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Author(s): Chen, Sihua; Qiu, Han; Xiao, Hua; He, Wei; Mou, Jian; Siponen, Mikko

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Consumption behavior of eco-friendly products and applications of ICT innovation

By

Sihua Chen[a], Han Qiu[a], Hua Xiao[a, b, *], Wei He[c, *], Jian Mou[d], Mikko Siponen[e]

[a] School of Information Management, Jiangxi University of Finance and Economics, China

[b] Library, Jiangxi Agricultural University, China

[c] School of Business Administration, Jiangxi University of Finance and Economics, China

[d] School of Business Pusan National University, Republic of Korea

[e] Faculty of Information Technology, University of Jyvaskyla, Finland

*Corresponding author: Dr. Hua Xiao
Library, Jiangxi Agricultural University
Nanchang, 330045, PR China
Phone: (86)-791-83813249
Fax: (86)-791-83813264
Email: huaxiao4273@163.com
Prof. Wei He
School of Business Administration
Jiangxi University of Finance and Economics
Nanchang 330013, PR China
Phone: (86)-791-83816813
Fax: (86)-791-83816019
Email: hewei@jxufe.edu.cn

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Abstract

The purchase of eco-friendly products is encouraged by the governments due to its contributions to the sustainable development of the environment. It is therefore important to examine factors influencing the purchase of eco-friendly products. This paper contributes to this domain. Based on the attitude-behavior-context (ABC) theory, this paper constructs a conceptual model, which explores how a consumer's perceived effectiveness affects his or her purchase of eco-friendly products. In this model, this paper attempts to examine the mediating role of consumption attitude of eco-friendly products as well as the moderating effect of applications of information and communication technologies (ICT) innovation. Moreover, by building a Hidden Markov Model (HMM), this paper further tests the conceptual model. More importantly, based on the HMM, the consumption probabilities of eco-friendly products of different perceived effectiveness under different applications of ICT innovation are computed. Furthermore, based on a dynamic time series, the consumption transition probability of eco-friendly products is further calculated. In addition, this paper explains and calculates the concepts continuity, dependence and inertia in consumption of eco-friendly products. Based on it, the algorithm is used to forecast the consumption behavior of the real environment to verify the reliability of the HMM and the accuracy of probability calculation. This paper contributes the extension of the existing studies and the provision of management implications and guidance for the consumption practice of eco-friendly products.

Keywords: ICT; sustainability; eco-friendly product; consumer attitude; consumption behavior; perceived effectiveness

1. Introduction

With the increased material consumption, people are facing more and more serious pollution from the consumption of products (Shao et. al., 2017; Song et al., 2019; Yuan et al., 2018). As such, people are compelled to reflect on their traditional consumption behaviors. Comparing with the traditional way of consumption, the eco-friendly consumption, of which the core is sustainable consumption, has increasingly become a positive way for people to alleviate environmental degradation (Grinstein, 2009).As a part of the green economy, eco-friendly consumption behavior is an important driving force for sustainable development. It has such advantages as high resource utilization efficiency and friendly to ecology, which has been widely concerned by the public (Jayaraman et al., 2019). Considering the important influence of eco-friendly consumption behavior on ecological environment, how to promote consumers' eco-friendly consumption behavior is the Chinese government's practical need to build the ecological civilization. Moreover, it is also the research focus of scholars in the field of consumer behavior.

With the increase of consumers' awareness of eco-friendly products, more and more people express their willingness to choose eco-friendly products (Yadav et al., 2019). Moreover, because of the stricter environmental regulations and the constrains of environmental resources, numerous companies commence to produce and sell eco-friendly products (Khan et al., 2017; Kumar et al., 2018; Yadav et al., 2019). To promote these eco-friendly products, it is important for these companies to understand consumers' perception and consumption attitude towards such products (Cherrier et al., 2011). In practice, however, although consumers say that they are very concerned about environmental issues, it is found difficult for them to turn their concerns into the actual consumption behavior of eco-friendly products. The degree to which sustainability enhances preference depends on the type of benefit consumers most value for the product category in question (Luchs et al., 2010). Driven by these practical needs, scholars began to focus on the consumption behavior of eco-friendly products and explore what influencing consumers use of such products (Joshi et al., 2015; Tripathi et al., 2016).

At present, scholars have studied the influence of demographic characteristics, psychological variables and external contextual factors on the consumption behavior of eco-friendly products. Demographic characteristics focus on the influence of gender, age, monthly income, occupation and education on the consumption behavior of eco-friendly products (Roman et al., 2015). Psychological

variables focus on the influence of perceived effectiveness, attitude, environmental protection values and environmental concerns on the consumption behavior of eco-friendly products (Nair et al., 2016; Costa et al., 2016; Awuni et al., 2016; Richa et al., 2018; Li et al.,2019). External contextual factors mainly focus on the impact of product advertisement, innovative products and information on the consumption behavior of eco-friendly products (Lin et al., 2015; Liu et al., 2017, Sheng et al., 2019).

Some scholars believed that an individual's perceived effectiveness had a strong explanatory power on the consumption behavior of eco-friendly products. The stronger the individual's perceived effectiveness is, the stronger the individual's belief in changing the environmental status quo will be, and the more inclined to adopt the consumption behavior of eco-friendly products. Berger et al. (1992) found that individual perceived effectiveness was an important variable affecting environmental attitudes and consumer behaviors. The research of Roberts (1996) further showed that the individual perceived effectiveness was the most significant variable that influenced an individual's eco-friendly consumption behavior more than other psychological variables and demographic variables.

A positive attitude towards eco-friendly products is a good starting point to produce eco-friendly consumer behavior. Some studies showed that about 30% of consumers had a positive attitude towards eco-friendly products. These consumers pay more attention to ecological packaging, food sources and other related issues. They believe that eco-friendly products are better in quality, safety, environmental protection, and are more beneficial to human health and environment (Vermeir et al., 2006; Tanner et al., 2003), and they are more likely to buy eco-friendly products (Liu et al, 2012). In other words, attitude plays the function of entry notion in the formation of consumers' willingness to consume. And approval of attitude is more likely to generate positive consumption intention (Sondergaard et al., 2005). If consumers are concerned about environmental protection, they are more open-minded and willing to make their own contribution to environmental protection through their own efforts, such as purchasing solar energy equipment, organic food and choosing to use green electricity (Welsch et al., 2009).

More and more attention has been paid to the consumption concept of "saving on resources, environmental protection and keeping health". The public gradually realize that the use of resources and pollution emissions can be reduced through eco-friendly consumption. However, with the improvement of consumers' environmental perceived effectiveness and eco-friendly attitude, the market share of eco-friendly products has not increased significantly (Bray et al., 2011). That indicates that the public's environmental perceived effectiveness does not necessarily turn into eco-friendly consumption behavior.

There is a gap between an individual's environmental perceived effectiveness and his eco-friendly consumption behavior (Vermeir et al., 2008; Tseng et al., 2013; Moser, 2015). To effectively promote the consumption of eco-friendly products, it is crucial to find out the reasons for this "gap" and improve the congruence between intention and behavior.

Some studies found that individuals showed a strong preference for eco-friendly products because of their perception of the benefits eco-friendly products brought to human health and environment. However, once entering the consumption process, individuals will weigh the convenience and functional attributes of products. The result is often that they prefer to the convenience attribute of products when making actual consumption decisions. And this leads to the gap between their consumption attitude and consumption behavior of eco-friendly products (Olson, 2013; Chen et al., 2014). Moreover, Antil (1984) did not support that perceived effectiveness had an important impact on the consumption behavior of eco-friendly products. As such, this paper argues that the relationship between individual perceived effectiveness and consumption behavior of eco-friendly products may be moderated by some factors, such as innovative application of technology (Lassar et al., 2005; Chang et al., 2007).

In addition, the innovative application of information and communication technology (ICT) may produces technical efficiency in the production and promotion of eco-friendly products. Take promotion of eco-friendly products as an example. People can recommend, forward and deliver information about eco-friendly products or services to relatives and friends on various network platforms. Such interaction based on networking can exert an important influence on an individual's behaviors (Zhang et al., 2018, 2019, 2020), such as engendering an individual's consumption behavior of eco-friendly products (Huang, 2012).It is found that some individuals are more willing to accept product innovation than others (Midgley et al., 1978; Feng et al., 2019), that is, the innovative application of ICT to eco-friendly products. Adjei and Clark (2010) believed that an individual's eco-friendly consumption behavior basically depends on such innovation.

ICT innovation has greatly influenced people's lives and has become an important context for current theoretical research (Zhao et al., 2017). Drawing upon the attitude behavior context (ABC) theory (Guagnano et al., 1995), this paper attempts to delineate the role and influence of ICT innovation on an individual's consumption behavior of eco-friendly products. We empirically tests the moderating effect of ICT innovation on the relationship between individual perception of eco-friendly products and the consumption behavior of eco-friendly products. In doing so, this paper attempts to make contributions to

bridge the gap between individual consumption attitude and consumption behavior of eco-friendly products. It generates new insights to the theoretical research on consumption of eco-friendly products. Furthermore, it provides theoretical support and empirical guidance for companies to produce eco-friendly products and contributes to promote the consumption of eco-friendly products in the whole society.

