co-emergence should be developed on a priority basis.

(vii) While a way to appease consumers growing anger may provide a constructive suggestion to this co-emergence, given that this anger remains intangible, the way to conceptualize voiceless voice of consumers anger should be taken seriously.

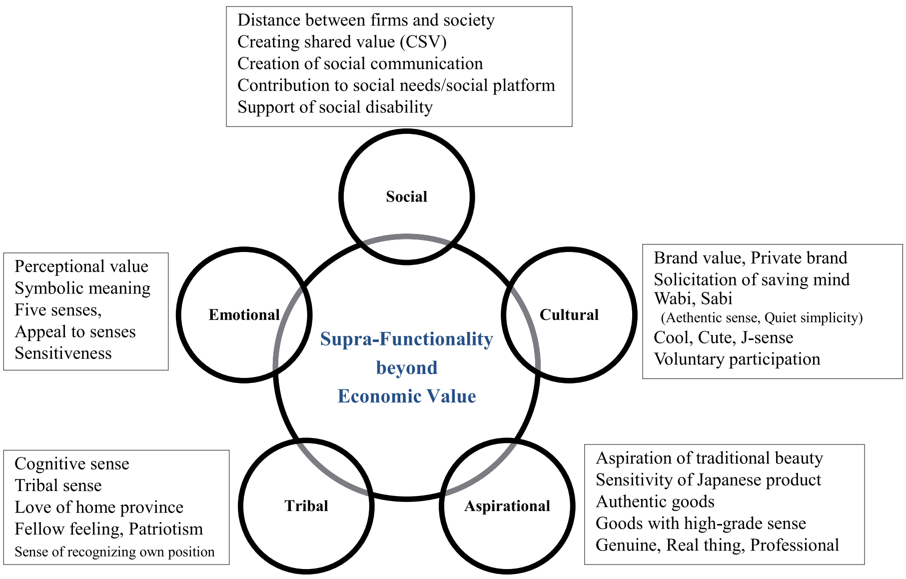
This study is thus expected to explore significant insight in elucidating the institutional sources of the resilience in the transition from the paradigm of captured GDP to that of un-captured GDP.

Points of future works are summarized as follows:

(i) In order to generalize the foregoing findings and policy suggestions, analyses of additional countries are expected to be conducted.
(ii) Comparative analysis of institutional factors governing the ICT prices trajectory and their attributing ICT advancement and dependency on the Internet should be conducted.

(iii) Interdisciplinary approach exploring a way to analyze innovation-consumption co-emergence should be attempted by integrating economics, psychophysiology and engineering.

Appendix 1. Basic concept of supra-functionality beyond economic value



Appendix 2. Public opinion survey concerning people's lifestyles

1. Conducted annually by Japan's Cabinet Office (JCO).
2. Samples of the Survey
   (1) Male and female living Japan with the age between 15 and 80.
   (2) 4000 samples extracted by two-stage stratified random method
3. Survey method

The questionnaires are left with respondents by means of door to door visit and pick up at a later date.

4. Survey period (in case of 2011 Fy survey)

10 days between March 21 and March 30, 2012.

5. Valid samples (in case of 2011 Fy survey)

2802 (valid samples ratio: 70.1%).

References

[1] Brynjolfsson E. Productivity paradox of information technology. Commun Assoc Comput Mach 1993;36(12):66–77.
[2] Brynjolfsson E, Hitt L. Paradox lost? firm-level evidence on the returns to information systems spending. Manag Sci 1996;42:541–58.
[3] Brynjolfsson E, Hitt L. Beyond the productivity paradox: computers are the catalyst for bigger changes. Commun Assoc Comput Mach 1998;41(8):49–55.
[4] Brynjolfsson E, Yang S. The intangible costs and benefits of computer investments: evidence from financial markets, Mimeo. MIT Solon School of Management; Dec 1999.
[5] Brynjolfsson E, McAfee A. Race against the machine: how the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and economy. New York: Digital Frontier Press; 2011.
[6] Chew M, Watanabe C, Tou Y. The challenges in Singapore NEWater development: co-evolutionary development for innovation and Industry evolution. Technol Soc 2011;33(3):200–11.
[7] Cowen T. The great stagnation. New York: Dutton; 2011.
[8] Dedric J, Kraemer K. The productivity paradox: is it resolved? is there a new one? what does it all mean for managers? CRITO Consortium Advisory board Panel: the end of the productivity paradox?. 2001. p. 2–12.
[10] Griliches Z. Hybrid corn an explanation in the economics of technological change. Econometrica 1957;25(4):501–22.
[11] Hofstede G. Cultures and organizations. London: McGraw-Hill International; 1991.
[12] Ilmola L, Casti J. Seven shocks and Finland. Innovation Supply Chain Manag 2013;7(3):112–24.
[13] Japan's Cabinet Office (JCO). National survey of lifestyle preferences. Tokyo: JCO; 2012.
[14] Kenney M. The growth and development of the internet in the United States. In: Cogut B, editor. The global internet economy. Massachusetts: MIT Press; 2003. p. 69–107.
[15] Kraemer KL, Dedrick J. Payoffs from investment in information technology: lessons from the Asia-Pacific Region. World Dev 1994;22(12):1921–31.
[16] Lichtenberg FR. The output contributions of computer equipment and personnel: a firm level analysis. Econ Innovations New Technol 1995;3:201–17.
[17] Lowrey A. Impacts of the great stagnation. New York Times; 2011.
[18] Mansfield E, Wein HH. A model for location of a railroad classification yard. Manag Sci 1958;4(3):292–313.
[19] Matsuda H. Why not buy, how to purchase. Tokyo: Asahi-shimbun; 2010.
[20] Matsuda H. Extricating from stagnation as a consequence of consumption hating. Tokyo: PHP Institute; 2012.
[21] McDonagh D. Satisfying needs beyond the functional: the changing needs of the silver market consumer. In: Proceedings of the international Symposium on the Silver market Phenomenon – business opportunities and Responsibilities in the aging society, Tokyo; 2008.
[22] McKinsey Global Institute. Internet matters: the net's sweeping impact on growth, jobs, and prosperity. New York: Mckinsey; 2011.
[23] Ministry of Internal Affairs and Communication (MIC). White paper on Japan's information and communication technology. Tokyo: MIC; 2012.
[24] Modigliami T. Life cycle hypothesis of savings, the demand for wealth and supply of capital. In: A paper Presented to the Rome Congress of Econometric society; 1965.
[25] Ogden T. The race vs. the stagnation. Stanford Social Innovation Rev 2012;(Spring).
[26] Rifkin J. The third industrial revolution: how lateral power is transforming Energy, the economy, and the world. New York: Palgrave Millan; 2011.
[27] Solow R. We'd better watch out: the myth of the post-industrial economy. N.Y Times Book Rev 1987;36.
[28] Tokumasu S, Watanabe C. Institutional structure leading to the similarity and disparity in innovation inducement in EU 15 countries. J Serv Res 2008;8(1):5–42.
[29] Triplett JE. The solow productivity paradox: what do computers do productivity. Can J Econ 1999;32(2):309–34.
[30] UNDP. Human development report 2007/2008. New York: United Nations Development Program; 2007.
[31] Watanabe C, Zhu B, Miyazawa T. Hierarchical impacts of the length of technology waves: an analysis of technolabor homeostasis. Technol Forecast Soc Change 2001;68(1):81–104.
[32] Watanabe C. Managing innovation in Japan: the role institutions play in helping or hindering how companies develop technology. Berlin: Springer; 2009.
[33] Watanabe C, Nasuno M, Shin JH. Utmost gratification of consumption by means of supra-functionality leads a way to overcoming global economic stagnation. J Serv Res 2011;11(2):31–58.
[34] Watanabe C, Kanno G, Tou Y. Inside the learning dynamism inducing the resonance between innovation and high-demand consumption: a case of Japan's high-functional mobile phones. Technol Forecast Soc Change 2012;79(7):1292–311.
[35] Watanabe C. Innovation-consumption co-emergence leads a resilience business. Innovation Supply Chain Manag 2013;7(3):92–104.
[36] Watanabe C, Naveed K, Zhao W. Institutional sources of resilience in global ICT leaders – harness the vigor of emerging power. J Technol Manag Grow Econ 2014a;5(1):7–34.
[37] Watanabe C, Naveed K, Zhao W. Structural source of the trap of ICT advancement: lessons from world ICT top leaders. J Technol Manag Grow Econ 2014b;5(2) [in print].
[38] Watson B, McDonagh D. Supra-functionality: responding to users needs beyond the functional. Eng Des 2004;30(5):8–11.
[39] World Economic Forum (WEF). The global information technology report 2012. Geneva: WEF; 2012.
[40] World Economic Forum (WEF). The global information technology report 2013. Geneva: WEF; 2013.
[41] Zhao W, Watanabe C, Tou Y. Co-emergence of institutional innovation navigates the new normal in growing economies. J Technol Manag Grow Econ 2013;4(1):69–81.
[42] Zhao W, Watanabe C, Griffy-Brown C. An exploration of competitive advantage in industry cluster within local institutional systems: the case of dalian software park in China. Technol Soc 2009;31(2):139–49.

Chihiro Watanabe graduated from University of Tokyo and is currently Professor Emeritus of Tokyo Institute of Technology, Visiting Professor of National University of Singapore, Visiting Professor of University of Jyväskylä, Finland and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com)

Kashif Naveed graduated with Bachelor's in Computer Science from Hamdard University Karachi, Pakistan, with Master's of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing Ph.D. in Economics and Business Administration from the University of Jyväskylä, Finland. (kanaveed@student.jyu.fi)

Weilin Zhao graduated from Dalian Maritime University, China with Bachelor's, Tokyo Institute of Technology with Master's and received Ph.D. from the same university. She is currently a Senior Associate of Economic Research Center, Fujitsu Research Institute, Tokyo. (zhao.weilin@jp.fujitsu.com)

PIV

DEPENDENCY ON UNCAPTURED GDP AS A SOURCE OF RESILIENCE BEYOND ECONOMIC VALUE IN COUNTRIES WITH ADVANCED ICT INFRASTRUCTURE: SIMILARITIES AND DISPARITIES BETWEEN FINLAND AND SINGAPORE

by

Chihiro Watanabe, Kashif Naveed and Pekka Neittaanmäki, 2015

Technology in Society, vol. 42, pp. 104-122

Technology in Society 42 (2015) 104–122

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore

Chihiro Watanabe [a, b, c, *], Kashif Naveed [b], Pekka Neittaanmäki [b]

[a] National University of Singapore, Singapore
[b] University of Jyväskylä, Finland
[c] International Institute for Applied Systems Analysis (IIASA), Austria

ARTICLE INFO

Article history:
Received 12 January 2015
Received in revised form 27 March 2015
Accepted 17 April 2015
Available online 22 May 2015

Keywords:
Trap in ICT advancement
Finland and Singapore as world ICT leader
Resilience beyond economic value
Un-captured GDP
Growth or happiness

ABSTRACT

The majority of countries with advanced information and communication technology (ICT) infrastructure have been experiencing extended stagnation due to an “embedded” trap in ICT advancement. However, certain countries have been able to sustain a high level of ICT-driven global competitiveness. This suggests that in these contexts there is resilience beyond economic value. Finland and Singapore can be considered countries of resilience with respect to ICT-driven global competitiveness because of their continued GDP growth despite the recession. While both countries share significant similarities including institutional strength in ICT, they demonstrate noteworthy disparities in their development trajectories: Singapore is growth-oriented based on captured GDP while Finland seeks happiness by shifting to un-captured GDP. This contrast can be attributed to their distinct co-evolution with their institutional systems characterized by government/business initiatives in ICT usage for economic efficiency and differences in the new economic index referred to as “happiness seeking”. Given the increasing significance of un-captured GDP derived from the dramatic advancement of the Internet, this paper, will use a comparative analysis of ICT-driven development trajectories in six leading countries in the field over the last two decades. This analysis reveals the different option for maintaining economic resilience. A new method for measuring un-captured GDP was developed to assess the consequences and state of un-captured GDP in six countries. Institutional sources leading to this state were analyzed and a source of resilience beyond economic value was conceptualized and articulated.

1. Introduction

The majority of advanced information and communication technology (ICT) countries have been experiencing extended stagnation (“great stagnation” (Cowen, 2011 [2])) as demonstrated by their low GDP growth from the middle of the first decade of this century which is illustrated in Fig. 1. (See annual growth rate in Appendix 1). Singapore is an exceptional case in this regard.

Part of the stagnation itself can be attributed to a “trap” in ICT advancement[1] derived from the two-faced nature of ICT, that is, while advancement of ICT generally contributes

* Corresponding author. 2-4-2 Kitasenzoku Ota-ku, Tokyo 145-0062, Japan. Tel.: +81 3 6426 2577.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] Against anticipation, excessive advancement of ICT results in its marginal productivity decline due to its prices decrease derived from its two-faced nature.

http://dx.doi.org/10.1016/j.techsoc.2015.04.003
0160-791X/

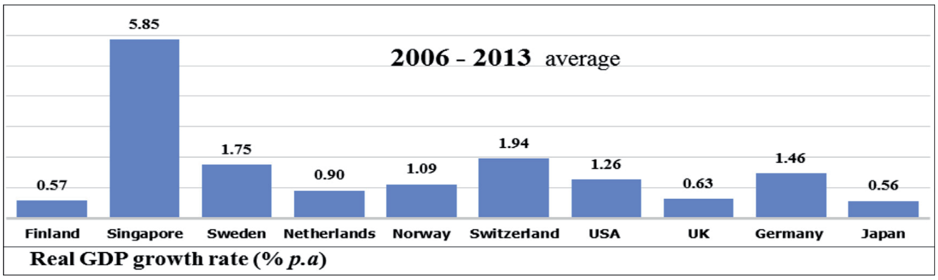


Fig. 1. Stagnation in economic growth in ICT advanced countries (2006–2013).
Source: World Economic Outlook Database (IMF, annual issues) [4].

Table 1
World ICT ranking top 5 countries (2011–2013).

ICT ranking	1	2	3	4	5
2013	Finland (3)	Singapore (2)	Sweden (6)	Netherlands (8)	Norway (11)
2012	Finland (3)	Singapore (2)	Sweden (4)	Netherlands (5)	Norway (11)
2011	Sweden (3)	Singapore (2)	Finland (4)	Denmark (8)	Switzerland (1)

Figures in parenthesis indicate global competitive ranking as tabulated in Table 2.
Sources: The Global Information Technology Report 2012, 2013, 2014 (World Economic Forum (WEF), 2012, 2013, 2014). The Global Competitiveness Report 2011–2012, 2012–2013, 2013–2014 (WEF, 2012, 2013, 2014).

to enhanced prices of technology by new functionality development, the dramatic advancement of the Internet reacts to decreased prices of technology due to its nature of "freebies", "easy copying" and mass standardization (Cowen, 2011 [2], Watanabe et al., 2014*b* [26], 2014*c* [27]).

Contrary to these circumstances, certain countries have been able to sustain a high level of ICT-driven global competitiveness, which suggests their resilience beyond purely economic value. Finland and Singapore can be considered resilient countries with respect to ICT driven global competitiveness as they have been maintaining the top level in the world rankings in ICT and also economic competitiveness as demonstrated in Tables 1 and 2 (WEF, 2014*a* [31], 2014*b* [32]).

Looking at Tables 1 and 2 we note that Finland and Singapore share the world's top ICT position both in 2012 and 2013, and also accomplishing a top global competitiveness position after Switzerland (Yusuf and Nabeshima, 2012 [33], WEF, 2013*a* [29], 2013*b* [30] 2014*a* [31], 2014*b* [32]).

Inspired by these conspicuous accomplishments in ICT-driven competence, Table 3 compares institutional factors governing competence in these ICT advanced six countries.

Table 3 demonstrates the conspicuous accomplishments of Finland and Singapore in global competitiveness, ICT competitiveness, human capital and quality of education with a similar size of population. However, if we look at the table carefully, we note that, in addition to these similarities, there are explicit disparities between the two countries. While Singapore demonstrates excellent economic performance such as a high GDP growth rate, low unemployment ratio and higher income level, and it is one of the advanced ICT countries, it remains far behind the "happiness and welfare" level as characterized by low inequality, high birth rate and happiness ranking[2] compared to Finland which demonstrates the highestlevels in these indicators compared to the other five countries compared.

This disparity reflects a number of factors including consumer behavior in their buying decision process and factors determining consumers choice in these two countries often characterized by the significant effects of national institutional systems (e.g., Hofstede, 1991 [3], Pieters et al., 1995 [16], Watanabe, 2009 [23]). For example, Internet merchants (Jarvenpaa et al., 2000 [8]). Rintamaki et al. (2006 [19]) have unveiled softer aspects of shopping, particularly such that the social dimension is decisive for consumers' shopping decisions in Finland's department stores. There is a similar tendency in Finland in the attitude formation towards online banking (Karjaluoto et al., 2002 [10]) and in factors affecting consumer choice for mobile phones (Karjaluoto et al., 2005 [9]). In contrast to these structures in Finland, Singaporean consumers generally pay attention to more pragmatic dimensions, such as price, content of products, transaction security and vendor quality, as demonstrated by Liao et al. (2001 [11]) in their survey

[2] Happiness ranking compares the degree of happiness in 156 countries taking following 7 factors: Happiness explained by levels of (i) GDP per capita, (ii) social support, (iii) healthy life expectancy, (iv) freedom to make, (v) generosity, (vi) perceptions of corruption, and (vii) influenced by the levels and trends of income inequality within the country and also between countries in the region.

Table 2
World competitiveness top 20 countries (2013).

1 Switzerland (1)	6 Sweden (4)	11 Norway (15)	16 Austria (16)
2 Singapore (2)	7 Hong Kong (9)	12 Taiwan (13)	17 Belgium (17)
3 Finland (3)	8 Netherlands (5)	13 Qatar (11)	18 New Zealand (23)
4 Germany (6)	9 Japan (10)	14 Canada (14)	19 United Arab Emirates (24)
5 United States (7)	10 United Kingdom (8)	15 Denmark (12)	20 Saudi Arabia (18)

Figures in parenthesis indicate the ranking in 2012.
Sources: The global competitiveness report 2012–2013, 2013–2014 (WEF, 2013, 2014).

Table 3
Comparison of factors governing competence in ICT advanced 6 countries (2013).

		Finland	Singapore	USA	UK	Germany	Japan	References
Population (million)		5.5	5.4	316.4	64.1	80.8	127.3	The Global Competitiveness Report 2014-2015 (World Economic Forum (WEF), 2014).
Global competitiveness (Rank out of 148)		(4) 3 [3]	(2) 2 [2]	(3) 5 [7]	(9) 10 [8]	(5) 4 [6]	(6) 9 [10]	*idem* ( ), [ ] indicate world ranking in 2014 and 2012
ICT competitiveness (Rank out of 148)		1 [1]	2 [2]	7 [9]	9 [7]	12 [13]	16 [21]	The Global Information Technology Report 2014 (WEF, 2014). See Table 6 [ ] indicates world ranking in 2012.
Global innovation (Rank out of 142)		4	7	6	2	13	21	The Global Innovation Index 2014 (INSEAD et al., 2014).
Human capital (Rank out of 122)		2	3	16	8	6	15	World ranking in 2012 The Human Capital Report (WEF, 2013).
Education (Rank out of 142)	Quality of primary edu.	1	3	41	31	25	21	The Global Competitiveness Report 2013-2014 (World Economic Forum (WEF), 2013).
	Quality of the edu system.	2	3	25	26	14	50	*idem*
	Quality of Math/Science edu.	2	1	49	50	21	34	*idem*
GDP per capita (1000 US$)		47.1 [14]	54.8 [8]	53.1 [9]	39.6 [23]	45.0 [18]	38.5 [24]	The Global Competitiveness Report 2014-2015 (World Economic Forum (WEF), 2014). [ ] indicates world ranking
GDP growth rate 2006-2013 (% p.a at fixed price)		0.57	5.85	1.26	0.63	1.46	0.56	World Economic Outlook Database (IMF, annual issues).
Unemployment ratio (%)		8.14	1.90	9.03	7.85	6.53	4.70	World Development Indicators (World Bank, 2014).
Inequality (GINI index)		19	45	47	39	35	34	2010 rank . Distribution of Household Income by Source (ILO, 2012)
Birth rate		1.9	1.2	2.1	1.9	1.4	1.4	2011 rank. World Health Statistics 2013 (WHO, 2013)
Happiness (Rank out of 156)		7	30	17	22	26	43	State in 2010-2012. World Happiness Report 2013 (The Earth Institute, Columbia Univ. et al., 2013).

on consumer attitudes to Internet-based e-shopping in Singapore.

These contrasting features in these two global ICT leaders with significant similarities, sheds light on possible development trajectory options amidst the "trap" embedded in ICT advancement: "happiness amidst great stagnation" as in Finland or excellent economic performance" rather than high levels of "happiness" as identified by this unique "happiness" index.

Advances in ICT can largely be attributed to the dramatic advancement of the Internet (McKinsey Global Institute, 2011 [14], ITU, 2013 [5], Watanabe et al., 2014*a* [25]), which has changed the computer-initiated ICT world significantly. Many authors pointed out the significance of the increasing role of un-captured GDP[3] by referring to Lowrey's postulate that "*th*e Internet promotes a free culture, the consumption of which provides utility and happiness to people but cannot be captured through GDP data that measure revenue" (Lowrey, 2011 [12]) and unveiled the increasing conflict between captured GDP and un-captured GDP leading to growing anger and frustration among consumers (Watanabe et al., 2014*c* [27]). This can be the one source of great stagnation on the demand side and provides insight by indicating the options many countries have been choosing in terms of their development trajectory: happiness amidst the great stagnation or excellent economic performance rather than high level of happiness (Rifkin, 2011 [17], Rifkin, 2014 [18]).

To date, quite few studies have been conducted to advance our understanding of the development trajectories of the nations (e.g., UNDP, 2007 [22], Ministry of Employment and the Economy, Finland, 2010 [15]). However, none have specifically analyzed the significance of these two trajectory options in the context of the ICT "trap" resulting from the dramatic advancement of the Internet and subsequent increasing shift from captured GDP to un-captured GDP.

Given the increasing significance of un-captured GDP because of the dramatic advancement of the Internet, this paper attempted to illustrate a new trajectory towards economic resilience which goes beyond purely economic value. Based on the comparative empirical analysis of ICT

[3] Un-captured GDP can be defined as added values providing utility (satisfaction of consumption) and happiness beyond economic value to people but cannot be measured by traditional GDP accounts (captured-GDP) that measure economic value. Supra-functionality beyond economic value (see below) can be the typical example.

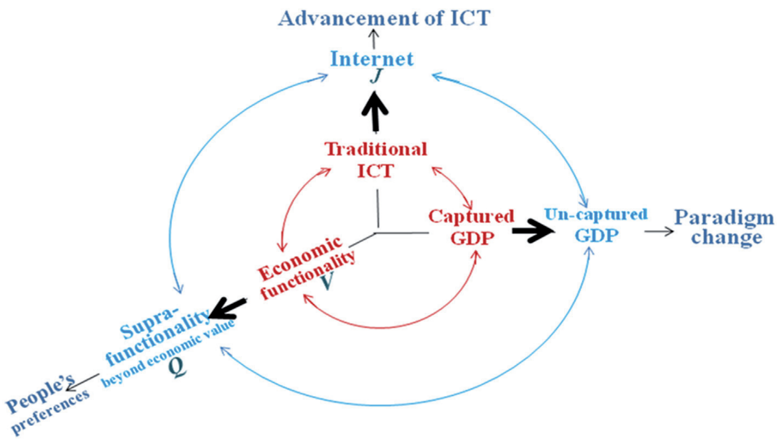


Fig. 2. Co-evolution between the internet, un-captured GDP and supra-functionality.

driven developing trajectories in six leading countries over the last two decades, particularly world ICT leaders, Finland and Singapore, we focus on understanding the factors and dynamics which position countries to be resilient. We analyzed performance in order to restructure a virtuous cycle between consumption and GDP increase in a co-evolutionary[4] and dynamic process between the dramatic advancement of the Internet, increasing shifts to un-captured GDP and consumer preference to supra-functionality beyond economic value[5] was analyzed.

Section 2 reviews the sources of the ICT advancement "trap" from the demand side. Section 3 compares the two countries performance toward a possible reconstruction of a virtuous cycle between consumption and GDP increase. Section 4 assesses the significance of dependency on un-captured GDP. Section 5 analyzes the institutional sources of "competence". Finally, section 6 briefly summarizes noteworthy findings, policy implications and also for the next steps in future studies.

2. Sources of the ICT advancement "trap" from the demand side

2.1. Co-evolution between the internet, un-captured GDP and supra-functionality

The advancement of the Internet accelerates a shift from captured GDP to un-captured GDP. While the Internet promotes a free culture, the consumption of which enhances utility (satisfaction of consumption) this cannot be captured through GDP that measures revenue (Lowrey, 2011 [12], Rifkin, 2014 [18]).

Table 4
Marginal propensity to Consume[6] in 6 countries before and after the Lehman Shock in 2008.

	1990–2007[a]	2008–2012[b]
Finland	0.42	0.23
Singapore	0.32	0.21
USA	0.74	0.64
UK	0.70	0.37
Germany	0.55	0.44
Japan	0.59	0.34

[a] 1990–2006 in USA and Germany.
[b] 2007–2012 in USA and Germany.
Original sources: Household Final Consumption Expenditure (United Nations Statistics Division, annual issues).

In line with the general shift from a commodity-oriented society to a service and information-oriented society, consumer preference has been steadily shifting from an economic functionality driven preference (which can be captured by GDP) to what we term "supra-functionality" beyond economic value (JCO, 2012 [7], Watanabe et al., 2014*c* [27]). Here, supra-functionality beyond economic value encompasses social, cultural, aspirational, tribal and emotional values which are not necessarily captured by GDP (Watson and McDonagh, 2004 [28], McDonagh, 2008 [13], Watanabe et al., 2011 [24]).

This shift in consumer preference induces the advancement of the Internet, which in turn accelerates a consumer preference shift. Thus, advancement of the Internet, shifts to un-captured GDP and consumer preference shifts to supra-functionality proceed co-evolutionary as illustrated in Fig. 2 (Watanabe et al., 2014*c* [27]).

[4] Co-evolution implies mutually inspiring virtuous cycle.

[5] Supra-functionality beyond economic value encompasses social (e.g., creation of and contribution to social communication), cultural (e.g., brand value, cool and cute), aspirational (e.g., aspiration of traditional beauty), tribal (e.g., cognitive sense, fellow feeling) and emotional (e.g., perceptional value, five senses) values (see detailed structure Watanabe et al., 2014*c* [27]).

[6] An increase in consumption caused by an addition to income divided by that increase in income, and depicted by coefficient b in the following consumption function: $C = a + bY$, $b = \Delta C/\Delta Y$ where Y: GDP (income) and a: base consumption.

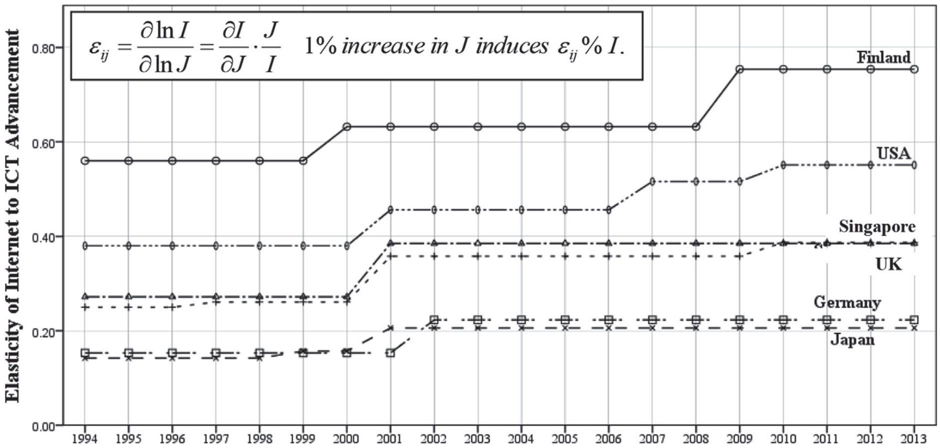


Fig. 3. Trends in the elasticity of the internet to ICT advancement (1994–2013).

2.2. Conflict between captured GDP and un-captured GDP

Under this co-evolutionary dynamism, conflict emerges between captured GDP and un-captured GDP during this shift. This conflict leads to growing anger and frustration among consumers resulting in the decline of consumption as demonstrated in Table 4 (Watanabe et al., 2014*c* [27]). This can be considered one source of the great stagnation from demand side.

3. Reconstruction of a virtuous cycle between consumption and GDP increase

3.1. Utility enhancement against consumption decline

During the great stagnation due to this "Trap" or conflict in ICT advancement derived from the two-faced nature of ICT on the supply side and also from the emerging conflict between captured GDP and un-captured GDP in demand side. From an economic perspective, the only possible option for sustainable growth comes from enhancing utility (satisfaction of consumption) through the Internet inducement of ICT stock. Therefore, theoretically, the virtuous cycle between consumption and GDP increase can be reconstructed by this enhancement (Watanabe et al., 2014*c* [27]. See Appendix 2):

$$J \to I \to U \to C \to GDP \to C$$

where J: Internet, I: ICT stock, U: utility, and C: consumption.

3.2. Performance toward reconstruction

Thus, our concern goes toward analyzing how well ICT leaders are doing in developing this type of reconstruction. An empirical comparative analysis of the performance of six countries on this cycle over the last two decades was conducted by utilizing the following data:

Internet dependency: ITU, world telecommunication/ICT indicators database[7] (ITU, 2014) [6].
ICT stock: Author's estimate with reference of The Conference Board, total economy database™, http://www.conferenceboard.org/data/economydatabase/ [20].
Household consumption: UN Statistics Division, Household Final Consumption Expenditure (UN, 2014) [21].
GDP: IMF, World Economic Database (IMF, 2014) [4].

3.2.1. Elasticity of the internet to ICT advancement

Performance toward the reconstruction is triggered by the efficiency of the Internet (J) inducement of ICT stock (I) and this can be assessed by the elasticity of the Internet to ICT stock[8] which represents the efficiency of the Internet in inducing ICT stock and can be quantified by computing the ratio of the percent change between them. This elasticity was computed using the significant correlation between J and I (see equations (A7) and (A8) in Appendix 3.1). Computation results are compared in Fig. 3 (see details Table A2 in Appendix 3.1).

Looking at Fig. 3, we note Finland which maintains world's top ICT position demonstrates a conspicuously high elasticity of the Internet to ICT stock increase and provides strong promising trend of increasing consumption and the reconstruction of a virtuous cycle between consumption and GDP increase. The USA follows Finland, and Singapore at the 3rd level in terms of this elasticity.

[7] ITU measures percent of population using the Internet based on the HH7 national questionnaire "*Have you used the Internet from any location in the last 3 (previously 12) months?*" (see details Appendix 6).

[8] Elasticity is the measurement of how responsive an economic variable (X) to a change in another (W). Elasticity of X to W (X elasticity to W) ε_{wx} implies 1% increase in X increases ε_{wx}% increase in W and represents the efficiency of X inducement of W.

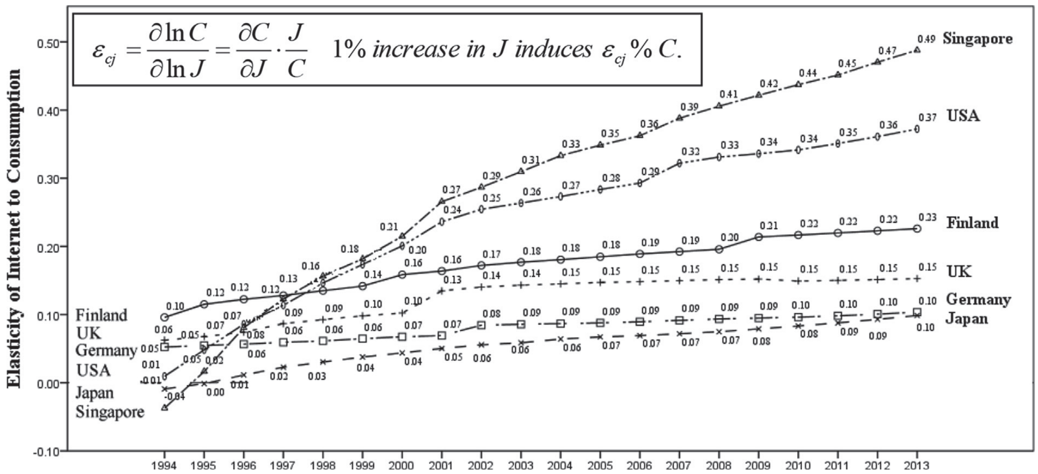


Fig. 4. Trends in the Elasticity of the Internet to Consumption (1994–2013). 2013 are estimated by trend.

3.2.2. Elasticity of the internet to consumption

Next, efficiency of the Internet in inducing consumption was assessed by a similar mathematical approach by measuring the elasticity of the Internet (J) to consumption (C). This elasticity was computed by means of a consumption function governed by I and J (see equations (A10) [9] and (A11) in Appendix 3.2). The results are compared in Fig. 4 (see details Table A3 in Appendix 3.2).

Looking at Fig. 4 we note that while the majority of advanced ICT countries have been shifting to stabilize their elasticity of the Internet to consumption, Singapore continues to increase its elasticity successively leading to a conspicuously higher level than the other countries compared. This conspicuous level is similar to its exceptionally higher GDP growth rate as reviewed in Fig. 1 and suggests us certain causality between them (see Appendix 4).

In contrast, Finland's elasticity of the Internet to consumption is much lower than Singapore which follows Finland in terms of its position as one of the world ICT leaders.

These contrasting observations prompt us to consider the hypothetical view that there might be certain fundamental disparities between Singapore and other ICT advanced countries, headed by Finland, with respect to measurement of consumption value.

Given the increasing co-evolution between the advancement of the Internet, un-captured GDP increase and a consumer preference shift to supra-functionality as defined in Section 2, this hypothetical view prompts us to further consider that, against traditional theory, utility under great stagnation does not necessarily reflect consumption in certain ICT advanced countries as a consequence of the increase in un-captured GDP. This can be plausible by given consumer preference shifts to supra-functionality beyond economic value (JCO, 2012 [7]) which are not necessarily captured by GDP (Watson and McDonagh, 2004 [28], McDonagh, 2008 [13]).

In order to test and demonstrate this hypothetical view, with the understanding that elasticity of utility to consumption demonstrates the extent of reflection of utility to consumption, we attempted to measure this elasticity that corresponds to less dependency on un-captured GDP.

4. Dependency on un-captured GDP

As reviewed in the preceding Section, under the ICT driven economy, utility consists of not only the value from economic functionality but also this new measure referred to as "supra-functionality beyond economic value". Furthermore, under the great stagnation both are governed by ICT stock (I) and Internet dependency (J). Based on these observations, a new method in measuring elasticity of utility to consumption (based on the extent of the reflection of utility to consumption corresponding to less dependency on un-captured GDP) was developed with the finding that, under such circumstances, this elasticity can be transformed into a total sum of elasticity of ICT to consumption and elasticity of the Internet to consumption (see Appendix 5). Since both elasticities can be estimated by the preceding estimates in Figs. 3 and 4, the elasticity of utility to consumption in six countries over the period 1994–2013 was measured by using these estimates (see equation (A15) in Appendix 5) as demonstrated in Fig. 5. The vertical axis of Fig. 5 indicates the elasticity of utility to consumption and demonstrates the extent of the reflection of utility to consumption which corresponds to the degree of captured GDP.

Looking at this Figure we note that while Finland demonstrates the most advanced un-captured GDP as demonstrated by the lowest level of elasticity of utility to

[9] While almost all factors in 6 countries examined demonstrate significant at the 1–10% level,Singapore's ICT and Germany's Internet demonstrate significant at the 15% and 30% level, respectively.

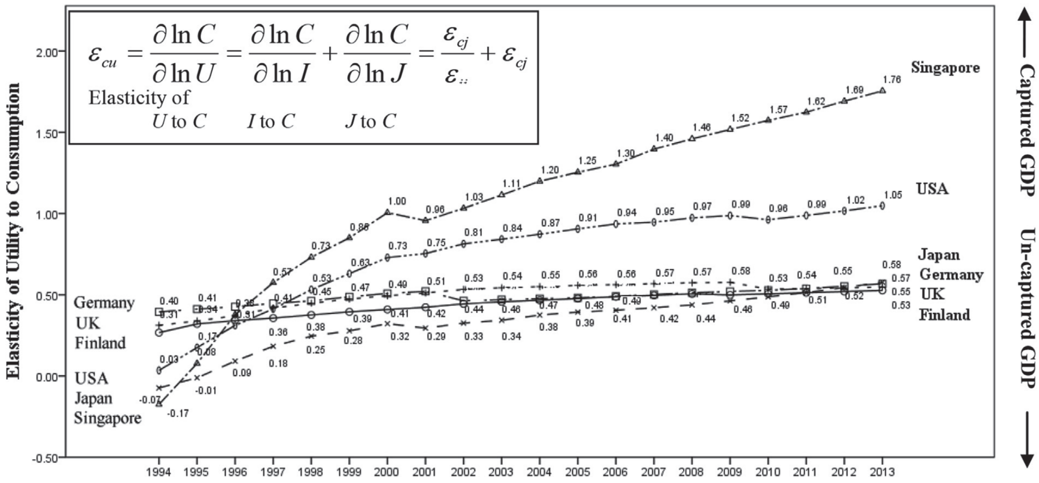


Fig. 5. Trends in elasticity of utility to consumption in 6 countries (1994–2013).

Table 5
Elasticity of utility to consumption in 6 countries in 2013.

	Finland	Singapore	USA	UK	Germany	Japan
Efficiency of J inducement of I 1. J elasticity to I (ε_{ij}) (Fig. 3)	0.75	0.39	0.55	0.39	0.22	0.21
Efficiency of J inducement of C 2. J elasticity to C (ε_{cj}) (Fig. 4)	**0.23**	**0.49**	**0.37**	**0.15**	**0.10**	**0.10**
Efficiency of I inducement of C 3. I elasticity to C ($\varepsilon_{ci} = \varepsilon_{cj}/\varepsilon_{ij}$) (2/1)	**0.30**	**1.27**	**0.68**	**0.40**	**0.47**	**0.48**
Extent of reflection of U to C 4. U elasticity to C (ε_{cu}) (2 + 3)	**0.53**	**1.76**	**1.05**	**0.55**	**0.57**	**0.58**

J: Internet, I: ICT stock, C: consumption, and U: utility. The bold figures in table refers to the figures used in Fig. 6.

consumption, it, together with Germany[10] and the UK, depended most highly on captured GDP among the six countries compared in the early half of the 1990s. This shifted steadily to un-captured GDP dependent nation leading to what some scholars have referred to as “happiness beyond economic value” during the great stagnation by means of captured GDP.

In contrast, Singapore, which remained at a lower income level than the other 5 countries in the early 1990s, was unable to efficiently capture GDP during this era and demonstrated the lowest level of elasticity of utility to consumption. However, it continued to rapidly increase in captured GDP leading to current conspicuously high captured GDP level and demonstrates a growth oriented economy, and high economic performance rather than this focus on uncaptured GDP or what is referred to as elements beyond “economic value” or “happiness”.

These observations demonstrate a contrast in dependency on captured GDP and un-captured GDP, Table 5. Fig. 6 compares the current state of elasticity of utility to consumption and its attributes in the six countries studied.

Looking at Table 5 we note that contrary to the lower level of the Internet elasticity to ICT (ε_{ii}), Singapore demonstrates the highest utility elasticity to consumption (ε_{cu}). This can be attributed to conspicuously high elasticity of ICT to consumption (ε_{ci}) derived from high elasticity of the Internet to consumption (ε_{ci}) despite the low level of the Internet elasticity to ICT (ε_{ii}). In contrast, Finland's highest Internet elasticity to ICT (ε_{ii}) reacts to the decrease of ICT elasticity to consumption (ε_{ci}). We suggest that this implies its ICT advancement induced by the Internet contributes in some-way to the supra-functionality beyond economic value rather than to purely economic value. Furthermore, this measure does not reflect consumption captured by GDP data, thus demonstrating this shift from captured GDP to un-captured GDP increases as ICT advances.

Fig. 6 demonstrates noting contrast between world ICT leaders, Finland and Singapore in this elasticity. While Singapore demonstrates conspicuously high elasticity, Finland demonstrates opposite, the lowest level among six countries compared.

[10] It should be noted that time series analysis of German's Internet inducement of consumption over the period 1994–2013 (Table A3) demonstrates significant at the 30% level due to inconsistency of statisticaldata in the early 1990s immediately after its integration in 1990.

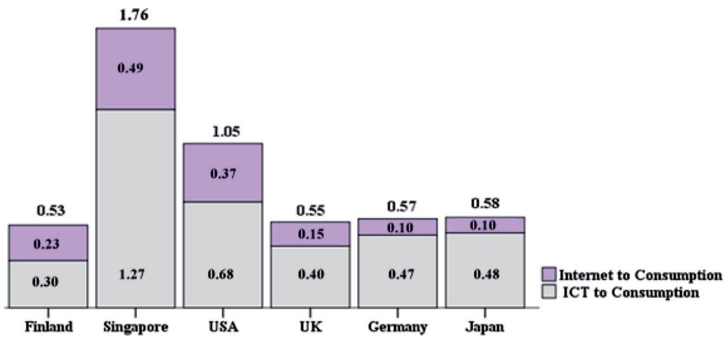


Fig. 6. Elasticity of utility to consumption in 6 countries in 2013.

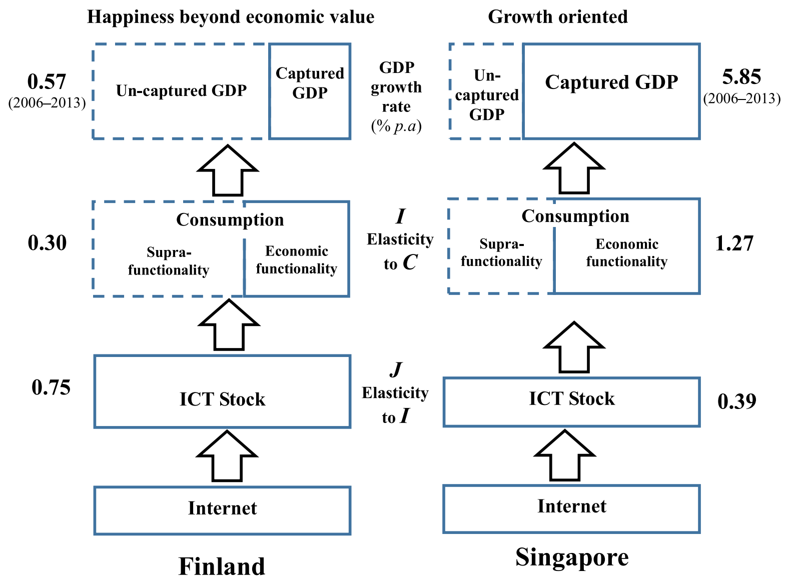


Fig. 7. Contrasting Development Trajectory in World ICT Leaders, Finland and Singapore (2013). *J*: Internet, *I*: ICT stock, *C*: Consumption. GDP growth rate is an average between 2006 and 2013.

With this observation in mind, Fig. 7 illustrates a contrast between the development trajectories in these world ICT leaders. This Figure clearly demonstrates a contrast between Finland and Singapore with respect to development trajectory. Finland effectively utilizes the Internet in inducing ICT stock as demonstrated by its highest Internet elasticity to ICT stock (Fig. 3). Its induced ICT stock contributes significantly to satisfying consumer preference to supra-functionality beyond economic value rather than just economic functionality. Consequently, increased ICT does not reflect a consumption increase which is measured by the GDP value resulting in a lower GDP growth rate. While its ICT makes a significant contribution to supra-functionality beyond economic value, it cannot necessarily be captured by GDP.

Contrary to Finland's behavior, while Singapore's ICT inducement by the Internet is smaller than Finland, it contributes largely to the consumer preference for economic functionality which is captured by GDP value leading to a the high GDP growth rate (5.85% in Singapore vs 0.57% in Finland in average 2006–2013) as observed in the very beginning of this paper (Fig. 1).

5. Institutional sources

5.1. Governing factors for ICT competitiveness

In order to better explain these contrasting trajectories in world ICT leaders, institutional sources leading to this contrast were analyzed. First, on the basis of the

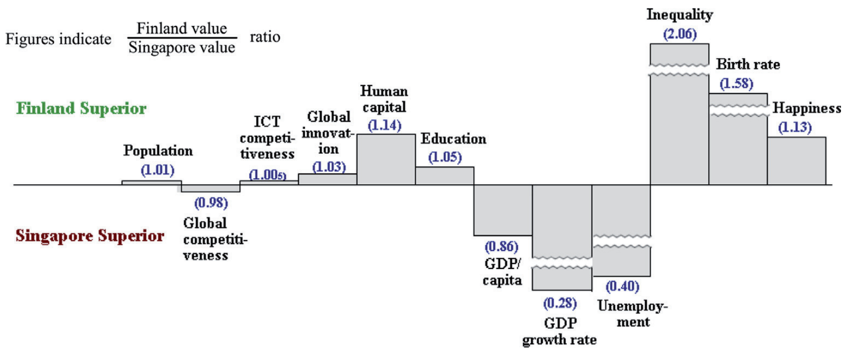


Fig. 8. Comparison of Factors Governing Competitiveness between Finland and Singapore. 1. Ratios of above factors are based on the respective values used for ranking. 2. Education is the average of 3 factors in Table 3. 3. GDP growth rate, unemployment and imbalance are ratios of deviation between average values of six countries.
Sources: See references in Table 3.

Table 6
ICT level by networked readiness index in 6 countries (2013).

	Finland		Singapore		USA		UK		Germany		Japan	
	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)
Networked readiness (NRI) index 2014	**1**	***6.0***	**2**	***6.0***	**7**	***5.6***	**9**	***5.5***	**12**	***5.5***	**16**	***5.4***
A. Environment subindex	**3**	***5.6***	**1**	***5.9***	**15**	***5.2***	**5**	***5.5***	**17**	***5.1***	**21**	***5.0***
1st pillar: Political and regulatory environment	3	*5.9*	1	*5.9*	22	*5.0*	5	*5.7*	10	*5.4*	16	*5.2*
2nd pillar: Business and innovation environment	9	*5.4*	1	*5.8*	7	*5.4*	10	*5.3*	31	*4.9*	40	*4.8*
B. Readiness subindex	**1**	***6.6***	**6**	***6.2***	**5**	***6.3***	**21**	***5.7***	**8**	***6.2***	**19**	***5.8***
3rd pillar: Infrastructure and digital content	1	*6.9*	16	*6.3*	4	*6.8*	15	*6.4*	11	*6.5*	21	*6.1*
4th pillar: Affordability	18	*6.4*	46	*5.9*	21	*6.4*	79	*5.2*	43	*5.9*	54	*5.7*
5th pillar: Skills	1	*6.5*	2	*6.4*	32	*5.6*	28	*5.7*	12	*6.0*	29	*5.7*
C. Usage subindex	**2**	***6.0***	**4**	***5.9***	**11**	***5.6***	**12**	***5.6***	**13**	***5.5***	**9**	***5.7***
6th pillar: Individual usage	6	*6.4*	10	*6.1*	18	*5.8*	8	*6.3*	19	*5.7*	16	*5.9*
7th pillar: Business usage	2	*6.0*	15	*5.2*	9	*5.6*	17	*5.1*	5	*5.8*	4	*6.0*
8th pillar: Government usage	8	*5.6*	1	*6.3*	11	*5.5*	17	*5.4*	27	*5.0*	22	*5.2*
D. Impact subindex	**2**	***5.9***	**1**	***5.9***	**8**	***5.4***	**9**	***5.4***	**14**	***5.2***	**16**	***5.1***
9th pillar: Economic impacts	1	*6.0*	6	*5.6*	9	*5.2*	14	*5.0*	8	*5.2*	11	*5.1*
10th pillar: Social impacts	7	*5.8*	1	*6.2*	12	*5.6*	9	*5.7*	20	*5.2*	23	*5.1*

Source: The Global Information Technology Report 2014 (World Economic Forum, 2014).

comparison of factors governing the level of ICT competitiveness used to compare countries in Table 3, Finland and Singapore were specifically compared as demonstrated in Fig. 8.

Fig. 8 demonstrates the disparity between two countries with respect to economic performance and happiness and welfare, even though these two countries look similar when comparing global ICT leaders in terms of global competitiveness, ICT competitiveness and quality of education.

These similarities and disparities prompt us to consider a hypothetical view that institutional sources embedded within both countries have lead to the contrasting development trajectories. With this hypothetical view we further analyzed the institutional sources governing ICT competitiveness and happiness and typical dimensions of similarity and disparity of two countries.

5.2. Governing factors of ICT competitiveness

The World Economic Forum (WEF) assesses ICT competitiveness of the countries of the world using the Networked Readiness Index (*NRI*). *NRI* consists of 4 dimensions, 10 pillars and 54 factors such as (i) Environment with 2 pillars (*political and regulatory environment*, and *business and innovation environment*) and 18 factors, (ii) Readiness with 3 pillars (*infrastructure and digital content*, *affordability*, and *skills*) and 12 factors, (iii) Usage with 3 pillars (*individual usage*, *business usage*, and *government usage*) and 16 factors, and (iv) Impact with 2 pillars (*economic impact*, and *social impact*) 8 factors.

Table 6 tabulates governing factors of ICT competitiveness (see ICT competitiveness rank in Table 3) in six countries in 2013 by means of *NRI*'s 4 dimensions 10 pillars.

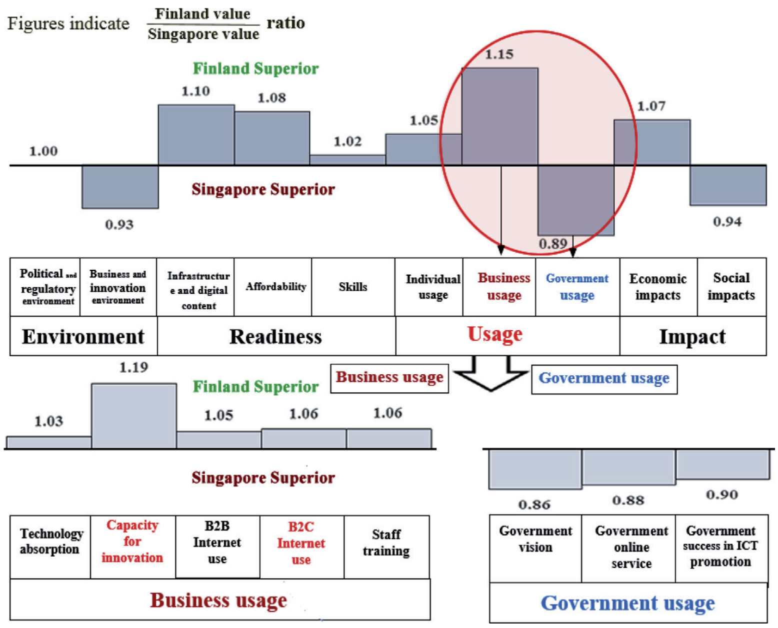


Fig. 9. Comparison of governing factors of ICT competitiveness between Finland and Singapore (2013).
Source: The Global Information Technology Report 2014 (WEF, 2014).

Table 6 highlights Finland and Singapore. However, if we examine what makes up their usage dimension (sub index) carefully, we note a clear contrast between them with respect to their pillars level. While Finland demonstrates a high level in business usage, unlike Singapore. This is totally opposite in terms of government usage. Contrary to Singapore's conspicuous level in its government usage, Finland is much lower.

In order to further explain this contrast, Fig. 9 compares factors of ICT competitiveness between Finland and Singapore focusing on their contrast in business usage and government usage at the factors level. Looking at this figure we note a distinctive difference in their ICT usage. Finland demonstrates superiority in business usage particularly in the firm's capacity for innovation. In contrast, Singapore demonstrates significant superiority in government usage in terms of a leading government vision, government online services and government success in ICT promotion. Since Singapore focusses on GDP growth and securing job opportunities, superiority in government usage leads to this captured GDP. The conspicuously high Internet elasticity to consumption as demonstrated in Fig. 4 can be considered a natural consequence of the nation's priority and policy.

Finland's superiority in business usage encourages more advancement in the area of consumer demand which has shifted from purely economic value. Given that consumer's preference has been shifting from economic functionality captured by GDP to supra-functionality beyond economic value initiated by un-captured GDP, this endeavor focuses on un-captured GDP. Consequently, despite Finland's highest Internet elasticity to ICT, induced ICT does not reflect a consumption increase which is measured by captured GDP as demonstrated by Fig. 4.

5.3. Governing factors of "happiness"

Contrary to the similarities in the foregoing ICT competitiveness at the aggregated level, the "happiness" ranking as a whole demonstrates a distinct disparity between as the two countries as compared in Table 3 and Fig. 8.

The happiness ranking published annually by the Earth Institute compares the degree of happiness in 156 countries using the following 7 factors: (i) GDP per capita, (ii) social support, (iii) healthy life expectancy, (iv) freedom to make decisions, (v) generosity, (vi) perceptions of corruption, and happiness influenced by (vii) the levels and trends of income inequality within the country and also between countries in the region. While some factors such as GDP per capita and income inequality are a reflection of the dimensions compared in Table 3 and Fig. 8, perception of happiness incorporates a multi-dimensional structure synchronizing multiple factors including these factors as reviewed earlier.

Table 7 compares the happiness ranking with contributing factors synchronizing and incorporating the foregoing structure between Finland and Singapore in 2013. Looking at this table we note that Finland demonstrates a distinct superiority in non-inequality, freedom to make life

Table 7
Comparison of factors governing happiness in Finland and Singapore.

	Influence by inequality	Explained by GDP per capita	Social support	Healthy life expectancy	Freedom to make life choices	Generosity	Perceptions of corruption	Total value
Finland	2.32	1.30	1.46	0.95	0.52	0.33	0.51	**7.39**
Singapore	1.53	1.39	1.36	0.96	0.43	0.19	0.69	**6.55**
Finland/Singapore	1.52	0.94	1.07	0.99	1.21	1.74	0.74	**1.13**

Source: World Happiness Report 2013 (The Earth Institute, Columbia University et al., 2013).

choices and generosity while Singapore demonstrates its superiority in GDP per capita and perceptions of corruption.

This contrast corresponds to the contrasting development trajectories as reviewed in Section 3 and also the varying strengths in terms of business usage and government usage in ICT competitiveness. For example, Finland's superiority in generosity, freedom to make life choices and also non-inequality correspond to consumer preference shifts from economic functionality to supra-functionality beyond economic valuenot captured in GDP. Singapore's superiority in GDP per capita, perceptions of corruption and high income inequality correspond to a growth oriented trajectory based on captured GDP. Government versus business usage in ICT competitiveness also supports this contrasting trend.

Fig. 10 clearly demonstrates this contrasting superiority between two countries.

These observations on the influence of institutional sources characterizing the similarities and disparities in ICT competitiveness and happiness between these two countries suggests the possibility of the influence of the national plan as well as a government plan (Yusuf et al., 2012 [33]).

5.4. Policy initiatives

Given that the contrast observed with respect to ICT usage and also some factors characterizing happiness in world ICT leaders can be attributed to their national as well as government informatization plans, Figs. 11 and 12 compare these plans by illustrating the history of informatization in Finland and Singapore. While both are noteworthy global ICT leaders in accelerating informatization, it is noted that the ICT advancement in Finland can largely be attributed to the combined efforts of private initiatives and public policies. Finland's ICT cluster, particularly Nokia, significantly boosted its economic performance. Contrary to these initiatives, Singapore's informatization has largely been dependent on strong government initiatives such as those typically observed in its successive e-Government action plans.

This contrast in national as well as government plans corresponds to the contrast in Finland's business usage and Singapore's government usage in ICT competitiveness as well as the contrast between Finland's generosity and freedom to make life choices and Singapore's perceptions of corruption in the happiness index.

5.5. Economic structure and historical perspectives

The institutional sources of this contrast in Finland's overall high happiness index during the great stagnation aligns with the data showing its shift to un-captured GDP and sustainable growth. This contrasts with the happiness index for Singapore which aligns with the focus on captured GDP. Both can largely be attributed to their economic structure and historical perspectives (Hofstede, 1991 [9], Watanabe, 2009 [22]) as compared in Table 8 and Fig. 13. This is the same in the contrast in national as well as government priorities. It goes without saying that these dimensions should be further analyzed in identifying their contrasting trajectories.

While in the preceding analyses on captured GDP and un-captured GDP in Sections 3 and 4 focused on particular

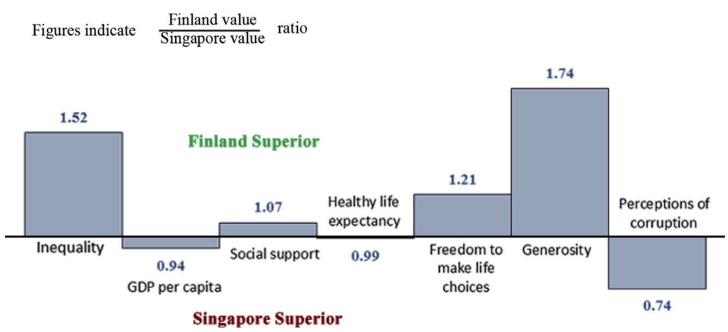


Fig. 10. Comparison of factors governing happiness in Finland and Singapore.

2013 SADe, Open Data Programme (2013 – 2015)
2012 Public Sector ICT Strategy, Govt. of Future, GIDE
2010 Legal right to broadband Internet, Suomi.fi
2008 The Broadband 2015, Ubiquitous Information Society
2002-07 **Euro replaces Markka**, eJUNA, e-Government, Information Society Council, KuntaIT
95 -00 **EU membership**, GSM phones exceeds NMT phones. FiCom in operation.
1994 Draft of "National Information Society Strategy".
1991-93 **"The Digital Big Bang".** GSM call, Linux,
1990 **The Financial Crisis in Finland**.
1988 **FICORA** (former TAC)
1982-86 **TEKES, The Science and Technology Policy Council**, EUnet, NMT450 ,NMT900, IRC
1980 **Finnish technology policy begins emphasize ICT.**
1970 Academy of Finland
1967 **Nokia Corporation**
1952 -60 Helsinki Olympic Games, IBM 650, ESKO
1939-45 World at War. The Finnish Army is the major employer in the telecommunications
1927-32 Telegraph Office + Finland Post. Automatic telephone exchanges started.
1917 **Independence,** Finnish Cable Factory (Nokia later)
1855 - 82 **1st** Telegraph line, Local telephone company
1638 1st steps of wireless comm. Postal in Finland (Itella)

	National plans	Government plans
2011-2014	Barrier-free information society GIDE, Open Data Programme, Intelligence in Transport	Public Sector ICT Strategy (2012-2020) SADe eServices and eDemocracy (2013)
2006-2010	National Knowledge Society Strategy Ubiquitous Information Society Intelligent Transport 2020 (2009) **Legal right to broadband internet**	IT Management in State Administration (2006) KuntaIT 2006, FINESSI 2007 Suomi.fi 2010 officially launched
2001-2005	Information Society Council (2003) Government Information Society Act on Electronic Signatures (2003)	e-Government Action Programme Openness of Government Activities (2002) suomi.fi launched (2002)
1996-2000	Information Society Advisory Board Decision-in-Principle (Public Management Reforms and Information Society, 1998)	eGovernment, JUNA (1999), Electronic ID Cards, PKI, Online Banking Personal Data Act 1999.
1991-1995	**Finland got EU membership (1995)** 'Finland – Towards an Information Society, A National Outline' (1995)	National Information Society Strategy (1994), Decision on electronic transactions (1995)
1986-1990	The Science and Technology Policy Council (1986) **Financial Crisis in Finland**	Re-Industrialization, de-regulations
1980-1985	Technology policy emphasizes ICT Telephone firms in competition. EUnet, NMT-450	**(1983) TEKES National Technology** Agent CMOS Progress Technology Project
1970	**Academy of Finland**	
1967	**Nokia Corporation** (Nokia Company+ Finnish Rubber..+Finnish Cable..).	SITRA, the Finnish Innovation Fund
1917	**Finland got Independence** Finnish Cable Factory (Nokia later)	

Fig. 11. History of Finland informatization.

aspects of reconstructing the virtuous cycle between (private) consumption and GDP increase, it goes without saying that other factors constituting GDP and also the industrial structure of the country should not be overlooked as significant institutional factors impacting the development trajectories discussed.

Singapore largely depends on international trade, particularly on exports, 62% of which are for Asian countries which depend largely on captured GDP. In contrast, Finland depends less on exports than Singapore and 55% of its exports are to EU countries which depend mostly on uncaptured GDP.

In addition the industrial structure plays a key role. Singapore depends largely on finance and insurance whereas Finland depends largely on government initiatives. Finland's business initiatives accelerate services as healthcare, social work and education.

Fig. 13 demonstrates the historical perspectives of world ICT leaders by correlating respective national as well as government initiatives with contrasting trajectories on

2010 eGov2015
2006 Intelligent Nation Master plan (iN2015)
2003 e-Government Action Plan II
2000 e-Government Action Plan
1999 Information Development Authority of S'pore (IDA) (NCB + TAS)
1992 Reconstituted Telecommunication Authority of S'pore (TAS)
1982 Telecommunication Authority of S'pore (Postal Services Dept. + Telecoms)
1981 National Computer Board (NCB) National Computerization Plan
1980 Civil Service Computerization Program
1974 Telecoms (STB + Foreign communications)
1967 Singapore Postal Services Department
1955 Singapore Telephone Board (STB)
1879 Introduction of telephones

	National plans	Government plans
2010-2015	iN2015	**eGov2015**
2006-2010	iN2015	**iGov2010**
2003-2006	Connected Singapore	e-Government Action Plan II
2000-2003	Infocomm21	e-Government Action Plan I
1992-1999	IT2000	Civil Service Computerization Program
1986-1991	The National IT Plan	Civil Service Computerization Program
1980-1985	The National Computerization Plan	Civil Service Computerization Program

Fig. 12. History of Singapore informatization.

Table 8
Comparison of economic structure between Finland and Singapore (2013).

	Finland	Singapore
Composition of GDP (%)		
Private consumption	55.2	35.0
Government consumption	24.9	9.8
Gross fixed capital formation	20.8	29.1
Net exports	−0.9	26.1
• Exports	*38.2*	*194.1*
• Imports	*−39.1*	*−168.0*
Total	**100.0**	**100.0**
Industrial Structure (Share of GDP %)		
Secondary Production	**26.9**	**24.5**
Manufacturing	16.6	18.6
Construction	6.5	4.4
Utilities	3.4	1.5
Other goods industries	0.4	0.0
Services	**70.5**	**70.6**
Wholesale and retail trade	10.0	18.2
Transportation and storage	5.1	7.0
Finance and insurance	2.5	12.2
Information and communication	5.2	4.0
Accommodation and food services	1.7	2.5
Other services[a]	46.0	26.7
Others	**2.7**[b]	**4.9**[c]
Total	**100.0**	**100.0**

[a] Healthcare, social work, real state, public administration, social security, education.
[b] Primary production (Agriculture, forestry and fishing).
[c] Ownership of dwellings.
Sources: Statistical Yearbook of Finland 2014 (Communication and Information Services, Statistics Finland, 2014), Structure of the Singapore Economy, 2013 (Ministry of Trade and Economy, 2014).

their un-captured GDP shifting and captured GDP oriented as reviewed in Fig. 5.

Provided that the respective national and government policies are induce new initiatives corresponding to the state of the trajectory, co-evolution between the elements within both systems should be further explored.

6. Conclusion

We analyzed the system dynamics in Finland and Singapore institutionally and economically, in light of the increasing significance of changes in global economic structural shifts due to ICT, such as a shift from captured GDP to un-captured GDP we attempted to develop a new method for measuring un-captured GDP and assessing the institutional sources incorporating factors including those from the happiness index. To test this measure we conducted a comparative empirical analysis of ICT-driven trajectories in six global ICT leaders over the last two decades, particularly focusing on Finland and Singapore. Noteworthy findings from this analysis include:

i. While the majority of ICT advanced countries have been experiencing great stagnation due to a "trap" in ICT advancement, certain countries have been able to sustain a high level of ICT-driven global competitiveness.
ii. Finland and Singapore demonstrate this and can be considered countries of resilience with respect to ICT-driven global competitiveness.
iii. While both countries share significant similarities which endorses their institutional strength in ICT, they demonstrate noteworthy disparities by their development trajectories: growth-oriented in Singapore and happiness-seeking in Finland.
iv. While Finland effectively utilizes the Internet in inducing ICT stock, its induced ICT stock contributes significantly to satisfying consumer preference to

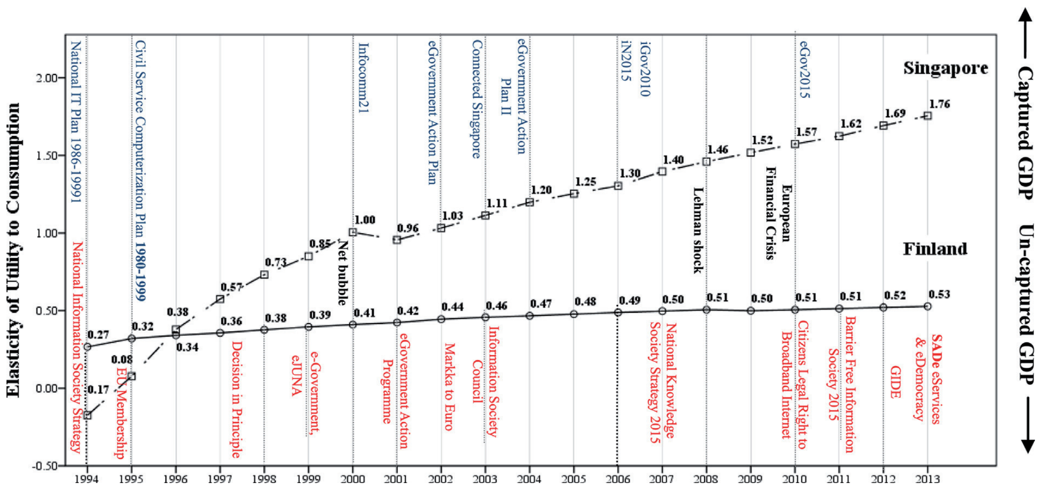


Fig. 13. Trends in national and government plans correlating to trajectories option **in Finland and Singapore** (1994–2013).

supra-functionality beyond economic value rather to economic functionality.

v. Consequently, increased ICT does not reflect a consumption increase which is measured by GDP value resulting in a lower GDP growth rate.

vi. In contrast to Finland, Singapore focusses mostly on satisfying consumer preference for economic value which is captured by GDP value leading to a conspicuously high GDP growth rate.

vii. Given the increasing significance of un-captured GDP derived from the dramatic advancement of the Internet, these contrasts provide significant insight to the development trajectory options amidst the changing economic realities of the 21st century.

These findings provide the following policy suggestions:

i. The sources of the great stagnation following 2008 should be carefully examined from both the supply and demand side.

ii. The co-evolutionary dynamism between the advancement of the Internet, increasing shifts of un-captured GDP and a consumer preference beyond economic value should be considered in policy making.

iii. Contrasting the development trajectories demonstrated by global ICT leaders should be further elucidated in order to conceptualize ICT-driven economic development in a system of increasingly un-captured GDP.

Future studies should consider taking other factors constituting GDP such as government consumption, capital formation and international trade. In this regard, perhaps a new national accounting system taking un-captured value could be developed. In addition, the conceptualization of the contrasting trajectories is highly stylized in this study and should be further developed for generalization. This would enable more applicability and adaptability to emerging economies. Finally, further comparative empirical analysis should be continued attempting to merge new theories to explain economic shifts particularly given the economic realities of the interconnected world of the 21st century and measures beyond GDP for global advancement.

Appendix 2. Governing factors of utility under the great stagnation

(1) Possible option for sustainable growth under the great stagnation

During the great stagnation there is a "trap" in ICT advancement resulting from contrasting ICT business models on the supply side and also from emerging conflict between captured GDP and un-captured GDP in demand side, only a possible option for sustainable growth can be expected by enhancing utility (satisfaction of consumption) through the Internet inducement of ICT stock (Watanabe et al., 2014*c* [27]). This mechanism can be demonstrated as follows.

(2) Co-evolution between consumption and GDP increase

Consumption shares significant amount of GDP (55%, 35%, 69%, 61% in Finland, Singapore, USA and Japan, respectively in 2013). Thus, its increase is indispensable for sustainable growth.

Since consumption depends on GDP (income) as depicted in equation (A1), construction of a co-evolution between consumption and GDP increase is the key to overcome great stagnation due to a trap in ICT advancement.

$$C = a + b\,Y \tag{A1}$$

where *C:* consumption, *Y:* GDP (income), *a:* base consumption, and *b:* marginal propensity to consume.

(3) Utility for consumption increase

Consumption is subject to utility *U* which represents satisfaction of consumption and is depicted as follows:

$$C = \mathrm{C}(U) \tag{A2}$$

Since *U* is governed by economic functionality (*V*) and supra-functionality beyond economic value (*Q*) in the ICT-driven economy (Watanabe et al., 2014c [27]), and given that it is a total sum of utilities stemmed from *V* and *Q* with

Appendix 1. Trend in economic stagnation in ICT advanced countries

Table A1
Annual real GDP growth rate in ICT advanced countries (2006–2013) - % *p.a.*

Year	Finland	Singapore	Sweden	Netherlands	Norway	Switzerland	USA	UK	Germany	Japan
2006	4.06	8.86	4.30	3.82	2.30	3.75	2.67	2.76	3.88	1.69
2007	5.19	9.11	3.31	4.20	2.65	3.85	1.78	3.43	3.39	2.19
2008	0.72	1.79	−0.61	2.09	0.07	2.16	−0.29	−0.77	0.81	−1.04
2009	−8.27	−0.60	−5.03	−3.30	−1.64	−1.94	−2.78	−5.17	−5.09	−5.53
2010	2.99	15.24	6.56	1.07	0.48	2.95	2.53	1.66	3.86	4.65
2011	2.57	6.06	2.93	1.66	1.34	1.79	1.60	1.12	3.40	−0.45
2012	−1.46	2.50	0.93	−1.59	2.90	1.05	2.32	0.28	0.90	1.46
2013	−1.21	3.85	1.64	−0.72	0.65	1.93	2.22	1.74	0.53	1.52
Avg.	**0.57**	**5.85**	**1.75**	**0.90**	**1.09**	**1.94**	**1.26**	**0.63**	**1.46**	**0.56**

Source: World Economic Outlook Database (IMF, annual issues) [4].

constant returns to scale, it can be depicted as follows (Euler's theorem):

$$U = U(V, Q) = \frac{\partial U}{\partial V} \cdot V + \frac{\partial U}{\partial Q} \cdot Q \tag{A3}$$

Right hand side of the equation (A3) depicts utility stemmed from economic functionality and supra-functionality beyond economic value, respectively.

that V and Q inducement of I could be only a possible solution to enhance utility under great stagnation:

$$\chi = I\left(\frac{\partial I}{\partial V} \cdot \frac{V}{I} + \frac{\partial I}{\partial Q} \cdot \frac{Q}{I}\right) \tag{A5}$$

(5) Utility enhancement under great stagnation

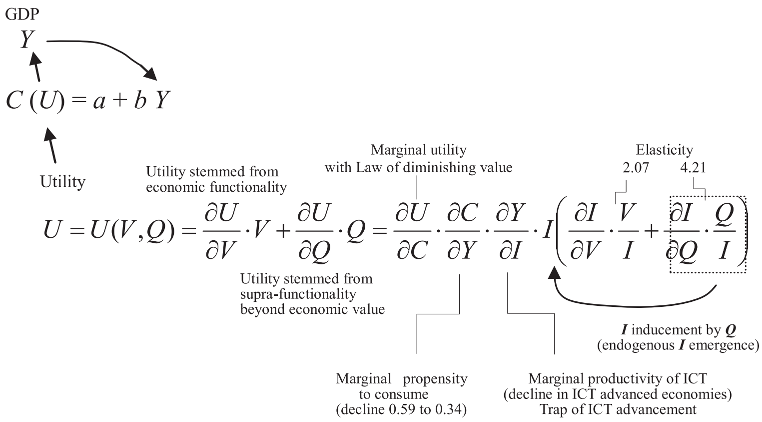


Fig. A1. Structure of utility under the great stagnation. V: economic functionality, Q: supra-functionality beyond economic value, I: ICT stock, and J: Internet. Figures demonstrate a case of Japan (1997–2007 and 2008–2012 comparison) (Watanabe et al., 2014*c* [27]).

(4) Utility with constraints under the great stagnation

In order to enhance the utility under great stagnation with declines in not only general decline of marginal utility ($\partial U/\partial C$) that declines governed by the Law of diminishing value, but also marginal propensity to consume ($\partial C/\partial Y$) and marginal productivity of ICT ($\partial Y/\partial I$) which are engines of utility enhancement in normal occasion, new enhancing mechanism identical to this particular great stagnation circumstances should be found.

In order to attain this target, new mechanism which is not influenced by the above declining factors should be explored. With this objective, if the above three declining factors are extracted from utility function, equation (A3) can be rewritten as follows:

$$\begin{aligned} U = U(V, Q) &= \frac{\partial U}{\partial V} \cdot V + \frac{\partial U}{\partial Q} \cdot Q \\ &= \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial Y} \cdot \frac{\partial Y}{\partial I} \cdot I\left(\frac{\partial I}{\partial V} \cdot \frac{V}{I} + \frac{\partial I}{\partial Q} \cdot \frac{Q}{I}\right) \end{aligned} \tag{A4}$$

Looking at this equation we note that the first 3 factors of the right hand side of the equation depict marginal utility, marginal propensity to consume and marginal productivity of ICT, respectively, and the remaining factors could only be an engine for utility enhancement under great stagnation.

This engine χ is depicted by a product of ICT stock (I) and sum of elasticity of V to I and Q to I as follows and suggests

On the basis of the foregoing review, under great stagnation due to a trap in ICT advancement, utility enhancing mechanism without influenced by declining factors can be illustrated as Fig. A1.

Fig. A1 demonstrates that (i) marginal utility, (ii) marginal propensity to consume, (iii) marginal productivity of ICT, (iv) ICT stock, and (v) elasticity of economic functionality as well as supra-functionality beyond economic value to ICT govern utility under great stagnation.

Since (i) marginal utility, (ii) marginal propensity to consume and (iii) marginal productivity of ICT decline due to the Law of diminishing marginal utility, conflict between captured and un-captured GDP, and a trap in ICT advancement, respectively, (iv) ICT stock inducement by economic functionality and/or supra-functionality can be only the solution to enhance utility for the compensation of consumption decline.

Given that supra-functionality induces ICT much higher than economic functionality and close relationship with the advancement of the Internet (Watanabe et al., 2014*c* [27]), enhancement of utility through the Internet inducement of ICT stock can be the possible solution in overcoming great stagnation by reconstructing a virtuous cycle between consumption and GDP increase as follows:

$$J \rightarrow I \rightarrow U \rightarrow C \rightarrow GDP \rightarrow C. \tag{A6}$$

Appendix 3. Measurement of elasticity

Appendix 3.1Elasticity of the internet to ICT advancement

Given the significant correlation between ICT stock (I) and the Internet (J) in the ICT-driven economy as depicted in equation (A7), elasticity of the Internet to ICT stock was computed as follows:

$$\ln I = a + b \ln J \tag{A7}$$

where a and b: coefficients.

Partial differentiation with respect to J leads to J elasticity to I ε_{ii} as depicted in equation (A8).

$$\varepsilon_{ij} = \frac{\partial \ln I}{\partial \ln J} = b \tag{A8}$$

By using equation (A7), coefficient b can be obtained by the time series regression over the period 1994–2013 as tabulated in Table A2 [11] thereby trend in J elasticity to I ε_{ii} can be identified as illustrated in Fig. 3.

Appendix 3.2Elasticity of the internet to consumption

Given the consumption in the ICT driven economy is governed by ICT stock (I) and the Internet (J), elasticity of the Internet to consumption was computed as follows:

$$C = C(I, J) \tag{A9}$$

This equation can be approximated as follows by conducting Taylor expansion to the secondary term[12]:

$$\ln C = a + b \ln I + c \ln J + d \ln I \cdot \ln J \tag{A10}$$

where a - d: coefficients

Partial differentiation with respect to J leads to the J elasticity to C ε_{ci} as depicted in equation (A11) (see Fig. 4).

Table A2
Correlation between the internet dependency and ICT advancement in 6 countries (1994–2013).

Finland	$\ln I = 4.054 + 0.560\, D_1 \ln J + 0.632\, D_2 \ln J + 0.754\, D_3 \ln J$	adj. R^2 0.936	D_1: 1994-99 = 1, D_2: 2000-08 = 1, D_3: 2009-13= 1
	(12.18*) (4.78*) (7.82*) (9.63*)	DW 1.02	
Singapore	$\ln I = 4.843 + 0.272\, D_1 \ln J + 0.385\, D_2 \ln J + 0.541\, D$	adj. R^2 0.935	D_1: 1994-00 = 1, D_2: 2001-13 = 1, D: 2009-11= 1
	(34.91*) (4.93*) (10.36*) (4.71*)	DW 1.06	
US	$\ln I = 4.250 + 0.380\, D_1 \ln J + 0.456\, D_2 \ln J + 0.516\, D_3 \ln J + 0.551\, D_4 \ln J$	adj. R^2 0.973	D_1: 1994-00 = 1, D_2: 2001-06 = 1, D_3: 2007-09= 1, D_4: 2010-13 = 1
	(30.10*) (8.10*) (12.87*) (14.71*) (15.90*)	DW 1.65	
UK	$\ln I = 4.844 + 0.250\, D_1 \ln J + 0.261\, D_2 \ln J + 0.358\, D_3 \ln J + 0.387\, D_4 \ln J - 0.214\, D$	adj. R^2 0.973	D_1: 1994-96 = 1, D_2: 1997-00 = 1, D_3: 2001-09= 1, D_4: 2010-13 = 1, D: 2002, 03 = 1
	(69.60*) (3.15*) (9.15*) (19.77*) (20.61*) (-3.32*)	DW 1.80	
Germany	$\ln I = 4.814 + 0.153\, D_1 \ln J + 0.223\, D_2 \ln J + 0.430\, D$	adj. R^2 0.938	D_1: 1994-01 = 1, D_2: 2002-13 = 1, D: 2009-11 = 1
	(63.27*) (4.67*) (10.67*) (5.33*)	DW 1.45	
Japan	$\ln I = 4.841 + 0.142\, D_1 \ln J + 0.157\, D_2 \ln J + 0.206\, D_3 \ln J + 0.342\, D$	adj. R^2 0.937	D_1: 1994-98 = 1, D_2: 1999-00 = 1, D_3: 2001-13= 1, D: 2011, 12=1
	(74.11*) (3.62*) (5.50*) (11.93*) (4.71*)	DW 1.03	

1. Figures in parenthesis indicate t-statistics (*: significant at the 1% level).
2. D_i ($i = 1$–3) and D are coefficient and constant dummy variables, respectively corresponding to the economic circumstances as follows:
   Years indicating in D_i and $D = 1$ while other years = 0.
3. In case of Singapore, for example,

		2001–2013			
	1994–2000	2001–2008	2009–2011	2011–2013	
D_1 (1994–2000)	1	0	0	0	Before Net bubble bursting
D_2 (2001–2013)	0	1	1	1	After Net bubble bursting
D (2009–2011)	0	0	1	0	Effects of the Lehman shock
1994–2000	$\ln I = 4.843 + 0.272 \ln J$				J elasticity to I 0.272
2001–2008	$\ln I = 4.843 + 0.385 \ln J$				J elasticity to I 0.385
2009–2011	$\ln I = 4.843 + 0.542 + 0.385 \ln J = 5.385 + 0.385 \ln J$				J elasticity to I 0.385
2012–2013	$\ln I = 4.843 + 0.385 \ln J$				J elasticity to I 0.385

$$\begin{aligned}\varepsilon_{cj} &= \frac{\partial \ln C}{\partial \ln J} = c + d \ln I + (b + d \ln J) \cdot \frac{\partial \ln I}{\partial \ln J} \\ &= c + d \ln I + (b + d \ln J) \cdot \varepsilon_{ji}\end{aligned} \tag{A11}$$

By using equation (A10), coefficients b, c and d can be obtained by the time series regression over the period

[11] SPSS software was used for this regression analysis, same as the analysis in Table 3.

[12] Based on translog (transcendental logarithmic) cost function (See Christensen et al., 1973 [1]).

1994–2013 as tabulated in Table A3. Synchronizing estimated elasticity of the internet to ICT stock (ε_{ii}) (Fig. 3), trend in J elasticity to C ε_{ci} can be identified as illustrated in Fig. 4.

Table A3
Impacts of the increase in ICT stock and the internet dependency on consumption in 6 countries (1994–2014).

Finland

$$\ln C = 10.120 + 0.142 \ln I - 0.129\, D_1 \ln J - 0.134\, D_2 \ln J - 0.148\, D_3 \ln J + 0.024 \ln I \ln J \qquad adj.\ R^2\ 0.999$$

(52.31*) (3.61*) (-3.99*) (-4.07*) (-4.51*) (3.32*) DW 2.54

D_1: 1994-99 = 1, D_2: 2000-08 = 1, D_3: 2009-13= 1

Singapore

$$\ln C = 12.638 - 0.371 \ln I - 0.638\, D_1 \ln J - 0.625\, D_2 \ln J + 0.139 \ln I \ln J - 0.054\, D \qquad adj.\ R^2\ 0.994$$

(11.46*) (-1.69****) (-3.13**) (-3.02**) (3.15*) (-3.54*) DW 2.49

D_1: 1994-00 = 1, D_2: 2001-13 = 1. D: 1998, 2003 = 1

US

$$\ln C = 16.692 - 0.248 \ln I - 0.532\, D_1 \ln J - 0.543\, D_2 \ln J + 0.114 \ln I \ln J + 0.017\, D \qquad adj.\ R^2\ 0.998$$

(33.60*) (-2.35**) (-5.97*) (-6.10*) (5.74*) (2.95**) DW 2.02

D_1: 1994-09 = 1, D_2: 2010-13 = 1, D: 2006, 08 = 1

UK

$$\ln C = 12.126 + 0.260 \ln I - 0.096\, D_1 \ln J - 0.092\, D_2 \ln J - 0.095\, D_3 \ln J - 0.108\, D_4 \ln J + 0.019 \ln I \ln J - 0.025\, D \qquad adj.\ R^2\ 0.999$$

(42.53*) (3.90*) (-2.45**) (-2.29**) (-2.28**) (-2.58**) (2.04***) (-5.45*) DW 2.22

D_1: 1994-96 = 1, D_2: 1997-00 = 1, D_3: 2001-09= 1, D_4: 2010-13 = 1, D: 2008, 11, 12 = 1

Germany

$$\ln C = 13.220 + 0.127 \ln I - 0.040 \ln J + 0.015 \ln I \ln J - 0.015\, D \qquad adj.\ R^2\ 0.997$$

(41.04*) (1.94***) (-0.74 #) (0.97 #) (-4.27*) DW 2.03

D: 1994, 02, 03, 09 =1

Japan

$$\ln C = 20.180 - 0.165 \ln I - 0.232 \ln J + 0.051 \ln I \ln J - 0.015\, D \qquad adj.\ R^2\ 0.971$$

(43.63*) (-1.83***) (-3.32*) (3.30*) (-3.63*) DW 1.72

D: 1998, 09 = 1

1. Consumptions in 2013 were estimated by trends.
2. Figures in parenthesis indicate t-statistics (*, **, ***, **** significant at the 1%, 5%, 10% and 15% level, respectively while # in German's J implies significant at the 30% level).
3. D_i (i = 1–4) and D are coefficient and constant dummy variables, respectively corresponding to the economic circumstances as follows:
   Years indicating in D_i and D = 1 while other years = 0.
4. In case of Finland, for example,

	1994–1999	2000–2008	2009–2013	
D_1 (1994–1999)	1	0	0	Before Net bubble bursting
D_2 (2000–2008)	0	1	0	After Net bubble bursting and before the Lehman shock
D_3 (2009–2013)	0	0	1	After the Lehman shock
J elasticity to I (ε_{ij})	0.560	0.632	0.754	
	$\ln C = a + b \ln I + c\, D_i \ln J + d \ln I \ln J$			
1994–1999	$\ln C = 10.120 + 0.142 \ln I - 0.129 \ln J + 0.024 \ln I \ln J$			
2000–2008	$\ln C = 10.120 + 0.142 \ln I - 0.134 \ln J + 0.024 \ln I \ln J$			
2009–2013	$\ln C = 10.120 + 0.142 \ln I - 0.148 \ln J + 0.024 \ln I \ln J$			
	$\varepsilon_{cj} = c\, D_i + d \ln I + (b + d \ln J)\, \varepsilon_{ij}$			
1994–1999	$\varepsilon_{cj} = -0.129 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.560 = -0.049 + 0.024 \ln I + 0.013 \ln J$			
2000–2008	$\varepsilon_{cj} = -0.134 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.632 = -0.044 + 0.024 \ln I + 0.015 \ln J$			
2009–2013	$\varepsilon_{cj} = -0.148 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.754 = -0.041 + 0.024 \ln I + 0.018 \ln J$			

Appendix 4. High elasticity of the internet to consumption as a source of high GDP growth

Given the J elasticity to C ε_{ci}, and consumption function $C = a + bY$, GDP increase rate can be depicted by the following equation:

$$\frac{\Delta Y}{Y} = \frac{\varepsilon_{cj}}{b} \cdot \frac{C}{Y} \cdot \frac{\Delta J}{J}. \tag{A12}$$

Since Singapore's b (marginal propensity to consume), C/Y (income to consumption level) and $\Delta J/J$ (Internet increase rate) are comparable to other countries compared, its conspicuous GDP increase rate can be attributed to high level of ε_{ci}.

Appendix 5. Elasticity of utility to consumption

Since utility under great stagnation due to a trap in ICT advancement can be depicted as $U = U(V, Q)$, and V and Q can be depicted as $V = V(I, J)$ and $Q = Q(I, J)$, respectively as reviewed in Section 2, U can be depicted as follows:

$$U = U(I, J) = \frac{\partial U}{\partial I} \cdot I + \frac{\partial U}{\partial J} \cdot J = \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial I} \cdot I + \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial J} \cdot J \tag{A13}$$

Then,

$$\varepsilon_{cu} = \frac{\partial C}{\partial U} \cdot \frac{U}{C} = \frac{\partial C}{\partial I} \cdot \frac{I}{C} + \frac{\partial C}{\partial J} \cdot \frac{J}{C} = \frac{\partial \ln C}{\partial \ln I} + \frac{\partial \ln C}{\partial \ln J} \tag{A14}$$

Left hand side of this equation depicts elasticity of utility to consumption and demonstrates the extent of reflection of utility to consumption while right hand side depicts contribution of elasticity of ICT stock and the Internet to consumption, respectively.

Since, $\frac{\partial \ln C}{\partial \ln J} = \varepsilon_{cj}$ *and* $\frac{\partial \ln C}{\partial \ln I} = \frac{\partial \ln C}{\partial \ln J} \cdot \frac{\partial \ln J}{\partial \ln I} = \frac{\varepsilon_{cj}}{\varepsilon_{ij}}$, elasticity of utility to consumption ε_{cu} and contribution of I and J to this elasticity can be identified by the results of the analysis in Section 3 as follows:

$$\varepsilon_{cu} = \frac{\varepsilon_{cj}}{\varepsilon_{ij}} + \varepsilon_{cj} = \varepsilon_{cj}\left(\frac{1}{\varepsilon_{ij}} + 1\right) \tag{A15}$$

ε_{ij} and ε_{cj} are illustrated in Figs. 3 and 4, respectively.

Appendix 6. Internet dependency: percentage of individuals using the internet

Indicator: Percentage of individuals using the Internet

Proportion of individuals who used the Internet from any location in last 3 months (previously 12 months) reported in ITU's HH7 (households and individuals) national survey.

and usage by households and individuals. The HH7 survey calculates the proportion of individuals who used the Internet from any location in the last 3 months.

Survey Question: "*Have you used the Internet from any location in the last 3 months?*"

The proportion of individuals who used the Internet is calculated by dividing the total number of individuals who used the Internet in last 3 months by the total number of individuals surveyed.

Source: ITU's World Telecommunication/ICT Indicators Database

ITU's World Telecommunication/ICT Indicators Database includes time series for more than 140 indicators and around 200 countries. The data are collected directly from telecommunication regulatory agencies and/or ministries and national statistical offices by means of an annual questionnaire, and subsequently verified, harmonized and complemented by ITU.

Table A4
ITU's HH7 Surveys for 'Percentage of individuals using Internet'

Indicators		Definitions and notes
HH7	Proportion of individuals who used the internet (from any location) in the last 3 months **Suggested model question:** "*Have you used the Internet from any location in the last 3 months?*"	The proportion of individuals who used the internet is calculated by dividing the total number of individuals who used the internet (from any location) in the last 3 months by the total number of individuals surveyed. The internet is a world-wide public computer network. It provides access to a number of communication services including the world wide web and carries e-mail, news, entertainment and data files, irrespective of the device used (not assumed to be only via a computer – it may also be by mobile phone, PDA, games machine, digital TV etc.). Access can be via a fixed or mobile network.

Source: Manual for Measuring ICT Access and Use by Households and Individuals (http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITCMEAS-2009-PDF-E.pdf).

Database: ITU's World Telecommunication/ICT Indicators Database

ITU's World Telecommunication/ICT Indicators Database is the main source of global, and internationally comparable, telecommunication/ICT statistics.

Definitions and Methods

Internet: The Internet is a world-wide public computer network. It provides access to a number of communication services including the World Wide Web, e-mail, news, entertainment and data files, irrespective of the device used.

Internet Access: Individuals may have accessed the Internet by any means including a computer, mobile phone, PDA, games machine, digital TV etc. Access can be via a fixed or mobile network.

Method

The ITU conduct several surveys for World Telecommunication/ICT Indicators database to measure ICT access

References

[1] Christensen L, Jorgenson D, Lau L. Transcendental logarithmic production frontiers. Rev Econ Stat 1973;55(1):28–45.
[2] Cowen T. The great stagnation. New York: Dutton; 2011.
[3] Hofstede G. Cultures and organizations. London: McGraw-Hill International; 1991.
[4] International Monetary Fund (IMF). World economic outlook database. Washington, D.C.: IMF; 2014.
[5] International Telecommunication Union (ITU). Measuring the information society 2013. Geneva: ITU; 2013.
[6] International Telecommunication Union (ITU). World telecommunication/ICT indicators database. Geneva: ITU; 2014.
[7] Japan's Cabinet Office (JCO). National survey of lifestyle preferences. Tokyo: JCO; 2012.
[8] Jarvenpaa SL, Tractinsky N, Vitale M. Consumer trust in an internet store. Inform Technol Manag 2000;1(1):45–71.
[9] Karjaluoto H, Karvonen J, Kesti M, Koivumaki T, Manninen M, Pakola J, et al. Factors affecting consumer choice of mobile phones: two studies from Finland. J Euromarketing 2005;14(3):59–82.
[10] Karjaluoto H, Mattila M, Pento T. Factors underlying attitude formation towards online banking in Finland. Int J Bank Mark 2002;20(6):261–72.
[11] Liao Z, Cheung MT. Internet-based e-shopping and consumer attitudes: an empirical study. Inform Manag 2001;38:299–306.
[12] Lowrey A. Impacts of the great stagnation. New York Times; 2011.
[13] McDonagh D. Satisfying needs beyond the functional: the changing needs of the silver market consumer. In: Proceedings of the International Symposium on the Silver Market Phenomenon - Business

Opportunities and Responsibilities in the Aging Society, Tokyo; 2008.
[14] McKinsey Global Institute. Internet matters: the net's sweeping impact on growth, jobs, and prosperity. New York: Mckinsey; 2011.
[15] Ministry of Employment and the Economy, Finland. Demand and user-driven innovation policy. Publication of the ministry of employment and the economy, Finland, Helsinki. 2010.
[16] Pieters R, Baumgartner H, Allen D. A means-end chain approach to consumer goal structures. Int J Res Mark 1995;12:227–44.
[17] Rifkin J. The third industrial revolution: how lateral power is transforming energy, the economy, and the world. New York: Palgrave Millan; 2011.
[18] Rifkin J. The zero marginal cost society. New York: Palgrave Macmillan; 2014.
[19] Rintamaki T, Kanto A, Kuusela H, Spence MT. Decomposing the value of department store shopping into Utilitarian, hedonic and social dimensions: evidence from Finland. Int J Retail Distrib Manag 2006;34(1):6–24.
[20] The Conference Board. Total economy database™. 2014. http://www.conference-board.org/data/economydatabase/ [Retrieved 26 December 2014].
[21] United Nations Statistics Division. Household final consumption expenditure. New York: United Nations; 2014.
[22] United Nations Development Program (UNDP). Human development report 2007/2008. New York: UNDP; 2007.
[23] Watanabe C. Managing innovation in Japan: the role institutions play in helping or hindering how companies develop technology. Berlin: Springer; 2009.
[24] Watanabe C, Nasuno M, Shin JH. Utmost gratification of consumption by means of supra-functionality leads a way to overcoming global economic stagnation. J Serv Res 2011;11(2):31–58.
[25] Watanabe C, Naveed K, Zhao W. Institutional sources of resilience in global ICT leaders – harness the vigor of emerging power. J Technol Manag Grow Econ 2014a;5(1):7–34.
[26] Watanabe C, Naveed K, Zhao W. Structural source of the trap of ICT advancement: lessons from world ICT top leaders. J Technol Manag Grow Econ 2014b;5(2):49–71.
[27] Watanabe C, Naveed K, Zhao W. New paradigm of ICT productivity: increasing role of un-captured GDP and growing anger of consumers. Technol Soc 2014c;41(1):21–44.
[28] Watson B, McDonagh D. Supra-functionality: responding to users needs beyond the functional. Eng Des 2004;30(5):8–11.
[29] World Economic Forum (WEF). The global competitiveness report 2012-2013. Geneva: WEF; 2013.
[30] World Economic Forum (WEF). The global information technology report 2013. Geneva: WEF; 2013.
[31] World Economic Forum (WEF). The global competitiveness report 2013-2014. Geneva: WEF; 2014.
[32] World Economic Forum (WEF). The global information technology report 2014. Geneva: WEF; 2014.
[33] Yusuf S, Nabeshima K. Some small countries do it better: rapid growth and its causes in Singapore, Finland, and Ireland. Washington, D.C: The World Bank; 2012.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Visiting Professor of National University of Singapore, Visiting Professor of University of Jyväskylä, Finland and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland. (kanaveed@student.jyu.fi).

Pekka Neittaanmäki graduated from University of Jyväskylä and is currently a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland. (pekka.neittaanmaki@jyu.fi).

PV

OPERATIONALIZATION OF UNCAPTURED GDP - INNOVATION STREAM UNDER NEW GLOBAL MEGA-TRENDS

by

Chihiro Watanabe, Kashif Naveed, Pekka Neittaanmäki and Yuji Tou, 2016

Technology in Society, vol. 45, pp. 58-77

Technology in Society 45 (2016) 58–77

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Operationalization of un-captured GDP - Innovation stream under new global mega-trends

Chihiro Watanabe [a, b, c, *], Kashif Naveed [a], Pekka Neittaanmäki [a], Yuji Tou [d]

[a] University of Jyväskylä, Finland
[b] National University of Singapore, Singapore
[c] International Institute for Applied Systems Analysis (IIASA), Austria
[d] Tokyo Institute of Technology, Japan

ARTICLE INFO

Article history:
Received 11 December 2015
Accepted 26 February 2016
Available online 15 March 2016

Keywords:
Un-captured GDP
Co-evolution of 3 mega-trends
Interactive return gain structure
Muscular economic environment

ABSTRACT

With the understanding that current ICT-driven global development depends on a trend shifting from traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality to new co-evolution of the Internet, un-captured GDP, and supra-functionality beyond economic value, the following hypothetical view was postulated:

The disparity between the world's ICT leader countries with respect to happiness/welfare amidst great stagnation (Finland) or conspicuous economic growth (Singapore) can be attributed to the difference of the state in the above shifting trends.

The foregoing hypothetical view was demonstrated on the basis of an empirical analysis measuring dependency on un-captured GDP, which is a key factor identifying the state of the shifting trends. This dependency is based on a comprehensive review of the consequences of three mega-trends that lead to the respective co-evolution and on the review of the development of trajectories relevant to these mega-trends.

