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The Role of Digital Knowledge Richness in Green Technology Adoption:

A Digital Option Theory Perspective

Yoo, Hosun* · Lee, Namyeon** · Kwon, Ohbyung***

〈Content〉

Ⅰ. Introduction

Eco-friendly products such as energy-saving computers, solar power devices, and electric automobiles are created using green technology that enables customers to save energy or live more efficiently in terms of their impact on the environment. Green technology helps firms and individuals reduce their energy and electricity consumption in the process of manufacturing (González, 2005), in information and communications technology facilities (Mitchell,

* Senior Researcher, Medical Device R&D Center at Seoul National University Bundang Hospital, Korea, r1395@snubh.org
** Assistant Professor, Department of Management at Sungkyul University, Korea, nylee@sungkyul.ac.kr
*** School of Management, Kyung Hee University, Seoul, Republic of Korea, obkwon@khu.ac.kr (corresponding author)

2008), and in production of hardware (Nunn, 2007). Wider use of green technology must be promoted in order for customers to keep pace with the future green economy.

However, only a few theoretical investigations have been conducted to explain consumer behavior regarding the adoption of green technology. In a study involving multiple regression analysis, Rice et al. (1996) and Sanitthangkul et al. (2012) examined the relationship of various demographic variables (gender, marital status, education background, income level, age, and occupation) to eco-product usage behaviors (e.g., energy saving, type of fuel) as independent variables. In some empirical studies, green technology adoption behavior was explained based on technology adoption theories in the information systems (IS) field (Ivan et al., 2010; Lee et al., 2013; Mishra et al., 2014). These studies examined various factors (usefulness, ease of use, personal beliefs, experience of green technology, social norm, and behavior of others) as independent variables in IS adoption theories. However, the influence of information technology (IT) on consumer behavior related to the adoption of green technology has not been adequately explained. In particular, why and how individual customers adopt green technology, with particular reference to the role of IT in green technology adoption, has not been empirically investigated.

Hence, this study rests its theoretical foundation on the Unified Theory of Acceptance and Use of Technology, version 2, or UTAUT2, one of the most up-to-date theories in technology adoption. The original UTAUT focused on adoption of enterprise information systems (Venkatesh et al., 2003). In 2012, Venkatesh et al. (2012) proposed this second version of the UTAUT, which is well suited to research on technology adoption at the individual level. In the UTAUT2, enterprise-level technology adoption is characterized by the mandatory acceptance of user autonomy and procuring of information systems based on user preference. On the other hand, adoption of personal IT is viewed from a different angle. Consequently, green technology adoption in everyday life on the individual level may be better explained by the UTAUT2 than the UTAUT or other enterprise-level technology adoption theories.

Extension of the UTAUT2 may make it even more useful in the context of green technology. In this paper, we see that the UTAUT2 was originally designed to investigate factors affecting IT adoption, not how IT influences adoption of different technologies. The UTAUT2 has been used to examine mechanisms of IT adoption such as mobile technology (Eckhardt et al., 2009), social media (Curtis et al., 2010), computers (Verhoeven, 2010), network technology (Lin and Anol, 2008), and websites (Verhoeven, 2010). Several studies utilizing the theory of reasoned action, motivational model, theory of planned behavior, model of personal computer use, diffusion of innovations theory,

social cognitive theory, and combinations of these have identified determinants of IT acceptance (Shin, 2009). However, none of these studies have included green technology. On its own, the UTAUT2 may be inadequate to demonstrate how IT influences adoption of different technologies. Hence, in this study, the UTAUT2 and the concept of digitized knowledge richness, which originated from digital option theory, are combined to examine customers' green technology adoption behavior.

Meanwhile, Chen and Chang (2013) presented that consumers have more willingness to pay products or services applied green technology because they perceived the products or service could positively affect the environment and themselves. Ottman (1992) mentioned this behavior as 'green consumerism'. It was defined as "individuals looking to protect themselves and their world through the power of their purchasing decisions. In their efforts to protect themselves and their world, they are scrutinizing products for environmental safety" (Ottman, 1992). Based on the concept of green consumerism, the goal of green technology is more focused on improving public benefit than private benefit. In the cases of above mentioned various information technology, they are used for enhancing personal efficiency, economic benefit, or playfulness. Therefore, it would be needed to find different factors which affect green technology adoption against general information technology.

Contrary to other studies in which the UTAUT2 is used to explain IT adoption behavior, we look at the relationship between IT and the UTAUT2 from a new angle, incorporating an important aspect of IT, that is, digitized knowledge richness, as a determinant of the UTAUT2. Digital option theory (Karimi et al., 2009) focuses on the role of IT in human decision-making processes. IT per se can increase the motivation to adopt newer technologies. According to digital option theory, the role of IT in the adoption process must be investigated because the intention of IT is to support human decision-making. In addition, IT can provide useful knowledge during a decision-making process in the form of problem identification, generation of alternatives, and evaluation (Bharadwaj et al., 2013; Kankanhalli et al., 2003; Lee and Hong, 2002). Knowledge is a core ingredient in the formation of consumer cognition. Hence, utilizing digital option theory, we consider the digitized knowledge provided by IT as an independent rather than a dependent variable.

Green technology adoption behavior is here investigated using an amended version of the UTAUT2 which includes digital option theory. First, the role of IT as a factor influencing user perceptions and adoption of green technology is examined. Because the UTAUT2 may not be perfectly suited to the study of green technology adoption, a slightly different approach is utilized in this study. Models in former studies stressed utility and/or hedonic motivation, but the

motivation to adopt green technology is external. Due to the mismatch of the UTAUT2 to this new context, a content analysis was performed using data collected during semi-structured individual interviews with 31 customers to identify new constructs not included in the UTAUT or UTAUT2. In this analysis, the UTAUT2 rather than the UTAUT was found to be better suited as a basis for the model proposed here because many products developed based on green technology have been developed for personal use, such as hybrid vehicles.

The next section of this paper elaborates the theoretical foundations of the study and derives the hypotheses to be tested. The research method is then described and followed by a report of the results. The final section discusses the findings and provides concluding comments.

Ⅱ. Theoretical Background

2.1 Green Technology

As increasing an importance of green technology, various researchers have been studied about green technology. ‘Green’ defined as the design, commercialization, use of processes and products that are feasible and economical while reducing the generation of pollution at the source, minimizing the risk to human health and the environment (Masud and Malika, 2012). In previous studies of green technology, its definition could be divided into two concepts: ‘green of technology’ and ‘green by technology’.

