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How Will Innovation Diffuse with Smart Customers?

- Exploring with Agent-based Model -

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서울대학교 대학원

산업공학과

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지도 교수 박 용 태

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Abstract

How Will Innovation Diffuse with Smart Customers?

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Due to the explosive advancement and dissemination of information technologies, near-perfect market information is available to customers via smartphone and internet. In turn, customers have not only become smarter but become heterogeneous with regards to their smartness; the smartness can play critical role in customers' purchase decision and diffusion of innovation. However, previous studies have not considered the influence of smartness in innovation diffusion.

Along this line, the primary objective of this study is to examine the diffusion patterns of innovation when customers' heterogeneity on smartness is considered as the determining factor. In doing that, the term 'smartness' is defined by introducing the concept of customer involvement and IT use, and the effect of smartness on the decision process is discussed. The agent-based modelling (ABM) approach is adopted for the methodology in this research since it has the ability to explicitly incorporate customers' heterogeneity and flexibility to accommodate sensitivity analysis. Specifically, the adoption process of customer agents with heterogeneous smartness is modelled; the patterns of diffusion in aggregated customers are explored through the agent-based modelling technique.

Although an exploratory study, this research contributes to diffusion analysis in that it attempts to take a new perspective on innovation diffusion in response to paradigmatic shift of customers' characteristics. Furthermore, it provides a better understanding of the customer behavior and insights on positioning innovation in a market by considering smartness of customers.

Keywords: Smartness, Smart customers, Diffusion, Agent-based modelling, IT use, Customer Involvement
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Chapter 1. Introduction

Recently, the explosive advancement and dissemination of information technologies (IT) has enabled customers to identify breakthroughs or innovative products with the near-perfect market information (Downes & Nunes, 2014). Customers are getting even smarter as they incorporate computing networks or mobile devices, whenever and wherever they wish to search detailed information about products, e.g. price, specification, reviews and etc. Also, customers have become heterogeneous in terms of smartness, as they have a different level of ability in utilizing IT as well as a different degree of engagement in a decision making process. This implies that the level of smartness of customers could largely affect their adoption decision (Downes & Nunes, 2014; Puccinelli et al., 2009; Ward & Morganowsky, 2002). For instance, customers who are highly motivated to investigate product information and have full capability to utilize IT will acquire more information than who are not motivated and have little capability (Bickart & Schindler, 2001; Puccinelli et al., 2009; Ratchford & Debabrata Talukdar, 2001; Shang, Chen, & Liao, 2006; Ward & Morganowsky, 2002). Several studies have revealed that the one with much product information has the higher probability to choose the satisfactory product than the one with less information (Puccinelli et al., 2009; Sanchez-Franco & Rondan-Cataluña, 2010; Ward & Morganowsky, 2002). Even though there are numerous studies considering heterogeneity of customer in the diffusion of innovation

(Alkemade & Castaldi, 2005; Baptista, 2000; Chatterjee & Eliashberg, 1990; Delre, Jager, Bijmolt, & Janssen, 2010; Delre, Jager, & Janssen, 2007; Goldenberg, Libai, Solomon, Jan, & Stauffer, 2000; Janssen & Jager, 2003; Liebermann & Paroush, 1982; Loch & Huberman, 1999; Rogers, 2003; Russell, 1980; Schramm, Trainor, Shanker, & Hu, 2010; Van den Bulte & Stremersch, 2004), no attempt has been made to consider 'smart' customers in the diffusion process. To fill the gap, this study aims to examine the diffusion pattern, e.g. the speed of diffusion, the total number of adopters, and etc., of innovation regarding customer heterogeneity in 'smartness'.

In this paper, 'smartness' is defined as a degree of engagement (customer involvement) and IT utilization (IT use) in a decision making process. That is, customers who are highly motivated to learn product information and have full capability to utilize IT are considered as '*smart customers*'. The reason why 'smartness' is defined in terms of customer involvement and IT use is that customers' characteristics such as the degree of engagement and IT utilization in the decision process can result in the different adoption decision regardless of the transparency of product information enabled by Internet. It has been suggested that the degree of engagement and IT utilization has an impact on the decision making process. For example, customers who are highly involved in searching product information have a specific desired state of a product, and they evaluate products with respect to their own preference (Zaichkowsky, 1985). Furthermore, customers who utilize IT in the decision making process tend to get information from online discussions, such as Internet forums, which leads to a bigger interest in the product category than those who are only disclosed to marketer-generated online information (Bickart & Schindler, 2001). This can affect the evaluation part in the decision making process.

The methodology taken in this study is agent-based modelling (ABM) technique. ABM has the ability to explicitly incorporate customers' heterogeneity and flexibility to accommodate sensitivity analysis. Numerous studies on customers' heterogeneous adoption behaviour in the diffusion process have employed an ABM technique (Alkemade & Castaldi, 2005; Delre et al., 2010; Delre et al., 2007; Goldenberg, Libai, & Muller, 2010; Hohnisch, Pittnauer, & Stauffer, 2008). Like those studies, ABM can effectively involve smartness in a diffusion model as one of factors in customers' heterogeneity. Taken together, the main purpose of this study is to explore diffusion patterns of innovation by developing an ABM model when customers' heterogeneity on 'smartness' is considered as a determining factor.

The remainder of this paper continues as follows. First, the customer heterogeneity in the diffusion of innovation is reviewed in Section 2. Next, the term 'smart customer' ('smartness') is precisely defined in Section 3. With the developed concept, the formulation of a model is presented in Section 4 with the detailed explanation of a model structure. In Section 5, the experiment design and simulation results are provided. Finally, the paper ends with discussions and conclusion by describing implications and limitations in Section 6.

Chapter 2. Literature review

2.1 Customer heterogeneity in the diffusion of innovation

In the sense that individual customers have different requirements, preferences, and information (Kiesling, Günther, Stummer, & Wakolbinger, 2012), customer heterogeneity in a diffusion process has received particular attention (Alkemade & Castaldi, 2005; Delre et al., 2007; Goldenberg et al., 2010; Guseo & Guidolin, 2015; Hohnisch et al., 2008). In the traditional diffusion models, such as logistic model or Bass model (Bass, 1969), customers are assumed to be homogenous, and the main driver of diffusion is communication, e.g. advertisement and interpersonal communication. The assumption of customer homogeneity is, however, oversimplified as many researchers pointed out as a limitation of Bass model (Kiesling et al., 2012). In particular, studies indicate that the relative utilities gained from the characteristic of the product, e.g. attribute, price, brand images, are becoming more significant (Christensen & Raynor, 2013).

In this regard, a number of studies have examined customer heterogeneity in a diffusion process. The classic study of customer heterogeneity is the one by Rogers (2003). In this study, customers are classified into five types with respect to innovativeness, which is the propensity to adopt. Also, some studies have showed that the heterogeneity of income can affect the diffusion process (Liebermann & Paroush, 1982;

Russell, 1980; Van den Bulte & Stremersch, 2004). Furthermore, several attempts have been carried out to examine the influence of the heterogeneous geographical locations of customers on the diffusion (Baptista, 2000; Goldenberg et al., 2000). Another main factor of diffusion that have examined by many researchers is the social network structure of individual (Alkemade & Castaldi, 2005; Delre et al., 2010; Janssen & Jager, 2003). They have made use of the ABM technique to represent the heterogeneous social network of individuals. In addition, the heterogeneous perception of innovation has also been studied in diffusion research (Chatterjee & Eliashberg, 1990; Delre et al., 2010; Delre et al., 2007; Janssen & Jager, 2003; Loch & Huberman, 1999; Schramm et al., 2010). They have employed the concept of individual utility function to reflect the individuals' different criteria. In these studies, customers are assumed to have different perceptions of products' quality, attributes, performance or price. Also customers have different sensitivities on promotion and social influence. Those differences are mirrored in the utility function. For example, the utility function is divided into a personal need part and a social need part and each part has different weights to show the individuals heterogeneity (Delre et al., 2007; Janssen & Jager, 2003). Further, each individual has preference variation of product attributes and price, and utility scores are calculated based on those preferences (Schramm et al., 2010). However, none of those studies have examined the 'smartness' of customers, which is expected to have a significant influence on the diffusion of innovation. The notion of 'smart' customer will be precisely defined in Section 3.

2.2 Agent-based modelling applied in the diffusion studies

Agent-based modelling is a tool for exploring an aggregated pattern derived from the interaction of agents defined in the model (Garcia, 2005; Kiesling et al., 2012). The agent is an autonomous entity living in the model, and has its own property and behaviours (Rand & Rust, 2011). They interact with each other based on their rules and the phenomena arise from their interactions. Thus a researcher can encodes the behaviour rules of agents and examine the emergent pattern of the system.