Noteworthy findings were obtained on the consequences of the development trajectory option, particularly on the shift from traditional co-evolution to new co-evolution resulting in differences in interactive return gain structure. Also significant policy suggestions essential for identifying government/business roles in the context of new innovation stream were received. The importance of transferring government ability in innovation, collaboration and absorption to business was stressed, as this creates a virtuous cycle between "muscular" economic environment development and increase in the "muscularity" of indigenous firms.

1. Introduction

1.1. ICT-driven development under Co-evolution of 3 mega trends

Advances in information communication technology (ICT) can largely be attributed to the dramatic advancement of the Internet.[1] This has changed the computer-initiated ICT world significantly. The Internet promotes free culture, the consumption of which provides utility and happiness to people but cannot be captured by GDP data (Lowrey, 2011 [18], Rifkin, 2014 [22]). With a greater volume of unpriced digital goods introduced each year, this traditional GDP heuristic is becoming less useful (Brynjolfsson and McAfee, 2014 [2]).

Un-captured GDP has become the major source of consumer's utility (happiness in consumption) as analyzed in an earlier paper (Watanabe et al., 2015 [32]). This corresponds to consumer preferences shift from economic functionality to supra-functionality beyond economic value, encompassing social, cultural, aspirational, tribal, and emotional values. This shift, in turn, induces further advancement of the Internet, leading to a co-evolution of the foregoing three mega-trends (advancement of ICT, paradigm change and people's preferences shift).

Consequently, the current ICT-driven global development

* Corresponding author. University of Jyväskylä, Finland.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] As shown by Tapscott in his best -seller "The Digital Economy" (1997) [26], the Internet has changed the way of business and daily life dramatically. The digital economy is also known as the Internet economy, the new economy, or web economy.

http://dx.doi.org/10.1016/j.techsoc.2016.02.008

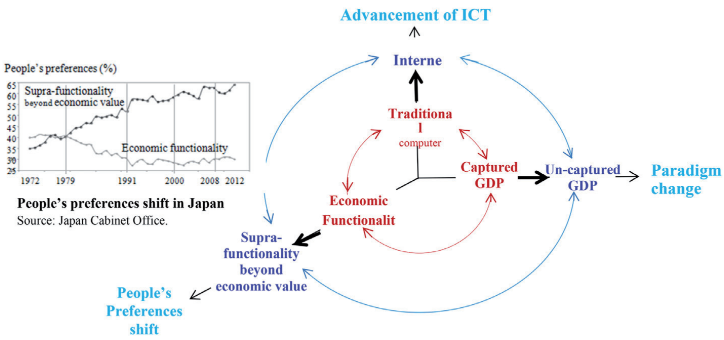


Fig. 1. Shifting Trend in the Co-evolution of the 3 mega-trends.

depends on the shifting trend in the following contrasting co-evolutional mega-trends as illustrated in Fig. 1:

a. Traditional co-evolution of ICT, captured GDP, and economic functionality.
b. New co-evolution of the Internet, un-captured GDP, and supra-functionality.

1.2. High competitiveness by global ICT leaders

1.2.1. Highest competitiveness during the great stagnation

While the majority of countries that are advanced in ICT confront "the great stagnation" due to a trap in ICT advancement (Watanabe et al., 2015, 2015 [31,32]), certain countries can sustain their highest ICT-driven global competitiveness as demonstrated in Table 1. This suggests resilience beyond economic value.

Table 1 suggests that Finland and Singapore, which hold the leading positions in both world ICT ranking and global competitiveness ranking, can be considered countries of resilience on ICT-driven global competitiveness.

1.2.2. Competitiveness structure in ICT-Advanced countries

Inspired by the foregoing observation, Table 2 compares institutional factors governing competence in 12 ICT-advanced countries in 2013.

Table 2 shows that Finland and Singapore, which are regarded as *ICT-driven countries of resilience on ICT-driven global competitiveness* share a notable similarity on institutional competitiveness as global competitiveness, ICT competitiveness, qualities of human capital and educational system and similar population size. They demonstrate significant disparity on economic performance (GDP/capita, GDP growth rate, unemployment ratio) and welfare/happiness level (inequality, birth rate, happiness).

1.3. Conspicuous contrast in growth rate between ICT leaders

Based on the foregoing review, Fig. 2 shows the contrast between economic performance represented by GDP growth rate and happiness/welfare level in 12 ICT-advanced countries.

Fig. 2 demonstrates a conspicuous contrast between the world's ICT leader countries, Finland and Singapore, with respect to their GDP growth rates and happiness/welfare levels. Despite the great stagnation of 0.57% *p.a.*, Finland enjoys the highest level of happiness/welfare, as demonstrated by inequality (the lowest level of inequality between nations measured by GINI index in 12 ICT-advanced countries compared), birth rate (the highest level after Israel and the US) and happiness score (the highest level after Denmark, Norway and Switzerland, which share the world top 3 levels). Singapore has the lowest level of happiness/welfare as well as the lowest inequality (highest GINI index) and birth rate and almost the lowest happiness score, notwithstanding its conspicuously high GDP growth rate as 5.85% *p.a.*

1.4. Hypothetical view

There is a conspicuous contrast between the world's ICT leaders as *ICT-driven countries of resilience with respect to ICT-driven global competitiveness*. Happiness/welfare under the great stagnation in Finland and economic growth in the "choking society" of Singapore prompt us towards a hypothetical view that such a contrast can be derived from the difference of the state in the shifting trend within 3 mega-trends (Fig. 1).

Table 3 compares the magnitude of the Internet use between Finland and Singapore in 2013.

The table shows that contrary to Finland's high dependency on the Internet, Singapore's dependency remains at a relatively lower level. Singapore's online shopping experience ratio remains at 30%, and its share of retail sales remains at 2% – much lower than Finland's 48% and 9%, respectively. A similar contrast can be observed

Table 1
World ICT ranking top 5 countries *(2011–2014)*.

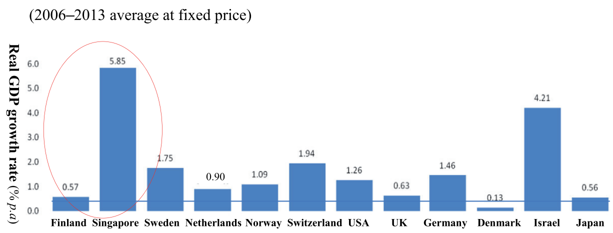
ICT ranking	1	2	3	4	5
2014	Singapore (2)	Finland (4)	Sweden (10)	Netherlands (8)	Norway (11)
2013	Finland (3)	Singapore (2)	Sweden (6)	Netherlands (8)	Norway (11)
2012	Finland (3)	Singapore (2)	Sweden (4)	Netherlands (5)	Norway (15)
2011	Sweden (3)	Singapore (2)	Finland (4)	Denmark (8)	Switzerland (1)

Figures in parentheses indicate global competitiveness ranking.
Sources: The Global Information Technology Report (WEF, annual issues), The Global Competitiveness Report (WEF, annual issues). [34-38]

Table 2
Comparison of factors governing competence in 12 ICT-advanced countries *(2013)*.

	FIN Finland	SGP Singapore	SWE Sweden	NLD Netherlands	NOR Norway	CHE Switzerland	USA USA	UK UK	DEU Germany	DNK Denmark	ISR Israel	JPN Japan
Population (million)	5.5	5.4	9.6	16.8	5.1	8.0	316.4	64.1	80.8	5.6	7.9	127.3
Global *rank* competitiveness	3	2	6	8	11	1	5	10	4	15	27	9
ICT *rank* competitiveness	1	2	3	4	5	6	7	9	12	13	15	16
Human capital *rank*	2	3	5	4	7	1	16	8	6	9	25	15
Quality of *rank* education system	2	3	17	12	18	1	25	26	14	21	56	50
GDP/capita (1000 US$)	47.1	54.8	57.9	47.6	100.3	81.3	53.1	39.6	45.0	59.2	37.0	38.5
GDP growth rate (2006–13% *pa*)	0.57	5.85	1.75	0.90	1.09	1.94	1.26	0.63	1.46	0.13	4.21	0.56
Unemployment ratio (%)	8.14	1.90	8.00	6.73	3.50	3.16	9.03	7.85	6.53	7.02	6.28	4.70
Inequality (GINI index)	19	45	30	28	38	26	47	39	35	28	41	34
Birth rate	1.9	1.2	1.9	1.8	1.9	1.5	2.1	1.9	1.4	1.9	2.9	1.4
Happiness *rank*	7	30	5	4	2	3	17	22	26	1	11	43

Sources: Watanabe et al., 2015 [32] Table 3. [39,40]



World Rank/level		FIN	SGP	SWE	NLD	NOR	CHE	USA	UK	DEU	DNK	ISR	JPN
ICT (rank)		1	2	3	4	5	6	7	9	12	13	15	16
Global competitiveness (rank)		3	2	6	8	11	1	5	10	4	15	27	9
Happiness / Welfare	Inequality (GINI index)	19	45	30	28	38	26	47	39	35	41	34	41
	Birth rate	1.9	1.2	1.9	1.8	1.9	1.5	2.1	1.9	1.4	2.9	1.4	2.9
	Happiness (Score)	7.5	6.5	7.5	7.5	7.7	7.6	7.1	6.9	6.7	7.3	6.1	7.3

Fig. 2. Conspicuous Contrast in GDP growth rate in ICT-Advanced countries *(2013)*. Sources: Same as Table 2.

Table 3
Comparison of the magnitude of the internet use between Finland and Singapore *(2013)*.

		Finland	Singapore
Internet dependency (%)		93	75
Online shopping (%)	Experience ratio	48	30
	Share of retail sales	9	2
	Clothing/footwear purchase	Popular	4
B2B Internet use (world rank)		1	16

Sources: ITU (2014) [11], WEF (2014) [38], Statistics Finland (2015) [25], Singapore Department of Statistics (2015) [24].

also in B2B Internet use.

As analyzed in an earlier paper (Watanabe et al., 2015 [32]), the lower level in the Internet dependency in Singapore corresponds to that country's lower level of dependency on un-captured GDP. In addition, lower dependency on the Internet translates to a lower level in shifting from economic functionality to supra-functionality beyond economic value that corresponds to consumers' contemporary preferences, as demonstrated also in an earlier paper (Watanabe et al., 2015 [31]).

These observations prompt us for a hypothesis developed further with respect to the shifting state in the co-evolution of the 3 mega-trends (Fig. 1); that is, **while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*", Singapore has kept to its former type of co-evolution.**

While a huge number of analyses have been conducted on the impacts of the advancement of the Internet, no-one has ever undertaken the analysis of the structural impacts of the above shift.

This paper attempts to demonstrate the above hypothetical view by measuring un-captured GDP of the two world's ICT leader

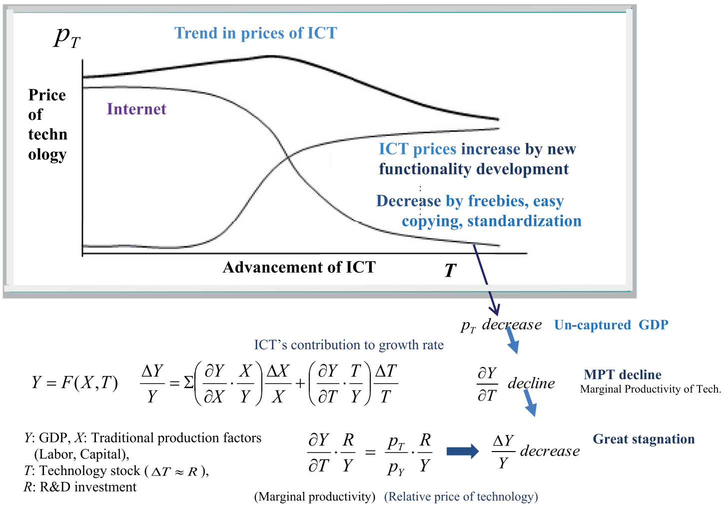


Fig. 3. ICT's two identical faces.

countries over the last two decades. That un-captured GDP explicitly demonstrates the state of the shifting trend in the co-evolution of 3-mega-trends.

To date, several attempts have been made to measure un-captured GDP in the context of *beyond GDP*, which includes "true wealth and the well-being of nations" (Wesselink et al., 2007 [33]), "quality of human life while living within the carrying capacity of the supporting ecosystems" (Costanza et al., 2009 [5]), "quest for a measure of social welfare" (Fleurbaey, 2009 [7]), "well-being, economic welfare and sustainability" (Bleys, 2012 [1]), and "global genuine progress" (Kubiszewski et al., 2013 [17]). However, no-one has so far attempted to measure un-captured GDP due to digital economy and derived from the dramatic advancement of the Internet. In order to link this issue to un-captured GDP problem driven by digital innovation, Brynjolfsson and McAfee (2014 [2]) have pointed out that "the rise in digital innovation means we need innovation in our economic metrics." Prompted by this understanding, a practical method to measure un-captured GDP was developed by following up earlier efforts in developing a new method for measuring the magnitude of un-captured GDP (Watanabe et al., 2015 [32]). Consequently, the state in the shifting trend in co-evolution of 3-mega-trends was identified.

Section 2 reviews the consequences of the 3 mega-trends. Section 3 compares the development trajectories impacting on un-captured GDP of the world's ICT leader countries. In Section 4, numerical analyses are conducted to demonstrate a hypothetical view to measure un-captured GDP. Based on this demonstration, Section 5 reviews the consequences of the strategic option. Finally, Section 6 briefly summarizes noteworthy findings, implications and suggestions for further advancement of service innovation.

2. Consequences of the 3 mega-trends

2.1. Advancement of ICT and the trap in it due to its two faces

As reviewed in an earlier paper (Watanabe et al., 2015 [31]), while advancement of ICT generally contributes in enhancing the prices of technology by increasing new functionality development, the dramatic advancement of the Internet tends to decrease prices of technology due to its nature (incl. freebies, easy copying and mass standardization), as demonstrated in the upper part of Fig. 3.

Consequently, the prices of technology in economies that are highly advanced in ICT may start experiencing a decreasing trend. This decrease in prices corresponds to the decline in marginal productivity of technology given the maximum profit behavior under the competitive circumstances, resulting in decreasing growth rate as outlined in the lower part of Fig. 3. This can be the structural source of the trap in ICT advancement for ICT-advanced nations/firms facing a vicious cycle between advancement of ICT and its marginal productivity decline. The above decrease in prices can be thought of as an economic representation of un-captured GDP.

2.2. Un-captured GDP

2.2.1. Emerging mechanism

While the dramatic advancement of the Internet has accelerated ICT advancement, it also has significantly changed the computer-initiated ICT world. The Internet promotes freer culture, the consumption of which provides utility and happiness to people. However, this utility and happiness cannot be captured through GDP that measures revenue. Such shifting from captured GDP to un-captured GDP could correspond to the transfer of production efforts as explained below.

Traditionally, all production efforts have been attributed to the motivation of the producer who tries to obtain a compensating return. However, certain production efforts have been transferred from producers to consumers, which justifies freebies to both producers and consumers.

Consequently, un-captured GDP has become the major source of consumer utility (happiness and gratification by consumption).

Thus, un-captured GDP can be traced, from both sides of the transaction, as.

(i) New function of online intermediaries such as e-commerce, online advertising and search engines, and

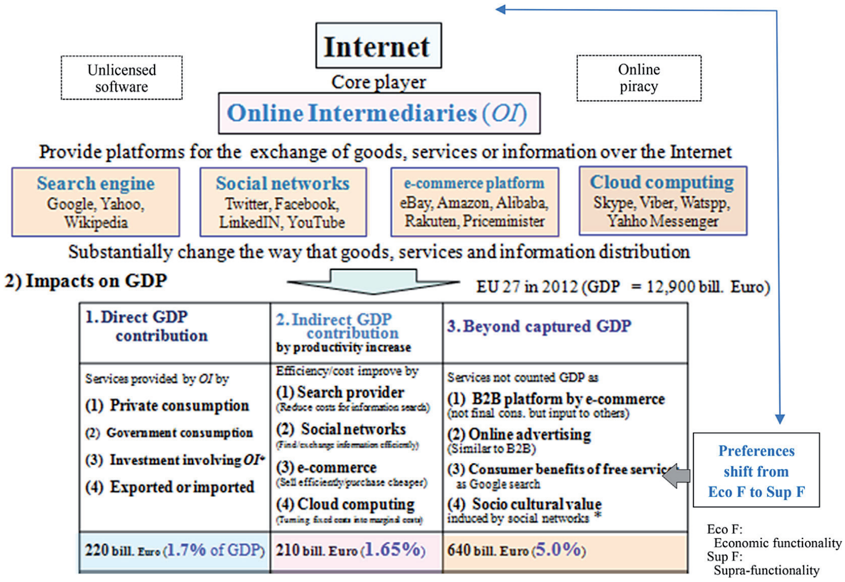


Fig. 4. Sources And impacts of un-captured GDP in the context of Co-evolution. Figures in the bottom raw indicate estimated impacts on EU 27 in 2012 exclusive of marked * (1 (3) and 3 (4)). Source: Based on Copenhagen Economics, 2013 [4].

(ii) Consumer's preferences shift from economic functionality to supra-functionality beyond economic value.

2.2.2. Both sides of un-captured GDP emergence

2.2.2.1. New services provided by online intermediaries. Emergence of un-captured GDP stems from the identical nature of online intermediaries who provide platforms for the exchange of goods, services or information over the Internet. Sources and impacts of un-captured GDP in the context of co-evolution of the Internet advancement and people's preferences shift are illustrated in Fig. 4.

While the dramatic advancement of the Internet creates significant value for e-commerce related to the B2B platform, this

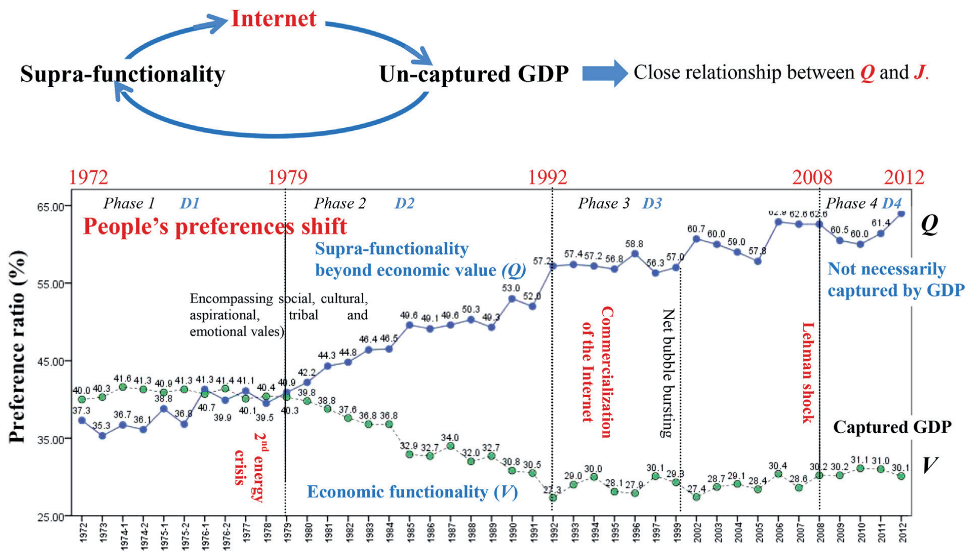


Fig. 5. Trends In the shift of Japanese People's preferences *(1972–2012)*. Source: National Survey of Lifestyle Preferences (Japan Cabinet Office, annual issues) [13].

Elasticity of Utility to Consumption in 6 Countries (2013)

	Finland	Singapore	USA	UK	Germany	Japan
Efficiency of *J* inducement of *I* 1. *J* elasticity to *I* (ε_{ij})	0.75	0.39	0.55	0.39	0.22	0.21
Efficiency of *J* inducement of *C* 2. ***J* elasticity to *C*** (ε_{cj})	**0.23**	**0.49**	**0.37**	**0.15**	**0.10**	**0.10**
Efficiency of *I* inducement of *C* 3. ***I* elasticity to *C*** ($\varepsilon_{ci} = \varepsilon_{cj} / \varepsilon_{ij}$) (2/1)	**0.30**	**1.27**	**0.68**	**0.40**	**0.47**	**0.48**
Extent of reflection of *U* to *C* 4. ***U* elasticity to *C*** (ε_{cu}) (2+3)	**0.53**	**1.76**	**1.05**	**0.55**	**0.57**	**0.58**

U: utility *C*: Traditional consumption, *J*: Internet Dependency, *I*: ICT stock,

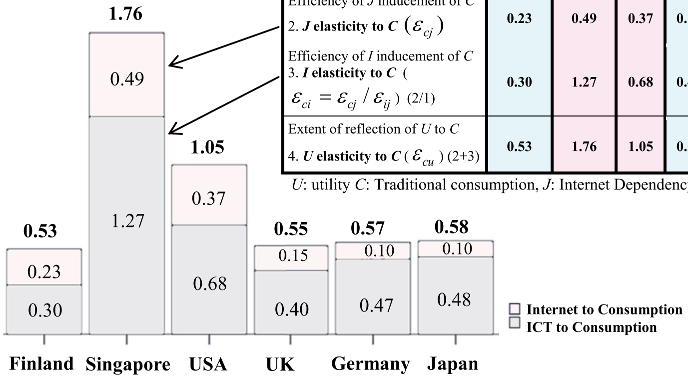


Fig. 6. Elasticity Of utility to consumption in six countries *(2013)*.

value is not captured in the traditional GDP as it does not represent final consumption but rather consumption by other business sectors as an input to final products. This applies to the value of online advertising as well. Like B2B, e-commerce is not final consumption and therefore not included in GDP. While consumers benefit greatly from free services such as Google search, the value of these services is not captured in GDP as there is no direct payment for the search engine. Huge socio-cultural values derived from social networks are similar to supra-functionality beyond economic value and also remain beyond the capture of traditional GDP.

The EU estimated that un-captured GDP, exclusive of that induced by social networks, amounts to 5% of EU27's GDP in 2012 (Copenhagen Economics, 2013 [4]). If the significant shift in people's preferences to supra-functionality beyond economic value, as estimated in an earlier paper (Watanabe et al., 2015 [31]), and the subsequent huge un-captured GDP had been derived from the mountainous socio-cultural value, the estimated value of 5% would be more than double. In addition, we should note that un-captured GDP derived from unlicensed software and online piracy, among other illegal or unauthorized ways, is indispensable for those in the computer-initiated ICT world.

2.2.2.2. Consumers' preferences shift. Dependency on un-captured GDP corresponds to the shifting trend in people's preferences from economic functionality to supra-functionality beyond economic value, as analyzed in an earlier paper (Watanabe et al., 2015 [31]). Supra-functionality induces further advancement of the Internet, as demonstrated in the same paper.

Thus, new co-evolution of the advancement of the Internet, increasing dependency on un-captured GDP and people's preferences shift to supra-functionality emerges as illustrated in Fig. 5.

The new co-evolution satisfies utility by corresponding to consumers' preferences shift to supra-functionality beyond economic value. Such utility, depending on un-captured GDP, does not increase consumption as measured by traditional GDP data.

Thus, elasticity of utility to consumption, which represents percentage increase in consumption in response to 1% increase in utility, demonstrates the state of a country's shift from traditional

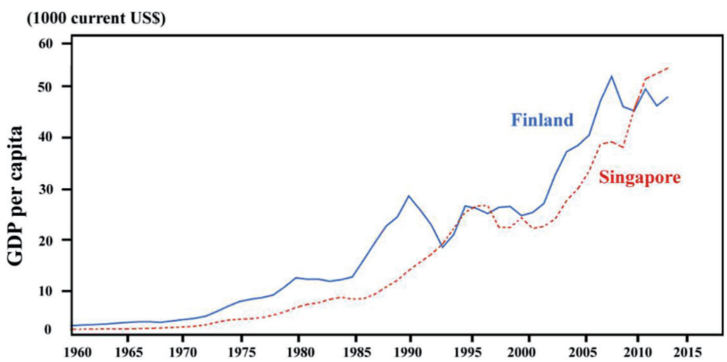


Fig. 7. Trends in GDP per capita in Finland and Singapore *(1960–2013)*. Source: World Development Indicators (The World Bank annual issues) [28].

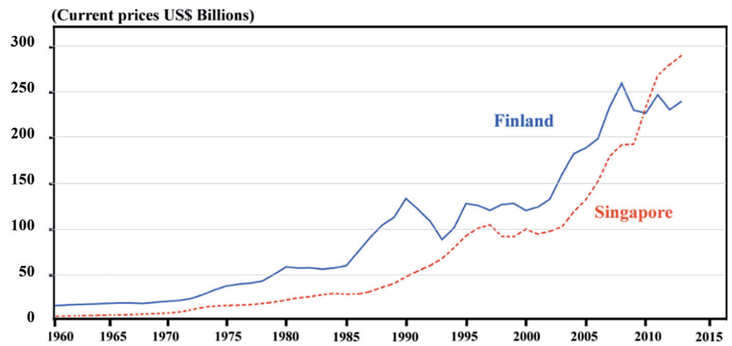


Fig. 8. Trends in GDP in Finland and Singapore in current prices *(1960–2013)*. Source: World Development Indicators (The World Bank annual issues) [28].

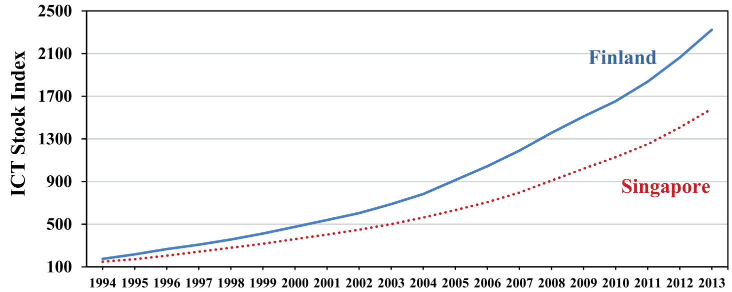


Fig. 9. Trends in ICT stock in Finland and Singapore - index (1994 = 100) *(1994–2013)*. Source: Author's estimate with reference to the Conference Board, Total Economy Database [27].

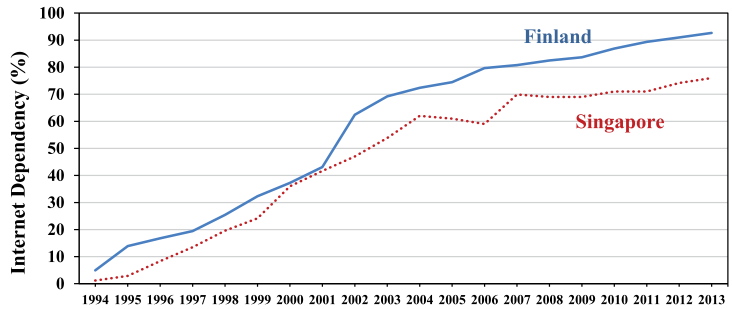


Fig. 10. Trends in internet dependency in Finland and Singapore *(1994–2013)*. Source: ITU's World Telecommunication / ICT Indicators Database [11].

co-evolution of ICT, GDP and economic functionality to this new co-evolution.

Fig. 6 compares this elasticity between six ICT-advanced countries in 2013 (Watanabe et al., 2015 [32]). The figure clearly demonstrates the contrast between the world's ICT leader countries, Finland and Singapore. Contrary to the low level of this elasticity (which represents high dependency on un-captured GDP and high state in the shift to new co-evolution) in Finland, Singapore demonstrates extremely high level of elasticity suggesting high dependency on traditional co-evolution based on traditional GDP, which enables high rate of GDP growth.

This observation supports the hypothetical view that while Finland has shifted from "*traditional co-evolution of ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*", Singapore has kept to the type of former co-evolution.

3. Trajectories impacting on un-captured GDP in the world's ICT leader countries

Inspired by the foregoing postulate that un-captured GDP can be traced, from both sides, as a new function of online intermediaries and consumer's preferences shift, the development trajectories

Table 4
Trends in ICT usages by individual, business and government in Finland and Singapore *(2010–2014)* – world rank.

		2010	2011	2012	2013	2014
Individual Usage	Finland	2	5	6	6	5
	Singapore	7	10	11	10	11
Business Usage	Finland	8	5	3	2	4
	Singapore	10	14	14	15	14
Government Usage	Finland	24	17	10	8	17
	Singapore	3	2	1	1	1

Sources: The Global Information Technology Report (WEF, annual issues).

3.2. ICT/internet development trajectory

Second, ICT development trajectories of ICT stock, Internet dependency and ICT usage in the two countries over the last two decades were compared.

3.2.1. ICT stock

Over the last two decades, Finland has maintained a growth level of ICT stock that is higher than that in Singapore, as compared in Fig. 9.

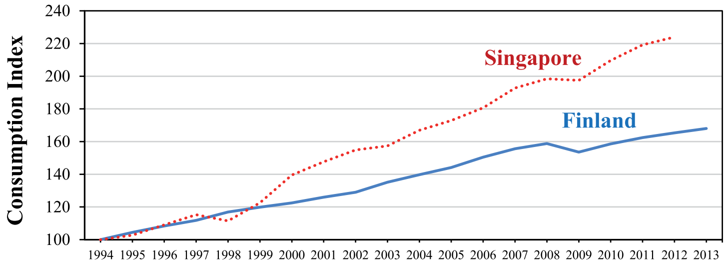


Fig. 11. Trends in household consumption in Finland and Singapore- index (1994 = 100): *(1994–2013)*. Source: UN Statistics Division, Household Final Consumption Expenditure (UN, 2014) [29].

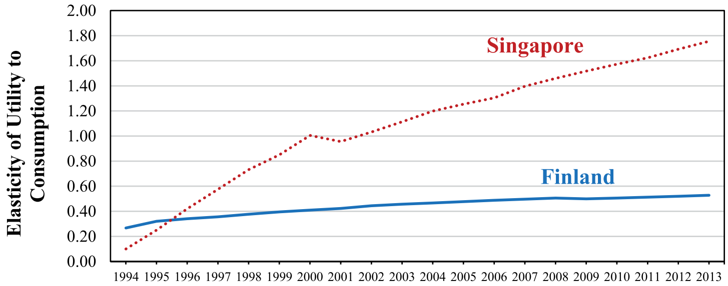


Fig. 12. Trends in elasticity of utility to consumption in Finland and Singapore *(1994–2013)*. In order to avoid statistical noise, Singapore's elasticity for 1994–1996 are adjusted taking backward trend between 1997–2000. Source: Authors Computation (Technology in Society 41(2), 2015, Fig. 5).

impacting on the emergence of un-captured GDP in the world's ICT leader countries were traced.

3.1. Captured GDP trajectory

First, GDP growth trajectories in Finland and Singapore were compared.

3.1.1. GDP per capita

Fig. 7 demonstrates that Finland and Singapore maintain parallel paths for their GDP per capita increase. Singapore slightly exceeds this path orientation level from 2010 onwards.

3.1.2. GDP at current prices

A similar trend can be observed in both countries also in their GDP at current prices, as shown in Fig. 8.

3.2.2. Internet dependency

Both countries maintained almost a similar level of Internet dependency in the 1990s. Since the start of the new millennium, however, Finland has maintained a level that is significantly higher than that of Singapore, as demonstrated in Fig. 10. This suggests that in case of the two countries there is a certain reason for the contrast in un-captured GDP dependency.

3.2.3. Trend in ICT usage: correspondence to People's preferences shift

ICT usage by individuals, business and government was compared. Given the dramatic advancement of the Internet and its correspondence to people's preferences shift to supra-functionality beyond economic value, countries' efforts for new co-evolution of 3 mega-trends should be devoted to enhancing the usage level of individuals and business and not only that of government.

Table 4 compares the trends in ICT usage by individuals, business and government in Finland and Singapore over the last 5 years.

The table indicates that while Finland has devoted itself

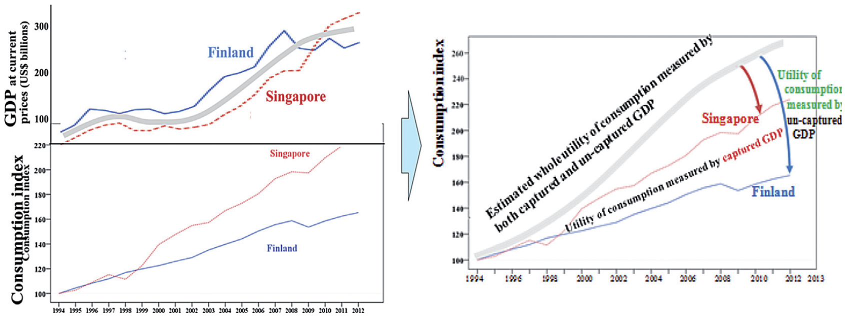


Fig. 13. Utility of consumption measured by un-captured GDP.

primarily to individual and business ICT usage, Singapore demonstrates a conspicuous reliance on its government's ICT usage rather than relying on individual and business usages. This observation suggests that Finland's shift to new co-evolutionary trajectory has been more extensive than that of Singapore.

3.3. Consumption behavior

Third, consumption behavior, both by volume and quality, was compared.

3.3.1. Household consumption

In order to examine the volume of consumption measured by captured GDP, the trends in household consumption in both countries were traced as illustrated in Fig. 11. The figure demonstrates that, notwithstanding with the similar level of income as shown in the comparisons of Figs. 7 and 8, Singapore depends on consumption at a much higher level than Finland. This contrast suggests the differences in the ways of consumption in the two countries: in Singapore the consumption is dependent on captured GDP and in Finland on un-captured GDP.

3.3.2. Dependency of GDP – elasticity of utility to consumption

By means of the measurement of the elasticity of utility to consumption, as introduced in Fig. 6, the trends in this elasticity in Finland and Singapore over the period 1994–2013 were measured as illustrated in Fig. 12. These trends support the above view with respect to dependency on consumption related to captured GDP in Singapore and consumption related to un-captured GDP in Finland.

4. Measurement of un-captured GDP

4.1. Suggestion based on factual observation

The foregoing factual observations with respect to development trajectories impacting on the emergence of un-captured GDP in Finland and Singapore, the world's ICT leader countries, suggest the following conceptual idea which is supportive of measuring un-captured GDP.

The significant difference in consumption levels between Finland and Singapore (Fig. 11), notwithstanding the similar level of GDP of those countries (Figs. 7 and 8), can be attributed to the difference in consumption based on un-captured GDP as illustrated in Fig. 13.

This difference can be attributed to the difference of the state of spin-off in the shifting co-evolution of the 3 mega-trends.

The locomotive for such spin-off impacting un-captured GDP can be:

(i) Stimulation from ICT advancement, and
(ii) Inducement by people's preferences shift.

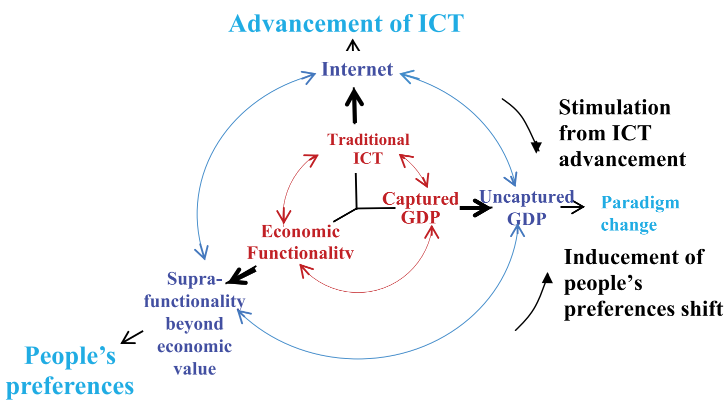


Fig. 14. The locomotive for the spin-off impacting un-captured GDP.

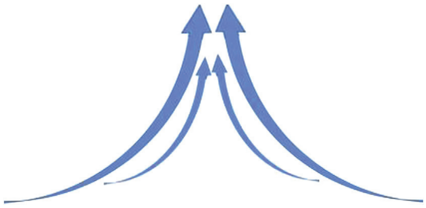


Fig. 15. Concept of the Locomotive of Spin-off derived from an Equilibrium Leading to Lifting Power.

as reviewed in Section 2 and illustrated in Fig. 14.

Both maintain equilibrium, leading to a lifting power as illustrated in Fig. 15. This can be depicted by the following equation consisting of primary impacts and secondary impacts.

Impacts on un-captured GDP

$$Z = A \cdot X^{\alpha} \cdot e^{\beta Y^{n}} \approx A \cdot X^{\alpha}(1+\beta \cdot Y^{n}) \qquad \beta \cdot Y^{n} << 1$$

Scale factor Primary impacts Secondary impacts

X and *Y* refer to stimulation/inducement by the advancement of the Internet and people's preferences change, α, β are coefficients, and *n* is the power factor.

4.2. Estimate of un-captured GDP in World's ICT leader countries

On the basis of the foregoing suggestions, an equation measuring the Internet-driven un-captured GDP was developed as summarized in the Appendix. Utilizing the equation, an empirical analysis identifying the governing factors of un-captured GDP in Finland and Singapore over the period 1994–2013 was carried out. The results of the analysis are summarized in Tables A1 and A2 in the Appendix.

Fig. 16 demonstrates the estimated un-captured GDP ratio (Un-captured GDP/captured GDP) in Finland and Singapore over the period of 1994–2013 with the highest and lowest possible estimates. Based on this, Figs. 17 and 18 show estimates of un-captured GDP at current prices in Finland and Singapore over the same period.

As the figures show, while Finland's captured GDP is lower than that of Singapore after 2010, Finland has a higher gross GDP (the sum of captured and un-captured GDP) as it depends on a much higher level of un-captured GDP than Singapore. This agrees with the preceding estimate comparing the elasticity of utility to consumption (Figs. 6 and 11) and suggests that Finland has shifted largely to un-captured GDP dependency while Singapore has kept its traditional GDP dependency.

People's preferences have been shifting to supra-functionality beyond economic value (Watanabe et al., 2015 [31]) and cannot necessarily be measured by GDP. In this, there is a great difference between the world's ICT leader countries: happiness and wellbeing amidst the great stagnation in Finland and economic growth amidst the choking society of Singapore (as explained in Section 1) can be explained by the contrasting un-captured GDP trends in the two countries.

4.3. Significance of a shift to new Co-evolution

With the above estimation of un-captured GDP in mind, in order to identify the possible shift from traditional co-evolution to new co-evolution, correlation between *the shift from computer-initiated ICT (I) to the Internet(J) initiative* and *the shift from captured GDP to un-captured GDP* in Finland and Singapore over the period 1996–2013 was analyzed. Aiming at measuring the advancement of the Internet in ICT-driven economy, the Internet productivity to ICT (*I/J*) was used as the proxy for this while un-captured GDP ratio (η) was used as the proxy for the shift to un-captured GDP.

The results of the analysis are summarized in Table A3, and the contrast between Finland and Singapore is illustrated by the correlation in Fig. 19. Looking at the figure, we note that Finland's inflection towards co-evolution of ICT advancement by means of the Internet productivity increase and increase in un-captured GDP dependency occurs around 2002 immediately after the bursting of the net bubble in 2000 and the subsequent emergence of

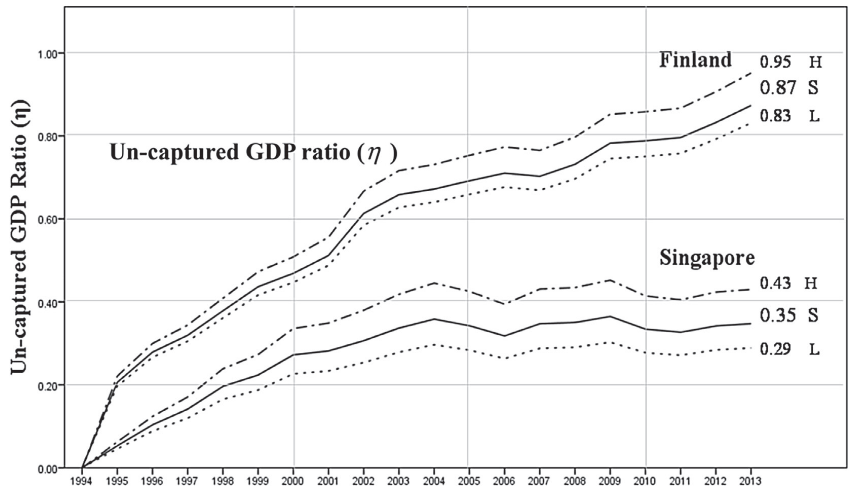


Fig. 16. Trends in un-captured GDP ratio in Finland and Singapore *(1994–2013)*. Un-captured GDP ratio (η) = Un-captured GDP/Captured GDP. S: Standard estimate, H: Higher possible estimate, L: Lower possible estimate.

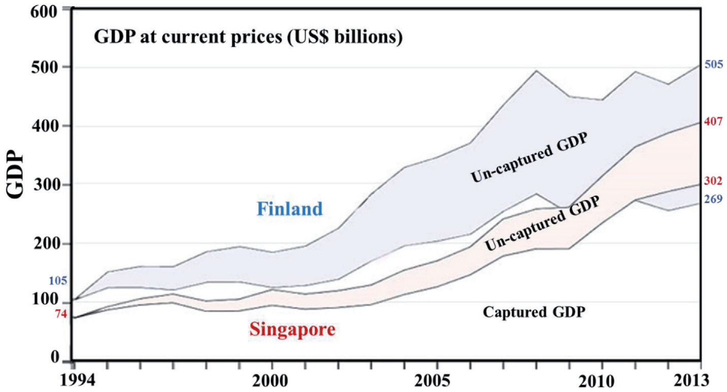


Fig. 17. Trends in captured and un-captured GDP in Finland and Singapore (*1994–2013*).

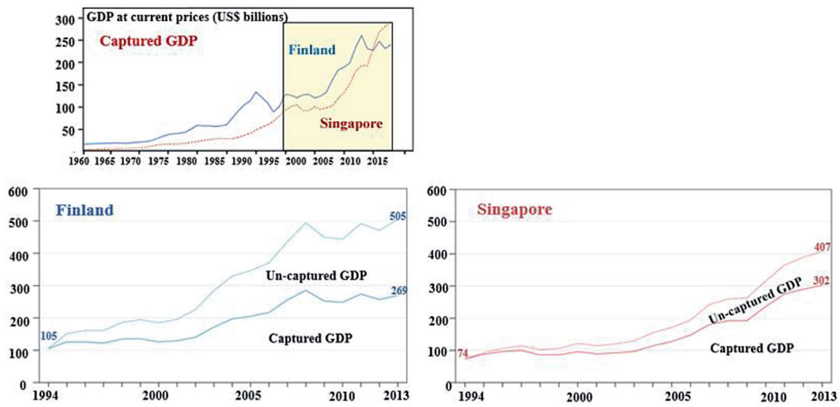


Fig. 18. Comparison of captured and un-captured GDP in Finland and Singapore *(1994–2013)*.Sources - Captured GDP: World Development Indicators (The World Bank, annual issues). Un-captured GDP: Author's estimate by Captured GDP x Un-captured GDP ratio (η).

substantial digital economy. Since then, Finland has shown higher elasticity of ICT advancement to un-captured GDP ratio, which suggests their active co-evolution. Contrary to such a conspicuous co-evolution in Finland, Singapore demonstrates its inflection to co-evolution fairly late, in around 2004, 2 years behind Finland and still with slightly negative elasticity.

As reviewed earlier, there has been significant co-evolution of the advancement of the Internet and un-captured GDP dependency and co-evolution of people's preferences shift with the advancement of the Internet as well. The contrasting co-evolution of the advancement of the Internet and un-captured GDP dependency in the two countries suggest that while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the advancement of the Internet, un-captured GDP, and supra-functionality beyond economic value*," Singapore has still kept to the former type of co-evolution.

Fig. 20 shows the contrast of co-evolution of each respective mega trend pair in Finland and Singapore over the period 1996–2013, adding a convincing demonstration on the above suggestion.

As illustrated on the left hand side of Fig. 21, the above-described shifting co-evolution leverages spin-off from the co-evolution of traditional mega-trends to new co-evolution of new mega-trends, leading to a spirally developing self-propagating dynamism similar to the development trajectory of multi-functional mobile phones (Watanabe et al., 2004 [30]). Such a dynamism can be depicted by the logistic growth function within a dynamic carrying capacity (LGDCC) that incorporates logistic growth carrying capacity. This is a self-propagating dynamism. On the other hand, simple logistic growth (SLG) function (sigmoid curve) incorporates fixed carrying capacity without any self-propagating function (Meyer and Ausbel, 1999 [20]).

The trajectories for Finland and Singapore in shifting to co-evolution dependent on un-captured GDP were examined by applying this theory. The table on the right side of Fig. 21 compares the applicability of the two countries' trajectories to LGDCC. While Finland fits better to LGDCC, Singapore remains with SLG without incorporating significant self-propagating factors. This comparison demonstrates that while Finland has been shifting to new co-evolutionary dynamism which is developing spirally, Singapore has remained with traditional co-evolution without self-

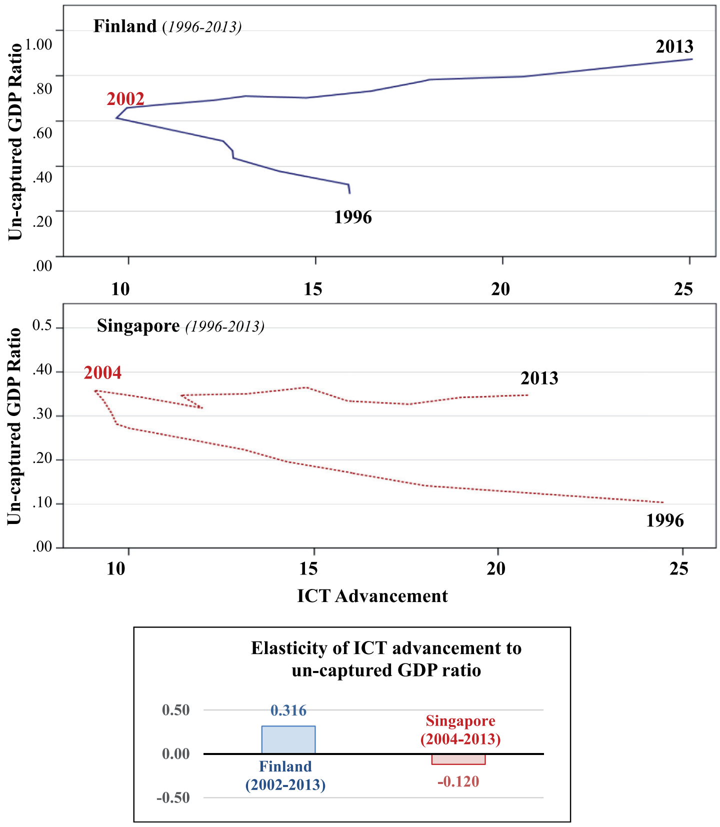


Fig. 19. Co-evolution of internet advancement and un-captured GDP shift in Finland and Singapore *(1996–2013)*. Internet advancement is measured by the Internet Productivity of ICT (*I/J*).

propagation.

All these analyses bear witness to the hypothetical view that while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*," Singapore has kept to the former type of co-evolution.

5. Consequences of the strategic option

Based on the above demonstration, the consequences of the strategic option were reviewed.

5.1. Interactive return gain structure from global interaction

5.1.1. Comparison of ICT-Advanced 12 countries

Fig. 22 compares the interactive return gain structure in ICT-advanced 12 countries.

Here the "Interactive return gain structure" implies nation's economic/industrial structure in a global economy and assesses whether the nation is gaining profits from abroad or losing domestic gains.

The top chart in Fig. 22 compares GDP growth rate in ICT-advanced 12 countries (Fig. 2), which again accentuates the contrasting trajectory between "happiness and welfare under the great stagnation" in Finland and other Nordic countries and "economic growth in a choking society" in Singapore and Israel. This contrast can be attributed to the difference in the state of the shifting co-evolution of the 3 mega-trends, as demonstrated in the preceding Section.

The chart in the middle of Fig. 22 compares the GNI (GNP)/GDP ratio. This ratio demonstrates the interactive return gain structure by comparing the state of gaining profits from abroad (value higher than 1) and the state of losing domestic gains (value lower than 1).[2]

It seems surprising that regardless of their notable GDP growth, both Singapore and Israel are losing their domestic gains while other countries are gaining profits from abroad in spite of being afflicted by the great stagnation.

[2] GNI (GNP) − GDP = Balance on income + Balance stemmed from the terms of trade. Balance on income has close relevance with Income balance in the international trade structure as Current balance = Trade balance + Service balance + Income balance + Current transfers (see the bottom chart in Fig. 22).

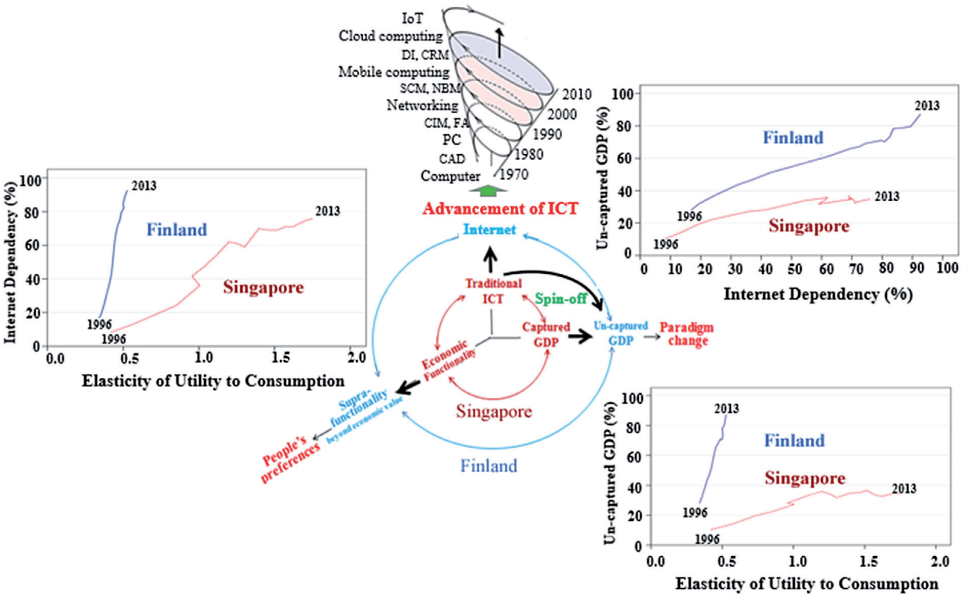


Fig. 20. Co-evolution of the internet, un-captured GDP and peoples preferences shift in Finland and Singapore *(1996–2013)*.

5.1.2. The structure resulting from losing domestic gains

It is a serious problem that "*growth-oriented countries lose domestic gains through interactions with other countries, notwithstanding their accentuating GDP growth*" as globally emerging digital innovation necessitates and accelerates multi-layer interactions.

This irony can be attributed to the consequences of the strategic option as shifting to un-captured GDP initiated new co-evolutionary trajectory or when clinging to captured GDP (which reacts to GDP growth) initiated traditional co-evolution.

Fig. 23 illustrates structural sources for losing domestic gains in growth-oriented countries such as Singapore.

Singapore has been depending largely on multi-national companies (MNCs) for its sustainable development (Yusuf and Nabeshima, 2012 [42]). Corresponding to the world-wide shift from captured GDP to un-captured GDP (Lowrey, 2011 [18], Rifkin, 2014 [22], Watanabe et al., 2015 [31], Brynjolfsson et al., 2014 [2]), MNCs have been developing knowledge and skills for un-captured GDP in Singapore and gained popularity for their products in the global market. On the other hand, Singapore's indigenous home companies (HCs) have relied on captured GDP for GDP growth and, as a result, their products have lost popularity in the global market. Consequently, Singapore has been losing domestic gains rather than gaining profits from the global market while maintaining their GDP growth that is conspicuously higher than in other ICT-advanced countries.

5.2. Engine and brake for improving the domestic gains structure

5.2.1. Institutional sources generating the engine and the brake

The above structure due to which Singapore is losing domestic gains can be attributed to its institutional systems that demonstrate its competence. Generally, strong organizational inertia (brake) exists that impedes change in the system. Therefore, an institutional engine that can leverage systems' change and is strong enough to overcome this brake is essential (Hofstede, 1991 [8]). Table 2 compares factors governing competence in Finland and Singapore. Singapore's strength in economic performance is accentuated by the contrast between a high level of captured GDP and weakness in happiness/welfare factors representing a low level of un-captured GDP.

5.2.2. Possible sources of the engine and the brake

5.2.2.1. Government and business initiatives in ICT usage. Based on the foregoing identification and inspired by the preceding review of the contrasting trends in the world's ICT leader countries with respect to their government and business ICT usages (Table 4), we can draw a detailed structure for ICT in government usage in Singapore and business usage in Finland (Watanabe et al., 2015 [32]). Fig. 9, among other data, indicates Singapore's government's superiority in vision, online service and ICT promotion while Finland demonstrates its superiority in innovation, absorptive capacity, staff training in business, and in B2C and B2B Internet use.

5.2.2.2. Institutional sources of disparity leading to contrasting trajectories. Similarly, we can identify contrasting factors in the state of happiness in Finland and Singapore (Watanabe et al., 2015 [32] Fig. 10): while generosity, lower inequality and freedom of choice contribute to Finland's higher rating, Singapore excels in perception of corruption and has higher income level.

5.3. Consequences of digital innovation

5.3.1. Consequences of digital innovation in World's ICT leader countries

Global expectations for the emergence of digital innovation, particularly of social innovation in this century, have been met, to a great extent, by new business models that can satisfy the historical needs more effectively, efficiently and sustainably. While

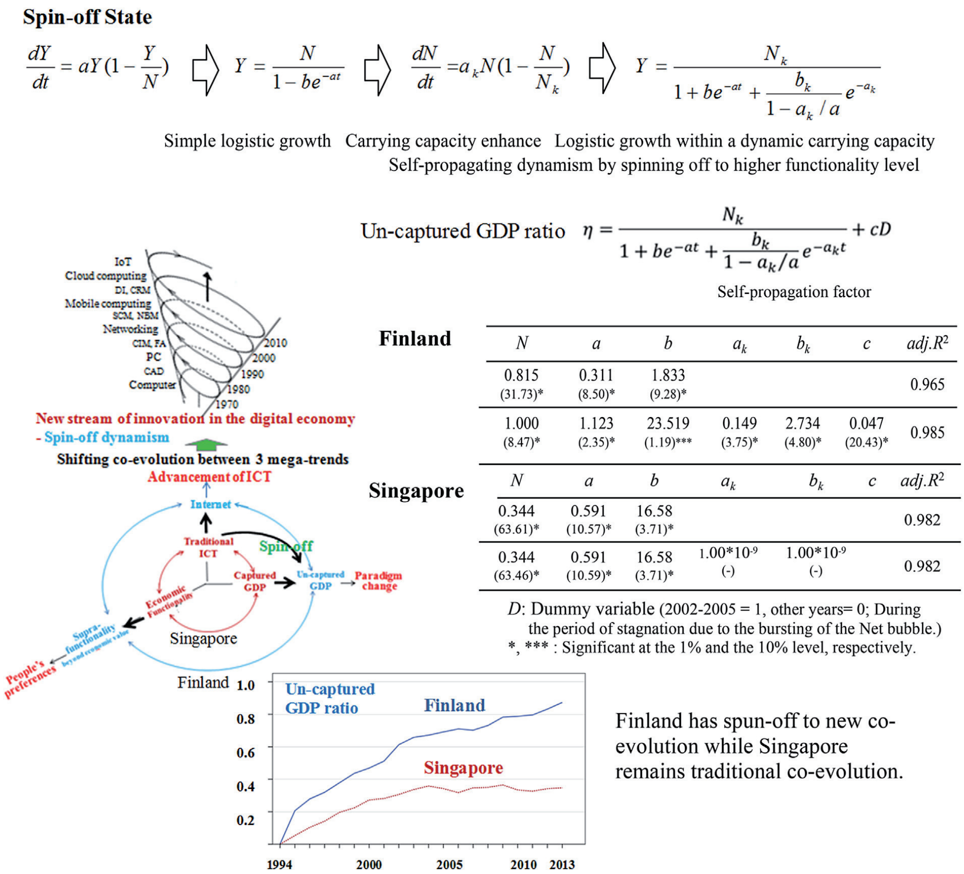


Fig. 21. Comparison between Finland and Singapore of spin-off dynamism leading to higher un-captured GDP dependence (*1994–2013*).

advancement of ICT has accelerated this process, as it facilitates interactions between stakeholders, social innovation is creating new sets of stakeholders with potentially different interest, goals, procedures and relations. Activation of interactions between these stakeholders is essential for sustaining qualified social innovation.

Thus, digital innovation creates new business models, which in turn leverage the advancement of ICT, especially in service innovation. All this depends on the institutional systems of the country.

Table 5 compares ICT-induced new business models in ICT-advanced 12 countries in 2013. As anticipated, Finland, the world's top ICT leader, holds the top position also in this ranking. However, Singapore, another of the world's top ICT countries, holds position 10 in the ranking, notwithstanding its top ICT position. This contrast suggests the need for further elaboration of the engine and brake in the context of digital innovation.

Table 5 Comparison of ICT-Induced New Business Models in 12 ICT-Advanced Countries *(2013)*- Rank among 143 countries[3]

Finland's most significant achievement and its strength can be accounted by its free general education which creates capacity for industry innovation, small income disparities, little poverty, and wide participation of women in working life (EU, 2015 [6]). These components construct the foundation of its social innovation (Karjaluoto et al., 2005, 2015 [15,16]).

Moreover, associational capacity and collaborative practices are essential for social innovation, and Finland demonstrates a high level of collaboration (Hoyssa, Bruun and Hukkinen, 2004 [9]). Skills and experience in learning, communicating and working together can be more important than many specified skills. Higher absorptive capacity in Finland (Pot and Vaas, 2008 [21]) makes it easier to step over structural holes in an institutional system (Kallio et al., 2010 [14]). Absorptive capacity consists of acquisition, assimilation, transformation, and exploitation. Building trust relationships between innovating partners for solving collective problems plays a decisive role (Kallio et al., 2010 [14]). Finland maintains superiority in creating a virtuous cycle based on trust (Hoyssa et al., 2004 [9]).

Table 6 demonstrates institutional sources of competence in industry's innovation capacity in Finland. The table supports the foregoing views and convinces us about their significant role as engines contributing to the emergence of ICT-induced new business models.

[3] Questionnaire survey "to what extent do ICTs enable new business models?"

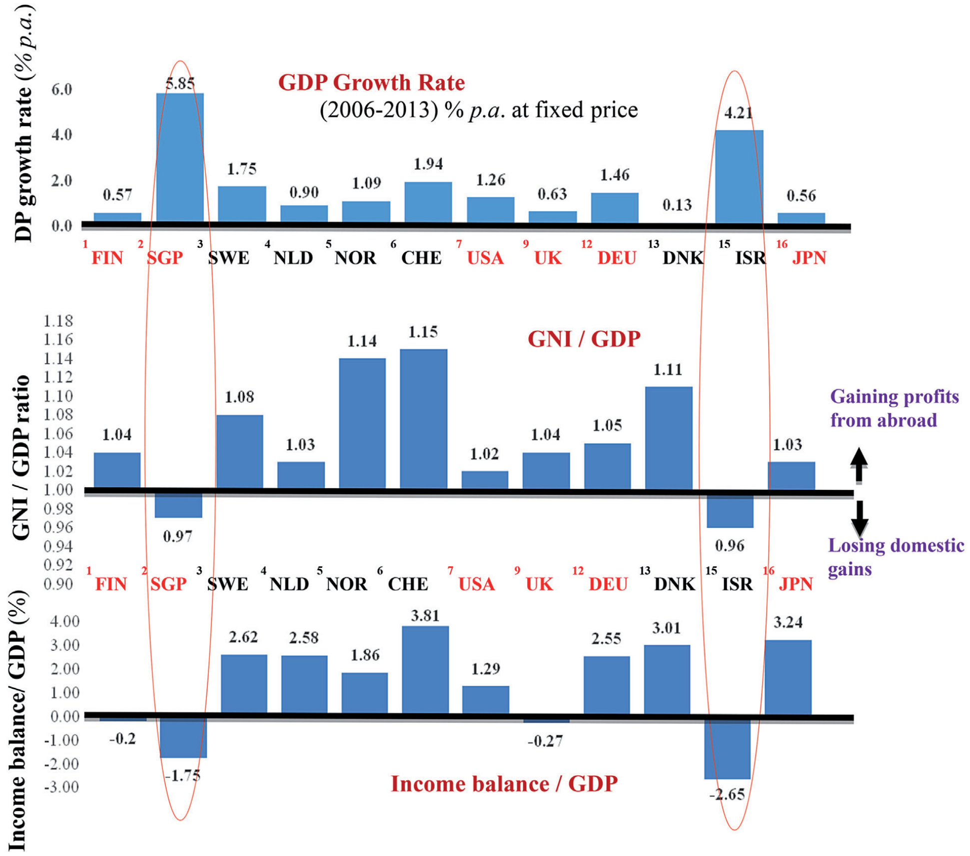


Fig. 22. Comparison of interactive return gain structure in 12 ICT-advanced countries *(2012, 2013 average)*. Figures on the country indicate the ICT competitiveness rank in 2013. Sources: World Economic Outlook Database (IMF 2013, 2014) [10], World Health Statistics 2014 (WHO 2014) [41], United Nations Statistics Division (2013, 2014), World Bank (2013, 2014).

Contrary to Finland, the biggest social innovation initiative in Singapore has long been provided by the Singapore government itself (Concern SG, 2015 [3]). This is the distinct government initiative in ICT usage demonstrated earlier. The government is actively engaged in shaping social institutions and practices through investment in human capital (Sherraden, 2015 [23]). What is unique about Singapore is not the nature of its social challenges in marginalized communities but that its ecosystem and economy are structured to be outward-facing and conductive to growth (Jacobs, 2013 [12]). Social policies are transformative rather than reactive, and institutional capacity is built to provide information which is accessible to researchers, service providers and policy planners.

While Singapore addresses the challenges of its evolving social landscape, there is a need for both short-term policy reviews and a mindset shift for the long term (Mathi and Mohamed, 2011 [19]).

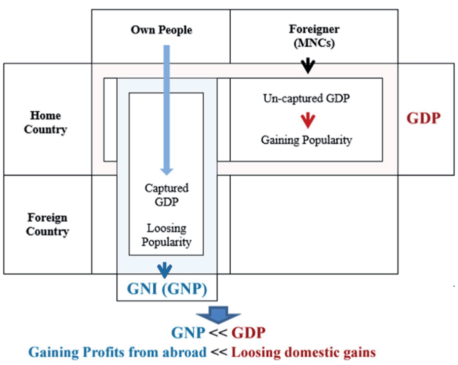


Fig. 23. Structural sources for losing domestic gains (The case of Singapore).

Table 5
Comparison of ICT Induced New Business Models in 12 ICT-Advanced Countries *(2013)*. - Rank in world 143 countries.[a]

1	3	6	6	10	11	14	15	17	19	25	32
FIN	SWE	NLD	UK	SGP	NOR	DEU	USA	CHE	JPN	ISR	DNK

[a] Questionnaire survey "to what extent do ICTs enable new business models?"
Source: The Global Innovation Index 2014 (WEF, 2014).

Table 6
Institutional Sources of Competence in Industry's Innovation Capacity in 12 ICT-Advanced Countries *(2013)* - Rank in world 148 countries.

	FIN	SGP	SWE	NLD	NOR	CHE	USA	UK	DEU	DNK	ISR	JPN	
ICT[1]	**1**	2	3	4	5	6	7	9	12	13	15	16	Networked Readiness Index
Innovation capacity[2]	**2**	18	7	9	12	1	5	8	3	13	4	6	Companies capacity to innovate
R&D expenditure[2]	**3**	8	7	18	19	1	5	12	4	10	6	2	Companies R&D spending
Collaboration[2]	**2**	4	10	12	14	1	3	5	9	22	8	17	University-industry collaboration in R&D
Absorptive capacity[1]	**7**	13	1	22	8	3	9	24	16	20	5	6	Firm level technology absorption
Trust[2]	**4**	23	2	5	3	8	9	14	16	1	33	30	Willingness to delegate authority

Sources: 1. The Global Information Technology Report 2014 (WEF, 2014). 2. The Global Competitiveness Report 2013–2014 (WEF, 2014).

The government's initiative has functioned efficiently in attaining its short-term policy target through GDP growth and by securing more job opportunities. Given the increasing shift from co-evolution initiated by traditional captured GDP to co-evolution initiated by un-captured GDP, it is essential to enhance industry's innovation capacity to improve the structure for gaining interaction returns. Thus, it would be a matter of urgency to transfer government competence to industry and create a muscular economic environment.

In endeavoring such transfer, Singapore's indigenous strength and cooperation in labor-employer relations cultivated by a long-lasting strong government initiative, as demonstrated in Table 7, should be fully utilized. The table demonstrates Singapore's exceptional strength in these relations, comparable to Nordic countries except Finland, and in distinct contrast with Israel.

Finland's ranking among Nordic countries in these relations is exceptionally low. Singapore's institutional knowhow has sustained its high ranking in these relations which are also essential for Finland for its social innovation quality.

5.3.2. *Implication of engine and brake*

These observations suggest the following contrast with respect to the engine and brake for improving the structure of interactive return gain in the context of service innovation in both countries, as shown through comparisons in Table 8.

The table suggests that Finland's advancement in shifting from traditional co-evolution to new co-evolution leveraged by the advancement of ICT, un-captured GDP, and supra-functionality beyond economic value as demonstrated in the preceding section can largely be attributed to business initiative with advanced innovation capacity, association capacity, collaborative practices, absorptive capacity, trusting relationship and increased number of women in labor force. All have contributed to the powerful engine to improve the structure of interactive return gain.

Contrary to such powerful engine in Finland by business initiative, while Singapore's strong government initiatives for accelerating its ICT advancement have played a significant role as an engine for the nation aspiring to the position of the world's ICT leader, these strong government initiatives have resulted in the delay of transferring business initiative which is essential in shifting from traditional co-evolution to new co-evolution.

Singapore has accomplished a broad-based "quantitative" social uplift over the last 5 decades as "*jobs for all, rising incomes for all, homes for all, quality schools and public healthcare for all, and neighborhoods and parks shared by all.*" Transferring the government's strong engine to business aiming at increasing the capacities of innovation, association and absorption would be an urgent task toward the next decade. Singapore's exceptional strength in labor-employer relations should be fully utilized for accomplishing these tasks.

Table 7
Cooperation in Labor-Employers Relations in 12 ICT-Advanced Countries *(2013)*. - Rank in world 143 countries.

1	2	3	4	5	6	9	18	21	26	42	58
CIE	SGP	DNM	NOR	NLD	SWE	JPN	DEU	FIN	UK	USA	ISR

Source: The Global Competitiveness Report 2013–2014 (WEF, 2014).

Through such transferring efforts, a "muscular"[4] economic environment can be created. Shaking out indigenous home companies (HCs) with low production capacities would enable highly competitive HCs to explore global markets. This would lead to increasing returns on foreign investment and improve the terms of trade. Ultimately, this would increase the "muscularity" of HCs, which in turn would create a "muscular" economic environment, thus constructing a virtuous cycle expected in the service innovation environment. This is illustrated in Fig. 24.

6. Conclusion

With the understanding that current ICT-driven global development depends on the shifting trend from traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality to new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality beyond economic value, the following hypothetical view was postulated:

The noting the disparity in the world's ICT leader countries, Finland and Singapore, with respect to happiness/welfare during the great stagnation in Finland and conspicuous economic growth in a choking society of Singapore can be attributed to the difference in the state in the above shifting trends.

On the basis of an empirical analysis measuring dependency on un-captured GDP, which is a key factor identifying the state of the shifting trend and based on the comprehensive review of the consequence of 3 mega-trends that lead respective co-evolution and also development of trajectories relevant to these mega-trends, the foregoing hypothetical view was demonstrated.

Noteworthy findings include:

(i) The divergence of development trajectories in ICT-advanced countries depends on the shift in the co-evolution of 3 mega-trends,
(ii) Emergence of un-captured GDP is typical to new co-evolution. It stems from the identical nature of online intermediaries which provide platforms for the exchange of goods, services or information over the Internet,
(iii) While Finland has shifted from traditional computer-initiated ICT and captured GDP co-evolution to the Internet and new co-evolution initiated by un-captured GDP from 2002, Singapore has still retained its traditional co-evolution,

[4] Structure with slim, efficient, strong, competitive and resilient performance.

Table 8
Engine and brake in the context of service innovation in Finland and Singapore *(2013)*.

Institutional factors	Finland	Singapore	References
Small income disparity			
Inequality (GINI index: 2010)	**19**	45	Distribution of Household Income by Source (ILO, 2012)
Capacity for innovation			
Capacity for industry innovation	**2**	18	The Global Information Technology Report 2014 (WEF, 2014)
Association capacity and collaborative practices			
University-industry collaboration in R&D	**2**	4	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Absorptive capacity			
Firm-level technology absorption	**7**	13	The Global Information Technology Report 2014 (WEF, 2014)
Trusting relationship			
Willingness to delegate authority	**4**	23	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Generosity (score)	**0.33**	0.19	World Happiness Report (The Earth Institute, Columbia Univ. et al., 2013)
Freedom to make life choices (score)	**0.52**	0.43	*idem*
Women in working life			
Women in labor force	**12**	76	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Government ICT usage			
Importance of ICT to government vision	16	**3**	The Global Information Technology Report 2014 (WEF, 2014)
Government online service	7	**1**	*idem*
Government success in ICT promotion	16	**4**	*idem*
Labor-employer relations			
Cooperation in labor-employer relations	21	**2**	The Global Competitiveness Report 2013–2014 (WEF, 2014)

Figures indicate world rank otherwise indicated.

(iv) Difference in the stage of the shift results in the difference in the structure of the interactive return gain,

(v) Among ICT-advanced countries, both Singapore and Israel, contrary to their notable GDP growth, are losing their domestic gains. Other ICT-advanced countries are gaining profits from abroad, notwithstanding being afflicted by the great stagnation,

(vi) This can be attributed to a world-wide shift from captured GDP to un-captured GDP. Multi-national companies (MNCs) in Singapore have been developing knowledge and skills for un-captured GDP, and this has led to their products gaining popularity in the global market. On the other hand, Singapore's indigenous home companies (HCs) have relied on captured GDP for GDP growth. As a result, their products have been losing popularity in the global market. Consequently, rather than gaining profits from the global market, Singapore has been losing domestic gains while maintaining GDP growth on a conspicuously higher level than other ICT-advanced countries.

(vii) From the new innovation stream, typically service innovation, new business models emerge. Advancement of ICT accelerates this as ICT leverages interaction between stakeholders who are essential for service innovation. Finland, one of the world's leaders in ICT, holds the top position also in ICT-induced new business models. Singapore, another country among the world's ICT leaders, holds the 10th position in the ranking, notwithstanding its top position in ICT. This contrast suggests a need for further elaboration of the engine and brake to improve the structure of interactive return gain in the context of service innovation.

These findings give rise to the following policy suggestions:

(i) Un-captured GDP should be developed on a priority basis as it corresponds to people's preferences in the global market and leads to improvements in the structure of interactive return gain.

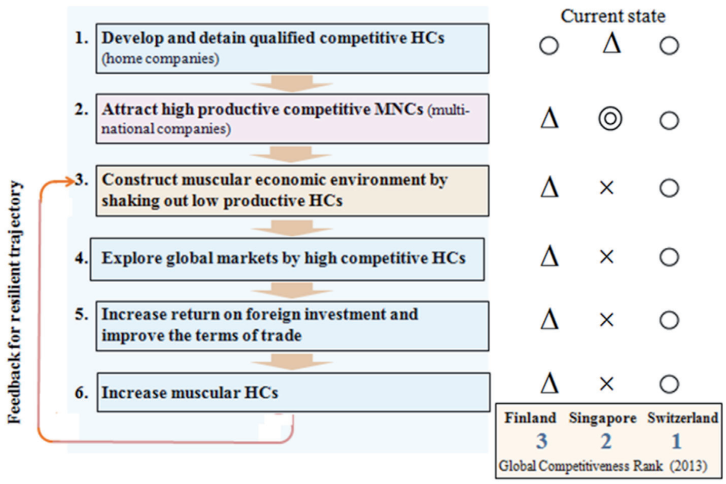


Fig. 24. Strategic Actions for Attaining the targeted trajectory.

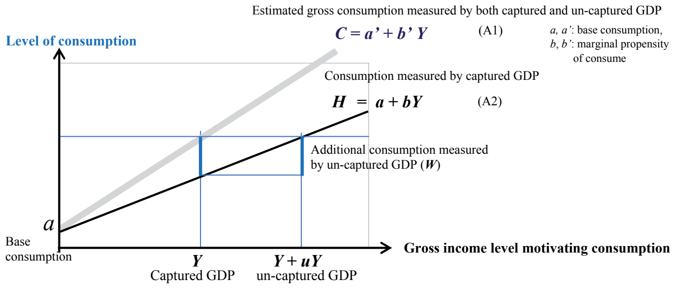


Fig. A1. Concept of Consumption Function with Un-captured GDP.

(ii) Therefore, shifting from traditional co-evolution to new co-evolution leveraged with the advancement of the Internet, un-captured GDP and supra-functionality beyond economic value should be accelerated.
(iii) Business initiative with advanced innovation, association and absorptive capacity, together with collaborative practices, trusting relationship and increase in the number of women in labor force should all be further developed.
(iv) While strong government initiatives to accelerate a country's ICT advancement play a significant role as an engine for the nation's aspirations to global ICT leadership, they may cause delays in the transfer of business initiative, which is essential for shifting from traditional co-evolution to new co-evolution.
(v) Transferring that strong engine possessed by the government to business, which aims at increasing its capacities in innovation, association and absorption, is thus important.
(vi) The exceptional strength of labor-employer relations in Singapore should be fully utilized for accomplishing these tasks. In this respect, Finland should learn from Singapore's institutional know-how.
(vii) Creating "muscular" economic environment by shaking out home companies with low production capacities should be encouraged. As a result, highly competitive home companies would engage in exploring global markets. This would lead to increasing returns on foreign investment and to improving terms of trade.
(viii) Construction of a virtuous cycle between increase in "muscularity" of home companies and development of a "muscular" economic environment should become priorities.

Future studies should focus on the new phase of digital innovation including IoT corresponding to shifting trends from traditional co-evolution to new co-evolution. A new phase of possible co-evolution stimulated by the new phase of digital innovation would also be an important subject to pursue.

In this context, typical features of current leading global platform ecosystem architectures initiated by ICT driven disruptive business model, and their impact on national economy, particularly on un-captured GDP should be analyzed.

Appendix. Measurement of the Magnitude of Un-captured GDP

(1) Analytical framework

Inspired by the conceptual image in Figs. 13 and 14, the magnitude of un-captured GDP was computed based on the following analytical framework:

1) Consumption function

2) Discrepancy between two consumption functions

$$W = C - H = (a' + b'Y) - (a + bY) = (a' - a) + (b - -b)Y = (a' - a) + buY \quad \text{(A3)}$$

(i) ICT advancement stimulation. Attributed to the internet (J) with secondary impacts of consumer's preferences (E)

$$buY = H \cdot J^{\phi} \cdot e^{\kappa E^m} + \delta \quad \text{(A4)}$$

where ϕ, κ: coefficients, m: power factor, and δ: adjusting factor ($= a' - a$).
(see Note).

(ii) Consumer's preferences inducement. Represented by elasticity of utility to consumption (ε_{cu}: E) with the secondary impacts of the Internet (J),

$$buY = A \cdot E^{\alpha} \cdot e^{\lambda J^n} + \delta \quad \text{(A5)}$$

where A, λ: coefficients, n: power factor.

3) Identification of un-captured GDP

Since (A4) and (A5) maintain equilibrium, leading to lifting power.

$$buY = H \cdot J^{\phi} \cdot e^{\kappa E^m} = A \cdot E^{\alpha} \cdot e^{\lambda J^n} \quad \text{(A6)}$$

$$H = A \cdot E^{\alpha} \cdot e^{\lambda J^n} \cdot \frac{1}{J^{\phi} \cdot e^{\kappa^m}} = A \cdot E^{\alpha} \cdot J^{-\phi} \cdot e^{\lambda J^n} \cdot e^{-\kappa E^m} \quad \text{(A7)}$$

$$\ln H = \ln A + \alpha \ln E - \phi \ln J + \lambda J^n - \kappa E^m \quad \text{(A8)}$$

Using an empirical regression analysis, coefficients A, α, ϕ, λ, κ can be identified. Power factors m and n can be identified by comparing statistical significance among possible m and n combinations.

By utilizing identified coefficients and power factors, un-captured GDP uY can be measured as follows:

$$uY = \frac{e^{\ln A} \cdot E^{\alpha} \cdot e^{\lambda J^n}}{b} + \frac{\delta}{b} \quad \text{(A9)}$$

Provided that the Internet-driven un-captured GDP has emerged triggered by the commercialization of the Internet in 1991, uY at the initial years of its commercialization can be negligibly small. The adjusting factor δ/b can be fixed by applying the fact that magnitude of un-captured GDP in 1994 was assumed negligibly small.

Un-captured GDP ratio is depicted as follows:

$$\eta = \frac{uY}{Y} \tag{A10}$$

Note.

Un-captured GDP stimulated by ICT advancement

$$\text{Un}-\text{captured GDP} \quad buY = \frac{\partial H}{\partial Y}\cdot uY = \frac{H}{Y}\cdot\frac{\partial H}{\partial Y}\cdot\frac{Y}{H}\cdot uY = H\cdot\gamma\cdot\eta$$

where γ : the elasticity of Y to H, and η : un-captured GDP ratio.

Since $\gamma = \gamma(J,\ E),\ \ \eta = \eta(J,\ E)$ (Watanabe et al., 2015 [32]), $\gamma\cdot\eta$ can be depicted by the following equation:

$$\gamma\cdot\eta = J^{\phi}\cdot e^{\kappa E^{m}} \approx J^{\phi}\cdot e^{\kappa E^{m}} + \frac{\delta}{H} \quad \left(\because\ \frac{\delta}{H}\approx 0\right)$$

$$\text{Thus,} \quad buY = H\cdot\gamma\cdot\eta = H\cdot J^{\phi}\cdot e^{\kappa E^{m}} + \delta$$

(2) Empirical result

Using Eq. (A8), coefficients governing un-captured GDP as depicted in Eq. (A9) were identified as demonstrated in Table A1. Marginal propensity to consume b was computed using the correlation between GDP and household consumption as demonstrated in Table A2.

The average marginal propensities to consume in Finland and Singapore over the whole period are 0.771 and 0.563, respectively.

Since the above regressions were conducted by using index (1994 = 100), marginal propensity to consume by actual values should be converted by multiplying H/Y ratio in 1994: 0.52 and 0.43 in Finland and Singapore, respectively leading to 0.401 and 0.242.

$$b_{Index} = \frac{\partial H_{Index}}{\partial Y_{Index}} = \frac{\partial \frac{H}{H_{1994}}}{\partial \frac{Y}{Y_{1994}}} = \frac{\partial H}{\partial Y}\cdot\frac{Y_{1994}}{H_{1994}} = \frac{b_{actual}}{\left(\frac{H}{Y}\right)_{1994}}$$

Figures in parenthesis indicate t-statistics (*1, *2 *3 means significant at the 1%, 5% and 10 level, respectively).

Table A3 summarizes the result of the analysis on a shift to new co-evolution using correlation between the Internet advancement and un-captured GDP shift in Finland and Singapore over the period 1996–2013.

Table A1
Governing Factors of Household Consumption in Finland and Singapore *(1994–2013)*

Finland	**S**	$\ln H = 6.435 + 1.185\ln E - 0.208\ln J + 1.03\times10^{-4}J^{1.6} + 0.917E^{2.0}$ (7.24*) (2.23*2) (-3.10*) (1.60*4) (0.69*5)	$adj.\,R^2$ 0.998 DW 1.58 AIC −191
	H	$\ln H = 6.520 + 1.230\ln E - 0.214\ln J + 1.70\times10^{-4}J^{1.5} + 0.887E^{2.2}$ (7.52*) (2.35*2) (-3.29*) (1.58*4) (0.64*5)	$adj.\,R^2$ 0.998 DW 1.61 AIC −190
	L	$\ln H = 6.380 + 1.158\ln E - 0.209\ln J + 1.03\times10^{-4}J^{1.6} + 0.939E^{1.8}$ (6.69*) (2.10*2) (-3.63*) (1.61*4) (0.69*5)	$adj.\,R^2$ 0.998 DW 1.60 AIC −190
Singapore	**S**	$\ln H = 3.721 + 0.740\ln E - 0.198\ln J + 1.00\times10^{-2}J^{1.00} + 1.575E^{-0.22}$ (3.28*) (2.14*2) (-3.32*) (5.41*) (1.37*4)	$adj.\,R^2$ 0.982 DW 1.63 AIC −122
	H	$\ln H = 3.856 + 0.735\ln E - 0.229\ln J + 1.70\times10^{-2}J^{0.90} + 1.484E^{-0.22}$ (3.27*) (2.08*2) (-3.64*) (5.31*) (1.25*4)	$adj.\,R^2$ 0.981 DW 1.63 AIC −121
	L	$\ln H = 3.593 + 0.745\ln E - 0.172\ln J + 0.60\times10^{-2}J^{1.10} + 1.658E^{-0.22}$ (3.27*) (2.18*2) (-2.99*) (5.49*) (1.48*4)	$adj.\,R^2$ 0.982 DW 1.62 AIC −122

S: standard estimate, **H:** higher possible estimate, **L:** lower possible estimate. S, H and L are chosen statistically for most significant 3 cases. Among the three, S demonstrates middle level and is statistically not inferior to H and L.
H: Household consumption (Index: 1994 = 100), E: Elasticity of utility to consumption, J: Internet dependency.
Figures in parenthesis indicate t-statistics (*, *2, *4, *5 means significant at the 1%, 5%, 20% and 50% level, respectively).

Table A2
Correlation between GDP and Household Consumption in Finland and Singapore (1994–2013) – Index (1994 = 100)

Finland	$H = 17.254 + 0.889D_1Y + 0.494D_2Y + 69.034D_2 + 5.238D$ $(3.42^{*1})\ (21.50^{*1})\ \ (1.84^{*3})\ \ (1.73^{*3})\ \ (2.84^{*2})$	$adj.R^2$ 0.986 DW 1.02
Singapore	$H = 87.127 + 0.648D_1Y + 0.365D_2Y - 79.47D_1 + 14.170D$ $(2.63^{*2})\ (17.07^{*1})\ \ (3.71^{*3})\ \ (-2.33^{*2})\ \ (2.15^{*2})$	$adj.R^2$ 0.976 DW 1.12

H: Household consumption index (1994 = 100), *Y*: GDP index (1994 = 100).
D1, *D2* and *D*: Dummy variable (1994–2007 = 1, 2008–2013 = 1, and 2007, 2012, 2013 = 1, other years = 0, respectively).

Table A3
Correlation between the Internet Advancement and Un-captured GDP Shift in Finland and Singapore *(1996–2013)*

Finland	$\ln\eta = 5.889 - 2.613D_{9401}\ln I/J + 0.316D_{0213}\ln I/J - 7.059D_{0213} \quad adj.R^2\ 0.948 \quad DW\ 1.43$ $(6.38^{*1})\ (-7.50^{*1}) \qquad (3.62^{*1}) \qquad (-7.40^{*1})$
Singapore	$\ln\eta = -0.772 - 1.148D_{9603}\ln I/J - 0.133D_{0406}\ln I/J - 0.106D_{0713}\ln I/J + 2.173D_{9603} \quad adj.R^2\ 0.983 \quad DW\ 1.64$ $(-3.39^{*1})\ (-23.13^{*1}) \qquad (-1.36^{*4}) \qquad (-1.29^{*4}) \qquad (-8.33^{*1})$

η: un-captured GDP ratio (2013 value was estimated by extending trend in 1994–2012), *I*: ICT stock, *J*: Internet dependency.
D_{mn}: dummy variable (period *m-n* = 1, other period = 0), *mn* reads as follows:9600 (1996–2000), 0113 (2001–2013), 9601 (1996–2001), 0213 (2002–2013), 9602 (1996–2002), 0313 (2003–2013), 9698 (1996–1998), 9913 (1999–2013), 9699 (11996–1999), 0013 (2000–2013), 9600 (1996–2000), 0113 (2001–2013).
Figures in parenthesis indicate t-statistics (*1 and *4 means significant at the 1% and 20% level, respectively).

References

[1] B. Bleys, Beyond GDP: classifying alternative measures for progress, Soc. Indic. Res. 109 (3) (2012) 355–376.
[2] E. Brynjolfsson, A. McAfee, The Second Machine Age, W.W. Norton & Company, New York, 2014.
[3] S.G. Concern, Social Innovation, 2015. http://www.concern.sg/SocialInnovation.
[4] Copenhagen Economics, The Impact of Online Intermediaries on the EU Economy, Copenhagen Economics, Copenhagen, 2013.
[5] R. Costanza, M. Hart, S. Posner, J. Talberth, Beyond GDP: the Need for New Measures of Progress. Pardee Paper 4, Pardee Center for the Study of the Longer-Range Future, Boston, 2009.
[6] EU, Social Innovation in Finland, 2015. https://webgate.ec.europa.eu/socialinnovationeurope/en/social-innovation-finland.
[7] M. Fleurbaey, Beyond GDP: the quest for a measure of social welfare, J. Econ. Literature 47 (4) (2009) 1029–1075.
[8] G. Hofstede, Cultures and Organizations, McGraw-Hill International, London, 1991.
[9] M. Hoyssa, H. Bruun, J. Hukkinen, The co-evolution of social and physical infrastructure for biotechnology innovation in Turku, Finland, Res. Policy 33 (5) (2004) 769–785.
[10] International Monetary Fund (IMF), World Economic Outlook Database, IMF, Washington, D.C, 2014.
[11] International Telecommunication Union (ITU), World Telecommunication/ICT Indicators Database, ITU, Geneva, 2014.
[12] M. Jacobs, Social Innovation: Lessons from Singapore, South Korea and Taiwan, The Guardian, 2013, 14 May 2013.
[13] Japan's Cabinet Office (JCO), National Survey of Lifestyle Preferences, JCO, Tokyo, 2012.
[14] A. Kallio, V. Harmaakorpi, T. Pihkala, Absorptive capacity and social capital in regional innovation systems: the case of the Lahti Region in Finland, Urban Stud. 47 (2) (2010) 303–319.
[15] H. Karjaluoto, J. Karvonen, M. Kesti, T. Koivumaki, M. Manninen, J. Pakola, A. Ristola, J. Salo, Factors affecting consumer choice of mobile phones: two studies from Finland, J. Euromarketing 14 (3) (2005) 59–82.
[16] H. Karjaluoto, N. Mustonen, P. Ulkuniemi, The role of digital channels in industrial marketing communications, J. Bus. Ind. Mark. 30 (6) (2015) 703–710.
[17] I. Kubiszewski, R. Costanza, C. Franco, P. Lawn, J. Talberth, C. Aylmer, Beyond GDP: measuring and achieving global genuine progress, Ecol. Econ. 93 (2) (2013) 57–68.
[18] A. Lowrey, Impacts of the Great Stagnation, New York Times, 2011.
[19] R. Mathi, S. Mohamed, Unmet Social Needs in Singapore, Lien Center for Social Innovation, Singapore, 2011.
[20] P.S. Meyer, J.H. Ausbel, Carrying capacity: a model with logistically varying limits, Technol. Forecast. Soc. Change 61 (3) (1999) 209–214.
[21] F. Pot, F. Vaas, Social innovation, the new challenge for Europe, Int. J. Prod. Perform. Manag. 57 (6) (2008) 468–473.
[22] J. Rifkin, The Zero Marginal Cost Society, Palgrave Macmillan, New York, 2014.
[23] M. Sherraden, Social Innovations Key to Singapore's Success, NUE News, 2015, 17 March 2015.
[24] Singapore Department of Statistics, Household Expenditure Survey, Singapore Department of Statistics, Singapore, 2015.
[25] Statistics Finland, Statistical Yearbook of Finland, Statistics Finland, Helsinki, 2015.
[26] D. Tapscott, The Digital Economy: Promise and Peril in the Age of Networked Intelligence, McGraw-Hill, New York, 1997.
[27] The Conference Board, Total Economy Database TM, 2014. Retrieved 26 December 2014, http://www.conference-board.org/data/economydatabase/.
[28] The World Bank, World Development Indicators, World Bank, Washington, 2014.
[29] United Nations Statistics Division, Household Final Consumption Expenditure, United Nations, New York, 2014.
[30] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of IT functionality development, Technol. Forecast. Soc. Change 71 (7) (2004) 723–750.
[31] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured gdp and growing anger of consumers, Technol. Soc. 41 (2015) 21–44.
[32] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure – similarity and disparities between Finland and Singapore, Technol. Soc. 42 (2015) 104–122.
[33] B. Wesselink, J. Bakkes, F. Hinterberger, P. Brink, Measurement beyond GDP, in: Background Paper for the International Conference beyond GDP: Measuring Progress, True Wealth, and the Well-being of Nations, Bruddels, 2007.
[34] World Economic Forum (WEF), The Global Information Technology Report 2012, WEF, Geneva, 2012.
[35] World Economic Forum (WEF), The Global Competitiveness Report 2012-2013, WEF, Geneva, 2013a.
[36] World Economic Forum (WEF), The Global Information Technology Report 2013, WEF, Geneva, 2013b.
[37] World Economic Forum (WEF), The Global Competitiveness Report 2013-2014, WEF, Geneva, 2014a.
[38] World Economic Forum (WEF), The Global Information Technology Report 2014, WEF, Geneva, 2014b.
[39] World Economic Forum (WEF), The Global Innovation Index 2014, WEF, Geneva, 2014c.
[40] World Economic Forum (WEF), The Human Capital Report 2014, WEF, Geneva, 2014d.
[41] World Health Organization (WHO), World Health Statistics 2014, WHO, Geneva, 2014.
[42] S. Yusuf, K. Nabeshima, Some Small Countries Do it Better: Rapid Growth and its Causes in Singapore, Finland, and Ireland, The World Bank, Washington, D.C, 2012.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Visiting Professor of National University of Singapore, Visiting Professor of University of Jyväskylä, Finland and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland. (kanaveed@student.jyu.fi).

Pekka Neittaanmäki graduated from the University of Jyväskylä and is currently a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland. (pekka.neittaanmaki@jyu.fi).

Yuji Tou graduated from Tokyo Institute of Technology, Japan and is currently an Associate Professor at Tokyo Institute of Technology, Japan. (tou.yuji@gmail.com).

PVI

CO-EVOLUTION BETWEEN STREAMING AND LIVE MUSIC LEADS A WAY TO THE SUSTAINABLE GROWTH OF MUSIC INDUSTRY - LESSONS FROM THE US EXPERIENCES

by

Kashif Naveed, Chihiro Watanabe and Pekka Neittaanmäki, 2017

Technology in Society, vol. 50, pp. 1-19

Technology in Society 50 (2017) 1–19

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Issues and Opinions

Co-evolution between streaming and live music leads a way to the sustainable growth of music industry – Lessons from the US experiences

Kashif Naveed [a], Chihiro Watanabe [a, b, *], Pekka Neittaanmäki [a]

[a] Faculty of Information Technology, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria

ARTICLE INFO

Article history:
Received 16 January 2017
Received in revised form
31 March 2017
Accepted 31 March 2017
Available online 5 April 2017

Keywords:
Music industry
Live music
Live-concert-streaming music industry
Co-evolution
Trust-based IDBM with CCSD
Cultural industries

ABSTRACT

While digitization of music, particularly streaming services, has gained increasing popularity, it has also led to a steady decline in the revenues of recorded music industry. This is causing strong concern regarding a potential collapse of the music industry comparable to other print media industries such as newspaper and book publishing.

However, recent changes in the music industry initiated by a resurgence of the live music industry are giving rise to some expectations for the survival and growth of the music industry. The parallel paths of increasing popularity of streaming services and a resurgence of live music suggest that these two dynamics are working together in a co-evolutionary way toward the sustainability of the music industry.

This paper attempts to elucidate the co-evolutionary dynamism between the increasing popularity of streaming music and the resurgence of live music.

An empirical analysis of monthly trends over the period of the last three decades in the US music industry by its sectors revealed that (i) the co-evolution between streaming and live music industries has functioned well over the last few years, (ii) the live music industry has incorporated a self-propagating function by assimilating innovations previously initiated by digital music, (iii) given the above co-evolution, the recent resurging trend in the music industry can be sustained, (iv) the advancement of digital innovations such as artificial intelligence, machine learning, fintech, virtual reality, big data, and social media by enabling such coevolution have transformed the live music industry into a "live-concert-streaming music industry" (*LCSMI*) that further enabling the participative creativity of its stakeholders. For these collaborative and cultural industries to function in harmony, trust between its participating stakeholders is very crucial.

This analysis suggests the significance of a trust-based ICT-driven disruptive business model (IDBM) with a consolidated challenge for social demand (CCSD) for the development of cultural industries.

1. Introduction

Music is an integral part of our societies all over the world. It is an art that strives to feed our soul and paint a canopy of emotions through songs [23], and music has always been playing an inspiring role in our cultural activities. Music as an industry [1] truly incorporates a wide-range of businesses. Digital music, which emerged in 2004, is considered to be premier example of digital innovation, having provided the music industry with new disruptive business models and new digital music products and services for consumers.

The United States plays a leading role in the global music

* Corresponding author. Faculty of Information Technology, University of Jyväskylä, Finland.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] Music industry is defined as an industry selling compositions, recordings and music performances. Individuals and organizations operating within the industry include: (i) musicians (artists) who compose and perform music, (ii) companies and professionals who create and sell recorded music, (iii) organizations involved with and giving music performances, (iv) professionals who assist musicians with their music careers, (v) those who broadcast music, (vi) journalists, (vii) educators, and (viii) musical instrument manufactures.

http://dx.doi.org/10.1016/j.techsoc.2017.03.005
0160-791X/

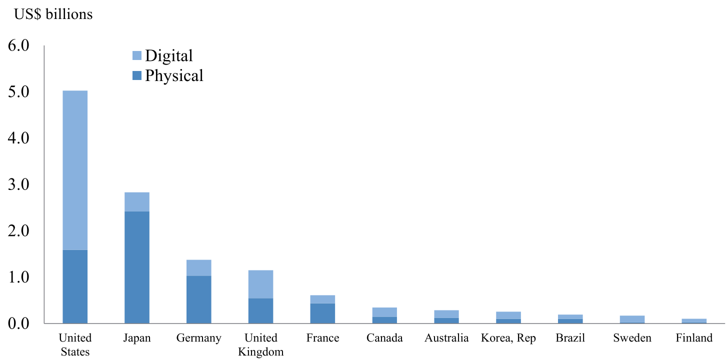


Fig. 1. International comparison of music industry by revenues *(2014)*.
Source: [17] Musically (Music Ally Data map, Global Music Industry Data on Sales.).

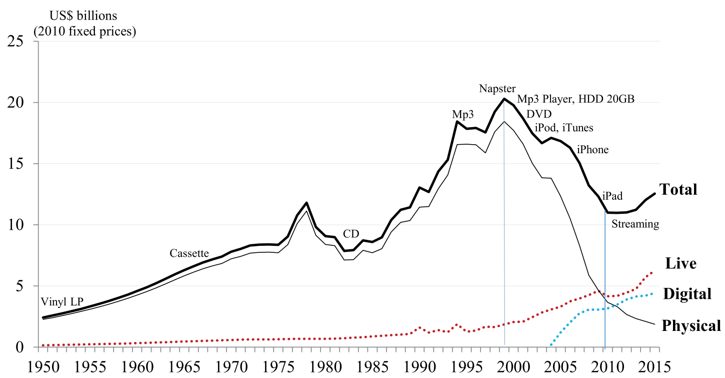


Fig. 2. Development trajectory of the US music industry by revenues *(1950–2015)*.
Sources: [21] RIAA (Recording Industry Association of America), [20] Pollstar (Trade publication for the concert tour industry).

industry and has played a pivotal role in the development and consumption of digital music.

Fig. 1 shows the magnitude of the recorded music industry [2] in leading countries by their revenues in 2014 which represents the major input share in music market. This figure clearly demonstrates the leading role of the US in the global music industry, particularly in the digital music.

The music industry has undergone huge changes recently. Although the digital music, particularly streaming services has gained increasing popularity, there is a steady decline in revenues of the recorded music industry. This has caused a potential impending collapse of the music industry similar to print media industries such as newspaper and book publishing.

Fig. 2 overviews the development trajectory of the US music industry over the period of 1950–2015 by revenues of its different sectors: live music and recorded music. The recorded music consists of both physical and digital music (See Appendix 1 for the significance and implications of this data).

