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Internet of Things: Exploring households' intention to use smart home technology

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Abstract

Smart home technology, an application of Internet of Things (IoT), provides householders with e.g., comfort, control and convenience. The technology has been around for sometimes, but its prevalence is not yet widespread, and thus the potentials have largely been underestimated. This paper aims to explore the antecedent factors influencing the adoption of smart home technology through analysis of a survey data comprising of 156 households. This paper, in addition to Structural Equation Modelling (SEM), applies an analytical thinking method called “Fuzzy-set Qualitative Comparative Analysis” to analyse the data. The SEM results indicate that consumer perceived innovativeness, perceived newness, social influence and attitude toward using smart home technology are notable antecedents of intention to use. Moreover, the results show that the perceived cost negatively affect the intention to use. FsQCA results, while confirming SEM findings, strengthen the results by revealing that there is no single solution that lead to the outcome, but multiple configurations of conditions lead to the outcome of interest. This paper contributes to the literature of IoT, in particular to smart home research. Some practical implications and research recommendations are discussed.

Keywords: Internet of Things, Smart home technology, Perceived cost, Fuzzy-set Qualitative Comparative Analysis

1. Introduction:

Internet is being excessively used, there are now more than 4 billion people around the world using the Internet for different purposes such as social media networking, Internet browsing, online purchasing, playing games and many other things (We are Social, 2018). According to this recent report, Internet users expands even further and it comes as no surprise that the use of Internet will take on new forms and be used in more innovative ways. One particular phenomenon that has particularly gained attention over the last decade along with the rapid growth of Internet users is the Internet of Things (Evans, 2011; Perera et al., 2014). Internet of Things (hereinafter refers to IoT) is an umbrella term used for the internetworking of physical objects and devices such as the connection

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of vehicles, buildings, home appliances and other physical objects to the Internet, thus transforming the objects from being “dumb” to “smart”. IoT technology and the interaction between Internet connected objects enable service providers to design and develop new digital devices and services to be used by, for example, households. Objects that are connected to the Internet can be controlled remotely enabling data collection and data exchange. The concept of Internet of Things is not a new phenomenon or a new invention, though has gained a lot of attention during recent years. Smart objects have already been around for a long time, for instance Coca Cola has been one of the first companies to use sensors in objects and devices for over 20 years (Smith, 2015).

The IoT also embraces another way of utilizing the advancement in the technology, which is highly dependent of sensor technology, for instance in the home appliances. Thus, this paper focuses mainly on smart home technology as one particular application IoT. Smart home environment is known also as smart house or intelligent home or connected home. Moreover, smart home is an application of ubiquitous computing that recedes into the background of citizens’ lives (Weiser, 1996). Smart home technology consists of hardware, sensors and switches in order to automate devices, appliances and systems. Smart home networked-connected appliances such as smart Microwave run in the background and can be controlled automatically in the residence.

From academic and practitioners’ perspectives, it is vital to know how the potential users of smart home technology perceive this innovation and form their attitudes whether to use the technology or not. In this paper, the central question guiding this research is: *what antecedent factors influence individual’s intention to use smart home technology?* To address this question, through an empirical investigation, this paper aims to identify determinant factors influencing one’s intention to use this particular technology. Literature on smart home technology research shows that consumer perceived innovativeness and perceived newness of an innovation directly affect attitude toward using the technology and thereby influencing the intention to use.

In addition to these factors, the current paper integrates other determinants such as social influence and perceived cost from Unified Technology of Acceptance and Use of Technology II (UTAUT2) developed by Venkatesh et al. (2012) which is a recent adaptation of the most widely used technology acceptance model (TAM: Davis, 1989). The smart home technology for health and social care support has been studied extensively (e.g., Liu et al., 2016; Martin et al., 2008), but far less attention has been paid to smart home technology use by the households.

This paper is organized as following. Section two provides the literature review on smart home technology in general. Section three provides the research model and presents the hypotheses. Section four discusses the research methodology, followed by discussion of the findings in Section five. Finally, discussions and conclusion are presented in Section six.