The former concept means a technology to reduce a cost of energy consumption and to increase an efficiency of design, operation, deploy. Contrarily, the latter is broader concept

<Table 1> Concepts of green technology

Researcher	Concepts
Gonzalez (2005)	Green technology improves the efficiency of the production process by reducing the consumption of materials and energy.
Australian Computer Society (2007)	Green technology is related to energy consumption and emission of CO2.
Nunn (2007)	Green technology is a way to manage IT resources and services efficiently.
Mines and Davis (2007)	Green technology is part of a fundamental change in the economy and society. It is a subset of the larger green (sustainable) business trend, which reconciles sustainable business practices with profitable business operations.
Murugesan (2008)	Green technology includes the dimensions of environmental sustainability, the economics of energy efficiency, and the total cost of ownership, which includes the cost of disposal and recycling.
Deloitte Touche Tohmatsu (2009)	Green technology should maximize computing capacities to minimize effects on environment.

than green of technology. The aims of this concept focused on solving environmental, social, economical problems. In other words, it is a technology that enhances sustainability of environment and society by using a green technology. The concepts of green technology are listed in Table 1.

In the perspectives of these concepts, the green technology could be distinguished by the aim of technology. While most of general IT have tried to enhance personal efficiency, objectives of green technology have focused on social and environmental efficiency and sustainability. However, previous studies of technology adoption have been applied factors used in technology adoption models of general information technology. Hence, we used independent factors are considered aims of technology in our research model.

2.2 The UTAUT2

The UTAUT2 is based on the UTAUT, which demonstrated the validity of the technology acceptance framework (Shin, 2009). The UTAUT has served as a baseline model and has been applied to the study of a variety of technologies in both organizational and individual settings. According to this model, behavioral intention is predicted by three antecedents: performance expectancy, effort expectancy, and social influence. Use is subsequently determined by facilitating factors, conditions in the environment, and behavioral intention. Venkatesh et al. (2003) also examined demographic and situational moderators influencing technology acceptance, including gender, age, experience, and voluntariness of use.

While the UTAUT explained employees' acceptance of technologies in the organizational context, the UTAUT2 expanded the theoretical scope of the model to the use of technology, such as green technology, by individual consumers in everyday life. In addition to the constructs related to utility (e.g., performance expectancy), which were strong predictors of behavioral intention in the UTAUT, motivation theory was included in the UTAUT2. Thus, hedonic motivation constructs were added in the UTAUT2. Unlike workers adopting workplace technologies, consumers must bear the costs associated with the purchase of devices and services (Venkatesh et al., 2003). Thus, a price value construct was also newly incorporated in the UTAUT2. Finally, the habit construct was added to the UTAUT2 in order to reflect the fact that intentionality is a key theoretical mechanism underlying the UTAUT and its related models, a mechanism that drives behavior (Venkatesh et al., 2003). With all these additions, the UTAUT2 is an improved research model explaining the adoption intention of technologies aimed at individual consumers. In research on adoption of green technology, it is more suitable than other models that focus on the technology adoption behavior of employees.

However, in the context of green technology adoption, not all factors in the original model of

the UTAUT2 are necessarily associated with adoption intention. For example, the study of Wu et al. (2007) on user behavior in the adoption of 3G mobile communication devices found no influence of effort expectancy on behavioral intention, whereas performance expectancy, social influences, and facilitating conditions were highly influential. A direct influence of external variables on user behavior was also revealed. Hence, factors contributing to explain green technology adoption must also be additionally identified. The variables included in the UTAUT2 must be empirically re-verified in this study of adoption of this new and different kind of technology: green technology.

2.3 Digital Option Theory: Digitized Knowledge

Karimi et al. (2009) defined digital options as "a set of digitally enabled processes" (p. 8). According to customer buying behavior theory, a customer's search for knowledge about a product and acquisition of that product using a web site or mobile application can be seen as a digitally enabled process, or a "digital option". IT can therefore be seen as a digital option generator (Sambamurthy et al., 2003). Digital options are important and dynamic technological capabilities that mediate between IT investment and performance. Digitized knowledge, which is generated by digital options, is the IT-enabled repository of knowledge that allows sharing of expertise and perspectives.

Digital option theory views digital options in terms of adoption intention. Implementing or purchasing an information system to enhance knowledge or to increase digitized knowledge richness at the individual or firm level is the fulfillment of adoption intention (Evans and Worster, 2000; Keen, 1991; Karimi et al., 2009). Digitized knowledge richness refers to IT-based systems of interaction among organizational members to support their sense-making, perspective-sharing, and development of tacit knowledge (Sambamurthy et al., 2003). From the point of view of customers, digitized knowledge richness can be seen as IT-based systems of interaction among or between end users. Such digitized knowledge can be presented in many forms.

For example, product-selling firms must support the generation and dissemination of tacit knowledge about their products or embedded technologies. Thus, customers can benefit from websites about green technologies such as hybrid vehicles. Comparison sites (e.g., http://www.hybridcars.com) provide lists of hybrid cars by type and list price, information on how hybrids work, descriptions of hybrid accessories, a comprehensive guide to plug-in hybrids, articles about hybrid vehicle research and technology, myths associated with hybrids, and driver evaluations. Some sites advocate hybrid cars, while others are neutral, displaying both criticisms and positive responses. The more

comprehensive the information provided on these sites regarding this green technology, the richer the knowledge about hybrid cars available to potential buyers.

Ⅲ. Research Model and Hypotheses

3.1 Preliminary Study

To determine the applicability of the UTAUT2 in the context of green technology adoption, a preliminary study was conducted. This study took a qualitative approach, so it was not possible to cover everything (Lin and Chen, 2012); emphasis was placed on depth rather than breadth (Ambert et al., 1995). To acquire in-depth information about a representative group of people, interviews were conducted with 31 customers in order to identify constructs for use in the model. Open-ended questions were chosen in line with the objectives of ascertaining the influence of IT on adoption of green technology and determining the suitability of former models to this new context. The open-ended format gave informants the freedom to answer from their own frame of reference (Bogdan and Bilken, 2012).

The preliminary study was intended to answer two research questions: (1) Are the IT adoption variables of the UTAUT2 still acceptable in the context of green technology? and (2) What new concepts should be added to the UTAUT2 to reflect the unique characteristics of green technology? In the semi-structured interviews conducted for content analysis purposes, 31 volunteer professors and graduate students in technology management ranging in age from 20 to 50 years old were selected in February and March 2012. They discussed their intention to purchase a hybrid car and responded to a semi-structured questionnaire. They were free to express their own thoughts in addition to answering the interview questions.