In Fig. 2, we note that the US music industry has continued to develop except during the period of economic recession in the early 1980s. However, this increase finally reached its peak in 1999 and after the expansion of the Internet, it declined. The direct relationship between the widespread access to the Internet and decrease in the record music sales can be observed, apparently because the Internet has enabled everyone to allocate, listen, download and stream music for free. Digital music emerged during 2004, but it was also seemingly unable to become the savior of the declining music industry. Another issue is the lack of trust relationship between artists and music companies. Many artists seriously thought of being too reliant to and unfairly compensated by the record companies and digital music service providers and they shifted their focus towards concert tours as their primary source of income.

In 2010, the continued decline in music industry revenues suddenly changed and turned upward largely due to the renaissance of live music industry [3]. The music revenues were increased by 15% between 2010 and 2013, and reached 30% until 2015. In recent years, live shows have become increasingly popular and valuable because live music is something fans

[2] Recorded music only, live music not included.

[3] The performances take place at clubs, music theaters, arenas, amphitheaters and local/regional music festivals.

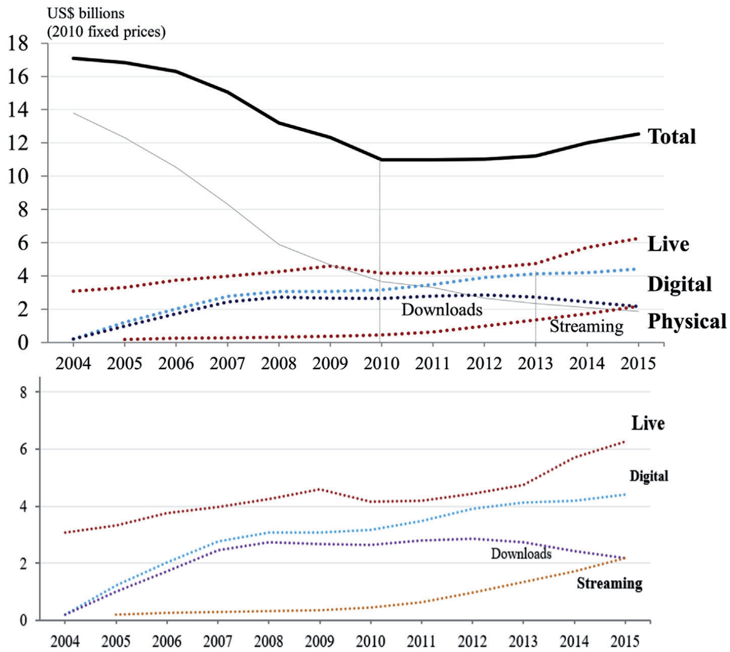


Fig. 3. Development trajectory of the US music industry by revenues *(2004–2015)*.
Sources: [21] RIAA and [20] Pollstar.

cannot fully experience merely by listening to recorded or online music. Due to this shifting trend the balance of power in the music industry has also firmly shifted away from record labels towards the value chain of live music. Nevertheless, the value chain of live music is incredibly complex with its multiple stakeholders (e.g., ticketing, secondary ticketing, venues, booking agents, promoters, taxes and other expenses, etc.), with each taking their revenue share and such layers of complexity necessitate the strong trust relationship among the participants of this value chain. [7], demonstrated that rise of the spread of the Internet, suggests that it may be one possible explanation for such a shift seen by some as contrary to the recording industry's interests. The internet has enabled even less-known artists to easily produce, market and distribute their music online building a solid fan base, whom they may attract and capitalize through their live concerts. The social media phenomenon and growth of online music communities have also contributed to the growth of the fan base, allowing the rising artists to easily connect through new digital marketing techniques for their already established acts. The author also pointed out another notable shift in the live music industry occurred with the widespread popularity of music festivals. Although it seems quite unlikely that live concerts could serve as the sole revenue stream for a viable music industry model, its rapid growth offers new valuable opportunities for the music industry [7].

Depicting this noteworthy resurgence of live music, Fig. 3 reviews the details of the actors supporting this resurgence game in the digital music era. Fig. 3 also suggests that streaming music has been gaining popularity and demonstrating the sustainable growth by substituting the music downloading services. There has been observed a clear shift in the number of consumers who select streaming as a primary source of their music consumption contrary to all other formats of recorded music. With every other format of the recorded music industry declining, it seems that the streaming music could be the potential driving force behind the growth of the live music industry [9].

This pattern suggested that there could be parallel paths of sustainable growth in which the resurgence of live music may have a co-evolutional dynamism. The result would be a virtuous cycle between sustainable growth of streaming services and the resurgence of live music.

In addition, the resurgence of live music can largely be attributed to its dependency on similar advanced digital innovations (Table 1). Another important factor is that music streaming services are gaining popularity despite the general declining trend in the music industry. This resurgence can also be attributed to the assimilation of the preceding digital innovations, particularly on those initiated by streaming services and on those introduced by downloading services.

Furthermore, the impacts of the changing consumer preferences should not be overlooked [9]. The general trend in the shift of people's preferences from economic functionality to supra-functionality beyond economic value (encompassing social, cultural, aspirational, tribal and emotional values, which are more personalized and people are more active) [31]. This may further accelerate our higher dependency on live music while maintaining streaming as a (temporal) complement of this radical shift, because of its comparative advantages of discoverability, accessibility and portability. In addition, in many industries a transformational shift is taking place from value creation to value co-creation, which is fundamentally changing the relationship between consumers and producers [4].

Thus, streaming, accompanied by live music sales, may actually be the driving force behind the survival and new growth of the

Table 1
Advanced digital innovation supporting the resurgence of live music.

Artificial intelligence	Creates algorithms enabling the creation of customized songs for users and helps artists to focus more on being creative.
Machine learning	Enables consumers to draw on past information, leading to increased trust among stakeholders.
Fintech	The rise of the blockchain and bitcoin creating new methods of sharing, creating and selling music.
Virtual reality	Artists can create interactive virtual worlds, allowing fans from all over the world to share experiences and open up new worlds and also enabling disabled (financially and physically) people to enjoy live music.
Big data analysis	Provides sources for real-time personalization by compiling wide-ranging personal information (e.g., purchasing history, listening habits, physical and mental conditions).
Social media	Exploring new distribution channels (e.g., Facebook, Twitter, You Tube)

music industry [9]. This led us to our hypothesis that the notable resurgence in live music can largely be attributed to its assimilation of digital innovations incorporated in digital music and this assimilation has been enabled by the co-evolution between streaming and live music industries.

This paper attempts to demonstrate this hypothesis.

To date, a number of studies have analyzed the music industry and provided a warning of its possible collapse. [11] suspected that recorded music might face this crucial situation point due to the general economic recession, the influence of private copying, and competition from other media. In addition, this situation was also due to the industry reaching its saturation level.

The boom of the music market due to the CD emerged in the beginning of 1980s, the subsequent sharp rise in sales and revenue figures masked the fundamental problems of the music industry. After the availability of music tracks online over the internet, the CD became obsolete and revenues of the music industry sharply declined.

[24] pointed out that the organizational inertia of the established music industry is the fundamental source of its decline. In addition, the overall market for recorded music has become a market for long-play formats, which reflects a business strategy that has been pursued mainly by the major record companies since the late 1960s. [23] showed that increase in music stealing might led to a vicious cycle where the decrease in revenues of the record labels and the decrease in investment savings for the development of artists resulted in declining popularity of recorded music.

Confronting this collapse, quite a few reports and articles suggested an expectation of a resurgence of music industry initiated by the live music industry.

[25] pointed out the following seven trends that were impacting the live music business:

(i) Fans expect a mix of options and more personalized experiences,
(ii) Hybrid music events bring in bigger audiences and more money,
(iii) Online ticketing unlocks powerful data and insights like never before,
(iv) Mobile technology improves the overall attendee experience,
(v) RFID (Radio frequency identification) technology and smart cards add value, once inside the event,
(vi) Social media provides hard cash benefits to event organizers, and
(vii) Live streaming events keep fans connected and engaged digitally.

Explaining this powerful shift, [13] pointed out that the music industry had been shifting in the following ways:

(i) Increasing dependency on brands for music strategy development,
(ii) Continued rise of emerging artists,
(iii) Continued streaming wars,
(iv) Highly brand- and technology-centric festival culture,
(v) Music as a bridge to consumers for fashion brands, and
(vi) Wearable technology blending with streaming music for new user experiences.

These trends suggest that live music will transform music into a new music industry. [9] suggested that “It is likely that a combined industry consisting of both streaming and live music will continue to grow in the near future.” He also anticipated that in order to take advantage of this trend, the artists would likely find the most success in promoting their music through streaming services and by conducting live tours.

However, all these analyses remain phenomenological observations or conceptual analyses, and to our knowledge none of the studies have analyzed the structural dynamism that may enable resurgence of the music industry using econometric modelling. This co-evolution of the increasing popularity of streaming music and the subsequent assimilation of the preceding innovations in digital music, are econometric sources of the resurgence of live music.

In light of the econometric system or “dynamism”, this paper undertook an empirical analysis focused on the US, because it leads the global music industry. The dynamism analysis was conducted by using the monthly development trajectories of different sectors of the US music industry over a period of the last three decades, with a special attention given to the era of digital music.

It was revealed that (i) the co-evolution between streaming and live music has functioned well over the last few years, (ii) the live music industry has incorporated a self-propagating function by effectively assimilating the innovations previously initiated by the digital music, (iii) given the above co-evolution, the recent resurging trend in the music industry can be sustained, (iv) the advancement of digital innovations such as artificial intelligence, machine learning, fintech, virtual reality, big data, and social media has enabled the above co-evolution and led the transformation of live music into a “live-concert-streaming music industry” (*LCSMI*). The *LCSMI* enables the participative creativity of its stakeholders. *LCSMI* corresponds to the historical demand of consumers and also of society.

As the consumer preferences has been shifting from *viewership → physical ownership → digital ownership → access → viewership and access*, so the consumers are not the passive listeners anymore, they want wide range of choices and are willing to actively participate, integrate and co-create value. The emergence of collaborative platform such as *LCSMI* reflects the historical demand of consumers but for the successful implementation of such collaborative business environment the importance of trust among its stakeholders is crucial.

In total, this analysis suggests the significance of a trust-based ICT-driven disruptive business model (IDBM) with consolidated challenge for social demand (CCSD) for the development of cultural industries.

Section 2 of this paper analyzes the co-evolutionary development of the streaming and live music industries. Section 3 demonstrates a self-propagating function incorporating by the live music by assimilating its preceding digital innovations initiated by the digital music. The transformation of live music into a live-concert-streaming music industry is demonstrated in Section 4. Section 5 briefly summarizes noteworthy findings, policy suggestions and future research.

2. Co-evolutionary development of the streaming and live music industries

In order to test the hypothesis developed in the preceding section, the correlational dynamism between the increasing popularity of streaming services and the boom of live music was analyzed, focusing on the period after the economic recession in September 2008, also called as the Lehman shock.

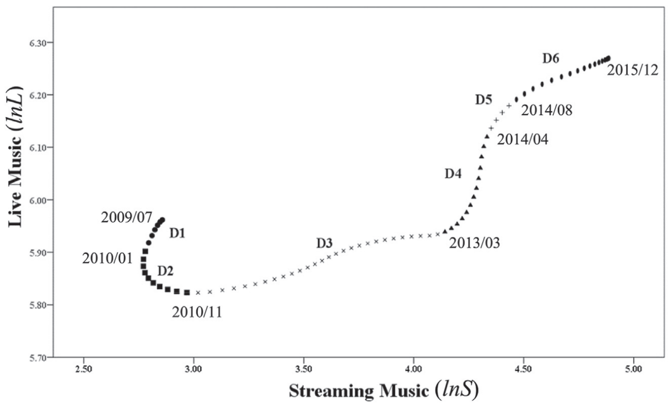


Fig. 4. Inducing role of streaming music in increasing revenues from live music in the US *(Jul. 2009 – Dec. 2015).*

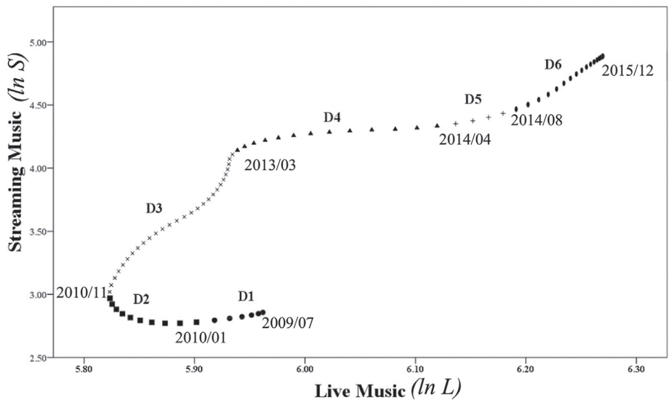


Fig. 5. Inducing Role of Live Music in Increasing Revenues from Streaming Music in the US *(Jul. 2009 – Dec. 2015).*
Note: Regression analyses in Figs. 4 and 5.

$$\ln Y_t = \alpha + \sum_{i=0}^{6} [\beta_i D_i] \ln X_{t-1} \qquad (Y, X = L, S(Fig.4),\ S, L(Fig.5))$$

***L*:** Live music monthly revenue *(million US$)*, ***S*:** Streaming music monthly revenues *(million US$)*,

$D_{i=1-6}$: Dummy variables.

D_1: 2009.07 – 2009.12, rest = 0. D_2: 2010.01 – 2010.10, rest = 0. D_3: 2010.11 – 2013.02, rest = 0.
D_4: 2013.03 – 2014.03, rest = 0. D_5: 2014.04 – 2014.07, rest = 0. D_6: 2014.08 – 2015.12, rest = 0.

Correlation of Fig. 4 *adj.* R^2 0.993 *DW* 1.05

$$\ln L_t = 5.455 + 0.172 D_1 \ln S_{t-1} - 0.365 D_2 \ln S_{t-1} + 0.121 D_3 \ln S_{t-1} + 0.837 D_4 \ln S_{t-1} + 0.161 D_5 \ln S_{t-1} + 0.167 D_6 \ln S_{t-1} + 1.426 D_2 - 2.989 D_4$$

(195.91) (17.22) (-4.21) (15.43) (14.50) (24.54) (28.13) (5.80) (-12.13)

Correlation of Fig. 5 *adj.* R^2 0.992 *DW* 1.04

$$\ln S_t = -38.272 + 6.906 D_1 \ln L_{t-1} - 1.844 D_2 \ln L_{t-1} + 7.121 D_3 \ln L_{t-1} + 0.971 D_4 \ln L_{t-1} + 6.944 D_5 \ln L_{t-1} + 0.6.894 D_6 \ln L_{t-1} + 51.917 D_2 + 36.700 D_4$$

(-26.59) (28.56) (-3.06) (29.09) (3.29) (29.64) (29.88) (13.63) (16.07)

The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

Table 2
Elasticity of Co-evolution between the streaming and live music industry in the US *(Jul. 2009-Dec. 2015)*.

		Elasticity		Remarks
		Streaming → Live	Live → Streaming	
D_1	*Jul.2009 - Dec.2009*	0.172	6.906	Vicious cycle (Both decrease)
D_2	*Jan.2010 - Oct.2010*	−0.365	−1.844	Negative cycle (Streaming increases, live decreases)
D_3	*Nov.2010 - Feb.2013*	0.121	7.120	Virtuous cycle (Both increase)
D_4	*Mar.2013 - Mar.2014*	0.837	0.971	
D_5	*Apr.2014 - Jul.2014*	0.161	6.944	⇩
D_6	*Aug.2014 - Dec.2015*	0.167	6.894	Co-evolution

Note: Elasticity of streaming *(S)* to live *(L)* ε_{LS} explains 1% increase in *S* increases ε_{LS} % increase in *L*, and represents the efficiency of *S* inducement of *L*. This elasticity corresponds to the slope of Fig. 4.

Fig. 5 shows the inducing role of streaming music in increasing the revenues from live music from July 2009 to December 2015, a time span we divided into six periods. Logarithmic monthly revenues (US$ million) of streaming music (explanatory variable) and live music (dependent variable) with one month time-lag for an explanatory variable were used for identifying causality. Coefficient dummy variables corresponding to the six periods were used (see Appendix 1 on data construction).

A similar analysis for the inducing role of live music in increasing the revenues from streaming music over the same periods was also conducted as demonstrated in Fig. 6.

Both analyses demonstrate statistically significant results (see the *Note* below the figures).

Effects and efficiencies of both inducements (inducement of live music revenues by streaming music and also of streaming music by live music) in each of the 6 periods are tabulated in Table 2.

When examining the figures and the table, we note the following behavior:

(i) While live music revenues declined after the economic recession due to the Lehman shock in September 2008 (periods D_1 and D_2), the trend changed to increasing from the late 2010 (period D_3) as streaming music commenced to induce live music revenues.
(ii) This inducement increased dramatically from the early 2013 (D_4).
(iii) Live music induced by streaming music in turn induced streaming music revenues with a one month time lag from the late 2010 onwards.
(iv) These revenue increases in streaming music induced by live music led to successive inducement of revenue increases in live music.
(v) Thus, the negative or the vicious cycle hanging over the correlation between the streaming music and live music industries converted to a co-evolutional relationship (mutually inspiring virtuous cycle) from the late 2010.
(vi) This co-evolution was further activated in the early 2013.

This co-evolutionary dynamism provides a reasonable explanation for the parallel paths of the increasing popularity of streaming services and the conspicuous growth of live music from 2010 on and its further acceleration since 2013 as observed in Fig. 3.

Table 2 clearly demonstrates there was a conversion from the vicious and negative correlation between streaming music and live music into a co-evolutional relationship. This relationship emerged in the late 2010 and further accelerated from the early 2013.

Furthermore, it is suggested that this co-evolution may have enabled the live music assimilation of the preceding digital innovations accumulated in streaming music, which also assimilated its preceding innovations from downloading music.

3. Self-propagating function incorporated in live music industry

This section was inspired by the findings obtained in the preceding section and the subsequent postulate that a co-evolutionary relationship between streaming music and live music exists, we built our model and tested it. It was further anticipated that this relationship might enable live music to assimilate of the preceding digital innovation accumulated in the streaming music. This set of innovation also assimilated the preceding innovation from downloading music. We expect to see that this assimilation would be a driving force for the resurgence of live music. This section analyzed the dynamics of this system.

The dynamics of assimilating the spillover technology can be summarized as follows [26]:

(i) When coming across a flow of spillover technology, cumulative learning plays a decisive role. Cumulative learning cultivates the capacity to distinguish this flow by assessing and classifying it into *should learn*, *should not learn*, and *cannot learn* categories, resulting in certain absorptive capacity to adapt any accepted spillover technology to own technology stock, and
(ii) Through a co-evolutionary exercise of absorption, assimilation capacity can be developed to enable it to incorporate the absorbed technology into the whole innovation value chain as production, diffusion and utilization.

Fig. 6 illustrates the concept of assimilation of spillover technology in this dynamism. Assimilation capacity[4] can be depicted as equation (1) [27].

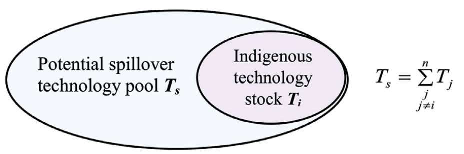


Fig. 6. Concept of assimilation of spillover technology.

[4] In the assimilation dynamism described, its capacity is a function of the ratios of volume and growth rate of the donor and the host. See the details of its mathematical development in [27].

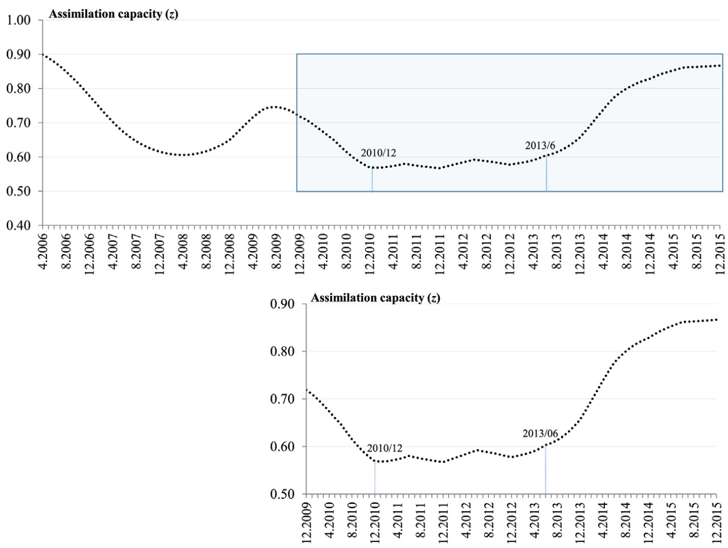


Fig. 7. Trend in assimilation capacity of the live music industry in the US *(2006–2015)* - 6 months moving average.

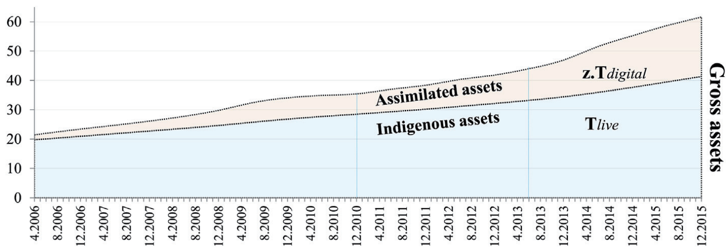


Fig. 8. Trends in indigenous and assimilated assets in the US live music industry *(2006–2015).*

In the case when live music assimilates the cumulative stock of the preceding digital innovation from streaming music, assimilation capacity and gross assets consisting of indigenous assets and assimilated assets can be depicted as equations (2) and (3), respectively.

$$\text{Assimilation capacity} \quad z = \frac{1}{1 + \frac{\Delta T_s}{T_s} \Big/ \frac{\Delta T_i}{T_i}} \cdot \frac{T_i}{T_s} \tag{1}$$

$$z = \frac{1}{1 + \frac{\Delta T_d / T_d}{\Delta T_l / T_l}} \cdot \frac{T_l}{T_d} \tag{2}$$

$$T = T_l + z \cdot T_d = \left(1 + \frac{1}{1 + \frac{\Delta T_d / T_d}{\Delta T_l / T_l}} \right) \cdot T_l \tag{3}$$

On the basis of this formula, trends in assimilation capacity and gross assets[5] of live music in the US over the period of 2006–2015 were measured as demonstrated in Fig. 7 and 8.

Fig. 7 shows that while the assimilation capacity of live music, representing a general case of mature industries, continued to decline particularly after the economic recession in 2009, this changed to an upward trend from the late 2010 and dramatically increased from the middle of 2013. Both changes correspond to the beginning of the co-evolution with streaming music, with a few months' time-lag, as demonstrated in Fig. 4.

Supported by the dramatic increase in the assimilation capacity, the share of assimilated assets in live music has increased significantly, particularly since 2013, reaching up to 50% of its indigenous assets in 2015 as demonstrated in Fig. 8.

This significant assimilation of digital innovation from digital music through the co-evolution with streaming music enabled live music to incorporate a self-propagating function which enhances the functionality of live music. Enhanced functionality prolongs the

[5] ***Gross music assets T*** $= T_{live} + zT_{digital}$ *where* $\boldsymbol{T_{live}}$: Live music assets, $\boldsymbol{zT_{digital}}$: Assimilated assets from digital music.

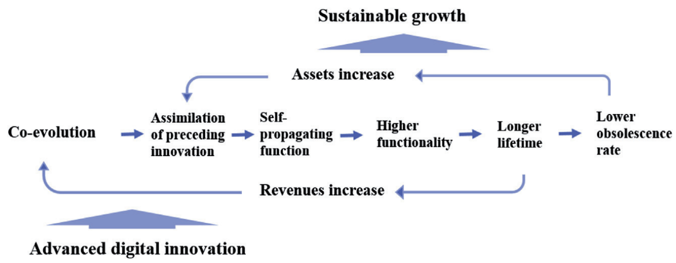


Fig. 9. Scheme for sustaining the resurging trend of music industry.

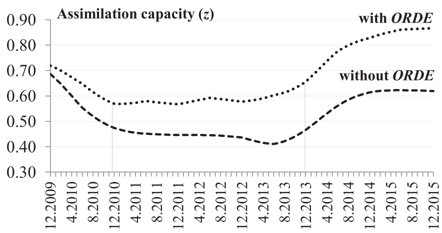


Fig. 10. Comparison of Assimilation Capacity with and withoutReflecting Obsolescence Rate Decreasing Effect (*ORDE*).

lifetime of live music, leading to a lower obsolescence rate (see Appendix 3). This contributes to the increase in its revenues and assets as illustrated in Fig. 9.

With this dynamism in mind, in the above analysis the obsolescence rate of live music decreased to reflect the consequence of a "live-streaming phenomena" that started from 2010 and its subsequent activation of co-evolution (see Appendix 4). Fig. 10 compares the level of assimilation capacity with the obsolescence rate decreasing effect (*ORDE*) does not function.

Fig. 10 demonstrates that the level of assimilation capacity decreases if *ORDE* does not function, thus supporting the dynamism illustrated in Fig. 9.

Since logistic growth function within a dynamic carrying capacity (*LGDCC*) exhibits self-propagating behavior ([28], see Appendix 5 on this dynamism), LGDCC was utilized to demonstrate that self-propagating function in live music.

Table 3 compares the *LGDCC* of the assets of the live music industry over the period of January 2004–December 2015 with the following asset conditions:

(i) Gross assets with *ORDE* ($T_I + z \cdot T_d$, ρ=9–6.5%)
(ii) Indigenous assets with *ORDE* (T_I, ρ = 9–6.5%)
(iii) Gross assets without *ORDE* ($T_I + z \cdot T_d$, ρ = 10%) where ρ : rate of obsolescence of assets.

Table 3 shows that (i) gross assets with *ORDE* are statistically more significant than (ii) indigenous assets with *ORDE* and (iii) gross assets without *ORDE*. In addition, the values of the factors governing dynamic carrying capacity ( ) are 7.39, 4.01 and 6.53, respectively, which demonstrates that (i) gross assets with *ORDE* incorporate the self-propagating function most significantly.

Furthermore, by comparing (i) and (ii), it is demonstrated that live music has turned out to be incorporating the self-propagating function by assimilating the preceding digital innovations accumulated in digital music through the co-evolution with streaming music.

In addition, by comparing (i) and (iii), it is demonstrated that this self-propagation process follows the dynamism as illustrated in Fig. 9 and suggests the significance of the advanced digital innovations for sustaining and activating the co-evolution between live music and streaming music industries, resulting in a sustainable growth of the music industry.

These observations and models support our hypothesis.

4. Transformation into a "live-concert-streaming music industry"

The analyses discussed in the preceding sections demonstrate that the recent noteworthy streak in the resurgence of the US music industry can be attributed to the co-evolution between the streaming music and live music industries and their assimilation of preceding innovations.

Given this long-awaited resurgence of the music industry in mind, our concerns goes to whether the co-evolution is based on a sustainable structure or a transient phenomenon.

In order to address this concern, this section analyzed the structure governing the future trends in the respective music industries and the tasks to be carried out to maintain the co-evolution of live music and digital music initiated by streaming

Table 3
Comparison of self-propagating function incorporated in the US live music industry *(Jan. 2004-Dec. 2015)*.

LGDCC			$Y(t) = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-\frac{a_k}{a}e^{-a_k t}}}$			
Live music assets condition	N_k	a	b	a_k	b_k	adj. R^2
(i) Gross assets with *ORDE*	148.189	0.179	1.725	0.010	6.912	0.993
	(5.51)	(2.05)	(2.50)	(14.96)	(5.62)	
(ii) Indigenous assets with *ORDE*	83.247	0.136	1.137	0.009	3.748	0.990
	(5.75)	(3.23)	(3.66)	(9.97)	(5.26)	
(iii) Gross assets without *ORDE*	141.417	0.108	5.741	0.009	5.992	0.971
	(1.71)*	(4.12)	(1.63)*	(4.54)	(1.61)*	

Y: assets of live music; N_k: carrying capacity; t: time; a, b, a_k, b_k: coefficients.
The figures in parenthesis indicate t-statistics: all are significant at the 1% level except *: 5% level.

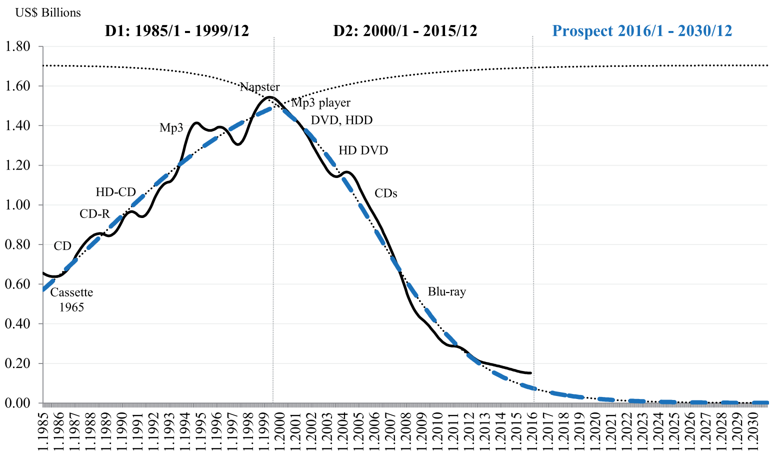


Fig. 11. Trend and prospect of the physical music revenues in the US *(1985–2030)*.

music.

4.1. Structure governing the trends in the music industry

Trends in music entering the market, as well as its assets there are normally subject to an epidemic function. However, these are sensitive to changes in external circumstances such as customer's preferences and the emergence of competitive businesses and innovations in music industry.

With this peculiar nature, trends in music industry can be depicted by the following hybrid logistic growth model [6]:

$$Y = \frac{N_X}{1 + b_{X1} D_1 e^{-a_{X1} D_1 t} + b_{X2} D_2 e^{-a_{X2} D_2 t}} \tag{4}$$

where Y: Music input into the market/its assets; N_X: Upper limit of diffusion (carrying capacity); X: P (physical music), D (digital music), L (live music); D_i: dummy variables corresponding to the change in external circumstances; t: time trend; and a_{Xi}, b_{Xi} ($i = 1$, 2): coefficients.

4.1.1. Trends in revenues in music industry segments

By utilizing this model, monthly trends in revenues of physical music, digital music and live music over the period of January 1985–December 2015 were estimated, and the fitness of the estimated trends with actual trends was evaluated first.

The estimated trends are illustrated in figs. 11–13, and the results of the fitness evaluation are summarized in the *Note* on the Figures, which demonstrates an extremely high level of fitness as the value of *adj.* R^2 is higher than 0.95 and 1% significance level of t statistics of all coefficients in all cases analyzed.

With this confirmation of reliability, Figs. 11–13 also illustrate the estimated future prospects of the revenues toward 2030 in three industry segments.

4.1.1.1. Physical music.

4.1.1.2. Digital music.

	N_X	D_1		D_2		*adj.* R^2
		a_1	b_1	a_2	b_2	
Physical		*1985/1 - 1999/12*		*2000/1 - 2015/12*		
	1.705	0.015	1.980	−0.026	0.001	0.983
	(60.89)	(15.00)	(28.46)	(-26.00)	(-36.76)	
Digital		*1985/1 - 2007/12*		*2008/1 - 2015/12*		
	0.443	0.066	42.08×10^6	0.016	84.775	0.981
	(14.29)	(22.00)	(21.51)	(5.33)	(6.97)	
Live		*1985/1 - 2013/3*		*2013/4 - 2015/12*		
	0.868	0.007	14.145	0.024	41.123×10^2	0.966
	(7.54)	(19.75)	(23.32)	(5.48)	(6.41)	

N_X: Carrying capacity, t: Monthly trend, a_1, a_2, b_1, b_2: Coefficients, D_1, D_2 dummy variables.Figures in parenthesis indicate t-statistics: all are significant at the 1% level.

4.1.1.3. Live music.

4.1.2. Future prospects of the music industry as a whole

Based on the preceding analysis of the trends and prospects of the three music industry segments, the future prospects of the music industry as a whole were examined next.

Given that the foregoing structure governing each respective music industry in the US continues, Fig. 14 demonstrates the estimate on the US music industry's future prospects towards 2030 by simply summing up the estimates of the future prospects of each of the music industries.

Fig. 14 demonstrates that the improving trends in live music continuing together with a slight increase in digital music, leading to a resurgence of the music industry as a whole from its lowest point in the early 2010s. As analyzed earlier, the parallel paths of the increasing trends in both live music and digital music can be attributed to the co-evolution between streaming music and live music. These findings suggest how to sustain this co-evolution, which could be the key strategy for the resurgence of the music industry.

[6] HLG model (Watanabe Naveed model). See Appendix 6.

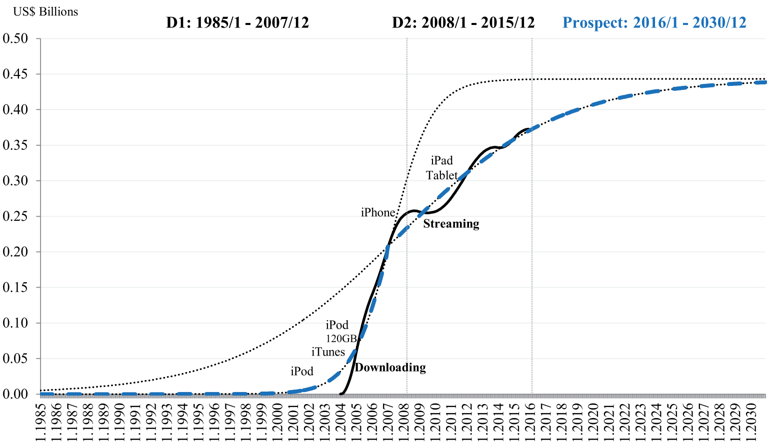


Fig. 12. Trend and prospect of the digital music revenues in the US *(1985–2030)*.

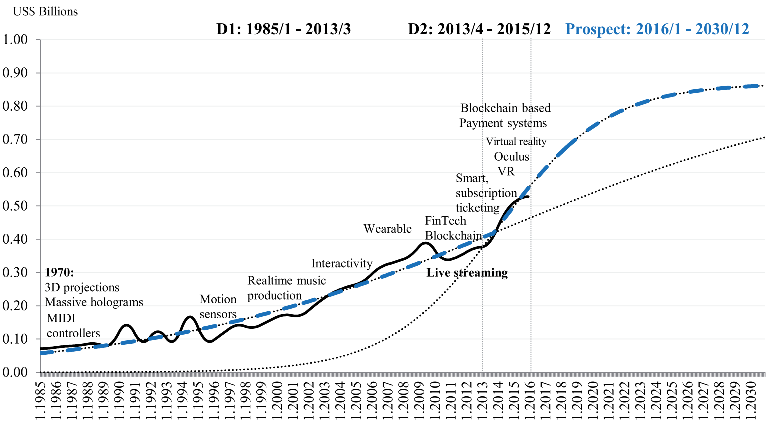


Fig. 13. Trend and Prospect of the Live Music Revenues in the US *(1985–2030)*.

$$Y = \frac{N_X}{1 + b_{X1} D_1 e^{-a_{X1} D_1 t} + b_{X2} D_2 e^{-a_{X2} D_2 t}}$$

Note: Regression analyses for Figs. 11–13 *(Jan. 1985 -Dec. 2015)*.

4.1.3. Sustainability of the resurging trends

While the prospect of a resurgence in Fig. 14 is based on the resurging trends chiefly in live music and digital music, streaming music is drawn by their co-evolution. It should be noted that the co-existence of two sectors in the same industry does not necessarily mean co-evolvement; sometimes it is a case of a substitution of one for the other and may result in killing the partner as in the case of downloading and streaming music.

Although the identification of the dynamism of such reactions of the three music industry segments is beyond this analysis, the results of the preceding analyses give us some confidence to believe that by activating and sustaining the co-evolution between live music and streaming music there will be a way towards the sustainability of the resurging trend in the music industry, as illustrated in Fig. 9.

With this confidence, the last analysis of this paper focuses on possible strategic options for activating the above co-evolution.

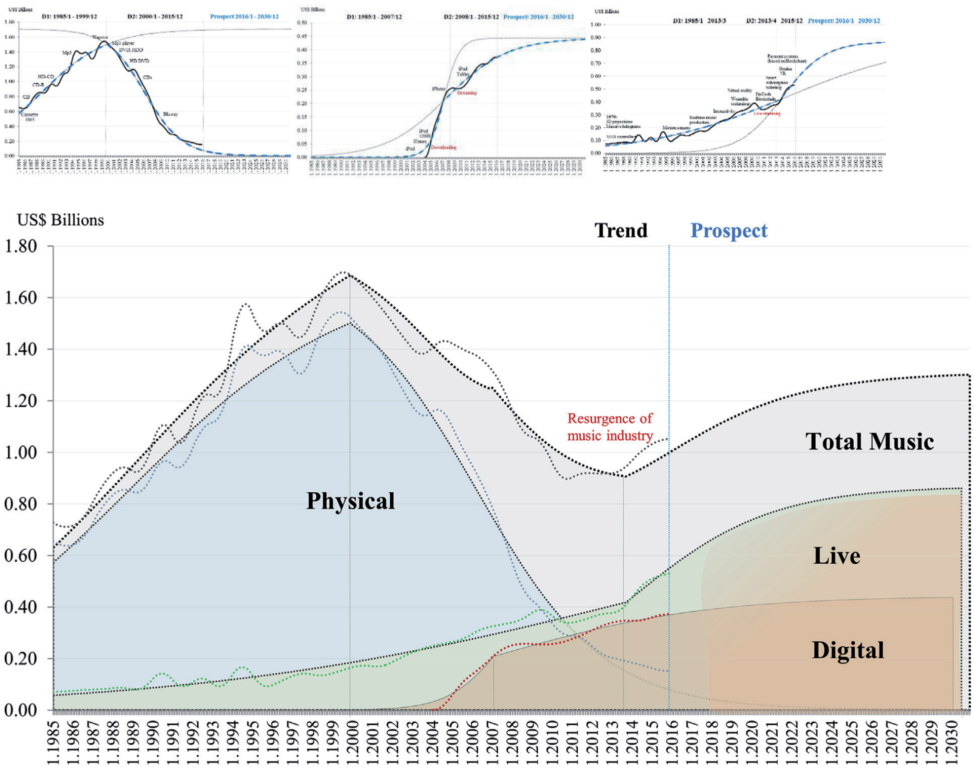


Fig. 14. Trends and future prospects of the US music Industry.
January 1985- December 2015: Trend, *2016 – 2030:* Prospect.

4.2. Transformation of music industries for sustainable Co-evolution

The above analyses suggest that the stakeholders involved in music industry have undergone structural changes, which inevitably drive disruptive changes in the business model of the industry.

The relationship between music fans (consumers) and other actors in the music business is also changing. Instead of owning CDs or other types of music embedded in physical media released by particular artists, fans now want an access to a widening choice of music. The change from ownership to access brings fans closer to the artist and transforms the role of commercial actors (or enablers) such as record labels [8]. As the music industry has moved from a product to a service business model, the loss of sales does not necessary reflect losing customers [18].

We have sought to move our focus from fans undermining the music industry through piracy to fans enhancing and co-creating value in partnership with artists and small record labels. Evidence is now emerging that the Internet is enabling some record labels, artists and fans to work together to co-create value for mutual benefits [4]. These participants work in the concert production through co-creation, interaction and participation in all phases of the production. By harnessing innovative technology, the participants can engage in co-creating memorable live concert experiences [8], and advancement of the Internet further promotes such participative creativity [4].

Live shows, which are something fans cannot fully experience online, have become increasingly valuable for both fans and artists, the market concert tours being the primary source of revenue for most artists.

While these dynamics have created a renaissance of live music, the value chain is incredibly complex, with multiple stakeholders taking their share (e.g., ticketing, secondary ticketing, venues, booking agents, promoters, tax and expenses). The share of the revenue that artists make from live music has declined every year since 2000. The ICT-driven disruptive business model (IDBM) is needed to transform that complex chain into a new more straightforward productive chain.

Under these circumstances, the only thing record labels, artists, music publishers and consumers can do is embrace the new technologies and allow the digital age to work to the advantage of everyone, with the hope that the wonderful art which we call music will keep its integrity for all of eternity [23]. Technological tools are becoming increasingly sophisticated, and the collaborative cultural landscape continues to evolve [10].

Thus, new business opportunities, particularly in the areas of digital distribution and live entertainment, will likely take the center stage as the progression of the Internet continues [7]. The ICT-driven disruptive business model (IDBM) consolidating the

Stakeholders' role

	Company	Employee (Artist)	User (Consumer)	Government
Live concert	**Concert promoter:** the individuals or companies responsible for organizing a live concert tour or special event performance. e.g., Live Nation & Ticketmaster.	**Tour artist:** The tour promoter signs an employment or live performance contract with particular artists to perform in live concerts.	**Fans/attendee:** The individual who attend the live concert or performance.	Event promotion, licensing, noise restrictions, security requirements.
Physical	**Record label:** It coordinates the production, manufacturing, distribution, marketing, promotion and enforcement of copyrights for sound recordings and music videos.	**Recording artist:** A singer, musician who records music, or who fills in missing musical parts on a song. A pop music star or a rapper who has a contract with a record label is an example of a recording artist.	**Physical music consumer:** Buy physical music goods (LPs, Cassettes, CDs etc.) for ownership rather than for resale or use in the production and manufacturing?	Fighting piracy and copyright infringements
Digital	**Digital music provider:** The companies who provide digital music downloading and streaming services such as iTunes, Amazon, Spotify, youTube.	**Artist:** It includes recording and independent artists, whose music is available for downloading and streaming through digital music provider companies or directly.	**Digital music Consumer:** Who download digital music or listen through online streaming services.	Lobbying to change laws against illegal file sharing (P2P), downloading and free usage.
Live concert streaming	**Live streaming concert provider:** the services that offer the live streaming of the concerts as an alternative to be physically present in the concerts.	**Artist:** By live concert streaming services the artists' live concerts can engage viewers from remote locations. The technologies such as virtual reality provide lot of opportunities.	**Virtual participant:** The consumers who are unable to attend live concerts physically and they choose to participate virtually through live concert streaming services.	Encourage fans enhancing and co-creating value.

Fig. 15. Concept of IDBM with CCSD in the music industry — live-concert-streaming music industry (LCSMI).

advantage of digital music into live music has raised all stakeholders' expectations. This supports the significance of co-evolution between streaming music and live music as demonstrated in the preceding analysis and suggests a leading role for the ICT-driven "live-concert-streaming music industry" (*LCSMI*) as the savior of the music industry.

Based on the review above, Fig. 15 illustrates the direction of the music industry towards a sustainable resurgence. This corresponds to the way of constructing a trust-based IDBM (ICT-driven disruptive business model) with CCSD (consolidated challenge for social demand) as has been demonstrated in the new stream of sharing economy like that initiated by Uber's ride-sharing revolution [35].

Fig. 15 highlights the specific features of "live-concert-streaming music industry" (*LCSMI*) that correspond to the following historical demand through co-evolution between the streaming and live music industries:

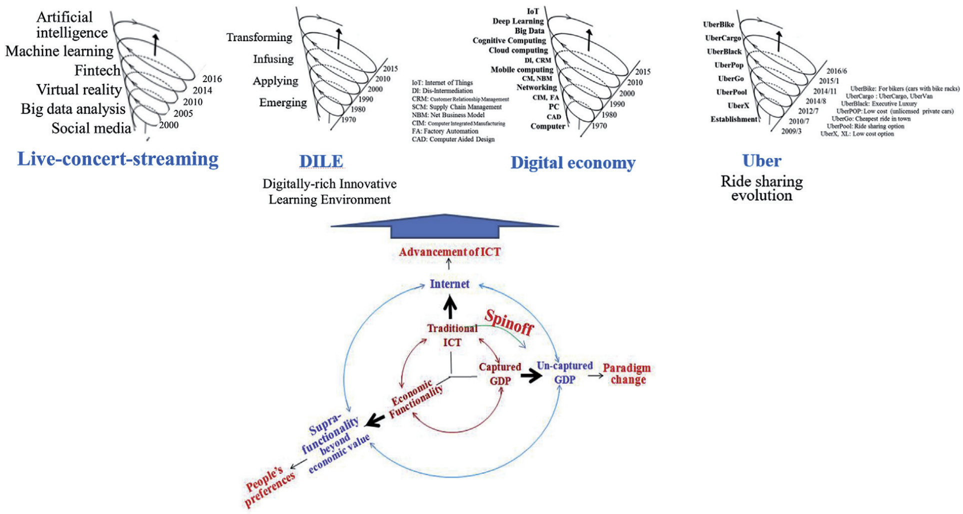


Fig. 16. Music industry in the Spinoff dynamism.

(i) Historical change in consumers propensity to music from *viewership* → *physical ownership* → *digital ownership* → *access* → *viewership and access*,
(ii) Shift in consumers preferences from passive listeners or viewers to access to widening choice of music, participation, integration, co-creation, and participative creativity,
(iii) Emergence of the collaborative cultural landscape,
(iv) Collaboration of live entertainment and digital distribution, and
(v) Long-lasting desire of consumers as well as organizers to transform live music's complex chain with multiple stakeholders into plain productive chain.

Advanced digital innovation, such as social media, big data, virtual reality, fintech, machine learning and artificial intelligence, has enabled the sustainability and activation of this co-evolution.

It should be noted that this co-evolution can be attributed to increasing trust among stakeholders supported by the overdrawing of the past information [14] and also by implementing the emerging technologies such as blockchain.

This direction corresponds to a new stream of innovation: spinning off from traditional to new co-evolution of the advancement of ICT with un-captured GDP dependency and shift to what is called "supra-functionality beyond economic value", has been demonstrated in the digital economy such as in Uber's ridesharing revolution and the digitally-rich innovative learning environments [32,33,34,35,36] are illustrated in Fig. 16.

This new stream of innovation impulses the resurgence of the music industry in a self-propagating way as illustrated in Fig. 17, which in turn demonstrates a testbed for a resurgence strategy for cultural industries.

Artificial intelligence	Creation of algorithms enabling the creation of customized songs for users and helping artists to focus more on being creative.
Machine learning	Enabling consumers to draw on past information, leading to increasing trust among stakeholders.
Fintech	The rise of the blockchain and bitcoin creating new methods of sharing, creating and selling music.
Virtual reality	Interactive virtual worlds created by artists to allow fans from all over the world to share experiences and open up new worlds, enabling also disabled (financially and physically) people to enjoy live music.
Big data analysis	Providing sources for real-time personalization by compiling wide-ranging personal information (e.g., purchasing history, listening habits, physical and mental conditions).
Social media	Used for exploring new distribution channels (e.g., Facebook, Twitter, You Tube)

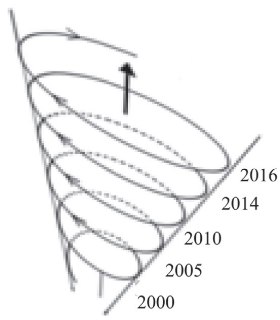


Fig. 17. Digital innovation supportive to sustainability of music industry resurgence.

5. Conclusion

This analysis shows that the recent resurgence of live music in parallel with the increasing popularity of streaming services could effectively save the music industry. The industry which is on the brink of an impending collapse due to diminishing revenues as a consequence of digitization. We pursued our analysis based on the possibility that the live music has effectively assimilated digital innovation from digital music through its co-evolution with streaming music.

An empirical analysis of monthly trends in the US music industry by sectors over the last three decades were conducted and revealed:

(i) A co-evolution between the streaming and live music industries has functioned well over the last few years,
(ii) The live music industry has incorporated a self-propagating function by assimilating its preceding innovations initiated by digital music,
(iii) Given the co-evolution between the streaming and live music industries, the recent resurging trend in the music industry can be sustained,
(iv) The advancement of digital innovation such as artificial intelligence, machine learning, fintech, virtual reality, and big data has enabled the sustainability and activation of this co-evolution while leading the live music industry to transform into a "live-concert-streaming music industry" (*LCSMI*) that enables participative creativity for all stakeholders,
(v) *LCSMI* corresponds to the historical demand of consumers as *a)* the consumers' propensity has shifted from viewership to physical ownership, digital ownership, access to viewership and access, *b)* consumers' preferences has shifted from passive listening or viewing to access to widening choice, participation, integration, co-creation, and participative creativity, *c)* emergence of collaborative cultural landscape, *d)* collaboration of live entertainment and digital distribution, and *e)* transformation of the complex chain of live music with multiple stakeholders into a more straightforward productive chain.
(vi) In this collaborative cultural environment the importance of trust among participating stakeholders (e.g. artists, music providers, ticket sellers, consumers etc.) has become even more crucial. The importance of trust together with the above points in turn suggest the significance of a trust-based ICT-driven disruptive business model (IDBM) with consolidated challenge for social demand (CCSD) for the successful development of our cultural industries

These findings give rise to the following insights about sustainable growth of the music industry:

(i) Establishment of a platform where streamed music services would participate with live music so as to construct a co-evolutionary relationship between them,
(ii) Participative creativity of stakeholders should be nourished,
(iii) Experiences of the preceding trust-based IDBM with CCSD initiatives in the sharing economy such as Uber's ridesharing revolution provide lots of learning opportunities,
(iv) The digitization of music and co-evolution of streaming and live music is very crucial and important step but it also needs an additional layer of trust to function successfully in a very collaborative environment. The implementation of emerging technologies e.g. blockchain distributed ledger might be helpful to further increase the transparency and visibility, building trusted relationships among the stakeholders of value chain.
(v) Active introduction of advanced digital innovations should be initiated by providing a testbed for the advancement of such innovations, and
(vi) Next generation of "live-concert-streaming music industry" (*LCSMI*) should be envisioned.

This paper explored a possible blueprint for the future of the music industry and provided a prototype of a dynamic system called the trust-based IDBM with CCSD for the further development of cultural industries. The historical demand for these systems can be applied not only to the music industry but also to other broader cultural industries, and lessons from the music industry can provide helpful guidelines.

Further research should focus on in-depth analysis of country-specific institutional systems accelerating the co-evolution between live music and streaming music industries. Further analysis of the optimal introduction of advanced digital innovations should be undertaken. For that, a wider empirical analysis covering more countries should be considered.

Given that the economic implications of this analysis are generally applicable to other similar industries as well, the analyses for the resurgence strategies for industries facing collapse such as print media industries could be helpful in understanding these dynamics and planning for the future.

Acknowledgement

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement 293446 – Platform Value Now: Value capturing in the fast emerging platform ecosystems.

Appendix. 1Data construction

Revenues from the music industries (≈ net shipments estimated by monetary value) [7] can be considered as music input (live and recorded music, respectively) into the market while cumulative stock of the revenues can be considered as music assets in the market [15,16].

Therefore, the monthly trends in revenues and their cumulative stocks of live and recorded (physical and digital) music industries in the US over the period 1950–2015 [8] were constructed as follows:

(1) Data collection

Annual revenue statistics available in current US$ (nominal value) over the period of 1974–2015 (for live and physical music) and 2007–2015 (for digital music) were collected.

(2) Estimation of missing data for unavailable years

Missing data for unavailable years (1950–1973 for live and physical music and 2004–2006 for digital music) was estimated by a forward and backward ensembles approach.

[7] Revenues = Sales + Interest income + Dividend income.Shipments (by monetary value) = Sales + InventoriesRevenues = Shipments − Inventories + Interest income + Dividend income ≈ Shipments.

[8] In order to estimate the initial values for cumulative stock estimate, year 1950 was considered reasonable for live and physical music and 2004 for digital music (See Fig. 1).

(3) Conversion to fixed prices

The annual revenues in current US$ were converted to fixed US$ (real value) by using the GDP deflator (base year = 2010).

(4) Disaggregation of annual data to monthly data

Since the life time of digital music is 12 years (2004–2015), in order to conduct significant time series analysis, all annual data were disaggregated to monthly data by using the Denton-Cholette temporal disaggregation method [22].

(5) Cumulative stock

Utilizing the above monthly revenues in fixed prices, cumulative stocks were estimated with the following equation. Annual obsolescence rate was estimated as 10% (0.83% per month) [9]. The details of the estimation of the obsolescence rate can be seen in Appendix 2.

Cumulative stock at time t $T_t = R_{t-m} + (1-\rho)T_{t-1}$ where R_t is revenues at time t, m (lead time for commercialization ≈ 0), and ρ is the rate of obsolescence of music assets (see Appendix 2). See Appendix 4 for estimated cumulative stock.

Appendix. 2Rate of Obsolescence of music assets

Innovation becomes obsolete when it loses functionality [1,30,12]. Thus, companies' efforts for sustainable growth correspond to the prolongation efforts of functionality development [30]. Here, functionality is defined as ability to improve the performance of production processes, goods and services by means of innovation [29] and corresponds to potential capacity before reaching the obsolescent stage [30]. Innovation life-cycles can be measured by the period between the emergence and obsolescence of a phenomenon by its losing functionality [1,12]. The average rate of obsolescence of an innovation can be estimated by taking the reverse of the length of this period.

Contrary to what applies to technology innovation, the concept of obsolescence of music assets is rather complicated. It is subject more strongly to cultural, economic and technology values. It varies depending on such institutional factors as the historical era, cohort, generation, fashion, handling practice, free music monster and piracy [3]. However, [19] identified the existence of cycles in popular music and [5] demonstrated that these cycles in the US in the latter half of the last century can be estimated to last for approximately 10 years: Cycle 1: 1951–1963 (*Rok'n'roll*), Cycle 2: 1964–1975 (*Beatles*), Cycle 3:1976–1989 (*Disco storm to classic rock*), and Cycle 4: 1990–2002 (*Rock's next rebirth*).

These cycles correspond to the focus of academic research in musicology, and bibliometric analyses on the obsolescence of music literature have provided supportive evidence [6,2] discovered that, while digital sharing technologies shorten the survival time of low-ranked albums, they do not hurt the survival of top-ranked albums.

With an understanding that popular music accounts for majority of sales in music industry, these cycles represent the period between the emergence and obsolescence of functionality of music assets measured by cumulative stock of music industry revenues.

By taking the reverse of the above cycles' length, the foregoing reviews suggest 10% p. a. as a reasonable average rate of obsolescence for music assets. In addition, since the length of these cycles prolongs as functionality increases ([30], see Appendix 3), the live-streaming phenomena that emerged in 2010 led to a decrease in the rate of obsolescence.

Appendix. 3Functionality, Lifetime and Obsolescence of Innovation

Logistic Growth Function within Dynamic Carrying Capacity (*LGDCC*) can be approximated by the Simple Logistic Growth Function (*SLG*) as follows:

$$
\begin{aligned}
Y &= \frac{N_k}{1+be^{-at}+\dfrac{b_k}{1-\dfrac{a_k}{a}e^{-a_k t}}} \\
&= \frac{N_k}{1+be^{-at}\left.\quad 1+\dfrac{b_k/b}{1-\dfrac{a_k}{a}e^{(a-a_k)t}}\right)} \\
&\approx \frac{N_k}{1+be^{-at}e^{\frac{b_k/b}{1-a_k/a}}(1+(a-a_k)t)} \\
&= \frac{N_k}{1+be^{\frac{b_k/b}{1-a_k/a}}}e^{-a\left(1-\left(b_k/b\right)\right.}\left.t\right) \\
&\approx \frac{N_k}{1+b\left.\quad 1+\dfrac{b_k}{b}\bullet\dfrac{1}{1-a_k/a}\right)e^{-a\left(1-\left(b_k/b\right)\right)t}} \\
&\equiv \frac{N_k}{1+b'e^{-a't}} \quad where \quad a' = a\left(1-\frac{b_k}{b}\right), b' \\
&\qquad = b\left.\quad 1+\frac{b_k}{b}\bullet\frac{1}{1-\dfrac{a_k}{a}}\right)
\end{aligned}
$$

Functionality can be depicted as follows:

$$FD = \frac{N_k}{Y} = 1+b\left.\quad 1+\frac{b_k}{b}\bullet\frac{1}{1-\frac{a_k}{a}}\right)e^{-a\left(1-\left(\frac{b_k}{b}\right)\right)t}$$

Its initial level is described as follows:

$$FD_0 = \frac{N_k}{Y_0}1+b\left.\quad 1+\frac{b_k}{b}\bullet\frac{1}{1-\frac{a_k}{a}}\right)$$

Thus, functionality, lifetime and obsolescence of innovation can be illustrated as follows [30]:

[9] After the live-streaming phenomena emerged in 2010, the effects of functionality increases on the decreasing the rate of obsolescence value were taken into account (see Appendices 2 and 3).

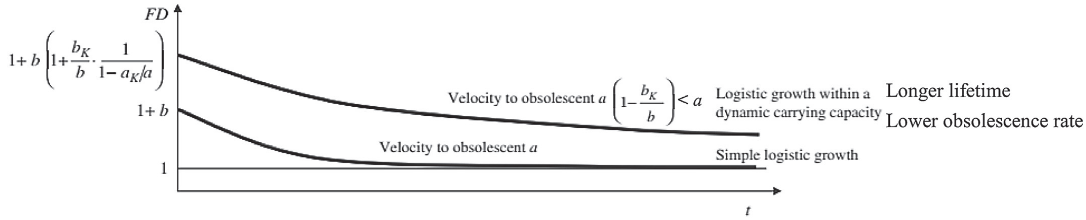
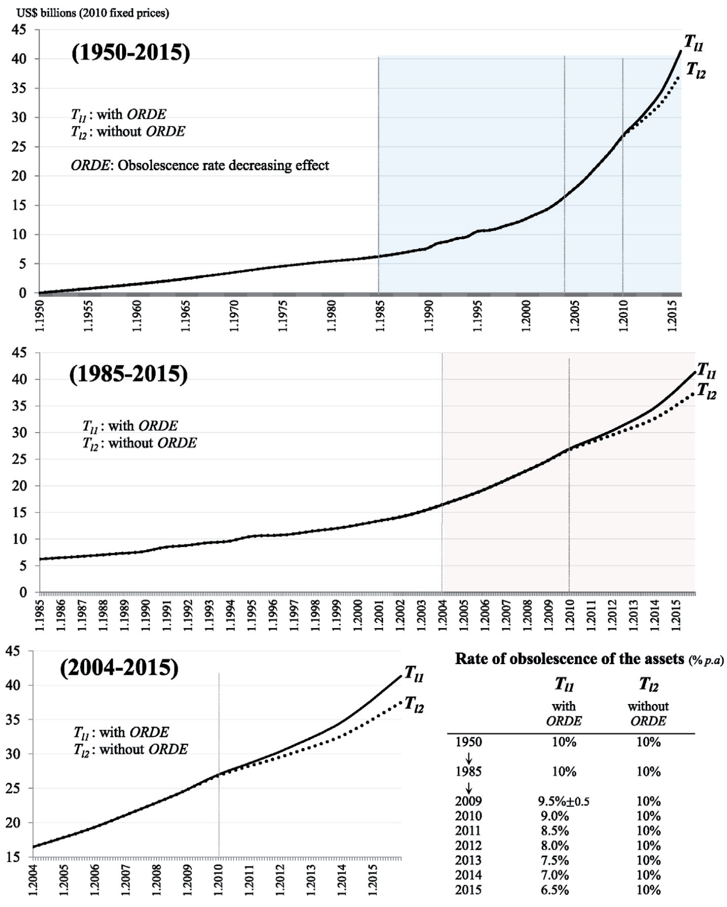


Fig. A1. Scheme of Functionality, Lifetime and Obsolescence of Innovation. This simple logistic growth function (*SLG*).

Appendix 4. Assets estimate for the US live music industry *(1950–2015)*

Two cases, with or without obsolescence rate decreasing effect (*ORDE*), from 2010 were estimated.

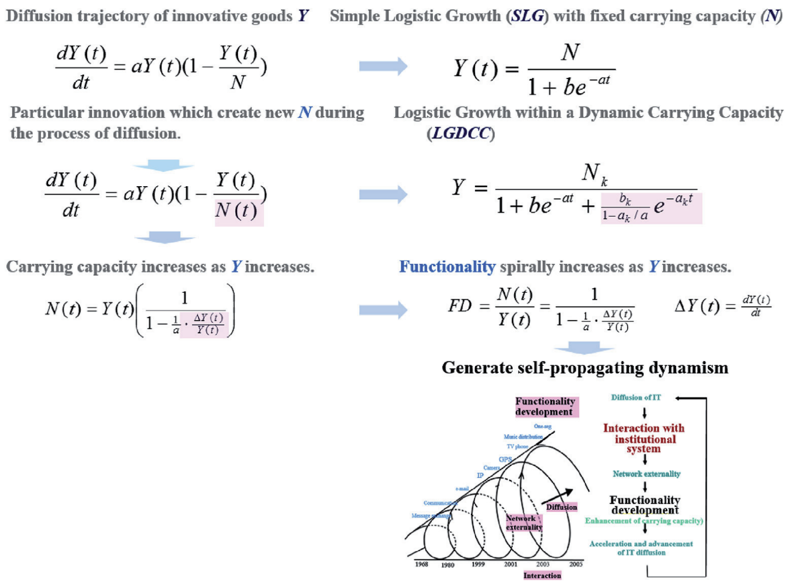


Rate of obsolescence of the assets (% *p.a*)

	T_{I1} with *ORDE*	T_{I2} without *ORDE*
1950	10%	10%
↓		
1985	10%	10%
↓		
2009	9.5%±0.5	10%
2010	9.0%	10%
2011	8.5%	10%
2012	8.0%	10%
2013	7.5%	10%
2014	7.0%	10%
2015	6.5%	10%

Fig. A2. Trend in Live Music Assets in the USA - Cumulative Stock of Live Music Revenues.
Source: Pollstar (Year End Business Analysis Edition, 2015).

Appendix 5. Dynamism in developing self-propagating function



Appendix 6. Model construction

Trends in music input into the market as well as its assets in market Y are normally subject to a phenomena similar to that demonstrated by an epidemic function as depicted in equation (A1).

$$\frac{dY}{dt} = aY\left(1 - \frac{Y}{N}\right) \tag{A1}$$

where N: upper limit of diffusion (carrying capacity), and a: coefficient governing the velocity of diffusion.

This equation is developed to a logistic growth function as depicted in equation (A2) [10].

$$Y = \frac{N}{1 + be^{-at}} \tag{A2}$$

where b: coefficient identifying the initial state of diffusion.

While Y seeks to attain level N, its velocity would be subject to external circumstances such as a change in paradigm, customers' preferences and emergence of competitive businesses and innovation. Therefore, equation (A1) should be rewritten to (A3), depending on circumstances 1 and 2.

$$\frac{dY}{dt} = a_1 D_1 \cdot Y\left(1 - \frac{Y}{N}\right) + a_2 D_2 \cdot Y\left(1 - \frac{Y}{N}\right) \tag{A3}$$

where D_1 and D_2: dummy variables demonstrating circumstances 1 and 2, respectively.

This is the same as the initial state of diffusion as represented by coefficient b.

Therefore, in case of two circumstances which make music industries react differently, each respective music industry follows the following hybrid logistic growth trajectory:

$$Y = \frac{N_X}{1 + b_{X1} D_1 e^{-a_{X1} D_1 t} + b_{X2} D_2 e^{-a_{X2} D_2 t}} \tag{A4}$$

where X classifies sectors of music industry as P (physical), D (digital) and L (live).

This hybrid logistic growth (*HLG*) model (Watanabe Naveed model) demonstrates a high level of fitness in relation to actual behaviors of music industries reacting to the circumstances' change.

[10] This simple logistic growth function (*SLG*) can be considered an approximation of a logistic growth function within dynamic carrying capacity (*LGDCC*) under the following conditions (see Appendix 3): $\frac{\frac{b_k}{b}}{1-} \frac{a_k}{a} e^{(a-a_k)t} << 1$, $(a - a_t)t << 1, \frac{b_k}{b} \cdot \frac{1}{1-\frac{a_k}{a}} << 1$ $\frac{b_k}{b} \le \frac{b_k}{b} \cdot e^{(a-a_t)t} << 1 - \frac{a_k}{a}$ therefore, $(a - a_k)t << 1, \frac{a_k}{a} + \frac{b_k}{b} << 1$

Appendix 7. *LGDCC* Logistic growth Regression Estimation.

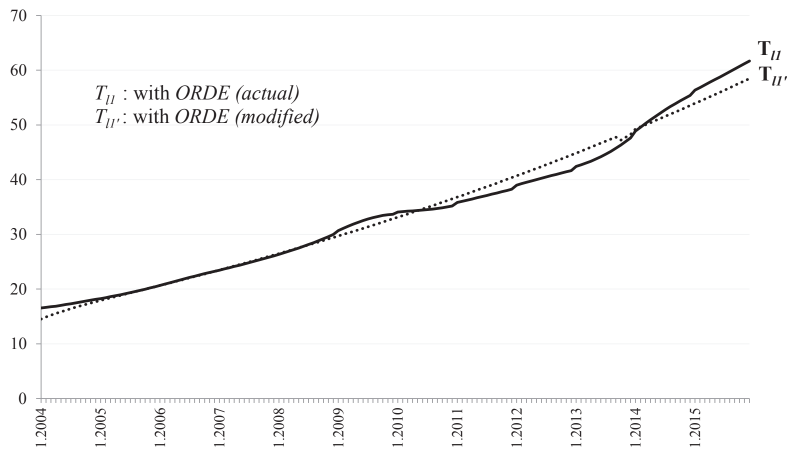


Fig.A3. *LGDCC* Logistic growth Regression Estimation.

Calculation $T_{l1} = (Y_{l1} + z \cdot T_d)$

1 ***LGDCC*** $Y_1 = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-\frac{a_k}{a}e^{-a_k t}}}$

2 **Computation** $\overline{Y_1}$ (*calculated by using the estimated coefficients*)

3 **Regression** $T_1 = a + \beta\overline{Y_1}$

4 **Computation** $\overline{T_1}$ (*calculated by using the estimated coefficients*)

4′ (1) **Average** $\overline{T'} = \frac{T+\overline{T}}{2}$ 2004/1 – 2015/12

4′ (2) **Average** $\overline{T''} = \frac{T+\overline{T}}{2}$ 2013/10 – 2013/12

5 ***LGDCC*** $\overline{T} = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-\frac{a_k}{a}e^{-a_k t}}}$

References

[1] S.L. Barreca, Technology Life-cycles and Technological Obsolescence, BCRI Inc, Birmingham, Alabama, 1998.
[2] S. Bhhattacharjee, R. Gopal, K. Lertwachara, J.R. Marsden, R. Telang, The effect of digital sharing technologies on music markets: a survival analysis of albums on ranking charts, Manag. Sci. 53 (9) (2007) 1359–1374.
[3] K. Bylin, Conditioned to steal: popular music and obsolescence in America, Hypebot.com. (2009). August. http://www.hypebot.com/hypebot/2009/08/conditioned-to-steal-popular-music-and-obsolescence-in-america.html. Retrieved 25 December 2016
[4] H. Choi, B. Burnes, The internet and value Co-creation: the case of the popular music industry, Prometheus 31 (1) (2013) 35–53.
[5] A. Cross, A lesson on the theory of the 13-year music cycle, J. Music. Things 25 (2012) 1–7. March.
[6] V. Diadato, F. Smith, Obsolescence of music literature, J. Am. Soc. Inf. Sci. 44 (2) (1993) 101–112.
[7] A. El Gamal, The Evolution of the Music Industry in the Post-Internet Era, CMC Senior Thesis, Claremont College, 2012, p. 532.
[8] P. Erika, Co-creating an Engaging Live-streamed Concert with Potential Viewers, Master's Thesis, Degree Program in Service Innovation and Design, Laurea University of Applied Sciences, 2016.
[9] B. Fly, How Does Music Consumption Impact the Music Industry and Benefit Artists? Accounting, Undergraduate Honors Thesis, University of Arkansas, 2016, p. 20.
[10] J. Freeman, Web-based Collaboration, Live Musical Performance and Open-form Scores, Int. J. Perform. Arts Digital Media 6 (2) (2010) 149–170.
[11] P. Gronow, The record industry: the growth of a mass media, in: R. Middleton (Ed.), Popular Music, III., Cambridge University Press, Cambridge, 1983.
[12] C. Jennings, D. Wu, J. Terpenny, Forecasting obsolescence risk and product life cycle with machine learning, IEEE Trans. Components, Packag. Manuf. Technol. 6 (9) (2016) 1428–1439.
[13] J. Kirshbaum, Seven Top Music Marketing Trends for 2016, Hypebot, January, 2016, http://www.hypebot.com/hypebot/2016/01//6-music-marketing-trends-in -2016-draft.html. Retrieved 22 December 2016.
[14] N. Luhmann, Trust and Power, John Wiley, Chchester, 1979.
[15] N. Meade, T. Islam, Modelling and forecasting the diffusion of innovation: a 25-year Review, Int. J. Forecast. 22 (2006) 519–545.
[16] T. Modis, Strngths and weakeness of S-curves, Technol. Forecast. Soc. Change 74 (2007) 866–872.
[17] Music Ally Data map (musically), Global Music Industry Data on Sales, 2015. http://www.musically.com. Retrieved 30 Novemeber 2016.
[18] G. Parry, O.F. Bustinza, F. Vendrell-Herrero, Servitisation and value co-production in the UK music industry: an empirical study of consumer attitudes, Int. J. Prod. Econ. 135 (1) (2012) 320–332.
[19] R.A. Peterson, D.G. Berger, Cycles in symbol production: the case of Popular music, Am. Sociol. Rev. 40 (2) (1975) 158–173.
[20] Pollstar, Pollstar Year End 2015 Special Edition, 2015. http://www.pollstar.com. Retrieved 15 December 2016.
[21] Record Industry Association of America (RIAA), RIAA Year-end Revenue and Shipment Reports, 2016. https://www.riaa.com/u-s-sales-database/. Retrieved 15 October 2016.
[22] C. Sax, P. Steiner, Temporal disaggregation of time series, R J. 5 (2) (2013) 80–87.
[23] S.D. Stafford, Music in the digital age: the emergence of digital music and its repercussions on the music industry, Elon J. Undergrad. Res. Commun. 1 (2) (2010) 112–120.
[24] P. Tschmuck, The Recession in the Music Industry: a Cause Analysis, Music Business Research, March 2010 https://musicbusinessresearch.wordpress.com/2010/03/29/the-recession-in-the-music-industry-a-cause-analysis/, Retrieved 29 December 2016.
[25] J. Turner, Seven trends impacting live music events, June 2015, Eventbrite (2015), http://www.festivalinsights.com/2015/06/trends-impacting-live-music-events/. Retrieved 22 December 2016.
[26] C. Watanabe, B. Zhu, C. Griffy-Brown, B. Asgari, Global technology spillover and its impact on industry's R&D Strategies, Technovation 21 (5) (2001) 281–291.
[27] C. Watanabe, M. Takayama, A. Nagamatsu, T. Tagami, C. Griffy-Brown, Technology spillover as a complement for high-level R&D intensity in the pharmaceutical industry, Technovation 22 (4) (2002) 245–258.

[28] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of it functionality development, Technol. Forecast. Soc. Change 71 (7) (2004a) 723–750.
[29] C. Watanabe, K. Matsumoto, J.Y. Hur, Technological diversification and assimilation of spillover technology: canon's scenario for sustainable growth, Technol. Forecast. Soc. Change 71 (9) (2004b) 941–959.
[30] C. Watanabe, S. Lei, N. Ouchi, Fusing indigenous technology development and market learning for greater functionality development: an empirical analysis of the growth trajectory of canon printers, Technovation 29 (2) (2009) 265–283.
[31] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured GDP and growing anger of consumers, Technol. Soc. 41 (2015a) 21–44.
[32] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT Infrastructure – similarity and disparities between Finland and Singapore, Technol. Soc. 42 (2015b) 104–122.
[33] C. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, Operationalization of un-captured GDP: the innovation stream under new global mega-trends, Technol. Soc. 45 (2016a) 58–77.
[34] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution of three mega-trends natures un-captured GDP: uber's ride-sharing revolution, Technol. Soc. 46 (2016b) 164–185.
[35] C. Watanabe, K. Naveed, P. Neittaanmäki, Consolidated challenge to social demand for resilient platforms: lessons from uber's global expansion, Technol. Soc. 48 (2017a) 33–53.
[36] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution between trust in teachers and higher education toward digitally-rich learning environments, Technol. Soc. 48 (2017b) 70–96.

Kashif Naveed is currently doing his Ph.D. in Economics and Business Administration from the University of Jyväskylä, Finland and he has completed his Masters of Science degree in Economics and Business Administration from the same university. Previously he had Bachelors' of Science degree in Computer Science from the Hamdard University Karachi, Pakistan. *(kashif.naveed.dr@gmail.com)*

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Research Professor of University of Jyväskylä, Finland, and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com)

Pekka Neittaanmäki graduated from the University of Jyväskylä in Mathematics and is currently Professor and a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland. (pekka.neittaanmaki@jyu.fi)

PVII

CO-EVOLUTION OF THREE MEGA-TRENDS NURTURES UN-CAPTURED GDP - UBER'S RIDE-SHARING REVOLUTION

by

Chihiro Watanabe, Kashif Naveed and Pekka Neittaanmäki, 2016

Technology in Society, vol. 46, pp. 164-185

Technology in Society 46 (2016) 164–185

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Co-evolution of three mega-trends nurtures un-captured GDP – Uber's ride-sharing revolution

Chihiro Watanabe [a, b, *], Kashif Naveed [a], Pekka Neittaanmäki [a]

[a] *University of Jyväskylä, Finland*
[b] *International Institute for Applied Systems Analysis (IIASA), Austria*

A R T I C L E I N F O

Article history:
Received 4 March 2016
Received in revised form
11 June 2016
Accepted 14 June 2016
Available online 16 June 2016

Keywords:
Ride-sharing revolution
ICT-driven disruptive business model
Uber's system success
Two-faced nature of ICT
Un-captured GDP

A B S T R A C T

Uber used a disruptive business model driven by digital technology to trigger a ride-sharing revolution. The institutional sources of the company's platform ecosystem architecture were analyzed to explain this revolutionary change.

Both an empirical analysis of a co-existing development trajectory with taxis and institutional enablers that helped to create Uber's platform ecosystem were analyzed.

The analysis identified a correspondence with the "two-faced" nature of ICT that nurtures un-captured GDP. This two-faced nature of ICT can be attributed to a virtuous cycle of decline in prices and an increase in the number of trips.

We show that this cycle can be attributed to a self-propagating function that plays a vital role in the spinoff from traditional co-evolution to new co-evolution. Furthermore, we use the three mega-trends of ICT advancement, paradigm change and a shift in people's preferences to explain the secret of Uber's system success.

All these noteworthy elements seem essential to a well-functioning platform ecosystem architecture, not only in transportation but also for other business institutions.

1. Introduction

The dramatic advancement of information and communication technology (ICT) in recent years has brought about a new reality in which information, people, organizations, logistics, and finance are constantly connected on a global level and mutually influence one another. This constant connection is starting to produce a hitherto non-existent synergy without being bound to the confines of existing industrial structure and technology fields. Therefore, the synergy allows the creation of new businesses and markets, and is also starting to change how we work and live (Council of Science, Technology and Innovation, 2016) [9].

Uber, an on-demand ridesharing service that connects passengers to local drivers in real time using smartphone technology, demonstrates this ICT-driven disruptive business model by triggering a ride-sharing revolution.

In light of its conspicuous accomplishment, to date, considerable studies have been undertaken in elucidating, conceptualizing and operationalizing Uber's system success. The studies can be classified into five streams: (i) prospect of automotive industry, (ii) ride-sharing revolution, (iii) disruptive innovation, (iv) ICT-driven innovation, and (v) new business model.

Schlze et al. (2015) [24] pointed out that automotive firms cope with turbulence caused by globalization, new government regulations, and advances in electronics, communication, and drive train technologies. In the mean time, these technologies are facilitating not only new product features but also new business models which Uber deployed as consumer preferences move toward mobility as a service rather than vehicles as products. They stressed the significance of a wide lens (Adner, 2012) [1] with change and stability. Avital et al. (2014) [2] stressed that an economy based on the exchange of capital, assets and services between individuals has grown significantly, spurred by the proliferation of Internet-based platforms that allow people to share underutilized resources and trade with reasonable transaction costs. The movement to the ride-sharing revolution triggered by Uber was also postulated by Blk (2014) [5], Koopeman et al. (2014)

* Corresponding author. University of Jyvaskyla, Finland.
E-mail addresses: watanabe.c.pqr@gmail.com (C. Watanabe), kanaveed@student.jyu.fi (K. Naveed), pekka.neittaanmaki@jyu.fi (P. Neittaanmäki).

http://dx.doi.org/10.1016/j.techsoc.2016.06.004
0160-791X/

Table 1
Parallel Paths between history of Uber and ICT advancement.

Year	Uber's Story	Advancement of ICT
2008 Winter	The story of Uber in Paris	Apple's iPhone (2007), Google's Android (HTC)
2009 March	UberCab (renamed to Uber in 2011) was established in SF	Many new smartphone models and OS launched.
2010 July	**UberCab** (on-demand car service via an iPhone app or SMS (short message service)) released in SF.	Apple iPad tablet, Instagram was founded.
2011 May	Expanded into a new city each month including NYC, Chicago and Washington DC	3 Billion Android downloads,
Dec	In operation in Paris (first outside of the US) Raised 44.5 m US$	Tablet pc's by Samsung, Sony, Acer, etc.
2012 July	**UberX** (low cost Uber: for-pay rideshare scheme, trips cost less than the same journey in an ordinary taxi)	Android and iOS dominated the market share. US smartphone sales passed featured phone sales.
2013 Summer	Faced competition from ride-sharing services like Lyft Experimental Uber Chopper (helicopters transporting service)	85% of US adults use the Internet, 2 Million apps, U.S. consumer spends 126 min per day on Mobile apps compared to 168 min on TV
2014 April	Banned by the government in Berlin	In person, Mobile payments in the US doubled to $3.7B
June	Taxi drivers in London, Paris, and Madrid staged a large-scale protest	59% of US smartphone owners do mobile shopping.
August	**UberPool** (matching passenger with another rider heading in the same direction)	Since 2010 the Digital media time spent on
October	Received an "F" (flunk) rating from the Better Business Bureau (BBB)	Smartphone increased by 394% and tablets by 1721%
November	**Uber Go** (officially the cheapest ride in town)	Both platforms account for 60% of total time spent.
2015 Feb	Established Uber Advanced Technology Center (collaboration with Carnegie Mellon)	78% of US mobile subscribers owned a smart phone.
April	UberEATS program (food delivery service)	US consumers spend 4.7 h on average on smartphone each day.
May	Uber Military Families Coalition, App accommodating for drivers for deaf or hard of hearing 58 countries and 300 cities	U.S. consumer now spends 198 min per day on Mobile apps compared to 168 min on TV
2015 Dec	Market value 62.5 B US$	U.S. has the highest average rate of monthly data consumption via smartphone: a colossal 20 GB.

[17], King (2015) [16] and Ehret (2015) [11]. Ehret referred Rifkin's "Zero marginal cost society" (Rifkin, 2014) [23] and suggested uncaptured GDP (Watanabe et al., 2016) [36] that Uber may emerge by stressing that "*Soon we will have access to most products and services at almost no marginal cost. Mega-corporation will cease to make profits and the capitalist market economy will be replaced by a collaborative commons, where people exchange ideas and support each other with creative solutions.*"

This emerging paradigm is disruptive to the conventional company-driven economic paradigm as evidenced by a large number of peer-to-peer based services (Avital et al., 2014) [2] on which Uber is based. Isaac et al. (2014) [15] appreciated Uber as one of the most disruptive, successful tech start-up company which has severely disrupted the taxi service industry. They pointed out that much of the success Uber has generated so quickly relies on (i) its ability to classify itself as a "technology company" instead of a transportation company, (ii) the ability to classify their drivers as independent contractors instead of employees, and (iii) a depressed market in which workers are willing to assume the burden of risks and costs associated with driving for the company. They pointed that much of the reason why Uber has been so threating to the traditional taxi industry lay in its efficient and innovative utilization of modern technology, particularly ICT. Baiyere et al. (2015) [4] supported this view by stressing that rapid continuous advancement in ICT corresponds to the emergence of disruptive ICT innovation increases. Horpedahl (2015) [14] highlighted smartphone apps are stressing that they allow consumers to bypass traditional taxicabs. All led to a new business model. Cohen et al. (2014) [7] reminded that some altogether new and different business has emerged over the several past years. These developments have started to challenge traditional thinking about how resources can and should be offered and consumed. This way of thinking supports the arguments that incremental improvements in our existing production and consumption systems are insufficient to transform our global economy toward sustainability (Lovins et al., 2011 [18], Stead et al., 2013 [26]). From these, a new business model inevitably emerges toward the shared economy. Cohen et al. (2014) [7] pointed out that shared mobility solutions can be attributed to multiple agents, including public and private providers, seek to develop business models which address deficiencies in public infrastructure and public transit systems, historically the exclusive purview of local and regional governments. They also warned that the common interest in sustainability among these different types of agents does not always lead to harmony, instead giving rise to agency conflicts that can reduce the positive sustainability impact of their individual and collective initiatives. Indeed, Uber has been confronting legal battles with the traditional automotive industry, particularly the taxi industry in some countries.

All the preceding streams intertwine with each other leading to a new system design or systems web. Uber's system success and ICT-driven disruptive business model, on which Uber is based, can be attributed to a co-evolution of this systems web. However, scholars have yet to undertake an analysis of a co-evolution of a systems web which connects these new streams.

Inspired by noting the contrast between the world's leading ICT countries with respect to happiness/welfare amidst great stagnation in Finland and conspicuous economic growth in Singapore, authors have demonstrated that current ICT-driven global development depends on a trend shifting from traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality to new co-evolution of the Internet, un-captured GDP, and supra-functionality beyond economic value. The authors then demonstrated that the above contrast can be attributed to the difference between the two states in the shifting trends described above (Watanabe et al., 2016) [36].

This paper elucidates and conceptualizes Uber's system success based on Uber's contrasting disruptive innovation development trajectory and contrasts the ICT-driven disruptive business model with the traditional taxi industry based on a traditional business model. An empirical analysis similar to the analysis done on the co-evolution of three mega-trends governing the difference of the state in the shifting trends was conducted.

Section 2 reviews Uber's conspicuous start-up. Section 3 analyzes institutional enablers creating platform ecosystems. Section 4 demonstrates co-evolution of three mega-trends leading to sharing economy. Section 5 briefly summarizes noteworthy findings, implications, and suggestions for future works.

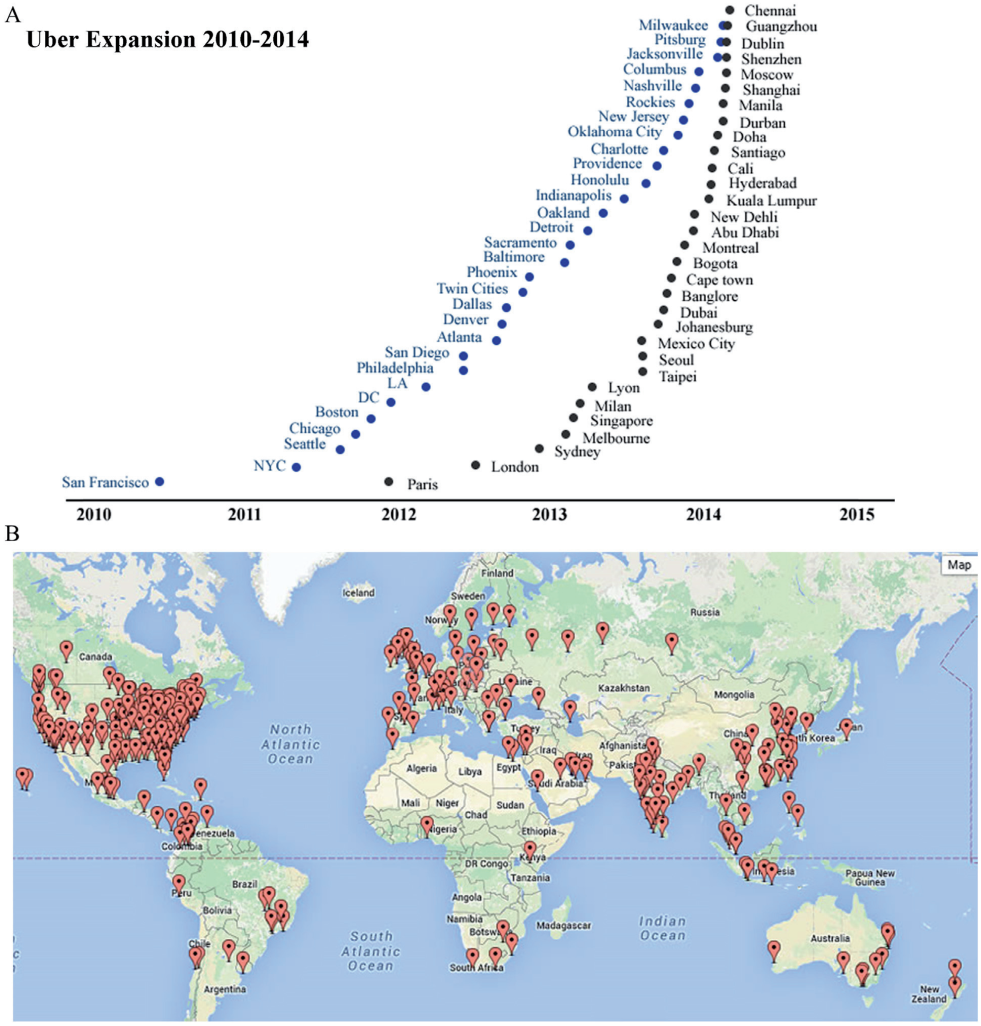


Fig. 1. A. Uber's expansion trajectory worldwide (Source Uber.com). B. Uber's expansion in 375 cities on world map *(as of Jan. 2016)* (Source: Author's geocoded map based on Uber's cities list at Uber.com (see Appendix 5)).

2. Uber, its conspicuous start-up

2.1. Digital technology driven disruptive business model

Ride-sharing company Uber is a high-tech company founded in March 2009 (Table 1). It is seen as the jewel of ICT as it brilliantly connects the transportation industry with ICT via its ride-sharing application and it leverages the sharing revolution (Belk, 2014) [5], leading to the transformation of the market for taxi cabs and limousines. It offers its service in over 375 cities worldwide in 2015 (Fig. 1A, B). Uber is regarded as the highest-valued venture-supported company. It is currently one of the fastest growing start-ups worldwide. It's value exceeds the value of the full US taxi and limousine industry.

Uber gives passengers a better service with cost and time savings in reaching a location, and it provides its drivers with a highly efficient operation without additional investment and license fees (Table 2). Its system is convenient also for drivers. They can work flexible hours and can reject unwanted clients.

Through a cashless system based on credit cards, Uber can trace and choose highly-rated drivers. Reliance on digital technology provides passengers with a transparent view of quality and prices. Similarly, drivers can memorize passenger's behavior. Thus, Uber has established a mutual rating system among the company, drivers, and passengers.

In this way, Uber has triggered a disruptive business model which is driven by digital technology. This technology has been significantly impacting traditional business, not only in transportation but also almost all business institutions.

Uber appraised itself for this business model as "*Uber epitomizes*

Table 2
Competitive analysis between Uber and taxi.

	Uber	Taxi	Remarks (Uber's unique advantage)
Advance booking	No	Yes	
Hiring method	Smart phone App	Flag/Call center/App/Dedicated taxi queue	
Payment	Cashless	Cash/Credit card	
Driver/Passenger rating	Available	NA	Co-evolution by mutual rating system
Pricing structure	Premium principle Flexible Surge pricing	Cost principle Structured	Customers pay for services for reliable, punctual, comfortable Clear overview of price before booking Respond to changes in supply and demand in the market
Fare sharing	Anyone	Limited to friends	
ETA to destination	Available	NA	Estimated Time of Arrival. Follow drivers on map
ETA of the ride	Available	Available (Apps only)	One-tap ride
Car	Self	Rented from taxi company	
Driver's perspectives	Flexible and independent	Rigid	Motivation why drivers choose Uber (Bureau of Labor Statistics)
Law and regulation	Gray area	Well defined	
Value capture to company	Commission fee	Rental fee, Advertisement	91%: Earn more income, 87%: To be my own boss, 85%: flexible and balancing with a better life.

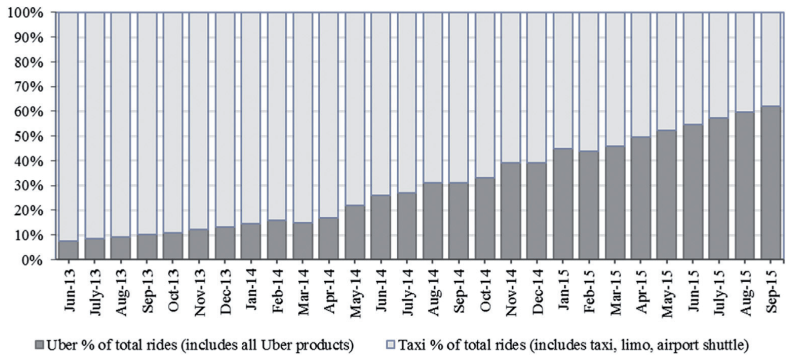


Fig. 2. The trend in share of rides by Taxi and Uber in the US *(Jun. 2013 – Sep. 2015)*.
Sources – Jan. 2014–Mar. 2015: Certify (2015) [6], other periods: authors' estimate based on TLC and Uber (See Appendix 1).

disruption. The company has changed the way we think about grabbing a ride, incorporating the same technology we take for granted today into a brand new experience for consumers and an opportunity for producers" (A Brief History of Uber) [29].

2.2. Astounding rise

As a general consequence of the numerical analysis of newly emerged innovation, elucidation of Uber's systems success was a challenge in exploring the dark continent without published statistical data.

Fig. 2 attempts to trace the trajectory of Uber's astounding rise. Conspicuousness of Uber's disruptive business model can be confirmed by the astounding rise in the number of its users. Based on expense reports from business travelers, Certify (2015) [6] revealed that an average 46% of all total paid car rides were through Uber in major markets across the US in March 2015. This demonstrates a steep rise particular in business use over the 14 months from a mere 15% in January 2014 as demonstrated in Fig. 2.

Uber's fast rise to success directly correlates with the decrease in the number of traditional taxi users. The share of taxi, limousine and shuttles of that number fell dramatically from 85% to 54% over this 14 months. This observation is rather biased towards Uber, as the report is focused on business travelers, it has been estimated that the number of people using Uber is higher than the number of people using a taxi now (Frier, 2015) [12].

2.3. Trend in the substitution for taxi

(1) Trends in Taxi Revenues, Trips and Prices (Jun. 2013–Sep. 2015)

Fig. 3-A –C demonstrate trends in taxi revenues, trips and prices in NYC over the period June 2013–September 2015.

As a consequence of Uber's astounding rise in a co-existing development trajectory with taxis, the number of trips in taxis demonstrates rapid decline (Fig. 3–A) which resulted in their revenues decline (Fig. 3–B) and subsequent increase in their prices (Fig. 3-C).

(2) Comparison of the Trends in Trips and Prices between Uber and Taxi

Fig. 4 demonstrates trends in Uber and taxi trips in NYC over the period June 2013–September 2015. Similarly, Fig. 5 demonstrates trends in Uber and taxi prices in NYC over the same period.[1]

[1] This analysis focuses on the state in NYC as it demonstrates pioneer state of ridesharing revolution in the US (Hickman, 2015 [13]; Silverstein, 2014 [25]; Stone, 2015 [4]), and all data in Figs. 4 and 5 are based on the state in NYC, except Uber share (U_D) in estimating Uber trip (U_T) in Fig. 4. Due to unavailability of reliable statistics on U_D in NYC, it based on the average Uber share in the US focusing on business use (Fig. 2) which should be interpreted slightly reserved to Uber trips in NYC.

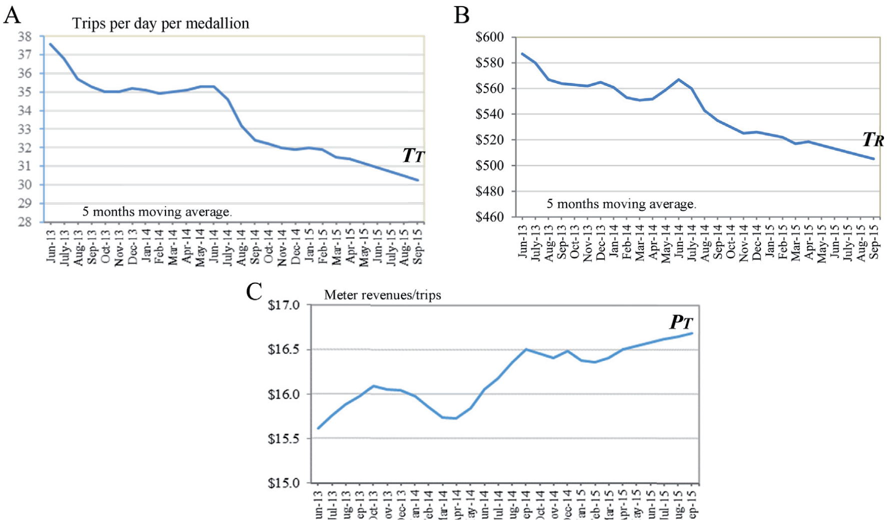


Fig. 3. A. Trend in taxi trips in NYC *(Jun. 2013 – Sep. 2015)*. B. Trend in meter revenues in NYC *(Jun. 2013 – Sep. 2015)*. C. Trend in taxi prices in NYC *(Jun. 2013 – Sep. 2015)*.
Sources: *TR* and *TT*- Jun. 2013–Mar. 2015: Hickman (2015) [13] based on NYC Taxi and Limousine Commission (TLC), another period: authors' estimate based on TLC. *PT* = *TR*/*TT* (See Appendix 1).

At the same time as Uber's astounding success, Uber's prices continued to decline and in May 2014 they reached the same level as taxis. The prices further declined with the introduction of UberPool in August 2014. The decline in prices was reversed as a consequence of Uber's surge pricing, and resulted in an "F" (flunk) rating from the Better Business Bureau (BBB) in October 2014 when complaints about unexpectedly high charges were cited. In response to such complaints and also to competition from competitors such as Lyft, Uber managed to decrease prices by introducing Uber Go in November 2014. This move, together with technology advancement effort by the establishment of the Uber Advanced Technology Center in February 2015, led to lower prices again in 2015.

3. Institutional enablers leveraging Uber's astounding rise

3.1. Sharing economy for physical products

Uber's astounding rise can largely be attributed to dissemination of sharing economy from digital products to physical products.

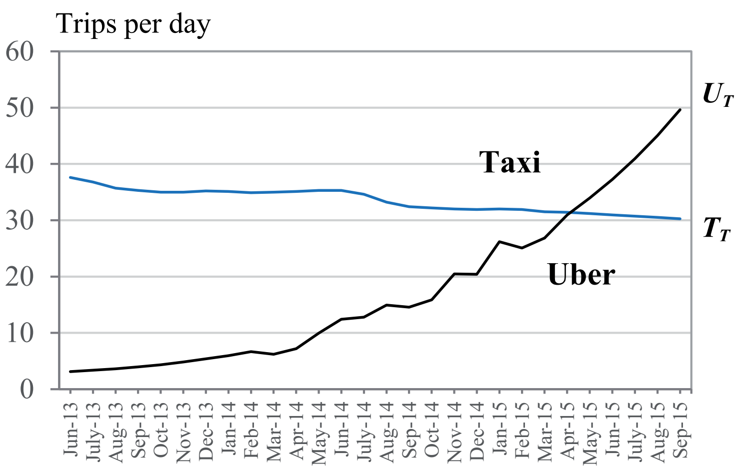


Fig. 4. Trends in Uber and taxi trips in NYC *(Jun. 2013 – Sep. 2015)*.
Sources – Taxi: Fig. 3–A. Uber: authors' estimate based on $U_T = \frac{U_D}{1-U_D} \cdot T_T$ where U_T: Uber trip, T_T: Taxi trip, U_D: Dependency on Uber (share of Uber trips out of sum of Uber and taxi trips as demonstrated in Fig. 2) (See Appendix 1).