2. Literature Review

Individual acceptance and use of Information Technology is one of the most studied topics in Information Systems research. Literature shows sheer amount of prior studies using different theoretical frameworks to understand the nuances of individual attitudes and behavioural intentions to adopt and use of technology. For instance, in the context of smart home technology, Peek et al. (2014) used factors such as social influence, perception of technology, and some characteristics of older adults to identify antecedent factors influencing the acceptance of technologies that support aging in place. The study results show that acceptance of technology by the elderly people is influenced by other factors rather than the key constructs of the TAM. The results show that older adults are more concerned with additional benefits of technology (e.g., increased safety and increased independence) rather than just perceived usefulness (p. 245).

In the context of wearable technology in healthcare, Gao, Li and Luo (2015) investigated the factors that influence individual's intention to adopt the technology by integrating three theoretical models (i) unified theory of acceptance and use of technology 2 (UTAUT2), (ii) protection motivation theory (PMT), and (iii) privacy calculus theory. The results show that intention to use technology is influenced by factors such as social influence, hedonic motivations and perceived privacy risk. Whereas, in the context of adoption of medical internet-connected devices, the authors reported that factors such as perceived expectancy, self-efficacy, effort expectancy, and perceived severity are considered to be more important (p. 1718).

Moreover, Brauner, Van Heek and Ziefle (2017) studied people's attitudes towards smart textiles and its relationship to the intention to use technology in home environment by making use of UTAUT2. The authors asserted that individual's intention to use technology is strongly influenced by three antecedent factors: habit, hedonic motivations, and performance expectancy. Furthermore, security of smart home environment has been an important research stream. Some authors stated that while smart homes as an application of the Internet of Things (IoT) technology are becoming increasingly popular, the security challenges and threats to the existing solutions for smart homes are less studied. The authors stated that new security algorithms tailored for the specific security characteristics of

smart homes should be developed in order to make the smart home environment secure and safer (Lee et al., 2014, p. 72). In the following section, the research theoretical background is discussed.

3. Research Model and Hypothesis Development

In accordance with the literature and inspired by conventional theory (i.e., Technology Acceptance Model) developed by Davis (1989), prior studies have extensively used this model to understand user's acceptance of technology (e.g., Kim and Shin, 2015; Nikou and Bouwman, 2014). TAM tries to explain the adoption process and underlying influential factors in technology acceptance. However, there are several critiques that TAM has limitations and cannot explain various forms of technology (Nysveen et al., 2005; Tarhini et al., 2015). One of the limitations of TAM is that it was designed to be used in an organizational context rather than in everyday life context, making it less appropriate theoretical framework for smart home research. Smart home technology is an everyday life context application which links technology and households, therefore cannot sufficiently be investigated by the TAM framework. Moreover, in the context of households, individuals incur a cost when transacting using the technology, an important factor that could significantly influence usage and cannot be ignored in a research on the antecedents of smart home technology acceptance. Therefore, there are other variables which could potentially influence the acceptance of the technology which are not present in the TAM.

The author of this paper, while acknowledges the importance of TAM constructs (perceived usefulness and perceived ease of use) on acceptance of technology research, aims to incorporate and include more recent adaptations of the original TAM into the theoretical background and the research model. In particular, the aim is to use some factors from the Unified Theory of Acceptance and Use of Technology II (i.e., UTAUT2: Venkatesh et al., 2012) which is a more recent adaptation of the TAM and is developed for the consumer context. Hence, it fits very well with the context of this paper. Moreover, previous studies (e.g., Kupfer et al., 2016) have already shown that components of UTAUT2 can also be used for modelling technology acceptance in the context of smart home technology. Therefore, some of the antecedent of technology acceptance, i.e., social influence and perceived cost from UTAUT2 will be included in the research model.

Other variables such as perceive personal innovativeness, perceived newness and attitude toward using a technology will be added to the model to comply with recent development in the IoT and smart home technology research (see Figure 1). Some studies such as (Kim and Shin, 2015) and (Thakur and Srivastava, 2014) showed that perceived cost and perceived innovativeness influence

users' behavioural intentions. Moreover, Barnicoat and Danson (2015) argued that positive attitude toward using technology has a direct impact on the intention to use technology. The dependent variable in the research proposed model is intention to use (i.e., smart home technology). These constructs are assumed to play a major role in the decision-making of individuals to use smart home technology. In addition to the main constructs, previous experience with smart home technology and the gender of the respondents will be used as control variables to find if these variables impact the path relationships in the model. In the following subsections, each construct is explained and we develop a theoretical rationale for the causal relationships in the proposed model.