To determine users' perceptions from the interviews, a qualitative content analysis was conducted (Kohlvacher, 2006). Data from the 31 interviews with customers who had purchased eco-friendly products were carefully collected and transcribed. The transcripts were then analyzed by content analysis (Wezemael et al., 2010). Two coders were selected from among the research assistants at our institution who were majoring in technology management. They parsed the paragraphs into multiple phrases. The text was then divided into meaning units, which were labeled with codes. For example, from the sentence "I think the hybrid car is good for the planet because it lowers my carbon footprint and saves money", the phrases "lowers my carbon footprint" and "saves money" were extracted and labeled under the heading, "characteristics of hybrid cars". Codes were examined for differences and similarities and divided into categories (Graneheim and Lundman, 2004) according to the advice of Wiersma (1995), who

<Table 2> Constructs identified from the content analysis.

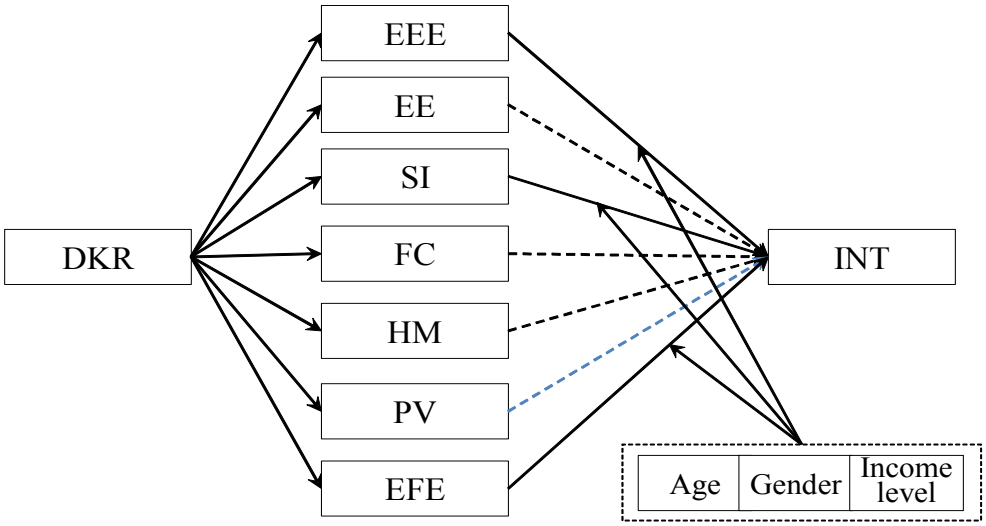
Constructs in the UTAUT2		Examples	Frequency (%)
Performance expectancy	Eco-efficiency expectancy	Energy efficiency, less energy consumption	37.9
	Eco-friendliness expectancy	Lower CO2 emissions, more eco-friendly, less exhaust, less pollution	39.3
Social influence		Environmental regulation, celebrity endorsement, eco-image, social responsibility	10.2
Price value		List price, price structure, tax exemption	6.3
Facilitating conditions		Infrastructure, warranty service	1.3
Hedonic motivation		Emotional, enjoyable, new	1.3
Effort expectancy		Comfort, ease of use	1.2
Misc.		Technical diversity	2.5

suggested that post hoc rather than a priori conclusions should be drawn from interview data.

In total, 279 phrases were extracted by the coders. The phrases were individually classified by the coders according to the constructs in the UTAUT2. Phrases which are not directly related to the UTAUTs constructs were classified as miscellaneous concepts. This was important to build survey items which are consistent to the content analysis results in terms of content validity, as well as construct validity. The coders then conferred to reach a consensus. After three rounds, they reached an agreement, the results of which are shown in Table 2. In special, tax exemption and subsidy, which are regarded as crucial for buying intention, were included in price value. Based on these results, we concluded that facilitating conditions, hedonic motivation, and effort expectancy could be dropped from the green version of the UTAUT2 technology adoption model.

3.2 Research Model

In this section, we describe the modified model and present the hypotheses that were used in this study to extend the UTAUT2 to the context of eco-friendly products. Consumer acceptance of eco-friendly products was evaluated using revised versions of the constructs of the UTAUT2 modified from that originally proposed by Venkatesh et al. (2003). The research model used in the current study, labeled the Eco-UTAUT2, included four constructs (eco-efficiency expectancy, eco-friendliness expectancy, social influence, and digitized knowledge richness) that determine behavioral intention directly or indirectly. Other than these, effort expectancy, facilitating conditions, hedonic motivation, and price value are represented to compare the Eco-UTAUT2 with the original UTAUT2. Three moderating variables were identified (gender, age, and income level) that have varying influences on the primary constructs. In applying



Notes: DKR: Digitized knowledge richness; EEE: Eco-efficiency expectancy; EE: Effort expectancy; SI: Social influence; FC: Facilitating condition; HM: Hedonic motivation; PV: Price value; EFE: Eco-friendliness expectancy; INT: Intention to purchase eco-products.
Solid line: Significant path
Dotted line: Insignificant path

<Figure 1> Research framework: the Eco-UTAUT2

this amended model to the context of eco-friendly products, we posited the Eco-UTAUT2 variables as key drivers of eco-friendly product adoption. Additional key drivers were defined and explained, and their relationship to transaction intention and acceptance of eco-friendly products was examined. Placed within the nomological structure of the UTAUT2, in which their interrelationships were precisely described, the variables were integrated into a coherent and parsimonious research model for use in the context of green technology (Figure 1).

The proposed research model has two variations from the UTAUT2. First, digitized knowledge richness is newly proposed as an antecedent of the variables in the UTAUT2. Secondly, the concept of causality is altered. These two changes are discussed below.

A positive association between digitized knowledge richness and the seven antecedents listed in Table 3 (EEE: eco-efficiency expectancy, EE: effort expectancy, SI: social influence, FC: facilitating conditions, HM: hedonic motivation, PV: price value, EFE: eco-friendliness expectancy, INT: intention to purchase eco-products) was posited in the Eco-UTAUT2 model of intention to adopt green technology. Based on the content analysis conducted in the preliminary study, performance expectancy was reconceptualized as eco-efficiency expectancy

and eco-friendliness expectancy (see Table 3). Knowledge that explains why and to what extent a product developed by green technology (i.e., a green product) outperforms non-green products with respect to eco-efficiency and eco-friendliness must be created by experts in offline professional meetings and conferences and then made accessible to customers. In general, sufficient knowledge about new technology is difficult to acquire from offline sources such as books, meetings, and lectures; such knowledge is seldom accessible to novice users through these channels. To resolve this problem, they use online space such as websites and social media, which are more useful for them and provide more efficient communication channels in which experts and novice customers can interact. The degree to which potential customers expect a green product to be ecologically efficient and environmentally friendly may therefore be related to digitized knowledge richness. Hence, we hypothesize that:

H1-1: Digitized knowledge richness is positively associated with eco-efficiency expectancy.

