THE CONNECTION BETWEEN EDUCATIONAL STRUCTURE AND ECONOMIC GROWTH IN OECD COUNTRIES

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ABSTRACT

Author Joel Parhiala	
Title The connection between educational structure and economic growth in OECD countries	
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Abstract This thesis investigates the connection between educational structure and economic growth in OECD countries, focusing on primary, secondary, and tertiary education levels as components of human capital. The theory section of the thesis delves into economic models developed to understand the factors influencing economic growth, with a particular emphasis on the role of human capital. It discusses both neoclassical and endogenous growth models, highlighting their differing perspectives on the role of human capital in economic growth. The thesis also addresses the challenges in measuring human capital and provides an overview of similar empirical literature. The empirical section constructs a dataset for 24 OECD countries between the years 1990 and 2019. The data are derived from four databases including Penn World Table, OECD. Stat, UNESCO, and The World Bank. Utilizing ordinary least squares (OLS), fixed effects, and random effects models, the study examines how different education levels impact GDP per capita growth. Research questions guiding the empirical analysis are: (1) How are different levels of education connected to economic growth, and is some level of education more important than others? (2) Is the connection between educational structure and economic growth dependent on the level of technological advancement in OECD countries? The findings answering the first question reveal that basic education significantly boosts long-term economic growth, secondary education shows mixed results with eventual positive contributions, and tertiary education consistently enhances growth. Regarding the second question, results suggest that the interaction between educational levels and technological advancement yields mixed results. Basic education´s benefits are complemented in technologically advanced contexts, while secondary education´s impact might be moderated in highly productive environments. Tertiary education remains crucial regardless of technological context, emphasizing its universal importance for long-term growth.	
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Tiivistelmä

Tässä tutkielmassa tarkastellaan OECD-maiden koulutusrakenteen ja talouskasvun yhteyttä keskittyen perus-, keski- ja korkea-asteen koulutukseen inhimillisen pääoman osatekijöinä. Tutkielman teoriaosuudessa syvennytään kasvuteorioihin painottaen erityisesti inhimillisen pääoman roolia. Osiossa käsitellään sekä uusklassisia että endogeenisia kasvumalleja ja korostetaan niiden erilaisia näkökulmia inhimillisen pääoman ja talouskasvun välisessä suhteessa. Tutkielma käsittelee myös inhimillisen pääoman mittaamisen haasteita ja tarjoaa yleiskatsauksen aihepiiriin liittyvään empiiriseen kirjallisuuteen. Empiirinen osio kokoaa aineiston 24 OECD-maasta vuosilta 1990–2019. Tiedot on kerätty neljästä tietokannasta, mukaan lukien Penn World Table, OECD. Stat, UNESCO ja Maailmanpankki. Tavallisen pienimmän neliösumman (OLS), kiinteiden vaikutusten ja satunnaisvaikutusmallien avulla tutkimuksessa tarkastellaan, miten eri koulutustasot vaikuttavat BKT: n kasvuun asukasta kohti. Empiiristä analyysia ohjaavat tutkimuskysymykset ovat: (1) Miten eri koulutusasteet kytkeytyvät talouskasvuun ja onko jokin koulutustaso muita merkittävämpi? 2) Onko koulutusrakenteen ja talouskasvun välinen yhteys riippuvainen OECD-maiden teknologisen kehityksen tasosta? Ensimmäisen kysymyksen suhteen tulokset osoittavat, että peruskoulutus edistää merkittävästi pitkän aikavälin talouskasvua, toisen asteen koulutuksen tulokset ovat vaihtelevia ja sillä on lopulta myönteisiä vaikutuksia ja korkea-asteen koulutus lisää johdonmukaisesti kasvua. Toisen kysymyksen osalta tulokset viittaavat siihen, että koulutustason ja teknologisen kehityksen välinen vuorovaikutus tuottaa vaihtelevia tuloksia. Perusopetuksen hyödyt täydentyvät mitä kehittyneempi maa on teknologisesti, kun taas toisen asteen koulutuksen vaikutukset ovat hillittyjä samassa ympäristössä. Korkea-asteen koulutuksen rooli on tulosten mukaan tärkeä teknologisesta kehityksestä riippumatta, mikä korostaa sen merkitystä pitkän aikavälin kasvulle.

Asiasanat
Inhimillinen pääoma, talouskasvu, koulutus, väestön koulutusrakenne, OECD

Säilytyspaikka
Jyväskylän yliopiston kirjasto

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1 INTRODUCTION

The primary objective of this thesis is to investigate the connection between educational structure and economic growth in OECD countries. In the thesis, the term educational structure is used to map different education levels into three major groups: primary, secondary, and tertiary education. The deviation is done for multiple reasons. In broader context, human capital formation, for instance schooling, does not happen homogenously (Hanushek & Woessmann, 2020; Krueger & Lindahl, 2001). The idea is that not every school year or school level contributes equally, for instance, to society. Therefore, using educational structure to measure certain economy's human capital formation can be seen as a reasoned viewpoint.

Since last century, different kinds of economic models have been constructed with the main idea of capturing and determining the importance of different factors on economic growth. There have been and will continue to be different views on this specific matter. As economic growth can be seen as a summary of activities of a society, it depends on every aspect of society. Different societies vary in fundamental level which can easily lead to situations where some factors' importance can be over- or underestimated. Thus, a comprehensive understanding of the factors and fundamentals of economic growth is crucial for comprehending the complexities of different economies and their interconnections. In the context of this thesis, examining existing growth theories will provide valuable insights into the connection between educational structure and economic growth in OECD nations, and lay a groundwork for deeper understanding on the topic.

The two primary strands to growth theories are divided into neoclassical growth models and endogenous growth models which differ on how the economic growth is understood and what is role of human capital in it.

First perspective to growth theories includes the neoclassical growth model constructed simultaneously by Solow (1956) and Swan (1956). In neoclassical theory the role of exogenous factors is emphasized. Factors such as population growth, labor force, capital accumulation, and rate of technological change are assumed to explain the long run economic growth. The model assumes that economies converge to their specific steady-state equilibrium and permanent growth is driven by technological progress.

The model was later modified to include human capital with the work of Mankiw, Romer, and Weil (1992). Their implication was to add human capital to the basic model in the same way as physical capital was included in it. Therefore, the fundamentals of the model did not change which leads to the conclusion that increment of human capital in the economy would lead to a rise in income in the medium term but would not alter the steady-state equilibrium.

The opposite view of the role of capital stock comes from another strand of growth theories which can be identified as endogenous growth models. Motivated by the work of Lucas (1988) and Romer (1986, 1990) these models see economic growth driven by endogenous, not exogenous force. The same factor of growth as in neoclassical models, technological progress, is explained inside the model. This offers a possibility to study its role since technological progress is not coming from outside the model. Factors such as human capital, innovation and research and development are seen crucial to technological progress which then leads to the fact they are also significant to economic growth. Therefore, increasement of human capital will then lead to an increase in the rate of long-term growth.

Although human capital has its own importance on determining the growth process, capturing the linkage between human capital and economic growth has not been uncomplicated. The common view is that policy initiatives strengthening the economy's human capital and knowledge base has its part of improving both individual's and nation's economic position.

A certain issue related to the studies of human capital and economic growth is the measurement of human capital. This leads to another interesting question on how to measure human capital. It could be said that there are two main directions which divide the existing studies. First and perhaps the most common way of measuring human capital is by using educational attainment data. Factors behind using this measurement can relate to several facts but the most obvious one is its easy accessibility. Nowadays, there are various databases which contain information on certain countries educational attainment ranging from Barro-Lee dataset to Cohen-Soto database. Another way to measure human capital is by using data which provide information not on quantity but quality of education. According to Hanushek (2016) adding measurement of educational quality to same model where educational attainment is included the attainment factor becomes unrelated to economic growth. This finding highlights the fact that human capital can be seen more as a cumulative process than a linear process.

Moreover, the complexity of human capital also underlines another issue related to this thesis's topic. Human capital is typically treated as homogenous concept in prior studies which is not a problem itself but as a large part of literature has focused on human capital as a whole unit, not that much of study has been done exploring the effects of various levels of education on economic growth. In recent papers, the focus has shifted towards understanding the role of human capital composition. Vandenbussche, Aghion and Meghir (2006) developed a model which showed that education levels have their effect on economic growth depending on economy's distance to world technological frontier. Economies close to the technological frontier benefit more from tertiary education as economies far from frontier benefit more from primary/secondary education. Same kind of results have shown by Zhang and Zhuang (2011) who found that different education levels benefit provinces of China depending on province's level of economic development.

These findings are closely related to the topic of this paper which is to discuss the connection between educational structure and economic growth in OECD countries. The empirical research is done by using data from Penn World Tables, OECD. Stat, UNESCO, and The World Bank. By using these four databanks, a solid dataset can be constructed on the topic. However, there are slight differences between databanks on how they report certain information, especially prior to 1990. Therefore, re-organization of certain variables had to be done to construct a comparable dataset.

Utilizing the constructed dataset and earlier empirical literature, this thesis aims to answer following research questions corresponding to the topic:

1. *How are different levels of education connected to economic growth, and is some level of education more important than others?*

2. *Is the connection between educational structure and economic growth dependent on the level of technological advancement in OECD countries?*

The remainder of the paper is organized in the following way. In the second chapter, theoretical insights are presented in the terms of human capital, and theories connecting human capital and economic growth. As the term human capital is defined broadly, motivation for using the educational structure as a proxy is provided. The economic growth theories augmented with human capital are divided into two specific sections wherein economic growth is justified first, with human capital accumulation, and second, with human capital stock growth.

In the third chapter, empirical literature is provided of the context of human capital composition and economic growth, closely linked to the topic of the thesis, and shortly of other viewpoints of analyzing human capital's connection to economic growth. In the end of the chapter, there is a section where the thesis' institutional setting is looked upon with little bit of talk about the possibility of errors in measuring human capital.

In the fourth chapter, used data and methods are presented with a highlight in the methods, especially on the question how to reliably analyze the educational setting's connection to economic growth. The methods sections include discussion on implemented models, and their fit on conducting the empirical study with the used data. Used methods include OLS, fixed effects, and random effects estimation.

In the fifth chapter, results of the paper and reliability of the empirical results are presented. The results of the different models are presented chronologically in the order they were implemented including key findings and comparison to related empirical literature, and in the end of the chapter, motivation is provided for variable and model selection.

In the sixth and the concluding chapter, conclusions and potential future implications are provided.

OpenAI´s AI-based GPT-4o tool has been used to aid this study. The tool has been used to locate errors in the RStudio program´s codes when constructing the models in the empirical part of the study, as well as in text editing for making text grammatically correct.

2 HUMAN CAPITAL AND GROWTH THEORIES

This section provides a look at two main topics.

First, a general overview is provided about the concept of human capital. The aim is to give an insight to the groundwork of human capital studies and explain the possible measurement problems regarding human capital. The connection between education and human capital is also explained since these two terms are usually linked together even though the first is a narrower and latter broader concept. Understanding the connection between education and human capital is crucial to the topic of this thesis since without definition of human capital the educational structure would remain unattached to the topic. The studies presented in the section have a microeconomic approach, but they have important implications for macroeconomic point of view.

Second, existing growth theories are defined and divided into two main groups according to their relation to human capital and economic growth. The first group includes theories that emphasize the role of human capital accumulation as a primary source of a certain economy's growth. The second group of theories can be summarized as an approach that describes the growth as being based on the actual human capital stock. These theories offer a wide range of views which can be used to understand the linkage between education and economic growth.

2.1 Concept of human capital

The term "human capital" can be defined as skills regarded as a resource or asset that a labor force possesses (Oxford English Dictionary, 2024). In terms of economic literature, most of the research draws on the work of Schultz (1961), Becker (1962, 1994) and Mincer (1958, 1974). This strand of microeconomic literature investigates rates of return on education and training based on human capital theory. Much of this work is done by calculating rates of return on individual level using wage regressions. Although microeconomic studies may concentrate on a more specific side of human capital, the findings are crucial to understanding the macroeconomic role of human capital. Human beings are an important part of the wealth of nations.

The importance of human capital was underlined amongst the first in modern economic literature in study by Schultz (1961). The study demonstrates the role of human capital by explaining various economic anomalies. Some of these economic puzzles are easier to understand than the others. As an example, the United States of the 1900s, migrant workers seemed to differentiate in earnings from non-migrant workers in a regular fashion. The situation corresponds closely to the comparison with young and old workers. As an explanation it is stressed that differences in the amount of human investment, e.g. education, may explain these earning differences. Although there might be other factors related to these cases, one cannot pass the productivity enhancing effect of human capital (Schultz, 1961).

Some economic puzzles related to the concept of human capital are more difficult to understand. The study highlights a few examples, such as ratio of capital to income decreasing over time, explaining the growth residual presented by neoclassical growth models and rapid growth of Europe after World War II. According to Schultz (1961) the role of all capital has had a critical effect on all these past examples. Increasement of human capabilities and knowledge related to these cases has had its own effect on productivity growth leading to rapid growth in situations where there has been a lack of all other forms of capital, except human capital.