3.1. Perceived cost

Perceived cost has widely been used in prior studies to empirically investigate the impact of this variable on users' intentions to use technology and have consistently been reported that high perceived cost has a direct, but *negative* effect on users' behavioural intentions to use technology (e.g., Shin, 2010; Wu and Wang, 2005). In the context of smart home technology, it is important to know “*if users think smart home technology is affordable or expensive*” and “*if they are willing to pay the prices asked for home networked-connected appliances and devices*”. In this paper, it is assumed that users' intentions are largely determined by their perceptions of cost of the technology. If users perceive the cost of smart home technology as expensive, they feel more restricted to adopt and use it. In other words, the higher the cost of smart home technology is, the lesser is the likelihood of its use. In line with these discussions, perceived cost of smart home technology is included in the research model, hence:

H1: *Perceived cost will have a negative effect on intention to use smart home technology.*

3.2. Perceived newness

Perceived newness of radical innovations, e.g., smart home technology, is assumed to play a major role in the decision-making of individuals (Ronteltap et al., 2016). Smart home technology, an application of Internet of Things, can be considered as a radical innovation because it involves substantially new technologies. Smart home appliances and products offer users a greater user-experience relative to existing products (“*dumb devices*”). As such, one can argue that the more radically a new innovation is perceived, the more useful will be perceived by its users. Thus, more useful products lead to more positive attitudes toward using the technology (Voss, Spangenberg, and Grohmann, 2003). Taken together, we suggest the following hypothesis:

H2: *Perceived newness will have a positive effect on attitude toward using smart home technology.*

3.3. Consumer perceived innovativeness

Consumer perceived innovativeness refers to the perception of consumers towards certain products and how it affects their attitudes toward using the technology (Hong, Lin, and Hsieh, 2017). Midgley and Dowling (1978) define consumer innovativeness as the tendency to buy new products more often and quickly than others. Others such as, Lowe and Alpert (2015, p. 4) posit that PCI is “the perceived degree of newness and improvement over existing alternatives”. Lu et al. (2005, p.251) argue that individuals with higher personal innovativeness are expected to develop more positive beliefs about the target technology, hence:

H3: *Consumer perceived innovativeness will have a positive effect on attitude toward using smart home technology.*

3.4. Social Influence

Social influence is defined as “the degree to which an individual perceives that important others believe she or he should use a new technology or a system” (Venkatesh et al. 2003, p. 451). In the context of smart home technology, it can be argued that the perceived social pressure of others to the technology directly influence one’s attitude toward using it, in other words, individual’s attitude positively increases with a higher social influence, hence:

H4: *Social influence will have a positive effect on attitude toward using smart home technology.*

3.5. Attitude toward using technology

Attitude toward using technology can be defined as “individual’s positive or negative feelings about performing the target behaviour” (Fishbein and Ajzen, 1975, p. 216). Different theoretical frameworks have also confirmed that attitude is a key antecedent of the intention to engage in a particular behaviour (Yang and Yoo, 2004). In this paper, we propose that an overall positive attitude formed through consumers’ perceived innovativeness, perceived newness and social influence (which are assumed to be common determinants in smart home research), plays a major role in intention to use of smart home technology. Park and Chen (2007) conducted a study on the acceptance of smartphones and found that attitude is a significant predictor of intention, hence:

H5: *Attitude toward using will have a positive effect on intention to use smart home technology.*

3.6. Intention to use

The core theoretical focus of this paper is to identify the key driving (antecedent) factors influencing individuals’ intention to use smart home technology. In the context of IoT technology, Bai and Gao

(2014) used an integrated model to find factors influencing individuals' willingness to use IoT technology and results indicated that perceived usefulness is the most notable and powerful predictor of individuals' intention to use the technology. In this paper, intention to use as a construct is considered as a proxy for consumer technology acceptance (Bai and Gao, 2014; Venkatesh, 2000). Figure 1 shows the proposed research model.