H1-2: Digitized knowledge richness is positively associated with eco-friendliness expectancy.

In the knowledge-rich environment of today's networked and web-focused society, consumers can easily find necessary information about green technologies, improve their understanding about these technologies, and access products. This accessibility of information may influence the amount of effort required to learn about green products. Hence, we hypothesize that:

H1-3: Digitized knowledge richness is positively associated with effort expectancy.

Social influence is rooted in the theories of reasoned action and planned behavior, which stress subjective norms as antecedents of technology adoption. Social influence constructs (i.e., subjective norms, social factors, and image) play a relatively insignificant role in predicting behavioral intention in voluntary use environments such as e-commerce websites and mobile applications (Hartwick and Barki, 1994; Venkatesh et al., 2003). However, in the context of green product consumption, voluntary use of environmentally friendly technologies may be influenced by social constructs, which may then moderate the effects of ease of use and usefulness on behavioral intention (Brown et al., 2002; Wu and Lederer, 2009).

Information from people and agencies with social influence is accessible via networks in cyberspace. For example, detailed knowledge as to how hybrid vehicles benefit the planet may be brought to future customers by public or school websites. In accordance with the "go green" policy of many U.S. school districts, information about the positive side of green technology is delivered to students and their parents. Informing future customers through school websites and e-mail is an important social learning strategy.

Departments of electricity and gas intentionally use cyberspace to teach energy-saving strategies and how to use clean technology. These efforts to increase digitized knowledge may enhance the social influence of individuals and agencies on customers' decision-making. Hence, we hypothesize that:

H1-4: Digitized knowledge richness is positively associated with social influence.

Facilitating conditions involve the infrastructure and availability of services and information associated with a new product or technology (Venkatesh et al., 2012). For example, changes in infrastructure are necessary to facilitate use of electronic cars because they require frequent charging. Ubiquitous charging equipment makes customers feel more comfortable and safe, and increases their intention to buy electronic vehicles. Online websites and mobile applications may aid them in locating charging sites. Therefore, we hypothesize that:

H1-5: Digitized knowledge richness is positively associated with facilitating conditions.

In an empirical study, Wati et al. (2011) showed that knowledge influences hedonic goals. Hedonic motivation is related to perceived pleasurability, which refers to the innate tendency to participate in an activity for the satisfaction of doing so because of the qualities inherent in the activity itself (Ryan and Deci, 2000). If green product consumption is voluntary rather than obligatory, a hedonic goal framework may be involved in the choice to use green products. Hence, we hypothesize that:

H1-6: Digitized knowledge richness is positively associated with hedonic motivation.

Detailed information about tax exemptions or government subsidies may influence decision-making about purchasing green products. Such information may increase the price value of a green technology product. Therefore, we hypothesize that:

H1-7: Digitized knowledge richness is positively associated with price value.

Based on the results of the content analysis (please see Table 2), we posit that eco-efficiency expectancy, eco-friendliness expectancy, and social influence will be positively associated with green technology-embedded eco-friendly products. Hence, three hypotheses (H2-1 ~ H2-3) were formulated as follows:

H2-1: Eco-efficiency expectancy is positively associated with intention to adopt green technology.

H2-2: Eco-friendliness expectancy is positively associated with intention to adopt green technology.

H2-3: Social influence is positively associated with intention to adopt green technology.

As for the other four causalities inherent in the

UTAUT2 (effort expectancy, facilitating conditions, hedonic motivation, and price value), it is assumed that these constructs are not significantly associated with green technology adoption based on the content analysis results (please see Table 2). To determine the validity of the results of the content analysis, these causalities were also included in the empirical study. Thus, the next four hypotheses (H3-1 ~ H3-4) are reflected in the empirical test.

H3-1: Effort expectancy will have no significant influence on intention to adopt green technology.

H3-2: Facilitating conditions will have no significant influence on intention to adopt green technology.

H3-3: Hedonic motivation will have no significant influence on intention to adopt green technology.

H3-4: Price value will have no significant influence on intention to adopt green technology.

Finally, as in the UTAUT2, control variables – age, gender, and income level – were also considered in the model.

Ⅳ. Methods

4.1 Measures

Using the definitions of the constructs outlined above, the survey items used to measure the research model variables in this study were primarily derived from qualitative studies. These items and their sources are listed in Table 3. Most of the scales were adapted for the present purposes. The scales for the constructs utilized in this study (i.e., effort expectancy, social influence, facilitating conditions, hedonic motivation, and price value) were adapted from the UTAUT2 (Venkatesh et al., 2003). The concept of digitized knowledge richness (DKR) was extracted from digital options offered online. Eco-efficiency expectancy (EEE) and eco-friendliness expectancy (EFE) were created in lieu of performance expectancy in the UTAUT2 as a result of the content analysis, as described earlier. A seven-point Likert-scale ranging from "strongly disagree" (1) to "strongly agree" (7) was used to measure responses.

4.2 Participants and Experimental Procedures

Data for this study were obtained through a survey of people. These participants had knowledge about hybrid cars, which is a representative eco-friendly product. Based on comprehensive reviews of the literature, a structured questionnaire was developed and a pilot test performed with 52 participants to ensure clarity of content, scope, and content validity. Respondents were required to have a willingness to have their own car. All respondents were asked to consider the hybrid car as an eco-friendly

<Table 3> Survey items

Model	Construct	Operational definition	Reference
UTAUT2	INT	Intention to purchase green technology	Amended from Venkatesh et al. (2012)
	EEE	The belief that the green technology improves eco-efficiency (amended from performance expectancy)	Amended from Venkatesh et al. (2012)
	EFE	The belief that green technology benefits the planet in an eco-friendly manner (amended from performance expectancy)	Amended from Venkatesh et al. (2012)
	EE	The belief that using green technology is easy	Amended from Venkatesh et al. (2012)
	SI	The perception that important others believe in using green technology	Amended from Venkatesh et al. (2012)
	FC	Training, guidance, infrastructure, and help-desk support that improves or hinders green technology use	Amended from Venkatesh et al. (2012)
	PV	Perceived benefit of using green technology compared with its cost	Amended from Venkatesh et al. (2012)
	HM	Motivation to have fun or pleasure derived from using green technology	Amended from Venkatesh et al. (2012)
Digital option theory	DKR	Knowledge sharing among members through information systems and development of tacit knowledge	Amended from Sambamurthy et al. (2003)

product. The pilot test provided preliminary evidence that the scales were reliable and valid. These 52 participants were not included in the main survey.