2. Literature review and theoretical analysis

2.1. Factors influencing eco-friendly consumption behavior

The eco-friendly consumption behavior is the consumption behavior that consumers strive to protect the ecological environment and minimize the negative impact of consumption on the environment during the purchase, use and post-treatment of products (Lao, 2013). Specifically, it includes the purchase of energy-saving products, the purchase of organic products, and the purchase of biodegradable or pollution-free products, etc. (Wu, 2014). In the long run, the consumption behavior of eco-friendly products is beneficial to the environment and society. However, its high cost actually brings difficulties to the conduct of such consumption behavior (Grinstein et al., 2009). As such, some researchers focused on exploring the promotion of eco-friendly consumption behavior (Li et al., 2019; Sheng et al., 2018).

The consumption behavior of eco-products is a very complex process, which is influenced by many factors such as internal factors and external contextual factors. Based on the planned behavior theory, motivation ability opportunity theory and cognitive behavior theory, scholars put forward that the influencing factors of individual eco-friendly consumption behavior mainly included three aspects: first, there are the demographic characteristics of samples and the source of samples and so forth; Secondly, there are internal factors, such as perceived effectiveness, environmental awareness and environmental responsibility (Chen et al., 2011; Matthes et al., 2014; Joshi et al., 2016; Sheng et al., 2019); finally, there are external contextual factors, such as technology, information strategy and marketing strategy (Chen, 2010; Olsen et al., 2014; Sheng et al., 2019).

As for the demographic characteristics, some scholars have found that the individuals who cared more about eco-friendly products were women, young and middle-aged people, people with higher education, higher income, higher professional class and higher economic and social status (Pickett et al., 1995; Tilikidou, 2001; Wang et al., 2011). This view has been supported by Pagiaslis et al., (2014) and Brahim (2019). Although demography has a certain impact on consumer behavior, most studies have

shown that the explanatory power of demographic characteristics is far less than that of psychological awareness (Cornwell, 1991; Singh et al, 2009; Xu, 2013). In recent years, the focus of academic research has shifted to the exploration of individual psychological factors.

Perceived effectiveness is the psychological expectation an individual has upon the effect of taking eco-friendly consumption behavior. Eco-friendly products meet the functional needs of consumers. In addition, it can reduce the damage to ecological environment and the waste of natural resources. Studies have shown that perceived effectiveness is the most significant factor among the psychological factors (Roberts, 1996; Straughan et al., 1999). Based on multiple linear regression analysis, some scholars have confirmed that perceived effectiveness is a determinant of consumer behavior of eco-friendly products (Kim et al., 2012). When individuals believe that their consumption behaviors are conducive to improving the environmental conditions and they can really feel the actual effect, they will be more likely to take eco-friendly consumption behavior. Therefore, the perceived effectiveness of eco-friendly products has a positive impact on the consumption behavior of eco-friendly products (Balderjahn, 1988).

Some studies have shown that when the personal perceived effectiveness is relatively strong, they will have a positive attitude towards eco-friendly products (Mostafa, 2007). And the attitude has a great impact on the consumption beliefs of eco-friendly products (Hartman, 2007), which will promote the corresponding consumer behavior (Wim et al., 2007; Prakash et al., 2017). In other words, individual perceived effectiveness has a significant impact on consumption attitude and consumption behavior of eco-friendly products (Berger et al., 1992). The level of perceived effectiveness has an impact on the degree of individual's adoption of eco-friendly consumer behavior (Hines, 1987). And the consumption attitude of eco-friendly products has a positive impact on their consumption behavior of eco-friendly products (Maloney et al., 2014; Liu et al., 2017). Therefore, this paper argues that the consumer attitude of eco-friendly products may play a mediating role in the relationship between perceived effectiveness and consumption behavior of eco-friendly products.

The driving force of individual consumption of eco-friendly products may be the novelty of eco-friendly products, that is, sometimes individuals are more willing to accept and use new products (Rogers, 1971). The reason may be that new products can satisfy their desire for innovation and change. Some scholars tried to understand this behavior from the perspective of external context, that is, obtaining information about the products through various communication channels (such as advertising, word-of-mouth, interpersonal communication, etc.) and then purchase and use these products (Im et al.,

2007). When a new technology or new product appears in the market, its characteristics such as environmental protection, energy conservation and emission reduction will attract many consumers. If the new technology or new product is evaluated well after use, it will be accepted by more people. On the contrary, if there is not enough innovation, it will be difficult for individuals to accept them (Rogers, 2002; Xue, 2017). In addition, the influence of perceived effectiveness of eco-friendly products on the consumption behavior of individuals is sometimes not obvious (Prakash et al., 2017; Kumar et al., 2018). As such, it is argued that the effect of perceived effectiveness on the consumption behavior of eco-friendly products will vary with the application of ICT innovation. Therefore, this paper attempts to introduce the application of ICT innovation as a moderator to study its moderating role in the relationship between perceived effectiveness and consumption behavior of eco-friendly products.

2.2. Consumption behavior of eco-friendly products

With the increasing popularity of consumer environmentalism in the world, more and more enterprises are willing to develop eco-friendly products (Chen, 2011) and more and more consumers are paying attention to eco-friendly products (Chen et al., 2012). However, in the actual consumption process, although the vast majority of consumers express great concern about environmental issues and support the consumption of eco-friendly products, the market share of eco-friendly products is not high (Tseng et al., 2013; Pang et al., 2017).

According to a new survey conducted by integer group, since the beginning of this century, the willingness of American consumers to pay premium for eco-friendly products has increased significantly. 43% of consumers express their willingness and 11% are strongly willing to pay for eco-friendly products. The data of the "2018 Green Sustainable Consumption Promotion Week" jointly sponsored by WWF shows that from 2015 to 2017 consumers of China's first and second tier cities saw a significant surge in their recognition of eco-friendly product logos, which rose from 58% to 83% (Xinhua news agency, August 16, 2018). To improve the utilization of eco-friendly products, all countries are making great efforts. Since 2020, the city of Geneva will prohibit the sales of disposable plastic products in all social gatherings, sports competitions and other events, as well as in retail stores in public places; more than 600 supermarkets and convenience stores in Vietnam will stop selling plastic straws from May 2020; at present, the United States, South Korea and Taiwan have introduced a ban on the use of nylon bags.

It seems that with the increase of consumer awareness of eco-friendly products, the consumption of

eco-friendly products has gradually become a fundamental way of life. However, due to the influence of some factors, the perceptual disturbance may reduce consumers' purchase intention and therefore prevent them from taking the consumption behavior of eco-friendly products. Also, some evidence shows that there is a significant gap between consumers' consumption intention of eco-friendly products and the actual behavior of eco-friendly products (Gupta et al., 2009).

2.3. The applications of ICT innovation in eco-friendly products

Enormous attention has been paid to the application of ICT innovation in environmental protection (Pothitou et al., 2017; Gong et al., 2020). In particular, the improvement of production efficiency and energy efficiency as well as the reduction of environmental pollution have been key focuses of previous research (David et al., 2018; Goldbach et al., 2018, Reda et al., 2019). However, the role of ICT innovations regarding eco-friendliness is debated (Salahuddin et al., 2015). On the one hand, ICT innovation can reduce global carbon dioxide emissions by building smart cities, energy Internet and intelligent transportation systems (Jiang et al., 2018; Monzon et al., 2017), whereas this is not suitable for all countries, especially the low-income countries (Danish et al., 2019). On the other hand, the widespread application of ICT innovation may lead to a significant increase in electricity consumption, which in turn consumes more energy and has a negative impact on environment (Salahuddin et al., 2015, 2016).

ICT innovation has been widely used in various fields. These applications are closely related to human lives and have an important impact on human behaviors, such as the influence on shopping mode, mobile payment, medical mode, scientific research and so forth (Gong et al., 2020). Moreover, the consumption trend and consumers' consumption behaviors are not only embodied in the daily consumption process, but also exist in the large information network (such as Internet, Internet of things, communication network etc). ICT innovation has great potential in shaping and changing consumers' behaviors. In particular, with the emergence of mobile Internet, Internet of things, cloud computing, they have largely changed the public's consumption mode. For instance, consumers may use search engine to query information, browse comments and review valence, book eco-friendly products on the website, and ask for help on social network before purchasing eco-friendly products.

More precisely, first, the applications of ICT innovation can help to form industrial chains in the communication industry which conserve energy and reduce emission. For example, on the one hand, the

emergence of low-energy consumption CPU, high-efficiency computer, intelligent motor, smart grid and intelligent buildings can contribute to achieve the goal of energy conservation and emission reduction through product design, production, use and maintenance. On the other hand, these applications help to build an energy-saving communication network center and form an energy-saving and emission reduction industrial chain in the communication industry. "Smart 2020" pinpointed that the most important role of ICT innovative application was to achieve energy efficiency in the real sectors. The report estimated that by 2020, the whole economy in the world could significantly reduce the carbon dioxide emissions thanks to the application of ICT innovation.

Second, as an important part of applications of ICT innovation, the Internet provides opportunities for enterprises to produce, transport and sell the eco-friendly products. The integration of Internet and logistics, the use of Internet of things, the Internet technology to build smart logistics enables the consumers to trace the origin of agricultural products. For example, consumers in Germany are willing to buy chocolate products with ecological labels at a higher price because they can trace the origin of the products and ensure that the production of these products does not bring damage to the ecological environment (Filho et al., 2017). This is further confirmed by the fact that a large number of Chinese consumers chase to buy the products with eco-labelling.