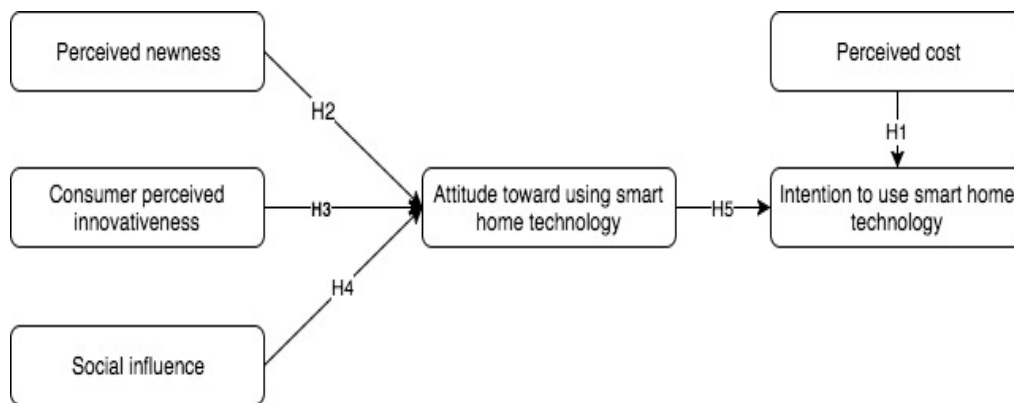


Figure 1: Research model.

4. Methodology

In this paper, Structural Equation Modelling (SEM) technique will be used to analyse the data. Moreover, in order to gain more insights on the factors influencing individuals' intention to use smart home technology and to complement the SEM findings, a configurational thinking method known as "fuzzy-set Qualitative Comparative Analysis" will also be used. FsQCA, is a variant of the Qualitative Comparative Analysis developed by Ragin (1987). Literature, show that this method is being increasingly used in various domains, including research on IoT (Huarng, 2015; Papert et al., 2017). This method provides distinct advantages in causal-oriented investigation (Krogslund et al., 2014) which cannot be gained from the mainstream regression-based methods, such as Structural Equation Modelling. More description of the method will be provided in upcoming sections.

4.1. Measurement

Items for measuring the six constructs in the model were drawn from previously validated studies. If needed, minor modifications were made on the items to match the context of this study. All variables included in the model have been assessed from a general perspective of the smart home technology and thus no questions regarding a particular smart home technology were asked. Consumer perceived innovativeness was measured with three items (Garcia and Calantone, 2002; Lowe and Alpert, 2015). Perceived newness was measure with 4 items from (Lowe and Alpert, 2015). Social influence and perceived cost were measure with 3 and 4 items, respectively from (Bhattacharjee, 2000; Venkatesh

et al., 2012). Attitude toward using and intention to use a technology were measured with 4 and 3 items respectively (Bagozzi and Burnkrant, 1979; McGuire, 1985; Yang and Yoo, 2004). Respondents were asked to evaluate all items on 7-point Likert scales ranging from “Strongly disagree” (1) to “Strongly agree” (7).

4.2. Data collection procedures

To collect data, a web-based survey was developed and administered to individuals and households in Finland. Before the actual distribution of the survey, it was pretested by a number of households with different demographic background, e.g., experienced with the smart home technology and gender. The aim was to use their feedback and comments to improve the clarity of the questions and avoid ambiguous expressions. In the next phase, the modified version of the survey was distributed to individuals who were randomly recruited through the author’s contacts over the course of six weeks. We have received 189 questionnaires. After removing the incomplete responses (e.g., with missing data), 156 questionnaires were eligible for the further analysis. In terms of sample size requirement, the collected responses exceeded the requirement of sample size suggested by (Hair et al., 2011). Hair et al. (2011) recommended that the sample size should be ten times the largest number of structural paths directed at a particular latent construct in the structural model.

We did not provide any incentives for answering the survey but respondents were assured that data would be treated anonymously and will be used at an aggregate level. This approach enabled us to control for potential common method bias (Chang et al., 2010). We also provided a short video about the smart home technology through the YouTube channel in order to make respondents familiar to the concept, smart home environment, and what kind of products and appliances are available in the market or will be available in future. It is also important to mention that respondents were free to watch the video. This technique has shown to be an effective approach helping respondents to form a general understanding about the phenomenon being under investigation (Luor et al., 2015). Furthermore, we asked respondents to indicate their previous knowledge and experience with regard to smart home technology. A non-response bias test was computed and we did not find any significant differences between responding and nonresponding participants with regard to age, gender, and employment status. Respondents were promised to receive a personalized report and an in-depth analysis of the research findings; this approach helped to reduce nonresponse bias (Sax et al., 2003).