The main survey was conducted by data brokerage agency during one weeks (i.e. second week May 2012) on the web in South Korea. A data brokerage agency randomly mailed a revised version of the original questionnaire to 900 suitable respondents. Potential respondents were initially contacted through a short personalized e-mail message that outlined the nature of the survey. Since the institution in which this study was conducted operates independently from any firms in the mobile industry, we considered no sampling bias to be present. Participants were sponsored; the survey agency paid participants in e-points, which can be exchanged for cash. Among the collected data, 21 records were excluded due to insincere responses (all questions answered with one point). Hence, 402 records in total were utilized in the analysis. All respondents who indicated that they had no intention to purchase any car within 5 years were

<Table 4> Characteristics of respondents (N=402).

Variables	Categories	Frequency	Ratio (%)
Gender	Male	197	49.0
	Female	205	51.0
Age	20's	97	24.1
	30's	131	32.6
	40's	123	30.6
	≥50	51	12.7
Monthly income	Under $1,800	82	20.4
	$1,800~2,700	98	24.4
	$2,700~3,600	89	22.1
	$3,600~4,500	67	16.6
	Over $4,500	66	16.5
Marital status	Single	149	37.1
	Married	253	62.9
Education	Senior high school	31	7.7
	Bachelors	296	48.7
	Masters	66	16.4
	Ph.D. or higher	9	2.2

excluded from the sample. The response rate was 44.7%. This rate compares favorably to response rates in other studies involving mailed surveys conducted on similar issues, and is consistent with the results of survey approaches in other studies. Moreover, according to Cohen (1998), the minimum number of records required for a study of this type was estimated at 103. Hence, the sample size acquired as a result of the data collection process (N = 402) was sufficient to perform the analysis.

The descriptive statistics relating to subjects' profiles are summarized in Table 4. Analysis of responses indicated that the sample was fairly equally divided between males and females (49.0% male).

Ⅴ. Data Analysis and Results

5.1 Measurement Model

The data were analyzed using the PLS software (version 2.0.M3) and SPSS (version 20.0). Convergent validity was assessed according to the reliability of the items, average variance extracted (AVE), and factor analysis results. Item factor loadings and squared multiple correlations from the confirmatory factor analysis are shown in Appendix A.

Regarding internal consistency (reliability), composite reliability scores for every construct (ranging from 0.880 to 0.962, as shown in Table 5) were well above 0.70. AVE measures the amount of variance that a construct captures from its indicators relative to the amount due to measurement error. The overall AVE score was calculated from the square roots of the AVE scores listed in Table 5. AVE scores for every

<Table 5> Results of reliability testing.

Constructs	Composite reliability	DKR	EEE	EE	SI	FC	HM	PV	EFE	INT
DKR	.930	.852								
EEE	.880	.176	.886							
EE	.952	.240	.480	.894						
SI	.942	.348	.557	.475	.937					
FC	.936	.252	.480	.304	.529	.914				
HM	.962	.244	.570	.470	.683	.459	.922			
PV	.960	.162	.383	.154	.488	.611	.475	.886		
EFE	.948	.344	.624	.449	.519	.303	.497	.212	.926	
INT	.944	.250	.557	.403	.646	.485	.585	.429	.546	.875

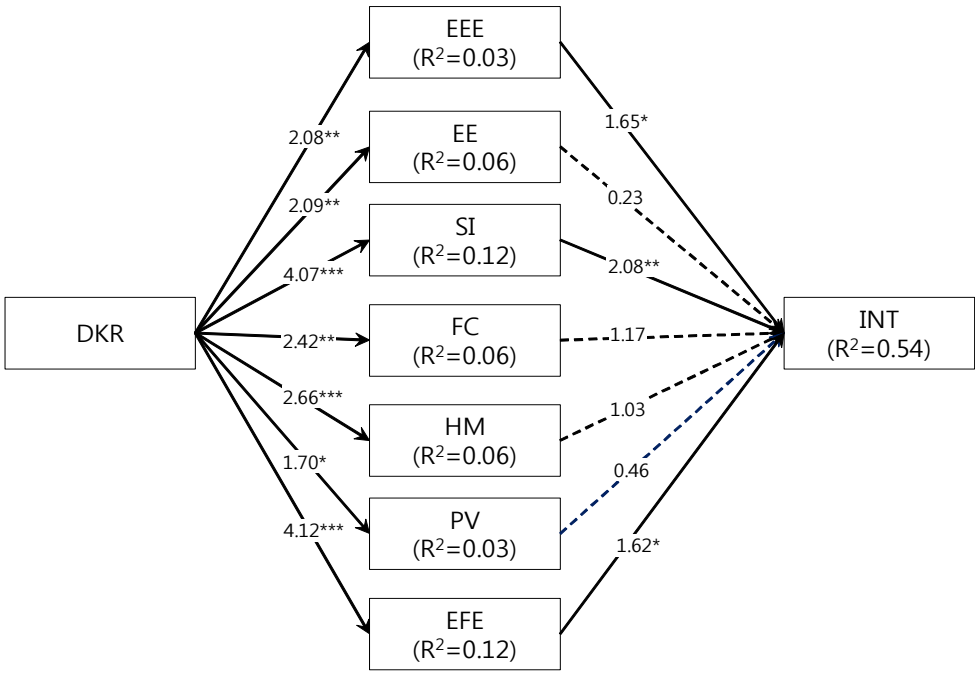
* Correlation coefficients were significant at the 0.01 level.

construct, ranging from 0.852 to 0.937, satisfied the necessary requirements. Barclay et al. (1995) suggested that item loadings for all constructs should exceed 0.70. In this study, the loadings of each item met this criterion (Appendix A). In addition, discriminant and convergent validity was established using the procedure outlined by Fornell and Larcker (1981), who suggested that convergent validity exists when item factor loadings exceed 0.70. The results of the factor analysis results in this study (Appendix A) were satisfactory according to this criterion.

Discriminant validity was assessed by examining the relationship between correlations among constructs and the square roots of AVE values (Fornell and Larcker, 1981). The square roots of the AVE values should exceed the correlations among the constructs, indicating that more variance is shared between a given construct and its indicators than between the construct and other constructs. Table 5 shows that the square roots of all the AVE values (i.e., the numbers on the diagonal) exceeded the correlations among constructs (i.e., the off-diagonal numbers), indicating that the discriminant validity of all the constructs was satisfactory.