Finally, the ABC theory proposed by Guagnano et al. (1995) put forward that personal attitude (a) and external situational factors (c), such as laws, regulations and information publicity, jointly determines the occurrence of individual behavior (b). For example, the rapid development of social media tools can widely spread the policies and knowledge related to eco-friendly products and therefore exert imperceptible influence consumers' consumption behavior of eco-friendly products (Asongu et al., 2018). This is reflected in the actual official survey data. For instance, the tweets about global warming on the social networks turn people's behaviors more positive (Huang, 2012). In addition, the Internet is conducive to guide consumers to increase their perception of environmental risk and therefore promote their consumption behavior of eco-friendly products (Zhang et al., 2020). To sum up, the applications of ICT innovation can promote the production as well as the consumption of eco-friendly products by influencing the supply of eco-friendly products, promoting the development of the complete value chain of eco-friendly products, and carrying out extensive publicity on policies to affect an individual's consumption perception of eco-friendly products. The following parts of this paper attempt to use survey data of China to explore the relationship between the applications of ICT innovation and the

consumption behavior of eco-friendly products. In so doing, it provides theoretical support for subsequent research.

2.4. Development of conceptual framework

The conceptual model, presented in Figure 1, consists of four constructs: perceived effectiveness, attitude towards eco-friendly products, applications of ICT innovation, consumption behavior of eco-friendly products. Their relationships are as follows:

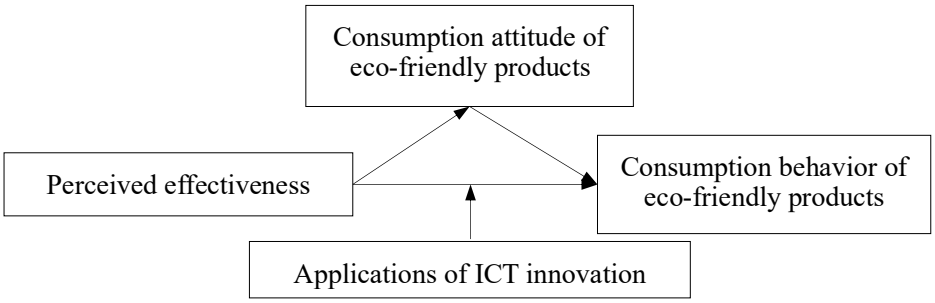

Fig. 1. Conceptual framework

2.4.1. Perceived effectiveness and consumption attitude of eco-friendly products

The perceived effectiveness of consumption of eco-friendly products comes from social psychology. It represents an individual's belief that his individual actions can make a difference in the consumption of eco-friendly products. Specifically, there are two ways of the influence of perceived effectiveness on attitude towards eco-friendly product. Firstly, perceived effectiveness can directly affect the attitude towards eco-friendly product (Kang et al., 2013;Chung et al.,2015;De et al.,2016). Secondly, perceived effectiveness may act upon environmental awareness to indirectly affect the attitude of eco-friendly products (Giulia et al., 2014). In summary, when consumers have a strong perceived effectiveness, they believe that through their purchase and use of eco-friendly products, they can not only obtain the material utility of these products, but also achieve the satisfaction from environmental protection and resource conservation (Stokes et al., 2015). This contributes to form a positive attitude towards eco-friendly products. Based on this, we propose the following hypothesis:

H1: Perceived effectiveness has a positive impact on consumption attitude towards eco-friendly products.

2.4.2. Consumption attitude towards eco-friendly products and consumption behavior of eco-friendly products

According to the planned behavior theory, people's attitude to environmental protection is the direct determinant of their environmental protection behavior (Ajzen, 1991). Individual's behavior of environmental protection is the specific embodiment of environmental protection attitude. In the studies of consumption behavior, prior literature has already verified that there was a significant positive relationship between the attitude of eco-friendly products and the purchase behavior of these products (Chan, 2001; Ariffin et al., 2016). It is acknowledged that there is a significant relationship between environmental attitudes and individual environmental behaviors (Han, 2014; Yadav et al., 2016). Some studies have shown that an individual's consumption attitude towards eco-friendly products can predict his or her consumption behavior of these products (Lee, 2008). In a word, most scholars support that there exists a positive relationship between consumption attitude of eco-friendly products and the consumption behavior of eco-friendly products. Thereafter, based on it, we propose the following hypothesis:

H2: Consumption attitude towards eco-friendly products has a positive effect on consumption behavior of eco-friendly products.

2.4.3. The mediating effect of consumption attitude of eco-friendly products

Perceived effectiveness is an important variable affecting environmental behavior (Gupta et al., 2009). When an individual believes that through his behavior he can effectively affect the environment and obtain satisfaction from it, he is more inclined to take positive environmental protection actions, and vice versa (Chan, 2001; Vining et al., 2002). In previous studies, scholars affirmed the important influence of perceived effectiveness on environmental behavior and they took it as the most significant variable in the influence on consumption behavior of eco-friendly products (Roberts, 1996), such as the use of ecological packaged products (Webster, 1975; Khare, 2014; Koenig et al., 2014). The perceived "benefit" or utility of an individual determines his or her consumption of eco-friendly products. For instance, the cost, loss, rewards and other nonmonetary factors in the process of individual consumption can promote the recycling behavior (Best et al., 2011). In a word, an individual's perception of "pleasure" and "ease of operation" in the process of consumption of eco-friendly products as well as the expected perceived effectiveness of environment protection will directly affect their consumption behavior of eco-friendly products (Khaola et al., 2014).

Attitude is an individual's positive or negative evaluation of specific behavior (Ajzen, 1991). Some

scholars have verified the causal relationship of personal value orientation and consumption behavior of eco-friendly products. Furthermore, they affirmed the mediating effect of perceived effectiveness and attitude (Thogersen et al., 2002). When people's perception of eco-friendly products is more effective, they will be more aware of the importance of eco-friendly products to human health and the living environment. Thereafter, they will be more eager to take corresponding measures. In addition, a large number of empirical studies have shown that attitude orientation has an impact on behaviors. For instance, the recycling attitude is influenced by factors such as perceived effectiveness and at the same time it also significantly predicted the recycling behaviors (Chu et al., 2003). Moreover, according to the theory of planned behavior (TPB), attitude is the determinant of behavior and an effective way to predict behavior. Therefore, individuals' positive attitude towards consumption of eco-friendly products may generate positive consumption behavior of eco-friendly products (Chan, 2001; Newton et al., 2015; Ritter et al., 2015; Wei et al., 2017). Based on this, we propose the following hypotheses:

H3a: Perceived effectiveness has a positive effect on consumption behavior of eco-friendly products.

H3b: Consumption attitude of eco-friendly products plays a mediating role between perceived effectiveness and consumption behavior of eco-friendly behaviors.

2.4.4. The moderating effect of applications of ICT innovation

Although most scholars' support that perceived effectiveness can promote an individual's consumption of eco-friendly products (Ajzen, 1985; Hiratsuka et al., 2018), some other scholars have found that the relationship between the consumption behavior of eco-friendly products and such variables as the perceived value of the environment is not significant. For instance, regardless that sometimes consumers have strong environment protection awareness, they may not take actions. As such, some scholars speculated that there might be some factors moderating the relationship (Olson, 2013). Specifically, high perceived effectiveness does not necessarily lead to positive consumption behavior of eco-friendly products. Contrarily, lower perceived effectiveness may sometimes lead to positive consumption behavior of eco-friendly products. This further indicates that the relationship between perceived effectiveness and consumption behavior of eco-friendly products may be affected by some other factors. In this study, we focus on the applications of ICT innovation and analyze its moderating effect on the relationship between individual's perception and behavior.

The applications of ICT innovation in environment is not referring to the application of a single technology or a single product. It is a systematic application which covers the layers of infrastructure, technology and application. And it is widely used in service industry, agricultural industry, construction industry, transportation industry and other sectors. It promotes energy conservation and emission reduction to realize the sustainable development of the consumption of eco-friendly products. For example, the use of unified inspection technology and certification for eco-friendly products will ensure the public the quality of the eco-friendly products on the market. It enables consumers to believe that products with the "eco-friendly products logo" may have corresponding efficacy and thus promote the actual purchase behavior of consumers (Lao 2013; Englis et al., 2013). In addition, there are differences in the ways of information transmission, which affect the relationship of the individual perception and behavior (Yoon et al., 2006). For example, the traditional communication media has a relatively small number of audiences and therefore a small impact on individual perception-behavior. As a result, this leads to a weak relationship between perceived effectiveness and consumers' behaviors; differently, wechat, network, mobile phone and other emerging media have a wide coverage. They are timely and interactive, which are favored by consumers. They deepen individuals' impression and thus strengthen the relationship between perceived effectiveness and behavior of consumers (Adjei et al., 2010; Chen et al., 2010; Wang et al., 2017). Based on this, we propose the following hypothesis:

H4: The applications of ICT innovation play a moderating role on the relationship of the perceived effectiveness and consumption behavior of eco-friendly products.

3. Questionnaire and data collection

3.1. Measurement

The measurement items used in this paper are from previously tested measures. Considering the particularity of the Chinese situation, all English scales were translated into Chinese based on strict standardized back translation procedure. We also modified the relevant sentences and wording in the scales until the final edition was considered satisfactory. The scale of perceived effectiveness mainly referred to Kim and Choi (2005) and Venkatesh's (2003) study. It has 6 items. The scale of consumption attitude of eco-friendly product mainly referred to Maloney's (1975) study. It has 5 items. The scale of consumption behavior of eco-friendly product mainly referred to Linden (2003) and Han's (2016) study. By combining the Chinese context, it has 4 items. Based on Liu's (2007) study, we conceptualize the

applications of ICT innovation from three perspectives: information resources, basic infrastructure of information and application of information technology. Specifically, information resources refer to the convenience for consumers to obtain information of eco-friendly products; basic infrastructure of information refers to the traceability verification of eco-friendly products; application of information technology refers to various application software technologies incorporated in the field of environment and related technologies applied in the process of promoting the consumption of eco-friendly products. By combining the studies of Peppard (2004), Ravichandran (2005), Pavlou (2006), Wan (2014) and Carmen (2015), we made some modifications and finally the scale has 11 items. For each item in the questionnaire, responses were collected on a 5-point Likert scale, where 1 show 'strongly disagree' and 5 indicates 'strongly agree'. A sample questionnaire is shown in Appendix-A.