5. Results

In this section, the results for both approaches, SEM and fsQCA are illustrated and discussed. First, we provide the descriptive statistics, followed by measurement and structural model results.

5.1. Descriptive analysis

In average, it took 17 minutes to complete the survey. The nonresponse bias test between early and late respondents was performed, we made two groups of respondents. The first group included respondents who replied within the first two weeks and the other group included respondents from who replied within the last two weeks. The test results showed no difference between these two groups. The average age was 28.5 years old and 109 (69%) of the respondents were male and 45 (31%) were female, two did not reveal their gender. Interestingly, almost two third of the participants have reported that they have watched the video and one third (N = 52) reported that they have previously used or experienced smart home technology before participating to this study.

5.2. Measurement model

A two-step approach recommended by Anderson and Gerbing (1988) was used to assess the measurement model and the structural model. A confirmatory factor analysis (CFA) was run for all the constructs depicted in Figure 1, to examine the internal consistency and discriminant validity of the measures. The results showed that all the times were nicely loaded into their respective constructs. As we used SmartPLS v.3 software to perform the analysis, it is worth mentioning that PLS-SEM studies lack a globally accepted method for assessing the overall model fit. Instead, it has been recommended to rely only on path coefficients and their significance (Hair et al., 2014).

Table 1: Measurement and internal validity, CR = composite reliability; AVE = average variance extracted.

| Construct | Item | Mean | Std. Dev. | Factor loadings | α | CR* | AVE* |
|--|---------|------|-----------|-----------------|----------|-------|-------|
| Attitude toward using technology | ATT-1 | 5.15 | 1.61 | 0.891 | 0.857 | 0.904 | 0.701 |
| | ATT-2 | 4.91 | 1.26 | 0.852 | | | |
| | ATT-3 | 4.98 | 1.17 | 0.792 | | | |
| | ATT-4 | 4.63 | 1.50 | 0.811 | | | |
| Perceived cost | PCost-1 | 2.86 | 1.45 | 0.854 | 0.750 | 0.800 | 0.578 |
| | PCost-3 | 2.72 | 1.40 | 0.762 | | | |
| | PCost-4 | 2.69 | 1.40 | 0.700 | | | |
| Consumer perceived innovativeness | CPI-1 | 5.68 | 1.12 | 0.851 | 0.849 | 0.909 | 0.768 |
| | CPI-2 | 3.94 | 1.85 | 0.899 | | | |
| | CPI-3 | 4.28 | 1.61 | 0.878 | | | |
| Intention to use smart home technology | INT-1 | 5.23 | 1.51 | 0.930 | 0.850 | 0.898 | 0.770 |
| | INT-2 | 5.48 | 1.37 | 0.876 | | | |
| | INT-3 | 3.60 | 1.75 | 0.824 | | | |
| Perceived newness | PNEW-1 | 4.70 | 1.45 | 0.779 | 0.860 | 0.902 | 0.699 |
| | PNEW-2 | 4.64 | 1.26 | 0.736 | | | |
| | PNEW-3 | 4.25 | 1.41 | 0.911 | | | |
| | PNEW-4 | 4.10 | 1.41 | 0.904 | | | |
| Social influence | SI-1 | 4.59 | 1.47 | 0.776 | 0.788 | 0.877 | 0.704 |
| | SI-2 | 5.16 | 1.15 | 0.861 | | | |
| | SI-3 | 4.95 | 1.25 | 0.876 | | | |

However, some measures are reported in this paper to show the assessment of model fit. Hooper et al., (2008) recommend selecting the standardized root mean square residual value (SRMR) for evaluating absolute measure of fit. Values for SRMR range from 0 to 1, and values lower than 0.08

are considered a good fit (Hooper et al., 2008). In this paper, the SRMR value is 0.074. The internal consistency was examined through the Cronbach's alpha, composite reliability and average variance extracted (AVE). Cronbach's alpha (α) values were all above the threshold of 0.70 (ranged from 0.750 to 0.860. AVE values ranged from 0.578 to 0.770, CR values ranged from 0.800 to 0.909, all well above the recommended minimum of 0.50 and 0.70, respectively (Bagozzi and Yi, 1988), see Table 1. The standardized item loadings for each construct are shown in Table 1, all exceeding the recommended value of 0.70. Discriminant validity was examined to evaluate if each construct's AVE square root was greater than its highest correlation with any other construct, and the results showed no discriminant validity issues (see Table 2).