In this vein, the agent-based modelling has been adopted by numerous studies to examine customers' heterogeneous behaviours in the diffusion process (Alkemade & Castaldi, 2005; Delre et al., 2010; Laciana & Oteiza-Aguirre, 2014; Schramm et al., 2010; Stummer, Kiesling, Günther, & Vetschera, 2015). With the agent-based modelling, researchers are able to explicitly model customers' heterogeneity and their decision making process (Kiesling et al., 2012). Also this methodology is adequate for exploratory research, because it can capture emergent market dynamics and answer what-if-type questions (Kiesling et al., 2012). Therefore, this study adopted the agent-based modelling to construct the heterogeneous customer agents in terms of smartness and to explore the effect of smartness in the diffusion of innovation.

Chapter 3. Defining 'smart' customers

A large amount of product information is available for everyone through information technologies, yet not everyone benefits from it. That is, the availability of product information does not guarantee the successful diffusion or adoption of a product. One reason is that people have different degree of engagement on a purchase process. For example, some people may actively search for various products, and compare specifications before making a decision, while others may not (Laurent & Kapferer, 1985; Puccinelli et al., 2009; Shang et al., 2006; Zaichkowsky, 1985). This can be explained with the customer involvement. Customer involvement refers to the degree of engagement of customer in the decision making process (Laurent & Kapferer, 1985; Puccinelli et al., 2009; Shang et al., 2006; Zaichkowsky, 1985).

The other reason is that people utilize IT in different levels in the purchase decision process, as people have different availability of IT infrastructure and access as well as the different capability to use IT (International Telecommunication Union, 2015). For some people, IT infrastructure would be unavailable or it would be costly in terms of time and money to learn how to use IT (Ratchford & Debabrata Talukdar, 2001).

By employing two factors, this paper defines the term 'smartness' of customer as following: a degree of engagement (customer involvement) and the degree of utilizing IT (IT use) in a decision making process. We assumed that the higher the degree of engagement and IT use, the smarter the customer

(See Figure 3.1). Thus, the ‘smart’ customer refers to a customer who is highly motivated to search for product information and have full IT utilization. To sum up, the term ‘smartness’ can be expressed with two dimensions, customer involvement and IT use. Having defined the term ‘smartness’, the following sections address how two dimensions affect the decision making process.

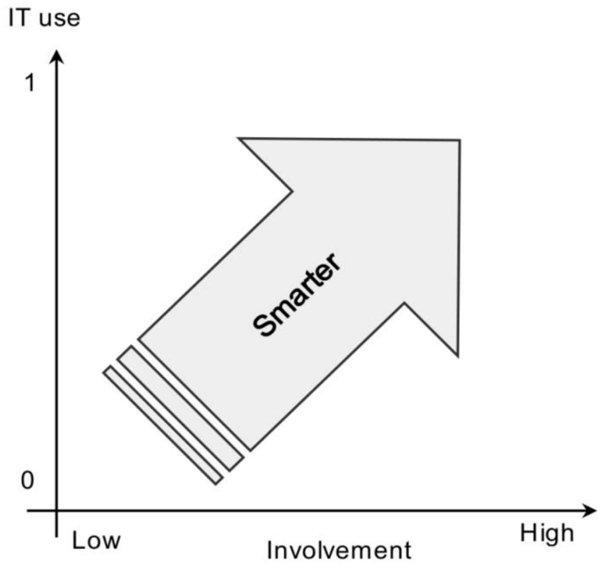

Figure 3.1. Two dimensions of smartness

3.1 Customer involvement and the decision making process

Involvement refers to the degree of engagement of customer in the decision making process (Laurent & Kapferer, 1985; Puccinelli et al., 2009; Shang et al., 2006; Zaichkowsky, 1985). In other words, it is the propensity to actively learn about products and intensively search for product information. For example, the high-involvement customers intensely collect, process, and integrate information, and finally arrive at a purchase decision, while low-involvement customers rarely make an effort on collecting and processing product information and usually make a decision instantaneously. This implies that the customer involvement affects the decision making process (Puccinelli et al., 2009). The decision making process can be divided into three phases: need recognition, information search, and evaluation.

When customers recognize the need, the high-involvement customers come up with the preferred level of product profile (Puccinelli et al., 2009; Zaichkowsky, 1985), i.e. the customers have a desired state of a product in terms of quality. On the other hand, low-involvement customers don't have an explicit desired state (Sanchez-Franco & Rondan-Cataluña, 2010). Throughout the paper, the term ideal quality will be use to refer the desired state of a product in terms of quality. In the information search stage, the high-involvement customers are highly motivated to search for various products and interested in acquiring product information, while low-involvement customers satisfy with a little amount of product information (Zaichkowsky, 1985). Therefore, the high-involvement customers consider a greater number of products than low-involvement customers. When evaluating the product candidates, highly involved customers have a complex evaluation process. They compare all products profile with their own preferences (Zaichkowsky, 1985). On the contrary, low-involvement customers simply prefer higher quality, since they don't have a specific desired product profile. In addition, highly involved customers are susceptible to online chat groups when evaluating the products (Van Dolen, Dabholkar, & De Ruyter, 2007). This implies that they are more sensitive to online social influence. Meanwhile, low-involvement customers show a greater susceptibility to the promotion than the high-involvement customers (Chandrashekaran & Grewal, 2003). This implies that low-involved customers are more sensitive to promotion intensity. As a consequence, the high-involvement customers take longer time to make a final decision than low-involvement customers.

In summary, it has been shown from the review that the customer involvement does affect the decision making process. The characteristics of high-involvement and low-involvement on the decision making process are summarized in Table 3.1.

Table 3.1. High and low involvement in a decision making process

Decision making process	**High Involvement**	**Low involvement**
1. Need recognition	Desired state	No specific desired state
2. Information search (Number of products considered)	Extensive (Many)	Minimum (One/Few)
3. Evaluation of product candidates	Complex	Simple
4. Time to spent in purchase	Long	Short/Minimum

3.2 IT use in the decision making process

IT, such as Internet and mobile network, plays a prominent role as a source of information. Through Internet, customers are more informed about the products than through other sources of information, and more information is being obtained at lower transaction cost (Ward & Morganowsky, 2002).

As IT becomes one of the major channels of purchase (Ratchford & Debabrata Talukdar, 2001) and sources of information, individual’s degree of IT use can have influence on the information search stage in the decision making process. In other words, the amount of product information acquired depends on individual’s degree of utilize IT. Further, Individual’s degree of IT utilization (IT use) differs depending on the individual’s capability of using information technologies (Ratchford & Debabrata Talukdar, 2001) and the availability of IT infrastructure (International Telecommunication Union, 2015). Consequently, the degree of IT use can lead to the different amount of information acquired.

In addition, IT use can affect the evaluation stage. It is said that the likeliness of purchase in other channels has increased when customers gather product information through Internet (Ward & Morganowsky, 2002). For instance, customers who get information from online discussions, such as Internet forums, tend to possess a bigger interest in the product category than those who are only disclosed to marketer-generated online information (Bickart & Schindler, 2001). All things considered, it is found that the degree of IT use has an influence on the decision making process.

Chapter 4. Model formulation

4.1 Model overview

The main goal of the model is to examine the impact of smartness on the diffusion of innovation. Therefore, the inputs are the degree of smartness of a market and the profiles of products. The smartness of a market is derived from the proportion of 'smart' customers in a market. In other words, the proportion of the high-involvement customers and the average degree of IT use determine the smartness of a market. The outputs are the diffusion curves of each product (brand level) and the aggregated diffusion curve of all products (category level), which allow us to study the impact of smartness on the diffusion at the macro and micro level.

In the model, there are two kinds of agent: product and customer. A product agent and a customer agent interact with each other, and the interaction differs depending on customer's smartness. Details of each agent and the interaction mechanism are provided in the following sections.

4.1.1 Product agent

A product agent is defined by three parameters which are quality, price and promotion intensity. The high value for the quality indicates that the quality of a product perceived by a customer is high. The high value for the price indicates that a customer perceives the product as expensive, which causes a negative impact on the utility score. Likewise, the high value for the promotion intensity indicates that the product is promoted intensively. Parameters of a product agent are summarized in Table 4.1. The values for each parameter are normalized to remove a scale effect. In the simulation, various profiles of products can be given. For instance, Product A is characterized by a high price, high quality and high promotion intensity, while Product B is characterized by a low price, high quality, and high promotion intensity. Specific profiles that we used in the simulation are discussed in Section 5.2.