3.2. Sampling and data collection

Table1 shows the profile of respondents. The respondents of this questionnaire are consumers in Chinese major cities of Nanchang, Hefei, Shanghai, Beijing and Shenzhen etc. The questionnaires are all sent to consumers in the form of online snowballing. The questionnaires are collected from January to March 2020. Altogether, we have received 689 questionnaires back where there were 591 questionnaires which have not had serious problems. The effective questionnaires rate is 85.78%. Table1 shows the profile of respondents.

Table 1

Demographic profile of respondents (N=591)

Characteristics of respondents	Classification	Sample Amounts	Percentage (%)
Gender	Male	296	50.1%
	Female	295	49.9%
Age(years)	<16	12	2.0%
	16-25	370	62.6%
	26-35	77	13.0%
	36-45	87	14.7%
	46-55	28	4.7%
	>56	17	2.9%
Education	Senior high school or below	64	10.8%
	Junior college	58	9.8%
	Bachelor's degree	343	58.0%
	Master's degree or PhD	126	21.3%
Occupation	Employee in state units and	88	14.9%

institutions		
Enterprise employee	89	15.1%
Self-employed person	10	1.7%
Freelance	23	3.9%
Student	349	59.1%
other	32	5.4%

4. Test of theoretical model

4.1. Reliability analysis

First of all, we confirm the reliability of each variable by using the Cronbach's α. From the results, we can find that the Cronbach's α value of each variable was all bigger than 0.8, which satisfied the criterion suggested by Hair et al. (2010). This indicates all variables have good reliability. Then, we used Mplus 8.3 to conduct confirmatory factor analysis (CFA). The standardized item factor loadings are all bigger than 0.5 and are significant at the P<0.001 level. The results are reported in table 2. The fitness indexes of a four-factor model and other competitive model are reported in table 3. The results show that the four-factor model has a good fit while the fitness indexes of other competitive models are not as good as that of the four-factor model. It indicates that these variables have good discriminant validity. In general, this confirms that the questionnaires used in this study have good discriminant validity.

This study adopted the controlling for effects of an unmeasured latent method to test the common method bias. The results show that after inputting the common method factor into the four-factor model, the fitness indexes of the model have not been improved a lot. Specifically, CFI increases 0.02, TLI increases 0.007, which indicates that the common method bias is not serious in this study.

Table 2

Reliability analysis.

Construct	Code	Loading	Cronbach alpha
The perceived effectiveness (Fee)	Fee1	.546	.853
	Fee2	.796	
	Fee3	.814	
	Fee4	.804	
	Fee5	.719	
	Fee6	.654	
The consumption attitude of eco-friendly products (Att)	Att1	.626	.888
	Att2	.881	
	Att3	.884	
	Att4	.767	

	Att5	.794	
The consumption behavior of eco-friendly products (Beh)	Beh1	.700	.842
	Beh2	.803	
	Beh3	.779	
	Beh4	.750	
The application of ICT innovation (ICT)	ICT1	.765	.948
	ICT2	.763	
	ICT3	.779	
	ICT4	.836	
	ICT5	.823	
	ICT6	.798	
	ICT7	.827	
	ICT8	.833	
	ICT9	.777	
	ICT10	.733	
	ICT11	.780	

Note: the factor loadings are all standardized.

Table 3

Results of the confirmatory factor analysis.

Measurement model	χ^2	*df*	χ^2/df	$\Delta\chi^2$	Δdf	CFI	TLI	RMSER	SRMR
Single factor model: Fee+Att+Beh+ICT	3089.97	299	10.33			.75	.729	.126	.077
Two-factor model: Fee+Att, Beh+ICT	2109.44	298	7.08	980.53	1	.838	.823	.101	.064
Three-factor mode:l Fee+Att, Beh, ICT	1655.79	296	5.59	453.61	2	.878	.866	.088	.058
Four-factor model: Fee, Att, Beh, ICT	1388.21	293	4.74	267.58	3	.902	.891	.08	.057
Four factor+method factor	1143.89	273	4.19	244.33	20	.922	.907	.073	.053

4.2. Description, statistics and correlation coefficient of variables

To control the influence of demographic characteristic variables on the consumption behavior of eco-friendly products, this paper selects gender, age, education and occupation as control variables (Tilikidou, 2001; Wang et al., 2011; Pagiaslis et al., 2014; Brahim, 2019). The mean value, standard deviation and correlation coefficient of each variable are shown in Table 4. It can be seen from table 4 that gender is significantly correlated to the consumption behavior of eco-friendly products; age is significantly correlated to perceived effectiveness and consumption behavior of eco-friendly products; education background is significantly correlated to consumption behavior of eco-friendly products; occupation is significantly correlated to perceived effectiveness. There is a significant positive

correlation between perceived effectiveness and consumption attitude (r = 0.737, P < 0.01) and a significant positive correlation between perceived effectiveness and consumption behavior (r = 0.452, P < 0.01). In addition, the consumption attitude of eco-friendly products is positively correlated with the consumption behavior of eco-friendly products (r = 0.55, P < 0.01).

Table 4

The correlation coefficient matrix

	Mean	Standard deviation	Gender	Age	Education	Occupation	Fee	Att	Beh	ICT
Gender	1.5	0.5	1							
Age	29.76	12.09	0.034	1						
Education	2.90	0.858	0.051	-0.048	1					
Occupation	3.93	1.663	0.013	-0.613**	-0.124*	1				
Fee	4.352	0.493	-0.05	-0.091*	-0.035	0.099*	1			
Att	4.39	0.476	-0.036	0.009	-0.014	-0.006	0.737**	1		
Beh	3.97	0.645	-0.099*	0.054	-0.102*	-0.056	0.452**	0.55**	1	
ICT	4.25	0.506	-0.054	-0.1*	-0.052	0.068	0.675**	0.71**	0.615**	1

Note: * <0.05, ** <0.01, ***<0.001(two tails).

4.3. Test of H1 and H2

To test H1-H4, we made a multivariant regression analysis, of which the perceived effectiveness is the independent variable, the applications of ICT innovation is the moderator, the consumption attitude of eco-friendly products and the consumption behavior of eco-friendly products are respectively the dependent variables. To avoid some alternative explanations to our model, this paper includes four control variables: gender, age, education background and occupation. As model 6 in table 5 shows, the perceived effectiveness and consumption attitude of eco-friendly products are positively correlated, which support hypothesis 1. The results of model 3 in table 5 shows that the consumption attitude of eco-friendly products and consumption behavior of eco-friendly product is significantly positively correlated and hypothesis 2 is supported.

Table 5

Results of multivariant hierarchical regression.

Variable	Consumption behavior of eco-friendly products(Beh)				Consumption attitude of eco-friendly products(Att)	
Step one: control variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Gender	-0.120*	-0.092	-0.095*	-0.092*	-0.034	0
Age	0.010	0.024	0.008	0.011	0.003	0.020
Education background	-0.078*	-0.069*	-0.073**	-0.071**	-0.007	0.004
Occupation	-0.022	-0.034	-0.022	-0.025	-0.001	-0.015
Step two: perceived effectiveness(Fee)		0.598***		0.147*		0.722***
Step three: consumption attitude of eco-friendly products(Att)			0.738***	0.626***		
R^2	0.024	0.230	0.321	0.326	0.002	0.551
F	3.581**	34.973***	55.192***	47.097***	0.229	143.770***

Note: (1) the regression coefficients are not standardized; (2) *<0.05, **<0.01, ***<0.001(two tails).

4.4. Test of the mediating effect

To test the mediating role of consumption attitude of eco-friendly product, based on Kenny et al. (1998)'s method, this paper test whether the mediating effect satisfies the following 4 conditions: (1) the independent variable and the dependent variable is significantly correlated; (2) the independent variable and the mediating variable is significantly correlated; (3) the mediating variable and the dependent variable is significantly correlated; (4) the direct effect, that is, if the independent variable has no significant effect on dependent variable, there is complete mediating effect. Otherwise, it indicates that there is partial mediating effect. As model 2 in table 5 shows, the perceived effectiveness (the independent variable) and the consumption behavior of eco-friendly product (the dependent variable) is significant correlated (B=0.598, p<0.001). So H3a is supported.

The second step is to test whether the independent variable and the mediating variable has significant relationship. Since H1 is supported, it means the perceived effectiveness (the independent variable) and the consumption attitude of eco-friendly product (the mediating variable) is significantly positively correlated (B=0.781, p<0.001). To test step 3 and 4, we use a hierarchical regression method. Specifically, the variables we input into the model are as follows: (1) control variables; (2) perceived effectiveness; (3) consumption attitude of eco-friendly products. The results of model 4 in table 4 shows

that the consumption attitude of eco-friendly products (the mediating variable) and the consumption behavior of eco-friendly products (the dependent variable) is significantly correlated (B=0.147， p<0.05). The results indicate that the consumption attitude of eco-friendly product partly mediates the relationship between perceived effectiveness and the consumption behavior of eco-friendly products. Therefore, H3b is supported. To further test the significance of the mediating effect, this paper applies the SPSS (Process 3.4)(model 4,n=5000)developed by Hayes (2018) and we find that the mediating effect of the consumption attitude of eco-friendly products is 0.4517, the confidence interval is (0.3522， 0.5529). It does not include 0. The result shows that the mediating effect is significant (see table 6).