Table 2. Discriminant validity (diagonal values show AVE square root)

| | ATT | PCOST | CPINNO | INT | PNEW | SOCINF |
|-----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Attitude toward using technology | 0.837 | | | | | |
| Perceived cost | 0.102 | 0.760 | | | | |
| Consumer perceived innovativeness | 0.478 | 0.012 | 0.876 | | | |
| Intention to use | 0.794 | -0.151 | 0.468 | 0.878 | | |
| Perceived newness | 0.275 | -0.192 | 0.018 | 0.095 | 0.836 | |
| Social influence | 0.710 | 0.138 | 0.423 | 0.533 | 0.260 | 0.839 |

In addition to all the validity tests explained above, we examined the common method bias through a two-step approach. We started with a Harman's single factor test and the test result showed that the majority of variance could not be attributed to one factor. The first factor accounts for 37% of the variance (Podsakoff et al., 2003). In the second step, all items were modelled as the indicators of a factor, as Malhotra et al. (2006) recommended. The test results showed poor model fit, thus we assume that the CMB was not an issue in this study.

5.3. Structural model

The SEM results indicated that the structural model had satisfactory levels of fit index (SRMR value is 0.074). As indicated in Figure 2, intention to use smart home technology was explained by a variance of 64%, indicating that the predictors explained a large amount of variation. Attitude toward using technology was explained by a variance of 56%. According to Figure 2, the structural model revealed that the standardized coefficients of all paths relationships were positively significant, except for the perceived cost \rightarrow intention to use path which is negative (H1, $\beta = -0.114$, $p = 0.001$). Thus, H1 is supported by the model. Moreover, consistent with H2-H4, perceived newness (H2, $\beta = 0.120$, $p < 0.001$), consumer perceived innovativeness (H3, $\beta = 0.582$, $p < 0.001$) and social influence (H4, $\beta = 0.230$, $p < 0.001$), were positively associated with attitude toward using smart technology, such that a more positive attitude toward using smart technology led to a greater intention to use the technology. As predicted, attitude toward using smart technology had positive effects on intention to

use technology (H5, $\beta = 0.787, p < 0.001$). It should be noted that, while higher perceived cost had a negative effect on user intention to use smart home technology, other determinants such as social influence, perceived newness and consumer perceived innovativeness had positive influence on the attitude toward using the technology. This finding indicate that individuals generally have a positive attitude toward adopting and using the technology, should the asked price for the technology be affordable and reasonable.