Investments improving human capabilities can be divided into five categories. Health facilities and services, on-the-job training, formally organized education, non-formal study programs and migration of people (Schultz, 1961). Depending on the starting level of the society human capital, the investments and their effect differentiate. As in underdeveloped countries, the basic functions related to health enhance the quality of human capital. For developed countries additional health services are not crucial as at some point the effect of them starts to diminish and the additional investments transfer to consumption. The focus starts to shift to investments concerning on-the-job training and formal education. (Schultz, 1961)

The definition of Schultz (1961) relates closely to an approach of Becker (1962) which defines human capital investments as activities that affect individual's future real income through embedment of resources. The key element of these approaches is how division to these categories is formed. Although, as definition of human capital investments describe human capital includes rather many activities. To limit the scope of human capital, attention is paid now to three ways that human capital can accumulate: formal schooling, on-the-job training and off-the-job training (Lynch, 1991). Of these three categories, on-the-job training and schooling are the most significant investments for an individual (Becker, 1994). Historically, investments in on-the-job training amount over half of total investments in education for certain economies (Mincer, 1962).

Education or training as an investment construct on simple basis, an individual invests time and foregone earnings to higher rates of return in future periods. On-the-job training involves also initial costs in a form of reduced wages during the training period (Parsons, 1974). In fact, the decision to make the investment on education or on-the-job training depends on an individual's decision on wealth-maximizing. If the future expected return from the investment is higher than the market rate of return, the decision should be made according to pure rationality.

From a macroeconomic perspective, the role of human capital attaches to a certain point of traditional microeconomic literature which is the private versus social returns of education (Sianesi & Reenen, 2003). As previously mentioned, the decision to choose education over other possibilities is dependent on an individual's preferences. The calculated rates of return on education in micro studies are in fact calculations of private returns from education. To broaden the viewpoint, macro perspectives including externalities of education should be used to estimate social returns of education. However, transforming from a microeconomic view to macroeconomic is not problem-free. As the scale widens, possible methodological problems appear considering that the first issue of measuring human capital is handled. The linkage of human capital and education to macroeconomics' perspective is presented in Figure 1.

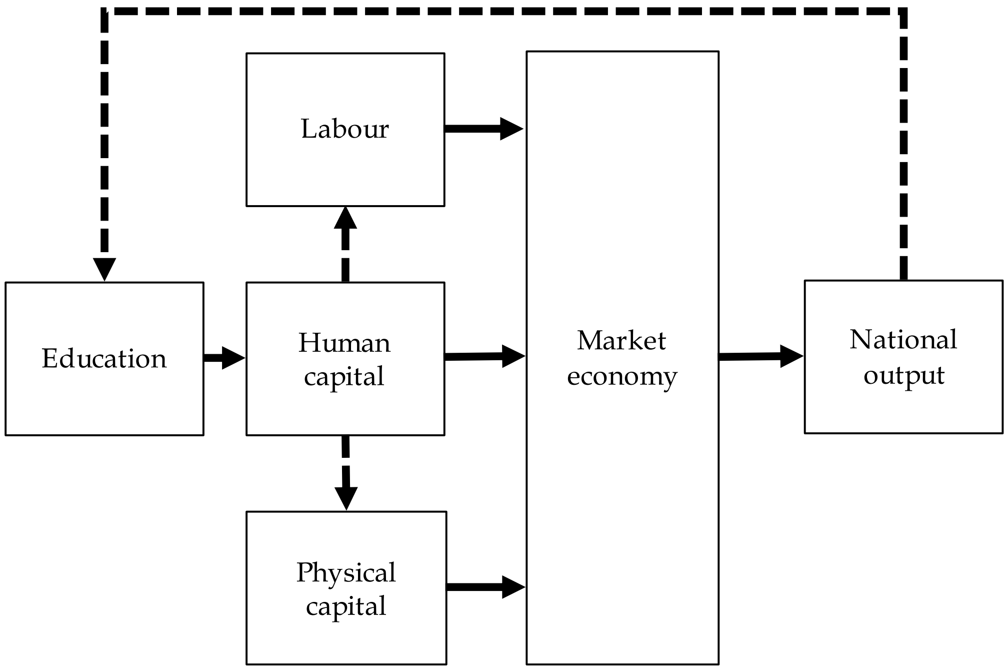

FIGURE 1 The connection between education and economic growth in a market economy. Adapted from Breton (2013).

2.2 Human capital accumulation approach

2.2.1 Augmented Solow model

Before looking at the augmented Solow model, it is reasonable to look at the basic model behind it. Based on the study by Solow (1956) and the simultaneous work of Swan (1956), economic growth can be explained by two factors which are capital and labor. Therefore, the production function can be interpreted as in the following formula.

$$Y = F(K, L),$$

where term Y is economic output, term K is capital stock, and term L is labor.

Important assumptions concerning the expressed production function are decreasing returns to capital and full employment of capital and labor stock. When these assumptions are in effect, model can be used to determine the steady-state equilibrium where investments are equal to depreciation of capital stock (Mankiw et al., 1992). Combining this information of the model and the production function it can be expressed in the form of following general Cobb-Douglas function.

$$Y = AK^{\alpha} L^{1-\alpha},$$

where A interprets level of technology and is restricted by rule, $A > 0$. In the function, term α is constant with the restriction of $0 < \alpha < 1$ (Barro & Sala-i-Martin, 2004).

This interpretation of basic Solow model can be seen as a motivational background for the actual work of Mankiw, Romer and Weil who constructed the augmented Solow model in which human capital is included to the standard neoclassical production function in an equivalent way as the physical capital stock. Hence, the production function with added term of human capital can be interpreted in the following way.

$$Y = AK^{\alpha}L^{\beta}H^{\gamma}$$

where it is assumed that $\alpha + \beta + \gamma = 1$. Term Y interprets economic output, term A total factor productivity or level of technology, K is physical capital, H is human capital and L is labor. As human capital is added to the function, economic growth is composed differently than in a basic Solow model. If it is supposed that human capital can accumulate as physical capital can, the convergence to the steady-state will happen but slower than in Solow model (Mankiw et al., 1992). Slower convergence is due to the fact that accumulation of human capital counters the effects of physical capital accumulation and therefore the economy will reach its steady-state slower than in basic Solow model (Mankiw et al., 1992).

The model predicts that there is a positive connection between per capita GDP and physical and human capital intensities which means that policies increasing the accumulation of physical and human capital should convert to a positive long run growth. Although the positive connection between long run growth and capital accumulation, a certain economy's long run growth does not depend on investments in both physical and human capital stock (Aghion & Howitt, 2008). For instance, an investment in human capital increases the economy's short run growth which ends when the economy reaches its new steady-state. This can be pictured by a situation where recent graduates replace the soon retiring workers who have the same education level as graduates. Therefore, the stock of human capital reaches its steady-state and the economy's growth returns to its long run path (Holmes, 2013). Due to the finding that economy's long run growth does not depend on investments on capital stock, this model underlines the importance of increasing capital accumulation which can then appear as positive rate of long run growth.

2.2.2 Lucas model

In the other branch of growth theories emphasizing the human capital accumulation approach, lies the model created by Lucas (1988). The model builds on the idea of individuals' optimization problem of the allocation of their time between current production and skill-acquisition. The individuals must make the allocation at every point of time and when choosing skill-acquisition over current production, individuals' productivity increases in forthcoming periods. The model can be interpreted in the following way (Lucas, 1988).

$$y = k^{\beta}(uH)^{1-\beta}$$

$$H = \delta H(1-u); \; \delta > 0$$

where term y is economic output, term H is the individual's current human capital stock, term u is the fraction of their time allocated to production, term k is physical capital stock and term δ is productivity of schooling. The first equation describes the relation between human capital and current production and the latter equation relation between current schooling time and accumulation of human capital (Aghion & Howitt, 2008).

When compared to augmented Solow model, a significant difference is that instead of diminishing returns of capital stocks, the Lucas model assumes constant returns. This assumption can be translated to the fact that factors in the production function can be accumulated by individuals (Lucas, 1988). For instance, doubling both human and physical capital per individual leads to also doubling the output per individual which then leads to an increasing growth rate of economy. The growth rate of the economy will then be defined by the accumulation of factors of production. As human and physical stock grow, higher incomes are generated which leads to a higher rate of investments (Holmes, 2013).

Another important fact is that human capital can be theoretically increased infinitely in the model. Human capital stock can be seen as a pile of knowledge which every generation of individuals built. Every increase in time spent studying or training adds to human capital stock, and as generations move on human capital stock accumulates. Looking from the viewpoint of policy-making this could be interpreted as that expansion of the field of education should benefit the economy since the accumulation of human capital increases economic growth (Lucas, 1988).

2.3 Growth based on human capital stock

The second strand of growth theories contains theories in which the human capital stock is seen as a driver of economic growth instead of human capital accumulation. These growth theories can be forth divided into two sub-categories related to their view of human capital and its role in the process of economic growth. Specifically, the first sub-category concentrates on the role of human capital in constructing the diffusion and adoption of new technologies. The second sub-category includes theories in which human capital is seen as crucial input to a research-development-innovation sector generating new innovations altering the long-term economic growth rates and paths (Valero, 2021). Namely, these two categories are presented under the name diffusion and adaptation of new technologies and innovation-based growth theories.

2.3.1 Diffusion and adaptation of new technologies

The groundwork of this sub-strand bases on the work of Nelson & Phelps (1966). Although, their model does not include assumptions of endogenous growth as it is understood in later models the basic idea of their approach bases on similar construction as formal endogenous models (Aghion & Howitt, 2008). The model can be formulated in the following way with two equations:

$$A(t) = T_0 e^{\lambda[t - w(h)]};\ w`(h) < 0$$

$$A(t) = f(h)\,[T(t) - A(t)],$$

where A(t) is practical level of technology, T(t) is theoretical level of technology, w(h) is lagged level of human capital intensity and λ is constant exponential rate that theoretical technology level advances exogenously (Nelson & Phelps, 1966). Two noteworthy entities arise from the model introduced by Nelson and Phelps.

From the first model, practical and theoretical levels of technology advance at the same rate which is denoted as λ. The difference between theoretical and practical levels of technology is shortened by human capital intensity. Therefore, the impact of human capital is dependent on the speed with which the theoretical level of technology has advanced. Although the first model interprets that human capital decreases the time lag between theoretical and practical levels of technology in a such instant fashion it can be seen as an unrealistic situation. For this specific reason, the second interpretation takes a more realistic view on these effects (Nelson & Phelps, 1966).

The second model can be summarized by the fact that the practical level of technology is dependent on human capital and the gap between theoretical and practical levels of technology. Increasement in human capital, such as rise of education attainment level, contributes to growth path of practical level of technology. Closing the gap between theoretical and practical levels of technology can be achieved by increasing human capital stock which can referred to as a country ability to catch-up with the frontier technology (Aghion & Howitt, 2008). As notable difference to first model, the second model states that effects of human capital are economy specific. Thus, benefits gained from increases in human capital stock are greater for more technologically advanced economies (Nelson & Phelps, 1966).

Work of Benhabib and Spiegel (1994) can be considered as an augmentation to Nelson and Phelps' model. In their paper, the Nelson and Phelps' model is expanded to include domestic endogenous innovation which in fact helps to understand the relationship between human capital and technological advancement. Specifically, the augmented model can be written in the following way.

$$A(t) = f(h)\,[T(t) - A(t)] + g(h)\gamma A(t),$$

where the latter term represents the country's endogenous technological process linked to country's ability to innovate domestically. The first part of equation is defined as the forementioned Nelson & Phelps' equation which maps the country's ability to catch-up with the frontier technology involving terms of level of human capital and lag of technological advancement (Benhabib & Spiegel, 1994).

As the model is used to explain the growth of total factor productivity, two mechanisms can be found. The first mechanism is the association of human capital with the domestical technological innovation. The second mechanism is the connection of human capital and technological catch-up with frontier technology. These two mechanisms affect economies' total factor productivity in a certain manner depending on economy-specific differences like as level of technological development and stock of human capital (Benhabib & Spiegel, 1994).

However, it is essential to consider the critiques of these mechanisms. Krueger and Lindahl (2001) argue that the empirical relationship between human capital and economic growth may not be as robust as Benhabib and Spiegel suggest. They point out that measurement errors in human capital data and the potential endogeneity of human capital investment can lead to biased estimates. Their critique underscores the importance of addressing these issues to obtain more accurate estimates of the impact of human capital on productivity growth.

2.3.2 Innovation-based growth theories

The role of nonrival human capital and knowledge in formulation of modern technologies is emphasized in the endogenous model of Romer (1990). The model is constructed using neoclassical means where economic growth is result of physical capital, human capital, and technological change. A difference to textbook neoclassical model is the expectations of endogenous technological change which strings the model to the strand of endogenous growth models. As in the model of Lucas (1988) the growth is understood to be generated within the model by the accumulation of the production variables. Especially, research and development activities based on the stock of human capital are seen one of the key drivers on the process of economic development.

According to Romer (1990) a permanent increase in the stock of human capital leads to an increasement in technological change and adds resources to the research and development sector. As human capital stock is needed to perform research-based activities, a positive change in the total stock will boost the economy through innovations. The connection between human capital stock and technological change works in both directions. A negative possibility is that the total stock of human capital may be too low which causes the economy to fall towards stagnation due to low levels of technological change which implies no growth in current and future output (Romer, 1990).

The findings of Romer (1990) relate to the later work of Aghion and Howitt (1992) where authors create a growth model based on the Schumpeterian process of creative destruction. The model does not provide the same kind of metric to human capital but the role of innovations on economic growth is proven and emphasized. Technological process resulting from competition amongst research and development companies defines exclusively the growth levels (Aghion & Howitt, 1992).

