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Who will be smart home users? An analysis of adoption and diffusion of smart homes☆

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ABSTRACT

A smart home is considered a primary service of the Internet of Things (IoT), and global leading companies are launching smart home services/products based on the IoT. However, the spread of smart homes has been slower than expected, and analysis of smart homes from a demand perspective is required. This study suggests implications for promoting the smart home market by analyzing factors affecting adoption and diffusion of smart homes. A technology acceptance model was used to describe the adoption of smart homes and a multivariate probit model was used to describe the diffusion of smart homes. The characteristics of smart homes such as network effects between services/products and the importance of personal information protection were considered in addition to demographic variables. The results of this study show that compatibility, perceived ease of use, and perceived usefulness have significant positive effects on purchase intention. In terms of purchase timing, unlike other information and communication technology (ICT) services/products, older consumers are more likely to purchase smart homes within a given time period than are younger consumers. Therefore, a strategy for promoting smart home purchases by young consumers is required to increase market demand.

1. Introduction

Interest in various Internet of Things (IoT) services is increasing as most objects can now be connected to a network through the IoT. Among these services, smart home services are regarded as killer applications in terms of marketability and consumer accessibility. A smart home is defined as "an intelligent environment that is able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt and meet the goals of comfort and efficiency" (Perumal et al., 2013). Smart home services include the control and automation of lighting, heating (e.g., smart thermostats), ventilation, air conditioning (HVAC), and security, as well as home appliances such as washers/dryers, ovens, and refrigerators/freezers.

Smart homes are emerging as a new competitive market for ICT companies as they seek to find new revenue sources due to saturation of the smart phone market. Major players leading the ICT ecosystem are rushing to release smart home services/products. For example, Amazon allows consumers to control their home appliances through Alexa, an artificial intelligence-based voice recognition technology. Google provides smart home services through 'Google assistant,' which includes personal assistant services based on voice recognition and artificial intelligence technology. For their smart home services, Amazon and Google offer smart speakers called 'Amazon Echo' and 'Google Home,' respectively. Telecommunications companies provide similar smart home devices such as speakers or set-top boxes.

Despite the competitive launch of smart home services/products, the global smart home[1] penetration rate of households is 7.5%, with revenue expected to reach $46,252 m in 2018 (Statista, 2018). Greenough (2016) pointed out that the smart home market is currently in a chasm between early adopters and the mass market. This chasm, in spite of suppliers actively providing smart home services, means that it is necessary to analyze smart homes from a consumer perspective. First, the adoption rate of smart home services will vary depending on the consumer utility for automatically controlling connected items such as

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[1] According to Statista (2018), smart home services/products include digitally connected and controlled devices, sensors, actuators, and cloud services that support automation, control hubs to connect sensors and actuators, B2C hardware, and software sales. However, smart TVs, smart gardening devices, and B2B/C2C sales such as hotels are excluded.

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home appliances. Therefore, it is important to analyze consumers' intentions to adopt smart home services and the factors influencing the adoption rate (diffusion) of smart homes in order to determine how to increase smart home demand.

In addition, smart homes have attributes that are different from other ICT services or products, such that specific analysis of smart homes is required. A smart home has individual products or services interconnected to one other. Therefore, compatibility is an important factor when choosing smart home services compared to other IoT services since smart home services require connections and communications among various home appliances. It is also not easy to purchase a smart home all at once because different services/products have different replacement cycles, many of which are long. The choice of one smart home service might depend on other smart home services as smart home services require communication within a smart home. Consequently, analysis of smart home services from a system perspective consisting of interworking (or combining) individual smart devices is appropriate rather than considering the selection of each device individually.

Few previous studies have analyzed smart homes from a user perspective, while a lot of research has occurred on smart home technologies. Some studies that have analyzed smart home technologies based on IoT are as follows. Soliman et al. (2013) suggested an approach to develop smart home applications based on IoT and Cloud. Li and Yu (2011) presented smart home system design based on IoT. Chong et al. (2011) analyzed the characteristics and disadvantages of smart home systems. Stojkoska and Trivodaliev (2017) presented a framework for narrowing the gap between current and future smart homes based on IoT. Feng et al. (2017) suggested how to apply IoT and a cognitive dynamic system to smart homes. Hui et al. (2017) provided seven major requirements for establishing a smart home. Mao et al. (2017) analyzed a design scheme of an intelligent home system.