5.2 Structural Model

In PLS analysis, examining the R2 scores of endogenous variables allows assessment of the utility of the variables, and examining the structural paths facilitates assessment of the explanatory power of the structural model. In this study, the model accounted for 54% of the variance (R2scores). In addition, all paths except FC→INT and PV→INT were significant at the 0.1, 0.05, or 0.01 level (Figure. 2). Digitized knowledge richness increased effort expectancy (β=0.24, $p<0.05$), facilitating conditions (β =0.25, $p<0.05$), hedonic motivation (β=0.24, $p<0.05$), eco-efficiency expectancy (β=0.18, $p<0.1$),



Notes: * Significant at the 0.1 level, ** Significant at the 0.05 level, *** Significant at the 0.01

<Figure 2> Results of the structural model results

eco-friendliness expectancy (β=0.34, p<0.01), price value (β=0.16, p<0.1), and social influence (β=0.35, p<0.01). Intention to purchase the green technology product was influenced by eco-efficiency expectancy (β =0.21, p<0.1), eco-friendliness expectancy (β =0.17, p<0.1), and social influence (β=0.28, p<0.05). As expected, hedonic motivation, facilitating conditions, and effort expectancy were not significantly associated with intention to adopt green technology. Figure 2 illustrates these results.

5.3 Moderating Effects

In order to investigate the moderating effects of demographic factors on eco-friendly product adoption, a moderation analysis was performed using the split sample approach (Ha et al., 2007; Serenko, 2006). This approach uses pre-established moderation levels that cannot be modified by researchers. For example, gender, recorded as male or female, naturally falls into two moderation levels.

To identify a moderation level for age, the dataset was divided into two sets, each representing a different generation. Members of each generation may be fundamentally different in terms of various characteristics, perceptions, and behaviors. Serenko et al. (2006) used 40

years of age on the day of the survey as a cut-off point. Subjects older or younger than 40 years old on the day of the survey fell into two categories: those < 40 years old (juniors) and those ≥ 40 years old (seniors). However, accepting a cut-off value at the average point for the entire sample for all variables may generate a bias because averages are affected by extremes, such as high income. To specify a moderation level for income, therefore, the median monthly income declared by the central bank was used. Median monthly income was used as a cut-off point on the day of the survey to create two categories of subjects: high- and low-income participants.

The moderating effects of demographic variables were tested by comparing the path coefficients produced for each moderator between groups. Path coefficients were calculated using t-values. Table 6 shows the results of these comparisons. Several significantly different structural relationships were revealed. First, gender moderated two of the relationships in the model. Male and female customers exhibited similar patterns of perceptual development in forming their intention to purchase green products. Two significant exceptions were found: SI→INT (males: β=0.362, females: β=0.202) and EFE→ INT (females: β=0.202). However, overall, gender had a very limited effect on the relationships between constructs in the green technology context.

Second, age was a moderating factor for three of the model's relationships: SI→INT (seniors: β =0.295, juniors: β=0.249), EEE→INT (juniors: β=0.243), and EFE→INT (juniors: β=0.256). Structural relationships were weaker for junior than for senior individual consumers. In terms of the SI→INT relationship, older individual consumers (i.e., the senior group) put more emphasis on the opinion of an important reference group (e.g., peers) in forming their intention to purchase green products (β=0.295), whereas younger people (i.e., the junior group) considered social influences with respect to green products to a lesser degree (β=0.249). Regarding the EEE →INT and EFE→INT relationships, significant results were found only for younger people (EEE →INT: β=0.243, EFE→INT: β =0.256) in terms of intention to purchase green products.

Lastly, income level moderated three of the model's relationships: SI → INT (high-income group: β=0.409, low-income group: β=0.205), EFE→INT (high-income group: β=0.144, low-income group: β=0.245), and HM→INT (high-income group: β=0.178). In terms of the SI →INT relationship, the higher-income group (β =0.409) emphasized social influence to a higher degree than the lower-income group (β=0.205). In addition, higher-income individual consumers who relied more on the opinion of an important reference group adopted green technology to a larger extent than their lower-income counterparts. In other words, social influence was more important in determining green technology

<Table 6> Results of model effects

Path	Gender				Age				Income level			
	Male		Female		Senior		Junior		High		Low	
	β	t	β	t	β	t	β	t	β	t	β	t
EEE→INT	.330	.080	.052	.440	.116	.701	.243**	2.006	.063	.493	.216	1.613
EE→INT	-.023	.202	.007	.074	-.008	.070	.019	.196	-.051	.678	.033	.316
SI→INT	.326**	2.662	.202*	1.773	.295**	2.352	.249*	1.901	.409 ***	3.766	.205*	1.671
FC→INT	.111	.866	.171	1.585	.160	1.579	.135	1.256	.131	1.380	.148	1.341
HM→INT	.104	.656	.131	1.185	.201	1.581	.045	.338	.178*	1.747	.091	.701
PV→INT	-.027	.105	.142	1.418	.069	.657	.015	.137	.082	.691	.022	.189
EFE→INT	.083	.790	.319***	3.532	.131	1.253	.256**	2.517	.144*	1.824	.245**	2.375

*** Significant at the .01 level, **Significant at the .05 level, *Significant at the .10 level.

adoption behavior for the former group. With respect to the EFE→INT relationship, the lower-income group (β=0.245) was stronger than the higher-income group (β=0.144). The HM→ INT relationship (β=0.178) had an impact on intention to purchase green products only for higher-income individual consumers.

Ⅵ. Discussion

6.1 Summary

Several meaningful conclusions can be drawn from the results of the empirical testing. First, social influence is more significant than conventional utilitarian and hedonic-based constructs such as those utilized in the UTAUT and UTAUT2 in explaining adoption behavior in the context of green technologies. The impact of social influence in this context is consistent with the theory of planned behavior, which asserts that subjective norms affect intention to purchase. The modified theory of planned behavior also suggests that subjective norms, ethical obligations, and self-identity are related to purchase intention (Ajzen, 1991; Shaw and Shiu, 2002). Shaw et al. (2005) proposed that the ethical behavior inherent in green product consumption was related to individual morality. Chang (2011) found that green product consumers were generally proud of their status, even going so far as to flaunt their green product buying behavior to others. The finding in this study that social influence is positively associated with green technology adoption seems to support this viewpoint.

Second, both eco-efficiency expectancy and eco-friendliness expectancy (performance expectancy-derived constructs identified in the content analysis) were significantly and positively associated with intention to adopt

green technology.