An implication of the model is that increasement in the units concentrated to the research and development activities cause higher aggregate levels of research and development which affects growth positively (Aghion, Akcigit, & Howitt, 2015). Although, under laissez-faire expectations the competition between firms may not be equitable which results in rather imitating than innovating actions in research and development companies (Aghion & Howitt, 1992). In macroeconomic framework, the results can be compared to the results of Romer (1990) since innovations led by the research and development sector generate technological process and later economic growth.

Theoretical support for this strand of studies can be derived from the study of Vandenbussche et al. (2006). The paper implements an endogenous growth model with the aim to understand growth rate through economy’s distance to the world technological frontier and composition of human capital. Human capital is proxied in the model as the fraction of the working age population with some higher education. The model emphasizes the important dynamics of skilled and unskilled labor force when economy is getting closer to the technological frontier (Vandenbussche et al., 2006).

Results show that lower levels of education, primary and secondary, tend to produce more imitators and higher levels of education, tertiary education, tend to produce more innovators. What is then optimal allocation of human capital composition? Their answer is that countries far from the technological frontier should emphasize more the role of primary and secondary education, as imitation of technologies can be seen as one of main drivers of total factor productivity. For more developed countries, the answer is the opposite, as these countries rely much more on the role of innovation regarding productivity and economic growth.

In the paper of Ramcharan (2004) theoretical framework is built to analyze connection between composition of human capital and economic development. The basis of human capital is constructed by dividing labor force into three categories: unskilled, low skilled and high skilled. The model builds on the assumption that educational investments start on a large scale, decrease over time, and depend on educational level. With these assumptions, the study tries to shed light on optimal education policy by analyzing the dynamics of educational investments and long run economic development.

The results show that composition of human capital significantly affects economic development through the dynamics of educational investments. Especially the initial investments in both basic and tertiary education are important since the potential long run development can be left unchanged with wrong-weighted education policy, i.e., promoting tertiary education when basic education stock is lacking. Therefore, understanding the economy's human capital composition is the key to optimal education policy as noted in the study of Vandenbussche et al. (2006).

3 EMPIRICAL LITERATURE

In this chapter, there is provided information regarding the existing literature. Since the aim of this thesis is to explore the connection between educational structure and economic growth, empirical literature is divided to studies focusing exactly on composition of human capital and economic growth and studies implementing different perspectives to this specific matter. Although the studies concentrate on different perspectives than human capital composition, the results of both perspectives are likewise. In the beginning of this chapter, there is provided an overlook on the possible measurement problems regarding human capital, and at the end of the chapter an overview of statistics and information on basic educational and economical details of OECD countries which can used to understand possible structural differences between them.

3.1 Challenges in the measurement of human capital

As the definition of human capital describes, the term itself contains knowledge, skills, and other acquired traits that a human being has. The problem related to the concept of human capital is how to estimate and compare it between different economies and over certain periods of time. One way to measure human capital accurately would be by estimating the output of education. Although, getting such a measurement is easier said than done. In fact, measuring the output would need tests before and after completing certain education levels to give data about the effect on human capital levels. Therefore, there is a need for different measures. Instead of measuring the output of education, human capital is commonly proxied by input of education. Amongst most used proxies are such as average years of schooling of the population, educational attainment, and school enrolment ratios (Sianesi & Reenen, 2003).

However, using such proxies can lead to an imperfect result measuring human capital. The issue is that using, for instance, average years of schooling as proxy, human capital is cropped to be only affected by schooling. As Pritchett

(2013) points out schooling does not equal learning. The trajectory from being at the school does not always contribute to learning at the school as there are other various possibilities how human capital can accumulate. Another issue related to using average years of schooling as proxy is that the measure defines the human capital stock as more of linear than cumulative process. A year of schooling does not raise the human capital stock by a universal amount regardless of which year of schooling it was for an individual. Secondly, a year of schooling affects the human capital stock depending on quality of education. The effect is not equally same for all kinds of schooling systems (Wößmann, 2003).

Related to schooling and its effects, Temple (1999) argues that focus of measuring human capital in the economic literature has been without a solid reason on schooling rather than training. The argument itself is not wrong. As Becker (1994), Schultz (1961) and Mincer (1962), amongst other contributors to human capital theory state that human capital has separate ways of accumulating, e.g. on-the-job training, or off-the-job training. Focusing on only one side of it can bias the estimation of its effects. However, a solid reason to use certain variables as proxies for human capital in the past has been the lack of good quality comparable data on other dimensions of human capital, such as data on on-the-job learning or post-school training.

More critical issues have been at the fundamental level. Main empirical literature concerning human capital has used data on quantity of education which, for instance, is represented by the measure of average years of schooling. When comparing economies with the same educational attainment levels or same average years of schooling, the quantity of education may be the same but there is still variation in the quality of education. In particular, the data on the quality of education have been lacking in the past but recently attention has shifted to its side resulting in more diverse aspects of economic studies on human capital and its effects on e.g. economic growth.

3.2 Composition of human capital and economic growth

The study by Psacharopoulos (1994) conducted a comprehensive review of global literature to assess the returns on investment in education, drawing upon research dating from the 1970s to the 1990s. Utilizing two primary methods, the analysis examined the complete approach, which delved into detailed age-earnings profiles based on educational levels, and the earnings function method, which employed regression analysis to understand the relationship between years of education and earning potential. The findings revealed that primary education consistently yielded the highest returns, with diminishing returns observed as education levels increased, alongside a decline correlated with a country's per capita income. Moreover, investing in women's education proved to be more profitable than investing in men's, while employees in the private sector tended to realize higher returns compared to those in the public sector (Psacharopoulos, 1994).

Furthermore, the study unveiled variations across gender, educational level, employment types, and geographic regions. Women tended to experience higher returns on education, and while returns on tertiary education exhibited a slight increase over time, disparities persisted based on factors such as curriculum type and sector of employment. Despite controversies surrounding selectivity bias and the notion of 'overeducation', the findings emphasized the continued attractiveness of investing in education, both from a private and societal perspective.

Petrakis and Stamatakis (2002) investigates the connection between economic growth and investment in human capital across different country development levels, employing a new endogenous growth theory and a stochastic model. Data from three groups—less developed, developed (OECD), and advanced (also OECD)—is categorized based on GDP, physical capital stock, and a composite index of development. Educational data are drawn from previous studies, while growth and capital stock data are sourced from various reports. Using a model adapted from endogenous growth theory, the analysis incorporates human capital and physical capital investment to examine growth patterns (Petrakis & Stamatakis, 2002).

Results from Weighted Least Squares regression reveal varying coefficient values among educational levels across country groups. Further testing confirms significant differences in the impact of education on growth among the groups, with advanced economies benefiting more from higher education while less developed countries rely more on primary and secondary education (Petrakis & Stamatakis, 2002). These findings are consistent with prior research, suggesting structural differences in how educational investment affects growth across different development levels.

Study by Agiomirgianakis et al. (2002) focuses on contribution of education to long run economic growth using panel data from 93 countries in timeline between 1960 and 1987. Estimations were implemented by using dynamic panel data techniques, namely the Mean Group (MG) and Pooled Mean Group (PMG) estimations. The explained variable, long run economic growth is estimated as GDP growth per capita. Educational variables were divided into three levels of education: primary, secondary, and tertiary education, and were estimated from data as school enrollment ratios of each educational level (Agiomirgianakis et al., 2002).

Results of study showed evidence with both estimation methods that educational variables have a positive effect on GDP growth. Although the effects are positive and significant for all educational variables, the level of education affects the contribution to long run growth. Thus, higher levels of education have a higher effect on growth than lower levels of education.

Papageorgiou (2003) discusses the connection between human capital accumulation and economic growth using a novel approach to cross-country growth accounting focusing on data spanning from 1960 to 1987. He proposes modifications to conventional methods and uses a dataset from the World Bank on physical capital and educational attainment. The methodology involves estimating regression models for different subsamples of countries based on income levels (Papageorgiou, 2003).

Findings indicate that the relative contributions of human capital to technology adoption and final goods production vary by country's wealth. In high-income countries, innovation led by post-primary education significantly impacts growth, while in low-income countries, primary education's growth positively influences economic growth. The study highlights the importance of distinguishing between the effects of primary and post-primary education on growth for a better understanding of the development process. Notably, primary education contributes significantly to output production in developing countries, emphasizing the importance of education in economic development.

Similar results but on regional level are found in study done by (Zhang & Zhuang, 2011) which investigated relation of composition of human capital and economic growth with GMM based theoretical model. They used data provided by provinces of China to explain effect of educational level to economic growth on regional level. In the paper, human capital was divided into two sub-categories, before tertiary and tertiary education, and was measured as initial years of schooling. The explained factor, economic growth, was measured as real GDP per capita. To compare differences of educational structures to regional economic growth, provinces were divided to three groups: eastern, central, and western parts of China (Zhang & Zhuang, 2011).

Results of the study showed that the educational structure of China supports economic growth, especially tertiary education having more important role on growth than before tertiary education. On the regional level these results converted to a fact that in more developed provinces tertiary education seemed to contribute to economic growth more than in less developed provinces. Therefore, investing in primary and secondary education in less developed areas would benefit them more than investing in tertiary education.

The study by Pereira and St. Aubyn (2009) investigates the connection between human capital formation and economic growth in Portugal from 1960 to 2001. Drawing on economic theory that suggests a positive correlation between education and growth, the study employs vector autoregression (VAR) analysis to explore the impact of education on GDP per worker and physical investment. The data include GDP, physical investment, employment, and average years of schooling, disaggregated into different educational levels. The study finds that human capital formation, measured by average years of schooling, had a significant positive effect on both GDP per worker and physical investment. The results suggest a crowding-in effect, where increased education stimulates physical investment, thus reinforcing economic growth. However, tertiary education did not show a significant impact on Portugal's growth experience (Pereira & St. Aubyn, 2009)

The findings also highlight the importance of considering different schooling levels separately, as they may have heterogeneous effects on growth. Primary and secondary education were found to be more crucial for growth in less developed countries, while higher education became more important in more developed economies. The study addresses methodological challenges in the literature, such as reverse causation and parameter heterogeneity, by employing VAR analysis and conducting Granger causality tests, impulse response functions, and computing long-run semi-elasticities (Pereira & St. Aubyn, 2009). Overall, the study contributes to understanding the connection between education and economic growth, emphasizing the need for country-specific analyses and disaggregated data to capture the diverse impacts of human capital formation on growth dynamics.

Study of Gyimah-Brempong et al. (2006) explores the effects of education levels on the growth rate of per capita income in African countries over period 1960-2000. As in other similar studies, human capital is divided into three groups: higher, secondary, and primary, and is measured as average number of education years completed by adult population (25-years-old or older).

Results show that increasing education human capital at all levels contributes significantly on the growth rate in African countries. Growing the stock of higher education human capital seems to have highest effects on growth rate, out of all educational levels. The authors believe that the estimates of higher education human capital might be overestimated but the direction seems to be right. Although as the study of Ramcharan (2004) notes, understanding the importance of economy-specific human capital composition is key to converting results to policy implications. The same issue is also brought up by Gyimah-Brempong et al. (2006) since the lower educational levels of African countries are underdeveloped compared to developed countries. Investing in higher education while the foundation of lower education is lacking, can be seen as a move to unsustainable direction for an economy.

The study by Holmes (2013) examines the contribution of different education levels to economic growth between 1966 and 2006 using cross-country data of 91 countries. The study focuses especially on the connections between the initial level of higher education and growth, as well as on channels of influence. Implementing Solow's growth model, results show a positive link between primary/secondary education and economic growth and between technical skills and economic growth. However, higher education is not found to have a significant impact on economic growth (Holmes, 2013).

Based on the results, the role of higher education in economic growth cannot be clearly demonstrated. Although primary and secondary education, and technical skills are positively associated with growth, tertiary education does not have a corresponding effect. The study also points out that the expansion of higher education may divert resources from other important skill areas.

Notably, studies of this nature have not been conducted in recent years, resulting in the literature review drawing primarily from research conducted 10-20 years ago. However, providing results from these studies ensures a comprehensive examination of existing literature relevant to the topic of this thesis rather than a selection from recent literature which may not fully connect to discussed topic, and therefore to this thesis. Table 1 presents an overview of the studies in this section including the information of authors, implementation years, aims of studies, data, and results and other notes.

TABLE 1 Summary of the relevant background literature

Author	Year	Aim of study	Data	Result and other notes
Psacharopoulos	1994	Assess the returns on investment in education.	Literature review.	Primary education consistently yielded the highest returns, with diminishing returns observed as education levels increased, alongside a decline correlated with a country's per capita income. Investing in women's education more profitable than men's, while employees in the private sector tended to realize higher returns compared to those in the public sector.
Agiomirgianakis et al.	2002	Examine the long-run effects of education on economic growth.	Panel data of 93 countries over the period 1960-87.	Higher levels of education have a higher effect on growth than lower levels of education. Initiatives towards expansion of higher education could improve economic development.
Petrakis and Stamatakis	2002	Investigate the connection between economic growth and investment in human capital across different country development levels.	Panel data for 24 OECD countries over the period 1970-1994.	Statistically significant differences in the impact of education on growth among the groups, with advanced economies benefiting more from higher education while less developed countries rely more on primary and secondary education.
Papageorgiou	2003	Investigate the connection between human capital accumulation and economic growth.	Panel data for 80 countries over the period 1960-1987.	Relative contributions of human capital to technology adoption and final goods production vary by country's wealth. In high-income countries, innovation led by post-primary education significantly impacts growth, while in low-income countries, primary education's growth positively influences economic growth.
Ramcharan	2004	Analyze connection between composition of human capital and economic development.	Only theoretical work.	The results show that composition of human capital significantly affects economic development through the dynamics of educational investments. Especially the initial investments in both basic and tertiary education are important since the potential long run development can be left unchanged with wrong-weighted education policy.