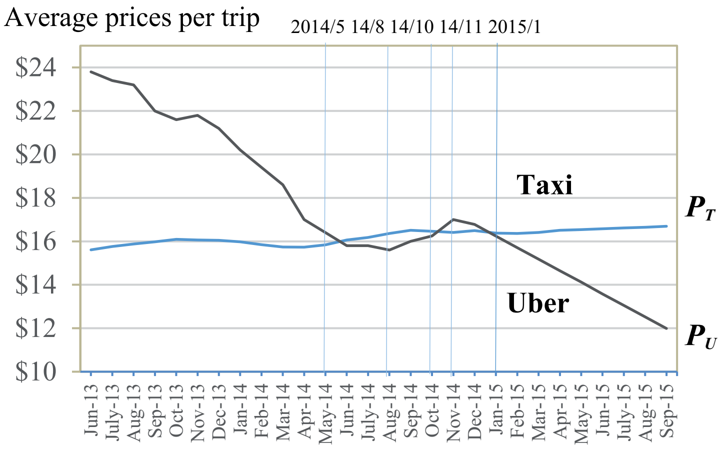


Fig. 5. Trends in Uber and taxi prices in NYC *(Jun. 2013 – Sep. 2015)*.
Sources – Taxi: Fig. 3-C, Uber – Jun. 2013–Nov. 2014: Lunden (2014) [20], other period: Authors 'estimate based on TLC, Uber, Stone (2015) [27] and Silverstein (2014) [25] See Appendix 1).

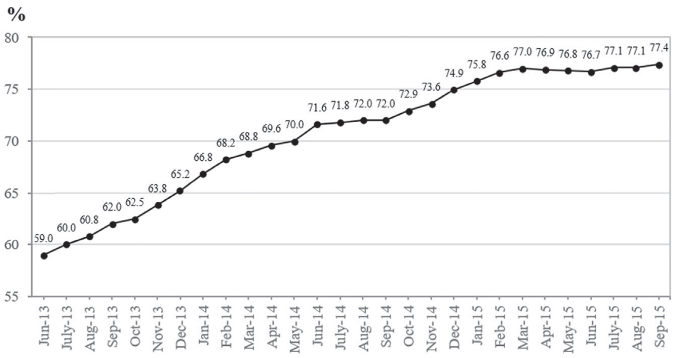


Fig. 6. The trend in smartphone share in the US mobile subscriber market *(Jul. 2013 – Sep. 2015)*. Smartphone share of the US mobile subscriber market: % of mobile subscribers aged 13 + owning a smartphone.
Source: comScore (2013–2015) [8].

Table 3
Governing factors of Uber prices in NYC *(Jun. 2013 – Sep. 2015)*.

$$\ln P_U = \underset{(4.06^{*1})}{6.361} \underset{(-1.80^{*4})}{- 0.717} D_1 \ln SP \underset{(-2.62^{*2})}{- 1.015} D_2 \ln SP \underset{(-1.49^{*5})}{- 0.551} D_3 \ln SP \underset{(-3.63^{*1})}{- 0.213} D_1 \ln U_T \underset{(2.52^{*2})}{+ 0.278} D_2 \ln U_T \underset{(-10.84^{*1})}{- 0.376} D_3 \ln U_T \quad adj.R^2\ 0.980 \quad DW\ 1.25$$

D1: 2013.6 – 2014.7 = 1, rest = 0. *D2*: 2014.8 – 2014.11 = 1, rest = 0, *D3*: 2014.12 – 2015.9 = 1, rest = 0.
Figures in parenthesis indicate t-statistics: significant at $*^1$:1%, $*^2$:2%, $*^4$:10%, $*^5$: 15% level.

Table 4
Contribution of Uber prices decrease in NYC *(Jun. 2013 – Sep. 2015) – % p.a.*

PU decrease $\frac{\Delta P_U}{P_U}$ rate	Contribution by			Period
	SP increase rate	U_T increase rate	Miscellaneous	
−3.07	−0.717 × 1.52 = −1.09	−0.213 × 11.92 = −2.54	0.56	2013/6–2014/7
1.87	−1.015 × 0.62 = −0.63	0.278 × 13.02 = 3.62	−1.12	2014/8–2014/11
−3.43	−0.551 × 0.51 = −0.28	−0.376 × 9.57 = −3.60	0.45	2014/12–2015/9

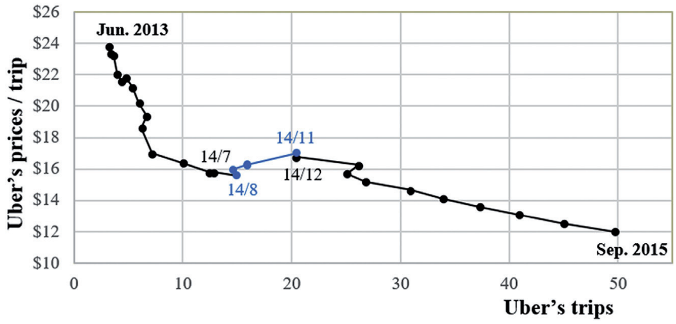


Fig. 7. Correlation between Uber's trips and their prices in NYC *(Jun. 2013 – Sep. 2015)*.

In line with people's preferences shift from economic functionality to supra-functionality beyond economic value (Watanabe et al., 2014 [34]), sharing economy in physical products (i.e., rooms and cars) has been gaining momentum.

The underlining paradigm of the original sharing economy is that users aim at increasing resource-use efficiency, to lower costs or to create new value. Online trading platforms such as Napster and eMula were amongst the first to provide users with shared access to digital music and videos. It was possible to download these digital products from lenders on the platform for free, and uploading and downloading happened simultaneously (Winterhalter et al., 2015 [37]).

People's preference shift to supra-functionality has led to requests for a similar platform also for physical products. People wish to use such products (which were provided passively, primarily with economic functionality) in a more sophisticated manner by their initiative (Adner, 2012 [1]).

Sharing economy for physical products initiated by Uber and AirbnB is needed by the market with such underlining paradigm.

3.2. Institutional enabler of sharing economy in physical products

(1) Advancement of ICT

The main enablers of the sharing economy are ICT and Internet connectivity, which allow effective peer-to-peer contact (The Economist, 2013 [28]).

Thanks to the dramatic advancement of the Internet, countless websites connect people on a peer-to-peer basis with separate resources of almost any kind (not only time, digital information and knowledge resources but also space and fixed assets) to the needs of others searching for these resources.

Such advancement, particularly of a smartphone, nurtures Uber by enabling high qualified services with lower cost[2] and shorter time. Fig. 6 demonstrates a trend in smartphone share in the US mobile subscriber market over the period July 2013–September 2015. Looking at Fig. 6 we note that while smartphone has gained popularity, and its share in the mobile subscriber market demonstrated a sharp increase in the US, there has been stagnation in the upward surge and a shift from quantity to quality in 2015 in nationwide in the US (comScore, 2013–2015 [8]).

(2) Passengers Initiative and Paradigm Shift to Ecosystem

Passengers initiative also strengthens, while the company's systematic market strategy brings benefits such as continuous reductions in costs and time for search and matching while eliminating information asymmetries and compiling a massive database.

Uber compiles a massive database on driver and rider behavior, which is essential to Uber price-setting and market-making. Also, it allows Uber and the regulators to ensure safety and to root out discrimination against passengers.

In addition to the introduction of the Internet, the paradigm shift from resources to ecosystem (from captured GDP to uncaptured GDP (Watanabe et al., 2014, 2015 [34,35]) has been leveraged by Uber in its creation of a new business. Shifting from traditional in-house-oriented business towards services making use of interactions between the stakeholders: company, drivers, and passengers.

Under the support of these institutional enablers, Uber was able to accomplish astounding rise by the following simple business model:

(i) Its smartphone-based app connects drivers, offering rides and passengers seeking them,
(ii) Passengers pay mileage-based fees through credit cards that company keeps on file, and
(iii) Uber takes a percentage of each fee and gives the rest to its driver.

3.3. Self-propagating virtuous cycle

(1) Governing Factors of Uber Prices Decline

Since Uber prices (P_U) are governed by the increase in smartphones demonstrated by its share in the mobile subscriber market (SP), learning and economy of scale effects, their trend can be

Table 5
Estimates of Medallion prices for the period preceding their stagnation (Jan. 2004–Jun. 2013).

$$Y = \frac{N}{1+be^{-at}}$$

	Estimate	*t-value*	*adj.* R^2
N	2247.11	7.23	0.976
a	0.02	14.21	
b	6.36	7.21	

Y: Medallion prices, *N*: Carrying capacity, *t*: Monthly trend, *a*, *b*: Coefficients.
All t-values demonstrate statistically significant at the 1% level.

[2] e.g., from downtown L.A. to the airport (Uber: 22 US$, Taxi: 46.5 US$ (56 $ with 20% tip)) in 2015.

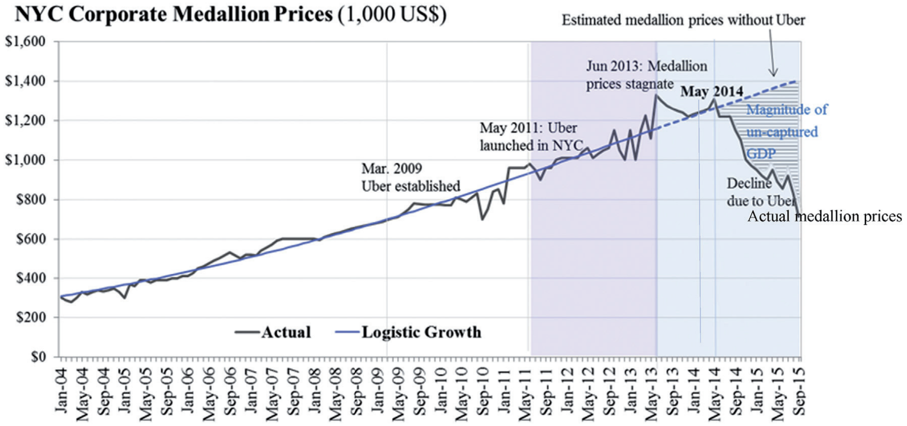


Fig. 8. Trends in corporate Medallion prices and their estimate without Uber in NYC – 2013 prices (Jan. 2004–Sep. 2015).
Source: NYC Taxi and Limousine Commission (TLC).

depicted as follows:

$$P_U = A \cdot SP^{\alpha} \cdot U_T^{-\lambda}$$
$$\ln P_U = \ln A + \alpha \ln SP - \lambda \ln U_T$$

A: scale factor, U_T: Uber trips, α :SP elasticity to P_U, and λ : learning coefficients (learning and economy of scale effects).

Based on this equation, Table 3 identifies governing factors of Uber prices in NYC over the period June 2013–September 2015 by dividing into three periods: 2013/6–2014/7 (sharp decline), 2014/8–2014/11 (change to increase due to surge pricing), and 2014/12–2015/9 (decline by introducing Uber Go and technology advancement effort) corresponding to Fig. 5 analysis.

Table 3 demonstrates that while SP elasticity to P_U maintains negative with smaller value in the 3rd period, learning co-efficient changed from negative to positive in the 2nd period and changed again to negative in the 3rd period. The former corresponds to the observation in Fig. 6 while the latter corresponds to the observation in Fig. 5.

Utilizing the results of Table 3, the contribution of Uber prices decrease can be identified as summarized in Table 4.

Looking at Table 4 we note that Uber's prices have been governed by the increase in its trips and own strategy together with the increase in smartphones. Contribution of trips increase can be attributed to learning and economy of scale effects (Watanabe et al., 2009 [32]) while contribution of smartphones increase can be attributed through ICT's self-propagating function that accelerates learning and economy of scale effects (Watanabe et al., 2004 [30], Watanabe et al., 2009 [32]).

As analyzed in Fig. 5, sharp decline in Uber prices stagnated from August 2004 and changed to upward trend by serious complaints about unexpectedly high charges due to surge pricing in October 2014. While this upward shifting factor remains, the price decline trend was maintained by introducing Uber Go in November 2014 together with technology advancement effort. This challenge in the 3rd period demonstrated high elasticity of trips to prices and compensated the stagnation of smartphones share increase in 2015. Upward trend in the 2nd period can be attributed to surge pricing strategy.

Table 4 demonstrates these rise and fall trends. Noteworthy is a resilient recovery in price decline in the 3rd period despite stagnation of smartphones contribution to this decline. This suggests a sophisticated dynamism in Uber's ICT-driven trips and prices coordination which is beyond simple ICT's self-propagating function as well as learning and economy of scale effect.

(2) Virtuous Cycle between Uber Trips Increase and Its Prices Decline

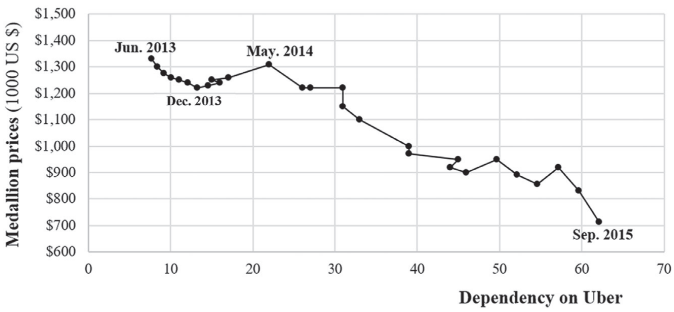


Fig. 9. Correlation between dependency on Uber and medallion prices in NYC (Jun. 2013.6 – Sep. 2015).
Sources: NYC Taxi and Limousine Commission (TLC) and Certify [6].

Inspired by the foregoing suggestion, Fig. 7 analyzes the correlation between Uber's trips and their prices in NYC over the same period.

Fig. 7 demonstrates three phases trends corresponding to the three periods in Table 4. While Uber's prices demonstrated sharp decline as smartphones increased in the 1st period, after recovering from the upward trend in the 2nd period, prices decline was maintained under trips increase initiative despite smartphones direct effect decreased. This dynamism prompts us the sources of Uber's success leading to its astounding rise as reviewed earlier. Given Uber as the jewel of ICT as reviewed in 2.1, this success is considered to depend on ICT's unique comprehensive function beyond simple self-propagation, learning and economy of scale effects.

4. Co-evolution of 3 mega-trends leading to a spinoff to sharing economy

4.1. Emergence of un-captured GDP

(1) Medallion Prices as a Proxy of the Trend in Taxi Demand

The medallion system (official taxi licenses with medallion, in place since 1937) sets an upper limit of the number of those cabs with licenses. As the demand grew, medallions became more and more valuable, resulting in higher medallions prices. Therefore, the trend in medallion prices can be considered as a proxy of a trend in taxi demand[3] and given its sustainable increase, Taxi medallions were considered the best investment in the US (Badger, 2014) [3].

Thus, this trend continuously increased, experiencing logistic growth as demonstrated in Table 5. This trend led to a sharp hike in medallion prices from 250 thousand US$ in January 2004 to a peak of 1.3 million US$ (for the corporate sector) in June 2013, as demonstrated in Fig. 8.

However, starting in May 2011, Uber added more and more drivers, the medallion prices started stagnating after a peak in June 2013. The prices then fell precipitously from May 2014, corresponding to the time when Uber prices reached the level of taxis prices as demonstrated in Fig. 5.

(2) Correlation between Dependency on Uber and Medallion Prices

The more cabs are booked through Uber, the less money the cab drivers make and the worse the taxi medallions look like as an investment. Medallion prices have continued to drop considerably after Uber, with prices declining, caught up with the price level of a traditional taxi in May 2014.

Fig. 9 illustrates the correlation between dependency on Uber (share of Uber trips out of sum of Uber and taxi trips) and medallion prices (as a proxy of taxi demand) in NYC over the period June 2013–September 2015.

Uber's astounding success brought its prices lower than a taxi in May 2014 (Fig. 5). Uber's success resulted in a significant decrease in medallion prices (Fig. 8). Reduced medallion prices (taxi demand decrease) induce further dependency on Uber, leading to a virtuous cycle between medallion prices decline and increase in this dependency, as demonstrated in Fig. 10.

This demonstrates a structural source of the contrast between precipitous fall of the medallion prices and astounding rise of Uber.

(3) Two-faced Nature of ICT and Subsequent Un-captured GDP

The impacts of Uber's sharing revolution on the medallion system in NYC can be classified into two periods:

(i) During the first two years after the launch of Uber in May 2011, Uber's share remained below 10% (Fig. 2), and its impact on medallion prices was limited. The medallion prices continued to increase, due primarily to the increase in demand for a taxi.
(ii) However, after this "pregnancy period," once Uber's share reached 10% in June 2013 overcoming the Chasm in a diffusion trajectory (Moore, 1999 [22]),[4] the sharing revolution made a structural change to the medallion price formation system, leading to the above-mentioned precipitous fall.

Table 5 suggests that without such sharing revolution which made a structural change in the price formation system, the medallion prices may continue to logistic growth as illustrated in Fig. 8 by a broken line. Contrast of actual and estimated medallion prices corresponds to the two-faced nature of ICT which postulates that while the advancement of ICT contributes to enhancing its prices by increasing new functionality development, dramatic advancement of the Internet tends to decrease ICT prices due to freebies, easy copying, and mass standardization, among other things as illustrated in Fig. 11 (Cowen, 2011 [10]).

This suggests the emergence of un-captured GDP as Uber advances. Advancement of ICT can largely be attributed to the dramatic advancement of the Internet, which has changed the computer-initiated ICT world significantly. The Internet promotes a free culture, consumption of which provides utility and happiness to people but cannot be captured through GDP data that measure revenue (Lowrey, 2011 [19]) leading to increasing dependency on un-captured GDP (Watanabe et al., 2014, 2015 [34,35]).

Uber's better service with cost and time savings for passengers by highly efficient operation without additional investment and license fees for drivers correspond to this concept. Therefore, discrepancy between actual medallion prices and estimated medallion prices without Uber in Fig. 8 can be considered as demonstrating the magnitude of un-captured GDP (See Appendix 2).

(4) Magnitude of the Emergence of Un-captured GDP

Inspired by the preceding observation with respect to emergence of un-captured GDP driven by the discrepancy induced by Uber, un-captured GDP emerged by Uber can be captured by measuring the discrepancy between taxi prices and magnitude of their decline effect derived from Uber as illustrated in Fig. 12. Since magnitude of taxi prices decline effect can be measured by the aggregated prices of taxi and Uber with respective trip share, un-captured GDP emerged by Uber can be measured by the following balance:

[3] Medallion prices demonstrate significant correlation with taxi trips as follows and support this view:

Correlation between Taxi Trips (T_T) and the Medallion Prices (MP) in NYC (monthly basis)

Jan. 2000 - May 2013 (Before *MP* stagnate due to Uber)

$$\underset{(-18.55)}{\ln MP = -9.573} + \underset{(30.56)}{4.174 \ln T_T} \qquad adj.R^2\ 0.986 \quad DW\ 1.52$$

Jun. 2013 - Sep. 2015 (After *MP* stagnate)

$$\ln MP = \underset{(-3.78)}{-2.102} + \underset{(16.36)}{2.595 \ln T_T} \underset{(-3.87)}{- 1.147 D} \quad adj.R^2\ 0.911 \quad DW\ 1.04$$

D: Dummy variables (Jun. 2013 and Sep. 2015 = 1, other months = 0).
Figures in parenthesis indicate t-value: all significant at the 1% level.

[4] Analysis based on the diffusion theory identifies this timing of Uber in NYC as early 2013 (See Appendix 2).

$$\ln MP_t = \underset{(77.43)}{8.435} \underset{(-11.50)}{- 0.554} D_1 \ln UD_{t-1} \underset{(1.06^{*7})}{+ 0.220} D_2 \ln UD_{t-1} \underset{(-14.22)}{- 0.420} D_3 \ln UD_{t-1} \underset{(-3.31)}{- 1.895} D_2 \underset{(-5.07)}{- 0.131} D \quad adj.\ R^2\ 0.948 \quad DW\ 1.77$$

MP: Medallion prices, *UD*: Dependency on Uber, D_1, D_2, D_3, D: Dummy variables.
D_1: 2013.6 – 2013.12 = 1, rest = 0. D_2: 2014.1 – 2014.5 = 1, rest = 0. D_3: 2014.6 – 2015.9 = 1, rest = 0.
D: 2013.7-8, 2015.9 = 1, other months = 0.

Dependency on Uber ⇄ **Medallion prices**

$$\ln UD_t = \underset{(15.22)}{17.022} \underset{(-13.11)}{- 2.051} D_1 \ln MP_{t-1} \underset{(3.06)}{+ 11.030} D_2 \ln MP_{t-1} \underset{(-11.88)}{- 1.910} D_3 \ln MP_{t-1} \underset{(-3.62)}{- 92.770} D_2 \quad adj.\ R^2\ 0.980 \quad DW\ 1.46$$

D_1: 2013.6 – 2013.12 = 1, rest = 0. D_2: 2014.1 – 2014.5 = 1, rest = 0. D_3: 2014.6 – 2015.9 = 1, rest = 0.

Fig. 10. Virtuous cycle between dependency on Uber and Medallion prices (Jun. 2013–Sep. 2015). Figures in parenthesis indicate t-statistics: all significant at the 1% level except *7: 30% level.

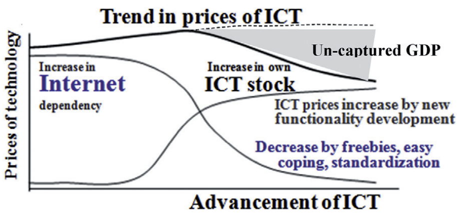


Fig. 11. Two-faced nature of ICT.

$$\text{Un-captured GDP} = P_T - P_A = P_T - \frac{T_T \cdot P_T + U_T \cdot P_U}{T_T + U_T} = P_T - \frac{P_T + \alpha \cdot P_U}{1 + \alpha} = \frac{1}{1 + \frac{1}{\alpha}}(P_T - P_U)$$

where *PT*: Taxi prices, *PU*: Uber prices, *PA*: Aggregated prices, *TT*: Taxi trip, *UT*: Uber trip, α: *UT*/*TT* ratio.

Fig. 12 demonstrates the significant parallel correlation between taxi prices (P_T) and estimated medallion prices without Uber (*Mpe*), as well as aggregated prices (P_A) and actual medallion prices (*MP*) (See Appendix 3). This endorses the view that the balance between

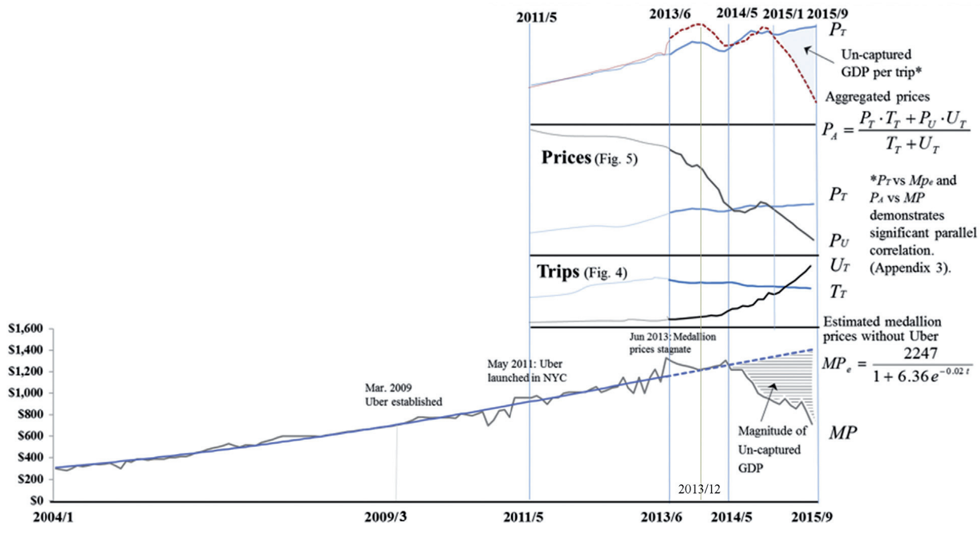


Fig. 12. Scheme of the measurement of the emergence of un-captured GDP emerged by Uber in NYC.

taxi prices and aggregated prices represents the emergence of un-captured GDP emerged by Uber.

4.2. Emergence of Uber-driven un-captured GDP

(1) Substance of the Uber-driven Un-captured GDP

Supported by the preceding endorsement, Fig. 13 demonstrates the magnitude of un-captured GDP per trip emerged by Uber.

Aggregated prices P_A are measured by the following equation: $P_A = \frac{P_T \cdot T_T + P_U \cdot U_T}{T_T + U_T}$

The substance of this un-captured GDP can be summed up as follows:

High-qualified services with lower cost and shorter time. An increasing initiative of passengers and the company's systematic market strategy of continuous reduction of costs and time in search and matching, eliminating information asymmetries and compiling a massive database.

Fig. 13 demonstrates that while Uber nurtured "negative un-captured GDP value" (its services were unable to catch up with those of taxi accumulated over the last 120 years) by June 2014, it succeeded in nurturing increasing un-captured GDP from the beginning of 2015 corresponding to its success in sustainable decline in prices from the end of 2014 (Fig. 5).

(2) Increase in the Emergence of Un-captured GDP

On the basis of the preceding review, the trend in the value of un-captured GDP per trip by Uber in NYC was measured as illustrated in Fig. 14. This Figure demonstrates that un-captured GDP induced by Uber has been increasing significantly from the beginning of 2015.

As emulating in the following equation, this can be attributed to a virtuous cycle between Uber's prices (P_U) decline and trips (U_T) increase.

$$\text{Un}-\text{captured GDP} \quad = P_T - P_A = P_T - \frac{T_T \cdot P_T + U_T \cdot P_U}{T_T + U_T}$$

$$= P_T - \frac{P_T + \alpha \cdot P_U}{1+\alpha} = \frac{1}{1+\dfrac{1}{\alpha}}(P_T - P_U)$$

where $\alpha = \frac{U_T}{T_T} ratio$

4.3. Spinoff to sharing economy

(1) New Functionality Development During Diffusion Process

Uber's conspicuous virtuous cycle between prices decline, and increased trips can largely be attributed to its self-propagating function incorporating new functionality development during its diffusion process as was prompted by the analysis in Fig. 7.

Diffusion trajectory of innovative goods Y (trips of taxis and Uber in this case) can be depicted by the following epidemic function:

$$\frac{dY(t)}{dt} = aY(t)\left(1 - \frac{Y(t)}{N}\right) \quad (1)$$

where N: carrying capacity (sealing the adoption of innovative goods) and a: coefficients governing diffusion velocity.

This equation leads to the following simple logistic growth (SLG) function:

$$Y(t) = \frac{N}{1 + be^{-at}} \quad (2)$$

where b: coefficient indicating initial state of the diffusion.

While the level of carrying capacity is assumed constant through the diffusion process in this function, in particular innovations, the correlation of the interaction between innovation and institutions displays a systematic change in the process of growth and maturity. This leads to the creation of a new carrying capacity in the process of its diffusion similar to equation (1) as follows:

$$\frac{dY(t)}{dt} = aY(t)\left(1 - \frac{Y(t)}{N(t)}\right) \quad (3)$$

This equation leads to the following logistic growth within a dynamic carrying capacity (LGDCC) function, which demonstrates the level of carrying capacity enhancement as the diffusion proceeds (Meyer et al., 1999 [21]):

$$Y = \frac{N_k}{1 + be^{-at} + \frac{b_k}{1-a_k/a}e^{-a_k t}} \quad (4)$$

where Nk: ultimate carrying capacity, and ak and bk: coefficients similar to a and b.

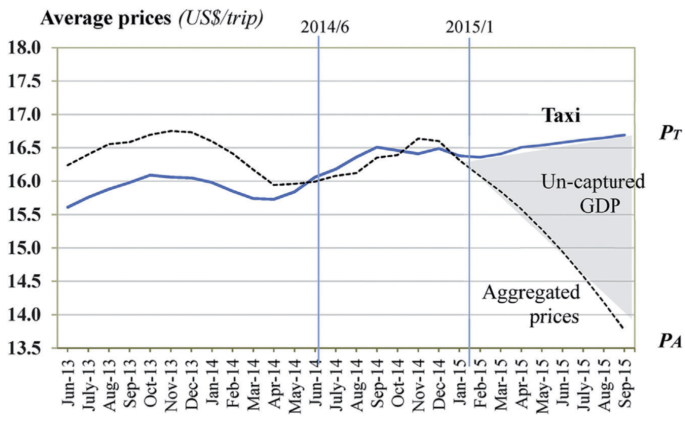


Fig. 13. Trends in taxi prices and aggregated prices in NYC (*Jun. 2013 – Sep. 2015*).

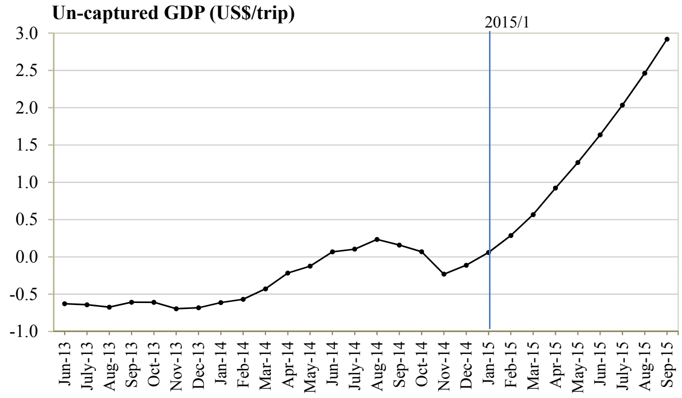


Fig. 14. Trend in the emergence of un-captured GDP emerged by Uber in NYC (*Jun. 2013 – Sep. 2015*).

Equation (4) demonstrates that the 3rd term of the denomination governs the dynamic carrying capacity and without this term results in SLG with a constant carrying capacity.

(2) Uber's Self-propagating Function

From equation (3), dynamic carrying capacity can be expressed as follows:

$$N(t) = Y(t)\left(\frac{1}{1 - \frac{1}{a}\cdot\frac{dY(t)}{dt}\Big/Y(t)}\right) \tag{5}$$

This demonstrates that *N(t)* increases together with the increase of *Y(t)*, and its growth rate as time goes by. This implies that the LGDCC function demonstrates functionality development in the context of the self-propagating behavior (Watanabe et al. (2004) [30], Watanabe et al. (2009) [32]).

Table 6 compares this self-propagating function in taxi and Uber in NYC by examining their adaptability to LGDCC.

Table 6 demonstrates that while taxis depend on SLG as its 3rd term of the denomination (a_k and b_k) demonstrates statistically insignificant, Uber demonstrates depending on LGDCC with statistically significant 3rd term of the denomination.

This demonstrate that Uber has developed with the self-propagating function.

(3) Spinoff from Taxi to Uber

This self-propagating function plays a vital role of the engine in spinning-off from traditional co-evolutional three mega-trends to new co-evolution as illustrated in Fig. 15. This spin-off plays significant role in inducing ICT-driven innovation (Watanabe et al. (2015, 2016) [35,36]). Here spin-off is defined as jumping to more sophisticated co-evolutional dynamism from traditional co-evolutional dynamism in inducing innovation (Watanabe et al., 2011 [33]).

From equation (5) functionality development in the LGDCC function can be depicted as follows:

$$\text{Functionality development} = FD = \frac{N(t)}{Y(t)} = \frac{1}{1 - \frac{1}{a}\cdot\frac{dY(t)}{dt}\Big/Y(t)} \tag{6}$$

This equation demonstrates that functionality development can be accelerated as its growth rate increases. Since functionality development plays a locomotive role in leveraging spin-off (Watanabe et al. (2011) [33]), equation (6) indicates self-propagating function leverages spin-off by inducing functionality development.

This spin-off can be observed in industries not only transportation (Fig. 16) but also music industry, game industry and printing and publishing industry. Nowadays, even education industry has been behaving the similar trend.

4.4. Dynamism of Uber's ICT driven disruptive business model

By the preceding analyses, the dynamism of Uber's ICT driven disruptive business model can be identified as illustrated in Fig. 17.

Co-existing development trajectory with taxi corresponds to two-faced nature of ICT that is behind the emergence of un-captured GDP.

This emergence can be attributed to a strong substitution from taxi to Uber accelerated by contrasting vicious cycle between price increase and trips decrease in taxi and a virtuous cycle between price decline and trips increase in Uber.

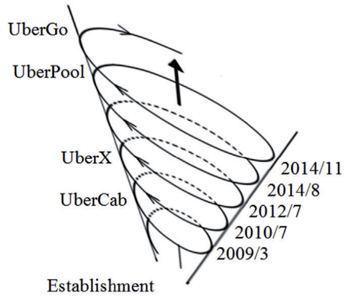
Uber's virtuous cycle can be attributed to ICT's self-propagating function that enhances the level of functionality as its diffusion proceeds.

This self-propagating function plays a vital role in spin-offs from traditional co-evolution to new co-evolution between ICT advancement, paradigm change to increasing un-captured GDP

Table 6
Adaptability of taxi and Uber's development trajectories to LGDCC (NYC).

	N_k	a	b	a_k	b_k	adj. R^2
Taxi (Jan. 2004 –Jun.2013)	2247.12 (6.42)	0.017 (12.61)	6.364 (6.63)	0.439 (0.00^{x})	10.30 (0.00^{x})	0.976
Uber (Jun.2013 –Sep.2015)	119.27 (41.41)	0.121 (36.67)	49.650 (11.13)	0.016 (2.42^{*3})	0.200 (1.43^{*5})	0.999

Taxi: based on medallion prices (Fig. 8), Uber: based on trips (Fig. 4) with spline interpolation (see Appendix 4).
LGDCC: Logistic growth with dynamic carrying capacity, $Y = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-a_k/a}e^{-a_k t}}$ (eq. (4)).
Figures in parenthesis indicate t-statistics: all significant at the 1% level except ^{*3}: 5%, ^{*5}: 15%, ^{x}: non-significant.



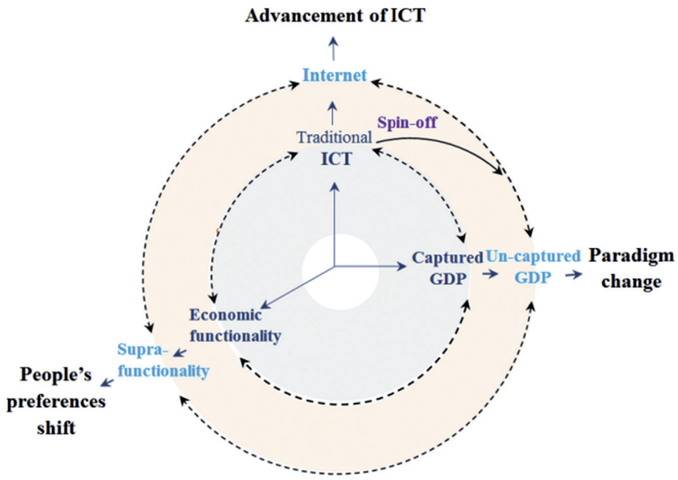


Fig. 15. Scheme of spin-off dynamism.

dependence, and people's preferences shift to supra-functionality beyond economic value.

This spin-off accelerates further lower cost and higher services, which accelerates the foregoing virtuous cycle.

Uber's success can be attributed to constructing such ICT driven disruptive business model.

Business models have been moving from pipes to platforms and we are in the midst of transformative shift in business design. Platforms allow participants to co-create and exchange value with each other. External developers can extend platform functionality and contribute back to the infrastructure of the business. Platform users who act as producers can create value on the platform for other users to consume. All have been demonstrated by Uber.

Uber's disruptive business model can be thus appreciated as a leader of transformative shift in business design by constructing the foregoing platform ecosystem.

5. Conclusion

5.1. Secret of the Uber's system success

In light of the disruptive digital-technology-driven business model that Uber has used to trigger a ride-sharing revolution, the institutional sources of the company's platform ecosystem architecture were analyzed.

Aiming at elucidating institutional enablers creating Uber's platform ecosystem, an empirical analysis of its co-existing development trajectory with taxi was attempted.

Noteworthy findings include:

(i) This co-existing development trajectory corresponds to two-faced nature of ICT that is behind the emergence of un-captured GDP,
(ii) This emergence can be attributed to a strong substitution from taxi to Uber accelerated by contrasting vicious cycle between price increase and trips decrease in taxi and a virtuous cycle between price decline and trips increase in Uber,
(iii) Uber's virtuous cycle can be attributed to ICT's self-propagating function that enhances the level of functionality as its diffusion proceeds,
(iv) This self-propagating function plays a vital role in spin-offs from traditional co-evolution to new co-evolution between ICT advancement, paradigm change to increasing un-captured GDP dependence, and people's preferences shift to supra-functionality beyond economic value,

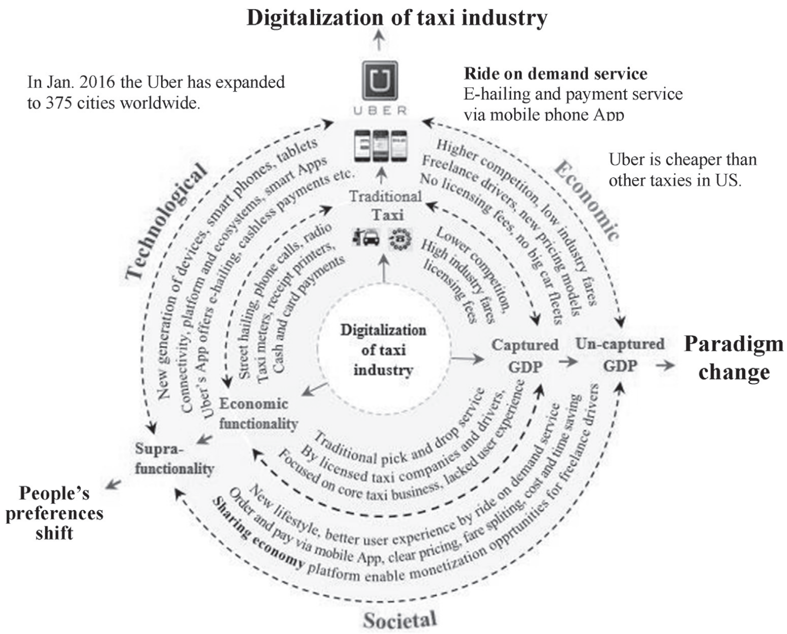


Fig. 16. Co-evolution of 3 mega-trends in transportation industry.

(v) This spin-off accelerates further lower cost and higher services, which accelerates the foregoing virtuous cycle, and
(vi) Uber's success can be attributed to constructing such ICT driven disruptive business model.

5.2. Noteworthy elements essential to well-functioning platform ecosystem architecture

These findings form the base for the following suggestions supportive to constructing a well-functioning platform ecosystems:

(i) Penetrate the current demand and challenge to meet it (e.g., sharing economy, saturation of taxi business, popularity of smartphone),

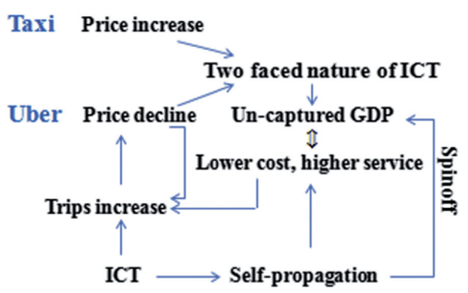


Fig. 17. The dynamism of Uber's ICT driven disruptive business model.

(ii) Fully utilize the advancement of ICT, particularly of the Internet (e.g., smartphone, digital payment, big data analysis),
(iii) Construct a co-evolution between sophisticated platform ecosystems and consolidation of broad stakeholders (e.g., mutual rating system among company, its drivers, and their passengers),
(iv) Take care of the platform orchestration for efficiency, development and innovation (e.g., successive innovation for novel services as competitor like Lyft boosting and also as against movement emerging),
(v) Thereby, creating a novel business model which has never been conceived before.

5.3. Implications of un-captured GDP

The emergence of un-captured GDP emerged by Uber can be attributed to:

(i) People's preferences shift to sharing economy and advancement of ICT, particularly of the Internet and subsequent smartphones,
(ii) Better services, with cost and time saving for passengers, high efficient operation without additional investment and licenses fees for drivers, and optimal price-setting and market making beyond marginal cost for company through a massive database on driver and passenger behavior, and
(iii) The paradigm shift from resources to the ecosystem that corresponds to the shift from captured GDP to un-captured GDP.

Thus, Uber's un-captured GDP can be considered as a consequence of the co-evolution between people's preferences shift, advancement of ICT and this paradigm shift.

This co-evolution has been leveraged Uber to create new business, to create services through interactions between stakeholders: company, drivers, and passengers.

All this can be attributed to systems success: platform ecosystem architecture under the contemporary digital economy.

5.4. Criticism to be solved

However, as a consequence of the transition to this new dynamism, there remain the following areas of criticism:

(i) Business philosophy for discrimination (e.g., equivalence of services for remote areas with low population density),
(ii) Safety issues,
(iii) Treatment of privacy issues, and
(iv) Compliance with labor standards.

Given the noted contrast between co-evolutionary success with institutional systems in host countries/cities and legal battles with quite a few countries/cities through Uber's global expansion, the sources of this contention as a a consequence of business strategy, platform ecosystems design, and institutional systems in host country/city should be further studied.

5.5. Future works

This analysis has explored a prototype of the analysis of the ICT-driven disruptive business model using the analysis of the co-evolution of three mega-trends that nurtures un-captured GDP.

Furthermore, analyses applying this approach is expected to be undertaken for similar disruptive business models in the (i) music industry, (ii) electronic gaming industry, (iii) printing and publishing industry, and (iv) education. In addition, business areas as fintech, legal and real estate should also be explored.

Acknowledgement

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement no: 293446 – Platform Value Now: Value capturing in the fast emerging platform ecosystems.

Appendix 1. Data construction

As a consequence of the numerical analysis of newly emerged innovation, elucidation of Uber's systems success was a challenge in exploring the dark continent without published statistical data. Therefore, the challenge started from constructing series of reliable statistical data which can be summarized as follows. A sensitive analysis of the estimated data was conducted to ensure the reliability of constructed data, (Appendix 4).

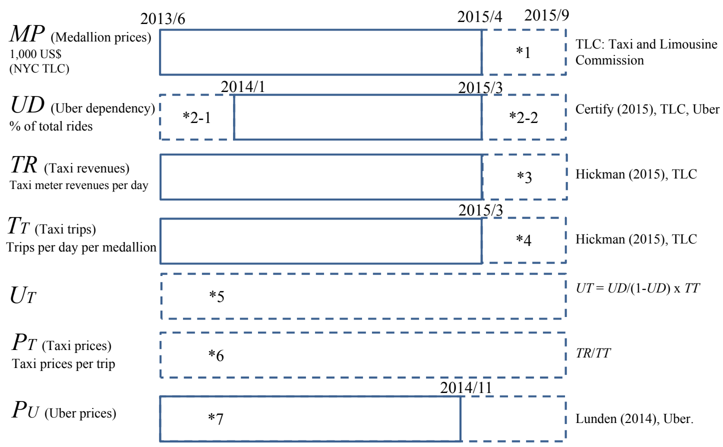


Fig. A1. Estimate of Supplemental Period *(2013/6 – 2015/9).*

*1 : Estimated parallel with individual's medallion prices

*2-1: $UD = Ae^{\lambda t}$

*2-2: $UD = a + bt + ct^2$

*3 : $TR = Ae^{\lambda t}$

*4 : $T_T = Ae^{\lambda t}$

*5 : $U_T = \frac{UD}{1-UD} \times T_T \quad U_T = \frac{N}{1+be^{-at}}$

*6 : $P_T = \frac{TR}{T_T}$

*7 : $PU = a + bt + ct^2$

Data were constructed by cross evaluating earlier work listed on the right-hand side and data/information by TLC and Uber. Supplemental estimate of the missing periods of the above estimates was based primarily on the spline functions illustrated above.

Appendix 2. Two-faced nature of ICT and un-captured GDP

A2.1 Two-faced nature of ICT and subsequent un-captured GDP

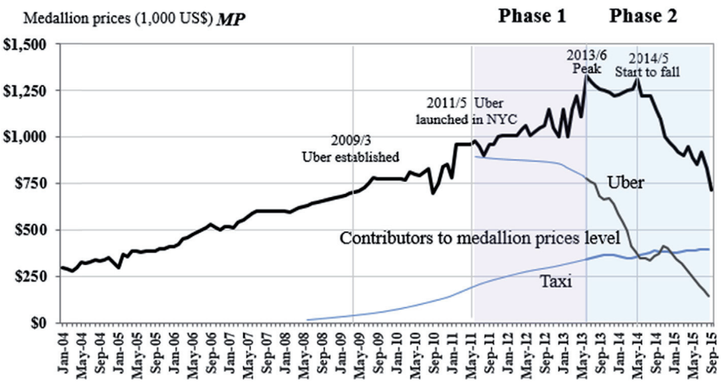


Fig. A2. Trend in Corporate Medallion Prices in NYC and Contributors *(2004–2015)*.
Source: NYC Taxi and Limousine Commission.

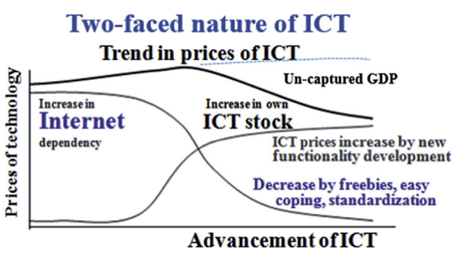


Fig. A3. Two-faced Nature of ICT.

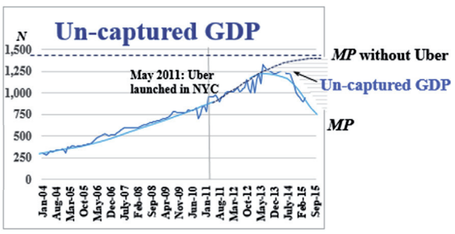


Fig. A4. Anticipating Un-captured GDP.

The trend in medallion prices as a consequence of co-existing diffusion trajectory of a taxi with prices increase and that of Uber with prices decrease suggests that this trajectory is subject to the two-faced nature of ICT that is behind the emergence of un-captured GDP.

A2.2 ICT prices trajectory and two-faced nature

(1) Modified Bi-logistic Growth

ICT prices can be depicted by the following modified bi-logistic growth as illustrated in Fig. A5:

$$p_I = \frac{N}{1 + b_j e^{-a_j J}} + \frac{N}{1 + b_i e^{a_i I}} \tag{A1}$$

where I: ICT stock, J: dependency on the Internet, N: carrying capacity, a_i, a_j *and* b_i, b_j: diffusion velocity of I and J.[5]

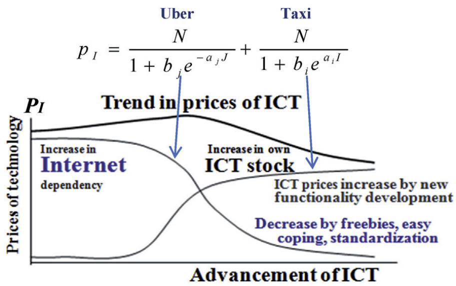


Fig. A5. Modified Bi-logistic Growth due to Two-faced Nature of ICT.

Equation (A1) can be developed as follows:

[5] Since the Internet has been playing a leading role in the whole ICT and providing significant impacts on the diffusion trajectory of ICT, carrying capacity of logistic growth in I and reverse logistic growth in J as well as their diffusion tempo ($a_i I$ *and* $a_j J$) were treated as behaved in the similar way ($a_i I = a_j J$).
When $I = 0, \quad p_I = \varepsilon(\approx 0), \frac{N}{1+b_i} = \varepsilon, b_i = \frac{N}{\varepsilon} - 1.$ *When* $I = \infty, p_I = N.$
When $J = 0, p_J = N - \varepsilon, \frac{N}{1+b_j} = N - \varepsilon, b_j = \frac{\varepsilon}{N-\varepsilon}.$ *When* $J = \infty, p_I = 0.$
Therefore, $b_i >> b_j$.

$$\frac{p_I}{N}=\frac{1+b_je^{a_jJ}+1+b_ie^{-a_iI}}{\left(1+b_ie^{-a_iI}\right)\left(1+b_je^{a_jJ}\right)}=\frac{2+b_je^{a_jJ}+b_ie^{-a_iI}}{1+b_je^{a_jJ}+b_ie^{-a_iI}+b_ib_je^{-a_iI}e^{a_jJ}}$$
$$\approx\frac{2+b_je^{a_jJ}+b_ie^{-a_iI}}{1+b_ib_j+b_je^{a_jJ}+b_ie^{-a_iI}}=1+\frac{1-b_ib_j}{1+b_ib_j+b_je^{a_jJ}+b_ie^{-a_iI}}$$
$$\frac{p_I}{N}-1=\frac{1-b_ib_j}{1+b_ib_j+b_je^{a_jJ}+b_ie^{-a_iI}}$$
$$\frac{N}{N-p_I}=\frac{1}{1-\frac{p_I}{N}}=-\frac{1+b_ib_j}{1-b_ib_j}-\frac{b_je^{a_jJ}}{1-b_ib_j}-\frac{b_ie^{-a_iI}}{1-b_ib_j}$$
$$\approx-\frac{1+b_ib_j}{1-b_ib_j}-\frac{b_j}{1-b_ib_j}(1+a_jJ)-\frac{b_i}{1-b_ib_j}(1-a_iI)$$
$$=\frac{1+b_ib_j+b_i+b_j}{b_ib_j-1}+\frac{a_jb_j}{b_ib_j-1}J-\frac{a_ib_i}{b_ib_j-1}I\equiv\alpha+\beta J+\gamma I \tag{A2}$$

$$where\quad \alpha=\frac{1+b_ib_j+b_i+b_j}{b_ib_j-1}=\frac{(1+b_i)(1+b_j)}{b_ib_j-1}<0,\quad \beta=-\frac{a_jb_j}{b_ib_j-1}<0,\quad \gamma=-\frac{a_ib_i}{b_ib_j-1}>0 \tag{A3}$$

In case of a co-existing diffusion of taxis and Uber, J and I correspond to UT (Uber trips) and TT (taxi trips) and Eq. (A2) can be represented as Table A1.

Table A1
Co-existing Trajectory of Taxis and Uber in NYC (*Jun. 2313 – Sep. 2015*).

$$\frac{N}{N-MP}=\underset{(-3.12)}{-1.355}-\underset{(-2.96)}{0.005}U_T+\underset{(8.54)}{0.103}T_T+\underset{(5.42)}{0.178}D\qquad adj.\,R^2\ 0.970\quad DW\ 1.35$$

Where N (carrying capacity) = 2247, (Table 5) MP: medallion prices, D: 2014. May, Aug., Sep. = 1.

Figures in parenthesis indicate t-statistics: all significant at the 1% level.

Figures in parenthesis indicate t-statistics: all significant at the 1% level.

This demonstrates that coexistence of taxi and Uber is subject to two-faced nature of ICT.

(2) Diffusion Coefficient

Coefficients governing modified bi-logistic growth in Eq. (A1) can be identified as follows (here J and I correspond to UT and TT):

$$\frac{\beta}{\gamma}=-\frac{a_jb_j}{a_ib_i}=-\frac{I}{J}\cdot\frac{b_j}{b_i}\,(\because a_iI=a_jJ)\quad Therefore,$$
$$b_j=-\frac{\beta}{\gamma}\cdot\frac{J}{I}\cdot b_i\equiv\eta b_i\left(\eta=-\frac{\beta}{\gamma}\cdot\frac{J}{I}<<1\ as\ b_j<<b_i\right)$$
$$\alpha=-\frac{1+\eta b_i^2+(1+\eta)b_i}{1-\eta b_i^2}\,(\alpha-1)\eta b_i^2-(1+\eta)b_i-(\alpha+1)=0$$

$$b_i=\frac{(1+\eta)-\sqrt{(1+\eta)^2+4(\alpha-1)(\alpha+1)\eta}}{2(\alpha-1)\eta}\,(>0)$$
$$b_j=\eta b_i=\frac{(1+\eta)-\sqrt{(1+\eta)^2+4(\alpha-1)(\alpha+1)\eta}}{2(\alpha-1)}\,(>0) \tag{A4}$$
$$as\ \alpha<0.\quad \alpha<-1\ is\ necessary\ for\ b_i,b_j>0.$$

$$a_i=\gamma\cdot\frac{1-b_ib_j}{b_i}=\gamma\left(\frac{1}{b_i}-b_j\right)(>0)\quad a_j$$
$$=-\beta\left(\frac{1}{b_j}-b_i\right)(>0)\quad b_ib_j<1,b_i<\sqrt{\frac{1}{\eta}},b_j<\sqrt{\eta} \tag{A5}$$

Thus, co-existing trajectory of taxis and Uber as demonstrated in Table A1 can be demonstrated as follows:

$$P_I=\frac{2247}{1+0.03e^{0.20U_T}}+\frac{2247}{1+0.31e^{-0.33T_T}}\qquad (A6\qquad *\qquad)$$

* Demonstrate the state in Sep. 2015 when $\eta=0.08$.

This modified bi-logistic growth demonstrates contributors to medallion prices level illustrated in Fig. A2.

(3) Trip Elasticity to Prices

The marginal contribution of Uber and taxis dependency to medallion prices change can be depicted as follows:

$$p_I=\frac{N}{1+b_je^{a_jJ}}\Rightarrow\frac{\partial p_I}{\partial J}=-a_jp_I\left(1-\frac{p_I}{N}\right),p_I=\frac{N}{1+b_ie^{-a_iI}}\Rightarrow\frac{\partial p_I}{\partial I}=a_ip_I\left(1-\frac{p_I}{N}\right) \tag{A7}$$

Thus, the elasticity of Uber and taxi dependency to prices elasticity can be depicted as follows:

$$\kappa_j\equiv\frac{\partial p_J}{\partial J}\cdot\frac{J}{p_J}=-a_jJ\left(1-\frac{p_J}{N}\right)=-\frac{a_jJ}{\alpha+\beta J+\gamma I}<0$$
$$\kappa_i\equiv\frac{\partial p_I}{\partial I}\cdot\frac{I}{p_I}=a_iI\left(1-\frac{p_I}{N}\right)=\frac{a_iI}{\alpha+\beta J+\gamma I}>0 \tag{A8}$$

This demonstrates that contrary to taxis prices increase as their trips increase, Uber prices decrease as its trips increase leading a virtuous cycle for Uber. All this support the analysis of institutional sources being behind the emergence of un-captured GDP.

A2.3 Prospect of un-captured GDP nurtured by Uber

As reviewed in Fig. 8, the magnitude of un-captured GDP can be measured by the balance between actual medallion prices and medallion prices without Uber.

While the former can be estimated by Eq. (A6), the latter can be estimated by Table A2. Table A2 demonstrates how the trend in medallion prices without Uber can be estimated both by logistic growth and parabolic growth. The latter provides a higher estimate.

Fig. A7 demonstrates prospect of un-captured GDP emerged by Uber estimated by the preceding approach.

A2.4 Timing when Uber overcame chasm

Chasm is a deep trench compelling new ventures start-up (Moore, 1991) [22].

It's timing in the logistic growth diffusion trajectory can be depicted as follows (Watanabe et al., 2011) [33]:

$$t = \frac{\ln\left(2-\sqrt{3}\right)b}{a} \tag{A9}$$

where logistic growth diffusion trajectory is: $Y = \frac{N}{1+be^{-at}}$

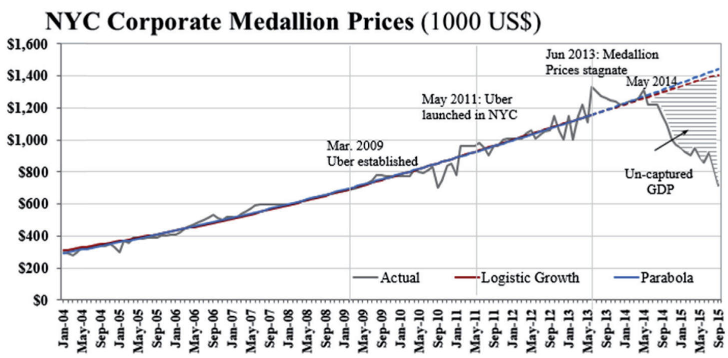


Fig. A6. Estimate of Uber's Impact on Medallion Prices Decline (Jan. 2004–Sep. 2015).

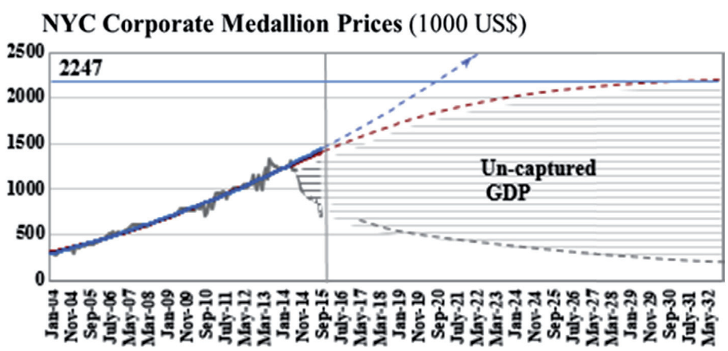


Fig. A7. Estimate of Un-captured GDP Anticipated by Uber *(May. 2014 – May. 2032)*.

Table A2
Estimates of Medallion Prices *(Jan. 2004 – Jun. 2013)*.

Logistic growth $Y = \frac{N}{1+be^{-at}}$				Parabolic growth $Y = a + bt + ct^2$			
	Estimate	*t-value*	*adj. R^2*		*Estimate*	*t-value*	*adj. R^2*
N	2247.11	7.23	0.976	a	288.30	25.80	0.977
a	0.02	14.21		b	5.31	11.91	
b	6.36	7.21		c	0.02	5.42	

Y: Medallion prices, N: Carrying capacity, t: Monthly trend, a, b, c: Coefficients.

In case of the following logistic growth within a dynamic carrying capacity (LGDCC) diffusion trajectory, a and b in the above equation can be approximated as follows (Watanabe et al., 2009) [31]:

$$t = \frac{\ln\left(2-\sqrt{3}\right)b'}{a'}, a' = a\left(1-\frac{b_k}{b}\right), b' = b\cdot\exp\left(\frac{b_k}{b}\cdot\frac{1}{1-\frac{a_k}{a}}\right) \tag{A10}$$

$$Y = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-a_k/ae^{-a_k t}}}$$

Provided that Uber has been developing in line with the LGDCC diffusion trajectory as demonstrated in Table 6 in NYC from its launching in May 2011 ($t = 1$), t in eq (A10) can be $t = 21.5$ (March 2013).

This demonstrates that Uber has overcome the Chasm at the timing just before its share reached 10% in June 2013.

Appendix 3. Correlation between Medallion prices and taxi/Uber prices

Fig. A8 illustrates the correlation between taxi/Uber aggregated prices (*PA*) and medallion prices (*MP*) over the period May 2014–September 2015.

Similarly, Fig. A9 illustrates the correlation between taxi prices (P_T) and medallion prices without Uber (*MPe*) over the period May 2014–September 2015.

PT vs. *MPe* and *PA* vs. *MP* demonstrates significant parallel correlation as far as 2015 is concerned and supports the significance of un-captured GDP measurement depending on the balance between *PT* and *PA* during the above period.

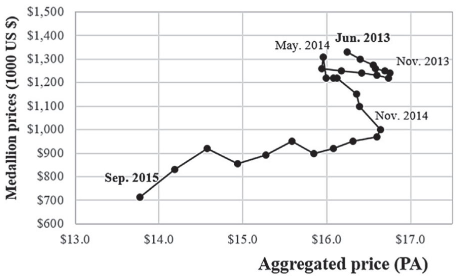


Fig. A8. Correlation between Taxi/Uber Aggregated Prices (*PA*) and Medallion Prices (*MP*) *(2014.5– 2015.9).*

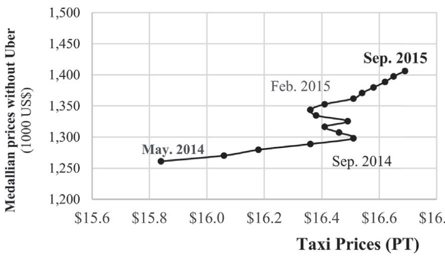


Fig. A9. Correlation between Taxi Prices (P_T) and Medallion Prices without Uber (*MPe*) *(2014.5 – 2015.9).*

Table A3
Correlation between Taxi/Uber Prices and Medallion Prices *(2014.5 – 2015.9).*

$$\ln MP = \underset{(5.38)}{3.3441} - \underset{(-4.81)}{5.607} D_1 \ln P_A + \underset{(5.24)}{1.227} D_2 \ln P_A + \underset{(5.81)}{19.247} D_1 \quad adj.\, R^2\ 0.931 \quad DW\ 1.73$$

MP: Medallion prices, P_A: Aggregated prices per trip and D_1, D_2: Dummy variables.
D_1: 2014.5 – 2014.11 = 1, rest = 0, D_2: 2014.12 – 2015.9 = 1, rest = 0.

$$\ln MP_e = \underset{(4.88)}{4.018} + \underset{(3.80)}{1.127} D_1 \ln P_T - \underset{(-2.84)}{2.731} D_2 \ln P_T + \underset{(3.90)}{1.144} D_3 \ln P_T + \underset{(3.84)}{10.813} D_2 \quad adj.\, R^2\ 0.945 \quad DW\ 1.26$$

MPe: Estimated Medallion prices, P_T: Taxi prices per trip and D_1, D_2, D_3: Dummy variables.
D_1: 2014.5– 2014.8 = 1, rest = 0, D_2: 2014.9– 2015.1 = 1, rest = 0, D_3: 2015.2– 2015.9 = 1, rest = 0.

Figures in parenthesis indicate t-statistics: all significant at the 1% level.

Appendix 4. Sensitivity of Uber trips estimate

A4.1 Estimate without and with Spline interpolation

In analyzing Uber diffusion trajectory (4.3 (1) and (2)), given the sensitive impacts of fluctuation on the trajectory formation within the limited samples, a comparative analysis was attempted by comparing Uber trips estimate with and without spline interpolation as shown in Fig. A10 and Table A4. The function used for the spline interpolation was based on the logistic growth function (Appendix 1).

Table A4
Comparison of Uber trips estimate (Jun. 2013–Sep. 2015).

Period	Trips per day	
	U_T	U_{r2}
1 Jun-13	3.12	2.75
2 July-13	3.37	3.09
3 Aug-13	3.62	3.47
4 Sep-13	3.96	3.9
5 Oct-13	4.34	4.38
6 Nov-13	4.82	4.92
7 Dec-13	5.38	5.51
8 Jan-14	5.96	6.18
9 Feb-14	6.65	6.92
10 Mar-14	6.18	7.74
11 Apr-14	7.19	8.66
12 May-14	9.96	9.67
13 Jun-14	12.40	10.79
14 July-14	12.80	12.03
15 Aug-14	14.92	13.39
16 Sep-14	14.56	14.89
17 Oct-14	15.86	16.52
18 Nov-14	20.46	18.31
19 Dec-14	20.40	20.25
20 Jan-15	26.18	22.25
21 Feb-15	25.06	24.62
22 Mar-15	26.83	27.05
23 Apr-15	30.96	29.66
24 May-15	33.95	32.43
25 Jun-15	37.27	35.36
26 July-15	40.94	38.44
27 Aug-15	45.03	41.67
28 Sep-15	49.64	45.03

UT: Uber trips estimated by taxis trips and Uber dependency (Appendix 1).
UT2: Uber trips estimate with spline interpolation.

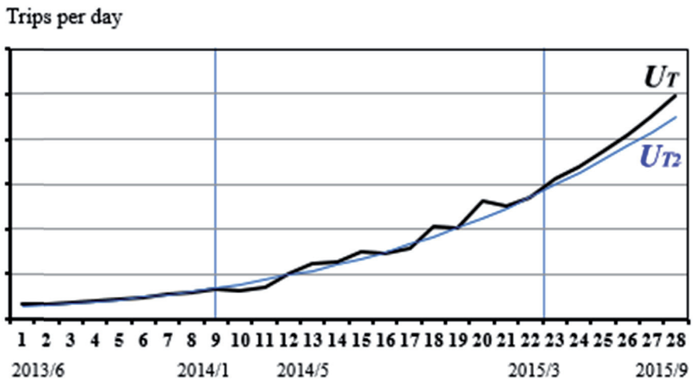


Fig. A10. Comparison of Uber Trips Estimate *(Jun. 2013 – Sep. 2015)*.

A4.2 Effects of the estimates of Uber-driven un-captured GDP

(1) Un-captured GDP emerged by Uber

Sensitivity analysis of the effects of the estimated data was conducted by comparing the effects of un-captured GDP measurement as demonstrated in Fig. A11. The result demonstrates no substantial differences between estimates with and without spline interpolation.

Aggregated prices *PA* are measured by the following equation: $P_A = \frac{P_T \cdot T_T + P_U \cdot U_T}{T_T + U_T}$

(2) Increase in the Emergence of Un-captured GDP Emerged by Uber

Similarly, no substantial differences in an increase in the emergence of un-captured GDP between estimated data with and without spline interpolation were confirmed as demonstrated in Fig. A12.

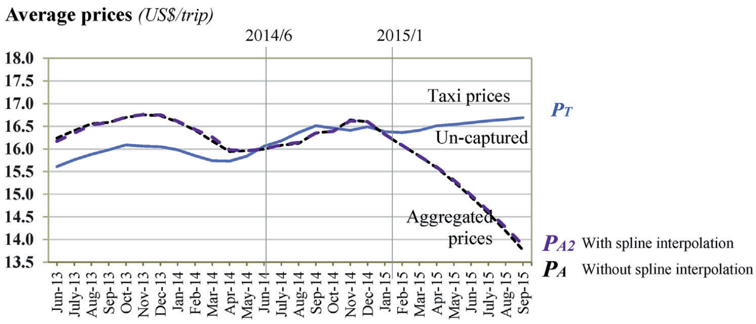
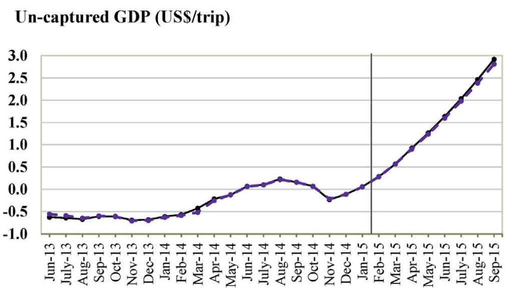


Fig. A11. Trends in Taxi Prices and Aggregated Prices in NYC *(Jun. 2013 – Sep. 2015)*.



Un-captured GDP

$$= P_T - P_A = P_T - \frac{T_T \cdot P_T + U_T \cdot P_U}{T_T + U_T}$$

$$= P_T - \frac{P_T + \alpha \cdot P_U}{1+\alpha} = \frac{1}{1+\frac{1}{\alpha}}(P_T - P_U)$$

where $\alpha = \frac{U_T}{T_T}$ *ratio*

Fig. A12. The trend in Un-captured GDP Emerged by Uber in NYC *(Jun. 2013 – Sep. 2015)*.

A4.3 Effects of Uber's Development Trajectory Estimate

While Uber's development trajectory, estimated using trips trend, without spline interpolation demonstrates the slight possibility of self-propagation by the LGDCC. Spline interpolation demonstrates explicit self-propagation by demonstrating the significance of the LGDCC.

While this difference does not have any significant effects on aggregated prices and un-captured GDP estimates, the effects on self-propagation can be attributed to a slightly higher pace (1–9%) of trips estimate after March 2015. This suggests that an optimal and not too rapid development pace seems essential for incorporating the self-propagating function.

Table A5
Estimates of Taxi and Uber's Development Trajectories in NYC by LGDCC

		N_k	a	b	a_k	b_k	*adj.* R^2
Taxi (2004/1–2013/6)		2247.12	0.017	6.364	0.439	10.30	0.976
		(6.42)	(12.61)	(6.63)	(0.00^{x})	(0.00^{x})	
Uber (2013/6–2015/9)	U_T	144.13	0.123	25.800	0.0001	3.04	0.992
		(2.95)	(12.68)	(3.29)	(0.10^{x})	(1.29^{*6})	
	U_{T2}	119.27	0.121	49.650	0.016	0.200	0.999
		(41.41)	(36.67)	(11.13)	(2.42^{*3})	(1.43^{*5})	

Taxi: based on medallion prices (Fig. 8), **Uber:** based on trips (Fig. 4) without spline interpolation (U_T) and with spline interpolation (U_{T2}) (See Table A4).
LGDCC: Logistic growth with dynamic carrying capacity, $Y = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-a_k/a}e^{-a_k t}}$ (eq. (4)).
Figures in parenthesis indicate t-statistics: all significant at the 1% level except $*^{3}$: 5%, $*^{5}$: 15%, $*^{6}$: 20%, ^{x}: non-significant.

Appendix 5. Uber's expansion in 375 cities worldwide (USA as of January 2016).

North America	North America	North America	North America	Central and South America
Abilene	Fayetteville, NC	Miami	San Luis Obispo	Barranquilla
Akron	Flagstaff	Midland-Odessa	Santa Barbara	Belo Horizonte
Albuquerque	Flint	Milwaukee	Santa Fe	Bogotá
Amarillo	Florida Keys	Minneapolis – St. Paul	Sarasota	Brasilia
Ames	Fort Myers-Naples	Mobile, AL	Savannah-Hilton Head	Bucaramanga
Ann Arbor	Fort Wayne	Modesto	Seattle	Cali – Colombia
Asheville, NC	Fresno	Monterrey	South Bend	Campinas
Athens	Gainesville	Montreal	Spokane	Cartagena
Atlanta	Georgia Coast	Myrtle Beach	Springfield, IL	Cucuta
Augusta	Grand Rapids	NW Indiana	St Louis	Goiania
Austin	Greater Maine	Nashville	State College	Ibagué
Bakersfield	Greater Maryland	New Hampshire	Stillwater	Lima
Baltimore	Green Bay	New Jersey	Tacoma	Medellín
Baton Rouge	Greenville, SC	New Jersey (Shore)	Tallahassee	Montevideo
Beaumont	Guadalajara	New Orleans	Tampa Bay	Panama, Panama
Bellingham	Hamilton	New York City	Taos	Porto Alegre
Birmingham, AL	Hampton Roads	Niagara Region	Tijuana	Rio De Janeiro
Boise	Harrisburg	Ocala, FL	Toledo	San Jose, Costa Rica
Boston	Honolulu	Oklahoma City	Toluca	Santiago
Bowling Green, KY	Houston	Omaha	Topeka	Santo Domingo
Burlington	Indianapolis	Orange County	Toronto	São Paulo
Central Atlantic Coast, FL	Inland Empire	Orlando	Tucson	Villavicencio
Champaign	Jackson	Ottawa	Tulsa	
Charleston, SC	Jacksonville	Outer Banks, NC	Tuscaloosa	
Charlotte	Kalamazoo	Oxford	Vancouver, WA	
Charlottesville-Harrisonburg	Kansas City	Palm Springs	Ventura	
Chattanooga	Killeen	Pensacola, FL	Waco	
Chicago	Kingston	Peoria & Bloomington-Normal	Washington D.C.	
Cincinnati	Kitchener-Waterloo	Philadelphia	Western MA	
Cleveland	Knoxville	Phoenix	Wichita	
Coeur D'Alene	Lafayette, LA	Piedmont Triad, NC	Wilkes-Barre Scranton	
College Station	Lancaster, PA	Pittsburgh	Wilmington, NC	
Columbia, MO	Lansing	Portland	Windsor	
Columbia, SC	Las Cruces	Portland, ME	Worcester	
Columbus	Las Vegas	Puebla	Yuma	
Connecticut	Lawrence	Quad Cities	the Hamptons	
Corpus Christi	Lehigh Valley	Quebec City		
Dallas-Fort Worth	Leon	Queretaro		
Dayton	Lexington	Raleigh-Durham		
Delaware	Lincoln	Reading, PA		
Denver	Little Rock	Reno		
Des Moines	London, Ont	Rhode Island		
Detroit	Los Angeles	Richmond		
Eastern Idaho	Louisville	Roanoke-Blacksburg		
Eastern North Carolina	Lubbock	Rockford		
Edmonton	Madison	Sacramento		
El Paso	Manhattan	Salt Lake City		
Erie	Maui	San Antonio		
Fargo	Memphis	San Diego		
Fayetteville, AR	Mexico City	San Francisco Bay Area		

Appendix 5. Uber's expansion in 375 cities worldwide (2) (Other countries than USA as of January 2016).

Europe	Europe	East Asia	South Asia	Australia and New Zealand
Amsterdam	Saint Petersburg	Beijing	Ahmedabad	Adelaide
Athens, GR	Sheffield	Changsha	Ajmer	Auckland
Basel	Sochi	Chengdu	Bangalore	Brisbane
Belfast	Sofia	Chongqing	Bhubaneswar	Canberra
Berlin	Stockholm	Dalian	Chandigarh	Geelong
Birmingham, UK	Strasbourg	Foshan	Chennai	Gold Coast
Bordeaux	Tallinn	Guangzhou	Coimbatore	Melbourne
Bratislava	Toulouse	Guiyang	Colombo	Mornington Peninsula
Bristol	Trojmiasto	Hangzhou	Guwahati	Perth
Brussels	Vienna	Hong Kong	Hyderabad	Sunshine Coast
Bucharest	Vilnius	Incheon	Indore	Sydney
Budapest	Warsaw	Jinan	Jaipur	Wellington
Copenhagen	Wroclaw	Macau	Jodhpur	
Dublin	Zagreb	Nanjing	Kochi	
Edinburgh	Zurich	Ningbo	Kolkata	

(*continued*)

Europe	Europe	East Asia	South Asia	Australia and New Zealand
Ekaterinburg		Qingdao	Mangalore	
Florence	**Middle East**	Seoul	Mumbai	
Geneva	Abu Dhabi	Shanghai	Mysore	
Genoa	Amman	Shenzhen	Nagpur	
Glasgow	Baku	Suzhou	Nashik	
Gothenburg	Beirut	Taichung	New Delhi	
Helsinki	Doha	Taipei	Pune	
Istanbul	Dubai	Tianjin	Surat	
Kazan	Eastern Province, KSA	Tokyo	Thiruvananthapuram	
Krakow	Jeddah	Wuhan	Udaipur	
Lausanne	Manama	Xi'An	Vadodara	
Leeds	Riyadh	Xiamen	Visakhapatnam	
Lille	Tel Aviv	Yantai		
Lisbon				
London	**Africa**	**South East Asia**		
Lyon	Alexandria	Bali		
Manchester	Cairo	Bandung		
Marseille	Cape Town	Bangkok		
Merseyside	Casablanca	Cebu		
Milan	Durban	Hanoi		
Minsk	Johannesburg	Ho Chi Minh City		
Moscow	Lagos	Ipoh		
Munich	Nairobi	Jakarta		
Nantes	Port Elizabeth	Johor Bahru		
Newcastle		Kuala Lumpur		
Nice		Manila		
Novosibirsk		Penang		
Oslo		Singapore		
Paris		Surabaya		
Porto				
Portsmouth				
Poznan				
Prague				
Rome				
Rostov-On-Don				

Source: Uber.com

References

[1] R. Adner, The Wide Lens, Portfolio/Penguin, New York, 2012.
[2] Avital, M., Andersson, M., Nickerson, J., Sundararajan, A., Alstyne, M.V. and Verhoeven, D., 2014. AIS Electronic Library, Atlanta, 1–7.
[3] E. Badger, Taxi Medallions Have Been the Best Investment in America for Years: Now Uber May Be Changing that, The Washington Post, 2014, 20 Jun. 2014.
[4] A. Baiyere, H. Salmela, Wicked yet Empowering: when it Innovations Are Also Disruptive Innovations, AIS Electronic Library (AISel), 2015.
[5] R. Belk, You are what you can access: sharing the collaborative consumption online, J. Bus. Res. 67 (2014) 1595–1600.
[6] Certify, Sharing the Road: Business Travellers Increasingly Choose Uber, A Ground Transportation Sharing Economy Report. 2015 Q1, 2015.
[7] B. Cohen, J. Kietzmann, Ride on! mobility business models for the sharing economy, Organ. Environ. 27 (3) (2014) 279–296.
[8] comScore, Reports on the US Smartphone Subscriber Market Share. ComScore, Reston, Virginia, 2013-2015.
[9] Council for Science, Technology and Innovation, The 5th Science and Technology Basic Plan, Cabinet Office, Government of Japan, Tokyo, 2016.
[10] T. Cowen, The Great Stagnation, Dutton, New York, 2011.
[11] M. Ehret, The zero marginal cost society: the Internet of things, the collaborative commons, and the eclipse of capitalism, J. Sustain. Mobil. 2 (2) (2015) 67–70.
[12] A. Frier, Uber Usage Statistics and Revenue, Business of Apps, 2015, 14 Sep.2015.
[13] J. Hickman, How Uber Is Actually Killing the Value of a New York City Taxi Medallion, The Street Quant Rating, 2015, 26 May. 2015.
[14] J. Horpedahl, Ideology Uber alles?: economics bloggers on Uber, Lyft, and other transportation network companies, Econ. J. Watch 12 (3) (2015) 360–374.
[15] E. Isaac, U.C. Davis, Disruptive innovation: risk-shifting and precarity in the age of Uber, BRIE Work. Pap. (2014) 2014–2017.
[16] S.P. King, Sharing economy: what challenges for competition law? J. Eur. Law Pract. 6 (10) (2015) 729–734.
[17] C. Koopman, M. Mitchell, A. Thierer, The sharing economy and consumer protection regulation: the case for policy change, in: The 8 Journal of Business, Entrepreneurship and the Law 2014-2015, 2014, pp. 529–540.
[18] H. Lovins, B. Cohen, Climate Capitalism in the Age of Climate Change, Hill & Wang, New York, 2011.
[19] A. Lowrey, Impacts of the Great Stagnation, New York Times, 2011.
[20] I. Lunden, Uber Rides High, Dominates Transport App Revenues and Downloads up to November, 7PARK DATA, 2014, 24 Nov. 2014.
[21] P.S. Meyer, J.H. Ausbel, Carrying capacity: a model with logistically varying limits, Technol. Forecast. Soc. Change 61 (3) (1999) 209–214.
[22] G.A. Moore, Crossing the Chasm: Marketing and Selling Technology Products to Mainstream Customers, Harper Business Essentials, Harper Collins, New York, 1999.
[23] J. Rifkin, The Zero Marginal Cost Society: the Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism, Palgrave Macmillan, New York, 2014.
[24] A. Schlze, J.P. MacDuffie, F.A. Taube, Introduction: Knowledge Generation and Innovation Diffusion in the Global Automotive Industry – Change and Stability during Turbulent. Industrial and Corporate Change, Oxford University Press, Oxford, 2015.
[25] S. Silverstein, These Animated Charts Tell You Everything about Uber Prices in 21 Cities, Business Insider Transportation, 2014, 16 Oct. 2014.
[26] J.G. Stead, W.E. Stead, The co-evolution of sustainable strategic management in the global marketplace, Organ. Environ. 26 (2) (2013) 162–183.
[27] B. Stone, Uber Is Winning over America's Expense Accounts, Bloomberg, 2015, 2015.
[28] The Economist, All eyes on the sharing economy, Econ. 406 (2013) 13–15.
[29] Uber, A Brief History of Uber, 2015. Techcrunch.com/gallery/a-brief-history-of-uber.
[30] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of IT functionality development, Technol. Forecast. Soc. Change 71 (7) (2004) 723–750.
[31] C. Watanabe, S. Lei, N. Ouchi, Fusing indigenous technology development and market learning for higher functionality development: an empirical analysis of the growth trajectory of Canon printers, Technovation 29 (2) (2009) 265–283.
[32] C. Watanabe, K. Moriyama, J.H. Shin, Functionality development dynamism in a diffusion trajectory: a case of Japan's mobile phones development, Technol. Forecast. Soc. Change 76 (6) (2009) 737–753.
[33] C. Watanabe, J.H. Shin, J. Heikkinen, W. Zhao, C. Griffy-Brown, New functionality development through follower substitution for a leader in open innovation, Technol. Forecast. Soc. Change 78 (1) (2011) 116–131.
[34] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured gdp and growing anger of consumers, Technol. Soc. 41 (2014) 21–44.
[35] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure – similarity and disparities between Finland and Singapore, Technol. Soc. 42 (2015) 104–122.
[36] C. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, Operationalization of un-captured GDP: the innovation stream under new global mega-trends, Technol. Soc. 45 (2016) 58–77.
[37] S. Winterhalter, C.H. Wecht, L. Kreig, Keeping reins on the sharing economy: strategies and business models for incumbents, St. Gallen Mark. Rev. 32 (4) (2015) 32–39.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Visiting Professor of National University of Singapore, Research Professor of University of Jyväskylä, Finland and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland.

Pekka Neittaanmäki graduated from the University of Jyväskylä and is currently a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland.

PVIII

CONSOLIDATED CHALLENGE TO SOCIAL DEMAND FOR RESILIENT PLATFORMS - LESSONS FROM UBER'S GLOBAL EXPANSION

by

Chihiro Watanabe, Kashif Naveed, Pekka Neittaanmäki and Brenda Fox, 2017

Technology in Society, vol. 48, pp. 33-53

Technology in Society 48 (2017) 33–53

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Consolidated challenge to social demand for resilient platforms - Lessons from Uber's global expansion

Chihiro Watanabe [a, b, *], Kashif Naveed [a], Pekka Neittaanmäki [a], Brenda Fox [b]

[a] Faculty of Information Technology, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form
26 September 2016
Accepted 31 October 2016
Available online 5 November 2016

Keywords:
Sharing economy
Digital service platform
Uber's global expansion
Legal battles
ICT-driven disruptive business model
Co-evolutionary acclimatization
Consolidated challenge to social demand

ABSTRACT

Many in the industry see the ride-sharing company Uber as the significant advancement through information and communication technology (ICT) particularly of the digital service platform and sharing economy. Uber has been exploring the new frontier of the ICT-driven disruptive business model (IDBM) and succeeded in its global expansion to over 479 cities in more than 75 countries worldwide in June of 2016.

Such rapid expansion provides constructive insights regarding the significance of IDBM, not only in transportation but also in almost all other business fields. While at the same time Uber's legal battles in some cities around the world raise a serious question regarding the rationale of IDBM.

In light of such a question, this paper examined the institutional sources contrasting success and failure in Uber's global expansion.

By the comparative empirical analysis, it was identified that the contrast could be attributed to a bi-polarization nature of ICT-driven logistic growth, and the success can be attributed to a co-evolutionary acclimatization that harnesses the vigor of counterparts.

This analysis suggests the significance of IDBM with a consolidated challenge to social demand (CCSD); it demonstrated that a co-evolutionary acclimatization played a transformative role in this accomplishment.

1. Introduction

Uber, a high-tech ride-sharing platform company, was founded in March 2009 and is regarded as the highest-valued venture-supported firm. It is seen as the significant advancement through information and communication technology (ICT) particularly of the digital service platform and sharing economy as it brilliantly connects the transportation industry with ICT via its ride-sharing application and it leverages the sharing revolution (Belk, 2014 [3]). Consequently, it fully enjoys the benefits of collaborative consumption characterized by (i) selling use of a product rather than ownership of a product, (ii) supporting customers in their desire to resell goods, (iii) exploiting unused resources and capacities, (iv) providing repair and maintenance services, and (v) using collaborative consumption (Matzler et al., 2015 [14]).

Uber is currently one of the fastest growing start-ups worldwide and has been exploring the new frontier of the ICT-driven disruptive business model (IDBM) (Watanabe et al., 2016 [28]). Based on this model, it has succeeded in its global expansion to over 479 cities in more than 75 countries worldwide in June of 2016. Its value exceeds the value of the full US taxi and limousine industry.

Such rapid expansion provides constructive insights regarding the significance of IDBM not only in transportation but also in almost all other business fields, including goods, professional services, space, and money (Cohen et al., 2014 [6]). In China, they have developed a sharing economy model for transport like Didi.

However, this rapid expansion resulted in the emergence of legal battles in some cities around the world (Arvind et al., 2014 [1]). Unlike licensed taxi drivers, private citizens providing ride-share services do not necessarily carry driver licenses, take licensing exams, purchase commercial insurance or even be required to honor all ride requests. For such reasons a German court, for example, banned Uber's basic service throughout the

* Corresponding author. Faculty of Information Technology, University of Jyväskylä, Finland.
E-mail addresses: watanabe.c.pqr@gmail.com (C. Watanabe), kanaveed@student.jyu.fi (K. Naveed), pekka.neittaanmaki@jyu.fi (P. Neittaanmäki), fox@xevents.com (B. Fox).

http://dx.doi.org/10.1016/j.techsoc.2016.10.006
0160-791X/

nation. Licensed taxi drivers are saddled with greater costs; that hampers their ability to compete with ride sharing (Arvind et al., 2014 [1]).

These battles raise a serious question regarding the rationale of IDBM.

To date, some studies have examined the rationale of the foundation of IDBM. Cannon et al. (2015) [4] pointed out that some characteristics inherent in the design of sharing economies lead to negative externalities. Arvind et al. (2014) [1] claimed that ride sharing is growing due to the circumvention of costs and regulations that govern incumbent businesses. They also claimed that, ride sharing could exploit loopholes to avoid rules and taxes, when this occurred, the sharing economy became the skimming economy. As legal battles explode worldwide, it shed the light on both the potential and shortcomings of IDBM. Many people identified problems and challenges as tax confusion, liability, and economic dependence (Cheng, 2014 [5]). Mastrorillo (2016) [13] contended that Uber and its business practices are epitomizing the white collar crime as they took advantage of vulnerable customers, no licensed drivers, basic employee rights and violated numerous industry laws and standards.

Contrary to these negative views, Rogers (2015) [18] expressed his dissatisfaction that public debate surrounding Uber had so far generated more heat than light, revealing little about the company's net impact on important public goods and values. Cusumano (2015) [8] pointed out that, while some startups had already run into legal and regulatory hurdles from city governments, courts, traditional unions or lobbies wanted to restrict or shut them down, the big question was really how traditional companies should compete with startups in the sharing economy.

By considering both of light and shadow effects of the ride sharing business, European Parliament (2015) [11] has summarized both aspects of social and economic consequences of Uber, as compared in Table 1.

It pointed out the challenge posed by governments including employment issues, internal market regulations, environment, taxation, and consumer protection.

Rudmin (2016) [19], from consumer science perspective, pointed out that distributed inventory accessed by digitally mediated sharing as with Uber, should be examined as an alternative inventory behavior.

While these works have shed light on the broad transformative problems of IDBM, inherent to newly emerging businesses, little attention has been paid to the inherent characteristics of ICT, on which IDBM is based and its subsequent solutions thereon.

Authors identified that Uber's disruptive business model can be attributed to a transformative shift in business design by constructing an ICT-driven platform ecosystem (Watanabe et al., 2016 [28]). Cusumano (2015) [8] pointed out that the sharing-economy startups threaten established companies to the extent that peer-to-peer networks could grow exponentially through the power of platform dynamics and network effects (Cusumano, 2015 [8]).

Oreg et al. (2015) [16] in their "Resistance to Innovation" warned that "People do not always choose the latest innovations. Many people find it more productive to keep using an old, familiar technology than rapidly adapt to a new technology." Becker (2008) [2] suggested a possible function of organizational routines as a part of the family of concepts such as institutions, norms or conventions that can be the source of both stability and change. Davis (2009) [9] identified that the highly dynamic environments require flexibility to cope with a flow of opportunities that typically is faster, more complex, more ambiguous, and less predictable than in less dynamic environments. Mella (2014) [15] postulated that the dynamic interconnections among systems of organizational routines could be the sources of endogenous organizational innovation.

These analyses provide a reasonable explanatory base in understanding the contrasting features of Uber's global expansion, with and without legal battles. The exponential growth of Uber supported by the dramatic advancement of ICT might be non-adaptive to the institutions without flexibility and insufficient time for routinization while it could be adaptive to institutions with flexible and sufficient time for routinization. Also, this contrast could be changeable depending on the dynamic interconnections among systems of organizational routines.

Given a bi-polarization nature of ICT-driven logistic growth (Watanabe et al., 2015 [25]) on which Uber depends on in its global expansion (Watanabe et al., 2016 [28]), this postulate prompts a hypothetical view that the foregoing contrast can be attributed to a bi-polarization nature of ICT-driven logistic growth and that success can be attributed to a co-evolutionary acclimatization that harnesses the vigor of counterparts. Furthermore, attainability of this target can be subject to the optimal velocity of expansion on the donor side and institutional elasticity of the host side.

This paper focused on the inherent characteristics of ICT on which IDBM is based. Using a comparative empirical analysis, this hypothetical view was demonstrated. A possible solution based on a concept of a co-evolutionary acclimatization satisfying the above conditions in both donor and host sides were also demonstrated.

Section 2 reviews ICT's indigenous functions that are driving ICT-driven disruptive business models (IDBM). Section 3 reveals pitfalls of the ICT advancement resulting in the emergence of conflicts in Uber's global expansion. Section 4 extracts lessons from Uber's global expansion success model. Section 5 briefly summarizes noteworthy findings, implications, and suggestions for future works.

2. Uber as the jewel of ICT

2.1. Two-faced ature of ICT and subsequent un-captured GDP emergence

Uber's global expansion can be attributed to its glory as the crown jewel of ICT. Authors demonstrated that current ICT-driven global development depended on a trend shifting from traditional co-evolution of computer-initiated ICT, captured GDP, and

Table 1
Social and economic consequences of Uber.

Efficiency gains	Allegations against Uber's business
Reduction of search cost	Unfair competition without following regulations/fare
Better overview of quality and prices	Could aspire to become monopolies
Provide ICT services assisting drivers	Cars/drivers could be unsafe/underinsured
Allow for better utilization of assets	Invade customers' privacy
	Discrimination by drivers/passengers
	Undermine working standards/poor compensation
	Present challenges related to taxation

Fig. 1-2. Spiral Development of ICT. **Fig. 1-3. Spiral Development of Uber.**

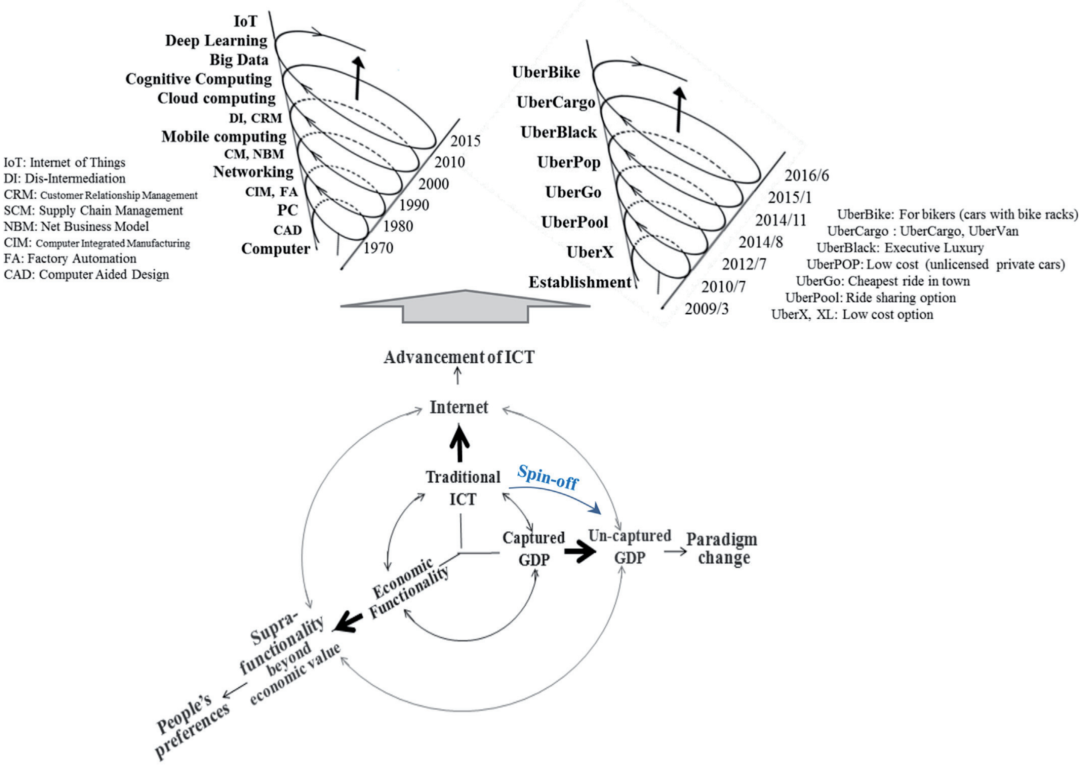


Fig. 1-1. Scheme of Spin-off Dynamism.

Fig. 1. Shifting trends in the Co-evolution of the 3 mega-trends leveraging spiral development of ICT and Uber.

economic functionality to new co-evolution of the Internet, un-captured GDP,[1] and supra-functionality beyond economic value as illustrated in Fig. 1-1 (Watanabe et al., 2016 [27]). Authors insisted that Uber's system success can be explained by this shifting co-evolutionary trend (Watanabe et al., 2016 [28]). They demonstrated that un-captured GDP was a key factor identifying the state of these shifting trends, and that two-faced nature of ICT was behind the emergence of un-captured GDP.

2.2. Spin-off from traditional co-evolution to un-captured GDP oriented new co-evolution

Uber's rapid expansion worldwide along with emerging legal battles in some cities recalls the rapid spin-off from a traditional captured GDP based cycle to an un-captured GDP based new cycle which accomplishes a spiral development similar to that of ICT from computer to IoT over the last four decades as demonstrated in Figs. 1–2 and 1–3. Authors demonstrated that Uber's conspicuous spin-off can be attributed to its ICT inherent self-propagating function incorporating new functionality development during its diffusion process (Watanabe et al., 2016 [28]).

2.3. ICT-driven disruptive business model

Thus, the dynamism of Uber's ICT-driven disruptive business model (IDBM) which can be the locomotive of its rapid global expansion resulting in a contrasting development between successful co-evolution with host institutions and legal battles are identified as illustrated in Fig. 2 (Watanabe et al., 2016 [28]).

Uber's co-existing development trajectory with taxis corresponds to the two-faced nature of ICT that is behind the emergence of un-captured GDP as mentioned earlier. This emergence can be attributed to a strong substitution from taxi to Uber accelerated by contrasting vicious cycle between price increases and trip decreases in taxis and a virtuous cycle between price decline and trip increases in Uber.

Uber's virtuous cycle can be attributed to ICT's self-propagating function that enhances the level of functionality as its diffusion proceeds. This self-propagating function plays a vital role in spin-

[1] Un-captured GDP can be defined as added values providing utility (satisfaction of consumption) and happiness beyond economic value to people but cannot be measured by traditional GDP accounts (captured GDP) that measure economic value. Supra-functionality beyond economic value can be the typical example.

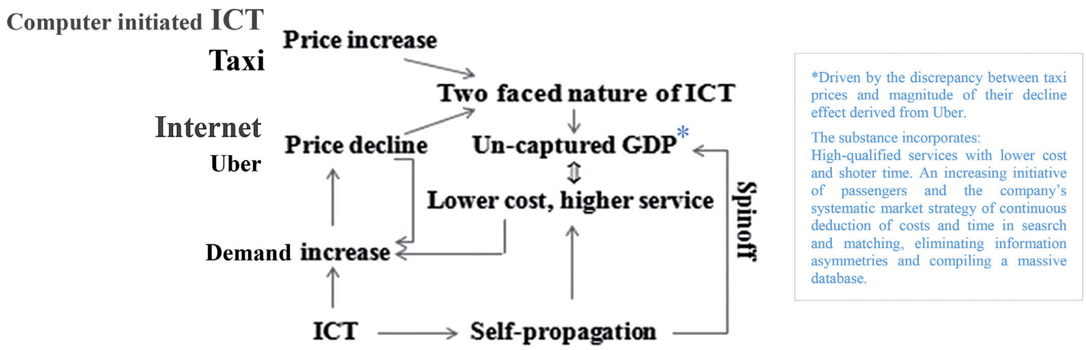


Fig. 2. The dynamism of ICT-driven disruptive business model (IDBM).

offs from traditional co-evolution to new co-evolution between ICT advancement, paradigm change to increasing un-captured GDP dependence, and people's preference shift to supra-functionality beyond economic value. Also, this spin-off accelerates further lower cost and higher services, which accelerates the preceding virtuous cycle.

It is evident that Uber's rapid global expansion can be attributed to constructing such ICT-driven disruptive business model (IDBM). Nowadays, business models have been moving from pipes to platforms, and we are in the midst of a transformative shift in business design. Platforms allow participants to co-create and exchange value with each other. External developers can extend platform functionality and contribute back to the infrastructure of the business. Platform users who act as producers can create value on the platform for other users to consume. Uber's development corresponded to this historical stream. Uber's disruptive business model can be thus appreciated as a leader of a transformative shift in business design by constructing the preceding platform ecosystem.

At the same time, we should not overlook the phenomena that sharing-economy startups threaten established companies to the extent that peer-to-peer networks can grow exponentially through the power of platform dynamics and network effects (Cusumano, 2015 [8]).

2.4. ICT's indigenous functions driving ICT-driven disruptive business model

The preceding two-sided nature of exponential growth typical of ICT inherent logistic growth reminds us to review the following ICT's indigenous functions:

2.4.1. Two-faced nature

While the advancement of ICT contributes to enhancing its prices by increasing new functionality development, dramatic advancement of the Internet tends to decrease ICT prices due to freebies, easy copying, and mass standardization, among other things as reviewed earlier and exists behind the emergence of un-captured GDP.