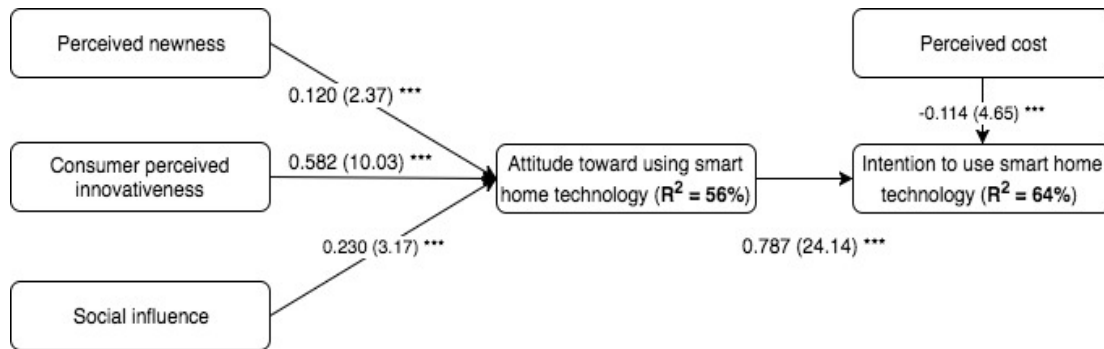


Figure 2: Structural model result

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

In addition to the gender of the respondents, their previous experience of smart home technology was used as control variables in the analysis. The intention was to examine if any group differences between (experienced vs. non-experienced) and also the gender (female vs. male) of respondents can be found. The multigroup analysis results showed significant differences between the experienced vs. non-experienced in the following path relationships. For instance, the results showed that the path between perceived newness to attitude toward using technology is not significant for the experienced respondents, but it is significant for the non-experienced respondents ($\beta = 0.167, p < .001$). This finding indicates that the degree to which an innovation is perceived to be new, positively influences the attitude of the respondents who have not used the smart home technology before. In other words, the more the smart home technology is perceived to be new, the more likely people build positive attitude toward using it. Moreover, the results showed that the path between consumer perceived innovativeness to attitude is significant for those who indicated that they have not used the smart home technology ($\beta = 0.274, p < .001$), but it is not significant for those who mentioned they have used smart home technology before.

With regard to gender, the multigroup analysis results showed that the path between perceived newness to attitude toward using technology is not significant for the males, but it is significant for the females ($\beta = 0.282, p < .001$). In other words, females' perceived newness of smart home

technology positively influences their attitude toward using the technology. Interestingly, it was found that for males the path between consumer perceived innovativeness to attitude is significant, but it is not significant for the females ($\beta = 0.249, p < .001$). These results imply that for those who have not used smart home technology before, in addition to the cost, social influence, consumer perceived innovativeness and perception about how innovative the technology is, positively influences their attitude toward using the technology and thus play an important role in their intention to use technology.

5.4. Fuzzy-set qualitative comparative analysis (fsQCA)

Fuzzy-set Qualitative Comparative Analysis and Crisp-set QCA are the main extensions of Qualitative comparative analysis (QCA). Qualitative comparative analysis is an analytic technique that uses Boolean algebra to implement principles of comparison (Schneider and Wagemann, 2007). This method helps to understand the causal conditions and asymmetric relationships between dependent variables and independent variable. While, the importance of empirical and practical insights gained from conventional correlational approaches cannot be underestimated, this paper aims to understand further the interdependencies, conjunctive paths and the causal relationships between antecedent variables. In other words, it aims to understand *how variables combine to cause a certain outcome* (Ragin, 1987, 2000).

This method can be used in both variable-oriented (quantitative) and case-oriented (qualitative) methods. By making use of Boolean algebra for logical comparison, each case in fsQCA analysis is presented as a combination of causal and outcome conditions. A truth table is constructed to simplify the information presented in the data (Ragin, 2014). The logical minimization is then used to represent the information in the truth table where the information is presented in the form of different combinations of conditions that lead to the outcome. Crisp-set is a conventional set and it is presented in the form of dichotomous, a case is either “in” or “out” of the set. For example, gender can be presented in the form of crisp-set, “in” (1 = female) and “out” (0 = male).

In contrast to crisp-set, a fuzzy-set allows membership in the interval between 0 and 1, while keeping the two qualitative states of full membership and full non-membership. For example, a fuzzy-set of high income people, people who are “fully in” the set (fuzzy membership = 1), some who are “almost fully in” the set (membership = 0.90), some who are neither “more in” nor “more out” of the set (membership = 0.5, also known as the “crossover point”), some who are “barely more out than in” the set (membership = 0.45), until to those who are “fully out” of the set (membership = 0). Scale in fuzzy-set can be continuous rather than on a dichotomous scale. One of the main differences of fsQCA

is that it allows to identify patterns of elements that lead to the outcome of interest. Moreover, fsQCA analysis provides configurations that only include necessary and sufficient conditions (more information in the next section).

5.5. Necessary analysis

The necessity analysis enables to assess if there are any variables (conditions, in term of the fsQCA approach) that can be identified as necessary for the outcome of interest (here is intention to use smart home technology) (Ragin, 2006). Necessary refers to a situation where a condition must be present for the occurrence of the outcome of interest and sufficient if it can produce an outcome by itself. Consistency value can be used to understand how relevant and important the necessity relationships are. If the consistency value exceeds 0.90, then it can be assumed that considerable relationships exist (Schneider and Wagemann, 2007). In this paper, the necessity analysis results showed that none of the conditions (variables) used in the analysis (i.e., perceived newness, perceived cost, consumer perceived innovativeness, social influence and attitude toward using technology) were seen as necessary conditions for the outcome (intention to use smart home technology). But, nevertheless, we cannot be certain, unless we run the main part of fsQCA analysis which is sufficiency analysis.