TABLE 1 (continues) Summary of the relevant background literature

Author	Year	Aim of study	Data	Result and other notes
Gyimah-Brempong	2006	Explore the effects of education levels on the growth rate of per capita income in African countries.	Panel data for 34 African countries over the period 1960-2000.	Increasing education human capital at all levels significantly contributes the growth rate in African countries. Growing the stock of higher education human capital seems to have highest effects on growth rate, out of all educational levels.
Pereira and St. Aubyn	2009	Examine the connection between human capital formation and economic growth in Portugal.	Dataset for Portugal over the period 1960-2001.	Highlight the importance of considering different schooling levels separately, as they may have heterogeneous effects on growth. Primary and secondary education were found to be more crucial for growth in less developed countries, while higher education became more important in more developed economies.
Zhang & Zhuang	2011	Investigate relation of composition of human capital and regional economic growth.	Panel data for 31 provinces in China over the period 1997–2006.	Educational structure of China supports economic growth, especially tertiary education having more important role on growth than before tertiary education. The level of regional economic development affects the human capital composition and economic growth dynamics.
Holmes	2013	Study the contribution of different education levels to economic growth.	Panel data for 91 countries over the period 1966-2006.	While primary and secondary education, and technical skills appear to be positively associated with growth, tertiary education does not have a corresponding effect. The expansion of higher education may divert resources from other important skill areas if done without careful coordination.

3.3 Institutional settings of educational and economic measures in OECD countries

In the following section information is provided on OECD countries' educational and economic structures. The available data are comparable between countries and over certain periods of time, though there are some exceptions amongst the variables. The economic statistics are commonly reported by all countries and the data can be obtained from various international agencies, such as OECD and World Bank. Most gaps in the data are found in educational statistics since the reporting practices of OECD countries seem to vary depending on the variable. A usual case is a situation where the consistency of reported data has gaps in older years and is limited to certain groups of countries.

3.3.1 Economic overview of OECD countries

Table 2 presents the information on annualized average growth rates of GDP per capita for 25 OECD countries in the 5-year periods between the years 1990-2020. The data are based on publicly available economic indicator series provided by OECD, and the countries are selected based on their membership of OECD. The table is constructed in the following way. Middle columns have the data on specific 5-year period averages and the column on the right-hand-side has the data on whole period average.

A few notable observations can be seen from the table. All twenty-five countries have experienced a growth of GDP per capita in the examined period. The average for the period has been 1.5 % growth. When compared to the whole groups' average, the extremes of the countries are notable. Countries such as Greece, Italy, Japan, and Switzerland have remained under one percent annual growth while countries such as Ireland, Republic of Korea, and Türkiye have exceeded the average with notable margin, all over three percent of annual growth in the examined period.

The data also show the economic cycles that have varied in the last 30 years. In the early 1990s the annual growth rates remained low, even negative for countries such as Finland, Iceland, and Switzerland. As the 2000s approached the dot-com bubble increased economies' growth which can be seen as whole groups' average increasing from 1.7 % to 3.2 %. The bubble started to subside when the 2000s continued but its effect can still be seen from the growth rates. Another interesting point from the data is that after the 2007-2008 financial crisis hit economies, the recovery has been slow for many countries, expect Ireland, Republic of Korea, and Türkiye. Some of the countries are still recovering from the aftermath of the crisis.

TABLE 2 Annualized percentage growth rates of GDP per capita in the period 1990–2020 (divided into five-year segments)

Country	1990–1995	1995–2000	2000–2005	2005–2010	2010–2015	2015–2020	1990–2020
Australia	1.5	2.8	2.0	1.1	1.2	0.5	1.5
Austria	1.9	2.8	1.5	1.1	0.6	-0.3	1.2
Belgium	1.5	2.6	1.8	0.9	0.8	0.1	1.2
Canada	0.3	2.8	2.0	0.5	1.3	-0.4	0.9
Denmark	1.9	2.6	1.4	0.2	0.9	1.0	1.2
Finland	-0.6	4.7	2.9	0.9	0.2	0.9	1.2
France	1.1	2.3	1.3	0.4	0.7	-0.3	0.8
Germany	2.0	1.8	1.0	1.4	1.9	0.3	1.3
Greece	0.5	3.0	3.5	-0.4	-3.7	-0.6	0.4
Iceland	-0.5	3.5	3.1	0.6	1.2	0.5	1.4
Ireland	4.9	8.4	4.2	-0.6	5.6	8.1	4.5
Italy	1.4	2.2	1.0	-0.6	-0.5	-0.4	0.3
Japan	1.8	1.1	1.3	0.3	1.7	0.2	0.8
Korea, Rep.	7.7	5.6	5.1	3.8	3.1	1.9	4.3
Luxembourg	2.8	3.6	2.4	1.1	0.2	-0.1	1.7
Netherlands	1.9	3.5	1.3	1.2	0.4	0.7	1.4
New Zealand	1.1	2.2	2.4	0.7	1.5	1.2	1.5
Norway	2.9	3.2	1.8	0.2	0.4	0.3	1.4
Portugal	2.1	3.6	0.9	0.5	-0.1	0.9	1.2
Spain	1.7	3.5	2.3	0.0	0.0	0.2	1.1
Sweden	0.1	3.5	2.7	1.3	1.9	0.7	1.4
Switzerland	-0.2	1.5	1.2	1.5	0.9	0.3	0.7
Türkiye	2.6	3.2	4.0	2.9	5.9	2.4	3.1
United Kingdom	1.2	3.2	2.3	0.1	1.3	-0.7	1.1
United States	1.2	2.8	1.8	0.5	1.6	1.1	1.4
Average	1.7	3.2	2.2	0.8	1.2	0.7	1.5

Note: Annual GDP is measured with constant PPPs, reference year 2015.
Source: OECD.stat

3.3.2 Educational structure of OECD countries

Table 3 presents the data on educational attainment of 25-64-year-olds for 23 OECD countries in the years 2005 and 2020. The two main columns in the table present educational attainment, divided to three levels: basic education, secondary education, and tertiary education. Countries are selected based on the same group that was used on Table 2. An exception compared to the earlier table's country pool is the removal of Japan and New Zealand, which were removed due to incomplete data on the database of OECD.

During the fifteen years between 2005 and 2020 the educational structure of the selected OECD countries has changed inevitably. The attainment of basic education as the highest education level has decreased from 32.1% to 21.1 %.

TABLE 3 Educational attainment (%) of 25–64-year-olds in the years 2005 and 2020

Country	2005 Basic education	2005 Secondary education	2005 Tertiary education	2020 Basic education	2020 Secondary education	2020 Tertiary education
Australia	35.0	33.3	31.7	16.2	34.4	49.3
Austria	23.1	52.3	24.6	14.3	51.5	34.2
Belgium	33.9	35.1	31.0	20.2	37.3	42.4
Canada	14.8	39.2	46.0	7.6	32.5	60.0
Denmark	19.0	47.5	33.5	18.6	42.0	39.3
Finland	21.2	44.2	34.6	8.8	43.3	47.9
France	33.2	41.4	25.4	18.5	41.8	39.7
Germany	16.9	58.6	24.6	13.9	54.9	31.3
Greece	42.3	36.2	21.5	23.6	43.7	32.7
Iceland	31.8	38.7	29.5	24.1	35.3	40.6
Ireland	35.5	35.5	29.1	14.5	35.5	49.9
Italy	49.9	37.9	12.2	37.4	42.6	20.0
Korea, Rep.	24.4	44.0	31.6	10.6	38.6	50.7
Luxembourg	34.1	39.3	26.5	25.8	22.8	51.3
Netherlands	28.2	41.7	30.1	19.1	38.8	42.1
Norway	22.8	44.5	32.7	17.5	37.2	45.3
Portugal	73.5	13.6	12.8	44.6	27.2	28.2
Spain	51.2	20.2	28.5	37.1	23.2	39.7
Sweden	16.4	53.9	29.6	16.1	39.3	44.6
Switzerland	14.8	56.5	28.8	10.7	44.0	45.3
Türkiye*	71.9	17.8	10.2	58.3	19.7	22.0
UK	33.2	37.1	29.7	18.3	32.3	49.4
United States	12.2	48.7	39.1	8.3	41.7	50.1
Average	32.1	39.9	28.0	21.1	37.4	41.6

Note: Basic education includes levels 0-2, secondary education levels 3-4, and tertiary education levels 5-8 (ISCED 2011 A Education levels). Countries removed due to incomplete data: Japan and New Zealand. * = Tûrkiye's year 2020 data are submitted with the year 2019 due to an omission in data. Source: OECD.stat

While secondary education has remained at the same level, attainment of higher education has increased from 28.0 % to 41.6 %. Although OECD has not set any official goals for the attainment of tertiary education, the development is progressing towards the same kind of future as the European Parliament has planned for the European Education Area. For the ERA, the set goal by 2030 is to have 50 % rate of 30 to 34-year-olds (Renard & Milt, 2024).

The averages of educational attainments do not show the whole picture about the educational development of selected OECD countries which can be seen from Table 4. The data present a variety of possibilities for the countries' development. While OECD average for the change on basic education attainment was -11.1 %, countries such as Portugal, and Ireland attained -28.9 % and -21.0 % change, respectively. As OECD average change of tertiary education attainment was 13.6 %, all selected countries achieved a positive change on the same metric. The growth was fastest for the countries such as Luxembourg, Ireland, United Kingdom, and Republic of Korea, all increasing the attainment over 19 %.

Another combining factor for these countries is the fact that the tertiary education attainment is over or close to 50 % in all of them.

When analyzing the educational structure with two levels, basic versus post-basic education, the change seems to be the highest in Portugal, Ireland, Australia, and Greece with the transition over 15 % from basic education to post-basic education. On average amongst the selected countries the same change has been 11.1 %. The composition of the average change is clear as the transition to higher education levels is derived from the decrease of basic education, 11.1 %, and the rest from the decrease of secondary education, 2.5 %.

TABLE 4 Change of educational attainment (%) of 25–64-year-olds between 2005 and 2020

	2005–2020		
Country	Basic education	Secondary education	Tertiary education
Australia	-18.7	1.1	17.6
Austria	-8.7	-0.9	9.6
Belgium	-13.7	2.3	11.4
Canada	-7.3	-6.7	14.0
Denmark	-0.3	-5.4	5.8
Finland	-12.4	-0.8	13.2
France	-14.7	0.4	14.3
Germany	-3.0	-3.7	6.7
Greece	-18.7	7.4	11.3
Iceland	-7.7	-3.4	11.2
Ireland	-21.0	0.1	20.9
Italy	-12.5	4.7	7.8
Korea, Rep.	-13.7	-5.4	19.1
Luxembourg	-8.3	-16.5	24.8
Netherlands	-9.1	-2.9	11.9
Norway	-5.3	-7.3	12.6
Portugal	-28.9	13.6	15.3
Spain	-14.1	2.9	11.2
Sweden	-0.3	-14.7	15.0
Switzerland	-4.0	-12.5	16.5
Türkiye*	-13.6	1.9	11.7
UK	-14.8	-4.9	19.7
United States	-3.9	-7.1	11.0
Average	-11.1	-2.5	13.6

Note: Source: OECD.stat

3.3.3 Government expenditures on education in OECD countries

Table 5 presents the data on total education expenditures as a percentage of GDP for 22 OECD countries from 2000 to 2020. The table includes expenditure data for five specific years within this period: 2000, 2005, 2010, 2015, and 2020, along with the overall change from 2000 to 2020.

Over the twenty-year period, the total education expenditures as a percentage of GDP in the selected OECD countries have shown varying trends.

On average, expenditures increased from 5.2 % in 2000 to 5.7 % in 2020, reflecting an overall increase of 0.6 %. This change highlights the growing investment in education across these countries, albeit with significant variation among individual countries.

Notably, some countries exhibited substantial increases in their education spending. Iceland, for instance, saw the highest increase of 2.2 %, moving from 6.4% in 2000 to 8.6% in 2020. Similarly, Norway increased its spending by 1.9 %, from 6.5% to 8.4%, and Germany and the United Kingdom each saw an increase of 1.5 %, reaching 5.6% and 5.5%, respectively.

Conversely, a few countries experienced decreases in their education expenditures relative to GDP. Denmark and the United States both saw a reduction of 0.7 %, with Denmark's spending dropping from 8.1% to 7.4% and the United States from 6.1% to 5.4%. Luxembourg also showed a decline of 0.4 %, moving from 4.2% to 3.8% over the same period.