Table 4.1. Parameters of Product agent

Parameter	**Details**
Quality	High value indicates that customers perceive high quality of product Numerical parameter: [0,1]
Price	High value indicates high price Numerical parameter: [0,1]
Promotion intensity	High value indicates the high intensity of promotion Numerical parameter: [0,1]

4.1.2 Customer agent

A customer agent is defined in terms of smartness, the social network and sensitivities to promotion, quality, social influence, and price. It is assumed that there is no relationship between smartness and four types of sensitivity. As explained earlier, one’s smartness is determined by the agent’s involvement type and its degree of IT use. Involvement type is a categorical parameter, which can be either high or low. If a customer agent's type is high-involvement, it has ideal quality value as a parameter. On the other hand, a customer agent with the low-involvement type doesn't have such parameter. IT use is a numeral parameter, which has a value between zero and one. The value zero means that the customer rarely uses IT in the decision making process, but use other sources such as catalogues, magazines, and advertisement in offline. The value one means the customer only uses IT and rarely use offline sources in its decision making process.

Next, sensitivity to promotion, quality, social influence, and price refers to how sensitive the customer is to each factor. These values are used when a customer evaluates the utility score of each product. In particular, our model incorporates the concept of budget (Jager, 2007) to imply the sensitivity to price. Customers have a different amount of budget which may lead to a different decision by comparing the utility of a product and the price to decide whether to adopt or not (Woodruff, 1997). Thus, assigning different budgets to each customer can reflect different sensitivity to price.

In addition to smartness and sensitivity, each customer has two kinds of social networks: offline social network and online social network. The social network is specified into two networks to reflect the different online and offline social influence. For example, if a customer better utilizes IT, then the social influence from online network will have a larger impact on its utility. In addition, as mentioned earlier high involvement customers are more influenced by online discussions and reviews (Bickart & Schindler, 2001).

These findings lead us to separate the social network into online and offline. For the structure of an offline social network, the small-world network is implemented (Watts & Strogatz, 1998). A small-world network represents the social network that one’s friends and acquaintances tend to be similar with others’ friends and acquaintances (Janssen & Jager, 2003). For the online social network, a random network is implemented since customers can be influenced by anyone whom they encountered in the online environment, e.g. internet forum, reviews, Facebook friends, etc. Furthermore, the number of online connections is set to be proportional to the degree of IT use. In other words, a customer with the high degree of IT use has more online acquaintances than a customer with the low degree of IT use. Parameters of a customer agent are summarized in Table 4.2.

Table 4.2. Parameters of Customer agent

Parameter		**Details**
Smartness	Involvement	Degree of one’s engagement in the decision making process Categorical parameter: High or Low
	IT use	Degree of one’s IT utilization in a decision making process Numerical parameter: [0,1]
Sensitivity to	quality	Importance of quality on one’s decision
	social influence	Influence of the adopters among neighbors on one’s decision
	promotion	Impact of promotion on one’s decision
Budget		Willingness to pay for a product category

Ideal quality	One's desired state of product in terms of quality Only applicable to a customer agent of high-involvement
Offline social network	Agent's social network in offline environment Network structure: Small-world network (Watts & Strogatz, 1998)
Online social network	Agent's social network in online environment Network structure: random network (Network size $\propto$ IT use)

4.1.3 Interaction between product and customer

Customers go through their decision making process by interacting with the products. A customer collects information of *n* products, evaluates each product based on its sensitivity to quality, promotion, social influence and budget, and calculates each product's utility. He or she selects a product with the highest utility among *n* products and compares it with a given threshold. If the utility score is higher than the threshold, the product is adopted. Otherwise, customer goes back to the information search stage. Within a given simulation time, the diffusion curves of products are obtained. The overall decision making process is shown in Figure 4.1, and the details are provided in Section 4.2.

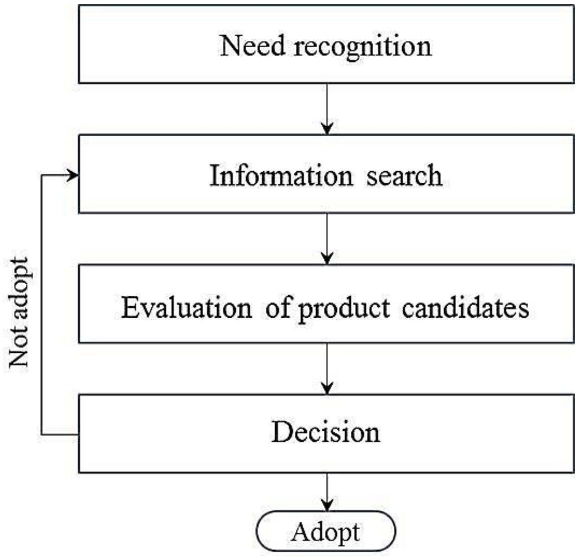

Figure 4.1. Overall decision making process

4.2 Model details in customers' decision making process

In this section, the details of a decision making process are explained. There are some differences in each step depending on the smartness of customer, and those are specified in the following sections (See Figure 4.2).

4.2.1 Need recognition

As depicted in Figure 4.1, the decision making process starts with recognizing the need to buy a certain product, e.g. smartphone. Need recognition can be triggered by an internal need or advertisement or word-of-mouth. In this stage, the high-involvement customer sets his or her ideal quality level as explained in Section 3.1. It is important to note that the desired level of quality is not always high. For example, a customer may want a low priced product with low quality. The low-involvement customer, on the other hand, doesn't have a specific desired level of quality and price (Sanchez-Franco & Rondan-Cataluña, 2010), and they merely prefer higher quality and lower price.

4.2.2 Information search

After customers recognize their needs, they start to find product candidates. The amounts of product information collected by customers differ depending on the degree of smartness: the combination of involvement type and the degree of IT utilization. For example, the high-involvement customer with the full IT utilization (smarter customer) will find more information than the low-involvement customer with the little IT utilization (less smart customer). In short, the smarter the customer, the larger the amount of product information obtained:

$$\text{The amount of product information obtained} \\ \propto (\text{IT use}) \times (Involvement\ type)$$

4.2.3 Evaluation with the utility function

Once product candidates are acquired, they are evaluated based on the utility function. The utility function is composed of four parts: promotion, quality, social influence, and price (Jager, 2007; Schramm et al., 2010). The structure of utility function is the same for every customer, but the calculation of each part is different depending on the customer's smartness.

First, the promotion part indicates the influence of promotion on the total utility. It is determined by multiplying the customers' sensitivity to promotion, and the promotion intensity of the product. In addition, since the low-involved customers are more susceptible to promotion (Puccinelli et al., 2009), they have a bigger impact of promotion on its total utility. Thus, a weight term is added in the promotion part of low-involvement customers' utility function. This is formulated as follows:

$$\text{Promotion effect}_{ij} = S_{i,pro} \times R_j \times \beta_{i,pro}$$

where,

$S_{i,pro}$	Customer *i* 's sensitivity to promotion
R_j	Promotion intensity of product *j*
$\beta_{i,pro}$	Weight on promotion effect of customer *i* regarding involvement type

$$\text{weight} = \begin{cases} 0.5, & \text{if customer } i \text{ is high} - \text{involvement} \\ 1, & \text{if customer } i \text{ is low} - \text{involvement} \end{cases}$$

Second, the quality part implies the effect of product quality on customer's total utility. One's utility on quality is determined by its sensitivity to the quality and quality of a product. However, calculating its quality score differs depending on its involvement type. The high-involvement customers value the product whose quality is similar to their ideal quality. Thus, their quality score of a product is calculated as an absolute value of one minus the difference between product candidate's quality and customer's ideal quality (Jager, 2007). This indicates that the smaller the difference between product candidate's quality and the customer's ideal quality, the greater the score is. On the other hand, the low-involvement customers simply prefer a product with higher quality. Therefore, their quality score is simply measured by the product's quality (Jager, 2007). This indicates that the higher the product candidate's quality is, the greater the score is. It can be formulated as:

$$\text{Utility on quality}_{ij} = \begin{cases} S_{i,qual} \times (1 - |A_j - Q_{ideal}|), & \text{if custmer } i \text{ is high} - \text{involvement} \\ S_{i,qual} \times A_j, & \text{if custmer } i \text{ is low} - \text{involvement} \end{cases}$$

where,

$S_{i,qual}$	Customer i 's sensitivity to quality
A_j	Quality of product j
Q_{ideal}	Preference on quality (ideal quality) of customer i