2.4.2. Self-propagating nature

Given ICT's exponential growth as demonstrated by logistic growth and the correlation of the interaction between its advancement and institutions displays a systematic change in the process of its growth and maturity, its advancement leads to the creation of a new carrying capacity in the process of its diffusion. Thus, the level of carrying capacity of ICT's logistic growth enhances as its diffusion proceeds leading to create logistic growth within a dynamic carrying capacity (LGDCC) as explained by Watanabe et al., 2004 [24] (see Appendix 1).

As the LGDCC carrying capacity increases together with the increase of ICT as time goes by which demonstrates functionality spiraling increases in the context of self-propagating behavior. This spiral increase leverages spin-off as reviewed earlier.

Uber's systems success leading its rapid global expansion can be attributed to these ICT's indigenous functions.

Table 2 demonstrates this fact by comparing development trajectories between taxis and Uber in NYC[2]. Looking at Table 2 we note that while the development of taxis depended on simple logistic growth (SLG) without self-propagating functionality development as the level of its carrying capacity was constant through its development process, Uber's development depended on LGDCC thereby it enjoyed self-propagating functionality development.

3. Pitfall of ICT advancement

3.1. Uber's expansion and battles

3.1.1. Rapid expansion

Supported by ICT's indigenous self-propagating functionality development dynamism Uber expanded rapidly leading to offering its services in over 479 cities in more than 75 countries worldwide by June of 2016 as illustrated in Fig. 3.

3.1.2. Emergence of legal battles

Proportional to such rapid expansion, legal battles emerged in some cities around the world. Typical cases of such contrast include:

Thailand has completely banned it as illegal. Germany banned certain services, same as France, Italy, Belgium, Netherland, Finland and Brazil. Contrary to these negative cases, in addition to Uber's initial foundation in the USA, Uber operates in Singapore, Saudi Arabia, London, Tokyo, Taiwan, Canada and Russia notwithstanding legal issues as illustrated in Fig. 4.

3.2. Bi-polarization fatality of logistic growth

The preceding contrast of the crown jewel of ICT reminds us of

[2] See Fig. 12 in Watanabe et al., 2016 [28] trends in taxi and Uber's development by their trips.

Table 2
Adaptability of Taxi and Uber's Development Trajectories to LGDCC (NYC).
LGDCC: Logistic growth with dynamic carrying capacity,* $Y = \frac{N_k}{1+be^{-at}+\frac{b_k}{1-a_k/a}e^{-a_k t}}$.

		N_k	a	b	a_k	b_k	adj. R^2
Taxi	*(Jan. 2004 − Jun.2013)*	2247.12 (6.42)	0.017 (12.61)	6.364 (6.63)	0.439 (0.00^{x})	10.30 (0.00^{x})	0.976
Uber	*(Jun.2013 − Sep.2015)*	119.27 (41.41)	0.121 (36.67)	49.650 (11.13)	0.016 (2.42^{*3})	0.200 (1.43^{*5})	0.999

Y: trips; N_k: carrying capacity; t: time; a, b, a_k, b_k: coefficients.
Taxi: based on medallion prices, Uber: based on trips with spline interpolation (see Watanabe et al., 2016 [28]).
SPSS software was used for this nonlinear regression analysis (Watanabe et al., 2016 [28]).
* Figures in parenthesis indicate t-statistics: all significant at the 1% level except ^{*3}: 5%, ^{*5}: 12%, ^{x}: non-significant.
Third term of the denomination indicates magnitude of dynamic carrying capacity formation, without which Y is simple logistic growth (SLG). a: velocity of diffusion, and b: initial stage of diffusion. a_k and b_k play similar function in dynamic carrying capacity formation.

Fig. 3. Uber's expansion in 479 cities in the world (as of June 2016).
Source: Uber.

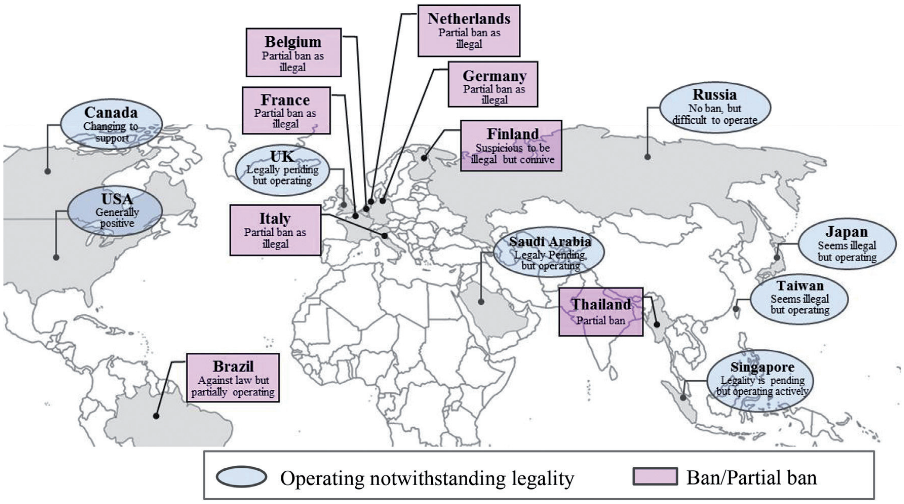


Fig. 4. Contrasting features of Uber's global expansion in 16 countries (as of June 2016).
Sources: Authors classification based on, NY Times, HuffPo, Reuters, WSI, CNN and local news reports.

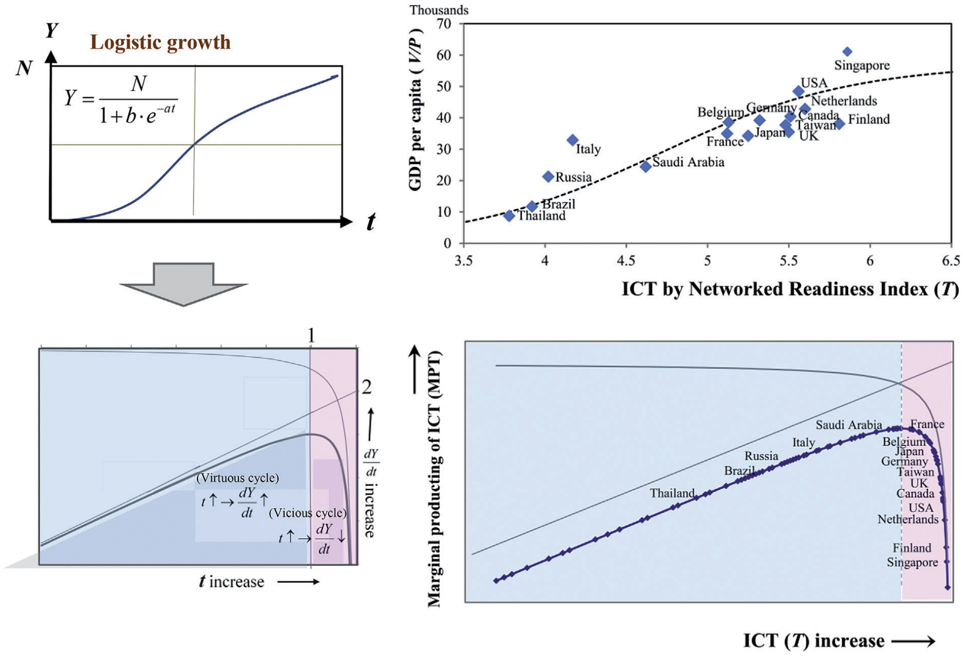


Fig. 5. Scheme of the Bi-polarization fatality of logistic growth.

another ICT's indigenous function, the bi-polarization nature of logistic growth that demonstrates ICT-driven development can be split into a virtuous cycle and a vicious cycle.

3.2.1. Bi-polarization fatality

Logistic growth trajectory (upper left figures in Fig. 5) can be developed to a bi-polarization trajectory as demonstrated in the lower left figures in Fig. 5 (Tokumasu and Watanabe, 2009 [20]) (see the details of mathematical development Appendix 2).

The figure in the lower left in Fig. 5 illustrates the bi-polarization trajectory of a logistic growth function. The figure indicates that in the normal logistic growth as a function of time t, marginal increase (dY/dt) increases as time goes by as generally anticipated within the time shorter than a certain threshold. However, it changes to reverse upon exceeding this threshold resulting in marginal increase decline against anticipation.

By the preceding review, the figure in the upper right demonstrates ICT-driven logistic growth in 100 countries in 2011 (Watanabe et al., 2014 [25]). Given that ICT advances proportional to time t, ICT-driven economic growth in 100 countries can be depicted by a logistic growth function consisting of ICT advancement (T) and GDP per capita (V/P) as demonstrating in the upper right in Fig. 5 (see 100 countries display Appendix 3).

Since this ICT–GDP per capita logistic growth demonstrates statistical significance (see Appendix 3), this trajectory leads to a bi-polarization between ICT advanced 30 countries and ICT growing 70 countries as illustrated in the lower left in Fig. 5. While the latter 70 countries enjoy ICT's marginal productivity increase as ICT advances, ICT advanced 30 countries suffer a vicious cycle between ICT advancement and its marginal productivity decline resulting in the great stagnation (Cowen, 2011 [7]). This can be attributed to trapping in ICT advancement derived from the two-faced nature of ICT reviewed earlier (Watanabe et al., 2015 [26]).

3.2.2. Co-evolutionary acclimatization

By the preceding reviews, Fig. 6 illustrates a whole perspective of a bi-polarization of ICT advancement as a consequence of a trap in ICT advancement derived from its two-faced nature.

A vicious cycle in ICT advanced economies can be attributed to a trap in ICT advancement (top in Fig. 6) derived from the two-faced nature of ICT, that is, while advancement of ICT, centered by the dramatic advancement of the Internet, generally contributes to enhanced prices of technology from new functionality development, the dramatic advancement of the Internet reacts to decreases in prices of technology due to its nature of freebies, easy copying, and mass standardization. Given that the firms seek to maximize profit in the competitive market, the marginal productivity of technology corresponds to the relative price of technology which, contrary to new services created by the advancement of the Internet, results in a decrease in ICT's contribution to growth. This can be considered the dynamism in emerging un-captured GDP that the Internet provides utility and happiness to people but cannot be captured through GDP data (Watanabe et al., 2015 [25]).

On the contrary, while ICT growing economies expect their growth increase through the marginal productivity of ICT increase as ICT increases, these economies cannot afford the required additional ICT investment by themselves. While ICT advanced economies enable further advancement of ICT, it results in declining its marginal productivity which can be considered as compensation for un-captured GDP emergence. Thus, such advancement should be shared for the advancement of ICT growing economies which enjoy a virtuous cycle between its advancement

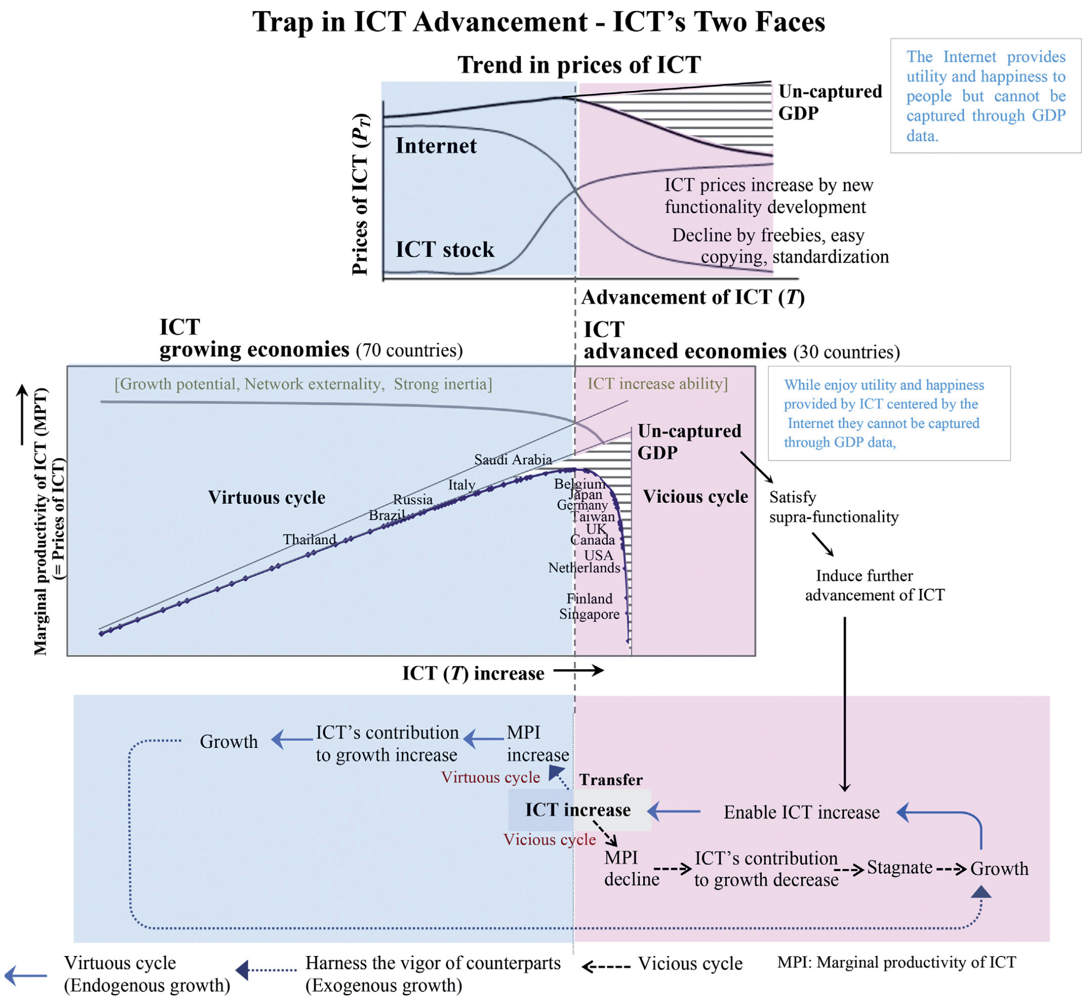


Fig. 6. Co-evolutionary Acclimatization against Bi-polarization (A case of 100 Countries in 2011).

and marginal productivity increase leading to sustainable growth as illustrated in the bottom in Fig. 6. By harnessing the vigor of ICT growing economies through their sustainable growth, ICT advanced economies can maintain their growth through the marginal productivity of technology increase without falling into a trap in ICT advancement as illustrated in the bottom of Fig. 6 (see details of this mechanism Appendix 4). This maintained growth enables ICT increase which can be shared with ICT growing economies for their sustainable growth as reviewed earlier.

These reviews suggest the co-evolutionary acclimatization system that harnesses the vigor of counterparts as illustrated in the bottom of Fig. 6 enables both ICT advanced, and growing economies to maintain sustainable growth. This system can be possible countermeasures to the trap in ICT advancement (Watanabe, 2013 [23]).

Cannon et al. (2015) [4] suggested that "collaborative co-regulation: designing a co-regulatory scheme that can effectively complement the inherent attributes of the sharing economies being regulated to improve effectiveness, the optimal level of protection of public interests over interest groups, and cost-effective feasibility is essential." This suggestion corresponds to the concept of the co-evolutionary acclimatization.

Given that Uber's system success depends on the development of ICT, its considerable legal battles proportional to its rapid expansion can be attributed to this bi-polarization feature. Similar to excessive ICT advancement results in a vicious cycle between ICT advancement and productivity decline, rapid Uber expansion results in a vicious cycle.

3.3. Optimal growth rate for self-propagation

Given the understanding that the adaptability of ICT

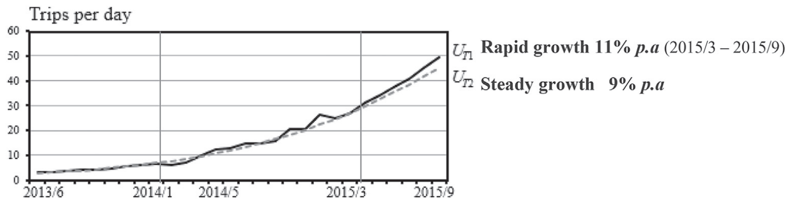


Fig. 7. Comparison of Uber trips estimate in NYC (Jun. 2013–Sep. 2015).

advancement can be subject to sufficient time for routinization and that the functionality of ICT can be developed through the interaction with institutions in a self-propagating manner, it can be postulated that optimal velocity of growth would be crucial to its self-propagating functionality development.

With the understanding that this self-propagating functionality development can be attributed to its adaptability to logistic growth within a dynamic carrying capacity (LGDCC) function, Uber's fit ability to this function subject to growth rates was compared (Fig. 7).

Table 3 demonstrates that while self-propagation can be expected in steady growth by fitting to LGDCC, it cannot be expected to have rapid growth. This supports the hypothetical view that sufficient time for routinization is required for Uber's expansion.

Koopman et al. (2014) [12] pointed out that new ventures should consider to what degree is the sharing economy creating new markets, rather than simply supplanting older forms of transactions.

3.4. Institutional elasticity in accepting Uber

It is postulated that institutional elasticity of the host is required for smooth acceptance of Uber in its global expansion.

As pointed by European Parliament (2015) [11], such institutional issues as employment issues, internal regulations, environment, taxation, and consumer protection are crucial for smooth acceptance of Uber. Analyzing critical points impeding Uber's smooth acceptance into cities with legal battles (see 3.5), internal regulations relevant to protecting the vested interests of incumbent organizations shared a central dimension. This dimension can be vividly represented by the flexibility of wage determination of the host countries/cities.

Warner (2002) [22] in his international survey on wage determination in 19 countries identified that flexibility of wage setting demonstrates negative correlation with dependency on union and collective bargaining agreements (CBA). Secondly, the 19 countries split into two clusters, "flexible setting group" including USA, UK, Canada and Japan, and "less flexible setting group" including western and southern European countries and Nordic countries as demonstrated in Fig. 8. Finland is a country with the lowest flexibility of wage setting and with the highest dependency on union and CBA. This result corresponds to the similar survey on Finland (Tyrväinen, 1995 [21]).

On the basis of the findings of these surveys, utilizing the ranking of flexibility of wage determination in 140 countries published annually by the World Economic Forum (WEF, 2015 [29]). Table 4 demonstrates a correlation between institutional elasticity and Uber acceptance in 16 countries by grouping the countries by those with a positive reaction to Uber and those with certain legal battles with Uber.

3.5. State of conflict in Uber expansion

Aiming at identifying factors contrasting Uber's global expansion, based on Table 4, states of conflict in Uber expansion in selected 16 countries were surveyed[3].

3.5.1. Generally positive

(1) **Singapore** [Legality is pending but operating actively]

1. Taxi drivers and passengers in Singapore are welcoming taxi app services.
2. This has led to a highly competitive taxi app market in Singapore, and existing taxi companies as Comfort Delgro and Trans-Cab endeavored to improve their services by introducing their mobile app services.
3. COE (Certificate of Entitlement) scheme based on the tripartism framework (consists of Ministry of Manpower, National Trades Union Congress, and Singapore National Employers Federation) plays a decisive role in Singaporean's efficient utilization of ride-sharing.
4. Requirements and complaints can be solved through dialogues with the regulators, employers and employees (drivers) under the tripartism framework.
5. Uber induced incorporating users (passengers) requirements into the tripartism framework by stimulating better services, thereby consolidation of all stakeholders: company, employee, user and government was constructed.
6. Government agile reaction to complaints from the incumbent through open dialogue with all stakeholders and by acknowledging new streams of innovation versus resisting played a key role.
7. The government is secretly* welcoming the taxi app services because:
   (i) Young people enjoy using services like Uber, and the government must not resist innovation,
   (ii) They provide job opportunities to Singapore citizens (toward aging society) and increase the overall productivity,
   (iii) The ride-sharing can be an approach to tackle problems of traffic clog and achieve efficient road usage.
   *Transport Minister urged that "we must always be fair to players, whether incumbent or insurgents and strike a balanced approach".
8. In April 2016, the government declared to allow Uber to pick up passengers, legally with vocational licenses (by 10 h training program, shorter than 60 h for taxi drivers)

(2) **Tokyo** [Seems illegal but operating]

[3] States are as of June 2016 based on, NY Times, HuffPo, Reuters, WSI, CNN and local news reports. Note that these states are subject to imminent change.

Table 3
Comparison of adaptability of Uber's development trajectories to LGDCC.(NYC, Jun. 2013–Sep. 2015).

	N_k	a	b	a_k	b_k	adj.R^2	
U_{T1}	144.13 (2.95)	0.123 (12.68)	25.800 (3.29)	0.0001 (0.10^x)	3.040 (1.29^{*6})	0.992	**Rapid growth**→Non self-propagation
U_{T2}	119.27 (41.41)	0.121 (36.67)	49.650 (11.13)	0.016 (2.43^{*3})	0.200 (1.43^{*5})	0.999	**Steady growth**→Self-propagation

See Table 2 equation and notations.
Figures in parenthesis indicate t-statistics: all significant at the 1% level except ^{*3}: 5%, ^{*5}: 15%, ^{*6}: 20%, x: non-significant.

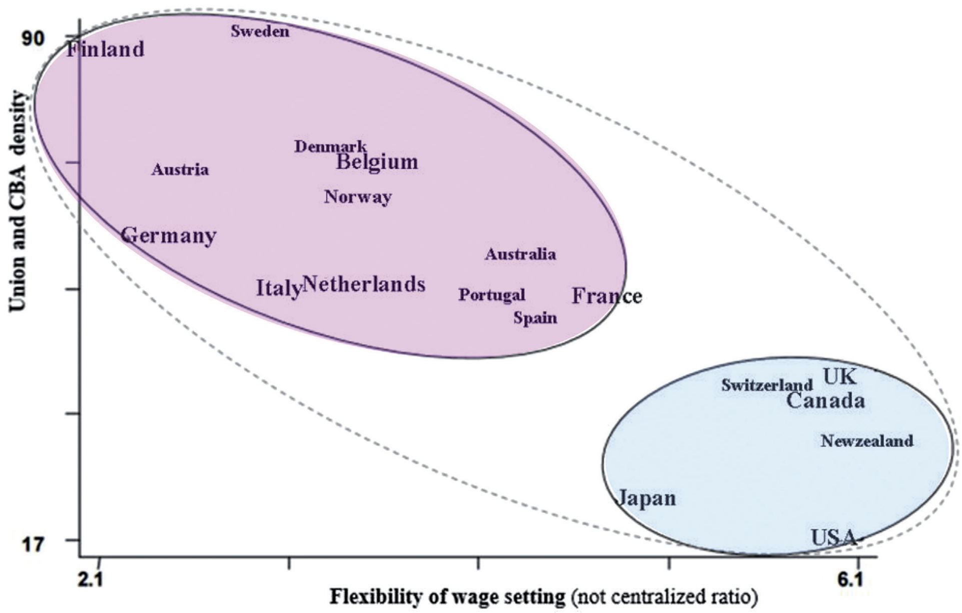


Fig. 8. Correlation between Centralization of Wage Setting and Union and CBA Density in 19 Countries in the Late 1990s.
CBA: Collective bargaining agreements. Union and CBA density = (Union density + CBA coverage)/2.
Source: Warner (2002) [22]

Table 4
Contrast of institutional elasticity in Accepting Uber in 16 countries.

Reaction to Uber	Ranking of flexibility of wage determination	Country	State
Generally positive	6	Singapore	Legality is pending but operating actively
	7	Japan	Seems illegal but operating
	14	Taiwan	Seems illegal but operating
	15	UK	Legality is pending but operating with expectation
	19	USA	Generally positive
	20	Saudi Arabia	Legality is pending but operating actively
	27	Russia	No ban, but difficult to operate
	33	Canada	Changing to support
With certain legal battles	69	France	Partial ban as illegal
	111	Thailand	Full ban
	123	Brazil	Against law and prohibited except certain cities
	129	Belgium	Partial ban as illegal
	131	Netherland	Partial ban as illegal
	132	Germany	Partial ban as illegal
	134	Italy	Partial ban as illegal
	140	Finland	Suspicious it is illegal but connive to operate

Ranking out of 140 countries of the score of the weighted average to the state how are wages set [1 = by centralized bargaining processes; 7 = by each company].
Source: The Global Competitiveness Report 2015–2016 (World Economic Forum, 2015 [29]).

1. Uber has had tremendous difficulties in making inroads into the Japanese market due to “Byzantine” and complicated regulations.
2. Uber was ordered to suspend its pilot project in Fukuoka city in Feb. 2015 because it violates the laws. Uber stopped the project in Mar. 2015

3. Tokyo has a rather tranquil market so far due to its qualified service seeking competitive market with 50,000 taxies (20% of the total in Japan and four times the number in NYC).
   Nov.2013 Uber started in Tokyo (limited launch. Expanded to whole Tokyo area from Aug. 2014).
   Jan. 2014 Tokyo Hire-Taxi Association also introduced a mobile app service.
   Jan. 2015 Japan's largest taxi company, Nihon Kotsu launched a mobile app Line Taxi.
   Mar. 2015 Japanese government stated Uber probably violates laws (unlicensed, safety).
   Uber reacted by continuing talks.
   Mar. 2015 Japan's e-commerce giant Rakuten entered the ride-sharing industry by purchasing 11.9% in Lyft.
   Oct. 2015 Prime Minister Abe instructed relaxing regulation for ride-share in isolated areas.
4. Although the legal framework in Japan does not allow private cars or ordinary persons to operate as a paid taxi, taxi companies in Tokyo recognized Uber as a business competitor and worked towards improving their services by developing new functions.
5 With government and broader industries involvement for social demand (traffic, aging, isolated rural) co-evolution emerged between IDBM (existing taxi companies also improved their services by introducing their mobile app services) and advancement of institutional systems by solving social demand.

(3) **Taiwan** [Seems illegal but operating]

1. In response to Taipei's taxi drivers' protests against Uber over the summer of 2014, Taiwanese government planned to pull the app from local stores as it does not meet the country's legislation.
2. In December 2014, Uber Taiwan was punished with fines and a cease and desists of the app for operating illegally.
3. Issues included failure to insure vehicles, operating as a business without a business license, metered fares unknown to passengers, metered fares not inspected by the Ministry of Transportation and Communication, and failure to report income and pay taxes. Many drivers had their licenses suspended for violations.
4. In December 2014 the Ministry of Transportation and Communications announced that the company was operating unlicensed taxis in violation of national law and that the government was considering blocking the service.
5. In March 2016 the officials of Ministry of Transportation and Communications said there are about 3000 private car owners are working for ride-sharing service, even though the service remains illegal in the country. The cabinet announced that Uber is not welcome in Taiwan since it has never paid local taxes and all of its transactions are processed overseas.
6. Also in March 2016, The Ministry of Transportation and Communications announced heavier fines. The fine for the first time offender driving a private car seating nine or fewer passengers or a truck weighing 35,00 kg or less is NT$50,000 (US$1534), and the vehicle's license plate will be suspended for two months. The fines for the second to the fourth offense have been raised to NT$ 60,000, NT$ 70,000, NT$ 80,000 respectively and license plate suspension for three, four and six months respectively. Fine for fifth or subsequent violations was set to NT$ 100,000 and license plates revoked.
7. In June 2016 the Transportation officials decided to step up the police crackdown on Uber drivers in the country's six municipalities. The Fair Trade Commission fined NT$ 1 million to Uber for the false statements on the company's website that may mislead private drivers into thinking that driving for Uber is lawful.
8. In response, Uber is determined to support their passengers and drivers by considering them an integral part of its business. Uber has been continuously paying the fines of its drivers. Since September 2014 Uber has been fined more than NT$ 56 million (US$1.7 million) for violating the Highway Act.
9. Uber is hoping to communicate with Taiwan's new government to effectively manage and include the sharing economy platform industry in legal frameworks and use innovation and big data technology to improve the quality of transportation.

(4) **London** [Legality is pending but operating with expectation]

1. Black taxis have been the kings of the British capital's roads for over a century, but now they are battling a high-technology rival that threatens their dominance. Uber is active in three cities (London, Manchester, and Leeds) in the UK.
2. Uber has won a significant legal victory in the UK, with London's high court ruling that Uber's app does not constitute a taximeter.
3. The legal challenge was brought by London's transport agency Transport for London (TfL), following pressure from the city's black cab and taxi drivers.
4. While taximeters devices which record distance travelled and are used to calculate fares are only allowed for licensed taxis, the judge ruled that the legal definition of a taximeter doesn't include "smart phones which rely on data from a server outside the vehicle."
5. Uber hailed the decision as a "victory for common sense," adding that the ruling means the company won't have to change how its app works in London.
6. London Mayor reported that "The technological innovation should not ban, unnecessarily, that which will serve a good purpose to the Londoners." This showed the positive impact of the service in the country. He also added that some solution needs to be sorted out so that the growth of Uber services does not impact the traditional black taxi drivers.
7. London's Licensed Taxi Drivers Association described the outcome as unbelievable. The transport authority has also asked the court to determine if the service is, in fact, legal.
8. Notwithstanding the above victory, Uber still faces ongoing legal challenges in London, including proposals to introduce compulsory five-minute wait times and the removal of car icons from the map in the Uber app.

(5) **USA** [Generally positive]

1. Uber has first laid its foundation in the US with great success. Later regulatory acts were brought against it by the local taxi drivers. It had taken the sharing economy to a next level. A very strong installation growth occurred in the USA with a rate of 1.4% slowly developing to be a strong economy with 20% by the end of the second quarter of its introduction.
2. Its main popularity is based on its demand side which has its base on the supply. The introduction of ride sharing system by Uber gave a new aspect for more people opting in as the prices were efficient in comparison to the taxi drivers. By the end of 2015, 55% of the ground transportation receipts were for Uber while 43% were for the taxi services.

3. Uber is operating in 75% of US locations although banned in Nevada and Oregon, and there were multiple on-going lawsuits. Among US cities, San Francisco tops the position with 79% usage, while Dallas is 60% and followed by Los Angeles with 54%.
4. While many cities in the US readily accepted this disruptive innovation, cities like New York, Texas, Portland, Birmingham, etc. stood against Uber because it had no regulations. Regulatory systems were made to be enforced. State legislators in Ohio and Florida are moving ahead with regulations governing Uber and other ride services that would designate all drivers as independent contractors, bolstering a critical but much-disputed aspect of Uber's business model.
5. The battle between Portland and Uber led to a 120-day pilot program, where Uber was allowed to operate legally in the city if and only if it followed the guidelines such as verifying that the drivers were under the TNC (Transportation Network Companies) or TLC (Taxi and Limousine Commission), insurance card and certificate. These regulations ensured safety for the riders if they opt for ridesharing.

(6) **Saudi Arabia** [Legality is pending but operating actively]
1. Saudi Arabia's discriminatory automotive policies against women have allowed Uber to achieve great success, due to females having limited options for transportation.
2. Women are not allowed to drive as it is feared to damage their ovaries leading to children born with clinical problems.
3. Since women cannot keep their jobs in Saudi Arabia because they have trouble finding reliable transportation to get to work, Uber triggered an institutional revolution for women's social participation as demonstrated by the fact that women make up 70% of Uber's customers.
4. With such expectation, Uber operates in the Islamic holy cities of Mecca and Medina, as well as the capital city of Riyadh, and the port cities of Jeddah and Dammam. The service is expected to be available in several more cities shortly.
5. While there remains the issue of compliance with traditional government regulations, negotiations with the institutional regulators in Saudi Arabia have been extremely positive compared to other countries reception towards the app business.
6. Thus, Uber is expected to grow 50–60% in trips per months in Saudi Arabia in 2016, which in turn accelerates social innovation in the country leading to a co-evolution between ICT-driven disruptive innovation and change in institutional systems triggered by women's social participation.
7. In June 2016, the Saudi Arabia's Public Investment Fund announced to invest US$ 3.5 billion in Uber. The investment is a part of the Saudi Arabia's 2030 vision to reduce the country's dependence on oil, its unemployment, and workforce inequality.

(7) **Russia** [No ban,but difficult to offer service]
1. Regulations in Russia are comparatively simple in comparison to other countries.
2. Moscow has already a culture of unlicensed taxis that makes Uber's expansion difficult.
3. Citizens can often hail one by standing on the street corner or via some apps that had existed for years before Uber arrived.
4. Since 2011, Russia's main search engine company, Yandex, has been running a taxi-app that now is simply know as Russia's Uber.
5. Uber also trails Gett, known as the Uber of Israel, which operates 10,000 cars in Moscow
6. In February 2016, the Moscow's Transport Department threatened to ban Uber from the city unless it signs an agreement to use officially registered drivers and share travel data with local authorities.
7. In March Uber reached an agreement with Moscow transport officials that gave it the green light to continue operating in the Russian capital.

(8) **Canada** [Changing to support]
1. Uber drivers in Canada are required to register, collect and remit HST/GST from their fares to the government, regardless of their income.
2. In December 2012, officials in the city of Toronto charged Uber with 25 municipal licensing infractions. Passengers may be fined for using Uber X, up to $ 20,000 according to a Toronto city councilor.
3. Uber was made legal in the city of Edmonton by passing a by-law. However, Uber ceased its operations in Edmonton in March 2016 citing the inability to obtain the necessary insurance. The City of Calgary, Alberta has charged at least 17 drivers illegally driving for Uber.
4. These drivers were operating without legally mandated insurance. Uber continues to operate illegally in the other regions of Canada.
5. Toronto Mayor expressed his support for Uber in 2014, and other cities are slowly beginning to look at regulatory options

(9) **EC** [Encouraging in principle]
1. On 2nd June 2016, The European Commission presented guidelines intended to support consumers, businesses and public authorities to engage confidently in the collaborative economy and to foster the development of new Internet-based sharing economy startups in Europe (EC, 2016 [10]). On the issue of restrictions, the report explained that the absolute ban or any quantitative restrictions on sharing economy services (Uber, Airbnb) should be proportionate to the public interest at stake, such as public safety or social policy and should only be used as a measure of last resort.
2. The European Commission Vice-President for Jobs, Growth, Investment and Competitiveness, stressed the importance of keeping Europe as open as the USA for new innovative business models while addressing the negative effects, but such businesses should not become a “parallel informal economy” operating free of regulation. He further stressed that the government's role should be to encourage a regulatory environment that allows new business models to develop while protecting consumers and ensuring fair taxation and employment conditions.

3.5.2. With legal battles

(1) **France** [Partial ban as illegal]
1. France government initially started to suppress the service with their policy and later started allowing Uber services in certain cases, not all the services.
2. UberX is the low cost service that allows only the licensed drivers to operate the cabs and UberPop is also a service but allows even the drivers without a driving license to operate the cab.

3. The government allowed the former but not the latter stating that it would severely affect the regular taxi drivers.
4. Uber did not accept the decision and filed against the government which led to huge violent protests by taxi drivers. Finally, Uber has suspended their UberPop services until hearing the final judicial result.
5. Uber announced that it would re-launch its UberPop services if the government considers Uber to be legal. But that seems to be highly unlikely.
6. Currently, UberPop is banned from functioning in France. Uber was facing equal protests from traditional Taxi drivers stating that it is not a fair competition as the taxi drivers are exempted from the taxes paid by them.

(2) **Thailand** [Full ban]

1. Following concerns raised by taxi drivers in Thailand over the lower rates charged by Uber drivers, the head of the country's Department of Land Transport (DLT) declared Uber illegal on November 28, 2014 alleging that Uber vehicles are not properly registered in Thailand, the charging methods of Uber drivers are not valid, Thai Uber drivers are not properly licensed, and the service discriminates against people who do not possess credit cards.
2. The Department also raised security concerns over Uber's credit card-only policy in Thailand, and the head of DLT said that Uber was also illegal under Thailand's Motor Vehicle Act B.E. 2522.
3. Following the announcement of the November 2014, Uber drivers faced a maximum 4000-baht fine if caught by police.
4. Meanwhile, a meeting of different government agencies was held to decide how Uber services would be managed in the future.

(3) **Brazil** [Against law and prohibited except in certain cities]

1. Uber has been used in Brazil since 2015, but only in four major cities: São Paulo, Rio de Janeiro, Belo Horizonte and Brasília. Since it is a user-friendly app and broke up the monopoly of cab drivers on individual transport, Uber use has increased a lot over the first half of 2015. Uber is the preference for passengers who appreciate safety, more diversity in payment options (due to credit cards) and promotional offers.
2. Since cab drivers are very organized in Brazil, they have frequently been protesting against Uber. They complain that since they pay taxes, Uber drivers or owners should too.
3. In some cases, cab drivers have been violent. In Belo Horizonte, they've persecuted Uber drivers. In Rio de Janeiro, threats are common, and there was a massive protest against Uber there in late July 2015. In Brazil, a man was attacked by mistake in the airport of Brazil's capital after cab drivers had thought he was an Uber user.
4. Due to the organization of cab drivers, their lobbying power is huge and in most cities where Uber is used, politicians are working for its prohibition.
5. In Sao Paulo and Brazil, local legislators have approved different projects to forbid Uber. The mayor of São Paulo has to decide if this prohibition will become law. The governor of Brazil voted the ban on Uber, although this doesn't technically legalize the service. In Rio de Janeiro and Belo Horizonte, Uber is still operating without legal constraints. But their municipal chambers are expected to be as strict as in the other cities.

(4) **Belgium** [Partial ban as illegal]

1. As in many other cities, established taxi drivers protested against UberPOP (which relies on non-professional drivers using their vehicles) since its arrival in Brussels in 2014.
2. With such protest, a Belgian court ordered Uber to stop the UberPOP service in September 2015.
3. In response to the court order, Uber decided to suspend its unlicensed UberPOP service in Brussels and concentrate on building up its more expensive UberX service, which uses professionally licensed drivers.
4. While Uber has more than 50,000 users in Brussels, they are obliged to use only UberX, a service launched in September 2015.
5. Therefore, while some 1000 Brussels drivers had used their cars to chauffeur passengers through UberPOP, drivers on the UberX service are very limited.

(5) **Netherland** [Partial ban as illegal]

1. UberPop service was launched as a pilot project in Amsterdam between July and September 2014 followed by an expansion project in Hague and Rotterdam.
2. Currently, the Uber offer its UberX, UberBlack, UberVan and newly launched UberBike service. The UberBike is exclusively targeted at cyclists; now they can order a taxi equipped with a bicycle rack that can fit one city bike or two racing bikes.
3. In December 2015 a court in Netherlands had banned the company's low cost service UberPop because of its violations of the law on licensing of drivers. The Transport inspectors carried out campaigns against the service and fined Uber a total of 450,000 euros for breaking taxi regulations with its UberPop service.
4. In November 2015, Uber withdrew its controversial UberPop service in Netherlands by following the order of Trade and Industry Appeals Tribunal in Hague and said the UberPop is a hindrance to the constructive dialogue about modernizing the existing taxi rules.
5. As Uber runs all of its European operations from Netherlands, so the company often faced criticism and accusations of processing revenues through its Dutch subsidiaries, because of the lower tax rate.

(6) **Germany** [Partial ban as illegal]

1. The taxi industry is archaic in Germany. Large taxi companies were driven by the profit motivation in a quasi-monopolistic market.
2. They have little reason to invest to improve customer service. Instead of upgrading their system by challenging innovation, they have chosen to continue using an inefficient and outdated system.
3. March 2015, the Frankfurt district court imposed a nationwide ban on local transport services using UberPop because its drivers didn't have licenses for transport.
4. So Uber had to stop its UberPop service. It resumed service under the name UberX with guarantees that its cars and drivers would comply with specific legal requirements. But taxi drivers remain skeptical. The taxi driver trade union declared it would watch whether Uber is abiding by local regulations.
5. Though UberPop was banned, it introduced another service Uber Black (luxury version of UberX). It is not completely prohibited but still legal proceedings are ongoing stating that they are hired cars different from taxi drivers.
6. Security and insurance issues remain as the drivers need not necessarily own their license.

7. Finally, another new service ‘UberTaxi’ was introduced that adhere to the local and legal requirements of the government.
8. Uber has criticized the German courts for trying to force the digital platform to comply with laws "dating back to the '50s." Uber brought its concerns about the restrictions to the European Commission.
9. Consequently, Uber's ride-sharing revolution resulted in disengagement from German institutional systems.

(7) **Italy** [Partial ban as illegal]

1. Traditional taxi drivers in Italy raised a protest against UberPop, which was yet another legal battle thrust upon Uber.
2. The court forbade UberPop for allowing unlicensed drivers for the taxi services. UberPop allows ride sharing services, and it also allows any person to use their car as a taxi which increases the risk to customers.
3. UberPop is just a variation version of Uber, which is being offered in the country regions where the operation of unlicensed taxis is prohibited.
4. Uber was given a time frame of 15 days to comply with the rules or encounter a fine of 20,000 euros for each day's delay in court meeting.
5. On May 26, 2015, the court ordered a complete ban on the UberPop services much to the shock of the organization.

(8) **Finland** [Suspicious it is illegal but connive to operate]

1. Taxies in Finland are fairly expensive (A typical 10 km ride costs 1.2–1.6 times higher than NYC).
2. Uber started its operations in Helsinki, Finland in 2014 and offered two products, Uber Black and UberPop on a six month trail. The app has been controversial from the beginning because of its direct hit on the operating model of existing taxi industry, which is highly regulated from pricing to the number of licensed taxis.
3. The Finnish Taxi Association requested the police authorities to step in and deal with unauthorized and controversial taxi traffic by ride sharing service in the same manner as in other countries.
4. The Finnish Tax Administration says it is concerned that some drivers working for Uber may be avoiding paying taxes.
5. The Tax Administration stressed that it is not authorized to determine whether Uber's services conform to Finnish law, which requires taxi service providers to obtain a specific authorization for their business.
6. Uber clarified itself as not a taxi company. But it's illegal to operate a cab without a license. The Finnish police instructed citizens not to use illicit taxis and call the police emergency service if they spot any such taxi. The police are using surveillance, citizen reports, and even sting operations to crack down on the drivers. The police weekend long road side checkpoints intended to catch drunk drivers also caught several illicit taxis, many of whom were working for Uber.
7. The Helsinki Court has found a 23 year old man guilty of illegally operating as a taxi driver with Uber's ride-sharing service in Helsinki for three and half months. The man received a 25 day fine amounting to 150 euros and was ordered to surrender his ill-gotten gains estimated at 12,000 euros to the state.
8. Recently, The Ministry of Transport and Communications has proposed new legislation to reform the transport in Finland and among other things propose the small freight and passenger transport permitted without a license up to an annual turnover of 10,000 euros.

3.6. Uber adaption in countries/cities depending on growth rate and institutional elasticity

3.6.1. Scheme of adaption to institutional systems

By the preceding analyses, it can be postulated that the contrast of Uber's global expansion without and with legal battles can be attributed to its co-evolution or disengagement with the host institutions. Furthermore, this contrast can be subject to the velocity of Uber “invasion” (its growth rate) and institutional elasticity of the host. While rapid growth enhances functionality development level significantly, it allows insufficient time for the host to routinization resulting in it being unable to accomplish its self-propagation as demonstrated in Table 3. Non-elastic institutions apt to internal regulations protect vested interests of incumbent organizations as demonstrated in Fig. 8.

With an understanding that there exists a certain threshold resisting innovation (Oreg et al., 2015 [16]), Fig. 9 illustrates a scheme of adaption of Uber in institutional systems. Critical legal battles in Germany and France, for example, can be attributed to rapid growth in their non-elastic institutions, while the relatively mild state in Finland notwithstanding its non-elastic institutions can be attributed to Uber's steady growth. Active operation in Singapore and Saudi Arabia notwithstanding legality can be attributed to a co-evolution with their elastic institutions which induces Uber's rapid growth in these countries. Tokyo's steady operation notwithstanding possible illegality can be attributed to its institutional elasticity with demanding nature in matured competitive environment and Uber's steady growth.

Noteworthy is those countries/cities without legal battles have constructed co-evolutionary acclimatization system and harnessing the vigor of counterparts as a possible countermeasure to the trap in ICT advancement as reviewed in 3.2 (see Fig. 6). This system induces CCSD (Consolidated Challenge to Social Demand) that consolidates broader stakeholders including company, employer, user and government for social demands like traffic, employment, environment, aging and disabled issues.

3.6.2. Consequence of Uber-driven IDBM with and without CCSD

The contrast between countries/cities with and without legal battles can be attributed to with or without CCSD as demonstrated in Fig. 10. While the former develops co-evolutionary dynamism, the latter results in disengagement.

3.6.3. ICT-driven disruptive business model with consolidated challenge to social demand

Preceding analysis suggests that ICT-driven disruptive business models with a consolidated challenge to social demand (IDBM – CCSD) as illustrated in Fig. 11 would be decisive for resilient IDBM co-evolving with the institutional systems of the host (cities which introduce Uber: Uber introducing cities *UIC*).

Uber is encouraging vertical and horizontal integration in the car-hire sector thereby it is reducing vertical fragmentation within taxi companies on company, employers and drivers relationship. Also, it is integrating the sector horizontally. Uber is compiling a massive database of driver and rider behavior essential to price-setting and market-making functions thereby reducing horizontal fragmentation of the sector (Rogers, 2015 [18]) Thus, Uber can be recognized as incorporating the inherent potential of IDBM with CCSD.

Given such inherent potential, Uber's success in its global expansion depends on the optimization of timing, pace, and selection of the hosts with different social demands suitable enough to constructing co-evolutionary acclimatization.

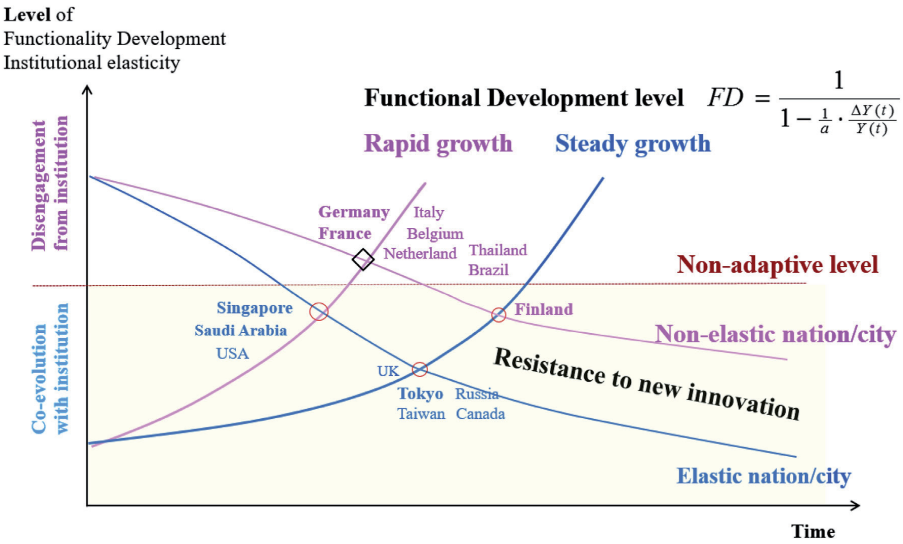


Fig. 9. Scheme of adaption of Uber in institutional systems.

Countries without legal battle

Uber induced CCSD leading to a co-evolution between ride-sharing revolution and advancement of the institutional systems.
Singapore: Induced incorporating user's requirements into the tripartism framework (company, employee, government) by stimulating social demand (transport, job, productivity).
Saudi Arabia: Enabled women's social participation by providing the reliable transportation leading to co-evolution.
Tokyo: Stimulated better service seeking competitive market broader stakeholder's involvement for social demand solution.

Countries with legal battle

Traditional quasi-monopolistic market protected by non-innovative government impeded Uber's revolution resulting in disengagement from the institutional systems.
Germany: Government non-innovative policy urging traditional legal requirements in response to traditional taxi companies' requirement to preserve existing profit securing system based on quasi-monopolistic market impeded Uber's disruptive innovation resulting in failing CCSD construction.

France, Italy follows the similar results.

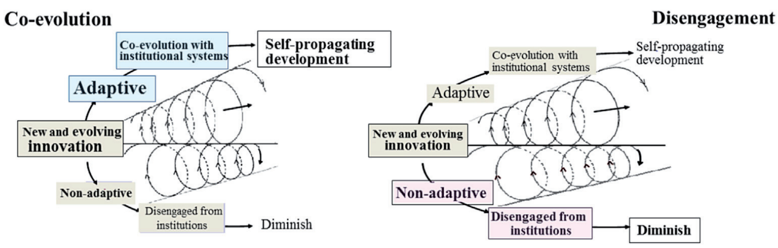


Fig. 10. Co-evolution and disengagement between Uber-driven IDBM and institutional systems.

4. Lessons from success model

4.1. Significance of shift to IDBM with CCSD

Nowadays, a key factor in obtaining business opportunity is the ability to solve social demand. A company to gain a profit must consolidate all stakeholders: company, employee, user, and government with respective heterogeneous objectives. Developing systems that address all stakeholders' demands in society as a whole can allow these disparate groups to successfully function

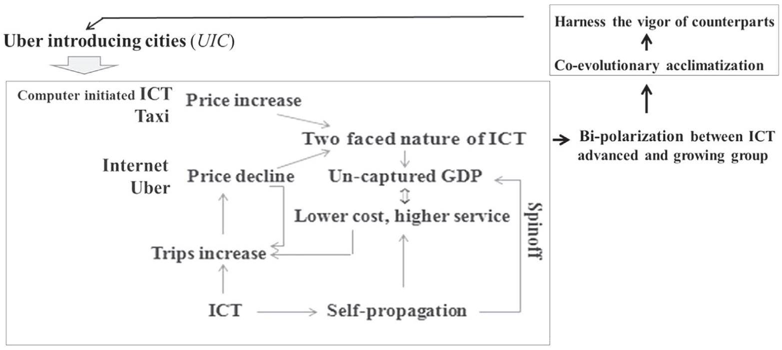


Fig. 11. Scheme for ICT-Driven disruptive business model with consolidated challenge to social demand (IDBM – CCSD).

together. In this process, the company can attain its profit seeking target as illustrated in Fig. 12.

The company that can attain such system success has the following required abilities:

(i) Penetration of the social demand that can be its business opportunity,
(ii) Organize and orchestrate all stakeholders, and
(iii) Attain the system success thereby gain profit.

Effective development and utilization of ICT enable such endeavors which up to now had no conception. This is the reason why Uber, the crown jewel of ICT can be recognized as incorporating inherent potential of IDBM with CCSD.

4.2. IDBM with CCDS in success model

Table 5 summarizes the structure of CCSD in success countries like Singapore, Saudi Arabia, and Tokyo. Singapore's success can largely be attributed to its tripartism framework consisting of Ministry of Manpower, National Trades Union Congress, and Singapore National Employers Federation, and based on trust among them. Uber enabled user's involvement in this framework thereby establishing the consolidation of all stakeholders as a company, employee, users and the government. Uber enjoys Singapore's well developed infrastructure and innovation seeking spirit. Thus, co-evolutionary acclimatization based on IDBM with CCSD has been established. Success in Saudi Arabia owed largely to Uber's contribution to women's social participation which inevitably consolidates broad stakeholders involved in education and industrial structure. Country's affluent financial base accelerates IDBM with CCSD. In Tokyo's case, while legal constraints are strong, nation's demanding nature and high potential demand with four times bigger market than NYC as well as matured competitive environment benefitted Uber to advance its business. Increasing demand in the aging society also accelerated unique IDBM with CCSD.

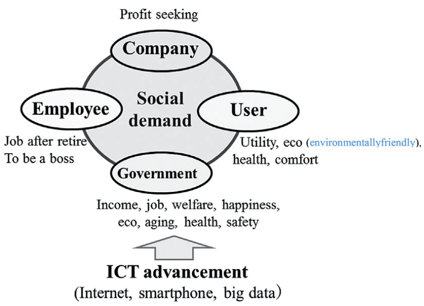


Fig. 12. Consolidated challenge to social demand.

4.3. Transformative role of co-evolutionary acclimatization

All success cases suggest the significance of CCSD through co-evolutionary acclimatization that creates IDBM with CCSD by harnessing the vigor of counterparts. The function of trust-based tripartism framework suggests the significance of ICT and trust toward IDBM with CCSD in the digitally-rich environment.

Koopman et al (2014 [12]). suggested that markets, competition, reputation systems, and ongoing innovation often solve problems better than regulation when we give them a chance to do so. Arvind et al (2014 [1]). suggested that platforms can be better than governments at spotting stalkers, running background checks on sharing service providers, and responding quickly to conflicts among members as platforms are closer to the action and they have an incentive to look after their communities. They also pointed out that the task is to share the pain and the wealth, and if this sharing happens, the wealth will grow and endure.

Cohen et al. (2014 [6]), by using agency theory, attempted to unveil the optimal relationship between service providers (agents) and the local governments (principals) to achieve the common objective of sustainable mobility. They claimed that the private rideshare operators had opted to avoid interaction with local governments resulted in legal action and other threats posed by local governments and taxi operators. They suggested that shared mobility service providers would be better served by finding ways to collaborate with local governments.

Posen (2015) [17] pointed out that the solution is not to force Uber to comply with outdated regulations; rather, regulators should rely on experimental regulations for safety, which will allow consumers to make their choice of which service they would like to use while ensuring their safety. Furthermore, by relying on the use of experimental regulations, regulators will be able to evaluate the effectiveness of the regulations as more information on these services becomes available. Experimental regulations of that nature will allow regulators to protect consumers and will allow consumers to have access to the services they want. Cusumano (2015)

Table 5
Structure in CCSD in success countries/cities.

	Consolidated challenge by all stakeholders	Social demand	Co-evolutionary acclimatization
Singapore	Tripartism framework User involvement Company, employee, user, government consolidation	Traffic service, Job opportunity, Overall productivity enhance, Digital innovation	Tripartism framework, Well developed infrastructure, Innovation seeking spirit
Saudi Arabia	Women (user, employee) Company involvement Government involvement	Women's social participation, Education, Industrial structure	Strong inertia to women's social participation, Affluent financial base
Tokyo	User welcome Company, employee concern Government involvement	Traffic service, ICT advancement, e-commerce, Depopulation, Aging society	High potential demand, Demanding nature, Matured competitive environment

[8] suggested that traditional enterprises should be able to provide more reliable, consistent, broader, and safer services than sharing-economy competitors.

All suggest the significance of the transformative role that co-evolutionary acclimatization plays.

Given that the key of Uber's system success can largely be attributed to the emergence of un-captured GDP driven by the discrepancy between taxi prices and magnitude of their decline effect derived from Uber[4] (Watanabe et al., 2016 [28]), how to transform this asset to hosts could be the fundamental question. We should note that co-evolutionary acclimatization dynamism incorporates this function as reviewed in Fig. 6.

A vicious cycle which ICT advanced economies suffer is in compensation for un-captured GDP emergence as illustrated in the center of Fig. 6. This un-captured GDP satisfies people's preferences shift to supra-functionality beyond economic value and plays a locomotive role for inducing further ICT advancement as illustrated in the right center of Fig. 6. While the further advancement of ICT accelerates to emerge un-captured GDP in ICT advanced economies, it is necessitated for sustainable GDP increase in ICT growing economies. However, they are running short of sufficient ability for this advancement. Therefore, upon appropriately transferred to ICT growing economies, transferred ICT may sufficiently contribute to increasing captured GDP in ICT growing economies which can be harnessed by ICT advanced economies for their balancing of captured and un-captured GDP as illustrated in the bottom of Fig. 6.

This illustration suggests that co-evolutionary acclimatization dynamism incorporates self-organizing ability in attaining optimal timing, pace, and selection of the host. Also, we should not overlook the transformative role that this system functions in transforming un-captured GDP (in ICT advanced economies) into captured GDP (in ICT growing economies) thereby enabling ICT advanced economies to maintain an optimal balance between captured and un-captured GDP as illustrated in Fig. 13.

Thus, we could conclude that triggering to activate latent self-organization ability that co-evolutionary acclimatization dynamism incorporates may provide the solution to Uber for its successful global expansion. This solution provides insightful suggestions for the trajectory management of the nations moving toward the era of IoT.

[4] The substance of this un-captured GDP can be summed up as follows (Watanabe et al., 2016 [28]):High-qualified services with lower cost and shorter time. An increasing initiative of passengers and the company's systematic market strategy of continuous deduction of costs and time in search and matching, eliminating information asymmetries and compiling a massive database.

5. Conclusion

In light of a question raised regarding the rationale of noting ICT-driven disruptive business model (IDBM) demonstrated by Uber the crown jewel of ICT, and given Uber's legal battles in a number of cities around the world as it rapidly expanded globally to over 479 cities worldwide, the institutional sources contrasting such success and failure were examined.

Aiming at elucidating these sources, focusing on the ICT's inherent function on which IDBM is based, comparative empirical analysis of Uber's global expansion was attempted.

Noteworthy findings include:

(i) Success or failure of Uber's global expansion can be attributed to its co-evolution or disengagement with host institutions,
(ii) This contrast can be subject to Uber's growth rate and institutional elasticity of the host,
(iii) Countries/cities without battles have constructed co-evolutionary acclimatization system and harnessed the vigor of counterparts,
(iv) This system induces CCSD (Consolidated Challenge to Social Demand) that consolidate the broad stakeholders including company, employer, user and government, based on trust among them, for social demands,
(v) Thus, IDBM with CCSD would be critical for resilient IDBM co-evolving with the institutional systems of the host,
(vi) Since Uber can be recognized as incorporating the inherent potential of IDBM with CCSD, its success in global expansion depends on the optimal balance of timing, pace, and selection of the host suitable enough to constructing a co-evolutionary acclimatization,
(vii) Transformative role incorporated in co-evolutionary acclimatization dynamism, upon functioning, may lead to this optimization, and
(viii) Therefore, triggering the activation of latent self-organization resources ability that co-evolutionary acclimatization incorporates may provide the solution to Uber for its successful global expansion.

These findings form the bases for the following suggestions supportive to sound development of worldwide IDBM:

(i) Careful and thorough consideration of IDBM development with CCSD,
(ii) The “quadpartism” framework enabling careful consultation among company, employee, user, and government,

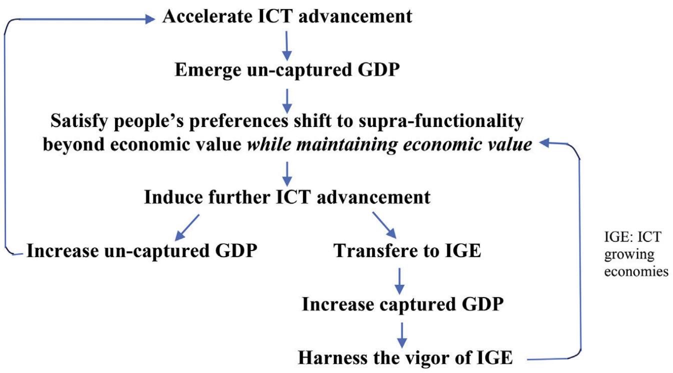


Fig. 13. Scheme of optimal dynamism for balancing captured and un-captured GDP.

(iii) Optimal balance between captured and un-captured GDP emergence,
(iv) Effective triggers activating the latent ability of self-organization incorporated in the co-evolutionary acclimatization system, and
(v) Instilling of the leading role of IDBM in solving social demands.

This analysis has explored a prototype of the analysis of IDBM for sound global expansion focusing on ICT inherent functions. A similar approach is expected to be undertaken for similar IDBM such as education, digital music, electric game, and printing/publishing.

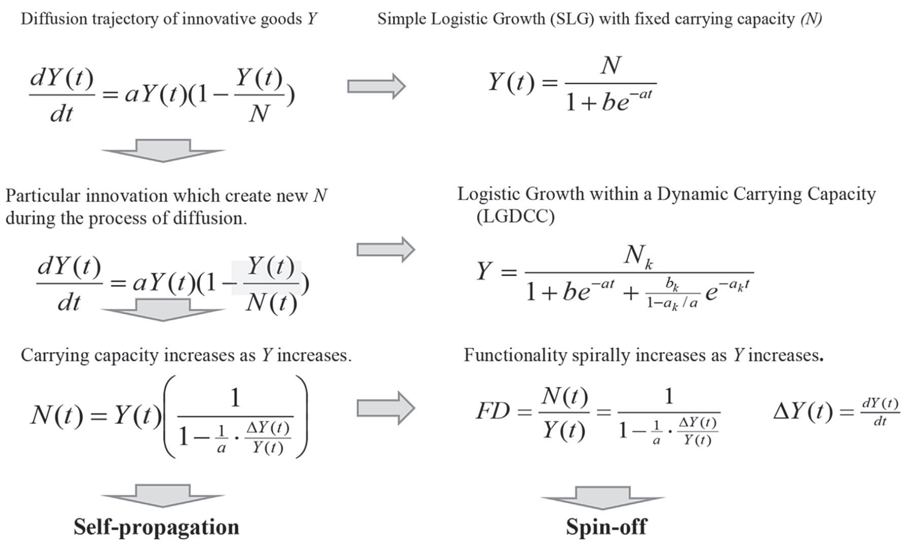
Given the significance of ICT and trust toward IDBM with CCSD in the digitally-rich environment, trust-based education toward digitally-rich learning environments would be particularly expected as a timely subject to undertake.

By doing the analysis of Uber, authors succeeded to project national level findings on un-captured GDP onto the business level. Further projection onto the user level should be explored. An empirical analysis of digital music may open an insightful path for this development.

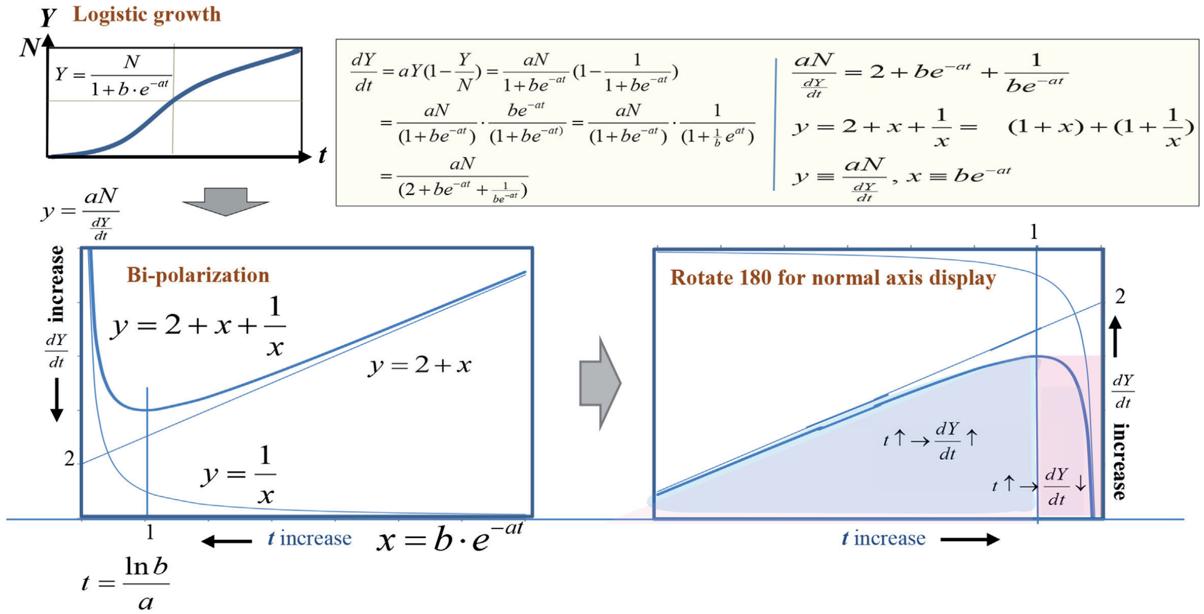
Acknowledgement

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement no: 293446 — Platform Value Now: Value capturing in the fast emerging platform ecosystems.

Appendix 1. Self-propagating nature of ICT leveraging spin-off



Appendix 2. Scheme of the bi-polarization fatality of logistic growth



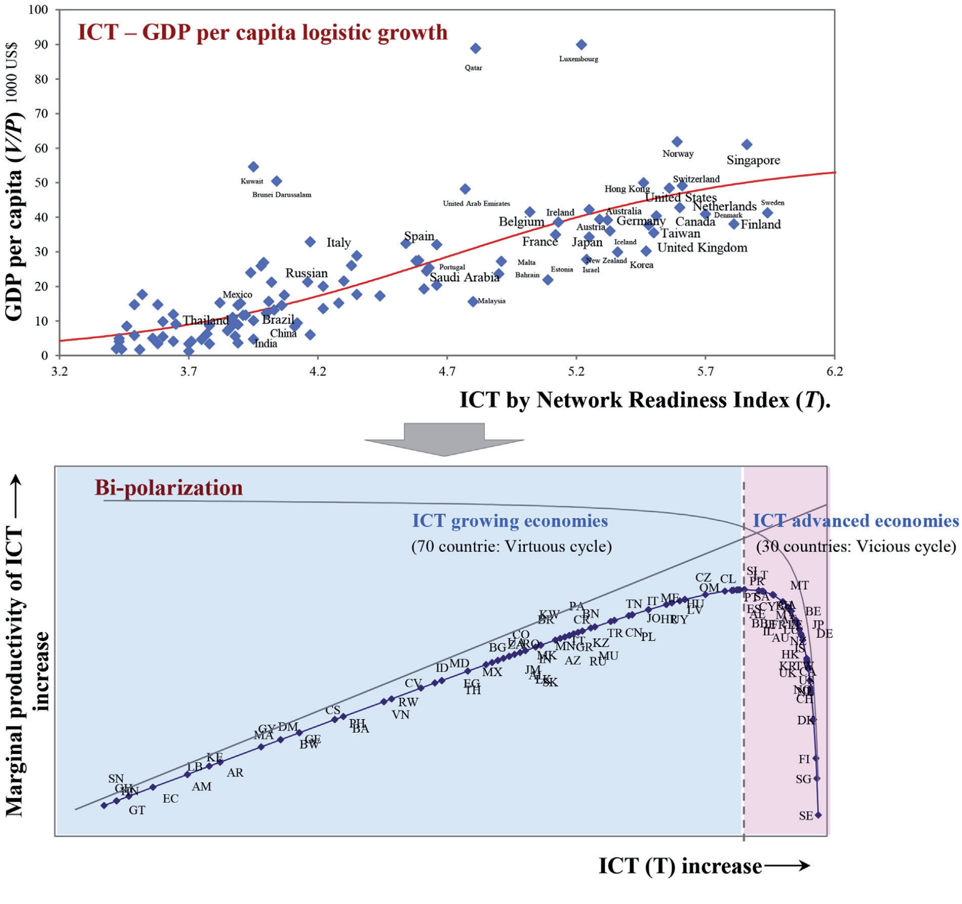
Appendix 3. ICT-driven logistic growth and its bi-polarization

(A Case of 100 Countries in 2011).

$$Y \equiv \frac{V}{P} = \frac{N}{1+b\cdot e^{-at}} + c\cdot D_1 + d\cdot D_2$$

N	a	b	c	d	adj R^2
57239 (9.62)	1.68 (7.58)	2697.28 (9.80)	46434 (14.54)	-12913 (-5.25)	0.885

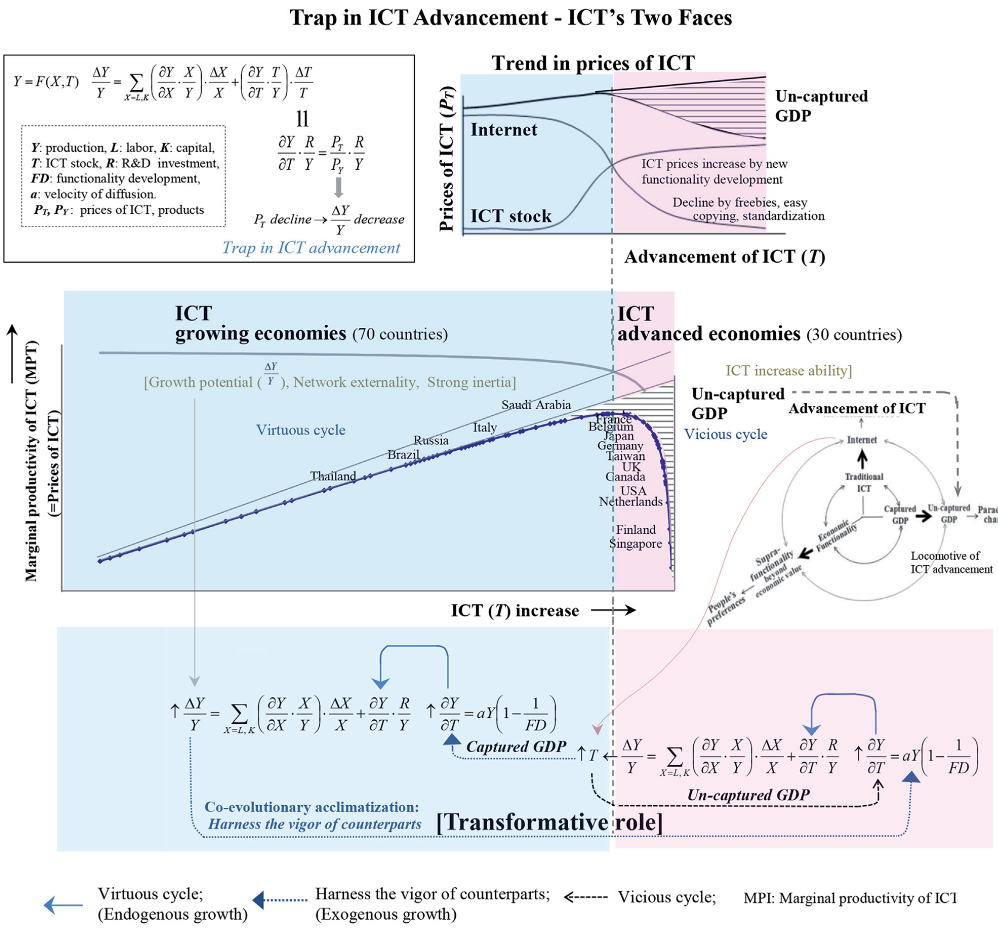
V: *GDP*, *P*: population, *N*: carrying capacity, *T*: ICT, D_1, D_2: dummy variables, *a*, *b*, *c*,,*d*: coefficients.
Figures in parenthesis indicate t-statistics: all significant at the 1% level.



ICT Ranking in 100 Countries (2011)

1.SE Sweden	6. NL Netherlands	11 TW Taiwan	16 DE Germany	21LU Luxembourg	26 MT Malta	34 SASaudi Arabia	65 BR Brazil
2. SG Singapore	7. NO Norway	12 KR Korea	17 AU Australia	22 BE Belgium	27BH Bahalan	38 ES Spain	69 IN India
3.FI Finland	8. US United State	13 HK Hong Kong	18 JP Japan	23 FR France	28 QA Qatar	48 IT Italy	72 ZA South Africa
4. DE Denmark	9. CA Canada	14 NZ New Zealand	19 AT Austria	24 EE Estonia	29 MY Malaysia	51 CN China	76 MX Mexico
5. CH Switzerland	10. UKUnitedKingdom	15 IS Iceland	20 IL Israel	25 IE Ireland	30 AE UAE	56 RU Russia	77 TH Thailand

Appendix 4. Transformative role of co-evolutionary acclimatization



References

[1] M. Arvind, V.A. Marshall, The dark side of the sharing economy and how to lighten it, Commun. ACM Assoc. Comput. Mach. 57 (11) (2014) 24–27.
[2] M.C. Becker, Handbook of Organizational Routines, Business & Economics, 2008.
[3] R. Belk, You are what you can access: sharing the collaborative consumption online, J. Bus. Res. 67 (2014) 1595–1600.
[4] B. Cannon, H. Chung, A framework for designing Co-regulation models well-adapted to technology-facilitated sharing economies, St. Clara High. Tech. LJ 31 (2015) 23–97.
[5] D. Cheng, Is sharing really Caring? A nuanced introduction to the peer economy, Policy Primer (2014) 1–28. October 2014.
[6] B. Cohen, J. Kietzmann, Ride on! Mobility business models for the sharing economy, Organ. Environ. 27 (3) (2014) 279–296.
[7] T. Cowen, The Great Stagnation, Dutton, New York, 2011.
[8] M.A. Cusumano, How traditional firms must compete in the sharing economy? Commun. ACM 58 (1) (2015) 32–34.
[9] J.P. Davis, K.M. Eisenhardt, C.B. Bingham, Optimal structure, market dynamism, and the strategy of simple rules, Adm. Sci. Q. 54 (2009) 1–89 (2009).
[10] European Commission, A European Agenda for the Collaborative Economy, 2 June 2016, European Commission Presentation, 2016.
[11] European Parliament, Social, economic and legal consequences of Uber and similar transportation network companies (TNCs), Eur. Parliam. Brief. (2015). October 2015.
[12] C. Koopman, M. Mitchell, A. Thierer, The sharing economy and consumer protection regulation: the case for policy change, 8 J. Bus. Entrepreneursh. Law (2014) 529–540, 2014–2015.
[13] E. Mastrorillo, Getting taken for a ride by Uber technologies incirporated, Sociol. Imagin. 5 (1) (2016) 1–9.
[14] K. Matzler, V. Veider, W. Kathan, Adapting to the sharing economy, MIT Sloan Manag. Rev. 56 (2) (2015) 71–77.
[15] P. Mella, C.M. Colombo, 2014. Endogenous innovation: when inner organizational dynamics afford and constrain change, Procedia Econ. Finance 8 (2014) 194–203.
[16] S. Oreg, J. Goldenberg, Resistance to Innovation – Its Sources and Manifestations, The University of Chicago Press, Chicago and London, 2015.
[17] H. Posen, Ridesharing in the sharing economy: should regulators impose Uber regulations on Uber? Iowa Kaw. Rev. 101 (2015) 405–433.
[18] B. Rogers, The Social Costs of Uber, 2015 vol.28, The University of Chicago Law

Review Dialogue, 2015, pp. 85–102.
[19] F. Rudmin, The consumer science of sharing, J. Assoc. Consumer Res. 1 (2) (2016) 198–209.
[20] S. Tokumasu, C. Watanabe, Institutional structure leading to the similarity and disparity in innovation inducement in EU 15 countries, J. Serv. Res. 8 (1) (2008) 5–42.
[21] T. Tyrväinen, Wage Determination, Taxes, and Employment: Evidence from Finland, Bank of Finland Studies, 1995, p. E:3.
[22] Warner, A. M., 2002. International Wage Determination and Globalization. Paper (revised) presented at the NBER Conference on Labor and the Global Economy.
[23] C. Watanabe, Innovation-consumption Co-emergence leads a resilience business, Innovation Supply Chain Manag. 7 (3) (2013) 92–104.
[24] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of it functionality development, Technol. Forecast. Soc. Change 71 (7) (2004) 723–750.
[25] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured GDP and growing anger of consumers, Technol. Soc. 41 (2015a) 21–44.
[26] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure – similarity and disparities between Finland and Singapore, Technol. Soc. 42 (2015b) 104–122.
[27] C. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, Operationalization of un-captured GDP: the innovation stream under new global mega-trends, Technol. Soc. 45 (2016) 58–77.
[28] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution of three mega-trends natures un-captured GDP: Uber's ride-sharing revolution, Technol. Soc. 46 (2016) 164–185.
[29] World Economic Forum (WEF), The Global Competitiveness Report 2015-2016, WEF, Geneva, 2015.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Research Professor of University of Jyväskylä, Finland, and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland.

Pekka Neittaanmäki graduated from the University of Jyväskylä in Mathematics and is currently Professor and a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland.

Brenda Fox graduated from the University of Waterloo, Canada with Bachelor degrees in Math and Computer Science. Currently CEO of Xevents Unlimited, Silicon Valley, USA and research contractor, International Institute for Applied Systems Analysis (IIASA).

PIX

CO-EVOLUTION BETWEEN TRUST IN TEACHERS AND HIGHER EDUCATION TOWARD DIGITALLY-RICH LEARNING ENVIRONMENTS

by

Chihiro Watanabe, Kashif Naveed and Pekka Neittaanmäki, 2017

Technology in Society, vol. 48, pp. 70-96

Technology in Society 48 (2017) 70–96

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Co-evolution between trust in teachers and higher education toward digitally-rich learning environments

Chihiro Watanabe [a, b, *], Kashif Naveed [a], Pekka Neittaanmäki [a]

[a] Faculty of Information Technology, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria

A R T I C L E   I N F O

Article history:
Received 23 August 2016
Received in revised form
24 November 2016
Accepted 28 November 2016
Available online 28 December 2016

Keywords:
Trust in teachers
Pedagogical love
Education productivity paradox
Digitally-rich learning environments
Blended learning
Un-captured GDP

A B S T R A C T

Based on a powerful notion that the quality of higher education is crucial for innovation in digital economy and that such quality is subject to a conception of trust in teachers to deliver good education and advancement of information and communication technology (ICT), the dynamism of co-evolution between them was analyzed.

Using a unique dataset representing the above system consisting of the rate of trust in teachers providing good education in the context of quality of education and their social status, of the level of higher education and the state of ICT advancement toward digitally-rich learning environments, an empirical numerical analysis of 20 countries was attempted. These countries were classified as *advanced*, *semi-advanced* and *growing*.

It was found that while ICT advanced countries have embarked on co-evolution of ICT, higher education and trust, ICT growing countries have not been successful in this due to a vicious cycle between ICT and trust. Finland's educational success can be attributed to co-evolution which corresponds to the emergence of un-captured GDP similarly to the leading edge of an ICT-driven disruptive business model. The paradox of education productivity in ICT growing countries can be attributed to disengagement.

It is suggested that steady ICT advancement fully utilizing external resources in digitally-rich learning environments may be essential to ICT growing countries in achieving higher education. On the other hand, continuing transcending innovation to transform learning environments into new digitally-rich learning environments should be maintained in ICT advanced countries.

A new approach for constructing the above-described co-evolution in a systematic way was thus explored.

1. Introduction

Good quality of higher education is crucial for economies that want to move up the value chain beyond simple production processes and products [36]. Since such quality is subject to trust in teachers for delivering good education [18,21,24,28] and advancement of information and communication technology (ICT) leading to digitally-rich learning environments [27], co-evolution between higher education, trust in teachers and advancement of ICT has been gaining increasing significance.

This paper aims to explore a new approach for constructing the above-mentioned co-evolution in a systematic way by using a unique dataset representing the above system consisting of the rate of trust in teachers to provide good education in the Global Teacher Status Index [28] that analyzes teacher's impact on educational performance [1], together with statistics on higher

* Corresponding author. Faculty of Information Technology, University of Jyväskylä, Finland.
E-mail addresses: watanabe.c.pqr@gmail.com (C. Watanabe), kanaveed@student.jyu.fi (K. Naveed), pekka.neittaanmaki@jyu.fi (P. Neittaanmäki).

http://dx.doi.org/10.1016/j.techsoc.2016.11.001
0160-791X/

[1] Aiming at identifying how the level of respect for teachers affects educational performance represented by such international comparative student assessment as PISA, VGF conducted a survey in 21 countries including the rating of "Trusting teachers to deliver a good education" (see Appendix 3). Given that trust in education consists of trust to a personality and also to system [13], this rate can be attributed to *trust to personality* and *trust to system* and the weights between them differ depending on the institution of respective countries examined. However, the objective of this analysis is to analyze the co-evolutional relationship between ICT, higher education and this value (whatever the weights of personality and system). In providing policy suggestions to each respective country analyzed, careful attention to the weights corresponding to respective countries would be paid.

education level [2] [36] and ICT advancement [3] [38], undertook an empirical numerical analysis of 20 countries in relation to this co-evolution dynamism.

While the rate of trust in teachers was focused on younger students corresponding to PISA assessors, given that the result of the assessment represents institutional states of teachers as well as educational system of the nation [4] (VGE, 2013) [24,25], analysis using the above data can be considered to provide reasonable insight corresponding to the primary objective.

The 20 countries examined were classified into 3 groups: ICT advanced countries (*IAC: Finland, Singapore, Netherlands, Switzerland, UK, USA, Korea, Germany, Israel, Japan*), ICT semi-advanced countries (*ISC: Portugal, Spain*), and ICT growing countries (*IGC: Czech Republic, Turkey, Italy, China, Brazil, Greece*).

Given the significant shift from traditional teaching practice to blended learning [5] toward digitally-rich innovative learning environments (DILE) and also the significant effect of the learners ability of "overdrawing" past information on trust [13], the state of the country in this shift has become crucial for its performance.

IAC have shifted to DILE and constructed a co-evolutionary dynamism between ICT, higher education and trust. This corresponds to emerging un-captured GDP as observed in the ICT-driven disruptive business model [33,35].

ISC are in transition from traditional teaching and learning environments to DILE and experiencing unsuccessful co-evolution due to a vicious cycle between ICT advancement and higher educational level enhancement.

IGC remain in traditional learning environments and suffer disengagement due to a mismatch between ICT advancement and trust in teachers.

These findings give rise to insightful suggestions to the respective countries concerning their successful co-evolution that depends on the state of their ICT advancement.

The paper is organized as follows: Section 2 reviews the significance of higher education in the progress towards digitally-rich learning environments. Section 3 analyzes co-evolutionary dynamism in those 20 countries. The structural source of the contrast of co-evolution and disengagement in the 20 countries is analyzed in Section 4. Section 5 briefly summarizes some noteworthy findings, implications, and suggestions for future works.

2. Trust-based higher education towards digitally-rich learning environments

While better educational outcomes are a strong predictor of economic growth, wealth and spending on education alone are not [17]. Finland demonstrates the world's most outstanding educational performance (e.g., [36,22]), but no single factor can explain that. Teachers' capacity to teach in classrooms and work collaboratively in professional communities has been systematically built through academic teacher education [21]. It has been pointed out that "pedagogical love," the relationship between students, teachers, parents and even educational administrators based on trust, may be the secret to Finland's educational success [24].

The importance of the concept of trust in the educational context has been increasingly recognized, and a growing body of literature supports the idea that trusting relationships between teachers and students are fundamentally important, both for the students' ability to learn and for effective teaching. With a trustful relationship, teachers can anticipate students' behavior and feel encouraged to actively participate in lessons without the fear of being compromised by the teacher [23]. Trust in the education environment provides students an opportunity to take initiative in their learning [3].

Contrary to these expectations, Varkey Gems Foundation (VGF) who conducted an international comparative survey on the Global Teacher Status Index claimed that "there is no correlation between trusting teachers and educational outcomes. For example, Brazil places the most trust in their teachers, yet has one of the lowest learning outcomes in the 21 countries surveyed" [24].

These contradictory attitudes can largely be attributed to the dramatic advancement of ICT that has significant impact on education environment [12,16,27] but also encounters some resistance [19].

Luhmann [13] defined trust in education as consisting of trust in personality and in the system as well. He postulated that trust is a consequence of "overdrawing" of past information, not only utilizing own previous experiences but also inference thereon, allowing the learners to minimize risk and uncertainty. This postulate suggests that while advancement of ICT may enhance higher education and trust in teachers by accelerating "overdrawing" of past information by means of ICT advancement, which leads to co-evolution between them, it may lessen the correlation between higher education and trust in teachers in case of a digital divide in the learning environment.

Despite teachers' resistance to the use of advanced technology in education, there has been an ICT-leveraged rapid increase in blended learning, and technology has increased the breadth and depth of access to education [4]. This is significant because it has been the hallmark of western education that co-location in time and space of teachers, students and resources is the *sine qua non* of education [12].

Learning environment as a broader setting than classroom, as the context in which learning is situated, has gained popularity. This environment consists of the physical and digital setting in which learners carry out their activities, and it includes all the tools, documents and other artefacts commonly found in that setting. Besides the physical and digital setting, also socio-cultural setting for ICT has become crucial in the innovative learning environment which should have the necessary technological, social and educational affordances to provide opportunities to learn [42].

In this innovative learning environment, teachers need to be adequately prepared to implement a state-of-the-art ICT curriculum. Programs of professional development for teachers are most effective if directed to the stage of ICT development reached by schools [1]. In this context, we note that a hybrid model that combines reinforcement learning with supervised learning outperforms a pure supervised learning model and a pure reinforcement learning model [9,14]. Cross-fertilization leads to new forms of learning which integrate aspects of both formal and informal learning. Learning and working processes become intertwined,

[2] Given the primary objective of the contribution of higher education to economies moving up the value chain beyond simple production processes and products, "higher education" encompasses secondary and tertiary enrollment rates as well as the quality of education as evaluated by business leaders. The extent of staff training is also taken into consideration because of the importance of vocational and continuous on-the-job training for ensuring constant upgrading of workers' skills ([36], see the details Table A6).

[3] Networked Readiness Index (NRI) measured by the [38] was used which measures worldwide advancement of ICT by computing the following four dimensions with ten pillars as indicated in parenthesis: (i) Environment (Political and regulatory environment, business and innovation environment), (ii) Readiness (Infrastructure, digital content, and affordability), (iii) Usage (Individual usage, business usage and government usage), and (iv) Impact (Economic impact and social impact).

[4] Cultural, political and economic factors and social standing play a role in the position of teachers in each country, and having an influence on how these might impact on education systems.

[5] Blended learning is a formal education program in which student learns at least in part through delivery of content and instruction via digital and online media with some element of student control over time, place, path, or pace (Wikipedia).

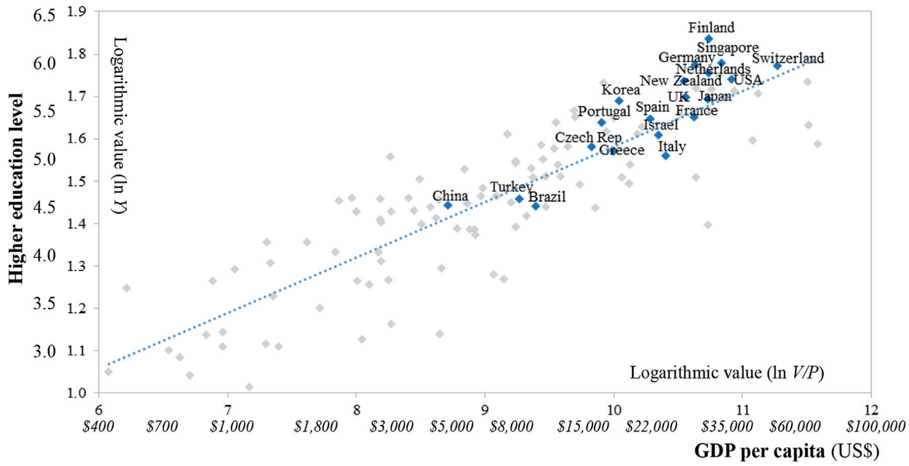


Fig. 1. Correlation between economic development and higher education level in 112 countries (2013).
Sources: [10,32].

thus benefiting from the strengths of both formal, school-based learning and real-life experience [11,42]. New and emerging technologies are provoking a re-conceptualization of teaching and learning [7].

Out of these trends, blended learning has emerged, reminding us of the significance of trust in teachers in providing good-quality blended learning as a hybrid model in an innovative learning environment.

However, despite the clear demonstration of the benefits of using technology in education, there continues to be a marked reluctance among academics to engage with online education [1]. It was revealed that teachers were much less positive than their students about the learning benefits of an online learning component [8]. Teachers' status can easily be eroded, as learners can compare teacher-designed resources with video lectures across the world on similar topics and chat directly with experts in the field through their blogs [6]. The potential for such comparisons often made teachers fear possible exposure to ridicule or unflattering comparisons [12]. Some teachers claim that technology has no beneficial effect on learning and is even instrumental in maintaining students in a state of semi-disengagement [8]. Teachers who fail to recognize the benefits of online learning are less likely to create effective blended courses [12]. In addition, many educators share experiences of students who are apathetic, and unwilling to engage in the learning experience, ultimately failing. These students have learned to withdraw from the classroom as a defense [3].

Peslak [20], utilizing the US annual survey of computers, ICT and other technology, as well as library resources, in 2000–2001 assessed their contribution to educational test scores and revealed that ICT factors do not show consistent, positive relationships with higher educational scores. As one possible reason for this educational productivity paradox he saw that more time was spent with computers than with actual education and learning activities.

These contradictions in positive and negative aspects of blended learning can be attributed to distinct phases of ICT development in the innovative learning environment. UNESCO's Institute for Information Technology has evaluated the degree to which ICT has been integrated in an educational system, by distinguishing four distinct stages: (i) emerging, (ii) applying, (iii) infusing, and (iv) transforming [27]. These stages offer us a lens through which we can observe how ICT has leveraged incremental and deep change in learning environments.

Faced with digitally-rich learning environments and in order to effectively utilize this potential for higher education, the key task for a nation is to find how to smoothly shift from traditional teaching practice to blended learning. One way to do this is by realizing the distinct stages of ICT integration in an education system.

Conflicts in a system generally emerge in the transitions between these stages before the transformation stage is reached. Success in transformation largely depends on the rigidity or flexibility of the school curriculum [7], which is strongly influenced by cultural, societal and institutional factors [1]. Therefore, optimal balance between ICT and older educational technologies reflecting national and regional cultures is the key component of the organization's strategy [1,27].

The foregoing review highlights the increasing orientation of trust-based higher education towards digitally-rich learning environments and elastic institutional system, enabling smooth transformation from traditional teaching practice to blended learning. However, no-one has analyzed the co-evolutionary dynamism between trust in teachers and higher education enabled by ICT advancement and a possible fear of disengagement in the transition phase considered as the fundamental source of the problem.

3. Co-evolutionary dynamism between trust in teachers, higher education and ICT advancement

3.1. ICT-driven education development

Dramatic advancement of the Internet beyond anticipation in terms of its diffusion speed and scope has led to ICT-driven economic development worldwide. Consequently, the economic development (e.g., GDP per capita) trajectory of 120 nations (see Appendix 1) can be depicted by a logistic growth function initiated by the advancement of ICT [41].

Given the strong correlation between economic development

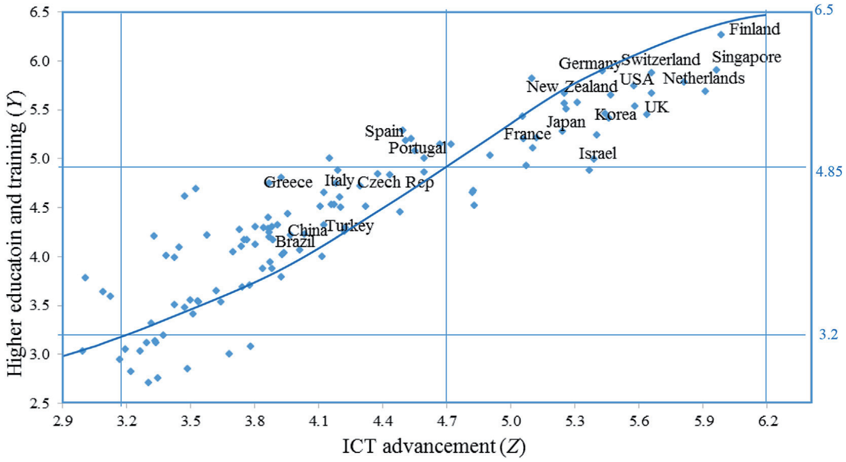


Fig. 2. ICT-driven education development in 120 countries (2013).
Sources: [32,34].

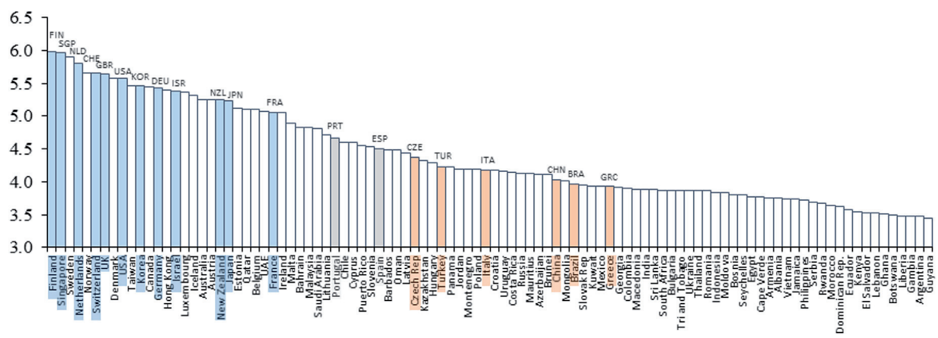


Fig. 3. Level of ICT advancement by NRI in 100 countries (2013).
Source: [34].

and enhancemed higher education level as demonstrated in Fig. 1, the contribution of ICT advancement to the risen education level can be depicted by a logistic growth function as demonstrated in the sigmoid curve in Fig. 2 (see Appendix 4).

$$\ln Y = 0.289 + 0.131 \ln \frac{V}{P}$$
$$(5.55) \quad (23.19) \quad \boldsymbol{adj.R^2} = \mathbf{0.830}$$

Y: Higher education level, *V/P*: GDP per capita, ICT top 120 countries excluding 8 countries with non-standardized performance, namely Luxembourg, Kuwait, Egypt, Botswana, Paraguay, Pakistan, Namibia, Suriname.

The countries named are the 20 selected countries [6]

The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

3.2. The stage of ICT advancement

Thus, advancement of ICT plays a significant role in enhancing education levels worldwide.

With such understanding in mind, Fig. 3 compares the advancement of ICT in 100 countries.

On the basis of global ICT advancement and its contribution to enhancing higher education together with trust in teachers, this paper focuses on the analysis of co-evolutionary dynamism between trust in teachers and higher education enabled by ICT advancement. We consider 20 countries for which reliable trust in teachers data is available (see Appendix 3).

Fig. 4 focuses on comparison of the level of ICT advancement in 20 countries by taking the average of NRI between 2012 and 2015 (see Appendix 1).

Looking at Fig. 4, we notice that the countries by their state of

[6] Based on the criteria introduced by Global Teacher Status Index [28] as representing each major continent and also different strands of educational systems (see Appendix 3).

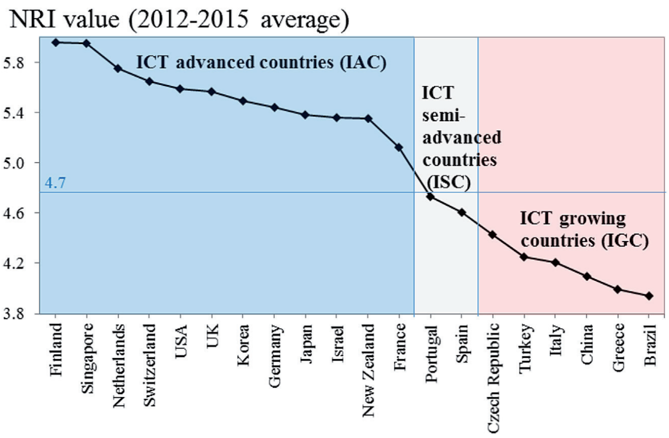


Fig. 4. Level of ICT advancement by NRI in 20 countries (2012–2015 average).
Source: [34].

ICT advancement in the world can be classified into ICT advanced countries (*IAC*), ICT semi-advanced countries (*ISC*), and ICT growing countries (*IGC*) as follows:

> ***IAC***: Finland, Singapore, Netherlands, Switzerland, USA, UK, Korea, Germany, Japan, Israel, New Zealand and France;
> ***ISC***: Portugal and Spain;
> ***IGC***: Chez Republic, Turkey, Italy, China, Greece and Brazil.

Given the significant role of ICT advancement in enhancing higher education level, as reviewed earlier, these states play a decisive role in education: for example, blended learning has played a significant role in enhancing education, and dependency on this learning corresponds to the state of ICT advancement [27,7].

Fig. 5 compares the level of higher education among 20 countries.

Fig. 6 compares the degree of trust in teachers among 20 countries.

With a hypothetical understanding that successful shift from traditional teaching practice to blended learning and toward digitally-rich learning environments can largely be attributed to co-evolutionary dynamics between ICT advancement, higher education and trust in teachers [31,32], this co-evolution in 20 countries is analyzed. Tables A3-5 compare the advancement of ICT, higher education level, and trust in teachers among 20 countries. Table A6 demonstrates the composition of higher education level.

3.3. *Co-evolutionary advancement between trust in teachers and higher education*

Utilizing the foregoing data, co-evolution between advancement of teachers and higher education level in 20 countries was analyzed by dividing them into 12 ICT advanced countries (*IAC*), 2 ICT semi-advanced countries (*ISC*) and 6 ICT growing countries (*IGC*). The result of the analysis is illustrated in Fig. 7. We note that, contrary to Varkey Gems Foundation's observation that "There is no correlation between trusting teachers and educational outcomes" (VGF, 2014), there are strong correlations between them depending on the state of ICT advancement. While higher education level depends on trust in teachers in *IAC* and *ISC*, this correlation is opposite to that in *IGC*. In *IGC*, it is anticipated that trust in teachers spoils students' education, declining their higher educational level. (For detailed explanation of the analysis see Appendix 5).

$$\ln Y = \underset{(3.47)}{0.811} + \underset{(3.92)}{0.504}D_1 \ln X + \underset{(3.54)}{0.436}D_2 \ln X - \underset{(-3.07)}{0.874}D_3 \ln X + \underset{(4.01)}{2.329}D_3 \qquad \boldsymbol{adj.R^2 = 0.872}$$

D_1, D_2, D_3: Coefficient dummy variables corresponding to IAC, ISC and IGC, respectively.