Table 6

The results of the mediating effect analysis.

Path	Effects	Estimates	SE	Boot LLCI	Boot ULCI
Fee-Att-Beh	Indirect effects	.4517	.0516	.3504	.5538
	Direct effects	.1466	.0668	.0155	.2777
	Total effects	.5982	.0481	.5044	.6921

4.5. Test of the moderating effect

Again, this paper adopts the hierarchical regression method to test H4, that is, the applications of ICT innovation plays a moderating role on the positive relationship of the perceived effectiveness and the consumption behavior of eco-friendly product. To reduce the correlation between the interaction term and the main effect, we centered the independent variable and the moderator. In the hierarchical regression, we use the consumption behavior of eco-friendly products as the dependent variable and input the following variables in the model: (1) control variables; (2) the two main effects (perceived effectiveness and applications of ICT innovation); (3) the product term of perceived effectiveness and the applications of ICT innovation. As the model 3 in table 7 shows, the product term of the perceived effectiveness and the application of ICT innovation reach the significant level (B=0.220， p<0.05), which indicates the moderating effect of the applications of ICT innovation is tested. Therefore, H4 is supported.

Table 7

The results of the moderating effect analysis.

Model 5	Coefficient	SE	P-Values	LLCI	ULCI
Constant	4.6339	1.6002	0.0039	1.4910	7.7768
Fee	-0.9933	0.3646	0.0066	-1.7094	-0.2773
Att	0.3206	0.0701	0	0.1829	0.4584
ICT	-0.4097	0.3913	0.2955	-1.1782	0.3588
Fee*ICT	0.2263	0.86	0.0087	0.0573	0.3952

4.6. Test of the overall effect of the conceptual model

Based on the 74 theoretical models of Bootstrap test procedure developed by Hayes (2018), the model of this paper corresponds with model 5. This paper applies the SPSS macro (PROCESS 3.4) (Model 5, n =5000) developed by Hayes (2018) to conduct the conditional process analysis. The results please see table 8 and table 9. Table 8 shows the interaction item of perceived effectiveness and applications of ICT is significant (B=0.2263，p=0.0087). The 95% confidence interval of Bootstrap test is (0.0573, 03952), which did not include 0. It indicates that the applications of ICT innovation play a moderating role on the positive relationship of the perceived effectiveness and the consumption behavior of eco-friendly products. Therefore, H4 is further supported. Table 9 shows that for moderate and high level of applications of ICT, the confidence interval of Bootstrap test is respectively (-0.1591, 0.0951)and(-0.0778, 0.2425)，which both include 0. It indicates the indirect effect of the consumption attitude of eco-friendly product is not significant, that is, the mediating effect of the consumption attitude of the eco-friendly product does not exist. For the low level of applications of ICT innovation, the confidence interval of Bootstrap test is (-0.2922, -0.0007), which did not include 0. It indicates the indirect effect of the consumption attitude of the eco-friendly product is significant. And this shows the mediating effect of the consumption attitude of eco-friendly product do exist. To sum up, when the application of ICT innovation is low, the mediating effect of the consumption attitude of eco-friendly product on the relationship of the perceived effectiveness and the consumption behavior of eco-friendly product do exist.

Table 8

The influence of perceived effectiveness on the consumption behavior of eco-friendly products under different application levels of ICT innovation.

ICT	Beh			
	Effect	SE	LLCI	ULCI
Low(3.7426)	-0.1464	0.0742	-0.2922	-0.0007
Moderate(4.2481)	-0.0320	0.0647	-0.1591	0.0951
High(4.7536)	0.0840	0.0816	-0.0778	0.2425

5. Quantitative analysis of regulatory effect by ICT Innovation

5.1. Profile of HMM

Based on the above analysis, we find that the application of ICT innovation plays a moderating role on the positive relationship of the perceived effectiveness and the consumption behavior of eco-friendly products. Meanwhile, the consumption attitude of eco-friendly products plays a mediating role between the perceived effectiveness and the consumption behavior of eco-friendly products. If we want to use this model to help the government to formulate the environmental policies, to guide the manufacturing enterprises to produce eco-friendly products, and to direct the information technology enterprises to conduct R&D in ICT field, a further empirical and quantitative analysis of the model are needed. Such uses of further methods and analysis are common in hypothetical-inductive methods (Siponen et al., 2020). Hence, this paper attempts to address the following issues based on a mathematical model and experimental data:

(1) What are the possibilities of a consumer with certain perceived effectiveness to consume the eco-friendly products under certain level of application of ICT innovation?

(2) What are the possibilities of a consumer with certain perceived effectiveness to continuously consume the eco-friendly products under different scenarios of application of ICT innovation? For example, with a high-level ICT application context, what is the probability that a consumer with mid-level perceived effectiveness will continue to consume eco-friendly products provided by the enterprise?

(3) How much dependence does the application of ICT innovation provided by the information technology enterprises brings to the consumers?

(4) How does enterprises assess whether a consumer change his or her former consumption habit in the consumption of eco-friendly products? And how to quantify consumers' consumption inertia?

To answer question (1), we need to establish a state probability model of perceived effectiveness, application of ICT innovation and consumption behavior of eco-friendly products. We plan to use

probability to answer the "possibility" question. Because the state probability arises under certain condition, this paper adopts the directed graph based Bayesian network model, which well satisfies the calculation requirement of conditional probability. To answer question (2), we need to add a time series to the Bayesian network model. In other words, we need to extend the static Bayesian network model to the dynamic Bayesian network based on time series.

On the basis of question (2), the dependence of question (3) and the inertia of question (4) are all about the probability of time series. What they need to calculate is the state transition probability. Therefore, based on the dynamic Bayesian network with time series, we introduce a state transition probability model. The Markov model is widely used to study the random state transition problem in time series. The state transition probability matrix can well answer the dependence and inertia question.

In general, it may be difficult for companies to observe consumers' consumption choice of eco-friendly products. Therefore, in the design of the probability model, we add a function to calculate the probability of the unknown state. That is, we adopt a Hidden Markov Model (HMM) based on Bayesian network to conduct empirical study. HMM is a statistical modelling method for instable time series (Zhang et al., 2013; Vamsikrishna et al., 2016). Some researchers used Markov process and HMM particularly to model human beings' behaviors (Moe et al., 2008; Malik et al., 2009; ElSalamouny et al., 2009). Because HMM has the following advantages such as providing a probability framework for inference and forecasting, incorporating the uncertainty, needing few training samples, having strong explanation, and reflecting the randomness of the subjects, with no aftereffect and so forth, it is widely used in behavior modelling.

As a mathematical model, by assuming an unknown state sequence, a HMM can produce a known observation sequence to infer an observation state sequence mode (Jacob et al., 2015). The foundation of HMM in a stochastic Markov process consists of a number of states and the transitions between them (Morteza et al., 2016). This paper attempts to construct a probability calculation model. By collecting the data of the consumers, it constructs a HMM based on the known observation sequence (perceived effectiveness, application of ICT innovation) to infer the unknown state sequence (the consumption behavior of eco-friendly products). This paper calculates the probability of consumers' consumption behavior of eco-friendly product in different combinations of observation states and forecasts different consumers' consumption choice of eco-friendly products in different applications of ICT innovation. Moreover, this paper tests the moderating effect of application of ICT innovation on the relationship of

the perceived effectiveness and the consumption behavior of eco-friendly products. As such, the HMM not only tests the above results which makes the conclusions more reliable, but forecasts the practice by considering the real context based on the calculation of the probabilities of the dynamic relationship between the behaviors and states. Owing to the focus of this paper being the influence of application of ICT innovation, the mediating effect of the consumption attitude of eco-friendly products will not be further discussed.

5.2. Definition of HMM

A hidden Markov model (Rabiner, 1989; Fox et al., 2006) is an automatic program with a hidden state consisting of unobservable variables and incorporating a hidden state Markov process. A HMM has the following parameters:

N: quantity of HMM states. HMM has a hidden state chain, of which each state is correlated with an observation probability density function. In the model built in this paper, N denotes the quantity of the states of the consumption behavior of eco-friendly product. Therefore, we have:

$$BEH = \{S_1, S_2, \cdots, S_{\mathrm{N}}\}$$

At time t the state of Markov chain is q_t, then:

$$q_t \in BEH$$

M: quantity of HMM observation states. In the model built in this paper, M denotes the quantity of the combination of the state of perceived effectiveness and the state of application of ICT innovation. Therefore, we have:

$$GRP = \{V_1, V_2, \cdots, V_{\mathrm{M}}\}$$

The observation value at time t is O_t, then:

$$O_t \in GRP$$

A: state transition probability matrix. A denotes the transition probability of the model in different states, then:

$$A = [a_{ij}]_{N \times N}$$

Where:

$$a_{ij} = P(q_{t+1} = S_j \mid q_t = S_i), 1 \le i, j \le N$$

It denotes the probability of the state S_j at next time $t+1$, supposing at any time the state is S_i.