Third, the impact of social influence on the purchase decision is expressed in the social influence part. The social influence is measured by customer's sensitivity to social influence and the proportion of adopters of a certain product in a customer's social network. As explained in Section 4.1.2, customers have two types of social networks: online social network and offline social network. The influence from each social network is applied to utility function according to IT use. That is, if a customer better utilizes IT, then the social influence from online network will have a larger impact on its utility. Otherwise, the social influence from offline network will have a larger impact. In addition, due to the high susceptibility of high involvement customers on the online social influence (Van Dolen et al., 2007), a weight term is added in their online social influence part. To sum up, the following is how it is applied:

$$\text{Utility on social influence}_{ij}$$

$$= S_{i,social} \times \{(IT_i \times N_{ij,online} \times \beta_{i,social}) + ((1 - IT_i) \times N_{ij,offline})\}$$

where,

$S_{i,social}$	Customer *i* 's sensitivity to social influence
$N_{ij,n}$	Proportion of adopters of product *j* among customer *i*'s neighbours in its social network type *n* (online or offline)
IT_i	Proportion of IT utilization for customer *i*
$\beta_{i,social}$	Weight on social influence of customer *i* regarding involvement type

$$\text{weight} = \begin{cases} 1, & \text{if custmer } i \text{ is high} - \text{involvement} \\ 0.5, & \text{if custmer } i \text{ is low} - \text{involvement} \end{cases}$$

Finally, the total utility is assessed by integrating the three parts and price. The utility of a product can be calculated by adding the utility on promotion, quality and social influence. The reason why the promotion term is added to the total utility is that through promotion, producer can convince customers that the utility of its product is actually higher than they currently believe (Jager, 2007). Therefore, the utility of a product is composed of utility on quality, utility on social influence, and promotion. Once customers get the utility of products, they make trade-offs between the utility and the price of a product. It can be represented as the total utility of product j for customer i, and is determined by the utility of a product, a customer's budget and price of product. A budget represents one's willingness to pay for a product category. Also, one minus product price is applied to show the negative impact of high price. This can be formalized as (Jager, 2007):

$$\text{Total utility}_{ij} = B_i \times (1 - P_j) \times (Promotion\ effect_{ij} + Utility\ on\ quality_{ij} + Utility\ on\ social\ influence_{ij})$$

where,

B_i Budget of customer *i*
P_j Price of product *j*

4.2.4 Decision

After all product candidates are evaluated, the total utility score of each product is derived. Then, the highest utility score among all product candidates is compared with a given threshold value. If the score is higher than the threshold, the customer purchases that product. Otherwise, the customer goes back to the information search stage and finds a new set of product candidates. This process is repeated until the simulation ends. Some customers may not adopt any product during the simulation, if the adoption conditions are not satisfied. Once customers adopt a product, they send a message to a random online or offline friend, which triggers other customer agents to search for product information. Details of a customers' decision making process that was explained so far are summarized in Figure 4.2.

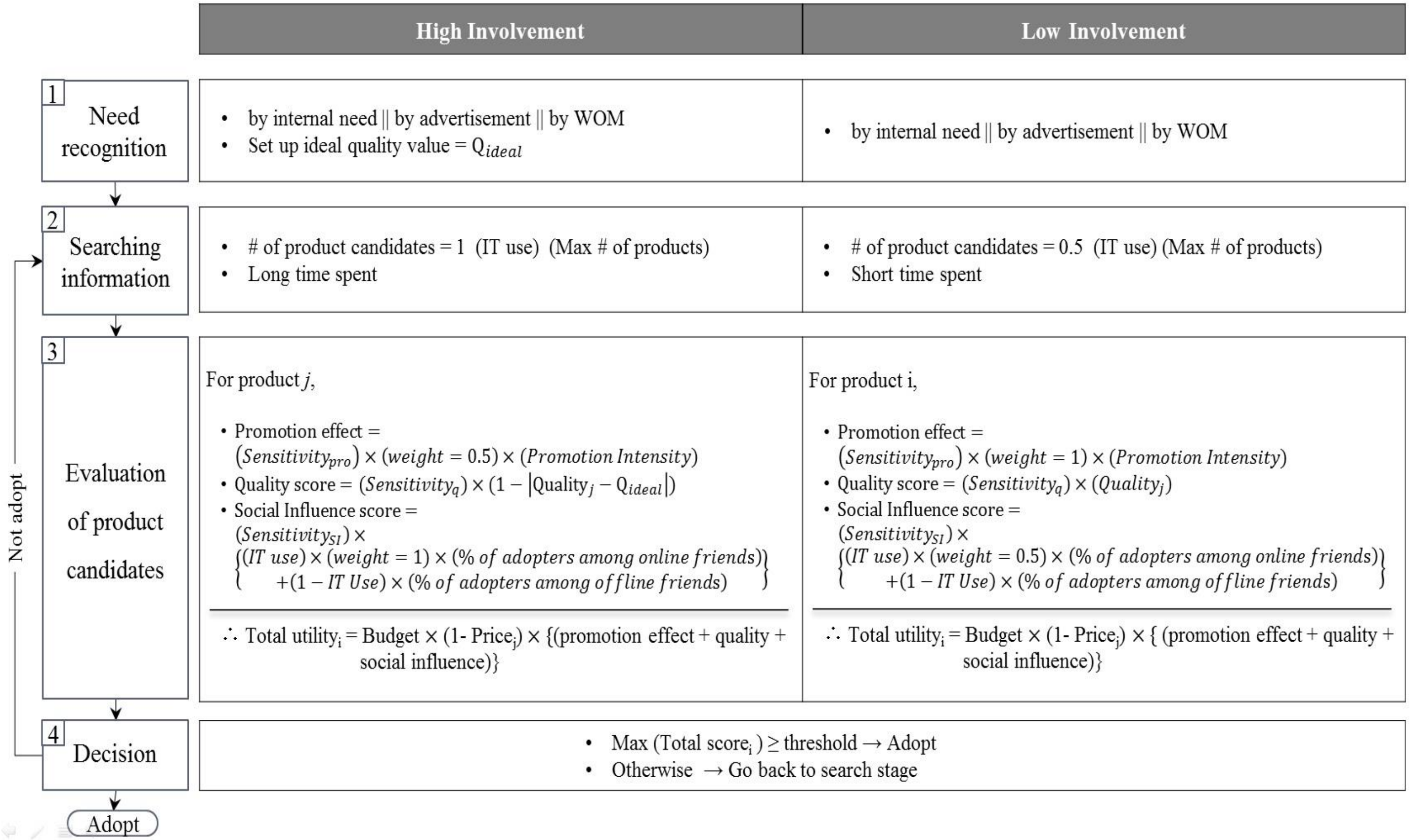

Figure 4.2. Details of customers' decision making process

Chapter 5. Simulation

5.1 Simulation overview

For this study, it is assumed that there exist several brands in a competitive market of a certain category, e.g. various brands in the smartphone market, and one brand produce one product. Thus, customers who want to buy a certain category, e.g. smartphone, will compare those products and select one of the products.

Prior to simulation, environmental and customer agents' parameters are set, which are fixed in all simulations. For the environmental parameters, the total population is 1000, and the simulation time is 30 days. In addition, the threshold value is set to 0.15, which can be adjusted by simulator to represent different behaviours of market. The moderate value for the simulation is decided by trial and error.

For customer agent's parameters, there are sensitivity to quality, promotion, and social influence, budget, ideal quality and social networks. The values of sensitivity to quality, promotion, and social influence are uniformly distributed between zero and one. Budget, which represents one's willingness to pay for a product category, also ranges from zero to one, and its distribution was determined by following the world population distribution by income which is published by Pew Research Center (2015). For ideal quality, it is important to note that its value has the triangular distribution with the mean as 0.5, which is assumed to be the most desirable quality value among the high-involvement customers. This can be adjusted by simulator to represent different characteristics of the high-involvement customers. For the structure of offline and online social network, the small-world network (Watts & Strogatz, 1998) with p=0.8, and the random network is used as mentioned in Section 4.1.2.

The parameters of a product agent, e.g. quality, price, and promotion intensity, have values between zero and one, as discussed in Section 4.1.1. The profile of a product is expressed as the combination of those values. The explicit values that we used for simulations are presented in the following section. Table 5.1 summarizes the parameters explained so far.