TABLE 5 Total education expenditures (% of GDP) in the period 2000–2020

Country	2000	2005	2010	2015	2020	2000–2020
Australia	4.9	4.9	5.5	5.3	5.6	0.7
Austria	5.6	5.2	5.7	5.5	5.6	0.0
Belgium	5.5	5.8	6.4	6.5	6.8	1.3
Canada	5.4	4.8	5.4	4.7	4.9	-0.5
Denmark	8.1	8.1	8.6	7.0	7.4	-0.7
Finland	5.7	6.0	6.5	7.0	6.6	0.9
France	5.6	5.5	5.7	5.5	5.7	0.1
Germany	4.1	4.6	5.1	4.9	5.6	1.5
Greece	3.2	4.0	4.1	3.7	4.5	1.3
Iceland	6.4	7.3	6.9	7.5	8.6	2.2
Italy	4.3	4.2	4.3	4.1	4.4	0.2
Japan	3.5	3.3	3.6	3.2	3.4	0.0
Luxembourg	4.2	4.9	5.0	3.8	3.8	-0.4
Netherlands	4.6	5.1	5.5	5.3	5.4	0.8
New Zealand	5.6	5.8	6.5	5.7	5.7	0.1
Norway	6.5	6.8	6.7	7.5	8.4	1.9
Portugal	5.2	5.1	5.4	4.9	4.9	-0.3
Spain	4.2	4.1	4.9	4.3	4.9	0.7
Sweden	6.7	6.5	6.5	7.4	7.9	1.2
Switzerland	4.7	5.1	4.8	5.0	5.3	0.6
United Kingdom	4.0	4.9	5.7	5.6	5.5	1.5
United States	6.1	6.2	6.7	4.9	5.4	-0.7
Average	5.2	5.4	5.7	5.4	5.7	0.6

Note: Countries removed due to incomplete data: Korea, Rep., Türkiye, and Ireland. Source: Databank - The World Bank

The data reveal that while some countries, such as Germany and Iceland, have significantly increased their investment in education, others like Denmark and the United States have reduced their spending relative to GDP. Despite these differences, the overall trend among the selected OECD countries indicates a modest increase in the prioritization of education funding.

When examining the data more closely, it is evident that several countries have managed to maintain or even boost their education expenditures consistently over the years. For example, Belgium’s spending rose from 5.5% to 6.8%, and Sweden’s from 6.7% to 7.9%. In contrast, countries like Portugal and Canada, despite some fluctuations, showed a slight decrease or near stability in their spending levels.

The changes in education expenditures can be linked to several factors, including economic conditions, government priorities, and demographic changes. The overall increase in average spending suggests a recognition of the importance of education in fostering economic growth and development.

4 EMPIRICAL RESEARCH

In this section the used data and methods are presented. The section starts with a brief description of the data, and descriptive statistics of the variables. On the second part of the section, the methods are discussed with the motivation behind the implemented estimation techniques.

4.1 Research questions and hypotheses

The primary aim of this thesis is to explore the intricate connection between various levels of education and economic growth, focusing on how these educational structures impact GDP per capita growth across different countries, particularly those within the OECD. This investigation is guided by two core research questions:

1. *How are different levels of education connected to economic growth, and is some level of education more important than others?*

2. *Is the connection between educational structure and economic growth dependent on the level of technological advancement in OECD countries?*

Based on the research questions, and similar empirical literature (e.g. Pereira & St. Aubyn, 2009; Petrakis & Stamatakis, 2002; Vandenbussche et al., 2006) on the topic following hypotheses are derived to be tested on the thesis.

Hypothesis 1: Different levels of education (basic, secondary, and tertiary) have distinct impacts on economic growth. Specifically, tertiary education has a stronger positive effect on economic growth compared to basic and secondary education.

Hypothesis 2: The impact of education on economic growth is moderated by the level of technological advancement. In countries with higher levels of technological advancement, the impact of tertiary education is greater compared to those in less technologically *advanced countries. In contrast, the impact of basic and secondary education is more pronounced in countries with lower levels of technological advancement.*

Understanding the link between education and economic growth is crucial for policymakers, educators, and economists, as it directly influences decisions regarding educational investments and economic strategies. Education is universally acknowledged as a key driver of economic development, yet the specific contributions of various educational levels—basic, secondary, and tertiary—require deeper examination. This thesis aims to fill this gap by providing empirical evidence on how each educational level affects economic performance and whether some levels are more influential than others.

Moreover, this research is motivated by the need to identify whether the impact of education on economic growth is uniform across different countries or if it varies significantly depending on specific national characteristics. For instance, countries at different stages of technological advancement might experience varying benefits from educational investments. Understanding these dynamics is essential for tailoring educational policies to maximize economic growth.

4.2 Data

The used data are derived from four different sources to construct a panel dataset covering 24 OECD countries between 1990 and 2019. The timeline and countries for the study are selected based on the following technical reasons. First, the available data on variables such as public expenditures on each education level is incomplete for many countries prior to 1990 which led to shortening the timeline from the planned 1970-2019 to 1990-2019. By doing this the coverage of the data improved significantly. Second, countries included in the study were selected based on their OECD membership and data availability. Only countries which have been full members of OECD for the chosen period and had enough data were chosen. As numerous databases report the variables used in this study, there is variation in the style of reporting between countries. For example, some OECD countries have reported certain information every five years in the past which complicates the data being comparable within the selected countries. Due to gaps in the data, data were evaluated, and countries were also chosen based on the reported data and its availability.

Table 6 presents the descriptive statistics for the key variables used in this study, providing an overview of the distribution and key attributes of these variables across the selected OECD countries over the study period.

TABLE 6 Descriptive statistics

Statistic	N	Mean	St. Dev.	Min	Max
Real GDP per capita	168	43 279	14 952	12 007	96 812
TFP proximity (USA=1)	168	0.92	0.14	0.56	1.47
Expenditures on basic education	124	18 628	48 352	242	399 515
Expenditures on secondary education	121	21 899	47 254	35	369 268
Expenditures on tertiary education	125	14 436	34 965	61	287 231
Basic education attainment	168	0.19	0.15	0.00	0.65
Secondary education attainment	168	0.50	0.13	0.00	0.75
Tertiary education attainment	168	0.29	0.12	0.07	0.61
Capital stock per capita	168	202 394	60 133	28 430	381 815
Trade (share of GDP)	168	0.82	0.56	0.16	3.60
Foreign direct investments	165	0.06	0.12	-0.06	0.81
Inflation rate	168	0.04	0.09	-0.02	0.89
Life expectancy	168	79.21	2.65	67.71	83.89

Note: N = number of country-year observations. Real GDP per capita and capital stock per capita are measured in constant national prices (at 2017US). TFP proximity measures a country's technological development relative to the level of the USA. Government expenditures on each education level are expressed in constant US (millions). Education level attainments define the ratio of 25-64-year-olds who have attained the level as the highest completed level. Trade openness and foreign direct investments are measured as a share of each year's GDP. Period is from 1990 to 2019.

From Table 6 it should be noted the variations in the number of observations (N) across different variables. While some variables, such as real GDP per capita, TFP proximity, and educational attainment levels, have a complete set of 168 observations, others, particularly the expenditures on different levels of education, have fewer observations, with N ranging from 121 to 125, and foreign direct investment with N of 165. This discrepancy in sample sizes is due to the availability of data, which varies across countries and years despite the shortening of the timeline of the data. Understanding these differences is crucial for interpreting the results, as they may affect the robustness and generalizability of the findings.

The data on real gross domestic production, total capital stock, and population are from Penn World Tables 10.1 by Feenstra et al. (2015). The dataset provides yearly data on output, capital, population, and capital stock for most selected OECD countries with only a few omissions.

Data on human capital composition, on various levels of educational attainment are collected from the database of OECD and educational attainment dataset by Barro and Lee (2013). Educational attainment data are for the age group of 25-64-year-olds and is divided into three levels of education: basic education, secondary education, and tertiary education. The classification is based on the following logic. Basic education contains levels 0-2, secondary education levels 3-4, and tertiary education levels 5-8 of International Standard Classification of Education-framework (ISCED 2011). The educational attainment is measured as a fraction of the population with each level as their highest completed education level.

The data of World Bank are used to collect the information on the variables foreign direct investment inflow, trade openness, and inflation rate. Foreign direct investment inflow (later FDI) is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital shown in the balance of payments. Trade openness is calculated as the sum of exports and imports of goods and services.

Information about government expenditures on basic education, secondary education, and tertiary education is derived from the database of UNESCO.

The variable used to measure a country's distance to the technological frontier is constructed from three variables, gross domestic production per capita, total capital per capita, and the capital share. First, total real GDP and total capital stock are divided by the quantity of population aged from 15 to 64. The data on population are from Penn World Tables 10.1. Second, as the variable capital share does not have existing comparable dataset, it is defined from the literature as constant variable equal to 0.7 (Topel, 1999; Vandenbussche et al., 2006). Third, capital per capita is subtracted from GDP per capita and multiplied with the assumed constant labor share resulting as a variable of total factor productivity (later TFP). Finally, the proximity to the technological frontier is calculated as the ratio between each country's total factor productivity to the value of the US. Therefore, the TFP proximity variable's values range on the scale relative to the USA meaning as variable's value gets closer to one, country is assumed to be closing the gap to the model's technological frontier. The methodology of constructing total factor productivity and proximity variable follows the methods of Vandenbussche et al. (2006).

4.3 Methods

4.3.1 Basic model

The ordinary least squares (OLS) model is used as the first method of the study to estimate the effects of educational structure on GDP per capita growth. This approach is commonly used in literature on economic growth and educational impacts (e.g. Barro, 1991; Mankiw et al., 1992; Sala-i-Martin, 1997).

Let y_{it} represent the 10-year difference in GDP per capita growth for country i in time t. This is explained by the vector of control covariates X_{it} and the educational variables EDU_{it} measured at time lags. The model can be specified as follows:

$$\ln(y_{it}) = \beta_1 X_{it} + \beta_2 EDU_{it} + \epsilon_{it}$$

In the basic model, the vector of coefficients β_1 captures the effect of control variables on GDP per capita growth. Variables in X_{it} include factors such as TFP proximity, capital stock per capita, trade as a percentage of GDP, inflation rate, and life expectancy. The educational variables EDU_{it} include measures of basic, secondary, and tertiary education attainment at time lags, as well as interactions between education levels and TFP proximity. Additionally, government expenditures on education at different levels (basic, secondary, tertiary) are included to capture the impact of public investment in education to economic growth.

The error term ϵ_{it} captures all other unobserved factors. For the OLS coefficient estimates to be valid, it is crucial that all relevant covariates are included in the model to ensure that the error term is uncorrelated with the explanatory variables ($E[\epsilon_{it}|X_{it}, EDU_{it}] = 0$). The linear form of the model assumes that the relationship between the dependent and independent variables can be adequately described by a linear function.

4.3.2 Fixed effects estimation

The panel model of fixed effects is used as the second method of the study. The significance of employing a fixed effects model in the context of this study is underscored by its ability to control unobserved heterogeneity. This is particularly relevant when considering the potential impact of unobserved country-specific characteristics, such as institutional quality or schooling environment, on the GDP per capita growth rate. These characteristics, which are not captured by the basic OLS model, could lead to biased coefficient estimates if they are correlated with the explanatory variables.

The fixed effects model addresses this issue by controlling for time-invariant unobserved country-specific effects, thus reducing biases in the estimated coefficients. Moreover, the inclusion of time dummies allows the model to account for time variance that could significantly impact GDP per capita growth across the sample countries.

In the context of the second method, the fixed effects model is utilized to analyze GDP per capita growth calculated as a 10-year difference. The model includes educational attainment at various levels (basic, secondary, and tertiary), and interactions between education levels and TFP proximity as explanatory variables. It also incorporates control variables such as public expenditures on each education level, capital stock per capita, trade as a share of GDP, foreign direct investments, inflation rate, and life expectancy.

$$\ln(y_{it}) = \beta_1 X_{it} + \beta_2 EDU_{it} + \alpha_i + \gamma_t + \epsilon_{it}$$

where y_{it} is the variable to be explained, β_1 the coefficient of the control variables X_{it}, β_2 the coefficient of the EDU_{it} which contains the explanatory variables, α_i the coefficient for country-specific effects, γ_t the coefficient for time-specific effects, and ε_{it} is the error term of the model.

4.3.3 Random effects estimation

The random effects model is employed as the third method of the study. The significance of utilizing a random effects model in this context lies in its ability to treat unobserved heterogeneity as random variables, which is particularly useful when analyzing data where unobserved factors are not correlated with the explanatory variables. This is especially relevant when considering the potential impact of unobserved country-specific characteristics, such as institutional quality or schooling environment, on GDP per capita growth rate. These characteristics, not captured by the basic OLS model, could lead to biased coefficient estimates if they are correlated with the explanatory variables.

The random effects model addresses this issue by treating country-specific effects as random and uncorrelated with the explanatory variables, thus providing more efficient estimators. Moreover, this model allows for generalizations beyond the sample, assuming that the cross-sectional units are randomly selected from a larger population.

In the context of this study, the random effects model is utilized to analyze GDP per capita growth calculated as a 10-year difference. The model includes educational attainment at various levels (basic, secondary, and tertiary) and interactions between education levels and TFP proximity as explanatory variables. It also incorporates control variables such as public expenditures on each education level, capital stock per capita, trade as a share of GDP, foreign direct investments, inflation rate, and life expectancy.