The *figures* in parenthesis indicate *t*-statistics: all are significant at the 1% level.

Inspired by these observations, Fig. 8 analyzes the effects of the higher education level on increasing trust in teachers. Fig. 8 demonstrates that while higher education demonstrates a positive correlation with trust in teachers in *IAC* and *ISC*, it shows an opposite effect in *IGC*: that is, while higher education stimulates trust in teachers in *IAC* and *ISC*, it results in decreasing the trust in *IGC*.

$$\ln X = -0.631 + 1.406D_1 \ln Y + 1.545D_2 \ln Y - 0.815D_3 \ln Y + 3.726D_3 + 0.114D$$
$$(-1.51)^{\#} \quad (5.86) \quad (6.07) \quad (-2.58)* \quad (5.89) \quad (2.85) \quad \boldsymbol{adj.R^2 = 0.707}$$

D: Dummy variables (France, UK = 1, others = 0).

The figures in parenthesis indicate t-statistics: all are significant at the 1% level, except * and # at the 2% and 15% level, respectively.

Fig. 9 demonstrates the result of the analysis of the correlation between ICT advancement and trust in teachers in 20 countries classified by ICT advancement state.

$$\ln X = 4.177 + 0.524D_1 \ln Z - 1.490D_2 \ln Z - 1.613D_3 \ln Z - 3.216D_1 - 0.169D$$
$$(7.82) \quad (2.50)** \quad (-4.24) \quad (-4.28) \quad (-5.24) \quad (-7.82) \quad \boldsymbol{adj.R^2 = 0.848}$$

D: Dummy variables (Japan, Israel, Czech Rep., Korea = 1, others = 0).

The figures in parenthesis indicate t-statistics: all are significant at the 1% level, except ** at the 3% level.

These analyses in Figs. 7 and 8 demonstrate that increase in trust in teachers stimulates higher education, which in turn induces trust in teachers leading to co-evolution between them in *IAC* and *ISC*, whereas in *IGC* both disengage, resulting in a vicious cycle.

3.4. Co-evolutional advancement between ICT and trust in teachers

Inspired by the foregoing findings on the co-evolution between trust in teachers and higher education in *IAC* and *ISC*, and their disengagement in *IGC*, correlation between ICT advancement and trust in teachers was analyzed next.

Fig. 9 shows that while advancement of ICT induces increase in trust in teachers in *IAC*, in line with the Luhmann's postulate [13], it demonstrates the opposite effect not only in *IGC* but also in *ISC*. Advancement of ICT contributes to the increase in trust in teachers in *IAC* as generally anticipated in case of digitally-rich learning

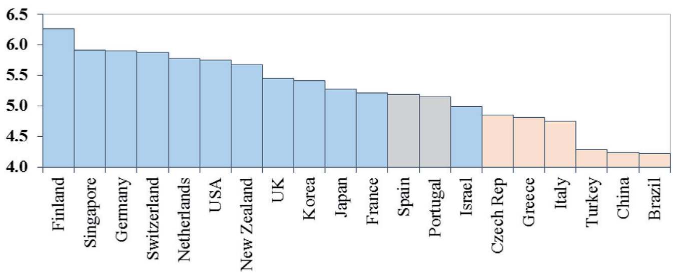


Fig. 5. Level of higher education in 20 countries (2013).
Source: [32].

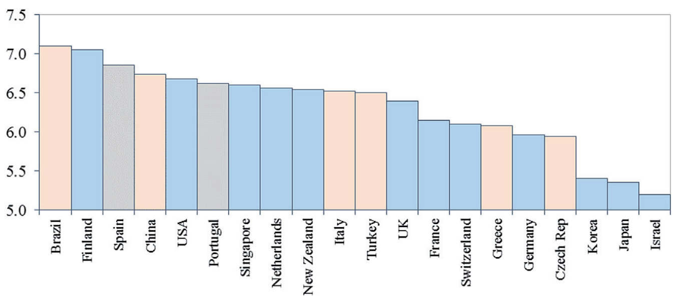


Fig. 6. Level of trust in teachers to deliver a good education in 20 countries (2013).
Source: [25].

environments. It is surprising to see that advancement of ICT has the effect of losing trust in teachers, not only in *IGC* but also in *ISC*.

$$\begin{array}{l} \ln Z = 2.535 + 0.360D_1 \ln X - 0.530D_2 \ln X - 0.591D_3 \ln X - 1.461D_1 - 0.099D \\ \qquad (10.03) \quad (5.98) \quad (-4.00) \quad (-4.38) \quad (-5.25) \quad (-7.76) \quad \boldsymbol{adj.R^2 = 0.982} \end{array}$$

Inspired by such surprising observation, Fig. 10 analyzes the effect of trust in teachers on ICT advancement.

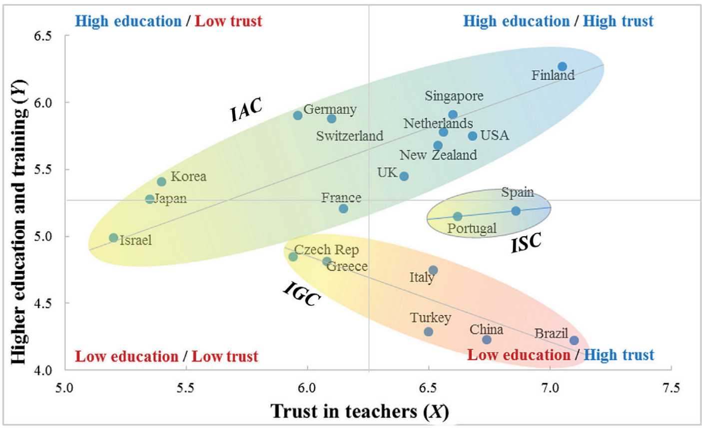


Fig. 7. Correlation between trust in teachers and higher education level in 20 countries (2013).

$$\ln Y = \alpha + \sum_{i=1}^{3} [\beta_i D_i] \ln X \quad i = 1 \; for \; \boldsymbol{IAC} \; (others = 0), i = 2 \; for \; \boldsymbol{ISC} \; (others = 0), i = 3 \; for \; \boldsymbol{IGC} \; (others = 0).$$

Sources: [25,32].

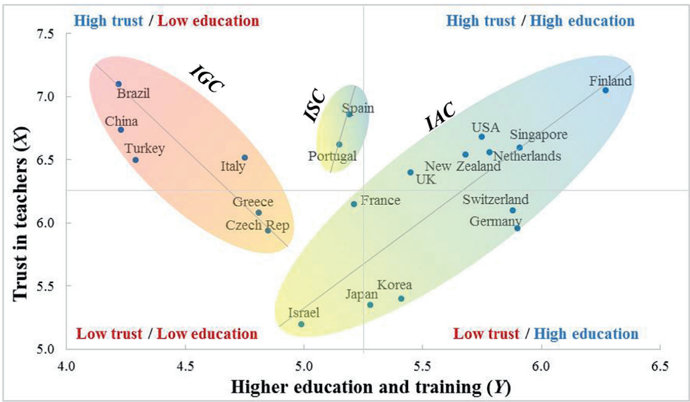


Fig. 8. Correlation between higher education level and trust in teachers in 20 countries (2013).

$$\ln X = \alpha + \sum_{i=1}^{3} [\beta_i D_i] \ln Y \quad i = 1 \; for \; \boldsymbol{IAC} \; (others = 0), i = 2 \; for \; \boldsymbol{ISC} \; (others = 0), i = 3 \; for \; \boldsymbol{IGC} \; (others = 0).$$

Sources: [25,32].

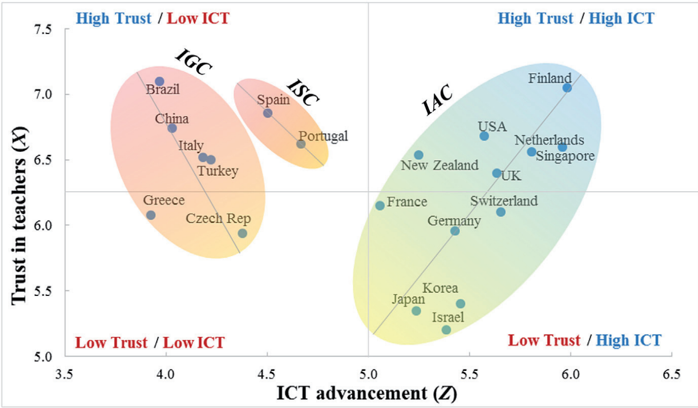


Fig. 9. Correlation between ICT advancement and trust in teachers in 20 countries (2013).

$$\ln X = \alpha + \sum_{i=1}^{3}[\beta_i D_i]\ln Z \quad i = 1\ for\ \textbf{IAC}\ (others = 0), i = 2\ for\ \textbf{ISC}\ (others = 0), i = 3\ for\ \textbf{IGC}\ (others = 0).$$

Sources: [25,34].

D: Dummy variables (France, New Zealand, Greece = 1, others = 0).

The figures in parenthesis indicate t-statistics: all are significant at the 1% level

Fig. 10 demonstrates a positive correlation between trust in teachers and ICT advancement also in *IAC*; as in Fig. 9, it changed to negative in *ISC* and *IGC*.

These analyses in Figs. 9 and 10 demonstrate co-evolution between ICT advancement and trust in teachers in *IAC* similar to its co-evolution between trust in teachers and higher education. The effect is opposite in case of *IGC*, similar to its disengagement in the earlier correlation. In case of *ISC*, contrary to its co-evolution between trust in teachers and higher education, it changed to disengagement in case of the correlation between ICT advancement and trust in teachers. This unexpected contrast in *ISC* between co-evolution of trust and higher education, on one hand, and disengagement of ICT advancement and trust in *ISC*, on the other, suggests a possible system conflict in the transition of distinct phases of ICT advancement toward digitally-rich learning environments.

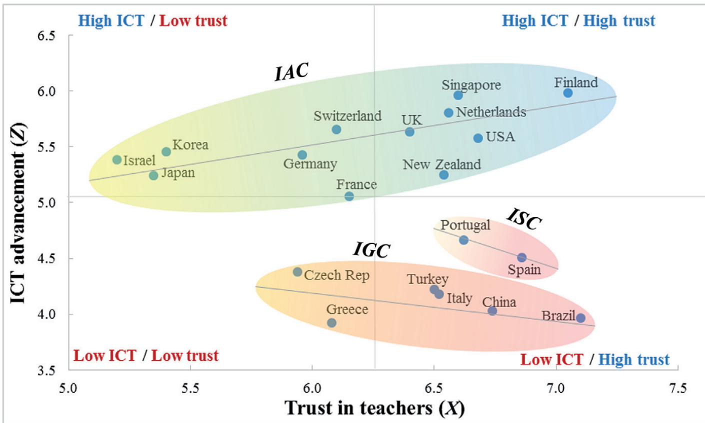
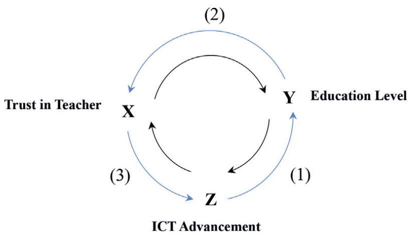


Fig. 10. Correlation between trust in teachers and ICT advancement in 20 countries (2013).

$$\ln Z = \alpha + \sum_{i=1}^{3}[\beta_i D_i]\ln X \quad i = 1\ for\ \textbf{IAC}\ (others = 0), i = 2\ for\ \textbf{ISC}\ (others = 0), i = 3\ for\ \textbf{IGC}\ (others = 0).$$

Sources: [25,34].



	ICT advanced countries (*IAC*)	ICT semi-advanced countries (*ISC*)	ICT growing countries (*IGC*)
(1) Z and Y	+	+	+
(2) Y and X	+	+	-
(3) X and Z	+	-	-

Fig. 11. Co-evolution and disengagement between ICT, educational level, and trust in teachers in 20 countries depending on ICT advancement.
+ : co-evolution (virtuous cycle), − : disengagement (vicious cycle).

3.5. Co-evolution and disengagement between ICT, education level, and trust in teachers

On the basis of the foregoing analyses, co-evolution and disengagement between ICT advancement (Z), higher education level (Y) and trust in teachers (X) in *IAC*, *ISC* and *IGC* can be summarized as illustrated in Fig. 11.

As summarized in Fig. 11, while correlation between ICT advancement and higher education was demonstrated in co-evolution of all *IAC*, *ISC* and *IGC*, correlation between higher education and trust demonstrates contrast between co-evolution in *IAC* and *ISC*, and disengagement in *IGC*. Similarly, correlation between trust and ICT advancement demonstrates contrast between co-evolution in *IAC* and disengagement in *ISC* and *IGC*.

4. Structural source of the contrast of co-evolution and disengagement between ICT, education level, and trust in teachers

Inspired by the preceding findings with respect to contrasting co-evolution and disengagement depending on the ICT development state [5], its structural source was analyzed.

4.1. Logistic growth in ICT-driven higher education and its bi-polarization

(1) bi-polarization fatality of logistic growth

As illustrated in Fig. 2, advancement of ICT contributes to enhancement of higher education level in line with a following logistic growth function:where Y: Higher education level, N: Upper limit (carrying capacity), Z: ICT advancement, a: velocity of diffusion, and b: initial state of education level.

This logistic growth results in a bi-polarization as illustrated in Fig. 13 [26,29,30,41]; see the details of this dynamism in Appendix 5).

The figure indicates that, while *marginal inducement of ICT through higher education enhancement* (dZ/dY) increases as ICT advances ($(dZ/dY)/dZ > 0$) when ICT advancement level exceeds a certain threshold, inflection point ($Z > \ln b/a$), it decreases when ICT advancement level remains lower than this threshold ($Z < \ln b/a$). This contrasting behavior between a virtuous cycle [7] and a vicious cycle as a consequence of a bi-polarization may play a decisive role in contrasting co-evolution and disengagement between ICT advancement, higher education and trust in teachers depending on the state of ICT advancement [34].

(2) Stages of ICT integration in education

According to the UNESCO's Institute for Information Technology has, the degree to which ICT has been integrated in an educational system can be described by four distinct stages: (i) emerging, (ii) applying, (iii) infusing, and (iv) transforming [27], as illustrated in Fig. 14. These stages offer us a lens through which we can observe how ICT has leveraged the incremental and deep change in learning environments (Groff, 2013) and provide us a reasonable explanation of the foregoing bi-polarization behavior.

The first three stages represent learning environments using ICT as a means to solely move toward more digitally-rich learning environments [7]. During these stages, *marginal productivity of ICT in enhancing higher education* (dY/dZ) increases as such use of ICT advances in the way that is generally anticipated [8]. However, the required ICT advances corresponding to ICT-driven new services cannot be afforded by such ICT use. This results in a vicious cycle: *marginal inducement of ICT* (dZ/dY) declines as the ICT use continues as illustrated on the left of Fig. 13.

Learning environments that seek a more holistic change and dramatically overhaul the existing environments have leveraged ICT to complete the process leading to the fourth stage, the transformation through ICT. At this stage, ICT is not used as a lever for advancing toward more digitally-rich learning environments but to transform learning environments into digitally-rich new environments [7]. Such new environments can absorb and effectively apply ICT-driven new services to higher education, which hitherto they could not afford. Therefore, in this transforming stage, *marginal productivity of ICT in enhancing higher education* (dY/dZ) declines as ICT advances in its initial stage, and absorption and application of new services cannot be afforded. However, strong desire to enhance higher education in digitally-rich learning environments induces transcending innovation to transform learning environments into digitally-rich new learning environments that can absorb and effectively apply ICT-driven new services to higher education [9].

This desire leads to a virtuous cycle between ICT advancement and *marginal inducement of ICT through higher education enhancement* (dZ/dY) as illustrated on the right of Fig. 13. This virtuous cycle enables absorption and application of ICT-driven new services to higher education, which hitherto could not be afforded, by leveraging ICT to transform learning environments into digitally-rich new learning environments. This behavior corresponds to the

[7] Virtuous cycle depends on ICT's contribution to “overdrawing” of past information for trust increase (see Appendix 5).

[8] Advances of ICT toward more digitally-rich learning environments generally contribute to enhanced rewards via the use of ICT for education by increasing new functionality development. Given that schools seek to maximize profits in competitive learning environments, marginal productivity of ICT corresponds to the relative price of ICT in education enhancement (see the detail in Appendix 5).

[9] Transcending innovation *transforms learning environments into digitally-rich new learning environments which can absorb and effectively apply ICT-driven new services to higher education* while also increasing trust. This function is equivalent to co-evolutionary acclimatization through harnessing the vigor of counterparts for maintaining a virtuous cycle in the ICT advanced environments [30]. In this case, it can be said that “to harness the vigor of time” as trust depends on "overdrawing" of past information [13].

Table 1
Learning environments by stages of ICT integration in education.

Learning Environments / Stage	Emerging	Applying	Infusing	Transforming
Vision	Limited, pragmatic, dominated by interested individuals	Driven by ICT specialists	Driven-by subject specialists	Entire learning community involved
Learning pedagogy	Teacher-centered	Teacher-centered; ICTs are a separate subject	Learner-centered; Collaborative	Critical thinking; Preferred learning styles; Collaborative, experimental
Development plan and policies	Accidental, restrictive, no planned funding	Limited; Centralized policies	Individual subject plans for ICTs; Permissive policies	ICTs are integral to overall school development plan (budget, professional development)
Facilities and resources	Limited and non-current digital resources; Restricted access	Diverse and varying in model, platform; Aligned with specific content and pedagogies	Diffused access to various digital resources; Support to implement these in various ways	Whole school learning and diverse learning environments; Web- based learning spaces, distance education, student self- management software
Understanding of curriculum	ICT literacy; Responsibility of individual teachers	Use of software and applications in discrete subjects (isolated)	Integrated; Resource-based learning, problem-solving project methodology	Virtual and real time contexts, modeling; Integrated curriculum delivery via the Web
Professional development	Individual interest	Training on ICT application; Involvement	Subject-specific; evolving	Integrated learning community; Innovative; Self- managed, personal vision and plan
Community	Accidental	Some parental and community involvement	Subject-based community, providing occasional guidance; Global and local networked communities	Broad-based learning community; Involving families, business, industry, organizations, universities, etc.; School as a learning resource for the community
Assessment	Responsibility of an individual teacher; Didactic; Paper-and-pencil based	Teacher-centered; Subject-focused	Learner-centered; Subject-oriented; Integrated; Multiple media to demonstrate alignment	Continuous; Holistic, open-ended, project- based; Learning community involvement

Source: [7] based on Center for Research on Lifelong Learning (2009).

Table 2
Transformative innovations for digitally-rich innovative learning environments.

First-order innovations	Second-order innovations
blogs, wikis	augmented reality (AR)
social networking sites	simulations
virtual learning environments (VLE)	digital games
laptops, netbooks and tablet PCs	console games
interactive whiteboards	remote-response systems
Web apps	mobile/handheld computing
digital cameras, scanners, projectors	programming applications
e-learning	pico projectors
digital portfolios	electronic books

Source: [7].

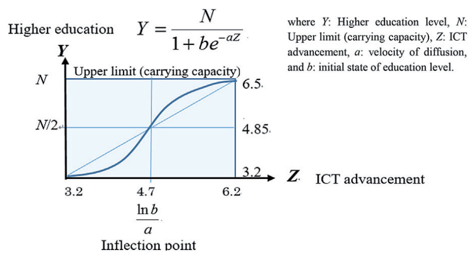


Fig. 12. Logistic growth function for ICT-driven higher education in 120 countries (2013).

emergence of un-captured GDP [10] as observed in the forefront of ICT-driven disruptive business model (IDBM) [33].

Foregoing review demonstrates the significance of stages of ICT integration in education in identifying the contrasting state of nation's ICT-driven higher education trajectory.

With such understanding, Table 1 summarizes a matrix of key features in respective learning environments by stages of ICT integration in education. A given learning environment or education system can be mapped onto this matrix by being evaluated on various dimensions, such as content, pedagogy, curriculum, etc. [7].

Table 1 demonstrates that the state of the Internet access as well as quality of education system and management system are particularly decisive in shifting from the first three stages to the fourth stage, the transformation through ICT.

With such identification, Fig. 15 identifies the state of transformation through ICT in 20 countries by correlating ICT advancement by *NRI* and Internet access in schools [11] On the basis of the collation of scores of governing factors of *NRI* (see Table A6) and with the key features of the stages of ICT integration in education featured in Table 1, Fig. 15 also identifies the stages of ICT integration in education in 20 countries.

Fig. 15 demonstrates that ICT advanced countries (*IAC*) have been moved to the transformation stage while ICT semi-advanced countries (*ISC*) and ICT growing countries (*IGC*) have still remained in the emerging, applying and infusing stages, thus providing support to the preceding analysis.

Table 2 demonstrates the locomotives of such transformative innovation which trigger un-captured GDP emergence.

Currently, first-order innovations are prevalent among many

[10] Un-captured GDP can be defined as added value providing for people utility and happiness beyond economic value. However, it cannot be measured by traditional GDP accounting that measures economic value [30].

[11] Internet access in schools is one of the key component of higher education and training level as demonstrated in Table A6. This table also demonstrates the significance of the quality of education system and also the ability of education management at a higher education level.

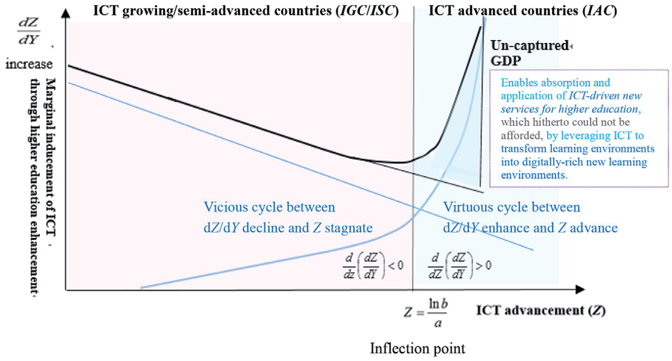


Fig. 13. Bi-polarization of ICT-driven higher education.

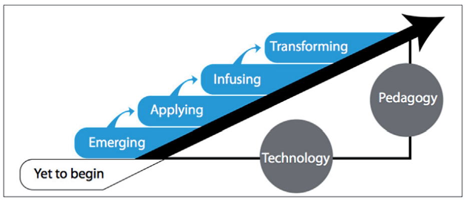


Fig. 14. Stages of ICT integration in education.
Source: [7] based on [1].

technology-rich learning environments, being implemented under the notion that by leveraging many of these tools together produces a dramatically different educational climate. Second-order innovations are more disruptive but essential to the emergence of un-captured GDP. They appear on the periphery of the educational landscape and are just beginning to see their full potential. These innovations are slowly gaining attention and traction at the forefront of digitally-rich learning environments and will likely see increased development and application over the next decade [7]. Furthermore, they are expected to accelerate the creation of ICT-driven disruptive business models and the emergence of subsequent un-captured GDP.

4.2. ICT elasticity to trust in teachers and to higher education

bi-polarization fatality of logistic growth suggests contrasting behavior among 20 countries depending on their state of ICT advancement. Furthermore, given that the inflection point that distinguishes contrasting trajectories also distinguishes higher education level as illustrated in Fig. 12, the trajectories of those 20 countries can be identified by the matrix classified by the thresholds governed by the inflection point.

With this understanding, ICT elasticity to trust in teachers [12]and also ICT elasticity to higher education in the 20 countries were classified with the foregoing matrix depending on their state of ICT advancement (see the details in Appendix 5).

(1) ICT elasticity to trust in teachers

On the basis of the identification of the positions of the 20 countries in digitally-rich learning environments with bi-polarization, the peculiar behavior of *ISC* in a transition from *IGC* to *IAC* indicates that, against our expectation, trust in teachers decreases as ICT advances.

This peculiar behavior was demonstrated by identifying ICT advancement (Z) elasticity to trust in teachers (X) and its composition as classified in Table 3 (see the composition of respective elasticity in Appendix 5).

This explains the reason why *ISC* demonstrates, against general expectations, the peculiar behavior of trust decreasing with advancing ICT.

This finding leads to another noteworthy finding, namely, that advancement of ICT may be in decline in higher education, depending on the position in the digitally-rich learning environments.

Therefore, similarly to Table 3, this behavior was demonstrated by identifying ICT advancement (Z) elasticity to higher education (Y) and its composition as classified in Table 4 (see the composition of the respective elasticity in Appendix 5).

This reveals the unexpected behavior that advancement of ICT results in decline of higher education level in a particular position in the digitally-rich learning environments, as has been observed in *ISC* in its transition from *IGC* to *IAC*.

4.3. The effect of blended learning and teachers' resistance

(1) The position of 20 countries in ICT-driven higher education trajectory

Realizing bi-polarization nature of the logistic growth that governs ICT-driven higher education trajectory in 120 countries toward digitally-rich learning environments, as reviewed in Fig. 13, and also by the classification of the possible trajectories in such bi-polarization as reviewed in Tables 3 and 4, the positions of 20 selected countries in their trajectories can be identified as illustrated in Fig. 16.

(2) Blended learning and teacher's resistance

Prompted by the empirical findings above, particularly by the peculiar behavior of *ISC* in transition from *IGC* to *IAC* bringing a decline in its higher educational level with the advancement of ICT, the effect of the shift to blended learning and teacher's resistance against this shift was reviewed as they demonstrate the concave

[12] Degree of percentage increase in trust in teachers by means of 1% increase in ICT advancement.

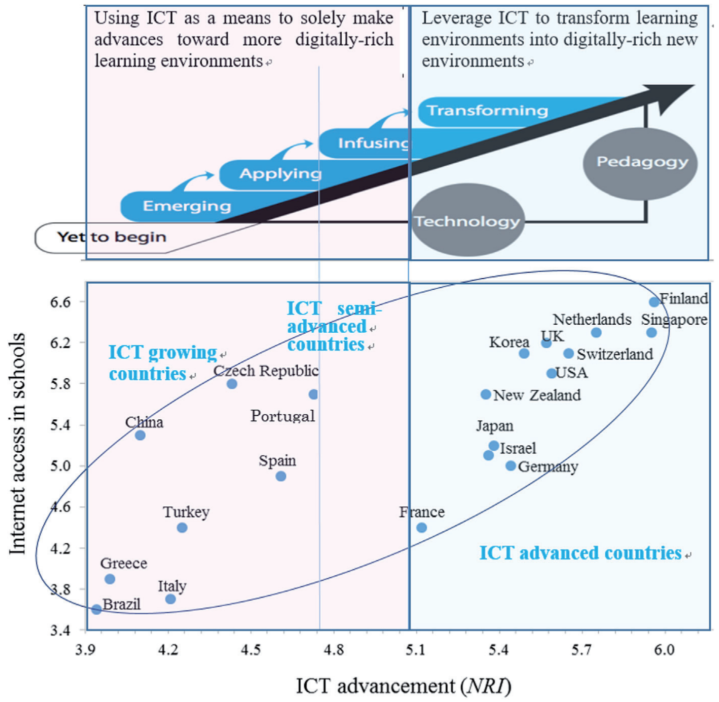


Fig. 15. Correlation between ICT advancement and internet access in schools in 20 countries (2013).
Sources: [32,34].

Table 3
Classification of ICT elasticity to trust in 20 countries (2013).
(2) ICT Elasticity to Higher Education

ICT level \ Education level	$Y > \frac{N}{2}$	$Y < \frac{N}{2}$
$Z > \frac{\ln b}{a}$	$\varepsilon_{XZ} = \frac{d \ln X}{d \ln Z} > 0$ (1% increase in Z induces ε_{XZ} ICT advanced 12 countries (*IAS*)	
$Z < \frac{\ln b}{a}$	$\varepsilon_{XZ} = \frac{d \ln X}{d \ln Z} < 0$ ICT semi-advanced 2 countries (*ISC*)	$\varepsilon_{XZ} = \frac{d \ln X}{d \ln Z} < 0$ ICT growing 6 countries (*IGC*)

educational level in the transition from traditional technical practice.

The use of the Web and other Internet technologies in education have exploded in the last couple of decades [4], leading to the creation of digitally-rich learning environments as reviewed in Tables 1 and 2

Fig. 17 illustrates a scheme of ICT advancement contributing to higher education. Blended learning, which introduces digital and online media to education system by harnessing the vigor of the advancement of the Internet, is certain to increase the speed of this trend [2,12].

Under these circumstances, contribution of ICT advancement to higher education can be developed in a hybrid manner through traditional teaching practice and blended learning as illustrated in Fig. 17 by the diphasic logistic sum of two functions with inflection and stability points [15].

While strong resistance by teachers to the use of new technology in education can impede the dependency on blended learning [1], once a certain higher education level has been attained, increasing dependency on blended learning will overcome such

Table 4
Classification of ICT elasticity to higher education in 20 countries (2013).

Education level / ICT level	$Y > \frac{N}{2}$	$Y < \frac{N}{2}$
$Z > \frac{\ln b}{a}$	$\varepsilon_{YZ} = \frac{\ln Y}{\ln Z} > 0$ ICT advanced 12 countries (*IAC*)	
$Z < \frac{\ln b}{a}$	$\varepsilon_{YZ} = \frac{\ln Y}{\ln Z} < 0$ ICT semi-advanced 2 countries	$\varepsilon_{YZ} = \frac{\ln Y}{\ln Z} > 0$ ICT advanced 6 countries (*IGC*)

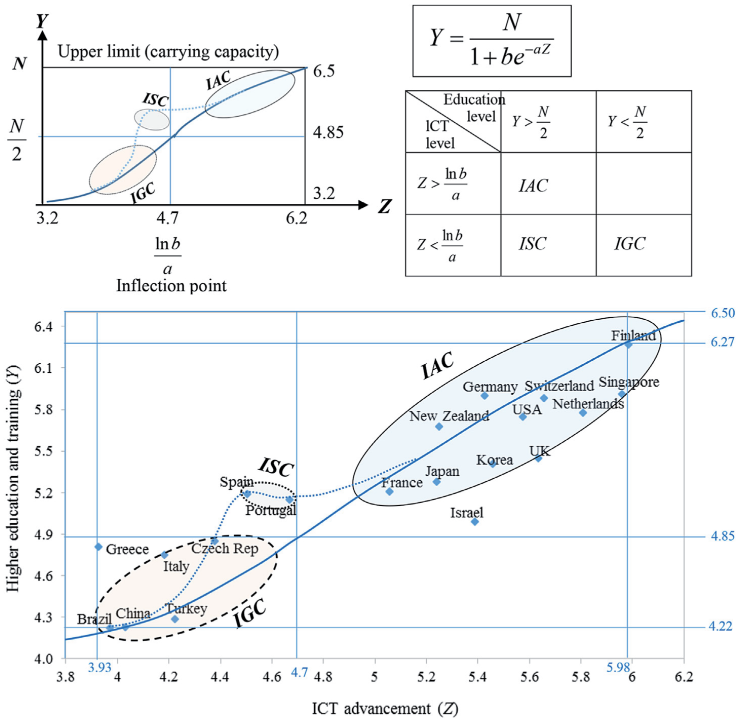


Fig. 16. Positions of 20 countries in ICT-driven higher education trajectory (2013).

resistance [12] leading to co-evolution between the advancement of ICT and further dependency on blended learning. This is demonstrated by the strong correlation between ICT advancement and higher dependency on the Internet access in schools as shown earlier in Fig. 15. The figure shows a significant correlation between ICT advancement and the Internet access in schools and suggests co-evolution between ICT advancement and blended learning boosted by the dependency on the Internet.

However, before such co-evolution can be realized, transition to blended learning results in decline in higher education at its transition period as illustrated in Fig. 17.

A careful examination of Fig. 16 reveals that *ISC* is in transition from *IGC* to *IAC*, which is contrary to a normal trajectory as demonstrated in *IGC*, and *IAC* shows a slightly negative coefficient. This corresponds to the decline in the transition period.

With such observation, Fig. 18 identifies the state of hybrid development of 20 countries in 3 groups.

Fig. 18 demonstrates that *ISC*'s concave trend is a consequence of

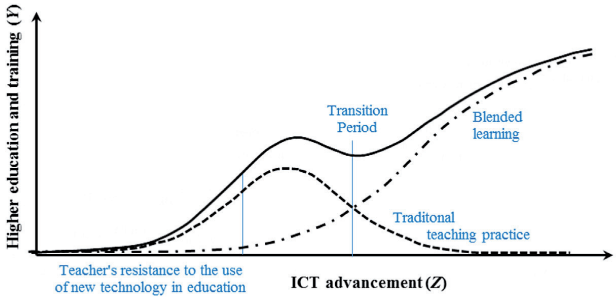


Fig. 17. Scheme of the contribution by ICT advancement to higher education by stage.

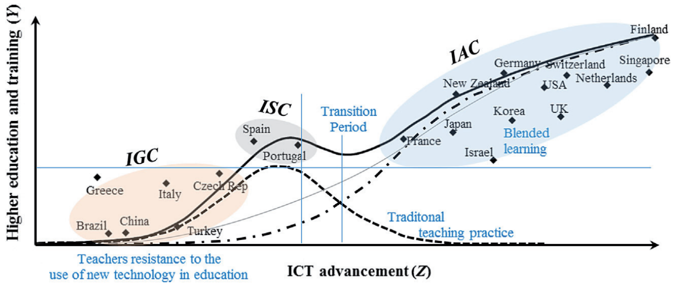
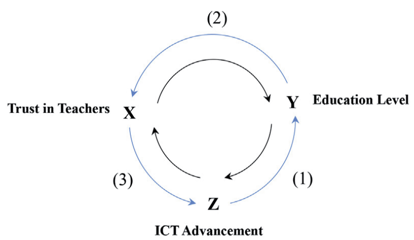


Fig. 18. State of hybrid development in 20 countries.



	ICT advanced countries (*IAC*)	ICT semi-advanced countries (*ISC*)	ICT growing Countries (*IGC*)
(1) *Z* and *Y*	+	-	+
(2) *Y* and *X*	+	+	-
(3) *X* and *Z*	+	-	-

Fig. 19. Re-assessment of co-evolution and disengagement between ICT, educational level and trust in teachers in 20 countries depending on ICT Advancement.
+ : co-evolution (virtuous cycle), −: disengagement (vicious cycle).

transition from traditional teaching practice to blended learning. This justifies the findings of Table 4, which reveals the unexpected behavior of advancement of ICT resulting in decline of higher education level in a particular position in digitally-rich learning environments, as has been observed in *ISC* in its transition from *IGC* to *IAC*.

4.4. Co-evolution and disengagement reassessed

The finding urges us to reassess the co-evolution and disengagement dynamism between ICT, higher education level, and trust in teachers in the 20 countries (Fig. 11). Fig. 19 presents the reassessment.

Fig. 19 reveals that contrary to general understanding as summarized in Fig. 11, advancement of ICT decreases higher education level in *ISC* as a result of its transition from traditional teaching practice to blended learning.

This re-assessment identifies the state of digitally-rich learning environments and subsequent co-evolution and disengagement for the 20 countries which depend on the state of their ICT advancement. This identification will provide insights to the respective countries regarding their priority countermeasures for co-evolution between ICT advancement, higher education enhancement and trust in teachers increase as suggested in Fig. 20.

5. Conclusion

With a strong notion that quality of higher education is crucial for the innovation of digital economy and this quality is subject to a sophisticated system with trust in teachers and advancement of ICT, dynamism of co-evolution between them was analyzed.

An empirical numerical analysis of 20 countries was attempted with the help of a unique dataset representing the above-described system consisting of the rate of trust in teachers for providing good education in the context of quality of education system and the social status of teachers, the level of higher education and the state of ICT advancement toward digitally-rich learning environments.

Noteworthy findings include:

(i) ICT-driven trust-based higher education is becoming crucial for nations' competitiveness in digitally-rich learning environments (DILE),
(ii) In such environments, ICT advancement, higher education, and trust in teachers are closely interweaved with each other,
(iii) The 20 countries examined can be divided into 3 groups: ICT advanced countries (*IAC: Finland, Singapore, Netherlands,*

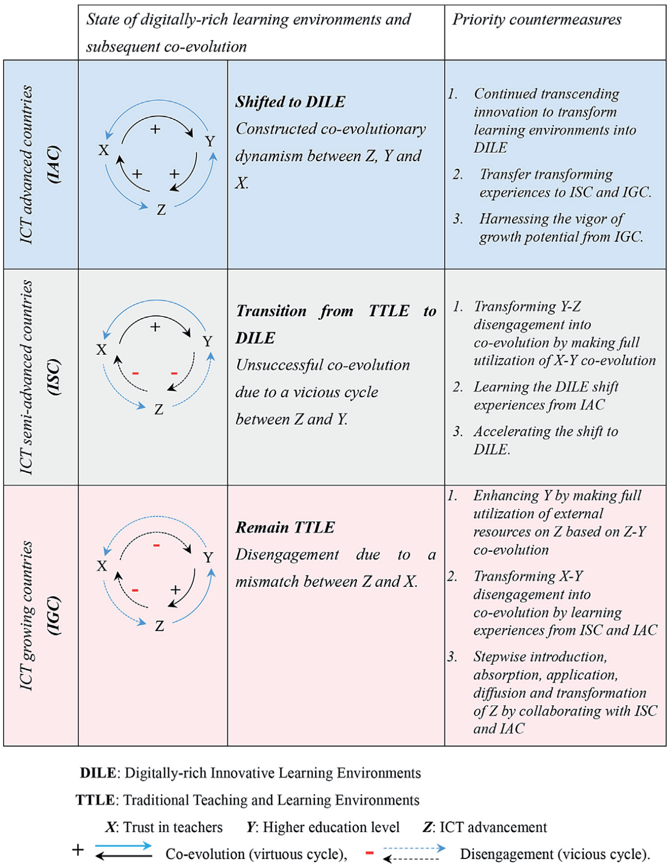


Fig. 20. State of digitally-rich learning environments, subsequent co-evolution and priority countermeasures.

Switzerland, UK, USA, Korea, Germany, Israel, Japan), ICT semi-advanced countries (*ISC: Portugal, Spain*), and ICT growing countries (*IGC: Czech Republic, Yurkey, Italy, China, Brazil, Greece*),

(iv) Given the significant shift from traditional teaching practice to blended learning towards DILE, the state of the country in this shift has become crucial for its performance,

(v) *IAC* has shifted to DILE and constructed co-evolutionary dynamism between ICT, higher education and trust,

(vi) This co-evolution corresponds to emerging un-captured GDP as observed in the leading edge of ICT-driven disruptive business model,

(vii) *ISC* is in the transition from traditional teaching and learning environments (TTLE) to DILE and to unsuccessful co-evolution due to a vicious cycle between ICT advancement and higher educational level enhancement, and

(viii) *IGC* remains TTLE and suffers disengagement due to a mismatch between ICT advancement and trust in teachers.

These findings give rise to insightful suggestions to the respective countries about their successful co-evolution being dependent on their state of ICT advancement:

(i) For *IAC*, continued transcending innovation, which transforms learning environments into digitally-rich new learning environments, should be maintained,

(ii) Successive innovation for further DILE is required so as to correspond to the decline in marginal productivity of ICT advancement for higher education enhancement,

(iii) Timely transfer of the co-evolutionary resources to *IGC* is needed to harness its vigor in a programmatic way,

(iv) Inspired by the emergence of un-captured GDP, ICT-driven disruptive business model toward digitally-rich learning environments should be explored,

(v) For *ISC*, clear understanding of the state of transition from *IGC* to *IAC* should be maintained,

(vi) Given the peculiar phenomena particular to this transition, namely, that advancement of ICT brings a decline in higher education, an optimal supplement compensating this decline should be taken,

(vii) Effective utilization of external resources for accelerating the shift to DILE should be provided,

(viii) For *IGC*, effective utilization of external resources for steady advancement of ICT should be undertaken on a priority basis, and

(ix) Consistent effort for a steady shift to DILE should be made in a programmatic way while maintaining an optimal balance with TTLE.

This paper explored a new systematic approach for co-evolution between ICT advancement, higher education enhancement and increase of trust in teachers, thus advancing the existing knowledge on this subject. However, we should note such limitations as (i) our dependency on the value of trust in teacher's data, which was available only for 21 countries (ii) shortage of detailed micro-analyses covering the effects of specific initiatives such as vision, leadership and curriculum. Further work should focus on in-depth analysis of institutional systems accelerating or impeding this co-evolution and on detailed micro-analysis of specific initiatives including vision, leadership and curriculum. Further analysis of peculiar behavior at a transition in digitally-rich learning environments is another important subject to be undertaken. For that, a wider empirical analysis covering more countries should be considered. Furthermore, with the notion that trust depends on "overdrawing" of past information, a business model constructing a co-evolutionary acclimatization through harnessing the vigor of time should be envisioned.

Acknowledgement

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement no: 293446 – Platform Value Now: Value capturing in the fast emerging platform ecosystems.

Appendix 1. Level of ICT advancement in the world

Table A1
Level of ICT advancement by NRI in 144 countries (2013)

	Country		Value		Country		Value		Country		Value
1	FIN	Finland	5.98	**51**	HRV	Croatia	4.17	**101**	IRN	Iran, Islamic Rep.	3.43
2	SGP	Singapore	5.96	**52**	URY	Uruguay	4.16	**102**	GTM	Guatemala	3.42
3	SWE	Sweden	5.91	**53**	CRI	Costa Rica	4.15	**103**	PER	Peru	3.39
4	NLD	Netherlands	5.81	**54**	RUS	Russian Federation	4.13	**104**	PRY	Paraguay	3.37
5	NOR	Norway	5.66	**55**	MUS	Mauritius	4.12	**105**	PAK	Pakistan	3.35
6	CHE	Switzerland	5.66	**56**	AZE	Azerbaijan	4.11	**106**	KHM	Cambodia	3.34
7	GBR	UK	5.64	**57**	BRN	Brunei Darussalam	4.11	**107**	SEN	Senegal	3.33
8	DNK	Denmark	5.58	**58**	CHN	China	4.03	**108**	VEN	Venezuela	3.33
9	USA	USA	5.57	**59**	MNG	Mongolia	4.01	**109**	HND	Honduras	3.32
10	TWN	Taiwan, China	5.47	**60**	BRA	Brazil	3.97	**110**	UGA	Uganda	3.30
11	KOR	Korea, Rep.	5.46	**61**	SVK	Slovak Republic	3.95	**111**	NAM	Namibia	3.29
12	CAN	Canada	5.44	**62**	KWT	Kuwait	3.94	**112**	TJK	Tajikistan	3.29
13	DEU	Germany	5.43	**63**	MEX	Mexico	3.93	**113**	NGA	Nigeria	3.27
14	HKG	Hong Kong	5.40	**64**	GRC	Greece	3.93	**114**	BGD	Bangladesh	3.22
15	ISR	Israel	5.39	**65**	GEO	Georgia	3.93	**115**	ZMB	Zambia	3.19
16	LUX	Luxembourg	5.37	**66**	COL	Colombia	3.91	**116**	ZWE	Zimbabwe	3.17
17	ISL	Iceland	5.31	**67**	MKD	Macedonia, FYR	3.89	**117**	SUR	Suriname	3.13
18	AUS	Australia	5.26	**68**	IND	India	3.88	**118**	KGZ	Kyrgyz Republic	3.09
19	AUT	Austria	5.25	**69**	LKA	Sri Lanka	3.88	**119**	BOL	Bolivia	3.01
20	NZL	New Zealand	5.25	**70**	ZAF	South Africa	3.87	**120**	CIV	Côte d'Ivoire	3.00
21	JPN	Japan	5.24	**71**	BGR	Bulgaria	3.87	**121**	GAB	Gabon	2.97
22	EST	Estonia	5.12	**72**	TTO	Trinidad and Tobago	3.87	**122**	MLI	Mali	2.97
23	QAT	Qatar	5.10	**73**	UKR	Ukraine	3.87	**123**	BEN	Benin	2.97
24	BEL	Belgium	5.10	**74**	THA	Thailand	3.86	**124**	CMR	Cameroon	2.95
25	ARE	UAE	5.07	**75**	ROU	Romania	3.86	**125**	NIC	Nicaragua	2.93
26	FRA	France	5.06	**76**	IDN	Indonesia	3.84	**126**	NPL	Nepal	2.93
27	IRL	Ireland	5.05	**77**	MDA	Moldova	3.84	**127**	TZA	Tanzania	2.92
28	MLT	Malta	4.90	**78**	BIH	Bosnia	3.80	**128**	ETH	Ethiopia	2.85
29	BHR	Bahrain	4.83	**79**	SYC	Seychelles	3.80	**129**	MWI	Malawi	2.83
30	MYS	Malaysia	4.82	**80**	EGY	Egypt	3.78	**130**	BFA	Burkina Faso	2.80
31	SAU	Saudi Arabia	4.82	**81**	CPV	Cape Verde	3.78	**131**	DZA	Algeria	2.78
32	LTU	Lithuania	4.72	**82**	ARM	Armenia	3.76	**132**	LBY	Libya	2.77
33	PRT	Portugal	4.67	**83**	ALB	Albania	3.75	**133**	MOZ	Mozambique	2.76
34	CHL	Chile	4.59	**84**	VNM	Vietnam	3.74	**134**	TLS	Timor-leste	2.72
35	CYP	Cyprus	4.59	**85**	JAM	Jamaica	3.74	**135**	MRT	Mauritania	2.71
36	PRI	Puerto Rico	4.55	**86**	PHL	Philippines	3.73	**136**	SWZ	Swaziland	2.69
37	SVN	Slovenia	4.53	**87**	SRB	Serbia	3.70	**137**	MDG	Madagascar	2.69
38	ESP	Spain	4.51	**88**	RWA	Rwanda	3.68	**138**	LSO	Lesotho	2.68
39	BRB	Barbados	4.49	**89**	MAR	Morocco	3.64	**139**	YEM	Yemen	2.63
40	OMN	Oman	4.48	**90**	DOM	Dominican Republic	3.62	**140**	GIN	Guinea	2.61
41	LVA	Latvia	4.43	**91**	ECU	Ecuador	3.58	**141**	HTI	Haiti	2.58
42	CZE	Czech Republic	4.38	**92**	KEN	Kenya	3.54	**142**	TCD	Chad	2.53
43	KAZ	Kazakhstan	4.32	**93**	SLV	El Salvador	3.53	**143**	SLE	Sierra Leone	2.53
44	HUN	Hungary	4.29	**94**	LBN	Lebanon	3.53	**144**	BDI	Burundi	2.30
45	TUR	Turkey	4.22	**95**	GHA	Ghana	3.51				
46	PAN	Panama	4.22	**96**	BWA	Botswana	3.50				
47	JOR	Jordan	4.20	**97**	LBR	Liberia	3.48				
48	MNE	Montenegro	4.20	**98**	GMB	Gambia, The	3.47				
49	POL	Poland	4.19	**99**	ARG	Argentina	3.47				
50	ITA	Italy	4.18	**100**	GUY	Guyana	3.45				

Source: The Global Information Technology Report 2013 [38].

Table A2
Level of ICT advancement by NRI in 20 countries (2012–2015)

Country	2012-15 average	2012	2013	2014	2015
Finland	**5.96**	5.81	5.98	6.04	6.00
Singapore	**5.95**	5.86	5.96	5.97	6.00
Netherlands	**5.75**	5.60	5.81	5.79	5.80
Switzerland	**5.65**	5.61	5.66	5.62	5.70
USA	**5.59**	5.56	5.57	5.61	5.60
UK	**5.57**	5.50	5.64	5.54	5.60
Korea	**5.49**	5.47	5.46	5.54	5.50
Germany	**5.44**	5.32	5.43	5.50	5.50
Japan	**5.38**	5.25	5.24	5.41	5.60
Israel	**5.36**	5.24	5.39	5.42	5.40
New Zealand	**5.35**	5.36	5.25	5.27	5.50
France	**5.12**	5.12	5.06	5.09	5.20
Portugal	**4.73**	4.63	4.67	4.73	4.90
Spain	**4.61**	4.54	4.51	4.69	4.70
Czech Republic	**4.43**	4.33	4.38	4.49	4.50
Turkey	**4.25**	4.07	4.22	4.30	4.40
Italy	**4.21**	4.17	4.18	4.18	4.30
China	**4.10**	4.11	4.03	4.05	4.20
Greece	**3.99**	3.99	3.93	3.95	4.10
Brazil	**3.94**	3.92	3.97	3.98	3.90

Value measured by the Networked Readiness Index (NRI).
Sources: The Global Information Technology Report 2012, 2013, 2014, 2015 [37–40].

Appendix 2. Co-evolutionary structure in 20 countries

Table A3
Level of ICT advancement by NRI in 20 countries (2013)

	Country	Value		Country	Value		Country	Value		Country	Value
1	Finland	5.98	**9**	USA	5.57	**21**	Japan	5.24	**45**	Turkey	4.22
2	Singapore	5.96	**11**	Korea	5.46	**26**	France	5.06	**50**	Italy	4.18
4	Netherlands	5.81	**13**	Germany	5.43	**33**	Portugal	4.67	**58**	China	4.03
6	Switzerland	5.66	**15**	Israel	5.39	**38**	Spain	4.51	**60**	Brazil	3.97
7	UK	5.64	**20**	New Zealand	5.25	**42**	Czech Republic	4.38	**64**	Greece	3.93

The figures on the left hand side indicate the world rank out of 144 countries (see Table A1).
Source: The Global Information Technology Report 2013 [38].

Table A4
Level of higher education in 20 Countries (2013)

	Country	Value		Country	Value		Country	Value		Country	Value
1	Finland	6.27	**7**	USA	5.75	**24**	France	5.21	**41**	Greece	4.81
2	Singapore	5.91	**9**	New Zealand	5.68	**26**	Spain	5.19	**42**	Italy	4.75
3	Germany	5.90	**17**	UK	5.45	**28**	Portugal	5.15	**65**	Turkey	4.29
4	Switzerland	5.88	**19**	Korea	5.41	**34**	Israel	5.00	**70**	China	4.23
6	Netherlands	5.78	**21**	Japan	5.28	**39**	Czech Republic	4.85	**72**	Brazil	4.22

The figures on the left hand side indicate the world rank out of 148 countries.
Source: The global competitiveness report 2013–2014 [36].

Table A5
Level of trust in teachers to deliver a good education in 20 countries (2013)

	Country	Value		Country	Value		Country	Value		Country	Value
1	Brazil	7.10	**6**	Portugal	6.62	**11**	Turkey	6.50	**16**	Germany	5.96
2	Finland	7.05	**7**	Singapore	6.60	**12**	UK	6.40	**17**	Czech Republic	5.94
3	Spain	6.86	**8**	Netherlands	6.56	**13**	France	6.15	**19**	Korea	5.40
4	China	6.74	**9**	New Zealand	6.54	**14**	Switzerland	6.10	**20**	Japan	5.35
5	USA	6.68	**10**	Italy	6.52	**15**	Greece	6.08	**21**	Israel	5.20

The figures on the left hand side indicate the world rank out of 21 countries (18. Egypt is excluded).
Source: 2013 Global Teacher Status Index [28].

Table A6
Composition of higher education level (2013)

Country	5th pillar: Higher education and training	5.01 Secondary education enrollment, gross %	5.02 Tertiary education enrollment, gross %	5.03 Quality of the education system	5.04 Quality of math and science education	5.05 Quality of management schools	5.06 Internet access in schools	5.07 Availability of research and training services	5.08 Extent of staff training
Finland	**6.27**	107.97	95.15	5.93	6.26	5.64	6.57	5.87	5.52
Singapore	**5.91**	107.00	72.00	5.77	6.29	5.75	6.30	5.44	5.23
Germany	**5.90**	103.32	-	5.14	5.05	5.10	5.03	6.10	5.12
Switzerland	**5.88**	95.46	56.75	5.98	5.80	6.09	6.11	6.47	5.57
Netherlands	**5.78**	121.46	65.41	5.17	5.31	5.66	6.25	6.09	5.14
USA	**5.75**	96.04	94.81	4.63	4.41	5.49	5.95	5.67	4.96
New Zealand	**5.68**	119.08	82.56	5.19	5.38	5.16	5.67	4.93	4.95
UK	**5.45**	105.34	59.75	4.62	4.37	5.89	6.16	5.61	4.73
Korea	**5.41**	97.08	103.11	3.82	5.10	4.45	6.11	4.81	4.21
Japan	**5.28**	102.20	59.74	4.10	4.66	4.04	5.16	5.52	5.35
France	**5.21**	113.59	57.67	4.21	5.19	5.80	4.41	5.42	4.33
Spain	**5.19**	128.52	82.63	3.60	3.86	5.83	4.92	4.82	3.72
Portugal	**5.15**	109.10	65.49	3.96	4.07	5.52	5.67	5.00	4.01
Israel	**5.00**	102.12	62.48	4.00	4.03	4.68	5.08	4.77	4.24
Czech Republic	**4.85**	90.78	64.85	3.69	3.96	3.95	5.79	5.00	4.03
Greece	**4.81**	109.46	89.38	3.10	4.28	3.85	3.91	3.83	3.47
Italy	**4.75**	100.40	64.98	3.64	4.26	4.98	3.67	4.79	3.21
Turkey	**4.29**	82.11	55.42	3.41	3.52	3.76	4.45	4.23	4.05
China	**4.23**	81.36	26.79	4.02	4.42	4.11	5.32	4.36	4.26
Brazil	**4.22**	105.83	25.63	2.98	2.56	4.54	3.60	4.71	4.30

Secondary education enrollment rate (ISCED levels 2 and 3)

Gross secondary education enrollment rate | 2011 or the most recent year available.

Sources: UNESCO Institute for Statistics (accessed June 21, 2013, and April 21, 2013); ChildInfo.org Country Profiles; national sources.

Tertiary education enrollment rate (ISCED levels 5 and 6)

Gross tertiary education enrollment rate | 2011 or the most recent year available.

Sources: UNESCO Institute for Statistics (accessed June 21, 2013); national sources.

Quality of the educational system

How well does the educational system in your country meet the needs of a competitive economy? [1 = not well at all; 7 = extremely well] | 2012–13 weighted average.

Source: World Economic Forum, Executive Opinion Survey.

Quality of math and science education

In your country, how would you assess the quality of math and science education in schools [1 = extremely poor—among the worst in the world; 7 = excellent—among the best in the world] | 2012–13 weighted average.

Source: World Economic Forum, Executive Opinion Survey.

Quality of management schools

In your country, how would you assess the quality of business schools [1 = extremely poor—among the worst in the world; 7 = excellent—among the best in the world] | 2012–13 weighted average.

Source: World Economic Forum, Executive Opinion Survey.

Internet access in schools

In your country, how widespread is Internet access in schools? [1 = nonexistent; 7 = extremely widespread] | 2012–13 weighted average.

Source: World Economic Forum, Executive Opinion Survey.

Local availability of specialized research and training services

In your country, to what extent are high-quality, specialized training services available? [1 = not available at all; 7 = widely available] | 2012–13 weighted average.

Source: World Economic Forum, Executive Opinion Survey.

Extent of staff training

In your country, to what extent do companies invest in training and employee development? [1 = not at all; 7 = to a great extent] | 2012–13 weighted average.

Sources: The Global Competitiveness Report 2013–2014, Executive Opinion Survey [36].

Appendix 3. Measurement of trust in teachers in the global teacher status index

1. The Varkey Gems Foundation (VGF) developed the "Global Teachers Status Index" in 2013 with the objective to understand the roles of cultural, political and economic factors, and social standing play in the status of teachers in different countries, and how these might impact on education systems.
2. VGF conducted a survey of 1000 representative respondents in each of the following 21 countries: Brazil, China, Czech Republic, Egypt, Finland, France, Germany, Greece, Israel, Italy, Japan, the Netherlands, New Zealand, Portugal, Turkey, Singapore, South Korea, Spain, Switzerland, the UK and the USA. These countries were chosen based on their performance in PISA [13] and TIMSS [14] assessments to represent each major continent and as representative of different standards of education systems.
3. The survey contains the question concerning trust in teachers for delivering good education by rating "Trusting teachers to deliver a good education." To address this issue, the survey asked respondents to rate (on rating scale of 10: from 0 = do not trust at all, to 10 = trust completely), **to what extent would you trust or not trust teachers to deliver good education for your children?**
4. Identity of this rating is conducted taking into account
   i. the contextual understanding of the social status of teachers, and
   ii. perceptions of the quality of the educational system
5. The data for the study was collected by the polling company Populus by using a WBS with a balanced sample of 16 to 70-year-olds formed by: age; gender; and region. Individuals were invited to participate in the survey from a large database of online internet mailing lists.
6. To ensure the reliability and representation of the national surveys the VGF claimed to adopt strict procedures, e.g., the quotes on age, gender and region in each country, samples monitoring on the basis of education levels, urban, rural locations and ethnic minorities. A country specific population census information to construct the final balanced sample for each country was used. The survey required the compulsory double opt-in registration of respondents by valid postcode and address as a proof of identification. To further assure the trustworthiness of the sample, the quality checks were built and any respondent failing such test was removed from the sample.
7. In literature the terms such as trust, confidence and trustworthiness are often used interchangeably. The literature on trust has various topics: definitions, measurement of trust, types of trust, the importance of trust relationship between stakeholders in different contexts, trust in governing complex systems and trust in digital age, etc. In the education context, lot of research exists about the importance of trust relationships between teachers, students, parents, leadership and policy makers, etc.
8. In literature it is mentioned that the measurement of trus**t** is an important but challenging task because it may have both quantifiable and non-quantifiable elements. The different methods to measure trust include counting the frequency of trusting behavior, extent of trusting behavior or using surveys to measure trusting attitudes, the last being the most common method. The measurement of trust by surveys and barometers (such as Edelman, Eurobarometer, European Social Survey, Gallup, International Social Survey Programme, PEW and World Values Survey) is a common practice but each approach has its own strengths and weaknesses.

Appendix 4. Regression analysis of groups with heterogeneous performance

Regression analysis of groups with heterogeneous performance as *IAC*, *ISC* and *IGC* (Figs. 7–10) are conducted by introducing coefficient dummy variables depending on the group, as follows (the case of Fig. 7):where α, β_i: coefficients, and D_i: dummy variables.

$$\ln \boldsymbol{Y} = \alpha + \sum_{\boldsymbol{i}=1}^{3} [\boldsymbol{\beta_i D_i}] \ln \mathbf{X}$$

[13] Performance for International Student (PISA).

[14] Trends in International Mathematics and Science Study (TIMSS).

$i = 1$ *for* ***IAC*** $(others = 0)$, $i = 2$ *for* ***ISC*** $(others = 0)$, $i = 3$ *for* ***IGC*** $(others = 0)$.

Data Construction.

Group	Country	Y	lnY	X	lnX	D_1	D_2	D_3	D_1lnX	D_2lnX	D_3lnX
IAC	Finland	6.270	1.836	7.050	1.953	1	0	0	1.953	0	0
IAC	France	5.210	1.651	6.150	1.817	1	0	0	1.817	0	0
IAC	Germany	5.900	1.775	5.960	1.785	1	0	0	1.785	0	0
IAC	Israel	4.990	1.607	5.200	1.649	1	0	0	1.649	0	0
IAC	Japan	5.280	1.664	5.350	1.677	1	0	0	1.677	0	0
IAC	Netherlands	5.780	1.754	6.560	1.881	1	0	0	1.881	0	0
IAC	New Zealand	5.680	1.737	6.540	1.878	1	0	0	1.878	0	0
IAC	Singapore	5.910	1.777	6.600	1.887	1	0	0	1.887	0	0
IAC	Korea	5.410	1.688	5.400	1.686	1	0	0	1.686	0	0
IAC	Switzerland	5.880	1.772	6.100	1.808	1	0	0	1.808	0	0
IAC	UK	5.450	1.696	6.400	1.856	1	0	0	1.856	0	0
IAC	USA	5.750	1.749	6.680	1.899	1	0	0	1.899	0	0
ISC	Portugal	5.150	1.639	6.620	1.890	0	1	0	0	1.890	0
ISC	Spain	5.190	1.647	6.860	1.926	0	1	0	0	1.926	0
IGC	Brazil	4.220	1.440	7.100	1.960	0	0	1	0	0	1.960
IGC	China	4.230	1.442	6.740	1.908	0	0	1	0	0	1.908
IGC	Czech Rep	4.850	1.579	5.940	1.782	0	0	1	0	0	1.782
IGC	Greece	4.810	1.571	6.080	1.805	0	0	1	0	0	1.805
IGC	Italy	4.750	1.558	6.520	1.875	0	0	1	0	0	1.875
IGC	Turkey	4.290	1.456	6.500	1.872	0	0	1	0	0	1.872

IAC: ICT advanced countries, ***ISC:*** ICT semi-advanced countries, ***IGC:*** ICT growing countries.
X: Trust in teachers, ***Y:*** Higher education and training.

Regression model

$$\ln Y = \underset{(3.47)}{0.811} + \underset{(3.92)}{0.504}D_1 \ln X + \underset{(3.54)}{0.436}D_2 \ln X - \underset{(-3.07)}{0.874}D_3 \ln X + \underset{(4.01)}{2.329}D_3 \quad \boldsymbol{adj.R^2 = 0.872}$$

D_1, D_2, D_3: Dummy variables corresponding to IAC, ISC and IGC, respectively.

The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

Correlation analysis with coefficient dummy variables— correlation with different slopes

$$\ln Y = \underset{(3.47)}{0.811} + \underset{(3.92)}{0.504}D_1 \ln X + \underset{(3.54)}{0.436}D_2 \ln X - \underset{(-3.07)}{0.874}D_3 \ln X + \underset{(4.01)}{2.329}D_3 \quad \boldsymbol{adj.R^2 = 0.872}$$

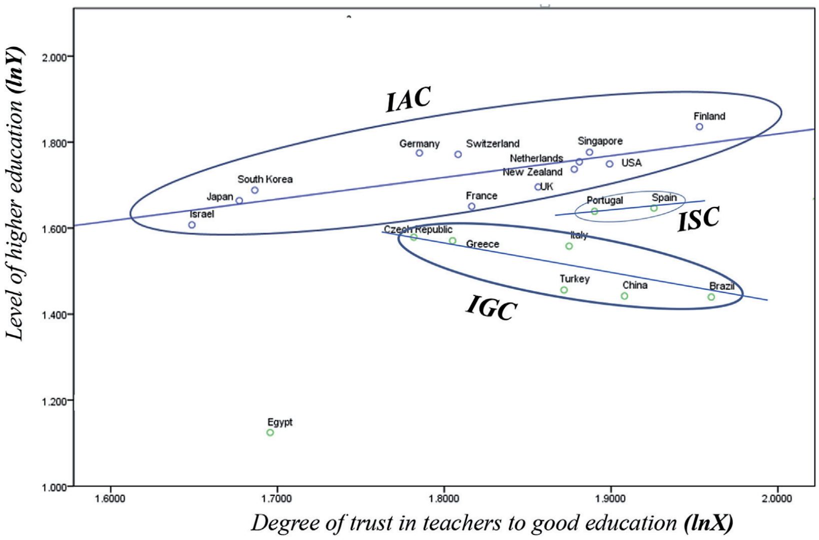
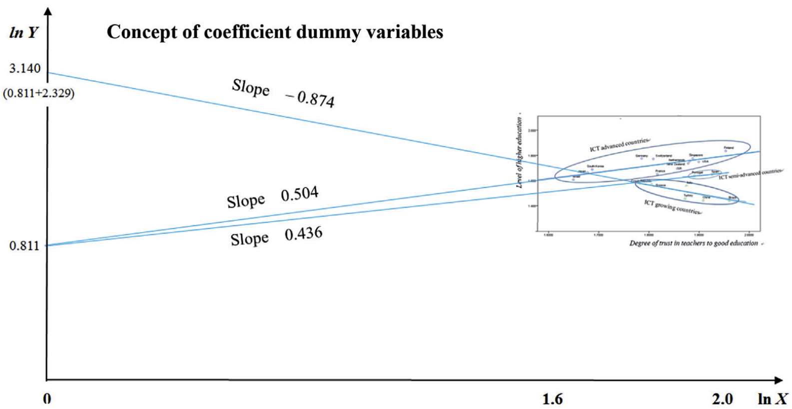


Fig. 7. Correlation between trust in teachers and higher education level in 20 countries (2013).



Appendix 5. Logistic growth function and its bi-polarization nature

A5.1. Estimate of logistic growth function for ICT-driven higher education in 120 countries in 2013

ICT-driven education development toward digitally-rich learning environments in 120 Countries in 2013 is illustrated by the following sigmoid curve as demonstrated in Fig. 2 (Fig. A1):

Focusing on the scope between (Z, Y) from (3.2, 3.2) to (6.2, 6.5) as highlighted in Fig. A1, since it is observed that the above trajectory shows sigmoid growth, the following logistic growth function was estimated:

$$\frac{dY}{dZ} = aY\left(1 - \frac{Y}{N}\right) \tag{A1}$$

$$Y = \frac{N}{1 + be^{-aZ}} \tag{A2}$$

where Y: Higher education level, N: Upper limit (carrying capacity), Z: ICT advancement level, a: velocity of diffusion, and b: initial state of education level.

With the observation that the carrying capacity and the inflection point of the sigmoid curve are estimated as 6.5 and 4.7, respectively as illustrated in Fig. A2, by means of heuristic spline interpolation approach, the following logistic growth function for 120 countries in 2013 was estimated.

$$Y' = \frac{3.30}{1 + 13.50e^{-1.74Z'}} \tag{A3}$$

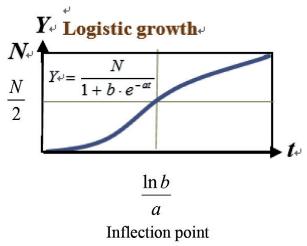
where $Y' = Y - 3.20$, $Z' = Z - 3.20$.

This estimated function behaves similarly to the observed sigmoid curve as $N = 3.30 + 3.20 = 6.50$, inflection point. $\overline{Z} = \frac{\ln b}{a} + 3.20 = 1.50 + 3.20 = 4.70$.

Thus, the estimated function is considered to demonstrate the ICT-driven education development trajectory in 120 countries in 2013.

A5.2. Scheme of the bi-polarization fatality of logistic growth

Logistic growth function as a function of time t (substitute t for Z in Eqs (A1–A3)) can be developed to the following bi-polarization function:



$$\frac{dY}{dt} = aY\left(1 - \frac{Y}{N}\right) = \frac{aN}{1+be^{-at}}\left(1 - \frac{1}{1+be^{-at}}\right)$$
$$= \frac{aN}{(1+be^{-at})} \cdot \frac{be^{-at}}{(1+be^{-at})} = \frac{aN}{(1+be^{-at})} \cdot \frac{1}{(1+\frac{1}{b}e^{at})}$$
$$= \frac{aN}{(2+be^{-at}+\frac{1}{be^{-at}})}$$

$$\frac{aN}{\frac{dY}{dt}} = 2 + be^{-at} + \frac{1}{be^{-at}}$$

$$y = 2 + x + \frac{1}{x}$$

$$y \equiv \frac{aN}{\frac{dY}{dt}}, \; x \equiv be^{-at}$$

Fig. A3. Illustrates this bi-polarization that is fatal to logistic growth function. The figure on the left illustrates the increase of time t and marginal Y (dY/dt) toward the origin of coordinates. Rotating this figure by 180 degrees leads to a normal axis display as illustrated on the right. This figure indicates that in the normal logistic growth as a function of time t, marginal Y (dY/dt) increases as time goes by and as it is generally anticipated within the time shorter than a certain threshold. However, there is a change to reverse once this threshold is exceeded, the marginal increase declining against expectations.

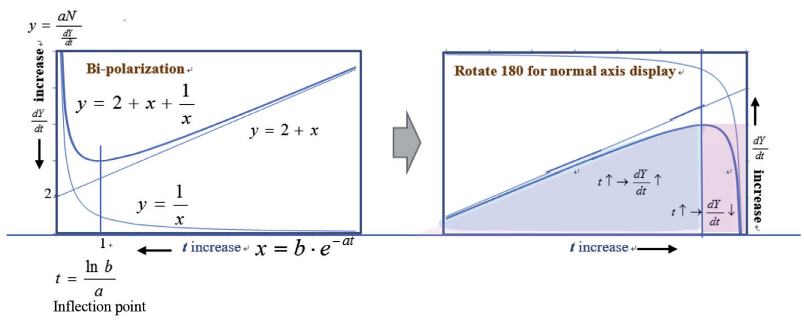


Fig. A3. Bi-polarization fatal to logistic growth function.

By the preceding reviews [41,29], given that ICT advance is proportional to time t, ICT-driven education development trajectory in 120 countries can be depicted by a logistic growth function consisting of ICT advancement (Z) and higher education (Y) as demonstrated in Fig. 2. Consequently, this trajectory leads to bi-polarization between ICT advanced countries (IAC) and ICT semi-advanced countries (ISC) as well as ICT growing countries (IGC) similar to the figure on the right in Fig. A3 and as demonstrated by the middle figure in Fig. A4.

Fig. A4 illustrates the whole perspective of the bi-polarization of ICT advancement as a consequence of a trap in ICT advancement derived from its two-faced nature [29,30]. Unexpected decline in *marginal productivity of ICT enhancing higher education* (dY/dZ) in *IAC* can be attributed to a trap in ICT advancement (the top figure in Fig. A4) derived from the two-faced nature of ICT, that is, while advancement of ICT, centered on the dramatic advancement of the Internet, generally contributes to enhanced prices of ICT by increasing new functionality development, the dramatic advancement of the Internet reacts to decreases in prices of ICT due to its nature of favoring freebies, easy copying, and mass standardization. Given that schools seek to maximize profit in competitive learning environments, the marginal productivity of ICT corresponds to the relative price of ICT which, unlike the new services created, declines as ICT advances.

This can be attributed to a mismatch between the value of such new services and learning environments in transition toward digitally-rich learning environments that absorb and effectively apply such services to higher education. This is similar to the emergence of un-captured GDP that the Internet provides: utility and happiness to people that cannot be captured through traditional GDP data [30].

In order to avoid such a vicious cycle, *IAC* endeavors to leverage transcending innovation to redesign learning environments into digitally-rich new learning environments that can absorb, effectively apply new services and also increase trust in a co-evolutional manner. As a result, a higher *marginal productivity of ICT* is expected as demonstrated in Fig. A5. A virtuous cycle is thus established between *marginal inducement of ICT through higher education* (dZ/dY) enhancement and ICT (Z) advancement as illustrated in the bottom figure in Fig. A4. In contrast, while ISC and IGC expect their higher education enhancement through the *marginal productivity of ICT* increase as ICT advances, as illustrated in the middle figure in Fig. A4, these countries cannot afford the required ICT advances by themselves. The result is a vicious cycle of dZ/dY declining as Z advances, as illustrated in the bottom figure in Fig. A4.

Marginal productivity of ICT enhancing higher education can be depicted as follows:

$$\frac{dY}{dZ} = aY\left(1 - \frac{Y}{N}\right) = aY\left(1 - \frac{1}{FD}\right) \quad \text{(A1 ')}$$

where *FD*: functionality development.

Transcending innovation increases *FD* by its co-evolution between absorbing, applying new services for higher education and increasing trust as ICT advances, leading to enhanced marginal productivity of ICT as illustrated in Fig. A5.

Table A7 summarizes ICT's role for digitally-rich learning environments between *IAC* and *ISC/IGC*.

Table A7
The contrast of ICT's role for digitally-rich learning environments between ICT advanced countries and semi-advanced/growing countries

ICT semi-advanced countries (*ISC*), ICT growing countries (*IGC*)	ICT advanced countries (*IAC*)
Using ICT as a means to solely move toward more digitally-rich learning environments While dY/dZ is enhanced as Z advances, the required Z advancement cannot be afforded, resulting in a vicious cycle of dZ/dY decline as Z advances.	Leveraging ICT to transform learning environments into digitally-rich new learning environments that can absorb and effectively apply ICT-driven new services to higher education. While dY/dZ declines as Z advances, there is a shift to a higher level of dY/dZ by means of transcending innovation, leading to a construction of a virtuous cycle between dZ/dY enhancement and Z advance.

A5.3. ICT elasticity to trust in teachers and higher education

Elasticity of ICT advancement to trust in teachers increase (Z elasticity to X) can be depicted as follows:where $y = \frac{aN}{\frac{dY}{dZ}} = \frac{aN}{aY\left(1-\frac{Y}{N}\right)} = \frac{N^2}{Y(N-Y)}$(substitute Z for t in the left figure in Fig. A3).

Therefore, this elasticity in 20 countries can be classified depending on their levels of education and ICT as demonstrated in Table A8.

Table A8
Classification of ICT elasticity to trust in 20 countries (2013)

Education Level / ICT level	$Y > \frac{N}{2}$				$Y < \frac{N}{2}$			
	$\frac{d\ln X}{d\ln Y}$	$\frac{dy}{dZ}$	$\frac{1}{(2Y-N)}$	$\frac{d\ln X}{d\ln Z}$	$\frac{d\ln X}{d\ln Y}$	$\frac{dy}{dZ}$	$\frac{1}{(2Y-N)}$	$\frac{d\ln X}{d\ln Z}$
$Z > \frac{\ln b}{a}$	+	+	+	+				
	ICT advanced 12 countries (*IAC*)							
$Z < \frac{\ln b}{a}$	+	-	+	-	-	-	-	-
	ICT semi-advanced 2 countries (*ISC*)				ICT growing 6 countries (*IGC*)			
Reference	Fig. 8 Fig. A3				Fig. 8 Fig. A3			

Table A8 demonstrates the structural sources contrasting positive elasticity in *IAC* and disengagement in *ISC* and *IGC*.

Furthermore, elasticity of ICT advancement to higher education enhancement (Z elasticity to Y) can be developed as follows:

$$\frac{d\ln X}{d\ln Z} = \frac{d\ln X}{d\ln Y} \cdot \frac{d\ln Y}{d\ln Z}$$

$$\frac{d\ln Y}{d\ln Z} = \frac{d\ln X}{d\ln Z} \cdot \frac{d\ln Y}{d\ln X}$$

Therefore, Z elasticity to Y.

Table A9
Classification of ICT elasticity to higher education in 20 countries (2013)

Education Level / Ela-sticity / ICT level	$Y > \frac{N}{2}$			$Y < \frac{N}{2}$		
	$\frac{d\ln X}{d\ln Z}$	$\frac{d\ln Y}{d\ln X}$	$\frac{d\ln Y}{d\ln Z}$	$\frac{d\ln X}{d\ln Z}$	$\frac{d\ln Y}{d\ln X}$	$\frac{d\ln Y}{d\ln Z}$
$Z > \frac{\ln b}{a}$	+	+	+			
	ICT advanced 12 countries					
$Z < \frac{\ln b}{a}$	-	+	-	-	-	+
	ICT semi-advanced 2 countries (*ISC*)			ICT advanced 6 countries		
Reference	Table A8	Fig. 7		Table A8	Fig. 7	

Table A9 demonstrates the structural sources contrasting positive elasticity in *IAC* and *IGC* with disengagement in *ISC*.

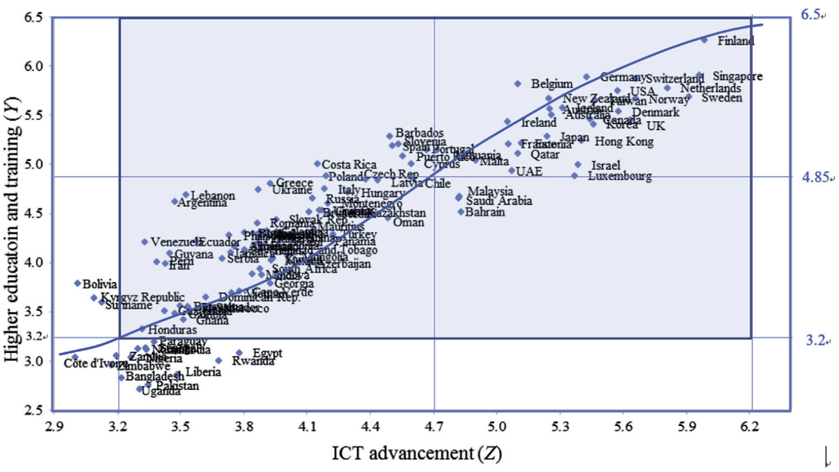


Fig. A1. ICT-driven education development in 120 countries (2013).
Sources: Same as Fig. 2.

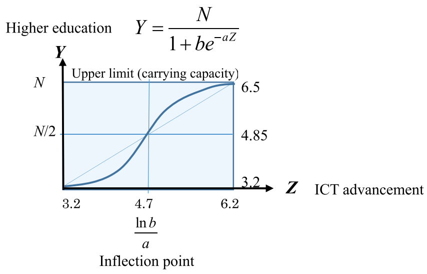


Fig. A2. Estimated logistic growth function.

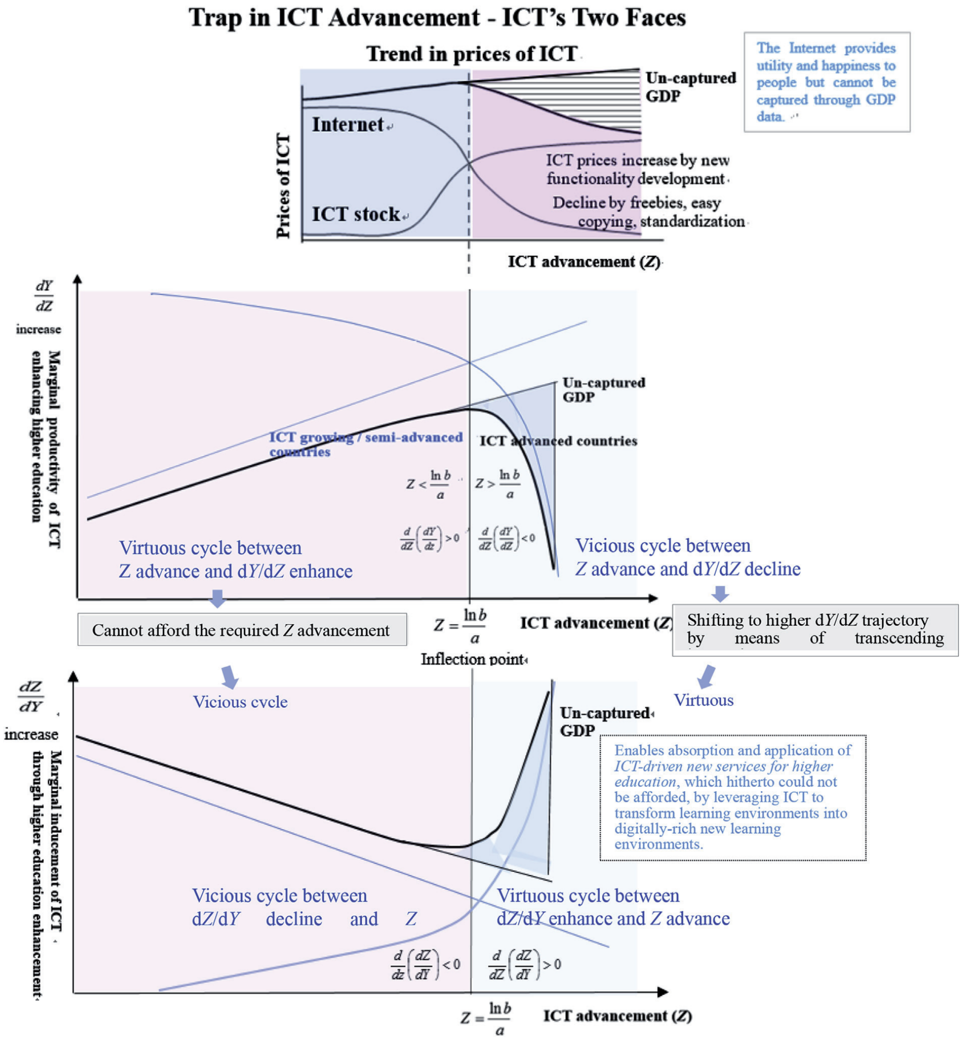


Fig. A4. Perspective of bi-polarization of ICT advancement.

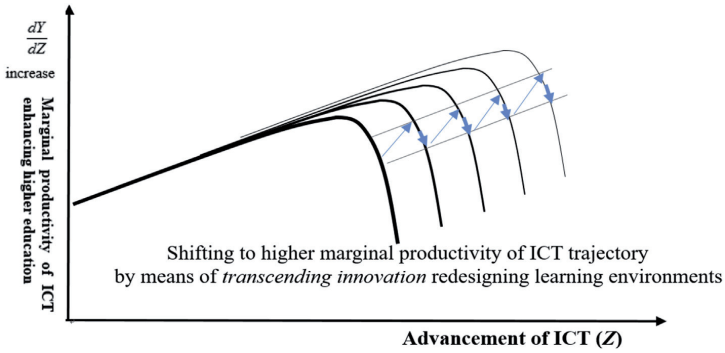


Fig. A5. Scheme of sustaining marginal productivity of ICT by means of transcending innovation.

References

[1] J. Anderson, T. van Weert, Information and Communication Technology in Education: a Curriculum for Schools and Programme of Teacher Development, UNESCO, Paris, 2002.
[2] C. Anderson, Barriers and enabling factors in online teaching, Int. J. Learn. 14 (12) (2008) 241–246.
[3] D. Brown, D.A. Skinner, Brown-skinner model for building trust with at-risk students, Natl. Forum Appl. Educ. Res. J. 20 (3) (2007) 1–7.
[4] P.S.D. Chen, A.D. Lambert, K.R. Guidry, Engaging online learners: the impact of web-based learning technology on college student engagement, Comput. Educ. 54 (4) (2010) 1222–1232.
[5] T. Cowen, The Great Stagnation, Dutton, New York, 2011.
[6] S. Greener, E-Modelling: helping Learners to Develop Sound e-learning Behaviours, Electron. J. e-Learning 7 (3) (2009) 265–272.
[7] J.S. Groff, Technology-rich Innovative Learning Environments. Report on OECD Innovative Learning Environments Project, OECD, Paris, 2013.
[8] C. Heaton-Shrestha, S. May, L. Burke, Student retention in higher education: what role for virtual learning environments? J. Furth. High. Educ. 33 (1) (2009) 83–92.
[9] J. Henderson, O. Lemon, K. Georgila, Hybrid reinforcement and supervised learning of dialogue policies from fixed data sets, Comput. Linguist. 34 (4) (2008) 485–511.
[10] IMF, The world economic outlook database, IMF, Washington, 2013.
[11] A. Iqbal, M. Kankaanranta, P. Neittaanmaki, Experiences and motivations of the young for participation in virtual worlds, Procedia Soc. Behav. Sci. 2 (2010) 3190–3197.
[12] L.M. Jeffrey, J. Milne, G. Suddaby, Blended learning: how teachers balance the blend of online and classroom components, J. Inf. Technol. Educ. 13 (2014) 121–140.
[13] N. Luhmann, Trust and Power, John Wiley, Chchester, 1979.
[14] T. Makela, M. Kankaanranta, S. Helfenstein, Considering learners' perceptions in designing effective 21st century learning environments for basic education in Finland, Int. J. Educ. Organ. Leadersh. 20 (3) (2014) 1–13.
[15] M.M. Mischan, J.R.S. Passos, S.Z. Pinho, L.R. Carvalho, Inflextion and stability points of diphasic logistic analysis of growth, Sci. Agric. 72 (3) (2015) 1–9.
[16] OECD, Are the New Millennium Learners Making the Grade? Technology Use and Educational Performance in PISA 2006, OECD, Paris, 2010.
[17] OECD, PISA 2009 Results: Students on Line – Digital Technologies and Performance (Volume VI), OECD, Paris, 2011.
[18] OECD, Trust: what it Is and Why it Matters for Governance and Education?, OECD, Paris, 2014.
[19] A. Oreg, J. Goldenbelg, Resistance to Innovation: its Sources and Manifestations, The University of Chicago Press, Chicago and London, 2015.
[20] A.R. Peslak, The educational productivity paradox, Commun. ACM 48 (10) (2005) 111–114.
[21] P. Sahlberg, The Secret to Finland's Success: Educating Teachers, September 2010, Stanford Center for Opportunity Policy in Education, 2010, pp. 1–8.
[22] M. Saarela, T. Karkkainen, Discovering gender-specific knowledge from finnish basic education using PISA indices, London, in: Proceedings of the 7th International Conference on Educational Data Mining, 2014, pp. 60–67.
[23] J. Schlte-Pelkum, M. Schweer, B. Pollak, Dyadic trust relations between teachers and students: an empirical study about conditions and effects of perceived trustworthiness in the classroom from a differential perspective, Beziehungen Unterricht und Schule 2014 (5) (2014) 1–14.
[24] T. Stehlik, Is "Pedagogical Love" the Secret to Finland's Educational Success?, 2016. http://www.aare.edu.au/blog/?p=1578. Retrieved 30 May 2016.
[25] The Hague University of Applied Sciences (HAAGSE), Trust and Education, OECD, Paris, 2015.
[26] S. Tokumasu, C. Watanabe, Institutional structure leading to the similarity and disparity in innovation inducement in EU 15 countries, J. Serv. Res. 8 (1) (2008) 5–42.
[27] UNESCO, Towards Policies for Integrating Information and Communication Technologies into Education, UNESCO, Paris, 2003.
[28] Varkey Gems Foundation (VGF), 2013 Global Teacher Status Index, VGF, London, 2014.
[29] C. Watanabe, K. Naveed, W. Zhao, Structural source of the trap of ICT advancement: lessons from world ICT top leaders, J. Technol. Manag. Grow. Econ. 5 (2) (2014) 49–71.
[30] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured GDP and growing anger of consumers, Technol. Soc. 41 (2015a) 21–44.
[31] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure – similarity and disparities between Finland and Singapore, Technol. Soc. 42 (2015b) 104–122.
[32] C. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, Operationalization of un-captured GDP: the innovation stream under new global mega-trends, Technol. Soc. 45 (2016a) 58–77.
[33] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution of three mega-trends natures un-captured GDP: uber's ride-sharing revolution, Technol. Soc. 46 (2016b) 164–185.
[34] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution between trust in teachers and higher education enabled by ICT advancement: a suggestion to ICT growing economies, J. Technol. Manag. Grow. Econ. 7 (2) (2016c) 7–38.
[35] C. Watanabe, K. Naveed, P. Neittaanmäki, Consolidated challenge to social demand for resilient platforms: lessons from Uber's global expansion, Technol. Soc. 48 (2017) 33–53.
[36] World Economic Forum (WEF), The Global Competitiveness Report 2013-2014, WEF, Geneva, 2013a.
[37] World Economic Forum (WEF), The Global Information Technology Report 2012, WEF, Geneva, 2012.
[38] World Economic Forum (WEF), The Global Information Technology Report 2013, WEF, Geneva, 2013b.
[39] World Economic Forum (WEF), The Global Information Technology Report 2014, WEF, Geneva, 2014.
[40] World Economic Forum (WEF), The Global Information Technology Report 2015, WEF, Geneva, 2015.
[41] W. Zhao, C. Watanabe, Y. Tou, Co-emergence of institutional innovation navigates the new normal in growing economies, J. Technol. Manag. Grow. Econ. 4 (1) (2013) 69–81.
[42] I. Zitter, A. Hoeve, Hybrid Learning Environments: Merging Learning and Work Processes to Facilitate Knowledge Integration and Transitions, OECD Education Working Papers, No. 81, OECD Publishing, 2012.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Research Professor of University of Jyväskylä, Finland, and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland.

Pekka Neittaanmäki graduated from the University of Jyväskylä in Mathematics and is currently Professor and a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland.

PX

ICT-DRIVEN DISRUPTIVE INNOVATION NURTURES UNCAPTURED GDP - HARNESSING WOMEN'S POTENTIAL AS UNTAPPED RESOURCES

by

Chihiro Watanabe, Kashif Naveed and Pekka Neittaanmäki, 2017

Technology in Society, vol. 51, pp. 81-101

Technology in Society 51 (2017) 81–101

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

ICT-driven disruptive innovation nurtures un-captured GDP – Harnessing women's potential as untapped resources

Chihiro Watanabe [a, b, *], Kashif Naveed [a], Pekka Neittaanmäki [a]

[a] Faculty of Information Technology, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria

A R T I C L E I N F O

Article history:
Received 10 May 2017
Received in revised form
25 July 2017
Accepted 31 July 2017
Available online 5 August 2017

Keywords:
Gender balance
Women board members
Untapped resources
Trilateral co-evolution
Cultural dimensions

A B S T R A C T

The harnessing of untapped resources has become essential for inclusive growth in digital economies particularly as developed economies continue to age demographically. The harnessing of women's potential is an urgent subject in this context, and successive initiatives have been flourishing in many countries.

However, given the institutional complexity of the issue, as well as considerable variety across nations, uniformed non-systematic approaches are hardly satisfactory in achieving a timely solution.

Against this back drop, this paper analyzed a new information communication technology (ICT)-driven disruptive innovation that may nurture un-captured GDP by harnessing untapped resources such as women's economic potential.

Using a unique dataset representing the state of gender balance improvement, an empirical numerical analysis of 44 countries was attempted. These countries were classified as emerging, industrialized, and with a specific culture based particularly on the traditions of a male-dominated society.

It was found that while industrialized countries, typically Finland, have achieved high performance in co-evolution between "econo-cultural development," ICT advancement, and gender balance improvement, emerging countries have been constrained by low ICT advancement. In addition, notwithstanding their high economic level, countries with a specific culture have been constrained by a traditional male-dominated culture, Japan being a typical case.

Based on these findings, lessons from industrialized countries for both emerging countries and countries with a specific culture were analyzed.

It was suggested that ICT should be strategically advanced depending on the state of what we are calling "econo-cultural development" for constructing co-evolution of gender balance improvement along with techno-economic development.

A new practical approach for harnessing untapped resources for sustainable growth was thus explored.

1. Introduction

The harnessing of untapped resources has become essential for inclusive growth[1] in digital economies that are rapidly aging. The harnessing of women's economic potential is urgent in this context.

Bridging the gender divide is not only a matter of fairness but also one of effective governance and inclusive growth [24]. It has been demonstrated that companies with more women board directors experienced higher financial performance [1]. Companies where women are most strongly represented at board or top-management level also perform best [16]. Women's presence in the labor market is increasingly significant for economic growth and development at both the national and enterprise levels. The growing participation of women in the labor market has been a major engine of global growth and competitiveness [10]. Thus, harnessing the vigor of women's potential is essential for inclusive economic growth in digital economies that are moving toward

* Corresponding author. Faculty of Information Technology, University of Jyväskylä, Finland.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] Inclusive growth is economic growth that creates opportunity for all segments of the population and distributes the dividends of increased prosperity, both in monetary and non-monetary terms, fairly across society [24].

http://dx.doi.org/10.1016/j.techsoc.2017.07.007
0160-791X/

aging societies. This can be seen as a soft engine for sustainable growth, substitutable for costly hard investment, which is particularly important for emerging economies [14]. For industrialized economies, this would help overcome the low growth and low birth rates of this era [15]. A growing body of evidence shows that utilizing the skills and talents of both men and women is beneficial for enterprises and society in general [10].

However, despite growing awareness of the benefits of gender equality in decision-making, the pace of progress in achieving this has been slow and varies considerably across countries [7,24,32]. The World Economic Forum [42] urged a fresh call to action to accelerate progress towards gender equality for harnessing female talent, half of the world's talent, towards the Fourth Industrial Revolution.

To date, a number of studies have identified the sources that impede gender balance improvement. The OECD [23] pointed to a range of external and internal barriers that present in all areas of the public domain, including: cultural barriers, structural barriers, lack of gender-disaggregated evidence and accountability mechanisms, and self-imposed barriers. The UNDP [29] revealed that while there is explicit evidence regarding a virtual cycle between economic growth and gender balance improvement, emerging countries cannot afford to overcome the constraints of low income. UNESCO [31] noted the limits of scientific resources in relation to women's initiatives. McKinsey & Company [17] stressed a clear link between gender equality in society and gender equality in the workplace as well as the proportion of women on executive committees and corporate performance.

Aligned with these increasing efforts regarding the points identified, and subsequent efforts aimed at providing effective solutions to eliminate impediments, a wealth of resources, good practices, organizational structures, and networks are already in place [10]. New initiatives have flourished in many areas [6].

However, given the institutional complexity of the issue, including considerable variety across nations, uniformed non-systematic approaches are hardly satisfactory in the achievement of a timely solution.

Moreover, a few papers have noted the significance of cultural dimensions in activating untapped female resources [2,4,27,40]. Hofstede [9] postulated that a nation's culture can be classified into five dimensions: “Power distance” (inequality), “Individualism” (the degree to which individuals are integrated into groups), “Masculinity” (the distribution of roles between the genders), “Uncertainty avoidance” (the extent to which a culture programs its members to feel either uncomfortable or comfortable in unstructured situations), and “Long-term orientation.” Wiles et al. [40] compared gender roles in magazine advertising in the Netherlands, Sweden and the US and identified that the “masculinity” of nations significantly influenced women's involvement in business. A similar observation was made by Daechun et al. [4] in their cross-cultural comparison of web advertisements between Korea and the US. Stedham et al. [27] also pointed out that in addition to “individualism” and “power distance,” “masculinity” clearly differentiated gender roles between Japan and the US. Carrasco et al. [2] supported a similar view in their analysis of the representation of women on boards in five European countries. All these analyses clearly identified the significance of cultural dimensions, particularly of “masculinity” and “individualism” in gender balance improvement (see Appendix 2 details of these concepts and survey results).

Furthermore, in line with the advancement of digital economies, the role of information and communication technology (ICT) in gender balance improvement has been broadly discussed. The United Nations [30] warned that while there was recognition of the potential of ICT as a tool for the promotion of gender equality and the empowerment of women, a “gender divide” had also been identified, reflected in the lower numbers of women accessing and using ICT compared with men. It also pointed out that unless this gender divide was specifically addressed, there was a risk that ICT might exacerbate existing inequalities between women and men, creating new forms of inequality. Webb et al. [39] alluded to similar dual possibilities. Moghaddam [19] maintained that identical roles for men and women were determined by cultural, social, and economic factors including ICT as a social product, and differed within and between cultures and countries. He stressed that ICT as a social product was not gender neutral, that ICT access and use were interwoven with socio-cultural issues, and that the gender gap was a product of all nations, albeit of a wider magnitude in developing countries. In light of these issues, Phumzile [25] highlighted the significance of ICT as a powerful means of advancing women's rights, empowerment, and gender equality, stressing that ICT use by women boosts countries' productivity and better meets women's socio-economic needs.

This paper was aimed at providing practical solutions in accordance with the institutional states of nations in the digital economy. It analyzed a possible trilateral co-evolution between economic growth, gender balance improvement, and digital innovation initiated by ICT advancement while taking into account the cultural dimensions of nations that block gender balance improvement.

Using a unique dataset representing the state of gender balance improvement in the function of economic growth, ICT advancement, and cultural dimensions, an empirical numerical analysis of 44 countries was undertaken. Through cluster analysis using the state of gender balance, income level, and the male-dominated cultural dimension, 44 countries were identified within one of the three clusters: emerging, industrialized, and with a specific culture.

It was found that while industrialized countries, such as Finland, have accomplished high performance in this trilateral co-evolution,

Table 1
Global rank of gender parity (2012–2016).

	1	2	3	4	G8 countries				Remarks
2016	Iceland	Finland	Norway	Sweden	DEU(13)	FRA(17)	GBR(20)	CAN(35)	Out of 144 countries
					USA(45)	ITA(50)	RUS(75)	JPN(111)	
2015	Iceland	Norway	Finland	Sweden	DEU(11)	FRA(15)	GBR(18)	USA(28)	idem 145
					CAN(30)	ITA(41)	RUS(75)	JPN(101)	
2014	Iceland	Finland	Norway	Sweden	DEU(12)	FRA(16)	CAN(19)	USA(20)	idem 142
					GBR(26)	ITA(69)	RUS(75)	JPN(104)	
2013	Iceland	Finland	Norway	Sweden	DEU(14)	GBR(18)	CAN(20)	USA(23)	idem 136
					FRA(45)	RUS(61)	ITA(71)	JPN(105)	
2012	Iceland	Finland	Norway	Sweden	DEU(13)	GBR(18)	CAN(21)	USA(22)	idem 135
					FRA(57)	RUS(59)	ITA(80)	JPN(101)	

* DEU: Germany, FRA: France, GBR: UK, CAN: Canada, ITA: Italy, RUS: Russia, JPN: Japan.
**Figures in parenthesis indicate rank.
Sources: The Global Gender Gap Report 2012–2016 (World Economic Forum, annual issues).