B: observation probability matrix (state mapping matrix). According to the current state (the consumption behavior state i of eco-friendly product), this model can calculate the probability of the observation value (the combination j consisting of perceived effectiveness and application of ICT innovation). And we have:

$$B = [b_{ij}]_{N \times M}$$

Where:

$$b_{ij} = P(O_t = V_j \mid q_t = S_i), 1 \le i \le N, 1 \le j \le M$$

It denotes the probability to observe O_j, supposing the state is S_i, at any time.

π : the initial state probability: the probability of each state at the initial time:

$$\pi = (\pi_1, \pi_2, \ldots, \pi_N)$$

Where:

$$\pi_i = P(q_1 = S_i), 1 \le i \le N$$

It denotes the probability of the initial state S_i.

HMM of the consumption behavior of eco-friendly products is shown as figure 2. In the figure, q_t denotes the hidden state of consumption behavior at the time t; O_t denotes the state combination of perceived effectiveness and application of ICT innovation at time t; A denotes the state transition matrix; B denotes the observation probability matrix.

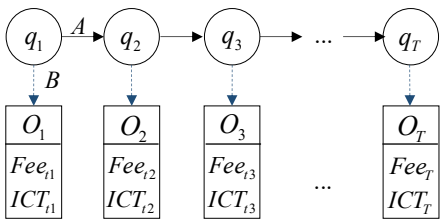

Fig. 2. Diagram of HMM process

5.3. Algorithm

First of all, we categorize perceived effectiveness, application of ICT innovation, and consumption behavior of eco-friendly products and can get the parameters of N and M of the HMM. Next, we use the classification algorithm of mean and variance to classify the three types of data and we get the observation sequence O from the consumption records.

HMM is defined as $\lambda= (A, B, \pi)$. We have three standard algorithms. They are Baum-Welch algorithm, Viterbi algorithm and forward-backward algorithm.

5.3.1. Forward-Backward algorithm

We use the forward backward algorithm (FBA) to solve the following problems: in a given view sequence column $O= (O_1, O_2, ..., O_T)$ (t is the length of observation sequence) and the model $\lambda=(a, B, \pi)$. Based on the solution of literature (Rabiner et al., 1986), the forward part (i.e. α process) and then the backward part (β process) of the algorithm are given. The forward variable $\alpha_t(i)$ is defined as follows: in the case of a given model λ, the probability of O to time $t(1\leq t\leq T)$ and the probability of state q_i of time t. Therefore, $\alpha_t(i)=P(O_1, O_2, ..., O_T, S_t=q_i|\lambda)$, where $i=1, 2, ..., n$(i.e. In the model, N is the number of hidden states), $t=1, 2, ..., T$, S_t is the state of time t. The solution $\alpha_t(i)$(for $i=1, 2, ..., N$) is initially $\alpha_1(i)=\pi_i b_i(O_1)$, which is defined recursively as follows (for $t=2, 3, ..., T$):

$$\alpha_t(i) = \left[\sum_{j=1}^{N} \alpha_{t-1}(j) a_{ji}\right] b_i(O_t) \tag{1}$$

Where $\alpha_{t-1}(j)a_{ji}$ is the probability of the joint event that $O_1, O_2,...,O_{t-1}$ are observed (given by $\alpha_{t-1}(j)$) and there is a transition from state q_j at time $t-1$ to state q_i at time t (given by a_{ji}); $b_i(O_t)$ is the probability that O_t is observed from state q_i. Similarly, we can define the backward variable $\beta_t(i)$ as the probability of the observation sequence from time $t+1$ to the end, given state q_i at time t and the model λ. Then, $\beta_t(i)=P(O_{t+1}, O_{t+2}, ..., O_t|S_t=q_i, \lambda)$. The solution for $\beta_t(i)(i=1, 2, ..., N)$ is initially given by $\beta_T(i)=1$ and defined recursively (for $t=T-1, T-2, ..., 1$) as follows (Chis, 2015):

$$\beta_t(i) = \sum_{j=1}^{N} a_{ij} b_j(O_{t+1}) \beta_{t+1}(j) \tag{2}$$

Where the observation O_{t+1} is generated from any state q_j. With the α and β values computed, the BWA iterative equations can be defined.

5.3.2. Baum-Welch algorithm

Given the model $\lambda=(A, B, \pi)$, the Baum-Welch algorithm (BWA) trains the HMM on a fixed set of observations $O=(O_1, O_2, ..., O_T)$. By adjusting its parameters A, B, π, the BWA maximizes $P(O|\lambda)$. The parameters of the BWA are updated iteratively (for $i, j=1, 2, ..., N$, and $t=1, 2, ..., T-1$) as follows:

$$\xi_t(i,j) = \frac{\alpha_t(i) a_{ij} b_j(O_{t+1}) \beta_{t+1}(j)}{P(O \mid \lambda)} \tag{3}$$

$$\gamma_t(i) = \sum_{j=1}^{N} \xi_t(i,j) \tag{4}$$

Where $\xi_t(i, j)$ is the probability of a path reaching state q_i at time t and transitioning to state q_j at time $t+1$. Summing over a set of observations, we can obtain values for the expected number of transitions from or to any arbitrary state. Thus, it is straightforward to update our HMM parameters (Chis, 2015):

$$a'_{ij} = \frac{\sum_{t=1}^{T-1} \xi_t(i,j)}{\sum_{t=1}^{T-1} \gamma_t(i)} \tag{5}$$

$$b'_j(k) = \frac{\sum_{t=1, O_t=k}^{T} \gamma_t(j)}{\sum_{t=1}^{T} \gamma_t(j)} \tag{6}$$

$$\pi'_i = \gamma_1(i) \tag{7}$$

We can now re-estimate our model parameters iteratively using $\lambda' = (A', B', \pi')$, where $A'=\{a'_{ij}\}$, $B'=\{b'_j(k)\}$ and $\pi'=\{\pi'_i\}$, as defined in equation (5), (6), (7).

5.3.3. Viterbi algorithm

Viterbi algorithm is used to seek the state sequence, which is a forecasting algorithm of HMM. For a HMM λ, input a group of *1...T* time observation combination state vector *O*:

$$O = \{O_1, O_2, \cdots, O_T\}, O_i \in GRP.$$

By Viterbi algorithm, we can get the probability matrix δ, of consumption behavior of eco-friendly products and the vector Ψ of the biggest probability behavior. The definition of Viterbi algorithm is as follows:

$$\delta_t(i) = \max_{q_1 q_2 \ldots q_{t-1}} P(q_1 q_2 \ldots q_{t-1}, q_t = S_i, O_1 \ldots O_t \mid \lambda)$$

We initiate at time *t=1*:

$$\delta_1(i) = \pi_i b_i(O_1) \tag{8}$$

$$\psi_1(i) = 0 \tag{9}$$

Then, at each time *t=2, ..., T*, we calculate the optimum partial path probability of the classified behavior *j(1<=j<=N)*. We use the recursive method to calculate.

$$\delta_t(j) = \max_i \delta_{t-1}(i) a_{ij} b_j(O_t) \tag{10}$$

At each time *t(1<=t<=T)*, we use function *argmax* to direct to coding of the biggest probability behavior.

$$\psi_t(j) = \arg\max_i \delta_{t-1}(i) a_{ij} \tag{11}$$

5.3.4. Flowchart

We adopt the following process to test and forecast the consumption behavior of eco-friendly product:

(1) Based on the investigation results of questionnaires, we adopt the algorithm of mean and

standard error to classify perceived effectiveness, application of ICT innovation, the consumption behavior of eco-friendly products and get the N and M parameters of HMM.

(2) Based on the consumption records of those consumers investigated, combined with questionnaires, referring to the parameters of N and M, we can estimate the state transition matrix A, the observation probability matrix B and initial vector π of each consumer.

(3) We use the data of the consumption records as the training set. Then we use Baum-Welch algorithm to reassess the state transition matrix A, and the observation probability matrix B.

(4) We use new parameter to build a HMM for each consumer. We calculate the optimum output probability of each state using the Viterbi algorithm. As such, we calculate the state sequence of each consumer's consumption behavior with the biggest probability in certain observation condition. The calculation process is shown in figure 3.

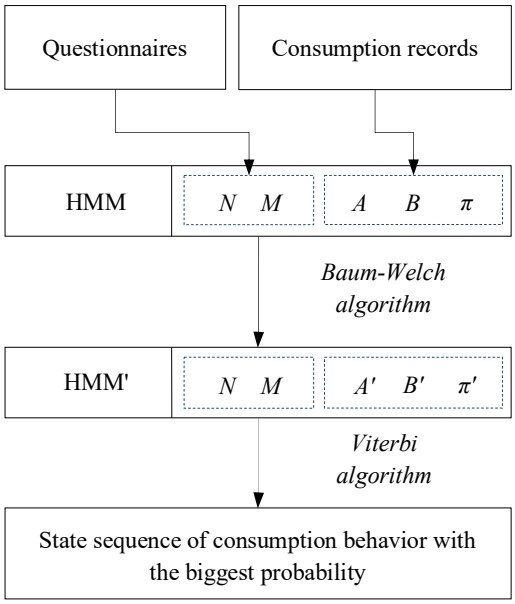

Fig. 3. Diagram of the calculation process

5.4. Analysis and results

5.4.1. Data collection

We randomly sent solicitation applications of consumption records to 368 consumers. As the consumption records involved personal privacy, we only collected the consumption records of 35 of them during the period from February to May 2020, including 5548 consumption records, 5271 of which were complete and effective records which can be used as to calculate. The demographic distribution of the respondents is as follows:

There were 21 males and 14 females, with an average age of 38.6 years. The age of 16 and under accounted for 0%, the age of 16-25 accounted for 8.6%, the age of 26-35 accounted for 22.9%, the age of 36-45 accounted for 51.4%, the age of 46-55 accounted for 11.4%, and the age of 56 and over accounted for 5.7%. In the survey, high school and below accounted for 14.3%, college accounted for 22.9%, undergraduate accounted for 37.1%, master and above accounted for 25.8%.