Table 5.1. Summary of parameters

Type	**Parameters**		**Values**	**Reference**
Environmental	Populations		1000	-
	Simulation time (days)		30	-
	Threshold		0.15	-
Customer agent	Smartness	Involvement	High or Low	-
		IT use	Value between 0 and 1	-
	Sensitivity to quality		$X \sim \mathcal{U}(0,1)$	-
	Sensitivity to price		$X \sim \mathcal{U}(0,1)$	-
	Sensitivity to promotion		$X \sim \mathcal{U}(0,1)$	-
	Budget		X ~ Tri (0, 1, 0.3)	World Income distribution (Pew Research Center, 2015)
	Ideal quality		X ~ Tri (0, 1, 0.5)	-

	Offline social network structure	Small-world network with p = 0.8	Watts and Strogatz(1998)
	Online social network structure	Random network (Network size $\propto$ IT use)	-
Product agent	Quality	Value between 0 and 1	-
	Price	Value between 0 and 1	-
	Promotion intensity	Value between 0 and 1	-

5.2 Simulation design

AnyLogic 7 Personal Learning Edition 7.3.1 was employed to conduct simulations. AnyLogic is a simulation tool developed by The AnyLogic Company. It supports the most common simulation methodologies: the agent-based modelling, system dynamics, and discrete event.

To find the effects of smartness on the diffusion pattern, we conducted two experiments. In the first simulation, we explored how the diffusion curves differ depending on the smartness in the given environment and products. For the price and promotion intensity of a product, two scenarios, e.g. high and low, were considered. For the quality of a product, three scenarios, e.g. high, ideal, and low, were considered to deal with the ideal quality. As a consequence twelve profiles of product were derived (See Table 5.2).

Table 5.2. Product profiles in Experiment 1

Profile	Price	Quality	Promotion intensity
A	0.1	0.9	0.9
B	0.1	0.5	0.9
C	0.1	0.1	0.9
D	0.1	0.9	0.1
E	0.1	0.5	0.1
F	0.1	0.1	0.1
G	0.9	0.9	0.9
H	0.9	0.5	0.9
I	0.9	0.1	0.9
J	0.9	0.9	0.1
K	0.9	0.5	0.1
L	0.9	0.1	0.1

As showed in Table 5.3, the first experiment further divided into three simulations. Simulation 1 and Simulation 2 examine the impact of IT use and Involvement on the diffusion, respectively. In Simulation 3, the impact of smartness is examined. The smartness of a market is determined by aggregating the smartness of all agents. Thus, it can be expressed by the average degree of all agents' IT use and the proportion of the high-involvement customers in the market. The aggregated diffusion curve, the diffusion curves of each product profile as well as the market share of twelve products were obtained as the output of the first experiment.

Table 5.3. Input settings and the expected outputs of Experiment 1

	Input setting	**Expected output**
Simulation 1	Variation in IT use	Aggregated diffusion curve
Simulation 2	Variation in Involvement	Aggregated diffusion curve
Simulation 3	Variation in Smartness	Aggregated diffusion curve Adoption rate curve Diffusion curves of twelve products Market share of twelve products

The second experiment analyses the customer's sensitivity on each parameter of product (price, quality, and promotion) by expanding Simulation 3. Input settings and value of parameters are unchanged from Simulation 3 except the profiles of product. For example, to examine the sensitivity on quality, three products are given instead of twelve products by only varying a value of quality and fixing values of price and promotion intensity (See Table 5.4). Likewise, the sensitivity on quality, price, and promotion are analysed respectively.

Table 5.4. Product profiles for the sensitivity analysis in Experiment 2

	Profile	**Price**	**Quality**	**Promotion**	**Details**
Simulation 4	A	0.5	**0.5**	0.5	Most desired quality by the high-involvement customers
	B	0.5	**0.9**	0.5	Best quality

	C	0.5	**0.1**	0.5	Worst quality
Simulation 5	A	**0.5**	0.5	0.5	Medium price
	B	**0.1**	0.5	0.5	Best price
	C	**0.9**	0.5	0.5	Worst price
Simulation 6	A	0.5	0.5	**0.5**	Medium promotion intensity
	B	0.5	0.5	**0.9**	Highest promotion intensity
	C	0.5	0.5	**0.1**	Lowest promotion intensity

5.3 Simulation results

In Simulation 1, the impact of IT use on diffusion was examined. As shown in Figure 5.1, the degree of IT has positive effect on the diffusion. As customers utilize IT on their decision making process, the diffusion speed and the total number of adopters increased. However, when the average degree of IT use is over 0.3, the effect of IT use in the diffusion became trivial. The observed correlation between IT use and the diffusion pattern might be explained in this way. By utilizing IT, customers obtain much more product candidates and are exposed to online WOM, which increase the likeness of adoption.

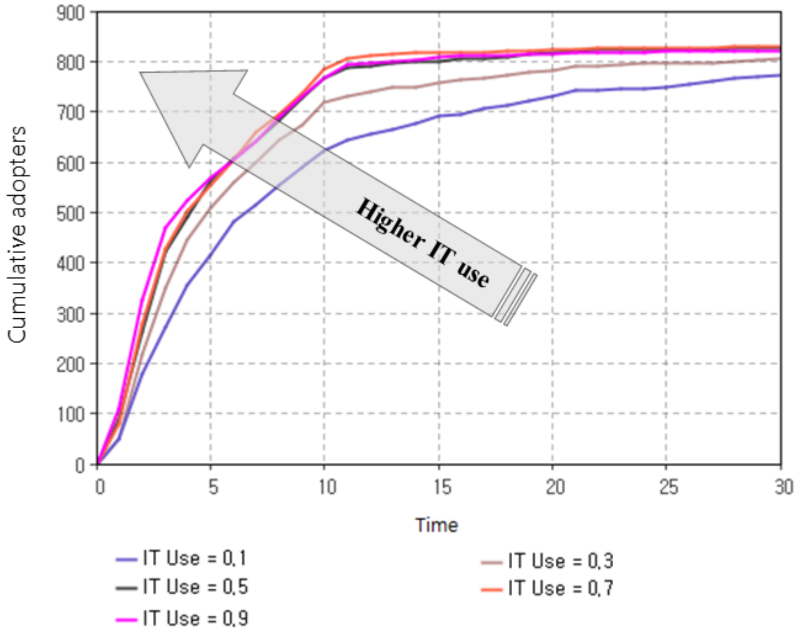

Figure 5.1. Simulation 1: Aggregated diffusion curves by IT use

In Simulation 2, the impact of customer involvement on diffusion was examined. As shown in Figure 5.2, the proportion of the high-involvement customers in a market has negative effect on the diffusion. As there are more high-involvement customers in a market, the diffusion speed and the total number of adopters decreased. A possible explanation for these results may be that as customer gets more involved in the purchase process, they consider more product candidates and spend more time on the decision making process trying to find the product they want. This corresponds to the characteristics of customer involvement, which was discussed in Section 3.1.

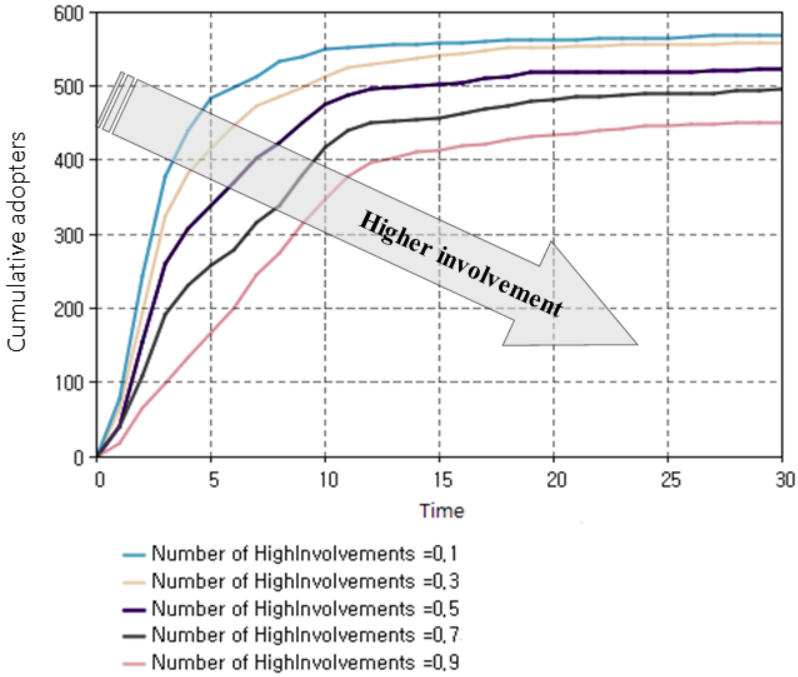

Figure 5.2. Simulation 2: Aggregated diffusion curves by Involvement

In Simulation 3, both IT use and Involvement was adjusted to analyse the impact of smartness on diffusion. As shown in Figures 5.3 and 5.4, as the smartness of the market increases, the diffusion speed decreases. Also, there are slight differences in the total number of adopters. It is interesting to note that as the smartness gets higher, the adoption rate graph (See Figure 5.4) shifts to the right. As smart customer spends more time than the less smart customers before adopting a product, this may look like smart customers are late adopters or laggards. However, since this study modelled heterogeneous customers while Rogers (2003) assumed homogeneous, it cannot be concluded that smart customers are late adopters or laggards. In addition, the present finding seem to be consistent with Big-bang disruption studied by Downes and Nunes (2014) that the new digital platforms which is enabled by the advancement of information technology brings the explosive diffusion of innovation. Like Big-band disruption (Downes & Nunes, 2014), the overall curve is shifted to the left compare to the traditional diffusion curve by Rogers (2003).