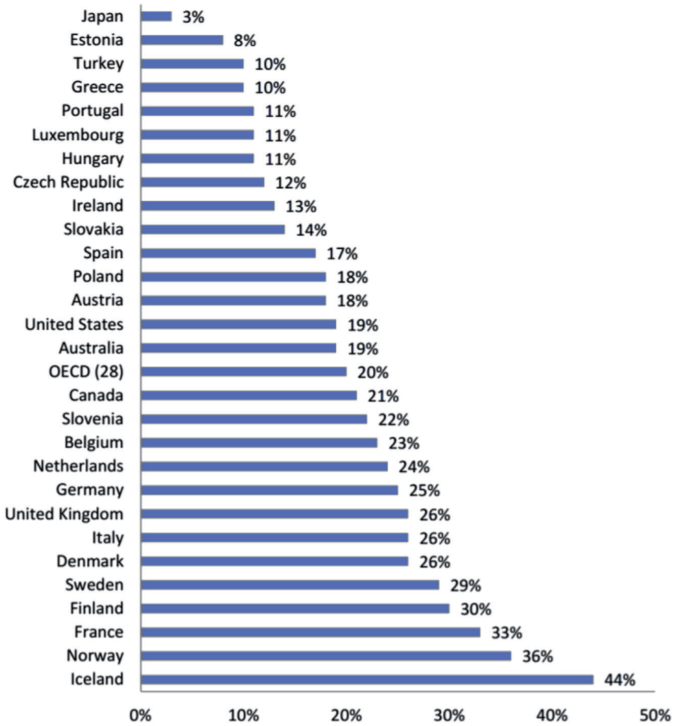


Fig. 1. Share of Women Board Members at Companies in the OECD 29 Countries (2015).
Source: Background Report, Conference on Improving Women's Access to Leadership [24].
Original sources: Database on Women and Men in Decision Making [5], Catalyst Census: Women Board Directors [3].

emerging countries have been constrained by low ICT advancement. Moreover, notwithstanding their high level of economy and ICT dependency, countries with a specific culture have been constrained by a traditional male-dominated culture, Japan being a typical case.

Based on these findings, there were several lessons that emerging economies and countries with a specific culture could learn from industrialized countries regarding success and failure in gender balance improvement.

It is suggested that ICT should be strategically advanced, depending on the state of what we refer to as "econo-cultural development" in constructing co-evolution with gender balance improvement.

A new practical approach for harnessing the potential resources for sustainable growth was thus explored.

This paper is organized as follows: Section 2 analyzes pathways to gender-balanced organizational leadership. Section 3 demonstrates gender-balanced leadership in the digital economy. Sections 4 and 5 address lessons from high-performance co-evolution in industrialized countries. Section 6 briefly summarizes noteworthy findings, implications, and suggestions for future studies.

2. Pathways to gender-balanced organizational leadership

2.1. The state of gender parity

Table 1 compares the global rank of gender parity over the period 2012–2016. It illustrates that while Iceland, Finland, Norway, and Sweden share the top four positions, Japan lags significantly behind. It is not only in the last position among G8 countries, but also lower than the 100th rank in all periods examined.

The contrast with respect to the state of gender parity corresponds to the share of female board members in companies that represents gender balanced corporate leadership [7,8,17,20,24]. Fig. 1 compares this share in the 29 OECD countries in 2015. It illustrates that Iceland, Finland, Norway, and Sweden which occupy the top global positions in the state of gender parity, also share the top five positions in terms of the share of female company board members, while Japan also ranks last in this domain. This

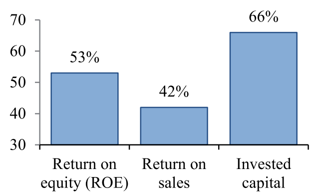


Fig. 2. Outperformance ratio of women board directors leadership in fortune 500 companies - comparison between highest and least share of WBDs (average in 2001–2004).
WBDs: Women board Directors.
Source: Catalyst, "corporate performance and Women's representation on boards [1].

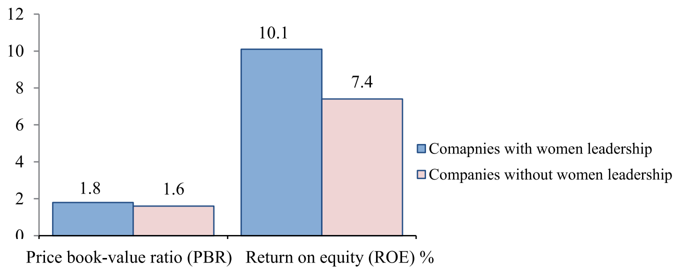


Fig. 3. Financial characteristics of companies with strong women leadership in MSCI world companies [20].
Source: MSCI ESG Research [20].

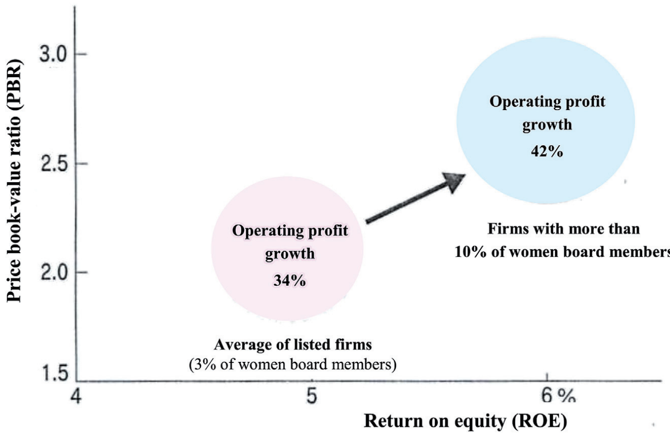


Fig. 4. Correlation between Share of Women Board Members and Business Performance in Japan's Firms (2015).
Circle size demonstrates the magnitude of operating profit growth.
Source: Nihon Keizai Shimbun [22].
All figures demonstrate significant corporate performance improvement by means of gender balance improvement, represented by the share increase in women board members.

correspondence suggests that the share of female company board members represents the state of gender balance. As reviewed earlier [16,17], demonstrated a clear link between the share of women board members, corporate performance, gender equality in the workplace, and gender equality in society. Gender equality in the workplace leads to higher economic performance, which in turn enhances gender equality in society.

2.2. Corporate performance improvement and gender-balanced leadership

Companies with a higher share of female board members experience higher financial performance.

Fig. 2 highlights this outperformance as 53%, 42%, and 66% higher in return on equity (ROE), return on sales, and invested capital, respectively, in Fortune 500 companies with the highest share of women board members compared with those of the lowest share.

A similar contrast can be observed in Fig. 3, which presents a similar comparison of premium returns and superior average valuation using price book-value ratios (PBR) and ROE in MSCI world companies. Companies with strong female leadership demonstrated higher performance than companies without, as 1.8% vs 1.6% and 10.1% vs 7.4%., respectively.

Fig. 4 presents further supportive evidence by comparing PBR, ROE, and operating profit growth between Japan's listed firms with a 3% proportion of women board members (average of listed firms) and those with more than a 10% proportion of women board members.

2.3. Intensity of gender balanced corporate leadership

2.3.1. Gender balance index

On the basis of the preceding review that an increase in the number of women board members contributes to the economic performance of a society, this sub-section assesses the effects of economic performance through gender balance improvement, the Gender Balance Index (GBI), which represents the state of gender balance and its affect on economic performance. Table 2 tabulates the GBI for 44 countries in 2013, with comparisons of similar values

Table 2
Gender balance index (GBI) in 44 countries (2013).

Country	Code	GMI (2013)	OECD (2015)*	WEF (2016)**
Norway	NOR	36.1	38	56
Sweden	SWE	27.0	27	41
Finland	FIN	26.8	28	43
France	FRA	18,3	33	49
South Africa	ZAF	17.9		
Denmark	DNK	17.2	24	35
Netherlands	NLD	17.0	25	32
Israel	ISR	15.7		
New Zealand	NZL	15.1		
Germany	DEU	14.1	24	33
Australia	AUS	14.0	19	24
USA	USA	14.0	19	24
Poland	POL	13.6	15	22
Canada	CAN	13.1	21	27
Turkey	TUR	12.7	9	11
UK	GBR	12.6	24	35
Austria	AUT	11.3	17	22
Switzerland	CHE	10.0	17	
Thailand	THA	9.7		
Hong Kong	HKG	9.5		
Spain	ESP	9.5	17	21
Belgium	BEL	9.2	23	30
Ireland	IRL	8.7	11	15
Czech Republic	CZE	8.6	7	14
China	CHN	8.4		
Italy	ITA	8.2	24	35
Philippines	PHL	7.9		
Greece	GRC	7.0	9	11
Singapore	SGP	6.9		
Malaysia	MYS	6.6		
India	IND	6.5		11
Peru	PER	6.3		
Columbia	COL	6.0		
Indonesia	IDN	6.0		
Mexico	MEX	5.8		
Brazil	BRA	5.1		
Russia	RUS	4.8		
Hungary	HUN	4.5	12	12
Taiwan	TWN	4.4		
Egypt	EGY	4.4		
Portugal	PRT	3.7	9	12
Chile	CHL	2.8		
Korea (Rep.)	KOR	1.9		
Japan	JPN	1.1	3	3

*Share of female board members at companies (%), **Value based on share of female in boards of publicly traded companies. Original sources are GBI: GMI Ratings' 2013 Women on Boards Survey [8], OECD: Background Report, Con-ference on Improving Women's Access to Leadership [24], and WEF: The Global Gender Gap Report 2016 [42].

surveyed by the OECD and WEF. The GBI depended on GMI Ratings' *2013 Women on Board Survey* [8] which includes data for 2013 on 5977 companies in 45 countries worldwide.[2]

In order to examine the reliability of the GBI, comparative analyses with similar data surveyed by the OECD and WEF were conducted. Fig. 5 compares these values with correlation analysis between the OECD data and the GBI as well as the WEF and the GBI. While there are number of differences in some countries' values (e.g., FRA, TUR, GBR, and ITA), as the three values did not depend on the same year or the same scope of companies, the GBI can be considered to represent the global gender balance position, with a reasonable correlation with those surveyed by the OECD and WEF.

Based on the foregoing examination, Fig. 6 demonstrates the 2013 GBI ranking for 44 countries.

[2] GBI covers 44 countries out of GMI Ratings' 45 countries by excluding Morocco due to unavailability of other relevant statistics.

2.3.2. Gender balance intensity

With an understanding that gender balance is sensitive to the income level of nations (e.g., Refs. [10,32,24]), and in order to compare a marginal GBI increase with an income level increase, Fig. 7 demonstrates gender balance intensity[3] by dividing the GBI by GDP per capita for the 44 countries (see Appendix 1 for details of the institutional states of the 44 countries).

Looking at Fig. 7 we note that while emerging countries with lower income levels, such as India, the Philippines, Indonesia, Thailand, and Egypt, demonstrate higher GBI intensity (higher marginal GBI increase by income increase), industrialized countries with higher income levels, such as European and North American countries, demonstrate relatively lower GBI intensity, suggesting that the GBI is not highly sensitive to income increases as in emerging countries. Interestingly enough is that highly industrialized countries such as Singapore, Switzerland, Korea, and Japan recorded the lowest ranks in GBI intensity, suggesting that their GBI is governed by particular cultural dimensions rather than income level.

2.4. Cultural barriers against gender balance

2.4.1. Cultural dimension of countries

As suggested in Fig. 7, GBI intensity is subject not only to income level but also to the cultural dimensions of countries. Among the cultural dimensions postulated by Hofstede [9], since "masculinity" (distribution of roles between the genders) and "individualism" (degree to which individuals are integrated into groups) are particularly significant for gender balance improvement, as reviewed earlier, it is considered that GBI intensity can be largely attributed to "masculinity" and "individualism" together with income level. Based on this understanding, intensified masculinity density (*IMD*), which represents a male-dominated society, is considered to impact substantially on GBI intensity. *IMD* can be estimated by the ratio of "masculinity" and "individualism intensity" as follows where individualism intensity is the ratio of "individualism" and income level.

$$\mathrm{IMD} = \frac{M}{{}^{I}\!/_{GDP\ per\ capita}} = \frac{M}{I} \cdot GDP\ pr\ capita$$

where M: Masculinity; I: Individualism; M/I: Intensity of male-dominated society.

Fig. 8 presents intensified masculinity density in 44 countries in 2013.

Fig. 8 demonstrates that besides the four countries recording the lowest GBI intensity (Singapore, Switzerland, Korea, and Japan), Hong Kong, Taiwan, and Austria recorded the highest *IMD* levels. Based on this observation, aiming at identifying cluster governing the GBI, Table 3 compares the correlation between *IMD* and GBI intensity, with variations of clustering between the four lowest GBI intensity countries (SGP, CHE, KOR and JPN) and seven countries (4 + HKG, TWN, and AUT).[4] Table 3 demonstrates that the cluster of four countries demonstrates statistically most significant.

Based on the foregoing comparative assessment, Figs. 9 and 10 compare the correlation between *IMD* and GBI intensity in 44 countries in 2013, with and without clusters. This comparison

[3] This intensity demonstrates marginal GBI increase by GDP per capita increase as follows: $\ln Y = a + \alpha \ln X + \beta \ln W$ (see Fig 16) $\alpha = \frac{\partial lnY}{\partial lnX} = \frac{\partial Y}{\partial X} \cdot \frac{X}{Y}$ $GBI\ intensity = \frac{Y}{X} = \frac{1}{\alpha} \cdot \frac{\partial Y}{\partial X}$ $where\ X:\ GDP\ per\ capita,\ W: Intensity\ of\ male\ dominated\ society,\ Y: GBI.$

[4] Since Fig. 7 demonstrates explicit clustering between MEX and FIN, countries with an intermediate GBI intensity level were clustered between FIN to JPN, excluding countries with the lowest GBI intensity level (4–7 countries).

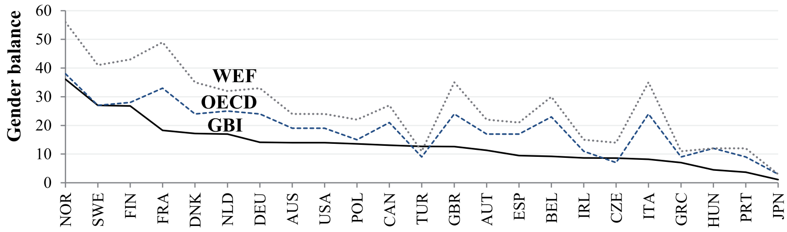


Fig. 5. Comparison of Gender Balance Measurement in 23 Countries.

$lnY = \underset{(-2.09)}{-0.789} + \underset{(8.56)}{1.12}\ lnOECD + \underset{(2.37)}{0.873}\,D \qquad \boldsymbol{adj.R^2}\ 0.757$

Y: GBI; D: Dummy variable (TUR = 1, others = 0).

$lnY = \underset{(-2.89)}{-0.920} + \underset{(10.61)}{1.053}\ \ln WEF + \underset{(3.00)}{0.936}\,D \qquad \boldsymbol{adj.R^2}\ 0.834$

D: Dummy variable (TUR = 1, others = 0).

The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

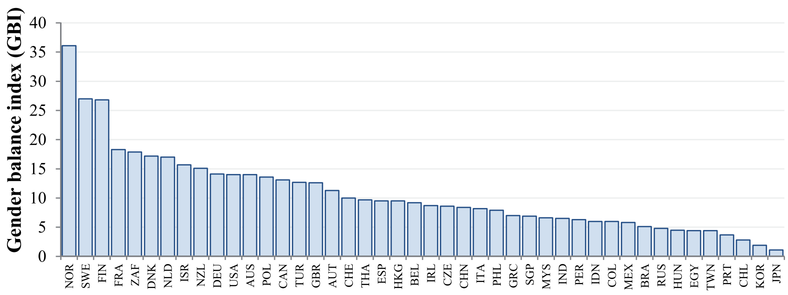


Fig. 6. Gender balance index (GBI) in 44 countries (2013).

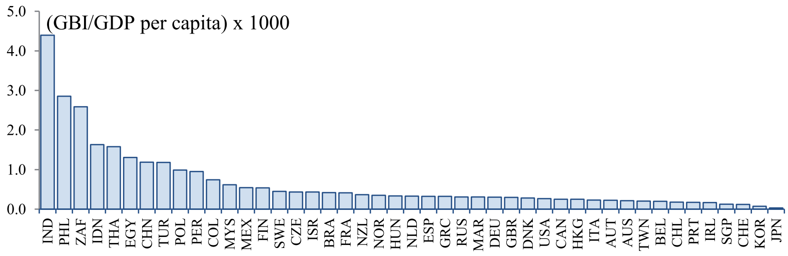


Fig. 7. Gender balance intensity in 44 countries (2013).

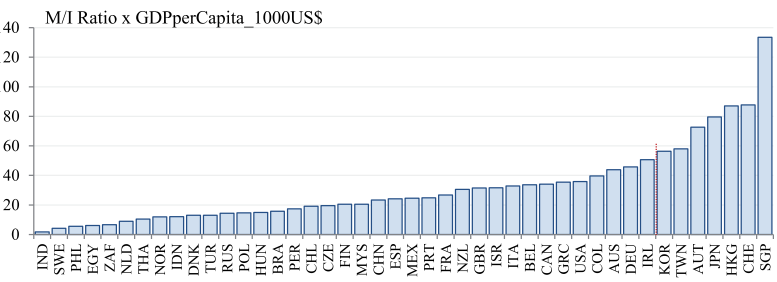


Fig. 8. Intensified masculinity density (*IMD*) in 44 countries (2013).

Table 3
Comparison of correlation between IMD and GBI intensity with variation of clustering of 44 countries (2013).

$$\ln \frac{GBI}{GDP\ per\ capita} = \underset{(3.13)}{0.926} - \underset{(-2.04)^{*}}{0.252} D_1 \ln IMD - \underset{(-6.71)}{0.639} D_{21} \ln IMD - \underset{(-8.59)}{0.657} D_{31} \ln IMD - \underset{(-3.88)}{1.184} D \quad adj.R^2\ 0.823 \quad AIC:\ -73.45$$

$$\ln \frac{GBI}{GDP\ per\ capita} = \underset{(3.13)}{0.912} - \underset{(-2.02)^{*}}{0.246} D_1 \ln IMD - \underset{(-6.84)}{0.634} D_{22} \ln IMD - \underset{(-8.66)}{0.659} D_{32} \ln IMD - \underset{(-3.83)}{1.173} D \quad adj.R^2\ 0.823 \quad AIC:\ -73.58$$

$$\ln \frac{GBI}{GDP\ per\ capita} = \underset{(3.04)}{0.857} - \underset{(-1.90)^{*}}{0.226} D_1 \ln IMD - \underset{(-6.94)}{0.613} D_{23} \ln IMD - \underset{(-8.80)}{0.667} D_{33} \ln IMD - \underset{(-3.70)}{1.132} D \quad adj.R^2\ 0.827 \quad AIC:\ -74.42$$

$$\ln \frac{GBI}{GDP\ per\ capita} = \underset{(2.94)}{0.778} - \underset{(-1.74)^{*}}{0.195} D_1 \ln IMD - \underset{(-7.15)}{0.584} D_{24} \ln IMD - \underset{(-9.31)}{0.695} D_{34} \ln IMD - \underset{(-3.46)}{1.034} D \quad adj.R^2\ 0.839 \quad AIC:\ -77.73$$

D_1 - D_3 and D are dummy variables.

D_1: (IND – MEX in Fig. 7) = 1, others = 0;
D_{21}: (FIN – JPN in Fig. 7) - D_{31} = 1, others = 0; D_{31}: HGK, AUT, TWN, **CHE, KOR, SGP, JPN** = 1, others = 0;
D_{22}: (FIN – JPN in Fig. 7) - D_{32} = 1, others = 0; D_{32}: HGK, AUT, **CHE, KOR, SGP, JPN** = 1, others = 0;
D_{23}: (FIN – JPN in Fig. 7) - D_{33} = 1, others = 0; D_{33}: HGK, **CHE, KOR, SGP, JPN** = 1, others = 0;
D_{24}: (FIN – JPN in Fig. 7) - D_{34} = 1, others = 0; D_{34}: **CHE, KOR, SGP, JPN** = 1, others = 0;
D: JPN and CHL = 1, others = 0.

The figures in parenthesis indicate t-statistics: all are significant at the 1% level except * 10%.

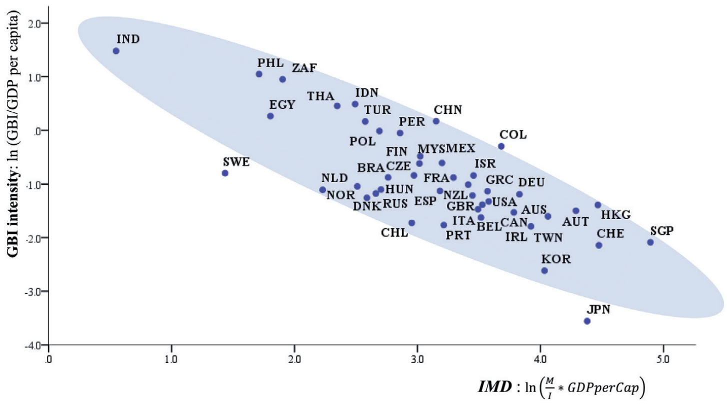


Fig. 9. Correlation between *IMD* and GBI intensity in 44 Countries without Clusters (2013).

$$\ln\left(\frac{GBI}{GDPperCapita}\right) = \underset{(6.56)}{1.903} - \underset{(-10.02)}{0.894} \ln\left(\frac{M}{I} * GDPperCap\right) - \underset{(-4.01)}{1.480} D_a + \underset{(2.95)}{1.090} D_b \quad adj.R^2\ 0.729$$

D_a and D_b are dummy variables. D_a: JPN, SWE = 1, others = 0; D_b: CHN, COL = 1, others = 0.
The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

demonstrates the statistical significance of the correlation with the clusters and validates the clustering discussed based on cultural dimensions.

With this understanding, Fig. 11 demonstrates three clusters of gender balance intensity in 44 countries in 2013. The 44 countries can be classified into three groups: emerging countries (EMC), industrialized countries (INC), and countries with a specific culture (CSC).

The EMC column includes 13 countries with a lower GDP per capita level than US$10,000 (except POL: US$13,700). The INC column includes 27 countries with a higher GDP per capita level than US$ 20,000 (except BRA (12,260), HUN (13,560), RUS (15,560), and CHL (15,710)). Finland occupies the top position in this group. The CSC group includes four countries with the lowest level of GBI intensity: SGP, CHE, KOR, and JPN. While they are highly industrialized, they incorporate the traditions of a male-dominated society.

These analyses demonstrate that gender balance improvement is subject not only to income level but also to some cultural dimension of countries, particularly "masculinity" and "individualism." Therefore, the issue of gender balance improvement should be discussed taking cultural elements into account.

3. Gender-balanced leadership in the digital economy

3.1. Co-evolution between the "econo-cultural" position, gender balance, and ICT advancement

Based on the understanding that harnessing women's potential by improving gender balance is essential for inclusive growth in the digital economy and that this issue is subject not only to income level but also to the cultural dimension - and following the findings obtained in the preceding section - the trilateral co-evolution between "econo-cultural development," gender balance improvement, and ICT advancement was analyzed by taking the "econo-

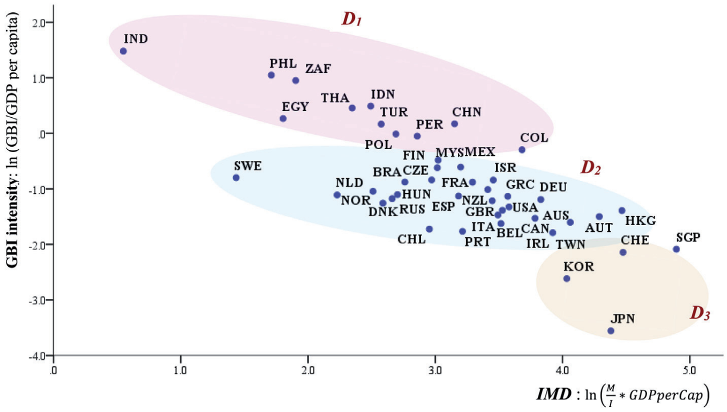


Fig. 10. Correlation between IMD and GBI intensity in 44 Countries with Clusters (2013).

$$\ln\left(\frac{GBI}{GDPperCapita}\right) = \underset{(2.94)}{0.778} - \underset{(-1.74)}{0.195}\ D_1 \ln\frac{M}{I}{*}GDPperCap - \underset{(-7.15)}{0.584}\ D_2 \ln\frac{M}{I}{*}GDPperCapita - \underset{(-9.31)}{0.695}\ D_3 \ln\frac{M}{I}{*}GDPperCapita - \underset{(-3.46)}{1.034}\ D \qquad adj.R^2\ 0.839$$

D_1- D_3 and D are dummy variables. D_1, D_2 and D_3 are correspond to D_1, D_{24} and D_{34} of Fig. 8, respectively.
D: JPN, CHL = 1, others = 0.
The figures in parenthesis indicate t-statistics: all are significant at the 1% level except * 10 %.

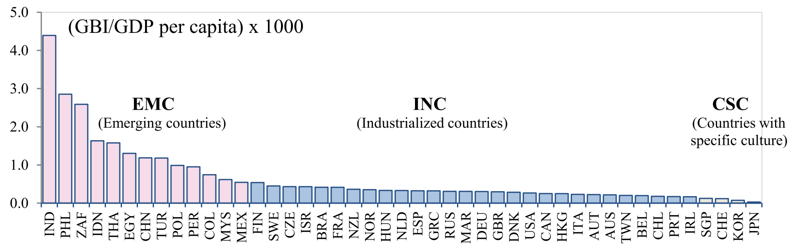


Fig. 11. Gender balance intensity in 44 countries by 3 clusters (2013).

cultural" position of respective countries into account. The GBI (Gender balance index) and the intensity of the male-dominated society (*IMS*: ratio of "masculinity" and "individualism") based on the cluster of EMC, INC, and CSC were used. "Econo-cultural development" was analyzed by means of income increase and improvement of the intensity of a male-dominated society.

Fig. 12 illustrates the dynamism inducing this trilateral co-evolution.

3.1.1. Contribution of gender balance improvement to economic growth

Fig. 13 illustrates the correlation between the GBI and GDP per capita, which is statistically significant. The EMC group demonstrates an extremely low elasticity[5] of gender balance improvement to GDP per capita, followed by the INC and CSC groups. This suggests that the EMC group pursues avenues toward economic growth other than through gender balance improvement. The higher income level of CSCs notwithstanding the lowest level of the GBI can be attributed to their highest elasticity and reveals the structural impediment blocking gender balance improvement.

3.1.2. Contribution of economic growth to ICT advancement

Fig. 14 illustrates the correlation between GDP per capita and ICT advancement, which is statistically significant. EMC, INC, and CSC share a similar level of elasticity, which suggests that all nations' ICT grows uniformly with income growth in the digital economy.

3.1.3. Gender balance improvement induced by ICT and blocked by the male-dominated society

While ICT advancement contributes to gender balance improvement, this improvement is blocked by cultural dimensions. Fig. 15 illustrates this multiple correlation, which is statistically significant.

CSCs demonstrate an extremely high negative elasticity of the intensity of male-dominated society to gender balance improvement. This can be a substantial source of the lowest level of gender balance improvement, notwithstanding a high level of income and

[5] Elasticity is the measurement of the responsiveness of an economic variable (X) to a change in Y. X elasticity to Y (elasticity of X to Y) ε_{YX} implies a 1% increase in X increases ε_{YX} % increase in Y and represents the efficiency of X as an inducement of Y.

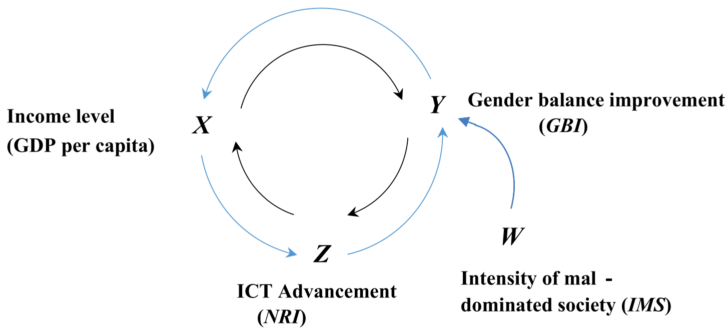


Fig. 12. Co-evolutionary Dynamism between the Econo-cultural Position, Gender Balance Improvement, and ICT Advancement.
GBI: Gender Balance Index, *NRI*: Networked Readiness Index, *IMS*: Intensity of male-dominated society (*M/I*).
Based on this dynamism, the following six co-evolutions were first analyzed:
1. $Y \rightarrow X$ Contribution of gender balance improvement to economic growth
2. $X \rightarrow Z$ Contribution of economic growth to ICT advancement
3. $Z, W \rightarrow Y$ Gender balance improvement induced by ICT and impeded by male-dominated society
4. $X, W \rightarrow Y$ Gender balance improvement supported by income growth and impeded by male-dominated society
5. $Z \rightarrow X$ ICT Contribution to income growth
6. $Y \rightarrow Z$ ICT Advancement stimulated by gender balance improvement.

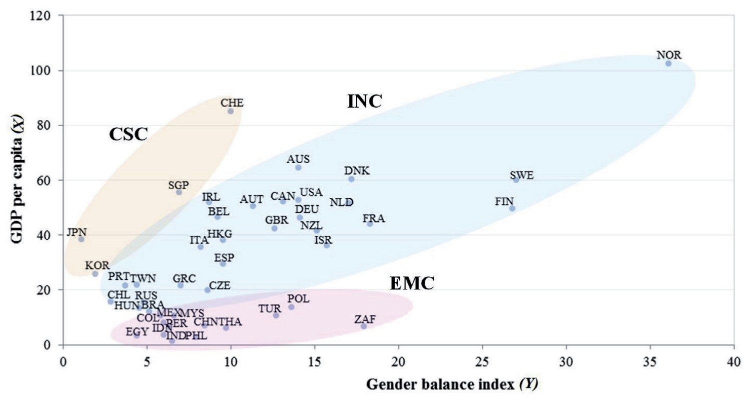


Fig. 13. Correlation between the GBI and GDP per Capita in 44 Countries (2013).

$$\ln X = \underset{(34.81)}{8.41} + \underset{(1.73)*}{0.21} D_1 \ln Y + \underset{(8.44)}{0.86} D_2 \ln Y + \underset{(7.60)}{1.26} D_3 \ln Y + \underset{(4.48)}{1.49} D_a - \underset{(-4.25)}{1.21} D_b \quad \boldsymbol{adj.R^2}\ 0.866$$

X: GDP per capita (x 10^3 US$); *Y*: Gender balance index, D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC and CSC, respectively.
D_a, D_b: Dummy variable (D_a: *JPN, KOR = 1*, others = 0. D_b: IND, PHL = 1, others = 0).
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level except * 10%.

ICT. EMCs represent the highest elasticity of ICT to this balance, expecting us of its gender balance improvement once they achieve ICT advancement.

3.1.4. Gender balance improvement supported by income growth and blocked by the male-dominated society

Similar to Fig. 15, while income increase contributes to gender balance improvement, this improvement is blocked by cultural dimensions. Fig. 16 illustrates this multiple correlation, which is also statistically significant.

Similar to Fig. 15, CSCs demonstrate an extremely high negative elasticity of the intensity of male-dominated society to gender balance improvement, as this is considered to be a substantial source of their lowest level of gender balance improvement, despite the high level of income and ICT. EMCs record the highest elasticity of income to this balance, expecting us of its gender balance improvement once they achieve growth. Considering this alongside Fig. 15, the construction of the co-evolutional cycle as *ICT advancement → income growth → gender balance improvement* would be the key strategy for sustainable growth in EMCs.

3.1.5. ICT contribution to income growth

Fig. 17 illustrates a correlation between ICT advancement and GDP per capita, which is also statistically significant. INCs demonstrate the highest elasticity of ICT advancement to GDP per capita increase, followed by CSCs with an almost similar level. EMCs lag behind the two groups, suggesting that they require further improvement in the introduction and utilization of ICT.

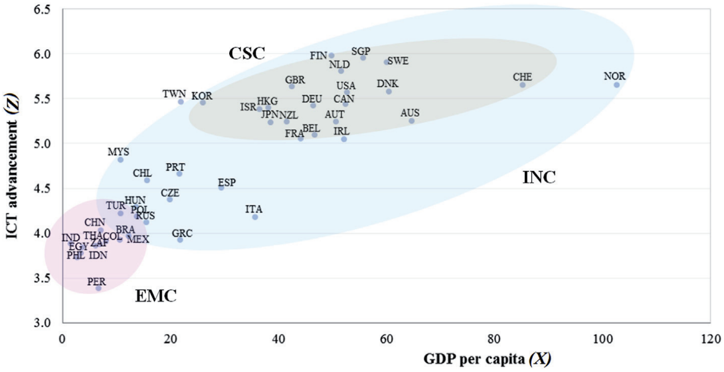


Fig. 14. Correlation between GDP per Capita and ICT Advancement in 44 Countries (2013).

$$lnZ = \underset{(1.58)*}{0.33} + \underset{(4.87)}{0.12}\, D_1 lnX + \underset{(6.10)}{0.12}\, D_2 lnX + \underset{(6.50)}{0.13}\, D_3 lnX \qquad \textbf{adj.}\boldsymbol{R^2}\ 0.739$$

Z: ICT advancement (*NRI*); *X*: GDP per capita (x 10^3 US$), D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC and CSC, respectively.
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level except * 10%.

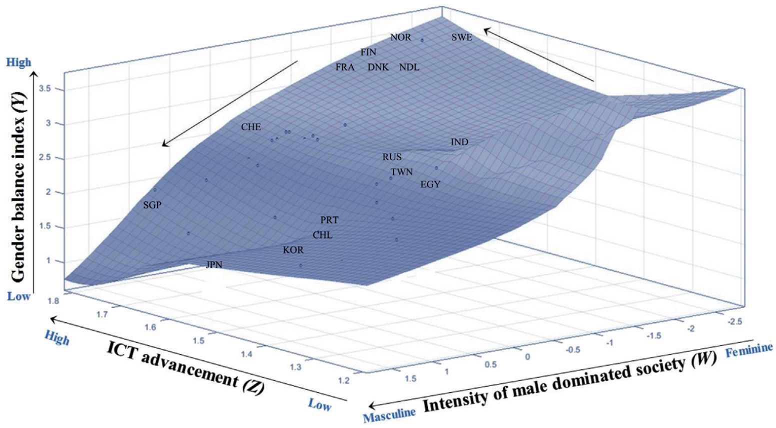


Fig. 15. Correlation between ICT Advancement, Intensity of Male-Dominated Society, and the GBI in 44 Countries (2013).

$$\ln Y = \underset{(-1.30)**}{-1.19} + \underset{(3.93)}{2.63}\, D_1 lnZ + \underset{(3.70)}{2.12}\, D_2 lnZ + \underset{(3.62)}{2.05}\, D_3 lnZ \qquad \textbf{adj.}\boldsymbol{R^2}\ 0.734$$
$$\underset{(-1.96)*}{-0.41}\, D_1 lnW - \underset{(-4.01)}{0.37}\, D_2 lnW - \underset{(-4.26)}{2.49}\, D_3 lnW + \underset{(3.55)}{1.64}\, D$$

Y: Gender balance index; *W*: Intensity of male dominated society (*M/I*); *Z*: ICT advancement (*NRI*); all are rogarithymic value.
D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC and CSC, respectively.
D: Dummy variable (SGP = 1, others = 0)
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level except * 5% and ** 15%.

3.1.6. *ICT advancement stimulated by gender balance improvement*

Fig. 18 illustrates a correlation between the GBI and ICT advancement, which is also statistically significant. INCs record the highest elasticity of gender balance improvement to ICT advancement, followed by CSCs and EMCs. This suggests EMC need dramatic advancements in women's ICT involvement and an increase in women's contribution to ICT advancement through effective ICT utilization and development.

3.2. *Consequences of co-evolutionary dynamism*

Fig. 19 illustrates trilateral co-evolutionary dynamism induced by the foregoing six co-evolutions.

Table 4 summarizes the elasticities of the trilateral co-evolution.

Looking at Table 4, we note that while EMCs demonstrate the highest level of elasticity of GDP per capita to gender balance improvement ($X \rightarrow Y$), due to an extremely low level of elasticity of gender balance improvement to ICT advancement ($Y \rightarrow Z$) and elasticity of ICT to GDP per capita ($Z \rightarrow X$), their performance regarding the trilateral co-evolution results in a low level. Contrary to this low performance by EMCs, INCs demonstrate explicit performance in their trilateral co-evolution. This can be attributed to their outperformed elasticity of gender balance improvement to ICT advancement ($Y \rightarrow Z$), supported by the lowest impediment of

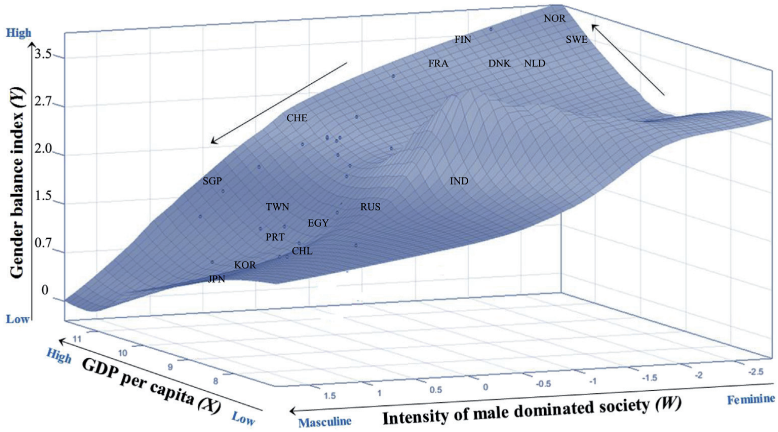


Fig. 16. Correlation between GDP per Capita, Intensity of Male-Dominated Society, and the GBI in 44 Countries (2013).

$$\ln Y = \underset{(-2.53)}{-2.35} + \underset{(5.13)}{0.56}\, D_1 lnX + \underset{(4.91)}{0.44}\, D_2 lnX + \underset{(4.92)}{0.41}\, D_3 lnX \quad \boldsymbol{adj.R^2}\ 0.794$$
$$\underset{(-2.60)*}{-0.48}\, D_1 lnW - \underset{(-3.87)}{0.32}\, D_2 lnW - \underset{(-1.92)**}{0.87}\, D_3 lnW + \underset{(-4.28)}{1.04}\, D$$

Y: Gender balance index; *W*: Intensity of male dominated society (*M/I*); *X*: GDP per capita; all of which represent logarithmic values.
D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC and CSC, respectively.
D: Dummy variable (JPN, CHL = 1, others = 0)
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level except * 5% and ** 15%.

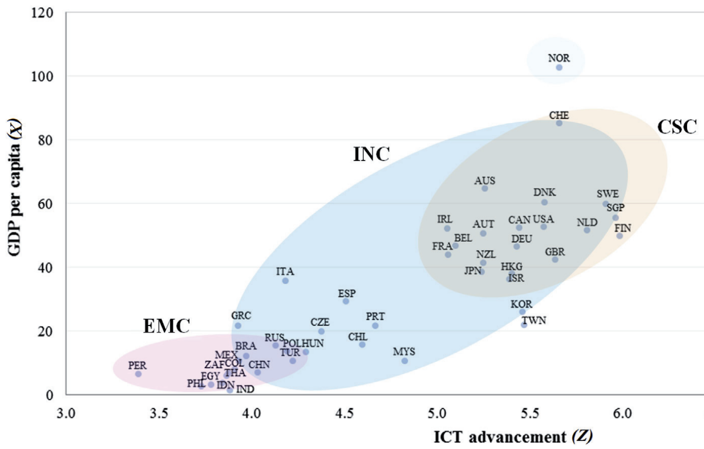


Fig. 17. Correlation between ICT Advancement and GDP per Capita in 44 Countries (2013).

$$lnX = \underset{(5.30)}{4.631} + \underset{(4.66)}{3.028}\, D_1 lnZ + \underset{(6.57)}{3.579}\, D_2 lnZ + \underset{(6.84)}{3.564}\, D_3 lnZ \quad \boldsymbol{adj.R^2}\ 0.815$$

The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level
X: GDP per capita (x 10^3 US$); *Z*: ICT advancement (*NRI*),
D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC, and CSC, respectively.
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level.
NOR is not included in the analysis.

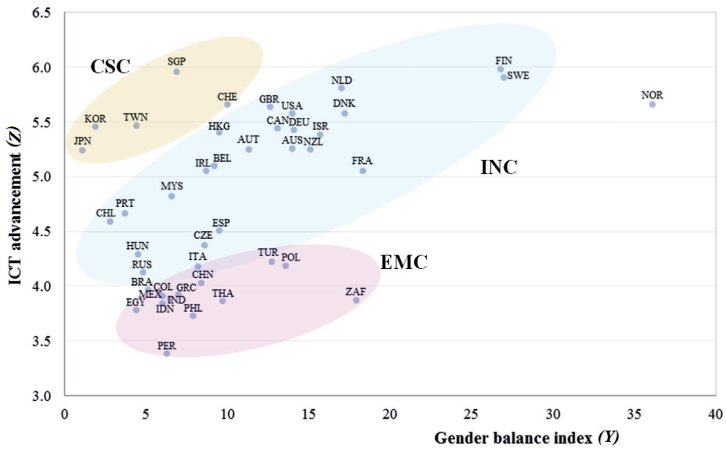


Fig. 18. Correlation between the GBI and ICT Advancement in 44 Countries (2013).

$lnZ = \underset{(23.16)}{1.227} + \underset{(2.30^{*})}{0.061}\, D_1 lnY + \underset{(7.19)}{0.162}\, D_2 lnY + \underset{(2.39^{*})}{0.089}\, D_3 lnY + \underset{(5.47)}{0.351}\, D \quad \boldsymbol{adj.R^2}\ 0.771$

Y:Gender balance index; *Z*: ICT advancement *(NRI)*, D_1, D_2 and D_3: Coefficient dummy variables corresponding to EMC, INC and CSC, respectively.
D: Dummy variable (*CHE, JPN, KOR, SGP, TWN* = 1, others = 0).
The figures in parenthesis indicate *t*-statistics: all are significant at the 1% level except * 2%.
NOR is not included in the analysis.

IMS ($W \rightarrow Y$). Finland, which has the leading position among INCs in terms of the highest GBI intensity, as demonstrated in Fig. 11, may provide insights into increasing this elasticity. CSCs demonstrate incredibly high impediments of IMS in GBI improvement ($W \rightarrow Y$), resulting in the lowest GBI intensity, as demonstrated in Fig. 11, notwithstanding the high level of elasticities of GBI and ICT to increases in GDP per capita ($Y \rightarrow X$ and $Z \rightarrow X$).

These findings serve as a call to learn from INCs, particularly Finland, possible measures to improve ICT-driven economic growth for EMCs and, in relation to IMS, to improve ICT advancement for CSCs [38].

4. Strategy for emerging countries – ICT-driven economic growth

Considering the significance of the role of ICT in gender balance improvement [30,39,19,25], Fig. 20 compares women's dependency on the Internet use (*WIU*). As anticipated, EMCs record an extremely low levels of this dependency (half the level of the other 2 groups). This fact suggests the significance of lessons from successful countries for further improving women's initiative and involvement in ICT development and utilization.

Since *WIU* largely depends on ICT advancement, as demonstrated in Table 5, ICT advancement would be the fundamental solution to enhance *WIU,* leading to women's further direct contribution to gender balance improvement [30].

This endorses the preceding postulate that the construction of a co-evolutional cycle as ICT advancement $\rightarrow$income growth$\rightarrow$ gender balance improvement would be the key sustainable growth strategy for EMCs.

Based on this understanding, provided that ICT incorporates a potential that enables all nations to attain a similar income level, Table 6 and Fig. 21 estimate possible ICT-driven income (GDP per capita) growth trajectories in EMCs, INCs and CSCs. The estimation was conducted by utilizing hybrid logistic growth model depicting identical development trajectories depending on countries' respective "econo-cultural" positions [21].

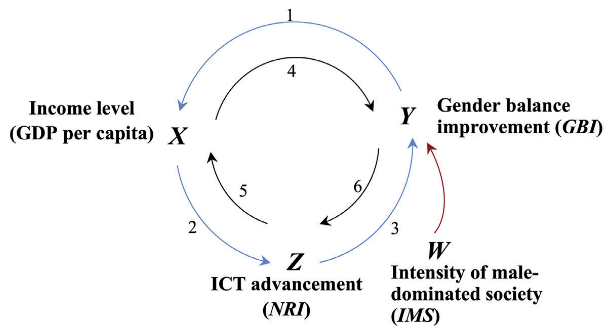
Given sufficient ICT advancement, Fig. 21 suggests that EMCs' ICT-driven income increase trajectory incorporates a rapid growth potential as it remains in the "early minority stage," with the potential of acceleration of its diffusion velocity [26].

From this observation, Fig. 22 estimates the potential income growth rate driven by ICT advancement.[6] Fig. 22 demonstrates that EMCs incorporate an extremely high growth potential (3 times higher than INCs and CSCs).

These analyses support the preceding postulate regarding co-evolutional cycles as ICT advancement $\rightarrow$income growth $\rightarrow$gender balance improvement would be the key sustainable growth strategy for EMCs and highlights the significance of ICT advancement for EMCs in triggering this virtuous cycle.

Given the shortage of indigenous capacity for due ICT advancement initiated by EMCs themselves, INCs and CSCs are expected to extend their ICT advancement capacity to those of EMCs in terms of growth; thus, they can expect to harness the vigor of EMCs' growth. Therefore, a co-evolutionary acclimatization structure can be expected to be constructed by harnessing the vigor of counterparts [19,30,36].

[6] The ICT-driven income logistic growth model can be depicted as follows: $\frac{dX}{dZ} = aX\left(1 - \frac{X}{N}\right)$ This can be developed to the following ICT-driven income growth rate: $\frac{\frac{dX}{dZ}}{X} = a\left(1 - \frac{X}{N}\right)$ where *X*: Income (GDP per capita), *Z*: ICT advancement, and *N*: carrying capacity.



		adj. R^2
1.	$\ln X = \underset{(34.81)}{8.41} + \underset{(1.73)^{***}}{0.21}\, D_1 lnY + \underset{(8.44)}{0.86}\, D_2 lnY + \underset{(7.60)}{1.26}\, D_3 lnY + \underset{(4.48)}{1.49} D_a - \underset{(-4.25)}{1.21} D_b$	0.866
2.	$\ln Z = \underset{(1.58)^{***}}{0.33} + \underset{(4.87)}{0.12}\, D_1 lnX + \underset{(6.10)}{0.12}\, D_2 lnX + \underset{(6.50)}{0.13}\, D_3 lnX$	0.739
3.	$\ln Y = \underset{(-1.30)^{****}}{-1.19} + \underset{(3.93)}{2.63}\, D_1 lnZ + \underset{(3.70)}{2.12}\, D_2 lnZ + \underset{(3.62)}{2.05}\, D_3 lnZ$ $\underset{(-1.96)^{**}}{-0.41}\, D_1 lnW - \underset{(-4.01)}{0.37}\, D_2 lnW - \underset{(-4.26)}{2.49} D_3 lnW + \underset{(3.55)}{1.64} D_e$	0.734
4.	$\ln Y = \underset{(-2.53)}{-2.35} + \underset{(5.13)}{0.56}\, D_1 lnX + \underset{(4.91)}{0.44}\, D_2 lnX + \underset{(4.92)}{0.41}\, D_3 lnX$ $\underset{(-2.60)}{-0.48}\, D_1 lnW - \underset{(-3.87)}{0.32}\, D_2 lnW - \underset{(-1.92)^{**}}{0.87} D_3 lnW - \underset{(-4.28)}{1.04} D_c$	0.794
5.	$\ln X = \underset{(5.30)}{4.63} + \underset{(4.66)}{3.03}\, D_1 lnZ + \underset{(6.57)}{3.58}\, D_2 lnZ + \underset{(6.84)}{3.56}\, D_3 lnZ$	0.815
6.	$\ln Z = \underset{(23.16)}{1.23} + \underset{(2.30)^{*}}{0.06}\, D_1 lnY + \underset{(7.19)}{0.16}\, D_2 lnY + \underset{(2.39)^{*}}{0.09}\, D_3 lnY + \underset{(5.47)}{0.35} D_d$	0.771

Fig. 19. Co-evolutionary Dynamism between the "Econo-cultural" Position, Gender Balance Improvement, and ICT Advancement in 44 countries (2013).
D: Dummy variables - D_1, D_2, D_3 (EMC, INC, CSC = 1, others = 0, respectively), D_a (JPN, KOR = 1, others = 0), D_b (IND, PHL = 1, others = 0), D_c (JPN, CHL = 1, others = 0), D_d (CHE, JPN, KOR, SGP, TWN = 1, others = 0), D_e (SGP = 1, others = 0).
The figures in parenthesis indicate t-statistics: all are significant at the 1% level except *2
%, **5%, ***10% and ****20%.

Table 4
Elasticities of Co-evolution in 44 countries (2013).

	Emerging countries (EMC)	Industrialized countries (INC)	Countries with specific culture (CSC)
1 $Y \to X$	0.21	0.86	1.26
2 $X \to Z$	0.12	0.12	0.13
3 $Z \to Y$	2.63	2.12	2.05
$W \to Y$	−0.41	−0.37	−2.49
4 $X \to Y$	0.56	0.44	0.41
$W \to Y$	−0.48	−0.32	−0.89
5 $Z \to X$	3.03	3.58	3.56
6 $Y \to Z$	0.06	0.16	0.09

X: Income level (GDP per capita), *Y:* Gender balance improvement (*GBI*).
Z: ICT advancement (*NRI*), *W*: Intensity of male-dominated society (*IMS*).

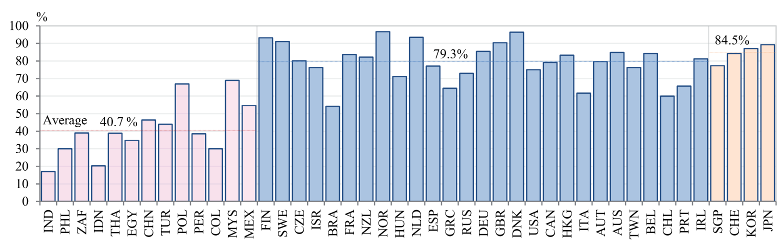


Fig. 20. Percentage of women using the internet in 44 countries (2013).
Source: ITU [10].

Table 5
Correlation between ICT advancement and Women's use of the internet (2013).

$$lnWIU = \underset{(7.13)}{2.576} + \underset{(2.86)}{0.770}\, D_1 lnNRI + \underset{(4.91)}{1.101}\, D_2 lnNRI + \underset{(5.01)}{1.080}\, D_3 lnNRI \qquad \textit{adj. } R^2 \ 0.805$$

where *WIU*: Women's dependency on the Internet use, and *NRI*: Networked readiness index.

The figures in parenthesis indicate t-statistics: all are significant at the 1% level.

Table 6
ICT-driven income growth trajectory in 44 countries (2013).
$X = \frac{N}{1+b_1 D_1 e^{-a_1 D_1 Z} + b_2 D_2 e^{-a_2 D_2 Z} + b_3 D_3 e^{-a_3 D_3 Z}} + cD_c + dD_d$

N	D_1		D_2		D_3		D		adj. R^2
	a_1	b_1	a_2	b_2	a_3	b_3	c	d	
71.764 (3.33)	2.519 (1.14**)	2.079×10^5 (1.37*)	1.335 (2.70)	0.736×10^3 (3.63)	1.811 (1.41*)	1.724×10^4 (1.47*)	37.610 (7.45)	−24.189 (-4.10)	0.911

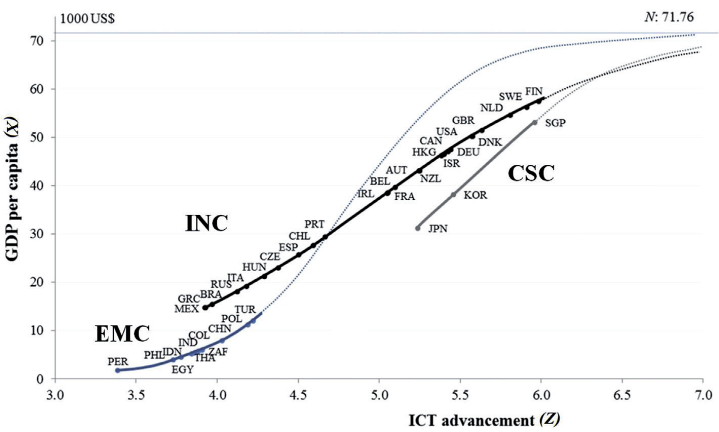


Fig. 21. Prospects of ICT-driven Income Growth Trajectories in 39 Countries.
39 countries excluding 5 countries treated D_c and D_d in Table 6 (NOR, CHE, AUS, TWN and MYS) are analyzed.

5. Strategy for countries with a specific culture − IMS and the improvement of ICT advancement

Realizing an explicit contrast between industrialized countries (INCs) and countries with a specific culture (CSCs) regarding gender balance improvement notwithstanding the non-substantial differences of income and ICT advancement levels, we have learned the following. It is essential for CSCs to learn extensive lessons from INCs in relation to gender-balanced organizational leadership, particularly ICT-driven trilateral co-evolution in enabling ICT

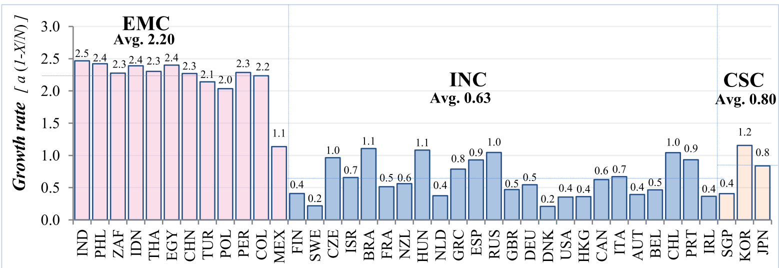


Fig. 22. Comparison of Growth Rate in 39 Countries (2013).

Growth rate is depicted by $\frac{dX/dZ}{X} = \frac{\Delta X}{X} = a\left(1 - \frac{X}{N}\right)$ where *X:* GDP per capita, *Z:* ICT advancement (*NRI*),*N:* Carrying capacity, *and a*: coefficient (diffusion velocity). NOR, CHE, AUS, TWN and MYS are not included.

Table 7
Contrast between Finland and Japan in gender-balanced organization leadership (2013).

		Finland	Japan	Reference
State of gender parity		2	105	Global rank (WEF [41])
Gender balance improvement based on of the state of		26.8	1.1	GBI [8],
women board members		28.0*	3.0*	OECD [24] %
		43.0**	3.0**	WEF [42]
GDP per capita (US$1000)		49.8	38.6	IMF [11]
Institutional systems	Individualism	63	46	Hofstede Cultural Index
	Masculinity	26	95	([9] state)
	Mas./Ind. ratio	0.41	2.07	
Individual women using the Internet (%)		93.2	89.3	ITU [13]
Networked Readiness Index		1	21	Global rank (WEF [41])

*: 2015, **: 2016.

Table 8
Trends in the share of women directors in Finland and Japan (2001–2016) - %.

Finland																
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average growth rate
5.0	6.0	7.0	8.5	10.5	12.0	13.5	15.0	16.0	18.0	19.0	21.5	22.5	23.0	24.0	25.0	11.6% *p.a*
Japan																
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average growth rate
3.6	4.5	4.6	5.0	5.1	5.8	6.5	6.6	7.2	7.0	8.1	8.5	8.9	9.4	9.8	10.3	11.6% *p.a*

advancement while improving the intensity of the male-dominated society (*IMS*).

In this context, the contrasting trajectories between Finland (the leading INC) and Japan (typical among CSCs) may provide insightful suggestions for CSCs in terms of *IMS improving ICT advancement* trajectory management.

With this in mind, Table 7 demonstrates contrast between Finland and Japan in gender balanced organization leadership.

Based on this contrasting structure, institutional sources leading to contrasting trajectories with respect to women's leadership in the two countries were analyzed.

Table 8 and Fig. 23 demonstrate trends in the share of women directors in both countries over the period 2001–2016. It should be noted that due to differences between the surveys and corporate promotion systems between the two countries (since both trends are not necessarily dependent on the same scope of companies, and neither do they represent the same hierarchical position in the company), Table 8 and Fig. 23 should be compared by focusing on their trends rather on absolute values. Traditionally in Japan, directors are classified on a lower hierarchy than board members,[7] while much closer in Finland (almost same as the board members in this survey). Furthermore, contrary to Finland's scope of companies covering only listed companies, Japan's survey was based on all companies with more than 5 employees (private companies) or 10 employees (public companies), including many SMEs whose corporate hierarchy system did not necessarily correspond to that of the listed companies.

Some ten years ago, the corporate boards of large companies were dominated by men. Since then, the situation has changed considerably in Finland, as demonstrated in Table 8 and Fig. 23. Both the corporate sector and the Finnish government have contributed to a substantial increase in women's participation on

[7] The share of women executive officers in Japan in 2011 consisted of: (i) 15.3% senior staff, (ii) 8.1% directors, and (iii) 5.1% general managers. Board members in the Finnish hierarchy are specific senior members from the latter category.

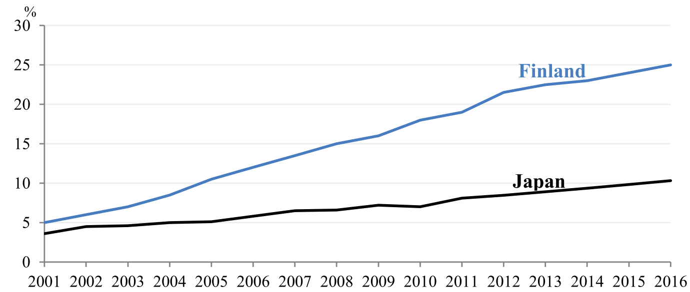


Fig. 23. Trends in the share of women directors in Finland and Japan *(2001–2016)* - %.s ources: Same as Table 8.

corporate boards [7]. The number of women directors in Finland's listed companies is among the highest in the world, as demonstrated in Figs. 5 and 6. Finland's progress has been achieved without quota legislation. It was initiated by companies' interest in creating a balance, whereby the considerable number of higher educated women with excellent ICT skills (Fig. 20) and women's share in the workforce would also be reflected at the managerial level. In this way, companies could benefit from the best professionals as their board members and among executives. Based on this self-propagating virtuous cycle, a revised Corporate Governance Code entered into force in January 2016, thus accelerating the virtuous cycle by encouraging companies functional diversity measures [7].

This virtuous cycle can be attributed to the following co-evolution dynamism between gender balance improvement and ICT advancement as:

Awaking women's potential ability in higher education with excellent ICT skills → encouraging them to contribute to higher functional ICT development and utilization in their companies → leading to them being qualified managers → gaining a higher reputation for women → inducing further ICT advancement.

Contrary to Finland's conspicuous gender balance improvement, Japan is reported as one of the worst-ranking industrialized countries regarding women's representation, as demonstrated in Figs. 5 and 6.

Japanese Prime Minister Shinzo Abe set a goal to increase the percentage of women in executive positions in Japanese companies to more than 30% by 2020. However, Japan's pace of improvement

Table 9
Comparison of self-propagating function incorporating in Finland and Japan (2001–2016).

		N_k	a	b	a_k	b_k	$adj.R^2$
Finland	***SLG***	28.60 (32.31)	0.23 (17.63)	1.06 (28.60)			0.996
	LGDCC	44.84 (8.57)	0.29 (88.90)	3.91 (7.34)	0.05 (5.15)	1.11 (5.33)	0.999
Japan	***SLG***	18.15 (4.11)	0.10 (5.59)	2.95 (3.57)			0.990
	LGDCC	21.28 (8.60)	0.13 (2.78)	1.43 (3.10)	0.07 (0.01)#	1.04 (0.01)#	0.990

Y(z): Share of women directors (%): N_k: carrying capacity; *Z*: ICT advancement; *a, b*, a_k, b_k: coefficients. Figures in parenthesis indicate t-statistics: significant at the 1% level except #: in-significant level.

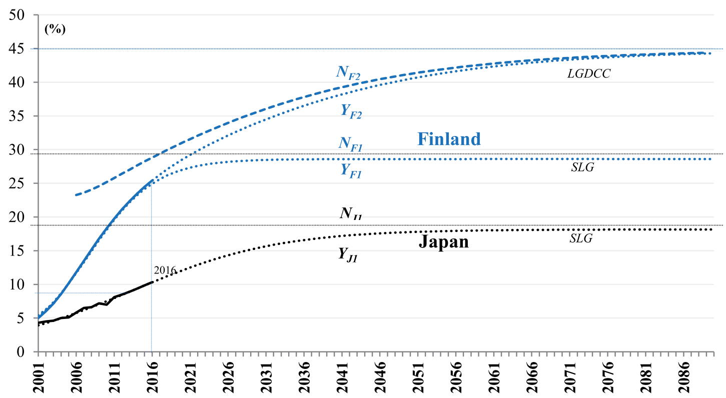


Fig. 24. Trends and Prospects of Women Directors Share in Finland and Japan - %.
Y_1: Trajectory without self-propagating function. Y_2: Trajectory with self-propagating function.
N_1: Carrying capacity in *SLG*. N_2: Carrying capacity in *LGDCC*.

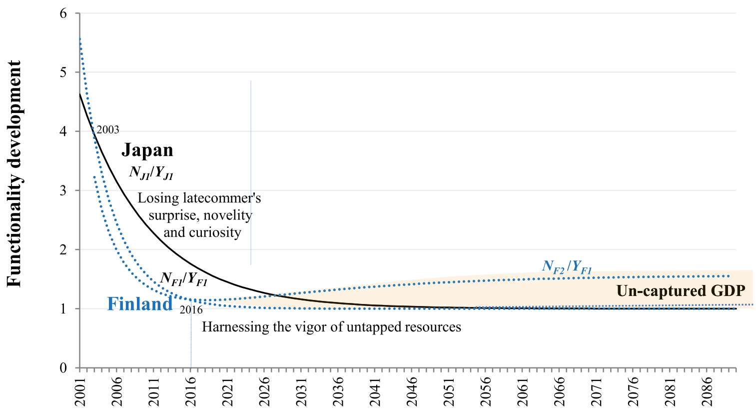


Fig. 25. Trends and prospects of functionality development by increasing women directors share in Finland and Japan.

was much slower than Finland's as demonstrated in Table 8. It was revealed that the institutional sources blocking Japan's improvement can be attributed to (i) the small number of female employees in the initial stage of employment (56%); (ii) the shortage of capable women possessing sufficient knowledge, experiences and decision making ability (47%); (iii) while there are women with potential capability, they have not yet satisfied sufficient necessary experiences for their positioning (30%); (iv) the majority of women retire before being promoted to board membership (26%); and (v) qualified women do not require promotion (17%) (Ref. [28]: The figures in parentheses indicate the share of multiple answers). All these attributes result from impediments by an ingrained male-dominated society.

Based on these observations, aiming at identifying the effects of "econo-cultural" systems contrasting ICT-driven gender balance improvement trajectories in the two countries, the incorporation of a self-propagating function in the respective trajectories was examined. Since this self-propagating function can be considered a core function of ICT [33–35], incorporation of this function demonstrates that gender balance improvement has been accomplished in a co-evolutionary manner.

As this self-propagating function can be attributed to its adaptability to ICT-driven logistic growth within a dynamic carrying capacity (*LGDCC*) function that increases functionality as grows, rather than the simple logistic growth (*SLG*) function that fades out functionality as grows [33], the fitness of two countries' *LGDCC* trajectories was compared.

Table 9 summarizes this comparison. Here, while Finland demonstrates a fit to ICT-driven *LGDCC*, Japan fits to a simple logistic growth (*SLG*) without this self-propagating feature.

Based on this analysis, Fig. 24 estimates the prospects of the share of women directors in Finland and Japan. Fig. 24 suggests that while the share of women directors remains 18% in Japan (Y_{J1}), Finland can expect to increase to levels as high as 45% (Y_{F2}). This high level can be attributed to the incorporation of the self-propagating function, without which the level would remain at 29% (Y_{F1}).

This contrast suggests the significance of the self-propagating function for sustainable gender balance improvement in the digital economy.

Fig. 25 illustrates the dynamism emerging as a result of this self-propagating function.

The self-propagating function can be attributed to the dynamism of increases in functionality development (*FD*) as growth increases (*Y* increase) [33]. *FD* can be estimated by the ratio of *N* and *Y* [34] where *N*: carrying capacity (N_1 by *SLG*, N_2 by *LGDCC*) and *Y*: share of women director (Y_1 by *SLG*, Y_2 by *LGDCC*).

Due to its traditional high intensity regarding its male-dominated society, Japan depends on *SLG*. Consequently, its *FD* (N_{J1}/Y_{J1}) continues to decline, resulting in a loss of latecomer surprise, novelty, and curiosity. On the contrary, Finland shifted from *SLG* to *LGDCC* in 2016, and its *FD* transformed from N_{F1}/Y_{F1} to N_{F2}/Y_{F1} in 2016, changing from a declining to an increasing trend.

Factors contrasting this FD decline in Japan and its increase in Finland can be identified as summarized in Table 10.

The lifting power of this FD increase can be attributed to the incorporation of the self-propagating function demonstrated by Finland in its *IMS improving ICT advancement*: *employment of higher educated women with excellent ICT skills → contribution to highly functioning ICT development and utilization in companies → leading to qualified management → gaining women's high reputation → further improvement of IMS.*

The discrepancy between N_{F1}/Y_{F1} and N_{F2}/Y_{F1} in Finland which has been remarkable from 2016, triggered by its shift from *SLG* to *LGDCC* can be considered similar to un-captured GDP [35,36]. Thus, Finland has been able to harness the vigor of women's potential as untapped economic resources and has explored the foregoing *IMS improving ICT advancement* trajectory.

ICT-driven "econo-cultural" disruptive innovation thus nurtures un-captured GDP, which corresponds to such business models as harnessing the vigor of untapped resources [36,37].

6. Conclusion

In light of the increasing significance of harnessing the vigor of women's potential in digital economies that are rapidly aging, an empirical numerical analysis focusing on the trilateral co-evolution between "econo-cultural development," gender balance improvement, and ICT advancement in 44 countries was attempted. Furthermore, the study aimed to present success lessons from well-balanced countries to countries incorporating structural constraints for balance improvement. To do this, a comparative analysis

Table 10
Factors decreasing and increasing functionality development in ICT-driven gender balance improvement in Japan and Finland.

Japan's FD decrease	Loss of identity, fresh attractiveness and latecomer surprise, novelty, and curiosity; the fading of fresh impacts that were initially expected; emerging disappointment.
Finland's FD increase	Exploring new identical, qualified, and epoch-making contributions leading to further gains in attractiveness and fresh impacts; adding new value; breaking the glass ceiling.

of ICT-driven gender balance improvement trajectories in Finland and Japan was conducted.

Consequently, the following noteworthy findings were obtained:

Gender balance improvement can be monitored using the Gender Balance Index (GBI) to ascertain the share of women on boards, which represents the state of gender parity. Since gender balance improvement is influenced by income level, gender balance intensity (GBI/GDP per capita) can be an effective supportive tool in identifying the state of gender balance improvement.

Furthermore, gender balance improvement is subject not only to income level but also to cultural dimensions, particularly to "muscularity" and "individualism." Taking these dimensions into account, the gender balance intensity level in 44 countries can be classified into emerging countries (EMC), industrialized countries (INC), and countries with a specific culture based particularly on the traditions of a male-dominated society (CSC).

INCs demonstrates explicit performance in the trilateral co-evolution between "econo-cultural development," gender balance improvement and ICT advancement. This explicit performance can be attributed to their high level of elasticity of gender balance improvement to ICT advancement.

EMCs remain at an extremely low level of this elasticity, resulting in the lowest performance in the trilateral co-evolution, notwithstanding the highest elasticity of growth to gender balance improvement. However, it is anticipated that once due sufficient ICT advancement prevails, a virtuous cycle leading to income growth and gender balance improvement can be expected.

Notwithstanding their high level of income and ICT advancement, CSCs remain at the lowest level of gender balance intensity, which can be attributed to their traditional high intensity male-dominated society.

Among INCs, Finland demonstrated conspicuous performance in this trilateral co-evolution by incorporating a self-propagating function in the gender balance improvement trajectory, while Japan (which lags significantly behind among 44 countries) was unable to incorporate this function primarily due to its male-dominated culture.

All suggest that ICT-driven "econo-cultural" disruptive innovation nurtures un-captured GDP, which corresponds to such business model as harnessing the vigor of untapped resources.

These findings give rise to the following insightful suggestions to respective countries about their successful trilateral co-evolution:

It should be realized the significance of harnessing the vigor of untapped economic resources incorporated in women's potential. In this context, we should recognize clear link between the share of women board members, corporate performance, gender quality in the workplace, and gender quality in society.

Every effort should focus on the construction of the trilateral co-evolution between "econo-cultural development," gender balance improvement, and ICT advancement.

The effective development and utilization of ICT should be of the highest priority for EMCs in constructing their trilateral co-evolution. The construction of a co-evolutionary acclimatization structure should be the significant endeavor for INCs and CSCs in this context.

Address cultural dimensions that block gender balance improvement efforts in CSCs by constructing an ICT advancement system in male-dominated societies. To do this, the construction of a self-propagating function should be challenged with the highest priority.

It should be noted that this construction should lead the way to enable the emergence of un-captured GDP, which in turn accelerates the harnessing of untapped resources.

Aiming at exploring a new systematic approach for improving gender balance, this paper attempted to explore a practical approach based on the prior exercises on the similar subject in the digital economy (e.g., harnessing the vigor of sleeping/untapped resources in sharing economy, trust-based digital education, resurgence of music industry).

Since this paper is the first step to exploring a practical approach to gender balance improvement supportive to whole stakeholders in different economies with heterogenous economic, cultural and digital development, it should be carefully noted that there remains strong requirement for further elegant research which should be endeavored based on the findings obtained by this first step approach.

The new approach regarding the intensity of the male-dominated society (IMS) was introduced with a focus on "masculinity" and "individualism" as cultural dimensions. Other factors such as work/employment culture, family issues, effects of tradition, and political factors remain unexplored. The effects of other cultural dimensions as "power distance," "uncertainty avoidance" and "long-term consideration" should also be examined.

Further work should focus on complementing unexplored analyses as well as in-depth analysis of success and failure trajectories with respect to gender balance improvement. Analyses of success and failure cases should be enriched. Micro dynamism of the IMS improving ICT development trajectory initiated by Finland should be further analyzed for operationalization in other countries, particularly CSCs.

Acknowledgement

The research leading to these results has received funding from the Strategic Research Council at the Academy of Finland under grant agreement 293446 — Platform Value Now: Value capturing in the fast emerging platform ecosystems.

Appendix 1. Institutional state of 44 countries analyzed

Table A1
State of Gender Balance, Cultural Dimension, and Internet Usage in 44 Countries (2013)
*Ind.: Individualism, Mas.: Masculinity. Original sources: GMI Ratings [8], IMF [12], Geert Hofstede [9], ITU [13].

Country	Country Code	Gender Balance Index (GMI)	GDP per capita (current US$)	GBI intensity (GBI/GDP per capita x1000)	Cultural dimension*			ICT Advancement (NRI)	Women Internet usage (%)
					Ind.	Mas.	Mas/Ind ratio		
Norway	NOR	36.1	102,564	0.35	69	8	0.12	5.66	96.7
Sweden	SWE	27.0	60,005	0.45	71	5	0.07	5.91	91.1
Finland	FIN	26.8	49,766	0.54	63	26	0.41	5.98	93.2
France	FRA	18,3	44,105	0.41	71	43	0.61	5.06	83.7
South Africa	ZAF	17.9	6,914	2.59	65	63	0.97	3.87	39.0
Denmark	DNK	17.2	60,494	0.28	74	16	0.22	5.58	96.4
Netherlands	NLD	17.0	51,595	0.33	80	14	0.18	5.81	93.5
Israel	ISR	15.7	36,410	0.43	54	47	0.87	5.39	76.3
New Zealand	NZL	15.1	41,555	0.36	79	58	0.73	5.25	82.2
Germany	DEU	14.1	46,475	0.30	67	66	0.99	5.43	85.5
Australia	AUS	14.0	64,664	0.22	90	61	0.68	5.26	84.9
USA	USA	14.0	52,705	0.27	91	62	0.68	5.57	75.0
Poland	POL	13.6	13,773	0.99	60	64	1.07	4.19	66.9
Canada	CAN	13.1	52,345	0.25	80	52	0.65	5.44	79.2
Turkey	TUR	12.7	10,761	1.18	37	45	1.22	4.22	44.0
UK	GBR	12.6	42,453	0.30	89	66	0.74	5.64	90.4
Austria	AUT	11.3	50,585	0.22	55	79	1.44	5.25	79.7
Switzerland	CHE	10.0	85,237	0.12	68	70	1.03	5.66	84.3
Thailand	THA	9.7	6,148	1.58	20	34	1.70	3.86	38.9
Hong Kong	HKG	9.5	38,170	0.25	25	57	2.28	5.40	83.3
Spain	ESP	9.5	29,397	0.32	51	42	0.82	4.51	77.1
Belgium	BEL	9.2	46,726	0.20	75	54	0.72	5.10	84.3
Ireland	IRL	8.7	52,094	0.17	70	68	0.97	5.05	81.2
Czech Republic	CZE	8.6	19,913	0.43	58	57	0.98	4.38	80.1
China	CHN	8.4	7,081	1.19	20	66	3.30	4.03	46.4
Italy	ITA	8.2	35,704	0.23	76	70	0.92	4.18	61.7
Philippines	PHL	7.9	2,769	2.85	32	64	2.00	3.73	30.0
Greece	GRC	7.0	21,773	0.32	35	57	1.63	3.93	64.5
Singapore	SGP	6.9	55,617	0.12	20	48	2.40	5.96	77.3
Malaysia	MYS	6.6	10,700	0.62	26	50	1.92	4.82	69.0
India	IND	6.5	1,480	4.39	48	56	1.17	3.88	17.0
Peru	PER	6.3	6,626	0.95	16	42	2.63	3.39	38.5
Columbia	COL	6.0	8,068	0.74	13	64	4.92	3.91	30.0
Indonesia	IDN	6.0	3,676	1.63	14	46	3.29	3.84	20.3
Mexico	MEX	5.8	10,659	0.54	30	69	2.30	3.93	54.6
Brazil	BRA	5.1	12,260	0.42	38	49	1.29	3.97	54.2
Russia	RUS	4.8	15,559	0.31	39	36	0.92	4.13	73.0
Hungary	HUN	4.5	13,564	0.33	80	88	1.10	4.29	71.2
Taiwan	TWN	4.4	21,888	0.20	17	45	2.65	5.47	76.3
Egypt	EGY	4.4	3,374	1.30	25	45	1.80	3.78	34.8
Portugal	PRT	3.7	21,626	0.17	27	31	1.15	4.67	65.7
Chile	CHL	2.8	15,714	0.18	23	28	1.22	4.59	60.0
Korea (Rep.)	KOR	1.9	25,998	0.07	18	39	2.17	5.46	87.1
Japan	JPN	1.1	38,552	0.03	46	95	2.07	5.24	89.3

*Ind. : Individualism, Mas.: Masculinity.
Original sources: GMI Ratings (2013), IMF (2014), Geert Hofstede (2014), ITU (2014).

Appendix 2. Hofstede's cultural dimensions of a nation

1. Five dimensions of a nation's culture

(1) **Power distance**: The power distance is defined as "the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally." In this dimension, inequality and power is perceived from the followers, or the lower level. A higher degree of this Index indicates that hierarchy is clearly established and executed in society, without doubt or reason. A lower degree of the Index signifies that people question authority and attempt to distribute power.

(2) **Individualism**: Individualism explores the "degree to which people in a society are integrated into groups." Individualistic societies have loose ties that often only relates an individual

to his/her immediate family. Its counterpart, collectivism, describes a society in which tightly-integrated relationships tie extended families and others into in-groups. These in-groups are laced with undoubted loyalty and support each other when a conflict arises with another in-group.

(3) **Masculinity**: In this dimension, masculinity is defined as "a preference in society for achievement, heroism, assertiveness and material rewards for success." Its counterpart represents "a preference for cooperation, modesty, caring for the weak and quality of life." Women in the respective societies tend to display different values. In feminine societies, they share modest and caring views equally with men. In more masculine societies, women are more emphatic and competitive, but notably less emphatic than the men. In other words, they still recognize a gap between male and female values. This dimension is frequently viewed as taboo in highly masculine societies.

(4) **Uncertainty avoidance**: The uncertainty avoidance is defined as "a society's tolerance for ambiguity," in which people embrace or avert an event of something unexpected, unknown, or away from the status quo. Societies that score a high degree in this index opt for stiff codes of behavior, guidelines, laws, and generally rely on absolute Truth, or the belief that one lone Truth dictates everything and people know what it is. A lower degree in this index shows more acceptance of differing thoughts/ideas. Society tends to impose fewer regulations, ambiguity is more accustomed to, and the environment is more free-flowing.

(5) **Long-term orientation**: This dimension associates the connection of the past with the current and future actions/challenges. A lower degree of this index (short-term) indicates that traditions are honored and kept, while steadfastness is valued. Societies with a high degree in this index (long-term) views adaptation and circumstantial, pragmatic problem-solving as a necessity. A poor country that is short-term oriented usually has little to no economic development, while long-term oriented countries continue to develop to a point.

Source: Hofstede [9].

2. Governing cultural dimensions in gender balance improvement in business

Authors	Business fields	Countries examined	Governing cultural dimensions
[40]	Magazine advertising	Netherlands, Sweden and the US	Masculinity
[4]	Web advertisements	Korea and the US	Masculinity
[27]	Business management	Japan and the US	Individualism, Masculinity, Power distance
[2]	Women in boards	Five European countries	Individualism, Masculinity, Power distance

Appendix 3. Data construction

Table A2
Trends in the Share of Women Directors in Finland and Japan (1989–2016) - %.
Original source: Health, Labor and Welfare White Paper in Japan [18]. Values indicated in blue are based on complemental estimates utilizing GMI Ratings data.

Complementary estimates were conducted based on respective original estimate, taking into account the OECD and WEF surveys and utilizing data from EC and EMI Rating.

Finland

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
5.0	6.0	7.0	8.5	10.5	12.0	13.5	15.0	16.0	18.0	19.0	21.5	22.5	23.0	24.0	25.0

Original source: The 6th Women Directors and Executives Report 2016 (FINNCHAM, 2016).

Values indicated in blue are based on complemental estimates utilizing FINNCHAM and the EC's Report on Equality between Women and Men in the EU.

Japan

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
2.0	2.0	2.3	2.9	2.5	2.6	2.8	3.1	3.7	3.2	3.4	4.0	3.6	4.5

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
4.6	5.0	5.1	5.8	6.5	6.6	7.2	7.0	8.1	8.5	8.9	9.4	9.8	10.3

Original source: Health, Labor and Welfare White Paper in Japan (Ministry of Health, Labor and Welfare of Japan, 2013).

Values indicated in blue are based on complemental estimates utilizing GMI Ratings data.

References

[1] Catalyst, Corporate Performance and Women's Representation on Boards, 2005. http://www.catalyst.org/media/companies-more-women-board-directors-experience-higher-financial-performance-accoeding-latest/. Retrieved 11 March 2017.
[2] A. Carrasco, C. Francoeur, I. Real, J. Laffarga, E. Ruiz-Barbadillo, Cultural differences and board gender diversity, HAL (2012) 2–28.
[3] Catalyst, Corporate Performance and Women's Representation on Boards, 2015. http://www.catalyst.org/knowledge/2015-catalyst-census-women-and-men-board-directors. Retrieved 10 March 2017.
[4] A. Daechun, S. Kim, Relating Hofstede's masculinity dimension to gender role portrayals in advertising, Int. Mark. Rev. 24 (2) (2007) 181–207.
[5] European Commission (EC), Database on Women and Men in Decision Making, EC, Brussel, 2016.
[6] European Commission (EC), 2017 Report on Equality between Women and Men in the EU, EC, Brussel, 2017.
[7] FINNCHAM, The Sixth Women Directors and Executives Report 2016-Women Directors on the Rise: Executive Positions Still Going to Men, FINNCHAM, Helsinki, 2016.
[8] GMI Ratings, 2013 Women on Boards Survey, GMI Ratings, New York, 2013.
[9] G. Hofstede, Cultures and Organizations, McGraw-Hill International, London, 2014.
[10] International Labour Organization (ILO), Women in Businesses and Management: Gaining Momentum, ILO, Geneva, 2015.
[11] International Monetary Fund (IMF), World Economic Outlook Database, IMF, Washington, D.C, 2013.
[12] International Monetary Fund (IMF), World Economic Outlook Database, IMF, Washington, D.C, 2014.
[13] International Telecommunication Union (ITU), World Telecommunication Indicators Database, ITU, Geneva, 2014.
[14] M. Jia, Z. Zhang, Critical mass of women on BODs, multiple identities, and corporate philanthropic disaster response: evidence from privacy owned Chinese firms, J. Bus. Ethics 118 (2) (2013) 303–317.
[15] H. Kim, How is South Korea closing the gender gap? World Econ. Forum (2015). http://www.weforum.org/agenda/2015/3qa-how-is-south-korea-closing-the-gender-gap. Retrieved 7 April 2017.
[16] McKinsey & Company, Women Matter 2007: Gender Diversity, a Corporate Performance Driver, McKinsey & Company, New York, 2007.
[17] McKinsey & Company, Women Matter 2016: Reinventing the Workplace to Unlock the Potential of Gender Diversity, McKinsey & Company, New York, 2016.
[18] Ministry of Health, Labor and Welfare of Japan (MHLW), Health, Labor and Welfare White Paper in Japan, MHLW, Tokyo, 2013.
[19] G.G. Moghaddam, Information technology and gender gap: toward a global view, Electron. Libr. 28 (5) (2010) 722–733.
[20] MSCI, Global trends in gender diversity on corporate boards, Women Boards (2015) 1–31. November 2015.
[21] K. Naveed, C. Watanabe, P. Neittaanmäki, Co-evolution between streaming and live music leads a way to the sustainable growth of music industry: lessons from the US experiences, Technol. Soc. 50 (2017) 1–19.
[22] Nihon Keizai Shimbun, Why Firms with Many Women Board Members Perform Better?, 2017. February 4, 2017.
[23] OECD, Women, Government and Policy Making in OECD Countries: Fostering Diversity for Inclusive Growth, OECD, Paris, 2014.
[24] OECD, Background Report: Conference on Improving Women's Access to Leadership, OECD, Paris, 2016.
[25] M.N. Phumzile, ICT as a Powerful Means to Advance Women's Rights Empowerment and Gender Equality, UN Broadband Commission Workshop Group on Gender, New York, 2013. September 2013.
[26] E. Rogers, Diffusion of Innovations, Simon and Schuster, New York, 1962.
[27] Y.E. Stedham, J.H. Yamamura, Measuring national culture: does gender matter? Women Manag. Rev. 19 (2) (2004) 233–243.
[28] The Japan Institute for Labor Policy and Training (JILPT), Survey on Career and Compatibility Support for Male and Female Full-time Employees, JILPT, Tokyo, 2013.
[29] UNDP, Promoting an Economic and Legal Environment for Women's Empowerment, Speech by Helen Clark, 2010. UN Women (2015), http://www.undp.org/content/undp/en/home/presscenter/speeches/2010/03/25/promoting-an-economic-andlegal-environment-for-womens-empowerment-.html.
[30] United Nations, Gender Equality and Empowerment of Women through ICT. Women 2000 and beyond, 2005 (United Nations, New York).
[31] United Nations Educational, Scientific and Cultural Organisation (UNESCO), Institute of Statistics, Women in Science, 2014. http://www.uis.unesco.org/_LAYOUTS/UNESCO/women-in-science/index.html#!lang=en.
[32] UNWomen, Collective Failure of Leadership on Progress for Women. Media Release, 2015. http//www.unwomen.org/en/news/stories/2015/3/collective-failure-of-leadership-on-progress-for-women. Retrieved 7 April 2017.
[33] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of it functionality development, Technol. Forecast. Soc. Change 71 (7) (2004) 723–750.
[34] C. Watanabe, S. Lei, N. Ouchi, Fusing indigenous technology development and market learning for greater functionality development: an empirical analysis of the growth trajectory of canon printers, Technovation 29 (2) (2009) 265–283.
[35] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution of three mega-trends natures un-captured GDP: uber's ride-sharing revolution, Technol. Soc. 46 (2016) 164–185.
[36] C. Watanabe, K. Naveed, P. Neittaanmäki, Consolidated challenge to social demand for resilient platforms: lessons from Uber's global expansion, Technol. Soc. 48 (2017a) 33–53.
[37] C. Watanabe, K. Naveed, P. Neittaanmäki, B. Fox, Co-evolution between trust in teachers and higher education toward digitally-rich learning environments, Technol. Soc. 48 (2017b) 70–96.
[38] C. Watanabe, K. Naveed, P. Neittaanmäki, Harnessing Women's potential as a soft engine for growth: lessons from contrasting trajectories between Finland and Japan for growing economies, J. Technol. Manag. Grow. Econ. 8 (1) (2017c) 7–38.
[39] P. Webb, J. Young, Perhaps It's time for a fresh approacj to ICT gender research? J. Res. Pract. Inf. Technol. 37 (2) (2005) 147–160.
[40] J.A. Wiles, C. Wiles, A. Tjernlund, A comparison of gender role portrayals in magazine advertising: The Netherlands, Sweden and the USA, Eur. J. Mark. 29 (11) (1995) 35–49.
[41] World Economic Forum (WEF), The Global Gender Gap Report 2013, WEF, Geneva, 2013.
[42] World Economic Forum (WEF), The Global Gender Gap Report 2016, WEF, Geneva, 2016.

Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Research Professor of University of Jyväskylä, Finland, and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com)

Kashif Naveed is currently doing his Ph.D. in Economics and Business Administration from the University of Jyväskylä, Finland and he also completed his Masters of Science degree in Economics and Business Administration from the same university. Previously he has Bachelor's of Science degree in Computer Science from the Hamdard University Karachi, Pakistan. (kashif.naveed.dr@gmail.com)

Pekka Neittaanmäki graduated from the University of Jyväskylä in Mathematics and is currently Professor and a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland. (pekka.neittaanmaki@jyu.fi)

PXI

THE TRANSFORMATIVE DIRECTION OF INNOVATION TOWARD AN IOT-BASED SOCIETY - INCREASING DEPENDENCY ON UNCAPTURED GDP IN GLOBAL ICT FIRMS

by

Kashif Naveed, Chihiro Watanabe and Pekka Neittaanmäki, 2017

Technology in Society, vol. 52, pp.

Technology in Society xxx (2017) 1–24

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms

Kashif Naveed [a], Chihiro Watanabe [a, b, *], Pekka Neittaanmäki [a]

[a] Faculty of Information Technology, University of Jyväskylä, Finland
[b] International Institute for Applied Systems Analysis (IIASA), Austria

ARTICLE INFO

Article history:
Received 20 August 2017
Received in revised form
8 November 2017
Accepted 18 November 2017
Available online xxx

Keywords:
IoT
Global ICT firms
Uncaptured GDP
Digital business solutions
Transformative strategy

ABSTRACT

Driven by the possibilities of the Internet of Things (IoT), global information and communication technology (ICT) firms have taken significant steps forward in recent years.

The Internet provides extraordinary services to people while promoting a free culture. However, such services cannot be captured through gross domestic product (GDP) data that measure revenue. Consequently, advancement of the Internet leads to increasing dependency on uncaptured GDP (added value providing people utility and happiness beyond economic value) and ICT price decreases.

Against such circumstances, global ICT firms are quickly embracing digital solutions for new competitiveness that urge them to restructure their business model toward digital business strategies. Aiming at demonstrating this hypothetical view, this paper attempts to explore new approach for analyzing such dynamism and examines some optimal solutions that are co-evolving with it.

An empirical analysis of digital business solutions in 500 global ICT firms over the period 2005–2016 was conducted with special attention to their specific features.

It was identified that research and development–intensive firms have fallen into a trap in ICT advancement, resulting in a decline in their marginal productivity of ICT that could be due to increasing dependency on uncaptured GDP. As a result, these firms are endeavoring to harness soft innovation resources and activate a self-propagating function that induces functionality development sublimating sophisticated digital business strategies, such as:

- Shifting from software to network (e.g., Apple and Google),
- Merging network and real (e.g., Amazon's merging of e-commerce and brick-and-mortal retail),
- Shifting from commodity to culture (e.g., Facebook and Samsung).

All can be considered as soft value addition in response to uncaptured GDP.

This analysis explores new insights for ICT firms in their transformative strategies toward an IoT-based society.

1. Introduction

1.1. IoT and the new productivity paradox

Driven by the Internet of Things (IoT),[1] the physical world is becoming an ecosystem composed of physical objects embedded with sensors and actuators connected to applications and services through a wide range of networks. The IoT has the potential to drive the next steps toward the digitization of our society and economy

* Corresponding author. Faculty of Information Technology, University of Jyväskylä, Finland.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] [18] defines IoT as scenarios where network connectivity and computing capability extend to objects, sensors, and everyday items not normally considered computers, allowing these devices to generate exchanges and consume data with minimal human intervention.

https://doi.org/10.1016/j.techsoc.2017.11.003
0160-791X/

[15]. It promises several benefits to its customers, varying from faster and more accurate sensing of our environment to more cost-effective tracking of industrial processes. The wide adoption of the IoT is expected to generate significant revenues to the providers of its applications and services [26].

The IoT will change the bases of competition and drive new business models for users and suppliers. Firms that use the IoT in novel ways to develop new business models or discover new ways to monetize the IoT data are likely to enjoy more sustainable benefits [[27,28]]. Report also discussed that the challenges in capturing the full potential of the IoT require innovation in technologies, business models, investment capabilities, and talent, together with policy actions to encourage interoperability, security, and protection of privacy and property rights. It was also noted the possibility of a new "productivity paradox" in the context of the IoT—a possible lag between technology investments and productivity gains at macroeconomic level.

1.2. From "computer paradox" to "productivity paradox" in the IoT

1.2.1. Computer-initiated productivity paradox

There have been long-lasting debates on the information and communication technology (ICT)–driven "productivity paradox."

Significant numbers of analyses demonstrated the impact of ICT advancement on the socio-economy triggered by Nobel Laureate Solow's "Productivity Paradox" [34] and reaction to it by Ref. [4]. This reaction was followed by more sophisticated models to tease out the relationship between ICT and productivity [5,22,23].

By the late 1990s, there were some signs that productivity in the workplace had been improved by the introduction of ICT, especially in the US. Brynjolfsson et al. found a significant positive relationship between ICT investments and productivity [6,7] encouraging popular consideration that there was no paradox [37].

1.2.2. Internet-initiated new productivity paradox

Late in the first decade of this century, a new paradox appeared to have emerged. This can largely be attributed to the third industrial revolution initiated by the dramatic advancement of the Internet [32]. The Internet has transformed how people live, work, socialize, and meet, and how countries develop and grow. It has changed from a network for researchers to a day-to-day reality for billions of people in two decades [27]. Consequently, the computer-initiated ICT world has changed significantly. The entire system has become interactive, integrated, and seamless. This interconnectedness is creating new opportunities for cross-industry relationships.

[13] argued that, "Contrary to the dramatic advancement of the Internet and subsequent ICT advancement, we were living through the consequence of a dramatic decrease in the rate of innovation." He argued that the consequence of slowing innovation was fewer new industries and less creative destruction, hence fewer new jobs. He stressed that, while the technological progress brought a big and predictable stream of growth across most of the economy, those assumptions were turning out to be wrong or misleading when it came to the Internet. He then suggested the possibility of the consequence of the two-faced nature of ICT.

From the dramatic advancement of the Internet and subsequent third industrial revolution inevitably emerged a new paradox of the advancement of ICT. Brynjolfsson, who first reacted to Solow's production paradox in 1993, raised the question, "Could technology be destroying jobs?" [8]. He argued by giving an example of the music industry: "Because you and I stopped buying CDs, the music industry has shrunk, according to revenues and GDP. But we're not listening to less music. There's more music consumed than before." He further mentioned that maybe it's not the growth that is deficient but the yardstick that is deficient and postulated the limit of GDP [9].

Inspired by these arguments [24], postulated that the Internet promotes more free culture, the consumption of which provides utility and happiness to people but cannot be captured through the GDP data that measure revenue.

1.3. Uncaptured GDP and its source

1.3.1. Sources of free culture

Considering the evolutional services that the Internet provides under free culture, several analyses and debates were initiated on the sources of its free culture.

1.3.1.1. Unique function stemmed from online intermediaries. [11] studied the impact of online intermediaries[2] (that play a core role in the Internet function) on GDP of EU27 countries in 2012 by identifying: (i) direct contribution through consumption increase, (ii) indirect contribution through productivity increase, and (iii) beyond measurement. The report estimated that, contrary to direct and indirect GDP contributions of EUR 220 billion (1.7% of GDP) and EUR 210 billion (1.65% of GDP), respectively, EUR 640 billion (5.0% of GDP) derived from B2B platforms by e-commerce, online advertising, and consumer benefits of free services like Google search was beyond measurement by the GDP statistics. The report also pointed out that these estimates were understated, as they didn't include the direct contribution by investments, which are hard to measure, and the sociocultural value created by social network development.

1.3.1.2. Consumer surplus. The research by Ref. [10] (Revised 2017) analyzing online booksellers found that significant consumer surplus gains were created by the increased product variety available through electronic markets and that efficiency gains resulted from increased competition leading to lower average prices. Their analysis indicates that the increased product variety of online bookstores enhanced consumer welfare by US$731 million to US$1.03 billion in the year 2000, which is seven to 10 times larger than the consumer welfare gain from increased competition and lower prices in this market.

[10] (Revised 2017) also mentioned the possibility of large welfare gains in other SKU-intensive consumer goods, such as music, movies, consumer electronics, and computers. Similar results were demonstrated by the white paper of Japan's ICT, analyzing consumer surplus in music and audio-visual services [30].

Analyzing the big economic opportunities and challenges in capturing the maximum value of IoT [28] estimated that consumer surplus derived from the IoT could be more than 10% of the global economy by 2025.

1.3.1.3. New goods and services derived from disruptive innovations. The [38] pointed out that the apparent slowdown in productivity in the industrialized countries could be simply due to the lack of capacity in statistical offices to properly measure the massive quality gains and hard-to-measure benefits of relatively new goods and services (e.g., Google, Facebook, Twitter) that are radical breaks with previous products or, in some cases, are provided for free to the users.

The report also discussed that, despite tremendous previous problems in accurately measuring the benefits of new goods and

[2] Online intermediaries provide platforms for the exchange of goods, services, or information over the Internet.

services, there is some evidence that statistical agencies are now better at capturing this value. But adjustment issues related to previous gains still remain to accurately measure productivity growth.

It also pointed out that current estimates for the non-market benefits of free goods and services like Google, Wikipedia, and Facebook do not make up for the shortfall in productivity growth. It may turn out that those estimates understate the non-market benefits, but it would be very hard to know.

Similar points were also made by The [14] claiming that "GDP is a bad gauge of material well-being and it is a time for fresh approach."

1.3.1.4. Online piracy. In addition to the foregoing beyond-measurement difficulties inherent to disruptive innovations caused by the dramatic advancement of the Internet, it was generally pointed out that a corresponding increase in online piracy is another difficult issue beyond GDP measurement.

1.3.2. Uncaptured GDP

Following these analyses and debates [47], discussed the two-faced nature of ICT and the emergence of uncaptured GDP as fatal to the advancement of the Internet [47–50]. They pointed out that, while advancement of ICT generally contributes to enhanced prices of technology by new functionality development, the dramatic advancement of the Internet contributes to decreased prices of technology due to its unique, inherent characteristics of freebies, easy copying, and mass standardization. With this understanding, they supported [24], postulate that the Internet promotes free culture, the consumption of which provides utility and happiness to people but cannot be captured through GDP data that measure revenue. The authors defined these added values that provide people utility and happiness beyond economic value under free culture as an uncaptured GDP.

1.4. Consequence of IoT

The Internet continues to grow rapidly and changes every aspect of our lives by introducing new ways of communication, learning, socialization, and doing business, further transforming our world into an IoT-based society [3,19]. The IoT has also changed the traditional meaning of the word "product" introduced in the era of "Product of Things (PoT)." In the era of the IoT, the product can be a technology, device, service powered by software, a flow of data, a software application for monitoring, automation, and analysis, or any combination of the above.