In the collection process, Alipay and WeChat payment system can query past consumption records, and there are fewer records missing. And for the consumption records, the indexes of the application of ICT innovation and consumption behavior of eco-friendly product can be recorded more completely. In these records, the training set using Baum-Welch algorithm accounts for 80% of the total data, and the remaining 20% is used to verify the model.

For the investigated consumption records, the environmental cognition and consumption attitude of eco-friendly products tend to be stable in a period of time. And a single consumer cannot cover all the set of observation states, so we need to integrate the survey results of 35 consumers' consumption records to cover all ICT innovation application states. Then we map the consumption behaviors of eco-friendly products caused by various application states of ICT innovation to verify the impact of applications of ICT innovation on consumption behaviors. Moreover, that the consumer refuses to consume the products without the eco-friendly characteristics is not reflected in the consumption records. All of these have a certain impact on the validity of the results.

5.4.2. Computation and analysis

First, we use the algorithm of mean and standard deviation to classify the perceived effectiveness, the application of ICT innovation and the consumption behavior of eco-friendly products according to the level from low to high. Then we can get 6 perceived effectiveness, 3 application states of ICT innovation and 5 consumption behaviors of eco-friendly products. The classifications of the indicators and their descriptions are seen in table 9.

Table 9

The state indicators and descriptions of perceived effectiveness, application of ICT innovation and the consumption behavior of eco-friendly products.

State type	State indicator	Indicator description
Perceived effectiveness(Fee)	Fee0	Knowing nothing about the influence of products on the environment
	Fee1	Whether the appearance design of the product will cause pollution to the environment
	Fee2	Whether the product packaging has low-carbon, environmental protection and other marks
	Fee3	Understand whether the main components of the product will cause pollution to the environment
	Fee4	Whether the production and circulation of products will cause environmental pollution
	Fee5	Whether the use and recovery of products will pollute the environment
Application of ICT innovation (ICT)	ICT0	Low level of application of ICT innovation
	ICT1	Moderate level of application of ICT innovation
	ICT2	High level of application of ICT innovation
Consumption behavior of eco-friendly products (Beh)	Beh0	Do not basically identify whether the product is harmful to the environment during consumption
	Beh1	When consuming, it is identified whether the product is eco-friendly, but whether the product meets the consumers' own needs and whether the product price is appropriate is more considered
	Beh2	Be willing to pay higher price to the eco-friendly consumption
	Beh3	When consuming, take eco-friendly consumption as possible
	Beh4	The products harmful to the ecological environment are refused to be consumed

We use the algorithm of section 5.3 to calculate the probabilities of consumption behavior of eco-friendly products caused by the different combinations of perceived effectiveness, application of ICT innovation. And we get the state mapping matrix. Table 10 shows the results of probability calculation. Each data of table 10 denotes a probability of a consumption behavior of eco-friendly products caused by the perceived effectiveness moderated by a certain application of ICT innovation. In the table, we find that with the same level of perceived effectiveness, it is significant that relatively low consumption behavior of eco-friendly products is moderated by relatively low application of ICT innovation. It is also

significant that relatively high consumption behavior of eco-friendly products is moderated by relatively high application of ICT innovation. The results are consistent with the results of SEM.

Table10

The calculation results of probability of consumption state of eco-friendly products caused by application of ICT innovation.

	Beh0	Beh1	Beh2	Beh3	Beh4
Fee0(ICT0)	.081	.069	.017	.015	.019
Fee1(ICT0)	.080	.078	.031	.027	.025
Fee2(ICT0)	.080	.087	.044	.041	.031
Fee3(ICT0)	.076	.089	.058	.056	.037
Fee4(ICT0)	.071	.091	.072	.070	.042
Fee5(ICT0)	.062	.087	.085	.085	.048
Fee0(ICT1)	.069	.054	.022	.019	.030
Fee1(ICT1)	.065	.056	.035	.034	.039
Fee2(ICT1)	.060	.058	.049	.048	.048
Fee3(ICT1)	.056	.060	.062	.063	.057
Fee4(ICT1)	.047	.058	.076	.077	.069
Fee5(ICT1)	.038	.051	.089	.092	.078
Fee0(ICT2)	.058	.039	.026	.025	.041
Fee1(ICT2)	.049	.034	.039	.040	.056
Fee2(ICT2)	.040	.023	.053	.055	.072
Fee3(ICT2)	.032	.025	.067	.070	.087
Fee4(ICT2)	.023	.020	.081	.085	.103
Fee5(ICT2)	.014	.015	.094	.099	.118

Figure 4 is a three-dimensional probability histogram, in which green represents high-level ICT applications, yellow represents medium-level ICT applications, and red represents low-level ICT applications. Detailed and dynamic 3D drawings can be accessed (http://threegraphs.com/charts/preview/9510/embed/).

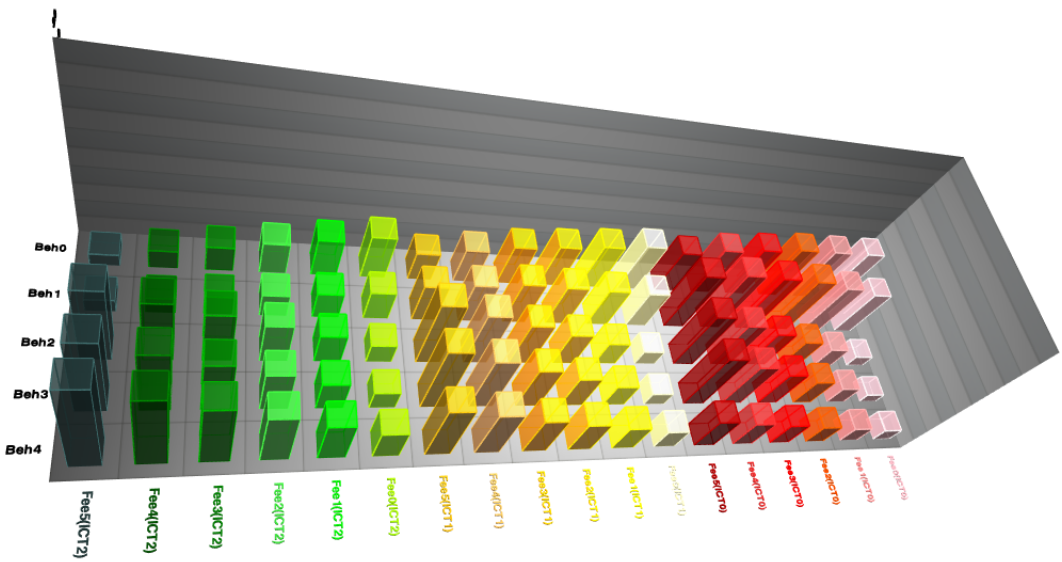

Fig. 4. Three dimensional statistical chart of probability calculation results caused by ICT status for consumption status of eco-friendly products

To further explore the high level of consumption behavior of eco-friendly products, we calculate the probability caused by perceived effectiveness moderated by the application of ICT innovation and find the data having the following characteristics: with the increase of perceived effectiveness, the high level of application of ICT innovation can produce more significant change of probabilities of high level of consumption behavior of eco-friendly products. As figure 5 shows, the vertical axis is the probability value which produces the Beh4 behavior, the horizontal axis is the classification of perceived effectiveness.

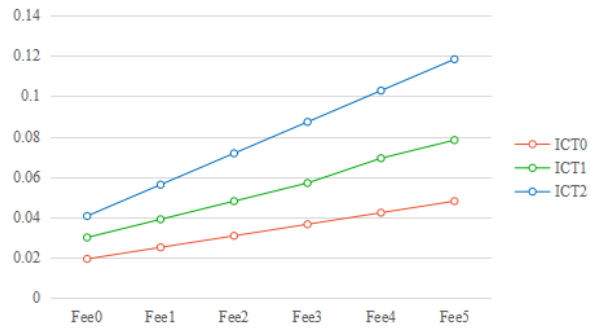

Fig. 5. The probability of the consumption behavior of eco-friendly products moderated by application of ICT innovation with different perceived effectiveness

We also calculate the transition matrix of consumption of eco-friendly products. Table 11 is the results of the calculation of the state transition matrix. When consumers choose consumption behaviors at each time, they tend to choose the consumption behavior similar to that of the previous time. Each data of Table 11 shows the probability from q_t to q_{t+1} of the consumption behavior of eco-friendly products.

Table 11

The state transition probability matrix of consumption behavior of eco-friendly products.

q_t	q_{t+1}				
	Beh0	Beh1	Beh2	Beh3	Beh4
Beh0	.565	.163	.070	.024	.178
Beh1	.086	.389	.166	.154	.206
Beh2	.103	.151	.398	.209	.139
Beh3	.099	.159	.207	.388	.146
Beh4	.099	.154	.127	.113	.508

The results of table 10 and table 11 provide reference for the eco-friendly manufacturers to make market analysis and short or long-term strategic planning. Moreover, it can provide guidance for the R&D enterprises of ICT innovation application to develop the products and services of dependence. Furthermore, this paper also assesses the accurateness of the results of HMM. By using the correct quantity of HMM identifying the biggest probability path to divide the quantity of the sample, we can get the accurate rate of identification. Please see figure 6.