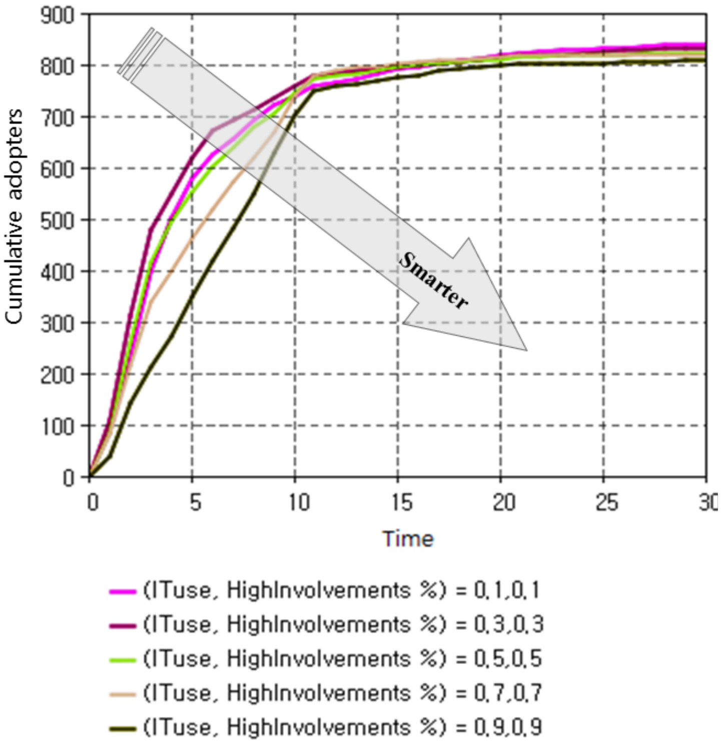

Figure 5.3. Simulation 3: Aggregated diffusion curves by Smartness

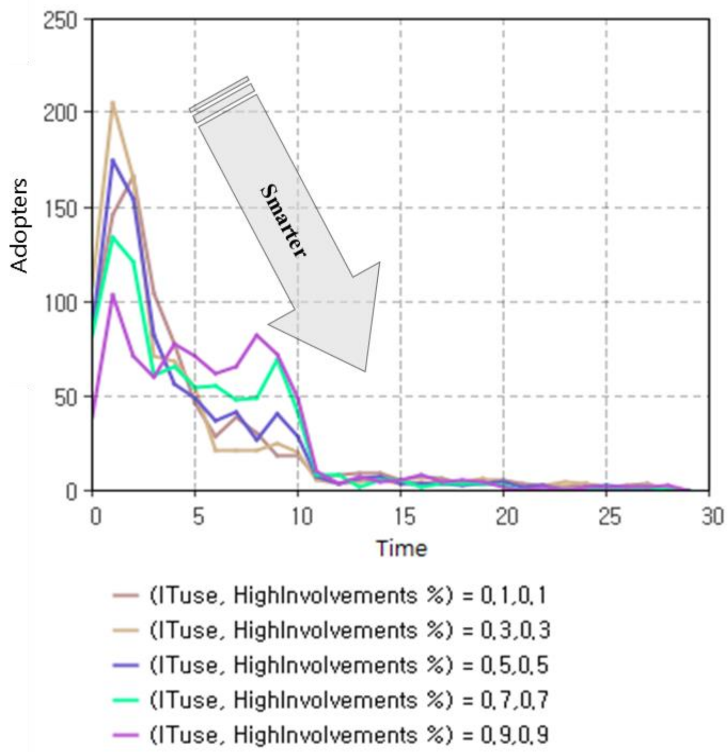

Figure 5.4. Simulation 3: Adoption rate curve

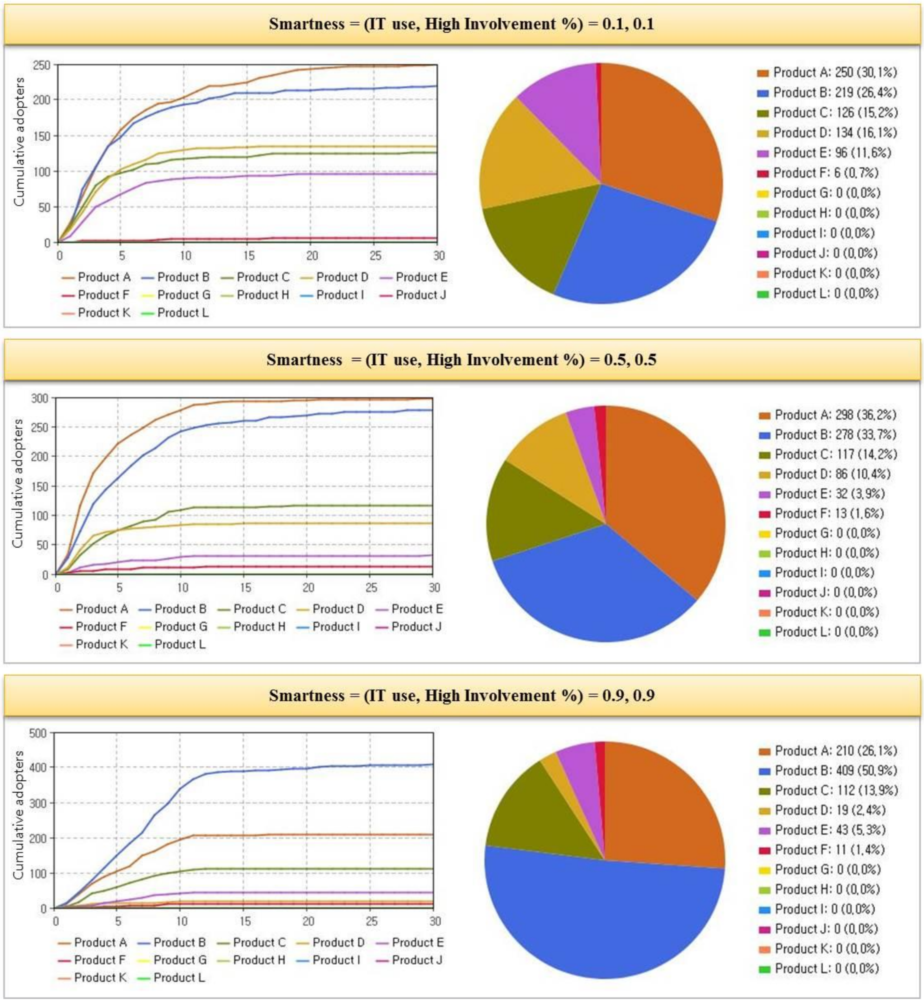

Figure 5.5. Simulation 3: Diffusion curves (left) and market shares (right) of twelve products by smartness

In addition, Figure 5.5 shows the diffusion curves and the market share of each product by smartness. In the least smart market, the market share is fairly distributed among five products. Those products commonly have a low price, and three of them have high promotion intensity. This is because less smart customers prefer inexpensive product and are easily tempted by promotions. Thus, it is important to make the product's price as low as possible and the promotion intensity as high as possible. In the smartest market, however, Product B dominates more than half of the market share. It is notable that Product B does not have the highest quality but the ideal quality value. Therefore, in smart market it is important to investigate the most desired level of quality.