Third, as expected based on the results of the content analysis, no significant relationship was found between other variables (effort expectancy, hedonic motivation, facilitating conditions, price value) and intention to adopt green technology. This finding seems quite reasonable in the context of hybrid vehicle adoption. In terms of effort expectancy, hybrid vehicles and vehicles powered by conventional gasoline or liquefied petroleum gas operate identically: the battery usage and exchange between fuel cells and gas are both accomplished automatically. Hence, the effort expectancy of hybrid vehicles is no higher or lower than that of other vehicles. Likewise, hedonic value is not clearly related to usage of hybrid vehicles. No specific reason or hedonic motivation exists for consumers to adopt hybrid vehicles. By contrast, to understand facilitating conditions and price value in the context of hybrid vehicle use, the concept of digitized knowledge richness may be useful. However, facilitating conditions and price value of hybrid vehicles are currently inferior to those of conventional cars. Although understanding has increased about facilitating conditions (e.g., charging locations) and price value (e.g., taxes), the effects are too minimal to motivate consumers to make the switch from conventional cars. In short, the impact of these four variables was nominal.

The hypothesized connection between digitized knowledge richness and adoption intention was supported by the results of studies on the role of IT in formation of attitudes toward eco-friendly production (Chang, 2011). For example, a firm may engage in green behavior in order to present an eco-friendly image to consumers, even though the firm may not actually be green. Consumers must distinguish this behavior from actual green activity with the aid of social media or any other internet-based knowledge source that provides evaluation of "green-like" products. Digital knowledge thus allows anyone to understand green products and their manufacturing firms more accurately. On the other hand, consumers generally perceive that green products are more expensive and of lower quality. Richer digitized knowledge could diminish this bias by providing actual performance data and price information and clearing up misunderstandings about green products.

Digital knowledge can also encourage people to try green technology when they learn that their peers are already using the technology successfully. This role of social influence in increasing adoption intention was partially confirmed in the study of Banerjee et al. (1995) on green advertising. The content analysis in that study indicated that 12% of green advertisements appealed to customers' utilitarian values (e.g., promotion, price level), while 38% and 50% of advertisements appealed to their emotional (e.g., fear) and normative (e.g., social responsibility, green action) values, respectively. However,

green advertising tended to rely more on social norms than utility, which is quite different from advertisements for other products.

6.2 Theoretical Contributions

This research was conducted because that the UTAUT2 does not fully represent the factors that affect customers' intention to adopt green technology voluntarily. Different roles of IT were identified in this study in the context of green technology adoption to those of the UTAUT2. Several interesting contributions were made in the process.

In this study, digital option theory and the UTAUT2 were combined. In the combine model, the empirical evidence showed that IT contributes to technology adoption theory, as put forward in the UTAUT2, but that it acts as a precedent of the determinants of technology adoption behavior, not just as a dependent variable. The indirect role of digital systems in green technology adoption and their ability to enrich digitized knowledge was empirically tested.

Furthermore, we newly combined the UTAUT2 and media richness theory. The empirical results reveal that rich digitized media are successfully connected to the components of the UTAUT2 we well as the UTAUT.

In addition, the UTAUT2 was found to be extendable to technologies other than conventional IT. Although the technology acceptance model (TAM) has often been applied in non-IT domains, use of the UTAUT2 in studies from the technology management perspective has been limited. However, we also determined that the UTAUT2 is not fully transferrable to the context of green technology. Some variables were not significant in this new context. In application of the UTAUT2 to contexts other than IT and green technology, confirmatory factor analysis should be performed, and variables added or deleted as necessary to ensure its suitability for use in these contexts.

6.3 Practical Implications

The significant relationship between digitized knowledge richness and green technology adoption identified in this study has implications for practitioners. Collaboration and personalization technologies, as digitized knowledge-enriching tools, were demonstrated to be useful for green product manufacturers and public institutions in order to communicate information about green products to consumers. Therefore, green product manufacturers should hire digital system developers who are able to embed collaboration and personalization technologies into websites or mobile applications.

Digitized knowledge richness does not necessarily mean an increased quantity of information. It does, however, imply a high quality of information. Peattie (1995) suggested that too much variety of information about

environmental issues may reinforce uncertainty about those issues. An unwanted side effect of this uncertainty is reduced trust in green products in terms of quality and reliability. Quality is therefore much more important than quantity when it comes to the richness of digitized knowledge. Practitioners who administer websites or other knowledge repositories must therefore take the quality of information into account.

The less knowledge is diffused, the more significant the impact of digitized knowledge richness becomes. When a new technology is initially introduced, knowledge is less diffused, and consumers have less tacit knowledge about it. In this scenario, networked knowledge is very useful to disseminate information to potential customers. Hence, developers of new products such as green technology must take IT into account to ensure effective and efficient diffusion of abundant knowledge about their products.

6.4 Limitations and Future Research

In this study, the relationship between price value and intention to adopt green technology was found to be insignificant. Because prices of green products will decrease in the future, price level may be re-entered into the UTAUT2 in future studies to become part of the green technology model proposed here.

This paper focused on intention to purchase, not intention to use, which was a rational approach because respondents had no problem expressing a desire to try the green technology when no financial commitment was required. However, in some circumstances, purchase of green technology is unnecessary if alternative green behaviors are already exhibited. For example, an eco-efficient computer is unnecessary if users already have a habit of turning the power off. In addition, environmental pollution can be reduced in many ways. For example, rather than purchasing a hybrid car, people can take public transportation, recycle, or purchase energy-saving appliances as alternative eco-friendly activities (Chang, 2011). Hence, intention to purchase may be quite different from intention to use in the context of green technology adoption. Wu and Lederer (2009) mentioned these differences in their study of adoption of eco-friendly products using the TAM. Further research from a business perspective must take intention to use into account to improve our understanding of consumers' green adoption behaviors.

This study did not consider how individual characteristics affected the constructs of the UTAUT2 in the context of green technology. Individual characteristics may potentially affect users' adoption intentions. For example, lonely consumers prefer minority-endorsed products, whereas non-lonely consumers prefer majority-endorsed products (Wang et al., 2012). Customers who are loners tend to be less consistent in their adoption behaviors and

preference than other customers. In addition, Wang et al. (2012) found that even lonely consumers mimic others' behaviors if their preferences have been revealed in public. This implies that public influence on utilitarian value (e.g., facilitating conditions, price value) or hedonic value may affect preferences regarding green technology consumption. Further study

Appendix A. Items, factor loadings, and squared multiple correlations (SMC).