The transformation of the traditional Internet, where data are "created by people," to the IoT, where data are "created by things" [25] will generate data at a much larger scale that requires more advanced technological capabilities, as most of the data collected today are not fully exploited. To be competitive and to capitalize on the highly promising business opportunities of the IoT, global ICT firms need to embrace sophisticated digital solutions and restructure their business models [3].

Due to the challenges and huge interest in the IoT, the importance of business models and digital business strategies cannot be over-emphasized [3]. and [21] stressed the significance of digital business strategies (DBS) and discussed the fundamental role of digital technologies in transforming business strategies, business processes, firm capabilities, and the nature of products and services.

They also highlighted the significance of digital business strategy as: (i) the significant role of ICT pervading digital resources in other functional areas such as operations, purchasing, supply chain, and marketing; (ii) going beyond systems and technologies; and (iii) explicitly linking digital business strategy to creating differential business value, thereby elevating the performance implications of ICT strategy beyond efficiency and productivity.

[3] also pointed out that it is clearly time to rethink the role of ICT strategy from that of a functional-level strategy subordinating business strategy to the digital business strategy that fuses ICT strategy and business strategy.

1.5. New business strategies spinning off from a PoT society to an IoT society

The authors, in their previous research, analyzed the business strategies of 500 global ICT firms in 2007 and 2010 (before and after the Lehman shock in 2008) and identified the following strategy for resilient market value creation in the digital economy[3] [46].

- Dependency on high R&D profitability while restraining its elasticity
- Effective utilization of external resources in innovation
- Hybrid management of technology between indigenous R&D and assimilation of spillover technology

In their sequel studies, the authors tried to compare the spinning-off dynamisms from traditional computer-initiated ICT innovation in the era of the PoT to Internet-initiated ICT innovations by using their developed co-evolutional framework between the advancement of ICT, a paradigm change, and a shift in people's preferences (Fig. 1).

The authors have found that, corresponding to a shift from computer-initiated innovation toward the new stream of Internet-initiated innovations, social preferences have shifted from economic functionality to supra-functionality. The economic impact of innovation has shifted from captured GDP (monetized revenues) to increasingly uncaptured GDP (un-monetized revenues) due to the digital nature, free availability of the products, and new business models [47–51].

In their further studies [31,50,51] the authors recognized the consolidated challenges in social demand and the importance of trust between stakeholders in introducing successful disruptive innovations [12]. in its sequel report also pointed out the significant contribution of online intermediaries in building trust.

The authors suggested that the digital business strategy corresponding to the new stream of innovations should be supported by a trust-based, ICT-driven disruptive business model (IDBM) with consolidated challenge to social demand (CCSD) incorporating the inherent self-propagating function.

The significance of the above suggestions should be recognized in the foregoing transformation of traditional ICT-driven functionality development strategy toward digital business strategy [1].

1.6. Dynamism transforming into digital business strategy

None of the previous research has elucidated the dynamism of this transformation leading global ICT firms to create digital business strategy corresponding to an IoT-based society.

This paper attempts to explore new approach to demonstrate the above hypothetical views by explaining the transformation dynamism, in shifting from the PoT toward the IoT and give constructive insights to global ICT firms for their digital business

[3] As shown by Tapscott in his best-seller "The Digital Economy" (1995), the Internet has changed the way of business and daily life dramatically. The digital economy is also known as the Internet economy, the new economy, or the web economy.

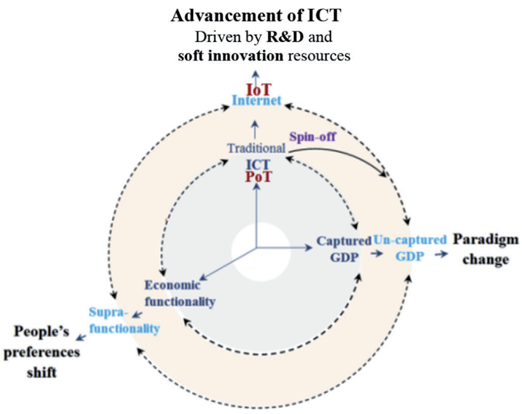


Fig. 1. Scheme of spin-off dynamism.

strategies.

Based on the findings obtained from the following preceding analyses illustrating the spin-off from traditional to new co-evolution, an empirical analysis was conducted by evaluating the new survival strategy of top 500 global ICT firms over the period of 2005–2016, with a focus toward the following new business models and also paying special attention to their specific features similar to:

- Similarity and disparity of world ICT leaders [48]; [49],
- Uber's ridesharing revolution [49]; [51],
- Trust-based digital education [52],
- Commodification of past experiences [45],
- Co-evolution of streaming and live music [31], and
- Harnessing the vigor of untapped resources by activating women's potential [53].

It was identified that high R&D-intensive firms have fallen into a trap in ICT advancement resulting in declining their marginal productivity of ICT that, which can be considered a consequence of two-faced nature of GDP. Consequently, these firms are endeavoring to increase self-propagating functionality development by sublimating sophisticated digital business strategies, which can be considered a soft value addition to deal with the issue of uncaptured GDP. Fig. 2 illustrates dynamism spinning-off to increasing dependency on uncaptured GDP.

This analysis thus explores a new insight for ICT firms for their transformative strategy toward an IoT-based society.

Section 2 of this paper reviews the shift of global ICT firms toward the IoT. Section 3 analyzes increasing dependency on uncaptured GDP in the global ICT firms. The sources inducing high self-propagating function are analyzed in Section 4. Section 5 briefly summarizes noteworthy findings, policy suggestions, and future research.

2. Shift of global firms toward IoT

2.1. Influence of R&D-Driven growth in global ICT firms

Given that sales *(S)* of global ICT firms are governed by ICT stock, their sales can be depicted as follows (see Appendix A):

$$\ln S = a + b \ln R \tag{1}$$

where *R:* R&D investments; and *a, b*: coefficients.

The top 500 global ICT firms were divided into three groups by using cluster analysis[4] based on their R&D and sales levels in year 2016 as illustrated in Fig. 3.

Based on the above findings, and utilizing equation (1), correlation between *(S)* and *(R)* in the top 500 global ICT firms by R&D level in 2016 was analyzed.

$$lnS = 2.319 + 0.997 D_1 \ln R + 1.013\, D_2 \ln R + \ 1.023 D_3 \ln R + 2.903\, D$$

S*:** Net sales, ***R*:** R&D investment, D_1, D_2, D_3, and *D* are dummy variables.D₁*:** High R&D-intensive firms, ***D₂*:** R&D-increasing firms, ***D₃*:** Low-R&D firms, ***D*:** Outliers.

The figures in parentheses indicate t-statistics: All are significant at the 1% level.

The result of the correlation analysis is statistically significant. This demonstrates that sales of the global ICT firms are governed by their ICT stock as cumulative stock of R&D investment constructs ICT stock.[5]

2.2. Business structure comparison of top 70 global ICT firms

With the foregoing understanding, Table 1 lists the top 70 R&D-intensive global ICT firms in 2016 and compares their business performance by R&D *(R)*, sales *(S)*, operating income *(OI)*, R&D intensity *(R/S)*, profitability *(OI/S)*, and R&D profitability *(OI/R)*.

Fig. 4 compares the performance of the top 70 R&D-intensive global ICT firms in 2005 and 2016.

2.3. Activation of global ICT firms

Over the last decade, dramatic advancement of the Internet worldwide paved the way to the acceleration of the IoT. This advancement was conspicuous after 2010, as initiated by global ICT firms as demonstrated in Fig. 3 and Table 2 (See Fig. 5).

2.4. Noteworthy shift of global firms from 2010 to 2016

Foregoing strong initiatives toward the IoT led by global ICT firms, particularly after 2010, resulted in a structural change of market value in leading firms. Table 3 traces the trend in the ranking of market value of the leading firms in 2005, 2010, and 2016.

The above review highlights the following noteworthy shift of global firms from 2010 to 2016 toward the IoT. First, leading global firms in the market, with respect to their market capitalization, have been shifted from those in the finance and energy sectors to ICT firms. Table 2b demonstrates that ICT firms comprise nine of the top 15 firms with respect to market value in 2016. The top three firms were all ICT firms.

Second, within ICT firms, the following shifts in their business focus have been evidently observed:

- From mechatronics to software (e.g., General Electric, IBM, and Siemens have decreased their status)

[4] K-means clustering analysis was used.

[5] This result leads to (*b*: elasticity). This suggests that marginal productivity of *R* is proportional to *R* productivity in *R*-driven growth trajectory, typical for the digital innovation.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

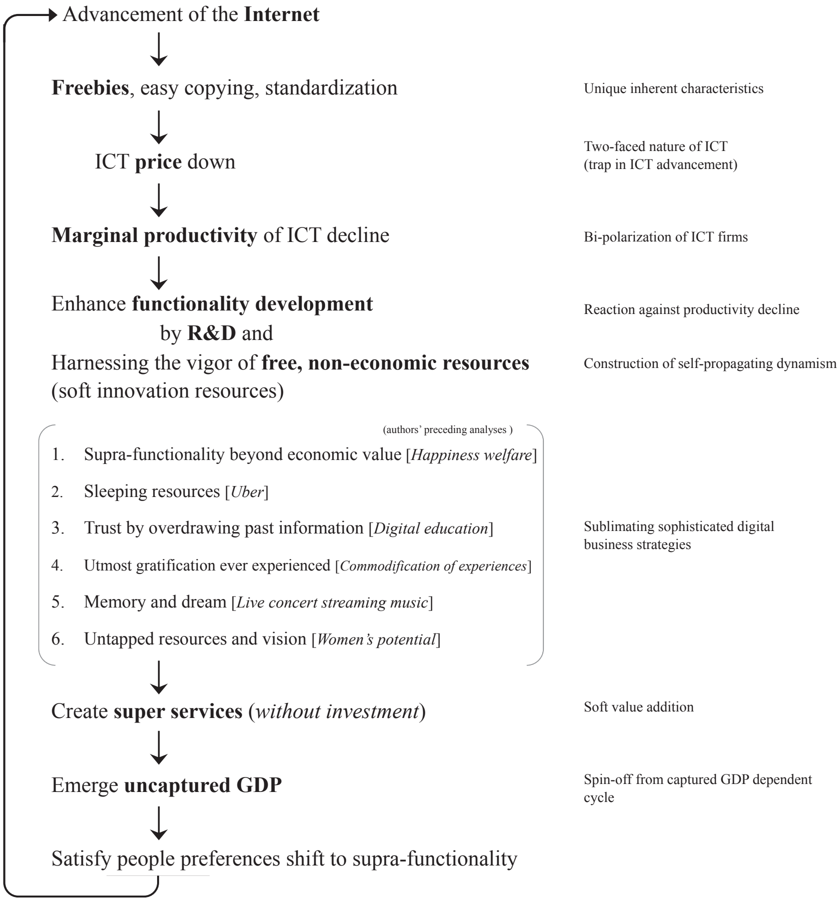


Fig. 2. Dynamism spinning-off to increasing dependency on uncaptured GDP.

- From software to network (e.g., Apple and Google have exceeded their status, while Microsoft has decreased its status)
- From Network to a merging of network and physical (e.g., Amazon has dramatically raised its status by merging e-commerce and brick-and-mortal retail)
- From commodity to culture (e.g., noting increase in status of Facebook and Samsung)

These noteworthy shifts can be considered a consequence of endeavoring to increase a self-propagating functionality development by sublimating sophisticated digital business strategies against a trap in ICT advancement resulting in declining marginal productivity of high R&D-intensive ICT firms. This accomplishment can be considered a soft value addition to deal with the issue of increasing dependency on uncaptured GDP.

The next section demonstrates this hypothetical view.

3. Increasing dependency on uncaptured GDP in global ICT firms

3.1. Development trajectory of global ICT firms

(1) Analytical Framework

As reviewed in the preceding section, sales (S) of the global ICT firms are governed by their ICT stock (T). With this situation, their development trajectory can be depicted as follows [47]:

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

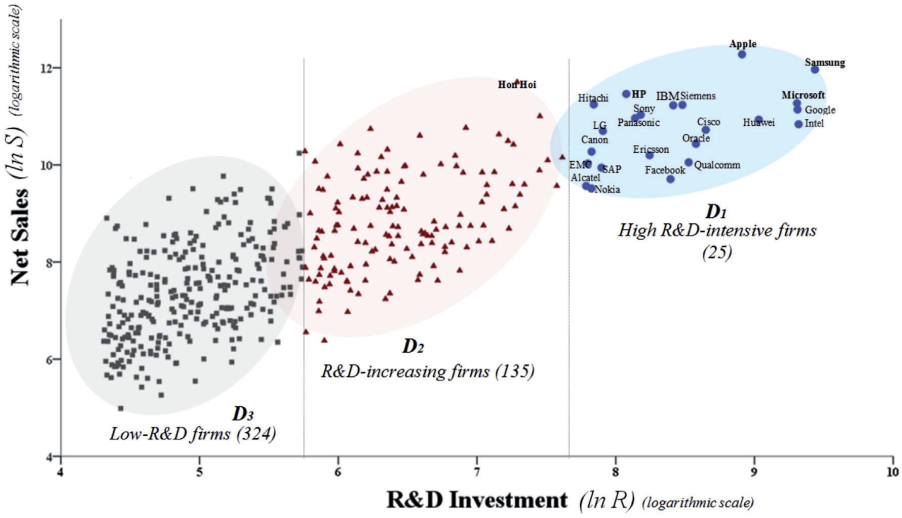


Fig. 3. Correlation Between R&D Investment and Sales in 500 Global ICT Firms (2016).
Note: The figures in parentheses indicate number of ICT firms. 16 outliners scattered in D_2 and D_3 were not presented.

Table 1
Digital Business Structure in Global ICT Firms in 2016 (Top 70 R&D-intensive ICT firms by R&D level).

R&D level	Firm	R&D *(R)*	Net sales *(S)*	Operating income *(OI)*	R/S	OI/S	OI/R	R&D level	Firm	R&D *(R)*	Net Sales *(S)*	Operating income *(OI)*	R/S	OI/S	OI/R
		EUR mil	EUR mil	EUR mil	%	%	%			EUR mil	EUR mil	EUR mil	%	%	%
1	Samsung	12528	157190	20692	8.0	13.2	165.2	36	Lenovo	1285	41253	−20	3.1	−0.05	−1.6
2	Intel	11140	50845	13016	21.9	25.6	116.8	37	Fujifilm	1243	18993	1457	6.5	7.7	117.3
3	Google	11054	68879	17783	16.0	25.8	160.9	38	NVidia	1223	4602	806	26.6	17.5	66.0
4	Microsoft	11011	78369	18683	14.1	23.8	169.7	39	Tencent	1177	14555	5717	8.1	39.3	485.5
5	Huawei	8358	55893	6479	15.0	11.6	77.5	40	Texas Inst	1176	11941	3946	9.8	33.0	335.6
6	Apple	7410	214674	65427	3.5	30.5	883.0	41	STM	1149	6335	121	18.1	1.9	10.6
7	Cisco	5701	45235	11875	12.6	26.3	208.3	42	Danaher	1138	18888	3298	6.0	17.5	289.8
8	Oracle	5316	34029	12036	15.6	35.4	226.4	43	Seagate	1136	10251	409	11.1	4.0	36.0
9	Qualcomm	5043	23221	5451	21.7	23.5	108.1	44	Yahoo!	1110	4564	−4266	24.3	−93.5	−384.2
10	Siemens	4820	75636	5809	6.4	7.7	120.5	45	ASML	1046	6287	1861	16.6	29.6	177.8
11	IBM	4515	75081	14586	6.0	19.4	323.1	46	Elec Arts	1019	4038	825	25.2	20.4	81.0
12	Facebook	4424	16467	5718	26.9	34.7	129.3	47	Sharp	992	18764	−1423	5.3	−7.6	−143.5
13	Ericsson	3806	26870	2356	14.2	8.8	61.9	48	eBay	973	7892	2018	12.3	25.6	207.5
14	Sony	3569	61787	2243	5.8	3.6	62.8	49	Marvell	968	2504	−750	38.7	−30.0	−77.5
15	Panasonic	3429	57559	2797	6.0	4.9	81.6	50	Broadcom	964	6268	1534	15.4	24.5	159.2
16	HP	3217	94934	7353	3.4	7.7	228.6	51	NEC	945	21505	743	4.4	3.5	78.6
17	LG	2718	44269	934	6.1	2.1	34.4	52	Schneider	937	26640	2220	3.5	8.3	236.9
18	SAP	2689	20793	4252	12.9	20.4	158.1	53	Juniper	913	4462	837	20.5	18.8	91.6
19	Hitachi	2544	76461	4597	3.3	0.1	180.7	54	Salesforce	875	6124	102	14.3	1.7	11.7
20	Canon	2504	28968	2708	8.6	9.3	108.1	55	Cerner	870	4065	717	21.4	17.7	82.4
21	Nokia	2502	13574	1842	18.4	13.6	73.6	56	Adv. Micro	870	3666	−308	23.7	−8.4	−35.4
22	EMC	2437	22691	3023	10.7	13.3	124.0	57	Sumitomo	845	22358	999	3.8	4.5	118.2
23	Alcatel	2409	14280	890	16.9	6.2	36.9	58	Twitter	826	2037	−413	40.6	−20.3	−50.0
24	Medtronic	2043	26484	4860	7.7	18.4	237.9	59	Freescale	817	4108	694	19.9	0.2	84.9
25	ZTE	1954	14176	955	13.8	6.7	48.9	60	Infineon	817	5795	557	14.1	9.6	68.2
26	Taiwan SEM	1827	23508	9104	7.8	38.7	498.4	61	Boston Sci	805	6868	944	11.7	13.7	117.4
27	SK Hynix	1543	14726	4180	10.5	28.4	270.9	62	LinkedIn	802	2747	−139	29.2	−5.0	−17.3
28	West Digital	1494	11935	754	12.5	6.3	50.5	63	Adobe	792	4405	831	18.0	18.9	104.9
29	Hon Hai	1463	124916	5219	1.2	4.2	356.7	64	NetApp	791	5094	426	15.5	8.4	53.9
30	Baidu	1444	9393	1651	15.4	17.6	114.3	65	Ricoh	778	15357	960	5.1	0.1	123.4
31	Mitsubishi	1426	33497	2296	4.3	6.9	161.0	66	SanDisk	768	5112	698	15.0	13.7	90.9
32	Micron Tec	1415	14873	2756	9.5	18.5	194.9	67	LAM	753	5406	987	13.9	18.3	131.0
33	MediaTek	1380	5943	727	23.2	12.2	52.6	68	Midea	745	18063	1845	4.1	10.2	247.7
34	Fujitsu	1371	36126	1113	3.8	3.1	81.1	69	Renesas	742	5285	788	14.0	14.9	106.2
35	Applied Mat	1332	8872	1387	15.0	15.6	104.1	70	NXP	734	5604	691	13.1	12.3	94.1

Note: Amazon is not presented because it did not meet the criteria of top 70 R&D-intensive firms in 2016, as its position was 95th. The same applies to GE, Toshiba and Alibaba.

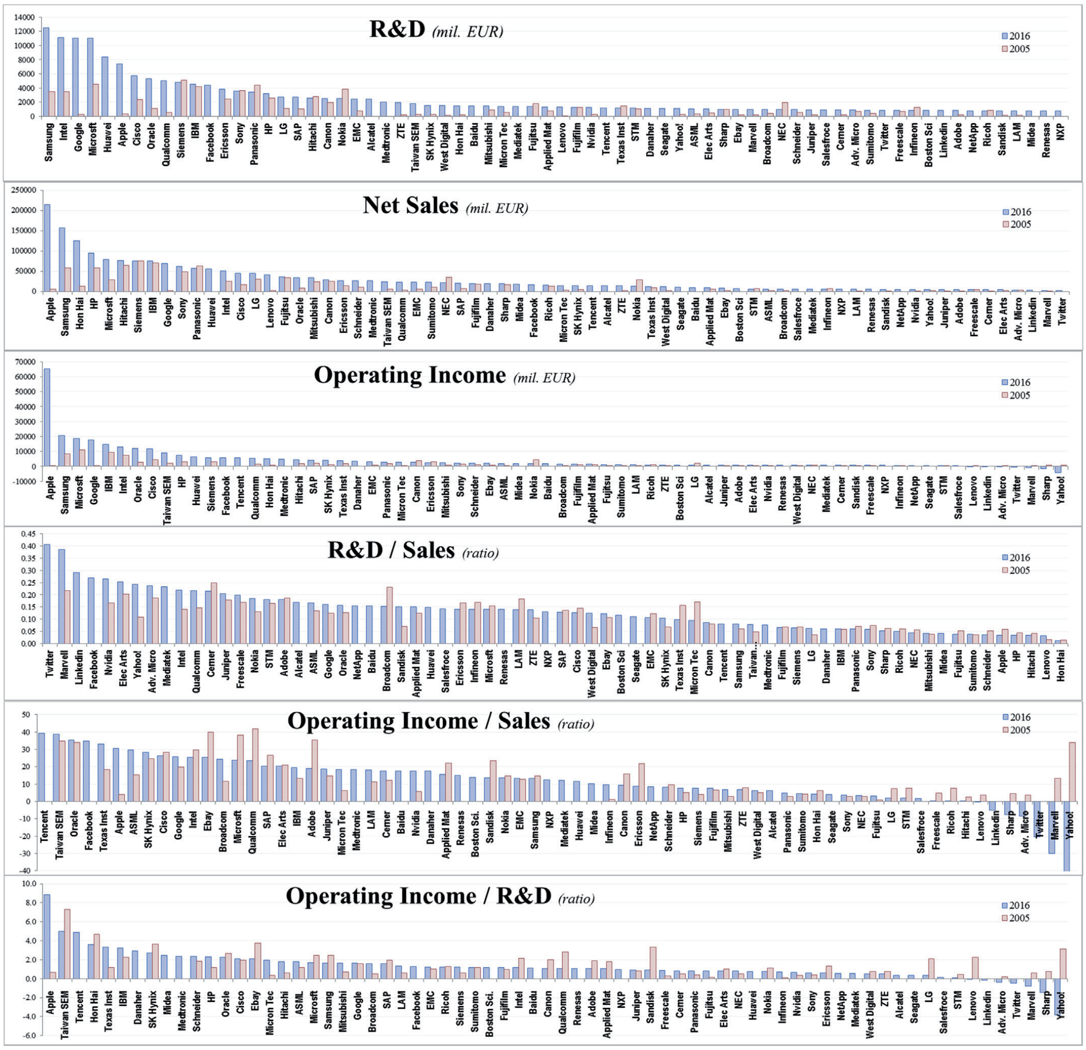


Fig. 4. Digital Business Structure in Global ICT Firms (Top 70 R&D intensive ICT firms in 2016).

$$S = F(X, T) = F(X(T)) \approx F(T) \tag{2}$$

where X: production factors other than *T*.

In long run, *T* can be treated proportional to R&D investment *(R)* and time trend *(t)*[6] [42].

Given the logistic growth nature of ICT, increasing trajectory of *S* in global ICT firms can be depicted by the following *R*-driven logistic growth function:

$$\frac{dS}{dR} = aS\left(1 - \frac{S}{N}\right) \tag{3}$$

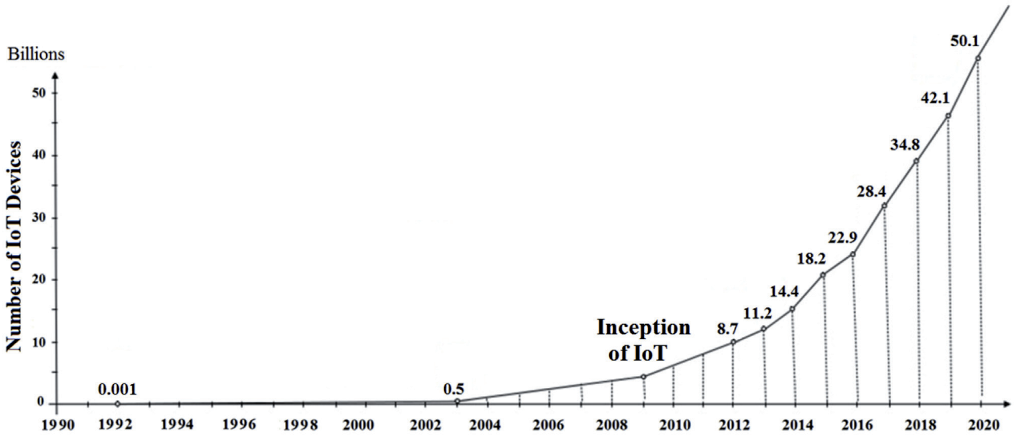
where *a*: velocity of diffusion, and *N*: carrying capacity (upper limit of diffusion).

Given the global ICT firms, equation (3) can be approximated as follows [43].

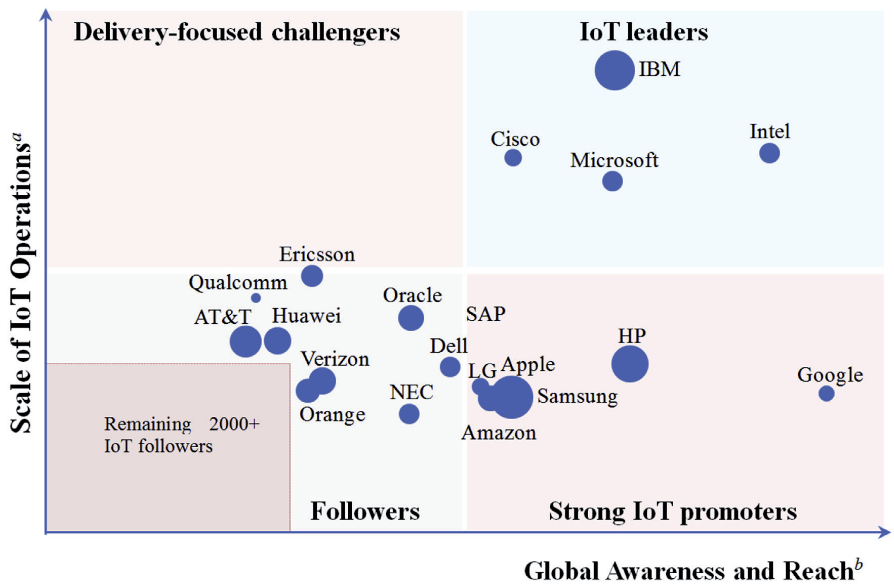
[6] ICT stock at time t can be measured by the following equation $T_t = R_{t-m} + (1-\rho)T_{t-1}$ and $T_0 = R_{1-m}/(\rho+g)$. Then, $T_t = R_{t+1-m}/(\rho+g)$. When t $\gg$ m − 1, $T_t \approx R_t/(\rho+g)$. R_t is generally proportional to time trend t in ICT firms.*m*: time-lag between R&D and commercialization,

ρ : rate of obsolescence of ICT, and g : growth rate of R&D at the initial period.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003



***a*. Trend in Growth of the IoT Worldwide** (1990-2020).
Source: The Connectivist (2014).



***b*. Leading Firms of the IoT** (2015).

● Size of Firm (by number of all employees worldwide).
[a] Measured by estimated number of employees performing IoT-related operations.
[b] Measured by number of news appearances and related search engine inquiries.
Source: IoT Analytics (2015).

Fig. 5. Advancement of IoT initiated by global ICT firms (2015) [20,36].

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

Table 2
IoT endeavor of top 25 global ICT firms.

1	Samsung	ARTIK platform, smart home, and digital health devices
2	Intel	IoT hardware, new-generation low-power chips for connected IoT devices, Intel IoT platform for connecting the data from your things to the cloud, Intel Galileo developer kit
3	Google	Self-driving cars, home automation, IoT beacons, work on IoT standards, IoT cloud
4	Microsoft	Windows 10 IoT Core operating system, Microsoft IoT Central, Azure IoT suite
5	Huawei	Huawei IoT management platform and smart solutions (e.g., Smart water, smart parking, smart logistics, smart energy, internet of vehicles)
6	Apple	HomeKit smart home and HealthKit health tracking platforms
7	Cisco	Cloud-based IoT software platform, connectivity hardware, IoT-related services and consulting
8	Oracle	IoT cloud service platform
9	Qualcomm	IoT development platform, chips, security services, acquisition of connected assets from NXP
10	Siemens	IoT industrial platforms, IoT security services, connected industrial machines
11	IBM	IBM Watson IoT, cloud services
12	Facebook	Learning about different cultures, beliefs, histories and technologies
13	Ericsson	IoT accelerator
14	Sony	Acquisition of Altair Semiconductor for M2M and IoT, Sony Smart Home Automation, mixed-reality hardware, image sensing chips
15	Panasonic	Supportive technologies for IoT/robotics, smart electronics using IoT
16	HP	Edge computing technology, acquisition of Aruba Networks, HP's Helion cloud platform (an open-source dev-ready cloud platform aimed at connecting devices)
17	LG	LG CNS IoT platform, Smart Green Platform
18	SAP	SAP HANA Cloud Platform for the IoT
19	Hitachi	Lumada intelligent IoT platform
20	Canon	Fusing optical technologies with digital health-care
21	Nokia	Open innovation challenge to leverage IoT technologies enabling a smart, safe and sustainable world
22	EMC	New services framework including management of devices, connectivity, data and storage
23	Alcatel-Lucent	Network application challenge with new access switch added analytics and SDN (software defined networking) capabilities
24	Toshiba	Imbedding of sensors in data-collection devices, the real time processing of big data
25	Amazon	Amazon Web Services (AWS) IoT cloud, Amazon Echo home automation device, Amazon dash buttons

R&D investment level in 2016 order.
While firms 1–23 correspond to Table 1, 24 and 25 are not included in Table 1 (see footnote of Table 1).

$$\frac{dS}{dR} = aS\left(1 - \frac{S}{N}\right) \approx \frac{\partial S}{\partial R} \tag{4}$$

Equation (3) is developed to the following simple logistic growth (*SLG*) function which incorporates special advantage in assessing the state and prospect of productivity and development trajectory objectively:

$$S = \frac{N}{1 + be^{-aR}} \tag{5}$$

where *b*: coefficient indicating the initial state of the diffusion.

Given that $be^{-aR} \equiv \frac{1}{x}$, marginal productivity of ICT can be depicted as follows:

$$\frac{\partial S}{\partial R} = aS\left(1 - \frac{S}{N}\right) = aN \cdot \frac{1}{1 + \frac{1}{x}}\left(1 - \frac{1}{1 + \frac{1}{x}}\right) = \frac{aN \cdot x}{(1 + x)^2} \tag{6}$$

(2) Empirical Analysis

Based on this analytical framework, development trajectory of global ICT firms over the period 2005 and 2016 was analyzed.

1) Specific features of global ICT firms

In conducting the analysis, following specific features of development trajectory identical to global ICT firms were carefully considered.

While digital innovation accelerates logistic growth of global ICT firms induced by logistic growth nature of ICT, this innovation emerges "mutation" firms with outlying behavior. They are generally newly founded young firms but expand at tremendous pace as demonstrated in Table 4 and Fig. 6.

In order to explore a new insight for ICT firms for their transformative strategy toward an IoT-based society, objective state and prospect of productivity and development trajectory of global ICT firms general (not certain particular noting firms) should be analyzed not biased by particular gigantic "mutation" firms. However, since *SLG* function depends on fixed carrying capacity common to all firms analyzed resulting in biased estimate by highest development state in gigantic firms.

Fig. 6 allows us to imagine *SLG* estimation of *R*-driven development trajectory of 500 global ICT firms is biased by several gigantic firms with extraordinary high level of sales such as Apple, Samsung and Hon Hai while majority of 500 global ICT firms belong to the sales level below Euro 60 billion.

Aiming at avoiding such bias by certain gigantic firms, comparative assessment of the bias of gigantic firms in distorting *R*-driven development of the majority of 500 global ICT firms was conducted by treating gigantic firms that may distort such behavior as dummy variable in the *SLG* function. This comparative assessment identifies such gigantic ICT firms which have high variance from the general behavior of global ICT firms, and measures the magnitude of that variance, without which the highest representation of *R*-driven development trajectory can be analyzed by using *SLG* function (see the details of this treatment in Appendix B).

Table 5 summarizes the result of the comparative assessment.

Table 5 suggests that Case *C* (sales top 3 gigantic firms, Apple, Samsung and Hon Hai distort 500 global ICT firms' *SLG* trajectory most significantly) demonstrates statistically most significant.

Table 3
Trend in market capitalization of global ICT Firms [16].

a **Ranking of Global ICT Firms within Top 100 Firms**

	2005	2010	2016
1	General Electric (2)	Microsoft (3)	Apple (1)
2	Microsoft (3)	**Apple** (10)	Google (2)
3	IBM (13)	General Electric (16)	Microsoft (3)
4	Intel (15)	Google (17)	**Amazon** (4)
5	Cisco (25)	IBM (21)	**Facebook** (6)
6	Dell (34)	Cisco (30)	**Tencent Holdings** (10)
7	Samsung (47)	**Oracle** (36)	**Alibaba** (12)
8	Nokia (50)	HP (38)	General Electric (13)
9	Siemens (55)	Intel (42)	Samsung (14)
10	HP (72)	Samsung (50)	Oracle (34)
11	eBay (82)	Siemens (63)	Intel (40)
12	Google (93)	**Qualcomm** (87)	Cisco (41)
13		**Canon** (98)	IBM (44)
14		Amazon (101)*	**SAP** (56)
15			Siemens (64)
16			**Broadcom** (93)

* While Amazon was ranked 101 in 2010, it is listed for reference, as it conspicuously jumped to rank 4 in 2016.
Firms marked in bold are newly ranked-in firms.

b **Ranking of Global ICT Firms within Top 15 Firms**

	2005	2010	2016
1	General Electric (2)	Microsoft (3)	Apple (1)
2	Microsoft (3)	Apple (10)	Google (2)
3	IBM (13)		Microsoft (3)
4	Intel (15)		Amazon (4)
5			Facebook (6)
6			Tencent Holdings (10)
7			Alibaba (12)
8			General Electric (13)
9			Samsung (14)

Figures in parentheses indicate market capitalization rank computed based on Forbes Global 2000 statistics.
Telecom firms are not included.
Source: Forbes Global 2000.

Table 4
Outlining features of top 5 global ICT firms.

		R&D		Sales		Operating income	
Year of foundation	1	Samsung	1969	Apple	1976	Apple	1976
	2	Intel	1968	Samsung	1969	Samsung	1969
	3	Google	1998	Hon Hai	1974	Microsoft	1975
	4	Microsoft	1975	HP	1939	Google	1998
	5	Huawei	1987	Microsoft	1975	IBM	1911
Ratio of Top 1 and 10		2.6		3.5		8.9	

2) Results of the analysis

By conducting the similar assessment, Table 6 tabulates results of the estimation of *SLG* function over the period of 2005 and 2016. All results are statistically significant.

3.2. Trend in marginal productivity of ICT in global ICT firms

3.2.1. Declining trend in the marginal productivity of ICT

Utilizing equation (6) in Section 3.1, Fig. 7 demonstrates a trend in the marginal productivity of ICT in global ICT firms over the period 2005–2016. Fig. 7 demonstrates explicit bi-polarization between high R&D-intensive firms (HRIF: D_1 in Fig. 6) out of 500 global ICT firms and remaining low R&D-intensive firms (LRIF: D_2 and D_3 in Fig. 6). HRIFs have fallen into a vicious cycle between R&D investment centered by ICT and its marginal productivity, as the former increase results in declining the latter. On the contrary, LRIFs have been enjoying a virtuous cycle between them, as R&D increase leads to marginal productivity increase.

Fig. 8 compares this bipolarization between 2005 and 2016. Looking at Fig. 8, we note that the inflection point shifted slightly higher from EUR 2.0 billion in 2005 to EUR 2.1 billion in 2016, corresponding to the increase in R&D investment during this period. However, the maximum level of marginal productivity of

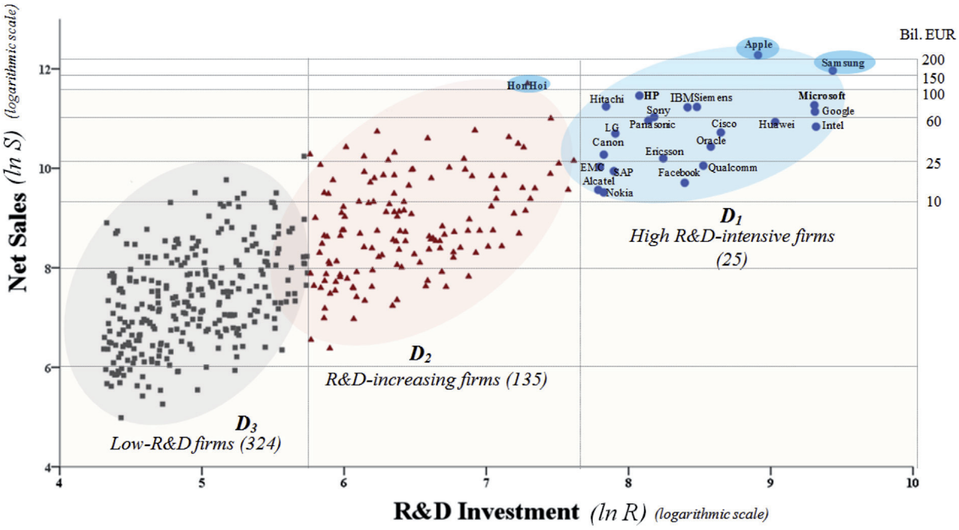


Fig. 6. Correlational Development between R&D and Sales in 500 Global ICT Firms (2016).
16 outliers scattered in D_2 and D_3 were not presented.

Table 5
Comparison of bias of gigantic firms in distorting R-driven SLG in majority of 500 global ICT firms (2016).
$S = \frac{N}{1+be^{-aR}} + cD$
where S: sales, R: R&D investment, N: carrying capacity, a, b, c: coefficients, D: dummy variable ($D = 1$ for designated outlier firms, $D = 0$ for other firms).

	N	*a*	*b*	*c*	*adj. R^2*	*D (outlier firms treated by dummy variable)[*]
A	68.72 (17.92)	1.21 (10.70)	16.36 (20.02)	96.87 (22.07)	*0.695*	Apple
B	58.24 (18.04)	1.44 (10.31)	15.55 (18.75)	97.82 (25.09)	*0.734*	Apple, Samsung
C	**59.62 (17.39)**	**1.32 (10.98)**	**15.91 (21.87)**	**99.09 (29.74)**	***0.784***	**Apple, Samsung, Hon Hai**
D	61.23 (16.77)	1.01 (10.72)	13.30 (21.63)	99.69 (29.22)	*0.780*	Apple, Samsung, Hon Hai, HP
E	50.38 (15.95)	1.33 (9.41)	12.71 (17.93)	90.72 (27.83)	*0.766*	Apple, Samsung, Hon Hai, HP, Microsoft
F	53.91 (14.63)	1.03 (9.27)	11.99 (18.87)	87.80 (27.79)	*0.766*	Apple, Samsung, Hon Hai, HP, Microsoft, Hitachi

[*] In addition to the above firms, Amazon and McKesson are included as outliers.
The figures in parentheses indicate t-statistics: All are significant at the 1% level.

ICT at the inflection point decreased during this period, reflecting the declining trend in this productivity in global ICT firms.

Table 7 compares HRIFs that have fallen into a vicious cycle between R&D investment and marginal functionality of ICT between 2005 and 2016. Numbers of HRIFs that have fallen into a vicious cycle have increased significantly from 16 in 2005 to 25 in 2016.

3.2.2. Structural source of decline in marginal productivity of ICT

Decline in marginal productivity of ICT can be attributed to the dependency on the Internet and its subsequent two-faced nature [47]. Advances in ICT can largely be attributed to the dramatic advancement of the Internet [17,27], which has changed the computer-initiated world significantly.

Advancement of ICT generally contributes to enhanced prices of technology by increasing new functionality development.[7] However, the dramatic advancement of the Internet actually causes a decrease in the price of technology due to its nature of freebies, easy copying, and mass standardization [13,47]. Consequently, prices of technology in highly ICT-advanced firms change to a declining trend, as illustrated in Fig. 9.

3.2.3. ICT leaders endeavor against marginal productivity of ICT decline

Given that the firms seek maximum profit in the competitive market, marginal productivity of technology corresponds to relative price of technology (ratio of technology prices and prices of product). Therefore, the Internet-driven price decrease corresponds

[7] Functionality development is generally defined as the ability to dramatically improve performance of production process, goods, and services by means of innovation [41].

Table 6
Estimation of development trajectory of the 500 global ICT firms (2005–2016).
$S = \frac{N}{1+be^{-aR}} + cD$
where *S*: sales, *R*: R&D investment, *N*: carrying capacity, *a*, *b*, *c*: coefficients, *D*: dummy variable ($D = 1$ for designated outliers, $D = 0$ for other firms).

	N	*a*	*b*	*c*	*adj.* R^2	*D* (outlier firms treated by dummy variable)
2005	53.80 (21.18)	1.55 (16.96)	22.02 (29.44)	42.63 (18.13)	*0.734*	Dell
2006	57.62 (22.19)	1.47 (16.30)	18.97 (30.62)	51.13 (20.52)	*0.757*	General Electric, Dell
2007	52.67 (22.11)	1.73 (15.05)	18.51 (27.09)	53.86 (22.08)	*0.735*	Metro, General Electric
2008	45.55 (20.81)	1.81 (13.43)	15.06 (25.10)	54.97 (23.72)	*0.741*	Metro, General Electric, Siemens
2009	54.96 (20.07)	1.58 (12.91)	15.49 (25.34)	58.68 (22.20)	*0.724*	Metro, General Electric
2010	55.46 (17.26)	1.35 (13.84)	14.70 (27.25)	58.53 (24.34)	*0.742*	Metro, HP, General Electric
2011	58.59 (20.32)	1.46 (13.88)	14.57 (26.74)	61.07 (22.58)	*0.738*	Hon Hai, Metro, HP, General Electric
2012	55.55 (16.31)	1.14 (11.73)	12.56 (24.50)	65.44 (23.38)	*0.727*	Samsung, Apple, Hon Hai, Metro, HP
2013	49.11 (17.90)	1.53 (10.52)	12.56 (21.04)	74.38 (25.86)	*0.730*	Samsung, Apple, Hon Hai, Amazon, McKesson, Tesco
2014	44.14 (17.18)	1.69 (9.46)	12.42 (19.45)	73.88 (26.29)	*0.725*	Samsung, Apple, NTT, AT&T, Hon Hai, Amazon, Tesco
2015	53.22 (17.81)	1.53 (10.94)	14.37 (20.82)	82.98 (27.32)	*0.739*	Samsung, Apple, Hon Hai, Amazon, McKesson, Metro, Tesco
2016	59.61 (19.45)	1.32 (11.40)	15.94 (21.04)	99.09 (29.68)	*0.784*	Samsung, Apple, Hon Hai, Amazon, McKesson

The figures in parentheses indicate t-statistics: All are significant at the 1% level.

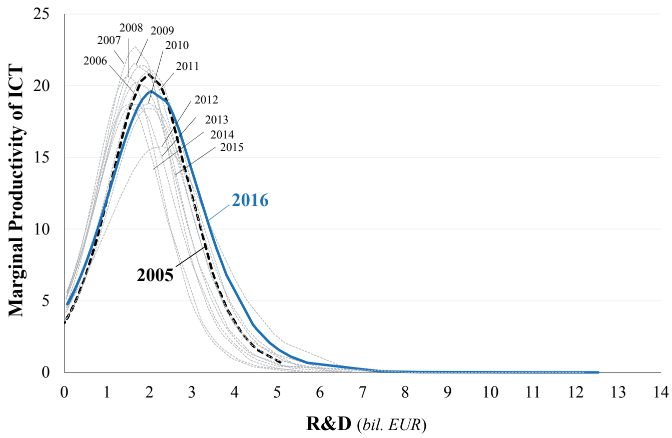


Fig. 7. Trend in marginal productivity of ICT in global ICT firms (2005–2016).

to marginal productivity decline.

This can be the structural source of marginal productivity decline in ICT leaders. Given such circumstances, ICT leaders endeavor to accelerate price increase by means of successive, efficient, new functionality development by minimum expenditures and minimizing price-decrease factors by outsourcing them to other parties [47]. Activating the ICT-inherent self-propagating function can lead to increasing uncaptured GDP[8] [49,51] as explained in Fig. 9.

3.3. Trend in dependency on uncaptured GDP in the global ICT leaders

3.3.1. Self-propagating dynamism

As reviewed in 3.1, the development trajectory of the global ICT leaders can be traced by the R&D-driven simple logistic growth function, as depicted by equations (4) and (5). While the level of

[8] Uncaptured GDP can be defined as added value providing utility (satisfaction of consumption) and happiness beyond economic value to people but cannot be measured by traditional GDP accounting (captured GDP) that measures economic value.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

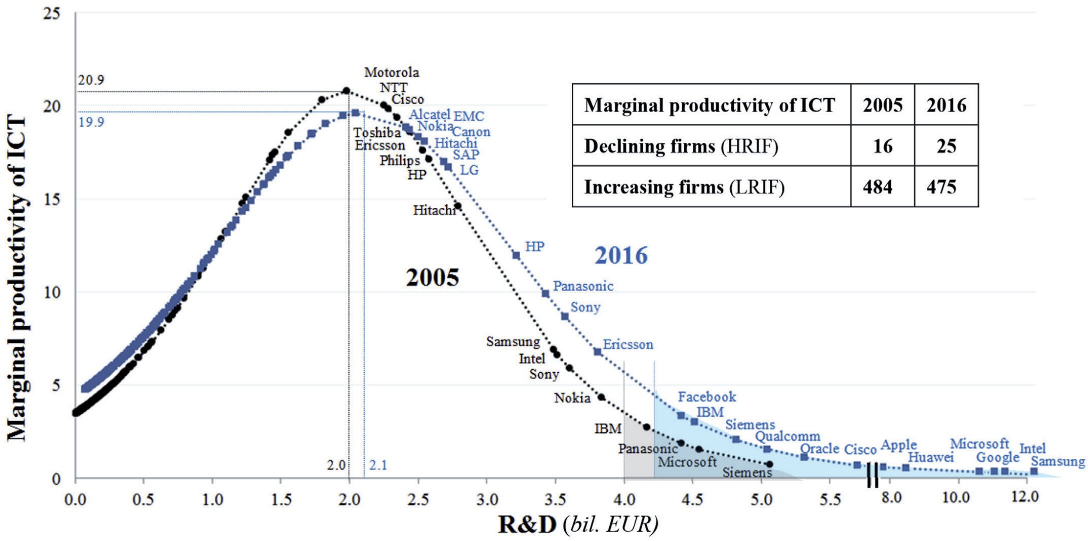


Fig. 8. Comparison of marginal productivity of ICT in 500 global ICT firms (2005, 2016).

Table 7
Comparison of HRIFs with R&D investment in 2005 and 2016.

	2005		2016	
	Firm	R&D (bil. EUR)	Firm	R&D (bil. EUR)
1	Siemens	5.06	Samsung Electronics	12.53
2	Microsoft	4.55	Intel	11.14
3	Panasonic	4.42	Google	11.05
4	IBM	4.17	Microsoft	11.01
5	Nokia	3.83	Huawei	8.36
6	Sony	3.60	Apple	7.41
7	Intel	3.52	Cisco Systems	5.70
8	Samsung Electronics	3.48	Oracle	5.32
9	Hitachi	2.79	Qualcomm	5.04
10	Hewlett-Packard	2.58	Siemens	4.82
11	Philips Electronics	2.53	IBM	4.51
12	Ericsson	2.44	Facebook	4.42
13	Toshiba	2.42	Ericsson	3.81
14	Cisco Systems	2.35	Sony	3.57
15	NTT	2.28	Panasonic	3.43
16	Motorola	2.25	Hewlett-Packard	3.22
17			LG Electronics	2.72
18			SAP	2.69
19			Hitachi	2.54
20			Canon	2.50
21			Nokia	2.50
22			EMC	2.44
23			Alcatel-Lucent	2.41
24			Toshiba	2.40
25			Amazon	0.59*

Order by level of R&D investment.
* Amazon is included in top 25 list as its market capitalization is conspicuous while its R&D investment is small and ranked 95th in 2016.
Note: blue color indicates 12 ICT firms with extraordinary high level of R&D.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

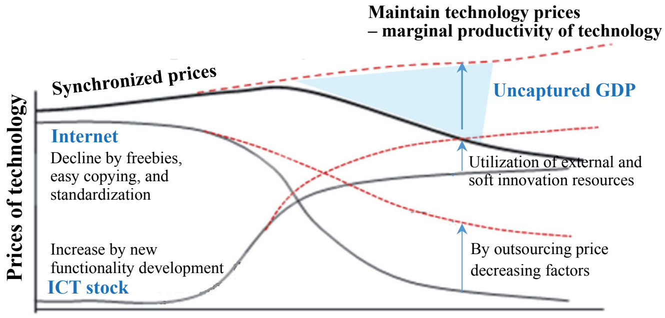


Fig. 9. Two-Faced Nature of ICT and Uncaptured GDP Emergence.
Note: At the initial stage of Internet commercialization, its price is extremely higher than that of ICT.

carrying capacity (N) is assumed constant through the development process in this function, in particular innovations, the correlation of the interaction between innovation and institutions displays a systematic change in the process of growth and maturity. This leads to the creation of a new carrying capacity in the process of its development, similar to equation (7) as follows:

$$\frac{dS(R)}{dR} = aS(R)\left(1 - \frac{S(R)}{N(R)}\right) \tag{7}$$

This equation leads to the following logistic growth within a dynamic carrying capacity (*LGDCC*) function, which demonstrates the level of carrying capacity enhancement as the development proceeds [29]:

$$S(R) = \frac{N_K}{1 + be^{-aR} + \frac{b_k}{1 - \frac{a_k}{a}e^{-a_k^R}}} \tag{8}$$

where Nk: ultimate carrying capacity, and ak and bk: coefficients similar to a and b.

Equation (8) demonstrates that the third term of the denomination governs the dynamic carrying capacity and, without this term, results in *SLG* with a constant carrying capacity.

From equation (7), dynamic carrying capacity can be expressed as follows:

$$N(R) = S(R)\left(\frac{1}{1 - \frac{1}{a}\cdot\frac{dS(R)}{dR}\Big/S(R)}\right) \tag{9}$$

This demonstrates that $N(R)$ increases together with that of $S(R)$ and its R&D-driven growth rate. This implies that the *LGDCC* function demonstrates functionality development in the context of the self-propagating behavior [39,43].

This self-propagating function plays a vital role of the engine in spinning-off from the traditional co-evolutional of three megatrends in the world of the PoT[9] to the new co-evolution toward the IoT, as illustrated in Fig. 1. This spin-off plays a significant role in inducing ICT-driven innovation [47,49]. Here, spin-off is defined as jumping to more sophisticated co-evolutional dynamism from traditional co-evolutional dynamism in inducing innovation [44].

Since the potential of functionality development can be traced by the ratio of development state and its upper limit (carrying capacity) [43], functionality development in the *LGDCC* function can be depicted from equation (9) as follows:

$$\text{Functionality development} = FD = \frac{N(R)}{S(R)} = \frac{1}{1 - \frac{1}{a}\cdot\frac{dS(R)}{dR}\Big/S(R)} \tag{10}$$

This equation demonstrates that functionality development can be accelerated as its growth rate increases. This explains functionality development in the context of self-propagating behavior. Since functionality development plays a locomotive role in leveraging spin-off [44], equation (10) indicates that the self-propagating function leverages spin-off by inducing functionality development (see Appendix C dynamism in developing self-propagating function).

With the understanding that this self-propagating function can be attributed to its adaptability to ICT-driven logistic growth within a dynamic carrying capacity (*LGDCC*) function that increases functionality as it grows rather than a simple logistic growth (*SLG*) function that fades out functionality as it grows [39], Table 8 estimates the *LGDCC* function of 500 global ICT firms in 2005 and2016[10] and results are statistically significant.

The self-propagating function can be attributed to dynamism of functionality development (*FD*) increase as growth proceeds (*S* increase) [40]. *FD* can be estimated by the ratio of N (carrying capacity) and S [43]. Therefore, the magnitude of the self-propagation

Table 8
LGDCC function in 500 global ICT firms in 2005 and 2016.

LGDCC $S(R) = \frac{N_k}{1 + be^{-aR} + \frac{b_k}{1 - \frac{a_k}{a}e^{-a_k^R}}}$

	N_k	a	b	a_k	b_k	*adj.* R^2
2005	75.28	1.27	26.65	0.35	0.34	0.999
	(30.37)	(177.19)	(25.42)	(2.50)	(6.71)	
2016	102.23	0.77	15.84	0.43	1.32	0.999
	(178.83)	(26.13)	(9.72)	(7.06)	(2.53)	

$S(R)$: sales; N_k: carrying capacity; R: R&D investment; a, b, a_k, b_k: coefficients.
Results are based on the third step approximation.
The figures in parentheses indicate t-statistics: All are significant at the 1% level.

[9] Under the PoT, computer- and semiconductor-initiated mass production played a vital role.

[10] Estimation of *LGDCC* depended on the three-step approximation approach (see Appendix D).

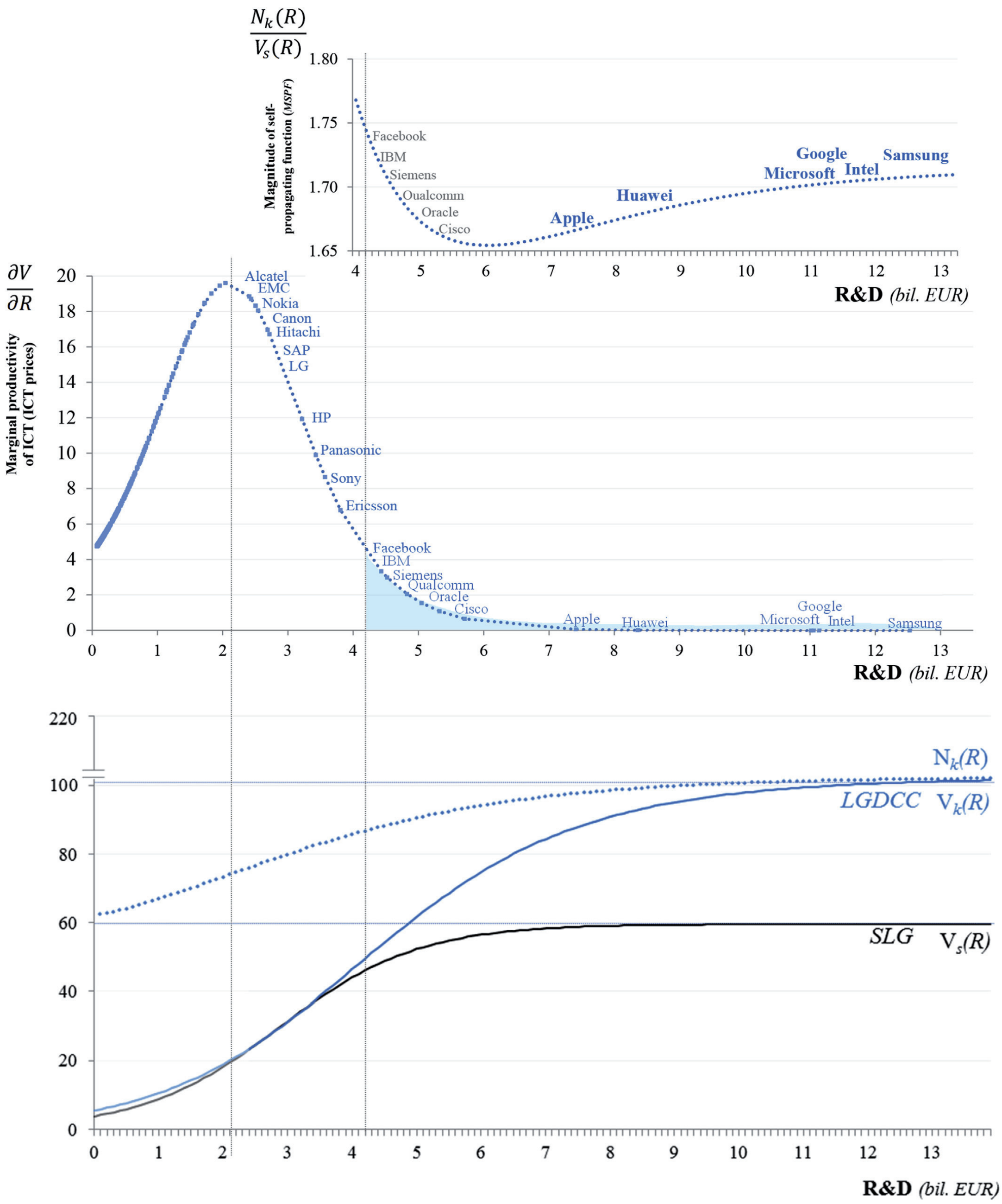


Fig. 10. Dynamism in Transforming Productivity Decline into Supra functionality (2016).
—New Open Innovation by Harnessing Soft Innovation Reso rces.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

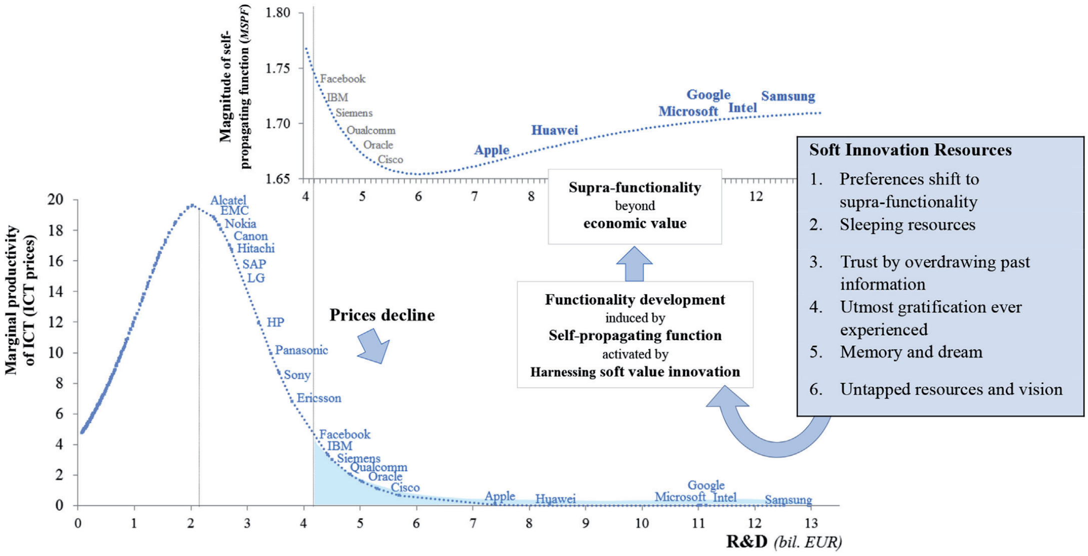


Fig. 11. Scheme of functionality development by harnessing soft innovation resources. —High R&D intensive global ICT firms (2016).

function can be estimated by the ratio of $N_k(R)$ (dynamic carrying capacity that leads development trajectory after incorporating the self-propagating function) and $S_s(R)$ (development trajectory estimated by *SLG* that demonstrates development level when no self-propagating function incorporates) [53].

Fig. 10 demonstrates trends in marginal productivity of ICT and magnitude of the self-propagating function in global ICT firms in 2016. This figure shows that, in repulsion to marginal productivity of ICT decline, self-propagating function increase in high R&D-intensive global ICT firms such as Samsung, Intel, Google, Microsoft, Huawei and Apple. Thereby these firms correspond to peoples' preference shift to supra-functionality beyond economic value as demonstrated in Fig. 1. This survival strategy can be called the long tail of the global ICT leaders [2].

The above analyses demonstrate the following noteworthy structural changes in global ICT firms toward the IoT acceleration after 2010:

- Dramatic decrease in ICT prices
- Subsequent decline in marginal productivity of ICT
- Intensive efforts in increasing functionality development by activating the self-propagating function.

It is postulated that this activation can be attained by harnessing the vigor of soft innovation resources, including sleeping/untapped resources, thus leading to increasing dependency on uncaptured GDP.

The next section demonstrates this hypothetical view.

4. Functionality development and the transformative direction of innovation

4.1. Scheme of functionality development

Fig. 11 demonstrates the dynamism of functionality development (which presents supra-functionality beyond economic value) induced by the self-propagating function which can be activated by harnessing the vigor of the following soft innovation resources:

- People's preferences shift to supra-functionality beyond economic value
- Sleeping resources (similar to ridesharing revolution by Uber)
- Trust by overdrawing past information
- Utmost gratification ever experienced
- Memory and dream
- Untapped resources and vision

This can be attained in reaction to marginal productivity of ICT decline due to the high dependency on ICT that incorporates a two-faced nature.

4.2. Transformative direction of leading global ICT firms

With the understanding of such dynamism aiming at demonstrating that high R&D-intensive global ICT firms succeeded in harnessing the vigor of soft innovation resources, Table 9 reviews the transformative direction of seven leading global ICT firms in harnessing such innovation resources over the period 1970–2020.[11]

Based on the preceding review, Fig. 12 summarizes the noteworthy transformative direction of ICT-driven disruptive business models accomplished by seven leading global ICT firms in response to marginal productivity decline. Such

[11] Seven selected ICT firms include the top six high R&D-intensive firms in 2016 as demonstrated in Fig. 10 and Amazon. Amazon was included in this review due to its conspicuously high market value in 2016 (ranked fourth, see Table 2) while R&D investment was limited.

Table 9
Transformative direction of seven leading global ICT firms.

	1970–1980	1981–1990	1991–2000	2001–2010	2011–2020
1. Samsung	**Mechatronics** **1938:** Samsung founded **1969:** Samsung-Sanyo electronics established **1970:** Black-and-white TV **1972:** Washing machine Refrigerator **1977:** Color television **1979:** Microwave ovens	**Computers** **1980:** Air conditioner **1983:** Personal computers (PCs) **1984:** Export of VCRs **1986:** Smallest video tape recorder **1987: SAIT established**	**Mobile Phones, Digital TVs** **1992:** Mobile phones HDD, DRAMs Industrial robots **China expansion** **1993:** Digital video recorder (DVD-R) **1994:** Electric car (SEV-III) **1995:** MPEG-3 technology **1996:** Fastest CPU (alpha chip) 33″ double-screen TV **1997:** World lightest TVs 30″ TFT-LCD display **1998:** Digital TV, flat-screen TV **1999:** Smartphone, wireless internet phone, multi-function phone **2000:** 50 millionth mobile phone	**Smartphones, Smart TVs** **2004:** World largest LCD TV (46″) Smartphones **2008:** World's 1st dual-color bezel TV **2009:** World's slimmest LED TV **2010: World's 1st TV app store** World's 1st FHD 3D TV	**Tablets, Wearables, VR, IoT** **2011:** Galaxy tablets Hard disk biz sold to Seagate **2012:** Samsung and Apple patent infringement controversy Samsung shares on the KOSPI index fell 7.7% **2013:** World's 1st curved TV **2014:** Gear VR devices Galaxy Note 4 World's 1st bendable UHD TV Stopped music streaming business, Music Hub app **2015:** Granted world's most patents World's largest curved UHD TV **2016:** IoT, partnership with Microsoft Smartwatch (Gear Fit 2, etc.) Icon-X, Galaxy Note 7
2. Intel	**Integrated Electronics** **1968:** Co-founded by Gordon Moore and Robert Noyce **1969:** Worlds 1st MOS **1970:** First property, first board **1971:** New era in integrated electronics **1972:** First international factory in Malaysia **1975:** Computers get personal **1979:** 486th position in Fortune 500	**Computer Boards, Chips** **1982:** PC industry takes off **1983:** US$1 billion annual revenue **1984:** One of the 100 best companies to work for in America **1985:** Super computer, Intel 386 processor **1987:** Second-generation super computer **1988:** Intel foundation established **1990:** Robert Noyce died	**Processors** **1992:** Largest semiconductor supplier in the world **1993:** Intel Pentium processor **1995:** Became a chipset leader **1998:** Intel strong ARM processor **1999:** Intel Pentium III, Xeon Processor **2000:** Intel Pentium 4 processor	**Cell Phone Microchips** **2002:** Hyper-threading technology, more power at lower cost **2003:** Cellular phone microchips **2004:** 46th in Fortune 100 Best Companies to work for **2005:** 40th anniversary of Moore's law **2006:** World's 1st quad-core processor **2008:** 45-nm transistor **2009:** Intel atom processor Going Green Paid US$1.25 billion to AMD in lawsuit settlement **2010:** Buys McAfee i7 Processor, Intel App-Up store	**Supporting Technologies for IoT and Wearables** **2011:** Intel Ultrabook **2012:** 450-nm manufacturing technology **2013: New generation of processors** i3, i5, i7 **2014:** Intel Quark chip powering IoT and wearable devices **2016:** Announces withdrawal from smartphone market
3. Google			**Information Search** **1998:** Google founded **2000:** World's largest search engine	**Gmail, Earth, YouTube, Smartphones, OS, Apps** **2001:** Image Search **2002:** Google News **2004:** Gmail **2005:** Google Earth, Maps, Talk, Video, Books, Mobile Search, Scholar **2006:** Android, Google Trends **2007:** YouTube **2008:** Google Chrome, Street View **2009:** Google Translate **2010:** Google Nexus phone	**Google (Play store, Glass, Balloons), Cloud, IoT** **2011:** Google Panda, acquired Motorola, Google + **2012:** Google Play store **2013:** Google Nexus 7 tablet Google Hangouts, Google Balloons **2014:** **2015:** **2016**
4. Microsoft			**Software**	**Software, Play Stations**	**Cloud, Platforms, Analytics, IoT**

(*continued on next page*)

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

Table 9 (*continued*)

	1970–1980	1981–1990	1991–2000	2001–2010	2011–2020
	1975: Microsoft founded **1979:** Shifted from New Mexico to Washington	**1981:** Microsoft incorporates IBM 1st PC with MS-DOS 1.0 **1986:** Moves to Redmond, Washington Microsoft stock goes public **1989:** Earliest version of Office suite **1990:** Microsoft launches Windows 3.0	**1995:** Microsoft launches Windows 95 Bill Gates outlines Microsoft's commitment to the Internet **1998:** Microsoft launches Windows 98 **2000:** Steve Ballmer named president and CEO for Windows 2000	**2001:** Windows XP, Office XP Xbox play station **2002:** Tablet PC **2003:** Windows Server 2003 MS Office System **2004:** Xbox 360 next generation **2006:** Zune music player **2007:** Windows Vista MS Office 2007 **2008:** Windows server, SQL server Visual Studio **2010:** Windows phone OS MS Office 2010	**2011:** Windows Phone, Xbox Kinect Office 365 **2012:** Surface tablets Windows 8, Windows phone 8, Windows Server **2013:** Surface 2, Pro 2, Xbox one Office 2013 **2014:** Buys Nokia devices & services Buys Minecraft, Office iPad, Android, Surface Pro 3 **2015:** Windows 10, Office 2016, Lumia 950, Lumia 95 XL Surface 3, Pro 4 **2016:** LinkedIn, Surface Studio, Dial, Book, Visual Studio 2017
5. Huawei		**Distributor** **1988:** Huawei founded as distributor of imported PBX products	**Fixed-Line and Digital Network Products** **1993:** Digital telephone switch with capacity over 10,000 circuits **1996:** Wins first big overseas contract for fixed-line network products from Hong Kong's Hutchison-Whampoa	**Mobile Networks** **2003:** Joint venture with 3Com Cisco Systems sues for copyright violations **2004:** Overseas sales surpass domestic sales for first time **2008:** Contract orders rose 46% to US$23.3 billion World's 3rd largest mobile network gear maker **2009:** World's top patent seeker Head the UN WIPO list	**Smartphones, Cloud, IoT** **2011** **2012** **2013** **2014** **2015:** Smartphones, Huawei P8 Huawei P8 Max
6. Apple	**Computers, Printers** **1976:** Apple I **1977:** Apple II **1978:** Apple (Writer, file type) **1979:** **1980:** Apple III	**Computers** **1981:** Apple ProFile **1982:** Apple printers (dot matrix, letter quality)	**Laptop Computers** **2000:** PowerBook Prismo Cinema Display 22″	**iPod, iTunes, Smartphones, Tablets** **2001:** iPod 1st gen **2002:** iPod 2nd gen, iBook 14″, iMac **2003:** iPod 3rd gen, PowerBook G4 **2004:** iPod Mini (1st gen) iPod (4th gen) **2005:** iPod Mini, (2nd gen) iPod Nano (1st gen) iPod (4th gen) iPod Shuffle **2006:** MacBook Pro (15″, 17″) iPod Hi-Fi, iPod Nano (2nd gen) iPod Shuffle (2nd gen) **2007**: Apple TV (1st gen) iPhone (4, 8 GB) **2008:** iPhone 3G (8, 16 GB) iPhone (16 GB) **2009:** iPhone 3 GS **2010:** iPad (WiFi + 3G), iPhone 4	**Smart Devices, Platforms, IoT** **2011:** iPad 2 (16, 32, 64 GB) iPhone 4S **2012:** iPad, iPad Mini, iPhone 5 **2013:** iPhone 6, iPhone 6 Plus iPad Air 2, iPad Mini 3 **2014:** Apple Watch, iPhone 6S iPad Mini 4, iPad Pro **2015:** iPhone 7, iPhone 7 Plus iPad Pro
7. Amazon			**Book Store** **1995:** Amazon launched **1997:** Amazon on NYSE, Nasdaq Buys bookpages.co.uk Launches Amazon UK **1998:** CDs and DVDs **1999:** Toys and electronics	**Top Online Retail Store** **2000:** Marketplace, Amazon's third-party business **A to the Z** in Amazon launches **2001:** Takeover Borders.com	**Fusing Physical and Digital** **2011:** Kindle Fire tablet **2012:** Buys Kiva, a robotics company, for US$775 million to contain technology just for itself **2013:** Big cloud systems contract of

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

Table 9 (*continued*)

	1970–1980	1981–1990	1991–2000	2001–2010	2011–2020
				Borders collapses 10 years later Amazon makes its first profit **2002:** Amazon Web Services cloud computing platform **2003: S**elling jewelry **2004:** Selling shoes **2005:** Amazon Prime membership **2006:** Amazon Fresh (food online) **2007:** Kindle e-reader **2008:** Games **2009:** Buys Zappos **2010:** Logistics infrastructure scaling Amazon Studios to create original television content	US$600 million for 17 US intelligence agencies Prime Air drone delivery plans **2014:** Amazon Echo voice device 8th generation fulfillment centers **2015:** Amazon brick-and-mortar store Amazon Flex a-piece-rate delivery (Uber model) Amazon passes Walmart in market capitalization **2016:** Amazon captures 50% of online spending in US Amazon doubles its distribution facilities **2017:** Amazon buys Whole Foods

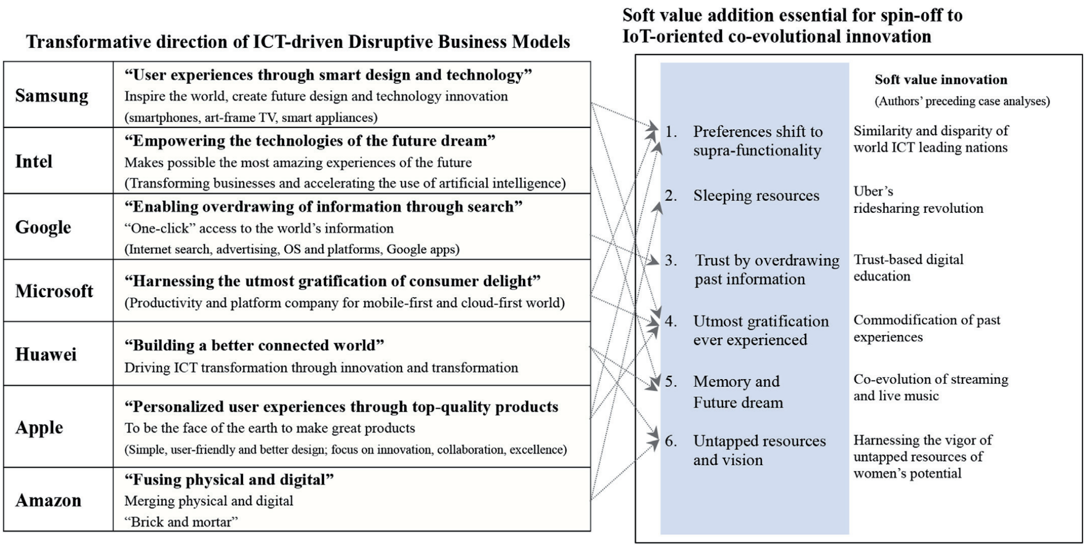


Fig. 12. Noteworthy direction of ICT-driven disruptive business models.

accomplishments are correlated with soft innovation resources identified as a soft value addition corresponding to uncaptured GDP and essential for the spin-off from traditional PoT-driven innovation to new IoT-oriented co-evolutional innovation as reviewed in section 1.6.

With respect to the transformative direction of IDBM, all seven leading global ICT firms demonstrate their success in harnessing the vigor of the soft innovation resources identified as soft value-addition corresponding to uncaptured GDP and an essential element for the spin-off from traditional PoT-driven innovation to a new IoT-oriented co-evolutional innovation.

4.3. Noteworthy lessons for harnessing the soft innovation resources

Supported by the success of self-propagating functionality development by harnessing the soft value innovation resources as demonstrated by seven leading global ICT firms, the transformative direction of trust-based IDBM with CCSD can be envisioned as illustrated in Fig. 13.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

Soft innovation (Authors' preceding case analyses)	Past	Current	Future
1. Similarity and disparity of world ICT leaders	**PoT** Captured GDP Economic functionality	**IoT** Uncaptured GDP Supra-functionality	**Beyond IoT** New concept of GDP Digital supra-functionality
2. Uber's ridesharing revolution	Sleeping resources (cars, drivers)	Effectively utilization of sleeping resources through technology platforms Trust-based tripartism cooperation frameworks	Driverless cars Autonomous electric taxi fleets In-road inductive charging
3. Trust-based digital education	Knowledge and experiences	Overdrawing of past information, developing trust	AI, VR Realtime language processing Teaching avatar assistants Brain computer interfaces Machines gain statistical intuition
4. Commodification of past experiences	Utmost gratification ever experienced	Conceptualization of invisible voice of consumers	Commodification of experiences
5. Co-evolution of streaming and live music	Past unforgettable memories and experiences	Invoking memories Live entertainment Participative creativity Synthesizing future dream	Collaborative value creation Virtual participation Augmented reality Machine-generated art and music
6. Harnessing the vigor of un-tapped resources by activating women's potential	Untapped resource Domestic responsibilities Limited participation and opportunities	Harnessing the women's potential Giving responsibilities Gender-balance equality	Ambitious vision for harnessing women's potential together with men to generate economic and social value

Accomplishments by Seven Leading ICT Firms

Noteworthy accomplishments initiated by the seven leading global ICT firms		
	Samsung	**"User experiences through smart design and technology"** Inspire the world, create future design and technology innovation (smartphones, art-frame TV, smart appliances)
	Intel	**"Empowering the technologies of the future dream"** Makes possible the most amazing experiences of the future (Transforming businesses and accelerating the use of artificial intelligence)
	Google	**"Enabling overdrawing of information through search"** "One-click" access to the world's information (Internet search, advertising, OS and platforms, Google apps)
	Microsoft	**"Harnessing the utmost gratification of consumer delight"** (Productivity and platform company for mobile-first and cloud-first world)
	Huawei	**"Building a better connected world"** Driving ICT transformation through innovation and transformation
	Apple	**"Personalized user experiences through top-quality products** To be the face of the earth to make great products (Simple, user-friendly and better design; focus on innovation, collaboration, excellence)
	Amazon	**"Fusing physical and digital"** Merging physical and digital "Brick and mortar"

Fig. 13. Transformative direction of trust-based ICT-driven disruptive business models with consolidated challenge to social demand.

5. Conclusion

This analysis focused on the increasing significance of the restructuring of business models in the global ICT firms toward an IoT-based society, the dynamism emerging this transformation, and optimal digital business strategies corresponding to this dynamism.

An empirical analysis was conducted by evaluating digital business solutions in 500 global ICT firms over the period 2005–2016 with special attention to their specific features initiated by particular gigantic "mutation" firms.

5.1. *Noteworthy findings include*

- R&D-intensive firms have fallen into a trap in ICT advancement resulting in declining their marginal productivity of ICT and suggest a new productivity paradox in the digital economy.
- This can be considered a consequence of two-faced nature of ICT, which, together with people's preference shift to supra-functionality beyond economic value, leads to increasing dependency on uncaptured GDP.
- To counterchallenge such situation these firms endeavor to activate the self-propagating function that induces functionality development sublimating sophisticated digital business strategies.
- This activation can be achieved by harness the vigor of soft innovation resources.
- This dynamism can be considered the soft value addition corresponding to uncaptured GDP.
- Firms with higher market value increase the self-propagating function efficiently which, in turn further increase their market value.

- This can generally be attributed to their sophisticated digital business strategies in increasing the high level of operating income to R&D.

These findings give rise to the following insightful suggestions to global ICT firms for transformation of their business models toward an IoT-based society:

- The significance of the transformation from traditional ICT-driven functionality development strategy to digital business strategy should be recognized.
- A trap in ICT advancement and subsequent increasing dependency on uncaptured GDP should be realized.
- High functionality development induced by a sophisticated self-propagating function should be endeavored by recognizing the consequences of uncaptured GDP.
- It should be noted that higher operating income corresponds to higher market value.
- Trust-based IDBM with CCSD should be realized corresponding to a business model inducing a sophisticated self-propagating function.
- Every effort should be focused on effective utilization of soft-innovation resources to correspond to the effects of uncaptured GDP.

This analysis explores a new insight for ICT firms for their transformative strategy toward an IoT-based society. Future work should focus on detailed case analyses on further exploring the soft-innovation resources beyond anticipation suggested by the success and failure of other firms in addition to the seven ICT firms examined in this paper. In this context, Amazon's unique business model which accomplishes extraordinary digital value notwithstanding limited R&D investment should be further elucidated.

The further identification of similar novel business concepts as suggested by the seven leading global ICT firms (e.g., *"overdrawing information through search", "merging net and real",* and *"fusing art and technology"*) should be made a priority.

The development of road maps toward the envisioned future would be another important responsibility and subject for future research. Challenge to the limitation of GDP in the digital economy would correspond to the current worldwide concerns.

Funding

The research leading to these results is the part of a project: Platform Value Now: Value capturing in the fast emerging platform ecosystems, supported by the Strategic Research Council at the Academy of Finland [grant number 293446].

Authors' curriculum vitae

Kashif Naveed is currently pursuing his Ph.D. in Economics and Business Administration from the University of Jyväskylä, Finland, and he has completed his Master of Science degree in Economics and Business Administration from the same university (kashif.naveed.dr@gmail.com).

Chihiro Watanabe graduated from the University of Tokyo, Japan, and is currently Professor Emeritus at the Tokyo Institute of Technology, Research Professor at the University of Jyväskylä, Finland, and a Research Scholar at the International Institute for Applied Systems Analysis (IIASA) (watanabe.c.pqr@gmail.com).

Pekka Neittaanmäki graduated from the University of Jyväskylä in Mathematics and is currently Professor and Dean of the Faculty of Information Technology, University of Jyväskylä, Finland (pekka.neittaanmaki@jyu.fi).

Appendix A. Influence of R&D-driven growth in global ICT firms

Given that sales (S) of the global ICT firms are governed by their ICT stock (T), their sales can be depicted as follows:

$$S = F(X, T) \tag{A.1}$$

where X: production factors other than T.

This equation can be approximated as follows by conducting Taylor expansion to the first term

$$\ln S = a + b \ln X + c \ln T \tag{A.2}$$

where a, b, c: coefficients.

Since X is governed by T in global ICT firms, it can be developed as follows:

$$X = F(T) \ln X = ax + bx \ln T \tag{A.3}$$

where a_x, b_x: coefficients.By substituting equation (A3) for ln X in equation (A2), $\ln S = a + b\,(a_x + b_x \ln T) + c \ln T$.

$$= (a + b{\cdot}a_x) + (b{\cdot}b_x + c) \ln T$$

$$\equiv \alpha + \beta \ln T \tag{A.4}$$

where. $\alpha = a + b{\cdot}a_x, \beta = b{\cdot}b_x + c$

Since (T) can be approximated by R&D investment (R) as follows (see footnote 5):

$$T \approx \frac{R}{\rho + g} \tag{A.5}$$

where ρ: rate of obsolescence of technology and g: increased rate of R&D investment at the initial stage.

Therefore, equation (A4) can be described as follows:

$$\ln S = \alpha + \beta \ln \frac{R}{\rho + g} \tag{A.6}$$

$$= \alpha + \beta \ln R - \beta \ln(\rho + g)$$

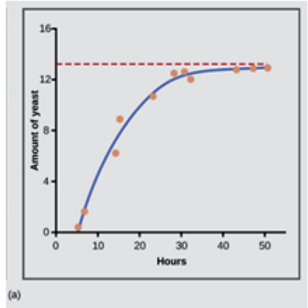
$$= [\alpha - \beta \ln(\rho + g)] + \beta \ln R$$

$$\equiv \alpha' + \beta \ln R$$

where. $\alpha' = \alpha - \beta \ln(\rho + g)$

With such understanding, correlation between (R) and (S) in 500 global ICT firms was analyzed in section 2.1.

Appendix B. *SLG* (simple logistic growth) estimate with dummy variables



(*a*) Yeast grown in ideal conditions in a test tube show a classical S-shaped logistic growth curve (SLG), whereas

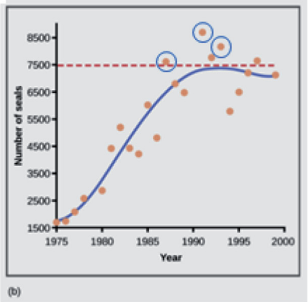
(*b*) Natural population of seals shows real-world fluctuation.

(*c*) Population growth estimate avoiding bias by unusual level (*c.f.*, outlier expansion of gigantic firms) by means of dummy variable treatment.

Sources

(*a*) and (*b*): Environmental limits to population growth by OpenStax College, Biology, CC BY 4.0.

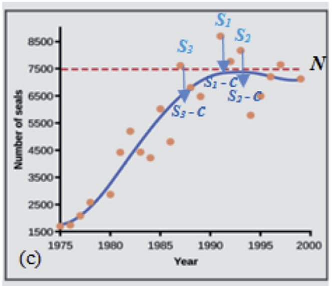
(*c*): Authors interpretation and development.



Treatment of bias avoidance by means of *SLG* with dummy variables

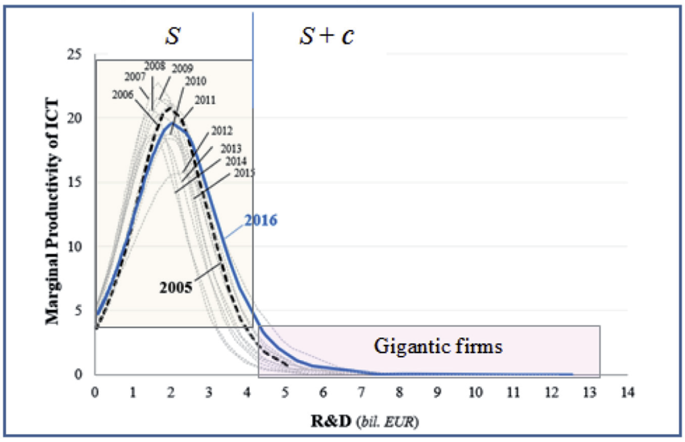
$$S = \frac{N}{1+be^{-aR}} + cD$$

Un-usual	S	Dummy variable D X_1	X_2	X_3	Others	Adjusted S
X_1	S_1	1	0	0	0	$S_1 - c$
X_2	S_2	0	1	0	0	$S_2 - c$
X_3	S_3	0	0	1	0	$S_3 - c$



Marginal productivity of ICT

$$\frac{\partial S}{\partial R} = aS\left(1 - \frac{S}{N}\right)$$



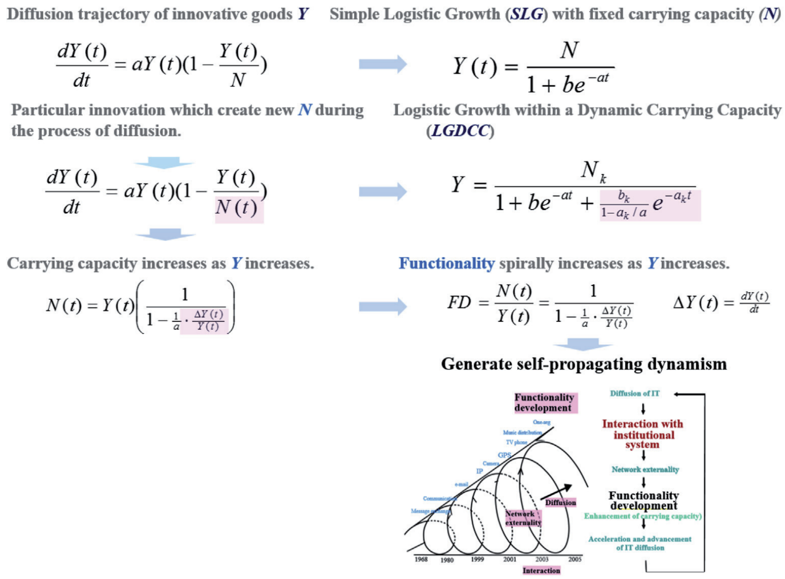
– Avoidance of Bias by Gigantic Firms in *SLG* Estimation

Appendix C. Dynamism in developing self-propagating function

Step 2. Estimate $a_e^{'}$, $b_e^{'}$ by using plausible.$N\pm\varepsilon$

Estimate *S* in logistic growth with dynamic carrying capacity *(LGDCC)*

$$\bar{S} = \frac{N\pm\varepsilon}{1 + b_e^{'} e^{-a_e^{'} R}}$$



Appendix D. Three-step approximation approach of logistic growth within a dynamic carrying capacity

$$S = \frac{N_k}{1 + be^{-aR} + \frac{b_k}{1 - \frac{a_k}{a} e^{-a_k R}}}$$

$$\approx \frac{N}{1 + b' e^{-a' R}}$$

$$a^{'} = a\left(1 - \frac{b_k}{b}\right) < a,$$

$$b^{'} = b\left(1 + \frac{b_k}{b} \cdot \frac{1}{1 - \frac{a_k}{a}}\right) > b$$

Source [43].

Step 1. Estimate simple logistic growth *(SLG)*

$$S_{(Actual)} = \frac{N\pm\varepsilon}{1 + b' e^{-a' R}}$$

Step 3. Estimate *LGDCC* by using $\bar{S}$

$$\bar{S} = \frac{N_k}{1 + be^{-aR} + \frac{b_k}{1 - \frac{a_k}{a} e^{-a_k R}}}$$

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.techsoc.2017.11.003

Uncited references

[33]; [35]

References

[1] N. Ahmad, P. Schreyer, Are GDP and Productivity Measures up to the Challenges of the Digital Economy? International Productivity Monitor 30, Spring, 2016, pp. 4–27.
[2] C. Anderson, The Long Tail: Why the Future of Business Is Selling Less of More, Hyperion Books, New York, 2006.
[3] A. Bharadwaj, O.A.E. Sawy, P.A. Pavloyu, N. Venkatraman, Digital business strategy: toward a next generation of insights, MIS Q. 37 (2) (2013) 471–482.
[4] E. Brynjolfsson, Productivity paradox of information technology, Commun. Assoc. Comput. Mach. 36 (12) (1993) 66–77.
[5] E. Brynjolfsson, L. Hitt, Paradox lost? Firm-level evidence on the returns to

information systems spending, Manag. Sci. 42 (1996) 541–558.
[6] E. Brynjolfsson, L. Hitt, Beyond the productivity paradox, Commun. ACM 41 (8) (1998) 49–55.
[7] E. Brynjolfsson, S. Yang, in: The Intangible Costs and Benefits of Computer Investments: Evidence from Financial Markets. Atlanta, Georgia: Proceedings of the International Conference on Information Systems, 1999.
[8] E. Brynjolfsson, A. McAfee, Race against the Machine, Digital Frontier, Lexington, MA, 2011.
[9] E. Brynjolfsson, A. McAfee, The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies, W.W. Norton & Company, New York, 2014.
[10] E. Brynjolfsson, Y. Hu, M. Smith, Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety at Online Booksellers, Management Science, Forthcoming, revised 2017. https://doi.org/10.2139/ssrn.400940.
[11] Copenhagen Economics, The Impact of Online Intermediaries on the EU Economy, 2013.
[12] Copenhagen Economics, The Impact of Online Intermediaries on the EU Economy, 2015.
[13] T. Cowen, The Great Stagnation: How America Ate All the Low-hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better: a Penguin ESpecial from Dutton, Penguin, New York, 2011.
[14] Economist, How to Measure Prosperity. https://www.economist.com/news/leaders/21697834-gdp-bad-gauge-material-well-being-time-fresh-approach-how-measure-prosperity (accessed 30.04.2016).
[15] EU, The Internet of Things: Digital Single Market, EU, Brussels, 2017.
[16] Forbes The Global, The World's Largest Public Companies, 2000. https://www.forbes.com/global2000/#44a1bfde335d, 2017 (accessed 01.08.2017).
[17] International Telecommunication Union (ITU), Measuring the Information Society 2013, 2013. http://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2013.aspx (accessed 27.07.2017).
[18] Internet Society, The Internet of Things: an Overview. Internet Society, 2015. https://www.internetsociety.org/doc/iot-overview (accessed 05.08.2017).
[19] Internet Society, Global Internet Report 2016, 2016. https://www.internetsociety.org/globalinternetreport/2016/wp-content/uploads/2016/11/ISOC_GIR_2016-v1.pdf (accessed 05.08.2017).
[20] IoT Analytics, IoT Company Ranking Report Q3/Q4 2015, 2015. https://iot-analytics.com/product/iot-company-ranking-q3q4-2015/ (accessed 25.07.2017).
[21] C. Kahre, D. Hoffmann, F. Ahlemann, in: Beyond Business-IT Alignment-digital Business Strategies as a Paradigmatic Shift: a Review and Research Agenda, Proceedings of the 50th Hawaii International Conference on System Sciences, 2017, pp. 4706–4715.
[22] K.L. Kraemer, J. Dedrick, Payoffs from investment in information technology: lessons from the Asia-Pacific region, World Dev. 22 (12) (1994) 1921–1931.
[23] F.R. Lichtenberg, The output contributions of computer equipment and personnel: a firm-level analysis, Econ. Innovations New Technol. 3 (1995) 201–217.
[24] A. Lowrey, Freaks, Geeks, and GDP. Slate, 2011. http://www.slate.com/articles/business/moneybox/2011/03/freaks_geeks_and_gdp.html (accessed 20.06.17).
[25] S. Madakam, R. Ramaswamy, S. Tripathi, Internet of things (IoT): a literature review, J. Comput. Commun. 3 (05) (2015) 164–173.
[26] O. Mazhelis, E. Luoma, H. Warma, Defining an Internet of things ecosystem, in: A. Andreev, S. Balandin, Y. Koucheryavy (Eds.), Internet of Things, Smart Spaces and Next Generation Networking, Lecture Notes in Computer Science (Book 7469), Springer, Heidelberg, 2012, pp. 1–14.
[27] McKinsey Global Institute, Internet Matters: the Net's Sweeping Impact on Growth, Jobs, and Prosperity, McKinsey & Company, San Francisco, 2011.
[28] McKinsey Global Institute, The Internet of Things: Mapping the Value beyond the Hype, McKinsey & Company, San Francisco, 2015.
[29] P.S. Meyer, J.H. Ausubel, Carrying capacity: a model with logistically varying limits, Technol. Forecast. Soc. Change 61 (3) (1999) 209–214.
[30] Ministry of Internal Affairs and Communication (MIC), White paper of Japan's ICT, 2016.
[31] K. Naveed, C. Watanabe, P. Neittaanmäki, Co-evolution between streaming and live music leads a way to the sustainable growth of music industry – lessons from the US experiences, Technol. Soc. 50 (2017) 1–19.
[32] J. Rifkin, The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World, Macmillan, New York, 2011.
[33] K. Rose, S. Eldridge, L. Chapin, The Internet of things: an overview, Internet Soc. (ISOC) (2015) 1–50.
[34] R. Solow, We'd better watch out, review of S.S. Cohen and J. Zysman, Manufacturing matters: the myth of the post-industrial economy, N. Y. Times Book Rev. 36 (1987).
[35] D. Tapscott, The Digital Economy: Promise and Peril in the Age of Networked Intelligence, McGraw-Hill, New York, 1994.
[36] The Connectivist, The Internet of Things – an Explosion of Connected Possibilities, 2014. http://theconnectivist-img.s3.amazonaws.com/wp-content/uploads/2014/05/Unknown.png (accessed 26.07.17).
[37] J. Triplett, The Solow productivity paradox: what do computers do to productivity? Canadian Journal of Economics 32 (2) (1999) 309–334.
[38] US Council on Competitiveness, No Recovery: an Analysis on Long-term U.S. Productivity Decline, Washington, D.C, 2016.
[39] C. Watanabe, R. Kondo, N. Ouchi, H. Wei, C. Griffy-Brown, Institutional elasticity as a significant driver of IT functionality development, Technol. Forecast. Soc. Change 71 (7) (2004a) 723–750.
[40] C. Watanabe, K. Matsumoto, J.Y. Hur, Technological diversification and assimilation of spillover technology: canon's scenario for sustainable growth, Technol. Forecast. Soc. Change 71 (9) (2004b) 941–959.
[41] C. Watanabe, J.Y. Hur, K. Matsumoto, Technological diversification and firm's techno-economic structure: an assessment of Canon's sustainable growth trajectory, Technol. Forecast. Soc. Change 72 (1) (2005) 11–27.
[42] C. Watanabe, Managing Innovation in Japan: the Role Institutions Play in Helping or Hindering How Companies Develop Technology, Springer Science & Business Media, Berlin, 2009.
[43] C. Watanabe, S. Lei, N. Ouchi, Fusing indigenous technology development and market learning for greater functionality development: an empirical analysis of the growth trajectory of Canon printers, Technovation 29 (4) (2009) 265–283.
[44] C. Watanabe, J.H. Shin, J. Heikkinen, W. Zhao, C. Griffy-Brown, New Functionality development through follower substitution for a leader in open innovation, Technol. Forecast. Soc. Change 78 (1) (2011) 116–131.
[45] C. Watanabe, W. Zhao, M. Nasuno, Resonance between innovation and consumers: suggestions for emerging market customers, J. Technol. Manag. Grow. Econ. 3 (1) (2012) 17–31.
[46] C. Watanabe, K. Naveed, W. Zhao, Institutional sources of resilience in global ICT leaders: harness the vigor of emerging power, J. Technol. Manag. Grow. Econ. 5 (1) (2014) 7–34.
[47] C. Watanabe, K. Naveed, W. Zhao, New paradigm of ICT productivity: increasing role of un-captured GDP and growing anger of consumers, Technol. Soc. 41 (2015a) 21–44.
[48] C. Watanabe, K. Naveed, P. Neittaanmäki, Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: similarities and disparities between Finland and Singapore, Technol. Soc. 42 (2015b) 104–122.
[49] C. Watanabe, K. Naveed, P. Neittaanmäki, Y. Tou, Operationalization of un-captured GDP: the innovation stream under new global mega-trends, Technol. Soc. 45 (2016a) 58–77.
[50] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution of three mega-trends nurtures un-captured GDP: Uber's ride-sharing revolution, Technol. Soc. 46 (2016b) 164–185.
[51] C. Watanabe, K. Naveed, P. Neittaanmäki, Consolidated challenge to social demand for resilient platforms: lessons from Uber's global expansion, Technol. Soc. 48 (2017a) 33–53.
[52] C. Watanabe, K. Naveed, P. Neittaanmäki, Co-evolution between trust in teachers and higher education toward digitally-rich learning environments, Technol. Soc. 48 (2017b) 70–96.
[53] C. Watanabe, K. Naveed, P. Neittaanmäki, ICT-driven disruptive innovation nurtures un-captured GDP: harnessing women's potential as untapped resources, Technol. Soc. 51 (2017c) 81–101.

Please cite this article in press as: K. Naveed, et al., The transformative direction of innovation toward an IoT-based society - Increasing dependency on uncaptured GDP in global ICT firms, Technology in Society (2017), https://doi.org/10.1016/j.techsoc.2017.11.003

PXII

MEASURING GDP IN THE DIGITAL ECONOMY: INCREASING DEPENDENCY ON UNCAPTURED GDP

by

Chihiro Watanabe, Kashif Naveed, Yuji Tou and Pekka Neittaanmäki, 2017

Journal of Technological Forecasting and Social Change, (*under review*)