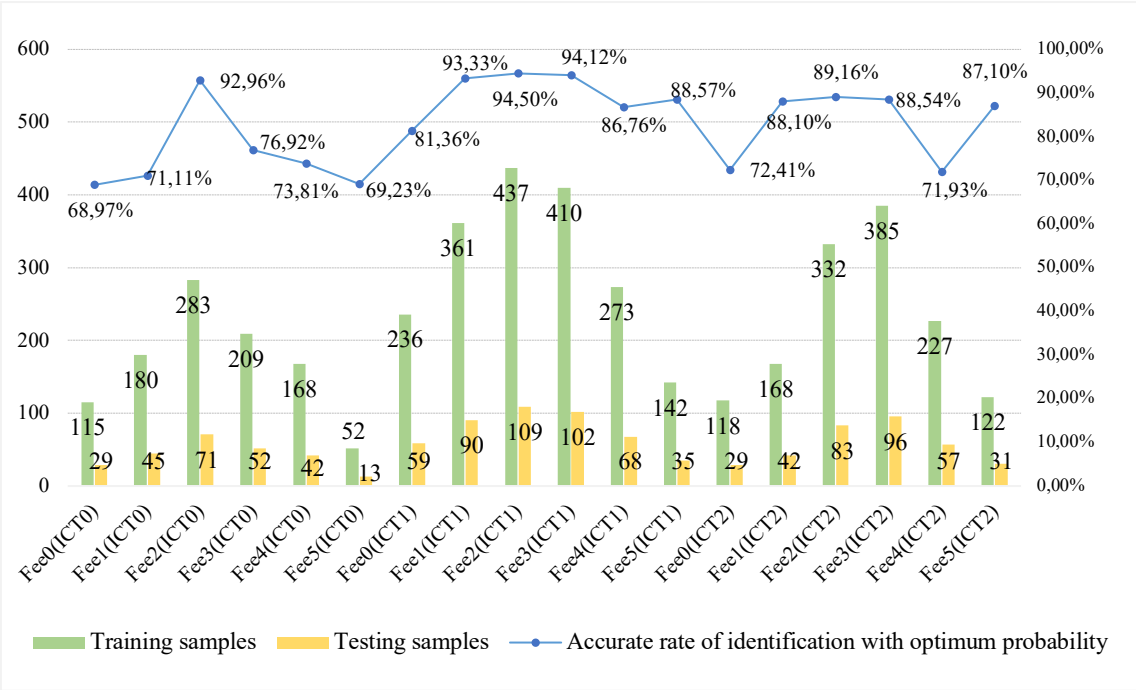

Fig.6. Statistical chart of verification results of HMM on consumer behavior of eco-friendly products

Figure 6 shows that there are certain errors by using the HMM algorithm to estimate the application of ICT innovation which has relatively small influence on the consumption behavior of eco-friendly products. But in large data sample, it can remain relatively high level. The forecasting data and method

can provide reference for the government to formulate the environmental policies.

6. Discussion of findings

6.1. Implication for theory

This paper constructs a conceptual model, which contains the relationship of the perceived effectiveness, the consumption attitude of eco-friendly products, the applications of ICT innovation, and the consumption behavior of eco-friendly products. Based on the sample data collected by questionnaires, this paper empirically tests this model. The research results contribute to the theoretical studies and managerial practice of consumption of eco-friendly products.

First of all, this paper enriches the relevant research on the consumption behavior theory of eco-friendly products. This paper confirms the relationship between the perceived effectiveness and the consumption behavior of eco-friendly products. That is, the perceived effectiveness has positive effect on the consumption behavior of eco-friendly products. More specific than previous studies, this study finds that the satisfaction and the sense of pleasure from the consumption of eco-friendly products can promote an individual's consumption behavior of eco-friendly products. As such, it further reveals the facilitation function of the non-economic rewards and the intrinsic motivation in the consumption of eco-friendly products. Besides, it provides theoretical basis for their management.

Secondly, by revealing the relationship between efficacy support, emotional support and consumers' basic psychological needs, this paper shows that in China, consumers usually buy eco-friendly products with positive attitude rather than "efficacy" perception. This provides a direction for future research.

Finally, this paper discusses the situational factors which provide explanations for the gap between consumers' perceived effectiveness of eco-friendly products and their eco-friendly consumption behavior. Consumers' consumption intention of eco-friendly products is influenced by both individual internal factors and situational factors. So consistent with the attitude-situation behavioral theory, consumers' behavior is moderated by external situational factors (product function, consumption situation, etc.) (Stern, 2000), such as application of ICT innovation. This means that individual consumption behavior of eco-friendly products is inseparable from the social environment and product innovation. This provides theoretical guidance for enterprises to produce and sell innovative products. For example, the government should encourage enterprises to develop environmental technology, ensure the quality of

eco-friendly products and avoid potential safety hazards; in the selling process, it should provide necessary and sufficient product information, such as eco-friendly labels, product certification and user instructions. In so doing, the consumers can get access to the eco-friendly products with diverse varieties, reasonable prices and significantly improved functional attributes.

6.2. Implication for practice

This paper theoretically and empirically confirms the moderating role the applications of ICT innovation plays on the positive relationship of the perceived effectiveness and the consumption behavior of eco-friendly products. Additionally, it quantitatively analyzes the moderating effect of the applications of ICT innovation. The results are conducive to eco-friendly product manufacturers to make ICT strategic decisions in the process of R&D and design, and are also helpful for ICT enterprises to make basic judgement on the potential of the market, the customer dependence and the risk prediction. The results also provide reference for the government to carry out environmental and ecological protection policies.

This paper constructs a state probability model of perceived effectiveness, the applications of ICT innovation and the consumption behavior of eco-friendly products to answer such question that which level of applications of ICT innovation can promote the consumption behavior of eco-friendly products for consumers with which level of perceived effectiveness.

Based on the Bayesian network model, by adding the state study based on time series, the static Bayesian network model is extended to the dynamic Bayesian network model. This model can calculate how likely the eco-friendly products provided by an enterprise in different level of application of ICT innovation can be consumed continuously by the consumers with different levels of perceived effectiveness. Our findings leads us to emphasize the consumer dependence the applications of ICT innovation provided by the information technology enterprises can bring.

Furthermore, this paper introduces a state transition probability model of the dynamic Bayesian network based on time series and calculates the state transition probability to evaluate whether consumers change their original consumption habits, and to quantify the consumers' consumption inertia. The research conclusions are helpful for eco-friendly product manufacturers to make ICT strategic decisions in the process of R&D and design. We also provides a study model for the government to carry out environmental and ecological protection policies.

7. Conclusion

Recently, the ICT innovation has been deeply embedded into the process of R&D, production and sales of the eco-friendly products. Considering these, based on such context, this paper constructs a conceptual model, which explores the influencing mechanism of the perceived effectiveness on the consumption of eco-friendly products. It discusses how the consumption attitude of eco-friendly products mediates the relationship of the perceived effectiveness and the consumption behavior of eco-friendly products as well as how the applications of ICT innovation moderate such influence. Based on the data collected online, this paper empirically tests the theoretical model and the hypothesis. The results show that: (1) The perceived effectiveness is positively correlated with the consumption attitude and consumption behavior of eco-friendly products; (2)The consumption attitude of eco-friendly products plays a mediating role between the perceived effectiveness and the consumption behavior of eco-friendly products; (3)The applications of ICT innovation plays a moderating role on the positive relationship of the perceived effectiveness and the consumption behavior of eco-friendly products. The higher the level of applications of ICT innovation, the weaker the positive correlation between the perceived effectiveness and the consumption behavior of eco-friendly product. The results of this paper contribute to promote the consumption of eco-friendly products and provides references for the related theoretical studies and practical applications.

This paper has the following contributions:

(1) This paper calculates the state transition matrix of the consumption behavior of eco-friendly products, which provides the reference of consumer dependence for the eco-friendly product manufacturers and ICT enterprises.

(2) This paper calculates the state mapping matrix of the consumption behavior of eco-friendly products to the perceived effectiveness and the state mapping matrix of the consumption behavior of eco-friendly products to the applications of ICT innovation. As such, it provides mathematical and empirical evidence for the eco-friendly product manufacturers to make sound market judgment.

(3) This paper forecasts consumers' consumption choice of eco-friendly products in different contexts. The forecasting method and the data are useful for both enterprises and the government.

This study has some limitations, which should be pointed out and improved in the future research. First, in terms of the consumption behavior of eco-friendly products, there are various influencing factors,

such as environmental knowledge, attraction of environment, concerns about environment and attachment to local places etc. Despite of these various factors, in this paper we only focus on some of these factors and introduce a contextual factor which is the reflection of the current information technology times. Then this paper confirms the moderating effect of the contextual factor-the applications of ICT innovation in the conceptual model. In addition, by building a HMM, this paper studies the influence of the applications of ICT innovation on the consumption behavior of eco-friendly products. However, the insufficient consumption records data may have some impact on the results of this paper. Finally, this paper has not covered all the possible applications of ICT innovation and has not proposed a more advanced transductive HMM which takes the technology development into account. All these increase the limitations of the forecasting. Thereafter, in the future study more influencing factors should be incorporated to enhance the explanation of the model. Also, the moderating effect of the applications of ICT innovation should be further tested.

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