Constructs	Variables	Factor loadings	SMC
Digitized knowledge richness (DKR)	DKR1	.745	.906
	DKR2	.738	
	DKR3	.761	
	DKR4	.793	
	DKR5	.788	
Eco-efficiency expectancy (EEE)	EEE1	.869	.728
	EEE2	.754	
Eco-friendly expectancy (EFE)	EFE1	.961	.931
	EFE2	.992	
	EFE3	.943	
	EFE4	.912	
	EFE5	.778	
Effort expectancy (EE)	EE1	.913	.937
	EE2	.914	
	EE3	.886	
	EE4	.893	
	EE5	.748	
Social influence (SI)	SI1	.795	.923
	SI2	.756	
	SI3	.789	
	SI4	.784	
	SI5	.751	
Facilitating conditions (FC)	FC1	.786	.863
	FC2	.828	
Hedonic motivation (HM)	HM1	.779	.951
	HM2	.817	
	HM3	.798	
	HM4	.785	
	HM5	.795	
Price value (PV)	PV1	.737	.945
	PV2	.747	
	PV3	.756	
	PV4	.755	
Behavior intention (INT)	INT1	.786	.912
	INT2	.776	
	INT3	.765	

will determine if hedonic motivation is significantly related to green technology adoption.

Lastly, as hybrid vehicles become more viable, the results of hypotheses might be changed, especially for the rejected hypotheses. For example, if the price of the hybrid vehicles becomes competitive to conventional vehicles, then users may perceive that price level is highly associated with intention to purchase.

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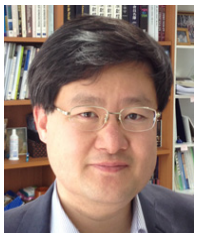
유호선 (Yoo, Hosun)

현재 분당서울대병원 의료기기 R&D 센터 연구원으로 재직 중이다. 경희대학교 국제경영학부에서 학사, 석사, 박사학위를 취득했다. 관심 연구 분야는 기술수용이론과 사회네트워크 등이다.

이남연 (Lee, Namyeon)

2014년부터 현재까지 성결대학교 학술연구교수로 재직 중이다. 경희대학교 국제경영학부에서 경영정보시스템전공으로 경영학박사를 취득하였고 차세대정보시굴연구센터에서 박사후과정을 수행했다. 2007년에는 미국 웨인주립대학 산업공학과 CINDI 연구소에서 근무하기도 했다. 관심 연구분야는 빅데이터 분석, 인간-컴퓨터 상호작용 등이다.

권오병 (Kwon, Ohbyung)



현재 경희대학교 경영대학에서 교수로 재직 중이다. 서울대학교 경영대학에서 학사, 한국과학기술원 경영과학과에서 공학 석사, 박사학위를 취득하였으며, 관신연구분야는 유비쿼터스 컴퓨팅, 소셜미디어, 데이터분석 등이다. Journal of Management Information System, International Journal of Information Management, Decision Support Systems 등 국제학술지에 논문을 발표했다.

<Abstract>

The Role of Digital Knowledge Richness in Green Technology Adoption:
A Digital Option Theory Perspective

Yoo, Hosun · Lee, Namyeon · Kwon, Ohbyung

Purpose

This study aims to understand the role of digital knowledge in accepting the green technology. This study combined digital option theory with the second version of the Unified Theory of Acceptance and Use of Technology (UTAUT2). Contrary to other studies in which the UTAUT2 is used to explain IT adoption behavior, we look at the relationship between IT and the UTAUT2 from a new angle, incorporating an important aspect of IT, that is, digitized knowledge richness, as a determinant of the UTAUT2.

Design/methodology/approach

Grounded in the UTAUT2, a content analysis was conducted to investigate novel constructs dedicated to explaining green technology adoption. In this study, an amended version of the UTAUT2 specific to green technology is offered that better explains the green technology adoption behavior of consumers. Using the items identified by content analysis, we developed a questionnaire with 36 survey items. We measured all the items on a seven-point Likert-type scale. We randomly selected 402 survey respondents from a set of panel data. After a pilot study, we analyzed the main survey data by using PLS 2.0M3 and SPSS 20.0, and employed structural equation modeling to test the hypotheses.

Findings

The results suggest that the UTAUT2 was found to be extendable to technologies other than conventional IT. Social influence is more significant than conventional utilitarian and hedonic-based constructs such as those utilized in the UTAUT and UTAUT2 in explaining adoption behavior in the context of green technologies. The hypothesized connection between digitized knowledge richness and

adoption intention was supported by the results of studies on the role of IT in formation of attitudes toward eco-friendly production. The results also indicate that digital knowledge can also encourage people to try green technology when they learn that their peers are already using the technology successfully.

Keywords: Green technology, UTAUT2, Digital option theory, Digitized knowledge richness

<국문초록>

그린기술 채택에의 디지털 지식풍부성의 역할:
디지털 옵션 이론 관점에서

유호선 · 이남연 · 권오병

연구 목적

본 연구의 목적은 그린 기술의 채택 현상을 디지털 지식의 제공 여부로 이해하는 것이다. UTAUT2를 이론적 기반으로 하되 디지털 옵션 이론과 결합하였다. 특히 일반적인 UTAUT2 관련 연구들이 IT자체에 대한 수용 현상을 설명하기 위해 사용된 것과는 달리 본 연구에서는 IT의 산물인 디지털 지식이 그린 기술이라는 대상을 채택하는데 긍정적인 영향을 주는지에 대해서 초점을 두었다.

연구설계/방법론/접근법

UTAUT2를 근거로 하되 그린 기술의 채택 현상을 설명하는데 유용한 요인들을 파악하기 위하여 내용분석을 실시하였다. 그 결과로 본 연구에서는 그린기술을 위한 수정된 UTAUT2 모형을 개발하였으며 그에 맞는 36개의 설문 문항을 개발하였다. 각 문항의 측정은 리커트 7점 척도를 채택하였다. 한 기관의 패널 자료로부터 총402명의 유효한 설문을 획득하였다. 사전 검증을 마치고 획득한 설문 결과를 PLS 2.0M3와 SPSS 20.0을 이용하여 분석하였으며 가설검증을 위해 구조방정식 분석을 수행하였다.

결과

통계분석 결과 개발된 UTAUT2 수정 모형은 수요자들의 그린기술 채택 현상을 적절히 설명하는 것으로 실증분석 결과 나타났다. 사회적 영향은 전통적인 UTAUT나 UTAUT2에서 사용하는 효용가치나 쾌락가치보다 그린기술의 채택하는 맥락 하에서의 수용 행위를 더 잘 설명하고 있었다. 또한 디지털 지식과 그린기술의 채택, 즉 환경 친화적 제품에 대한 태도에 영향을 주는 요인들 사이의 인과관계는 유의한 것으로 판정되었다. 아울러 디지털 지식은 어떤 잠재적 사용자들이 그린기술을 잘 활용하고 있는 그들의 동료들로부터 학습하기 위해서 유용한 매체인 것으로 밝혀졌다.

키워드: 그린기술, UTAUT2, 디지털옵션이론, 디지털 지식 풍부성

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