The model specification is as follows:

$$\ln(y_{it}) = \beta_1 X_{it} + \beta_2 EDU_{it} + \alpha_i + \epsilon_{it},$$

where the variable definitions are the same as in the implemented fixed effects model. The difference to the used fixed effects model is that in the random effects model there is not a time-specific variable defined due to the restriction limiting the number of explanatory variables including intercept to smaller number than used time periods. Therefore, the random effects model was implemented without time-specific effects.[1]

By incorporating random country-specific effects, the model accounts for the unobserved heterogeneity that might otherwise bias the results. This allows for a more nuanced understanding of the factors influencing GDP per capita growth, considering both the overall trends and individual variations among countries.

[1] Specifically, this restriction is due the Swamy-Arora (1972) estimator used in modelling the random effects models. See Croissant and Millo (2008) for more information on the issue.

5 RESULTS

This section provides an analysis of the results of implemented models to test the two hypotheses of the thesis. First, general aspects are presented with the help of six scatterplots mapping the connection between education levels and economic growth. The information gained from these scatterplots provides an insightful starting point for more applied models. Second, the results of OLS, fixed effects, and random effects models are presented and discussed. After the general discussion of the results, they are linked and compared to empirical literature. In the end of the section, reliability of the results is discussed and motivation for constructing the used methods and variables is presented.

5.1 General aspects

Figure 2 presents a comprehensive analysis of the connection between education attainment and real GDP per capita growth (natural logarithm of 10-year-difference) across varying educational levels and time spans. The plots are systematically arranged to depict current level, lagged value of ten years, and 10-year-change of basic, secondary, and tertiary education attainment against economic growth. Each plot is accompanied by a line of best fit and an R-value, providing a quantitative measure of correlation.

The plots suggest a varying connection between education and economic growth. Basic education attainment shows a positive correlation with economic growth, transitioning to a bit smaller positive correlation when in lagged form. Notably, the change in basic education attainment decreases to correlation close to zero. These results may suggest that the initial positive impact of basic education may not be sustained in the long run. This could imply that while basic education lays the foundation for economic development, it is the advancement to higher levels of education that continues to drive growth as economies evolve, therefore the close to zero correlation with the change of basic education.

Secondary education attainment exhibits a similar but reverse pattern, with a weak negative correlation in the current and lagged term, but a positive correlation in the 10-year-change of the secondary education attainment. This implies that the current and lagged effects of secondary education on economic growth may not be as pronounced or may even be slightly negative. However, over a longer period, such as a decade, the positive impacts of the educational level's change may become evident. This could suggest that the benefits of secondary education, which often include the development of more specialized skills and knowledge, may take time to translate into economic growth, and are captured against economic growth when examining not the current or past level but the actual change of education level on population.

Tertiary education attainment presents the same kind of connection as secondary education, with a negative correlation in the current term and a weak negative correlation in the lagged term, yet a positive correlation is observed in the 10-year-change. This could suggest that the of tertiary education and its contribution to economic growth may take time to take full effect. The advanced skills and knowledge acquired through tertiary education can lead to e.g. innovation, higher productivity, and economic expansion but interestingly the question remains on how the transition between these two works, or at least it cannot be clearly stated from these graphs.

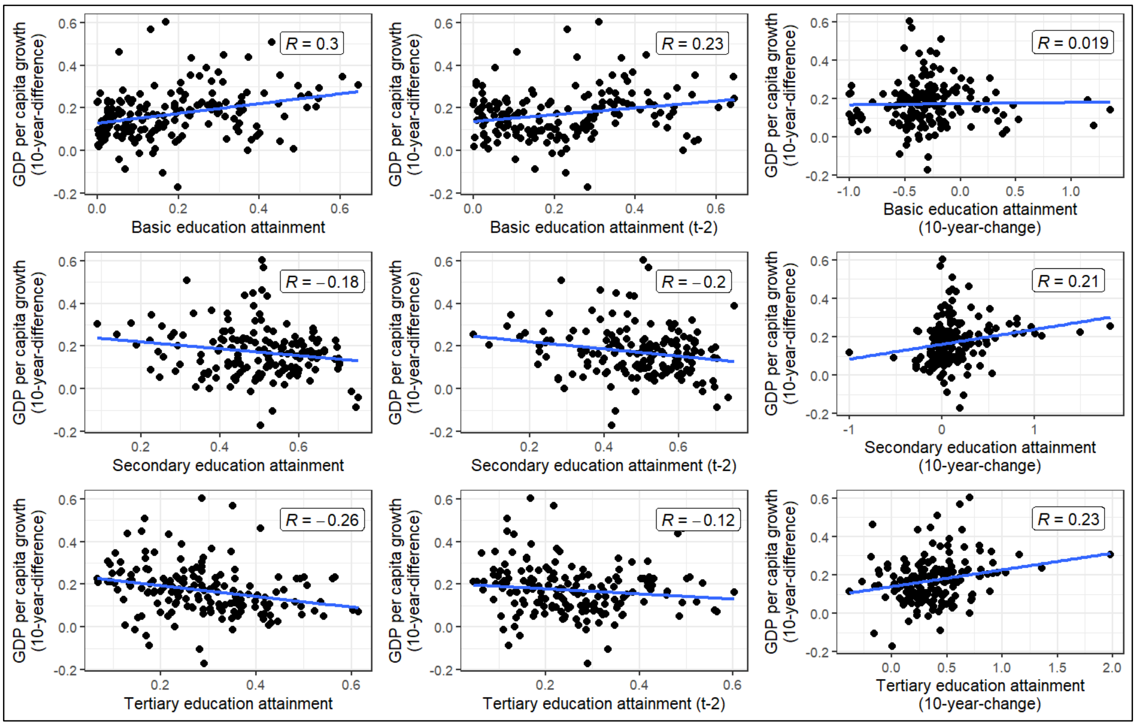

FIGURE 2 Scatterplot mapping educational level attainment and change to economic growth. Note: Term (t-2) occurring with each education attainment variable refers to the values of educational variables lagged two periods backwards which in this case translates to ten years.

5.2 Analysis of the results

5.2.1 Basic equation

Table 7 presents the OLS regression results for the impact of different education levels on real GDP growth per capita over a 10-year period (natural logarithm). The table is divided into two sets of models. The first includes only the education variables which contain education variables lagged by two periods (10 years) and the change of education variables (10-year-change). The second incorporates additional control variables such as TFP proximity, capital stock per capita, trade as a percentage of GDP, inflation rate, and life expectancy.

In the both models, basic education (t-2) shows a significant positive impact on GDP growth, with coefficients of 0.145 ($p<0.01$), and 0.174 ($p<0.01$), respectively. This indicates that higher levels of basic education from two periods prior are associated with increased economic growth. However, the 10-year change in basic education is not significant in either model, suggesting that changes in basic education levels do not have a strong impact on growth.

For secondary education, the lagged value (t-2) has a marginally significant negative impact on GDP growth, with coefficients of -0.144 ($p<0.1$), and -0.139 ($p<0.1$) in the respective models. This could imply that higher levels of secondary education from two periods prior may initially have a constraining effect on growth, possibly due to transitional dynamics in the labor market. The 10-year change in secondary education, however, shows a positive and significant impact in the first model with a coefficient of 0.044 ($p<0.05$), but this effect is not significant in the second model. This suggests that improvements in secondary education over a decade can contribute positively to economic growth.

Tertiary education (t-2) does not show a significant impact on GDP growth in either model, with coefficients of -0.044, and -0.106, respectively. However, the 10-year change in tertiary education is significant in both models, with coefficients of 0.081 ($p<0.01$), and 0.058 ($p<0.01$). This indicates that changes in tertiary education are positively associated with economic growth, highlighting the importance of higher education in fostering long-term economic development.

In the second set of models, TFP proximity (t-1) is not significant in any of the models, suggesting that productivity levels alone do not have a direct impact on GDP growth within the observed period. Capital stock per capita (5-year average) shows a consistent and significant negative impact on GDP growth across all models, with coefficients around -0.049 to -0.056 ($p<0.05$). This indicates potential diminishing returns to capital or inefficiencies in capital allocation.

Trade as a percentage of GDP (5-year average) is not significant in any model, suggesting that trade levels do not have a direct impact on GDP growth within the observed period. The inflation rate (5-year average) shows a positive and significant impact on GDP growth, with coefficients around 0.034 ($p<0.05$), 0.028 ($p<0.1$), and 0.038 ($p<0.05$) in the respective models. This might indicate that moderate inflation rates are associated with economic growth, possibly due to the stimulative effects on spending and investment. Life expectancy (t-1) is not significant in any model, indicating that changes in life expectancy alone do not have a direct impact on economic growth within the observed period.

TABLE 7 OLS regression results (education variables included)

	Dependent variable: Real GDP growth per capita (10-year-difference)					
	(1)			(2)		
	Basic	Secondary	Tertiary	Basic	Secondary	Tertiary
Basic education (t-2)	0.145** (0.053)			0.174** (0.056)		
Basic education (10-year-change)	0.012 (0.017)			0.002 (0.017)		
Secondary education (t-2)		-0.144+ (0.076)			-0.139+ (0.084)	
Secondary education (10-year-change)		0.044* (0.022)			0.019 (0.030)	
Tertiary education (t-2)			-0.044 (0.075)			-0.106 (0.071)
Tertiary education (10-year-change)			0.081** (0.026)			0.058** (0.022)
TFP proximity (t-1)				0.143 (0.091)	0.125 (0.095)	0.150 (0.092)
Capital stock per capita (5-year-average)				-0.049* (0.021)	-0.048* (0.020)	-0.056* (0.022)
Trade (% of GDP) (5-year-average)				0.036 (0.028)	0.033 (0.028)	0.036 (0.028)
Inflation rate (5-year-average)				0.034* (0.015)	0.028+ (0.016)	0.038* (0.015)
Life expectancy (t-1)				-0.010 (0.009)	-0.004 (0.009)	-0.014 (0.010)
Constant	0.143*** (0.014)	0.236*** (0.041)	0.153*** (0.026)	0.788** (0.249)	0.844*** (0.241)	0.933*** (0.267)
Observations	168	168	168	138	138	138
R^2	0.043	0.068	0.054	0.186	0.162	0.170
F Statistic	3.695*	6.046**	4.721*	4.237***	3.582**	3.799***

Note: The standard errors reported in the parentheses have been adjusted for heteroscedasticity. Significance cutoffs: + p<0.1; * p<0.05; ** p<0.01; *** p<0.001. Period 1990-2019.

Table 8 presents the OLS regression results, where the dependent variable is the same as in the previous models, and the models are complemented with additional variables such as government expenditures on each education level, and interaction term for TFP proximity and educational attainment.

For basic education, both the lagged value (t-2) and the 10-year change do not show significant impacts on GDP growth, with coefficients of -0.043 and -0.019, respectively. This suggests that past levels and changes in basic education are not strong predictors of economic growth within the observed period. However, the interaction between basic education (t-1) and TFP proximity (t-1) is highly significant, with a coefficient of 0.401 (p<0.001). This indicates that the positive effects of basic education on GDP growth are significantly enhanced when combined with higher levels of productivity. This could be interpreted so that the closer the country gets to a technological development frontier, the more it benefits from basic education. Although, this finding is reverse to empirical literature, here the connection seems to be rather positive than negative.

Secondary education exhibits a mixed influence. The lagged value (t-2) of secondary education is not statistically significant, with a coefficient of 0.121. In contrast, the 10-year change in secondary education is marginally significant, with a coefficient of 0.102 (p<0.1). This suggests that long-term improvements in secondary education contribute to economic growth, although past levels do not have a strong immediate impact. The interaction between secondary education (t-1) and TFP proximity (t-1) is not significant, with a coefficient of -0.274, indicating that the combined effect of secondary education and productivity on growth is complex and may require further investigation.

Tertiary education shows a varying impact on GDP growth. The lagged value (t-2) of tertiary education is not significant, with a coefficient of -0.032. However, the 10-year change in tertiary education is marginally significant, with a coefficient of 0.091 (p<0.1), suggesting that improvements in tertiary education over time can positively influence economic growth. The interaction between tertiary education (t-1) and TFP proximity (t-1) is not significant, with a coefficient of 0.049, indicating that the effect of tertiary education on GDP growth does not vary significantly with the level of productivity.

TFP proximity (t-1) itself shows positive and marginally significant effects across all education models, with coefficients of 0.165 (p<0.1) in the basic education model, 0.311 (p<0.1) in the secondary education model, and 0.252 (p<0.05) in the tertiary education model. These results underscore the importance of productivity improvements in driving economic growth.

Government expenditures on education yield varying results. For basic education, government spending is not significant. For secondary education, government expenditures are also not significant. However, for tertiary education, government expenditures show a significant negative impact on GDP growth, with a coefficient of -0.048 (p<0.001). This suggests that higher government spending on tertiary education may not directly translate into economic growth after controlling tertiary education attainment.