Simulation 4 is to analyse the customer's sensitivity on product quality (See Figure 5.6). In the market with low and medium smartness, high quality product is adopted the most. The reason is that most of the customers in the markets prefer the higher quality. Also, due to the low degree of IT use and their low level of involvement they have low chance to find and compare various products. On the other hand, in the smartest market, customers have a specific ideal quality and utilize IT as much as they can to find the best product. As a result, the medium quality product, which has the most desired quality by the high-involvement customers, gets the largest market share. The results reveal the importance of investigating the ideal quality which is consistent with the result of Simulation 3.

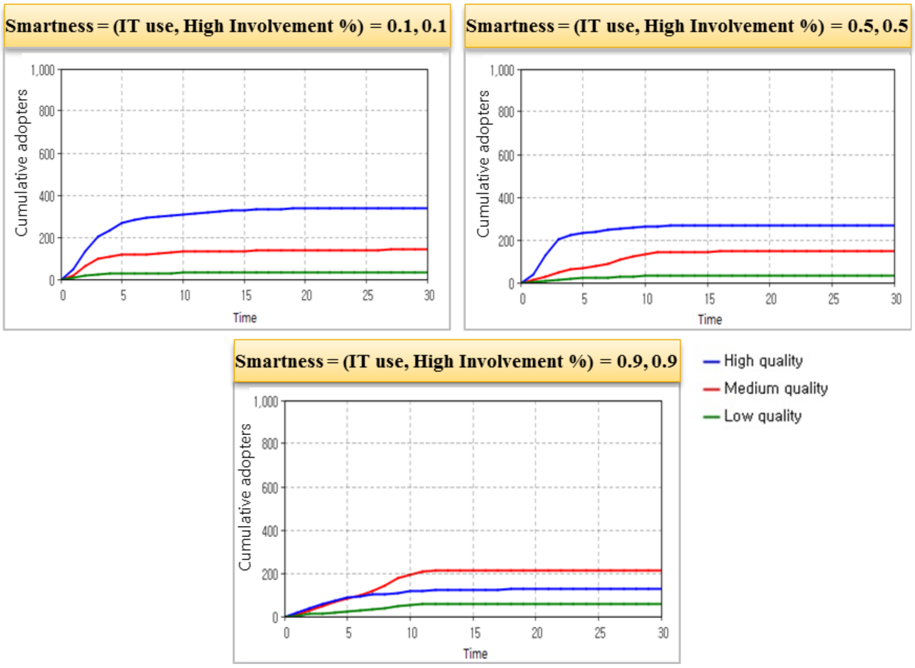

Figure 5.6. Simulation 4: Aggregated diffusion curves by quality in the markets of different smartness

Next, in Simulation 5, the sensitivity on price was examined. As depicted in Figure 5.7, the product with low price has the most of the market share followed by the medium priced product in the least smart market. Even though customers prefer lower price regardless of their smartness, the product with high price still has some market share. That is, less smart customer may not find the product with low price due to their low degree of IT use. Consequently, they have no choice but to adopt the product with medium or high price. In the smartest market, without doubt, the product with lowest price dominates the market. The reason is that smart customers can utilize IT as much as they can to find the most inexpensive product, and this leads to the zero adoption of medium and high-priced product.

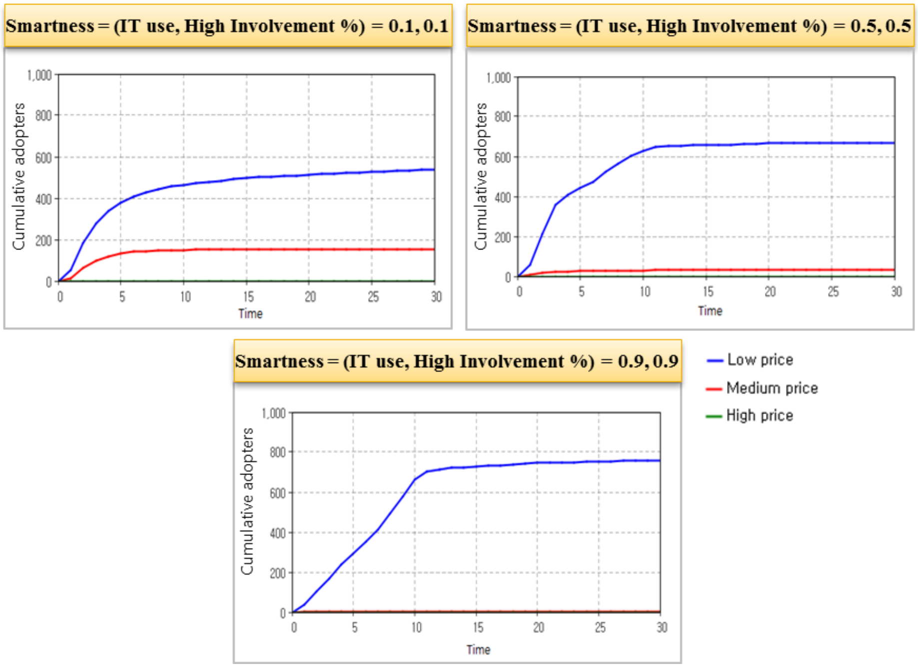

Figure 5.7. Simulation 5: Aggregated diffusion curves by price in the markets of different smartness

Finally, in Simulation 6, the sensitivity on promotion intensity was analysed. As can be seen from Figure 5.8, the product with the highest promotion intensity is adopted the most in the least smart market. In such market, most of the customers are vulnerable to a promotion. However, there are some chances for the product with the medium and low promotion intensity, because of the same reason explained in Simulation 5. In the smartest market, as all customers are sensitive to promotion and they utilize IT in a high degree, the product with highest promotion intensity dominates the market.

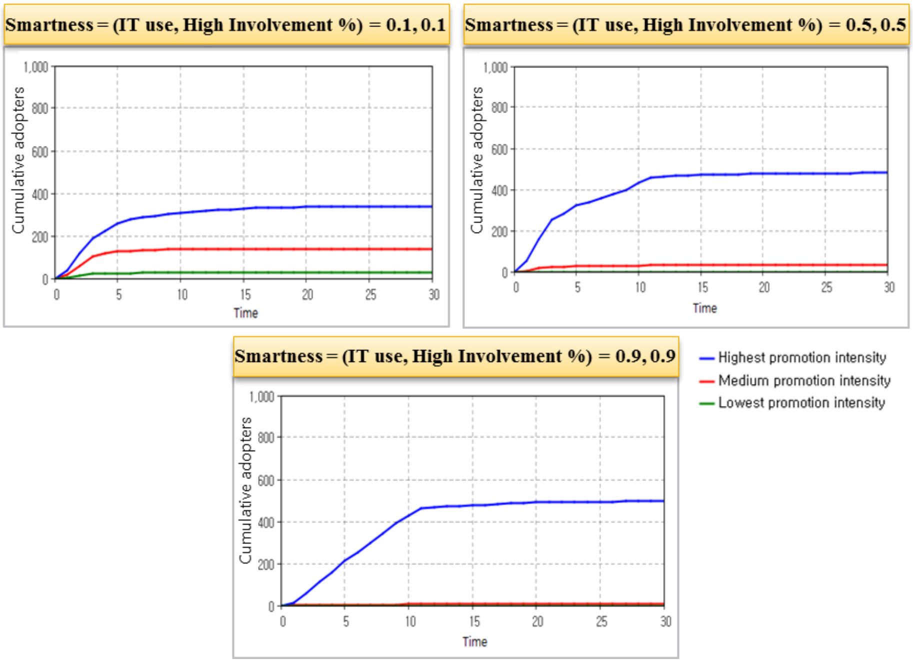

Figure 5.8. Simulation 6: Aggregated diffusion curves by promotion intensity in the markets of different smartness

Chapter 6. Discussions and conclusions

6.1 Summary and comparing the results with the empirical data

This study aims to examine the effect of smartness on the diffusion process. To achieve the goal, the term ‘smartness’ was defined with the concept of customer involvement and the individuals’ ability to utilize IT. Then the relation between smartness and the decision making process was discussed. With the findings, heterogeneous behaviour of customers was formulated with an agent-based model. Finally, two experiments were conducted to examine the effect of smartness on diffusion process.