There have been attempts to analyze smart homes from the user's perspective. Yang et al. (2016) analyzed user adoption of smart home services using a partial least squares method. Park et al. (2018) analyzed adoption of smart homes using a technology acceptance model. Kim et al. (2016) estimated willingness to pay for smart home services using a contingent valuation method. Richter and Pollitt (2016) analyzed the choice of smart electricity service using a discrete choice model. While these studies empirically analyzed smart home services from the user's point of view, none of them simultaneously analyzed adoption and diffusion. In addition, previous studies analyzed individual smart home services/products without considering a system perspective.

This study suggests a strategic direction to overcome the chasm following early adopters by analyzing how acceptance depends on the characteristics of smart home services and factors affecting the diffusion of smart home services. The remainder of this paper is organized as follows. Section 2 describes the research models, and section 3 describes the survey design and empirical data for adoption and diffusion of smart homes. Section 4 presents an analysis of the main factors influencing adoption and diffusion of smart home devices as part of a smart home system. Lastly, section 5 presents a summary of our results and provides a market revitalization strategy for smart home systems.

2. Methodology

2.1. Data

Micro-level consumer data is required to analyze factors affecting consumer adoption and diffusion of smart home services. However, revealed preference data for smart home service markets, especially market data on individual consumer choices, are difficult to obtain since the smart home market is in its early stages. Therefore, instead of using revealed preference data, this study used stated preference data from surveys that included usage behavior for smart home services.

Two different surveys were used in this study. One attempted to clarify the intention to adopt IoT services, while the other investigated usage behavior of IoT services. The two surveys were used together as each individually was not designed to analyze both adoption and diffusion factors simultaneously. Characteristics of smart homes were required to analyze adoption according to the attributes of smart homes, while purchase timing data was needed to analyze diffusion. The first survey was designed to analyze consumer adoption and did not include purchase timing data. On the other hand, the second survey included data on the intention to use, but the characteristics of services were not investigated. Therefore, the first survey was used to analyze adoption, while the second survey was used for diffusion despite the lack of a uniform survey population.

The respondents of the first survey used for adoption analysis were 310 South Korean smartphone users who could be potential smart home service users. Data were collected through a mobile survey. All 310 individuals were smartphone owners, 152 of whom (49%) were male, and 158 (51%) were female. By age, 23% were in their teens, 19% in their 20s, 22% in their 30s, 19% in their 40s, and 18% in their 50s or older. The respondents of the second survey used for the diffusion analysis were 2113 smartphone users, aged 20 to 65. The survey was conducted online. Of the respondents, 1059 (50%) were male, and 1054 (50%) were female. By age, 22% were in their 20s, 30% were in their 30s, 26% were in their 40s, 16% were in their 50s, and 5% were in their 60s. The samples were not significantly different from the age and gender distributions of South Korea. In the second survey, smart home services were divided into three categories based on home appliance size. Respondents were asked about status of use, intention to use, and when to purchase (if the respondents were willing to become users) of large, medium, and small home appliances.

$<$ 4% of respondents currently use a smart home service, but 46.4% of respondents showed high intention to use in the future. This study suggests approaches for activating smart home services by analyzing influential factors.

2.2. Model specifications

2.2.1. Extended technology acceptance model for analyzing adoption of smart home services

The technology acceptance model (TAM), originally developed by Davis (1989), is one of the most popular methodologies for analyzing consumer acceptance intentions. TAM analyzes consumer acceptance intentions through perceived usefulness and perceived ease of use. According to Davis (1989), perceived usefulness is defined as a user's ability to utilize the system to improve his/her performance, while perceived ease of use is the degree to which the user can use the system without effort. TAM has been sufficiently explanatory for analyzing user acceptance in previous studies. However, Legris et al. (2003) pointed out that it is necessary to extend TAM according to the characteristics of the technology analyzed because consumer objectives for adopting ICT are different for each technology. In this study, therefore, TAM was extended by additionally considering compatibility and privacy protection factors beyond the perceived usability and perceived ease of use of the basic TAM. The extended TAM was used to analyze consumer acceptance of smart home services as shown in Fig. 1.

As pointed out earlier, compatibility is a critical factor in adopting smart home services since it is important to assess how smart home services are interoperable with various home appliances and external services. Compatibility was considered an important factor for adoption of ICT products in Chen et al. (2009), Corrocher (2011), and Wu and Wang (2005). In addition, Liébana-Cabanillas et al. (2014), Hwang (2014), and Yang et al. (2016) analyzed the effects of compatibility on acceptance of smart homes, fintech, and wearable services, respectively. Therefore, this study assumes that high compatibility of smart home services could be a factor enhancing consumer convenience.

Personal information protection has also been recognized as an