TABLE 8 OLS regression results (education and TFP variables included)

	Dependent variable: Real GDP per capita (10-year-difference)		
		(3)	
	Basic	Secondary	Tertiary
Basic education (t-2)	-0.043 (0.073)		
Basic education (10-year-change)	-0.019 (0.022)		
Secondary education (t-2)		0.121 (0.156)	
Secondary education (10-year-change)		0.102+ (0.053)	
Tertiary education (t-2)			-0.032 (0.085)
Tertiary education (10-year-change)			0.091+ (0.047)
TFP proximity (t-1)	0.165+ (0.099)	0.311+ (0.180)	0.252* (0.119)
Capital stock per capita (5-year-average)	-0.060** (0.023)	-0.070** (0.023)	-0.091*** (0.025)
Trade (% of GDP) (5-year-average)	0.042 (0.038)	0.050 (0.043)	-0.021 (0.048)
Inflation rate (5-year-average)	-0.003 (0.020)	-0.007 (0.024)	-0.005 (0.024)
Life expectancy (t-1)	-0.001 (0.009)	0.015 (0.010)	-0.007 (0.011)
Government expenditures on basic education (t-2)	-0.015 (0.009)		
Basic education (t-1) *TFP proximity (t-1)	0.401*** (0.113)		
Government expenditures on secondary education (t-2)		-0.007 (0.008)	
Secondary education (t-1) *TFP proximity (t-1)		-0.274 (0.216)	
Government expenditures on tertiary education (t-2)			-0.048*** (0.013)
Tertiary education (t-1) *TFP proximity (t-1)			0.049 (0.178)
Constant	0.813** (0.291)	0.786* (0.335)	1.404*** (0.318)
Observations	89	82	89
R^2	0.289	0.239	0.315
F Statistic	3.576***	2.514*	4.043***

Note: The standard errors reported in the parentheses have been adjusted for heteroscedasticity. Significance cutoffs: + p<0.1; * p<0.05; ** p<0.01; *** p<0.001. Period 1990-2019.

5.2.2 Fixed and random effects models

Table 9 presents the results from both fixed effects (FE) and random effects (RE) regression analyses, exploring the same setting as in the previous models. The presented models are categorized into 4 and 5 models indicating the set variables that are used. In category 4, only educational and control variables are used excluding TFP related variables. In category 5, all variables are used to derive the results. An important note regarding the fixed and random effect modes is that they represent an optimal model selection based on information presented in section 5.2.5. However, the analysis for models 4 and 5 is also conducted by using only fixed effects model and random effects model. The results from these implementations can be found in Appendix (see Table 10 and 11).

In the random effects model, the lagged value of basic education (t-2) shows a positive and statistically significant impact on GDP growth, with a coefficient of 0.163 ($p<0.05$), indicating that past levels of basic education contribute positively to economic growth. However, the 10-year change in basic education is not statistically significant in either the RE or FE models, with coefficients of -0.015 and -0.020, respectively. In the fixed effects model, the lagged value of basic education (t-2) loses its significance, with a coefficient of -0.088, suggesting that while basic education levels are important, their influence might be less stable when accounting for time-invariant factors specific to each country.

For secondary education, the results are mixed. In the RE model, the lagged value of secondary education (t-2) is not significant, with a coefficient of -0.136, but the 10-year change in secondary education is marginally significant, with a coefficient of 0.078 ($p<0.1$). This marginal significance suggests that long-term improvements in secondary education can contribute to economic growth, although the immediate past levels do not have a strong effect. In the FE model, neither the lagged value nor the 10-year change in secondary education is significant, with coefficients of 0.044 and 0.022, respectively.

The influence of tertiary education on GDP growth appears minimal. The lagged value of tertiary education (t-2) shows no significant impact in both RE and FE models, with coefficients of -0.092 and -0.074, respectively. Similarly, the 10-year change in tertiary education does not significantly affect GDP growth, with coefficients of 0.033 in the RE model and 0.062 in the FE model.

TFP proximity (t-1) exhibits a significant positive impact on GDP growth in the FE model, with a coefficient of 0.456 ($p<0.01$), and a marginally significant impact in the RE model for tertiary education, with a coefficient of 0.297 ($p<0.05$). This indicates that improvements in productivity are crucial for enhancing economic growth and can amplify the benefits of education.

The interaction terms between education and TFP proximity provide additional insights. The interaction between basic education (t-1) and TFP proximity (t-1) is highly significant in the FE model, with a coefficient of 0.620 ($p<0.001$), suggesting that the positive effects of basic education on GDP growth are significantly enhanced by higher levels of TFP proximity. For secondary education, the interaction with TFP proximity is significantly negative, with a coefficient of -0.682 ($p<0.01$), indicating a complex connection where higher productivity might reduce the marginal benefits of secondary education. The interaction between tertiary education and TFP proximity is not significant, with a coefficient of -0.038, implying that the effect of tertiary education on GDP growth does not vary with TFP levels.

The effects of government expenditures on education vary by education level. For basic education, expenditures are not significant. For secondary education, the expenditures are also not significant. However, for tertiary education, expenditures have a significant negative impact on GDP growth, with coefficients of -0.034 ($p<0.01$) and -0.047 ($p<0.01$) in both models. This finding is the same as in previous OLS models indicating that the transition from government spending on tertiary education may not translate into economic growth, at least not directly.

TABLE 9 Fixed and random effects regressions results

	Dependent variable: Real GDP per capita growth (10-year-difference)					
		(4)			(5)	
Model:	(RE) Basic	(RE) Secondary	(RE) Tertiary	(FE) Basic	(FE) Secondary	(RE) Tertiary
Basic education (t-2)	0.163* (0.072)			-0.088 (0.105)		
Basic education (10-year-change)	-0.015 (0.026)			-0.020 (0.016)		
Secondary education (t-2)		-0.136 (0.098)			0.044 (0.110)	
Secondary education (10-year-change)		0.078+ (0.046)			0.022 (0.043)	
Tertiary education (t-2)			-0.092 (0.085)			-0.074 (0.079)
Tertiary education (10-year-change)			0.033 (0.042)			0.062 (0.042)
TFP proximity (t-1)				0.111 (0.102)	0.456** (0.162)	0.297* (0.125)
Capital stock per capita (5-year-average)	-0.112** (0.036)	-0.094*** (0.025)	-0.087** (0.030)	-0.068 (0.041)	-0.058 (0.055)	-0.116** (0.038)
Trade (% of GDP) (5-year-average)	0.015 (0.059)	0.022 (0.060)	-0.006 (0.054)	-0.016 (0.134)	-0.030 (0.173)	-0.058 (0.053)
Inflation rate (5-year-average)	0.016 (0.016)	0.009 (0.019)	-0.006 (0.022)	0.010 (0.010)	0.001 (0.014)	-0.022 (0.020)
Life expectancy (t-1)	-0.003 (0.008)	0.006 (0.007)	-0.003 (0.007)	0.164 (0.129)	0.044 (0.134)	-0.009 (0.010)
Government expenditures on basic education (t-2)	0.0002 (0.007)			-0.012 (0.009)		

TABLE 9 (continues) Fixed and random effects regressions results

Basic education (t-1) *TFP proximity (t-1)				0.620*** (0.120)		
Government expenditures on secondary education (t-2)		0.007 (0.007)			0.003 (0.009)	
Secondary education (t-1) *TFP proximity (t-1)					-0.682** (0.214)	
Government expenditures on tertiary education (t-2)			-0.034** (0.013)			-0.047** (0.015)
Tertiary education (t-1) *TFP proximity (t-1)						-0.038 (0.230)
Constant	1.587*** (0.445)	1.349*** (0.359)	1.526*** (0.408)			1.625** (0.500)
Observations	89	82	89	89	82	89
R^2	0.254	0.254	0.263	0.308	0.316	0.334
F Statistic	21.239**	20.191**	19.771**	2.566*	2.361*	30.120***

Note: The standard errors reported in the parentheses have been adjusted for heteroscedasticity. RE models also are corrected for serial correlation. RE = Random effects models, and FE = Fixed effects models. Significance cutoffs: + p<0.1; * p<0.05; ** p<0.01; *** p<0.001. Period 1990–2019.

5.2.3 Key findings

The analysis of the connection between education levels and economic growth in OECD countries reveals insights into the impacts of basic, secondary, and tertiary education. The results from the regression analyses provide evidence to address the research questions and test the hypotheses regarding the connection between educational structure, economic growth, and technological advancement.

Regarding the first research question, the regression results indicate that different levels of education indeed have distinct impacts on economic growth, supporting Hypothesis 1. Basic education has a significant positive impact on GDP growth per capita, particularly in the models that account for lagged values. Specifically, the lagged value of basic education shows significant positive coefficients, suggesting that higher levels of basic education from two periods prior are associated with increased economic growth. This indicates that foundational education contributes to long-term economic performance. However, the impact of changes in basic education is not significant, implying that the benefits of improvements in basic education take time to manifest in economic growth.

Secondary education presents a more complex picture. The lagged value of secondary education shows a marginally significant negative impact on GDP growth, suggesting potential transitional dynamics or structural adjustments that might temporarily hinder economic performance. However, the 10-year change in secondary education shows a significant positive impact in some models, indicating that long-term improvements in secondary education contribute positively to economic growth. This mixed result highlights the transitional challenges and the eventual positive contributions of secondary education to the economy.

Tertiary education consistently shows a significant positive impact on economic growth when considering the 10-year change. The significant coefficients for the 10-year change in tertiary education indicate that changes in tertiary education are positively associated with economic growth. This supports Hypothesis 1, emphasizing the role of higher education in fostering long-term economic development. The results could suggest that tertiary education has a stronger positive effect on economic growth compared to basic and secondary education, highlighting its critical role in advanced economies.

The second research question addresses whether the connection between educational structure and economic growth depends on the level of technological advancement. The results provide mixed evidence for Hypothesis 2. The interaction terms between education levels and TFP proximity offer insights into the moderating role of technological advancement. For basic education, the interaction with TFP proximity is highly significant, indicating that the combined effect of basic education and productivity enhancements is crucial for economic growth. This suggests that in technologically advanced contexts, the benefits of basic education are amplified.

For secondary education, the interaction with TFP proximity shows a significant negative coefficient in the fixed effects model, implying that the benefits of secondary education on growth might be moderated or even reduced in highly productive environments. This finding suggests that secondary education might have a more pronounced impact in less technologically advanced countries, where foundational skills are crucial for economic development.

Tertiary education's interaction with TFP proximity is not consistently significant, indicating that the direct benefits of tertiary education on economic growth are not heavily influenced by productivity levels. However, the significant positive impact of the 10-year change in tertiary education underscores its importance regardless of the technological context. This partially supports Hypothesis 2, suggesting that while tertiary education is universally beneficial, its impact is not significantly moderated by the level of technological advancement.

Overall, the findings reveal that different levels of education have distinct and significant impacts on economic growth. Tertiary education emerges as particularly important for long-term economic development. The interaction between education and technological advancement highlights the complex dynamics at play, with basic and secondary education showing varied impacts depending on the productivity context. These insights underscore the critical role of education in driving economic growth and the need to tailor educational policies to the technological and economic conditions of each country.

5.2.4 Comparison to empirical literature

The empirical section of this thesis contributes to the empirical literature examining the connection between educational levels and economic growth. This section compares the findings to the results of several studies, highlighting similarities, differences, and the broader implications of the results.

Petrakis and Stamatakis (2002) explored the connection between human capital investment and economic growth across different development levels. Their findings indicated that advanced economies benefit more from higher education, while less developed countries rely on primary and secondary education. Findings of this study partially share this view, as tertiary education in observed OECD countries (which are mostly advanced economies) shows a strong positive effect on economic growth. However, results also show significant effects for basic education, suggesting that foundational education remains important even in more developed contexts. This suggests a complementary rather than substitutive connection between different education levels and growth.

Agiomirgianakis et al. (2002) found that higher levels of education have a more substantial effect on long-term economic growth than lower levels. The results of this thesis align with this conclusion, showing significant positive impacts of tertiary education on real GDP growth per capita. This supports the policy recommendation to expand higher education to foster economic development, as emphasized by researchers of the study. However, the findings also highlight the sustained importance of basic and secondary education, which may imply a more balanced approach to government investments on each education level.

Papageorgiou (2003) emphasized the role of primary education in developing countries and post-primary education in high-income countries for economic growth. While this thesis focuses on OECD countries, generally high-income, the significant positive impact of tertiary education aligns with Papageorgiou's findings. However, the results also suggest that basic education remains relevant in these contexts, potentially due to its foundational role in supporting higher educational attainment and overall human capital development.

Pereira and St. Aubyn (2009) examined the impact of human capital formation on economic growth in Portugal, finding that primary and secondary education were more crucial for growth in less developed phase, while higher education was more important when the technological level of the country had developed closer to technological frontier. The findings of this thesis are consistent with this view, as tertiary education plays a significant role in the economic growth of OECD countries. However, the significant impact of basic education suggests a more integrated approach, where different education levels collectively contribute to growth.

Holmes (2013) found a positive link between primary/secondary education and economic growth but not for higher education. This contrasts with the acquired findings, where tertiary education shows a positive impact on economic growth. The difference might stem from the varying periods and regions studied, with Holmes focusing on a broader range of countries over a different timeline. However, the results suggest that in the OECD context, higher education has become increasingly important, possibly due to the advanced stage of economic development and the need for highly skilled labor.

5.2.5 Reliability of the results

5.2.5.1 Variable selection

The used data are divided into 5-year sections to reduce the possibility of business cycle effect. Hence, the initial data ranging from 1990 to 2019 results in six 5-year periods, and one 4-year-period. As used variables such as, TFP proximity, real GDP per capita, and educational variables, may be pro-cyclical, the correlation between the variables may be driven by business cycle rather than true relationship. To counter these effects the real GDP per capita growth is measured as 10-year-difference of natural logarithms (ln y_t - y_{t-2}), educational variables in 10-year-lags (annotated t-2), TFP proximity in 5-year-lag (annotated t-1), and relevant control variables in 5-year-averages. Additionally, control variables including capital stock per capita, life expectancy, and government expenditures on each education level are measured in natural logarithms. This transformation stabilizes variance, linearizes connections, and allows coefficients to be interpreted as percentage changes, enhancing the robustness and interpretability of the empirical analysis. Other variables included in the model, such as educational variables, TFP proximity, trade openness and foreign direct investments, were not transformed since they are already measured in percentages, making further transformation unnecessary.