The main finding is that smartness has a significant influence on the diffusion pattern. Experiment 1 shows that the innovation diffuses slower and the total number of adopters is slightly fewer in the smart market. In the micro perspective (brand level), one or few innovation with inexpensive price and the high promotion intensity tends to monopolize both smart and less smart market. However, there are different behaviours on product quality. In the smart market, the products with the ideal quality have been adopted the most by customers, while the high quality products have been selected the most in the less smart market. To sum up, the product with the most desired quality by smart customers dominates the smart market, though it diffuses slowly.

The sensitivity analysis in Experiment 2 reveals that smarter customers are more sensitive to price and promotion. The possible explanation could be that smart customers have the ability and willingness to search and evaluate for the best product. Thus as customers get smarter, the innovation should effectively satisfy their needs.

To provide minimal validation of the findings, the result of Simulation 1 (in Experiment 1) was compared with the empirical data. A smartphone, which is the most powerful innovation that has changed our life, was selected as the target innovation. In addition, several assumptions were made. First, five countries, e.g. South Korea, United Kingdom, United States, China and Indonesia, are selected for the markets with different smartness. Second, ICT development index (IDI) from International Telecommunication Union (International Telecommunication Union, 2009, 2011, 2015) was used as the proxy of IT use (See Table 6.1). Third, the proportion of the high-involvement customers in each country is assumed to be the same, as it is difficult to find the data that represents customer involvement. Table 6.1 shows ICT Development Index on a scale of 10, and the relative rank between five countries. It is found that South Korea is the smartest market followed by UK, US, China, and Indonesia.

Table 6.1. IDI index as a proxy of IT use (International Telecommunication Union, 2009, 2011, 2015)

Year / County	2002	2007	2008	2010	2015	Rank
South Korea	5.83	7.26	7.80	8.52	8.93	**1**
UK	5.27	6.78	7.03	7.61	8.75	**2**

US	5.25	6.44	6.55	7.20	8.19	**3**
China	1.95	3.11	3.17	3.62	5.05	**4**
Indonesia	1.54	2.13	2.39	2.97	3.94	**5**

The smartphone penetration rate by country from 2011 to 2016 [1] was used to compare the diffusion pattern of each country. As depicted in Figure 6.1, smartphone diffuses faster in the smarter countries. This is consistent with the result of Simulation 1 in Experiment 1.

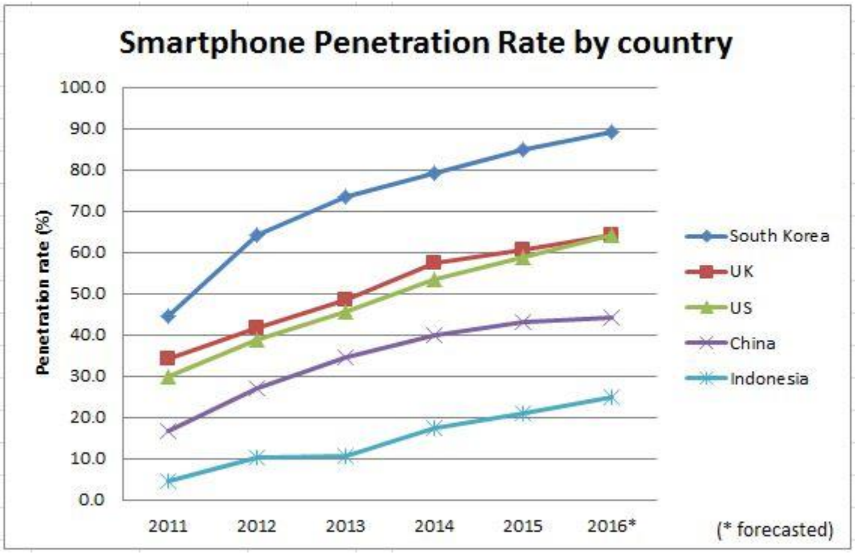

Figure 6.1. Smartphone penetration rate by country

[1] South Korea: Ministry of Science ICT and Future Planning (2016) ; UK: eMarketer (2013); US: Statista Market Analytics (2016); China: eMarketer (2015); Indonesia: eMarketer and Statista Market Analytics (2016)

6.2 Implications and limitations

There are three theoretical implications of this study. Firstly, this work contributes to existing diffusion studies of customer heterogeneity by proposing the new factor, e.g. smartness, and examining its effect on the diffusion of innovation. Particularly, smartness is defined in terms of customers' capability (IT use) and characteristics (Involvement), which is meaningful and adequate for the current market with the near-perfect product information and information transparency. Secondly, the effects of smartness in the adoption process was precisely explored by reviewing relevant literatures, and integrated in the model. For example, the decision making process was divided into four stages (need recognition, information search, evaluation, and decision), and how customer involvement and IT use influence each stage was explained. Furthermore, their influence on each term, e.g. price, quality, promotion intensity, and social influence, of the utility function was presented in details in the evaluation stage. Lastly, ABM is employed to deal with the customer heterogeneity with respect to smartness. An ABM technique can explicitly model customers' heterogeneity and their decision making processes, capture emergent market dynamics and is adequate for what-if-type question (Kiesling et al., 2012). In this regard, this agent-based model examines the impact of smartness on diffusion by controlling the smartness of each customer, and allows the interaction between customer and product agents.

This work also gives practical implication. Considering smartness of customers would provide understanding the customer behavior and insights on positioning innovation in a market. For example, in order to target smart customers, e.g. smartphone market in South Korea, it is important to investigate the most desired quality and provide such innovation with reasonable price. Also, the provider should provide full product information on the Internet, and focus on online promotions and monitor online reviews which increase likeness of purchase of smart customers. On the other hand, in order to target less smart market, e.g. smartphone market in Indonesia, it is important to lower the price as much as possible and focus on traditional promotions such as commercials and offline word-of-mouth, considering the finding that the price is the key factor for non-smart customers.

The agent-based model proposed in this paper considered many factors, e.g. the structure of online and offline social network, trigger by internal need, word-of-mouth effect, and advertisement effect, to make the model more sophisticated and realistic. Also extensive literatures were reviewed to carefully select the values of parameters and inputs to consider all possible scenarios in the experiments. However, the main weakness of this study is that the selection of parameter values was not based on the empirical data. Although the effect of IT use on the diffusion of innovation was shown with the empirical data in the previous chapter, the systemic validation and calibration with the empirical data should be provided to enhance effectiveness of the model.

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초 록

정보통신 기술의 발달과 파급으로 인해 오늘날의 고객들은 완벽에 가까운 시장 및 제품 정보를 스마트폰 및 인터넷을 통해 얻을 수 있게 되었다. 즉, 혁신 채택 과정에서 고객들은 점점 스마트(smart)해지고 있을 뿐만 아니라, 각 고객의 스마트한 정도(degree of smartness)는 상이하게 나타나고 있다. 이러한 고객의 스마트함(smartness)은 혁신 채택 의사결정 과정에 영향을 끼칠 수 있으며 궁극적으로 혁신의 확산에 영향을 끼칠 수 있다. 하지만 이전 혁신 확산 연구들은 스마트함을 혁신 확산의 요인으로 고려하지 않았다.

본 연구의 목적은 고객의 스마트함이 혁신 확산 패턴에 끼치는 영향을 탐색하는 것이다. 그 과정에서 고객 관여와 정보통신 활용 능력이라는 두 개념을 이용하여 고객의 스마트함을 정의하고, 그것이 혁신 채택과정 각 단계에 미치는 영향을 알아본다. 연구 기법으로는 행위자 기반 모델 기법을 채택하였다. 행위자 기반 모델링 기법이란 시스템 내에 존재하는 행위자들의 행동 법칙을 기반으로 이들의 상호작용에 의해 시스템에 등장하는 거시적인 현상을 관찰할 수 있는 시뮬레이션 기법으로서 고객의 이질성을 반영한 확산을 연구하기에 가장 적합한 연구 방법이다. 이 기법을 이용하여 스마트한 정도에 따라 다른 고객 행동 법칙을 모델링하고 시뮬레이션을 통해 혁신 확산에 끼치는 영향을 탐색하였다.

본 연구는 고객의 스마트함이라는 새로운 혁신 확산 요소를

제시함으로써 기존 혁신 확산 연구에 기여하며, 고객의 성향이 급변한 시장 상황을 반영하여 새로운 분석 방법을 제시했다는 것에 의의가 있다. 또한 스마트 고객의 행동 양상에 대한 이해와 스마트 고객으로 형성된 시장에 혁신을 출시할 때 필요한 통찰력을 제공한다.

주요어: 스마트 고객(Smart customer), 스마트함(Smartness), 확산, 행위자 기반 모델(Agent-based modelling), 고객 관여(Customer involvement), 정보통신
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