5.2.5.2 Model selection

The starting point for applying the different methods to investigate the connection between different education levels and economic growth was to use OLS regressions. Results from these models could be used as baseline for more advanced models. As noted in previous chapters, OLS regression's assumptions might not be fully satisfied with the models that were implemented. It can be argued there will be unobserved country-specific effects which alter the dependent variable, real GDP per capita growth, and are not captured by the basic OLS model. These unobserved effects would affect the error term in the model resulting in biased coefficients. There are various methods to tackle this problem of which this study implements random effects (RE) and fixed effects (FE) estimation techniques.

To determine the most suitable regression models for the empirical study, the Hausman and the Breusch-Pagan test were employed. These tests guided the study in selecting between fixed effects (FE) and random effects (RE) models, and between random effects (RE) models and pooled regression models.

The Hausman test was initially used to choose between the fixed effects and random effects models. This test compares the coefficients from the FE and RE models to identify any significant differences. The null hypothesis assumes that the coefficients from the FE and RE models are consistent, while the alternative hypothesis suggests inconsistency. A small p-value (less than 0.05) leads to rejecting the null hypothesis, indicating the fixed effects model should be used (Greene, 2003).

The results of the Hausman tests are the following for the models wherein control variables were included without TFP related variables (see Models 4 of Table 9). For the basic education model, a p-value was 0.7364, leading to the selection of the random effects model. For the secondary education model, a p-value was 0.3852, resulting in the selection of the random effects model. For the tertiary education model, a p-value was 0.9719, also leading to the selection of the random effects model.

The models in which all control variables including TFP related variables were used the test results were following (see Models 5 of Table 9). For the basic education model, a p-value was 0.000907, resulting in the selection of the fixed effects model. For the secondary education model, a p-value was 0.001485, leading to the selection of the fixed effects model. Lastly, for the tertiary education model, a p-value was 0.9993, resulting in the selection of the random effects model.

Following the Hausman test, the Lagrange multiplier (LM) test designed by Breusch and Pagan (1980) was conducted to confirm the presence of heteroscedasticity and further validate the model selection. This test checks for heteroscedasticity among entities in the model. The null hypothesis assumes homoscedasticity, while the alternative hypothesis suggests heteroscedasticity. If the p-value from the Breusch-Pagan test is below the chosen significance level (typically 0.05), we reject the null hypothesis, indicating heteroscedasticity and validating the need for RE models over OLS models (Greene, 2003).

The results of the Breusch-Pagan tests for the models confirmed significant effects in the basic education model with a p-value of 9.24e-07, in the secondary education model with a p-value of 1.786e-06, and in the tertiary education models with p-values of 5.686e-06 and 1.483e-06, respectively. These results indicate the presence of heteroscedasticity, supporting the use of random effects models as determined by the Hausman test.

Tests were also conducted to determine if time-fixed effects were necessary for the fixed effects models, including the basic and secondary education models. This involved fitting a model with time dummies and comparing it to a model without them using an F-test for time effects with the null hypothesis stating that no time-fixed effects are needed (Kleiber & Zeileis, 2008).

The basic education model with fixed effects resulted in a p-value of 1.623e-05. The p-value is significantly less than 0.05, indicating that time-fixed effects are necessary for this model. Similarly, for the secondary education model with fixed effects the p-value was 9.355e-06. Again, the p-value is significantly less than 0.05, indicating that time-fixed effects are also necessary for this model.

These results confirm the necessity of including time-fixed effects in both fixed effects models. This suggests that time-specific factors have a significant impact on the GDP per capita growth rate in these educational contexts. Integrating time-fixed effects into the models ensures a more accurate representation of the data and enhances the reliability of the findings.

5.2.5.3 Autocorrelation

The Breusch-Godfrey/Wooldridge test for serial correlation was applied to investigate idiosyncratic errors within fixed effects and random effects models in panel data analysis (Greene, 2003). The aim was to ensure the models accurately reflected the data dynamics without autocorrelation interference.

The test's results were mixed. For the random effect models of all education levels the results showed significant serial correlation, indicating potential error patterns over time, possibly due to unobserved variables or data structure. The fixed effects models of basic and secondary education showed no significant serial correlation, suggesting random error fluctuations and well-specified models.

To adjust for the serial correlation detected in the random effects models, robust standard errors were corrected using methods originally constructed by Arellano (1987) to allow for general structure heteroscedasticity and serial correlation.[2]

[2] Another possibility to adjust for the serial correlation could be using e.g. Newey and West (1987) estimators for panel data. See Millo (2017) for more in-depth discussion on standard errors suitable for panel data regressions.

6 CONCLUSIONS

The results of this thesis enhance the understanding of the connection between educational structure and economic growth, particularly within OECD countries. The term educational structure refers to the categorization of education levels into primary, secondary, and tertiary education, reflecting different contributions to human capital formation.

Two primary strands of growth theories—neoclassical and endogenous growth models—offer insights into how economic growth is influenced by education. Neoclassical models, as proposed by Solow (1956) and Swan (1956), emphasize exogenous factors like population growth and technological progress, later modified to include human capital. In contrast, endogenous growth models by Lucas (1988) and Romer (1986, 1990) highlight internal factors like human capital, innovation, and research and development as drivers of growth.

This thesis employed three methods: ordinary least squares (OLS), fixed effects, and random effects models to estimate the impact of educational structure on GDP per capita growth. The models included control variables such as TFP proximity, capital stock per capita, and public expenditures on education. The fixed effects model controlled for unobserved heterogeneity, and the random effects model treated country-specific effects as random, providing more efficient estimators.

Key findings reveal that different education levels have distinct impacts on economic growth. Basic education significantly boosts GDP growth per capita, especially with lagged values, indicating its long-term benefits. Secondary education shows mixed results, with lagged values suggesting transitional challenges but long-term changes contributing positively. Tertiary education consistently shows a significant positive impact on economic growth, underscoring its critical role in advanced economies.

The interaction between educational levels and technological advancement yields mixed results. Basic education's benefits are complemented in technologically advanced contexts, whereas secondary education's impact might be moderated in the same context. Tertiary education remains crucial regardless of technological context, emphasizing its importance for long-term growth.

Comparing these findings to empirical literature, the results align with studies like Petrakis and Stamatakis (2002) and Agiomirgianakis et al. (2002), which highlight the greater impact of higher education in advanced economies. However, the significant role of basic education suggests its foundational importance even in developed contexts, supporting a complementary connection between different education levels.

Overall, this thesis underscores the critical role of education in driving economic growth and highlights the need for tailored educational policies that carefully consider technological and economic conditions. Tertiary education emerges as particularly significant, but the importance of basic and secondary education should not be overlooked, as they collectively contribute to human capital development and economic performance.

The results of this thesis also create a motivation for further avenues regarding the studies interested in different education levels connection to economic growth. First, a possible direction that the study could be expanded is to look more on different dynamics of education levels combined on economic growth. For instance, one could combine basic and secondary education, or secondary and tertiary education and map these effects on economic variables, e.g. growth. Second, an interesting addition to models with different education levels could be variable capturing education quality effects, or more generally human capital quality effects. Perhaps, the current development is directed towards these kinds of analyses since the datasets on different tests for students and adults are constantly expanding to cover even longer time periods.

In the future, studies of this kind can be carried out more reliably following e.g. methods of Hanushek (2016) who suggests that the quality of education, measured through international assessments like the PISA tests, can significantly impact economic growth. This perspective emphasizes the importance of cognitive skills over merely the quantity of education.

Therefore, future research could incorporate measures of educational quality and cognitive skills to provide a more comprehensive understanding of how different levels and qualities of education affect economic growth. This aligns with the broader literature that highlights the need to move beyond traditional metrics of educational attainment and focus on the actual skills and knowledge imparted through education.

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APPENDIX

TABLE 10 Fixed effects model results

	Dependent variable: Real GDP per capita growth (10-year-difference)					
	(4)			(5)		
	Basic	Secondary	Tertiary	Basic	Secondary	Tertiary
Basic education (t-2)	0.056 (0.112)			-0.088 (0.105)		
Basic education (10-year-change)	-0.022 (0.021)			-0.020 (0.016)		
Secondary education (t-2)		-0.123 (0.111)			0.044 (0.110)	
Secondary education (10-year-change)		0.071* (0.031)			0.022 (0.043)	
Tertiary education (t-2)			0.334** (0.127)			0.312** (0.117)
Tertiary education (10-year-change)			0.053 (0.036)			0.058 (0.037)
TFP proximity (t-1)				0.111 (0.102)	0.456** (0.162)	0.053 (0.177)
Capital stock per capita (5-year-average)	-0.107* (0.049)	-0.073 (0.057)	-0.170*** (0.049)	-0.068 (0.041)	-0.058 (0.055)	-0.175*** (0.053)
Trade (of GDP) (5-year-average)	-0.107 (0.159)	-0.037 (0.221)	0.038 (0.167)	-0.016 (0.134)	-0.030 (0.173)	0.035 (0.156)
Inflation rate (5-year-average)	0.013 (0.012)	0.012 (0.014)	0.020 (0.019)	0.010 (0.010)	0.001 (0.014)	0.016 (0.017)
Life expectancy (t-1)	0.221 (0.210)	0.045 (0.160)	0.125 (0.253)	0.164 (0.129)	0.044 (0.134)	0.101 (0.243)
Government expenditures on basic education (t-2)	0.00002 (0.010)			-0.012 (0.009)		
Basic education (t-1) *TFP proximity (t-1)		0.0002 (0.010)			0.003 (0.009)	
Government expenditures on secondary education (t-2)			0.001 (0.040)			-0.010 (0.047)
Secondary education (t-1) *TFP proximity (t-1)				0.620*** (0.120)		
Government expenditures on tertiary education (t-2)					-0.682** (0.214)	
Tertiary education (t-1) *TFP proximity (t-1)						0.049 (0.261)

TABLE 10 (continues) Fixed effects model results

Observations	89	82	89	89	82	89
R^2	0.103	0.140	0.177	0.308	0.316	0.185
F Statistic	0.883	1.114	1.627	2.566*	2.361*	1.284

Note: The standard errors reported in the parentheses have been adjusted for heteroscedasticity. Significance cutoffs: + p<0.1; * p<0.05; ** p<0.01; *** p<0.001. Period 1990–2019.

TABLE 11 Random effects model results

	Dependent variable: Real GDP per capita growth (10-year-difference)					
	(4)			(5)		
	Basic	Secondary	Tertiary	Basic	Secondary	Tertiary
Basic education (t-2)	0.163* (0.072)			0.063 (0.073)		
Basic education (10-year-change)	-0.015 (0.026)			-0.016 (0.019)		
Secondary education (t-2)		-0.136 (0.098)			-0.054 (0.115)	
Secondary education (10-year-change)		0.078+ (0.046)			0.069 (0.055)	
Tertiary education (t-2)			-0.092 (0.060)			-0.074 (0.065)
Tertiary education (10-year-change)			0.033 (0.040)			0.062 (0.045)
TFP proximity (t-1)				0.207+ (0.107)	0.356+ (0.201)	0.297+ (0.157)
Capital stock per capita (5-year-average)	-0.112** (0.036)	-0.094*** (0.025)	-0.087*** (0.023)	-0.083+ (0.047)	-0.126** (0.047)	-0.116** (0.036)
Trade (of GDP) (5-year-average)	0.015 (0.059)	0.022 (0.060)	-0.006 (0.064)	0.015 (0.054)	-0.004 (0.052)	-0.058 (0.056)
Inflation rate (5-year-average)	0.016 (0.016)	0.009 (0.019)	-0.006 (0.022)	-0.014 (0.015)	-0.002 (0.019)	-0.022 (0.019)
Life expectancy (t-1)	-0.003 (0.008)	0.006 (0.007)	-0.003 (0.006)	-0.007 (0.005)	0.007 (0.008)	-0.009 (0.007)
Government expenditures on basic education (t-2)	0.0002 (0.007)			-0.001 (0.007)		
Basic education (t-1) *TFP proximity (t-1)				0.532*** (0.104)		
Government expenditures on secondary education (t-2)		0.007 (0.007)			0.006 (0.010)	

TABLE 11 (continues) Random effects model results

Secondary education (t-1) *TFP proximity (t-1)					-0.186 (0.226)	
Government expenditures on tertiary education (t-2)			-0.034** (0.011)			-0.047*** (0.012)
Tertiary education (t-1) *TFP proximity (t-1)						-0.038 (0.219)
Constant	1.587*** (0.445)	1.349*** (0.359)	1.526*** (0.362)	0.859 (0.556)	1.401* (0.626)	1.625*** (0.478)
Observations	89	82	89	89	82	89
R^2	0.254	0.254	0.263	0.416	0.330	0.334
F Statistic	21.239**	20.191**	19.771**	48.931***	30.287***	30.120***

Note: The standard errors reported in the parentheses have been adjusted for heteroscedasticity and serial correlation. Significance cutoffs: + p<0.1; * p<0.05; ** p<0.01; *** p<0.001. Period 1990–2019.