5.6. Procedures in fsQCA analysis

There are several steps and phases in fsQCA analysis that should be followed sequentially. First, we need to convert all the variables (conditions) included in the analysis and measured on a continuous scale into fuzzy sets, this practice is called “calibration”. As indicated before, the values of a fuzzy-set ranges from (0 to 1). A value of (0) indicates fully out or no set membership and a value of (1) indicates fully in or full set membership (Ragin, 2008). According to Woodside (2013) three anchors can be defined to determine the degree of membership for each condition. These anchors indicate for full membership a fuzzy score = 0.95, for full non-membership a fuzzy score = 0.05, and for cross-over point a fuzzy score = 0.50. After all values were calibrated into fuzzy sets, a truth table of 2^k rows is constructed, where k is the number of predictor variables (conditions), and each row represent a possible combination (Mikalef and Pateli, 2017).

Ragin (2008) suggested to set the consistency levels to > 0.75 , consistency measures the degree to which a subset relation has been approximated and it is similar to significance in correlational methods (Schneider and Wagemann, 2010). When constructing the truth table and reviewing the configurations, we can delete those configurations that did not comply with this rule. The solution coverage is used to assess the empirical relevance of a consistent subset, similar to the explained variance (R^2) in regression analysis (Mendel and Korjani, 2012). The fsQCA analysis produces three

different solution sets: (a) parsimonious, (b) intermediate, and (c) complex. Ragin (2008) suggested to use the intermediate solutions to articulate the results. The interpretation of the intermediate solutions is tricky and the domain knowledge of the researcher play an important role (Ragin, 2008). The following notations will be used when fsQCA results are discussed. Black circles (●) indicate the presence of a condition and blank circles (○) indicate its absence. Blank spaces indicate “do not care,” in other words, the causal condition may be either absent or present (Ragin and Fiss, 2008). When prior experience with smart home technology is included in the analysis, we show them in the form of crisp variables. Thus, black circles (●) indicate “no (not used before)” and blank circles (○) indicate “yes (used before)”. For gender, we use black circles (●) to show females and blank circles (○) to show males.

5.7. Fuzzy-set Qualitative Analysis results

In this section the fsQCA results are presented and discussed. The results are identified based on the casual configuration of five conditions (variables), namely, perceived newness (PN), consumer perceived innovativeness (CPINNO), perceived cost (PCOST), social influence (SI), and attitude towards using (ATT) leading to the occurrence of the outcome (intention to use smart home technology). The fsQCA results, without inclusion of any control variables, are presented in Table 3. As it can be seen five configurations of conditions were obtained. The overall consistency is 0.852 and the overall solution coverage value is 0.951, indicating that these five solutions cover 95% of the cases (respondents).

Solution 1, indicates that the presence of attitude toward using the technology is the only sufficient condition for the outcome of interest to occur and has the highest solution converge value (0.924) among all the other solutions. This emphasises the importance of attitude toward using a new innovation and indicates that the presence of this condition alone can lead to outcome of interest. *Solution 2*, indicates that the presence of perceived cost and the negation (absence) of consumer perceived innovativeness and negation of perceived newness are sufficient conditions for the occurrence of the outcome. This solution, emphasises the importance of perceived cost confirming the SEM results that perceived cost play an important role. *Solution 3*, indicates that the presence of the perceived cost and perceived newness in addition to negation of consumer perceived innovativeness lead to the outcome of interest.

Interestingly, *solution 4* indicates that the negation of social influence and perceived cost and the presence of perceived newness and consumer perceived innovativeness are sufficient conditions for the outcome of interest to occur. From consistency point of view, this configuration is the most

important configuration (0.955). *Solution 5* shows that the presence of social influence, perceived cost, and consumer perceived innovativeness are sufficient conditions to lead to the outcome of interest. *Solution 4* and *5* similarly indicate the presence of consumer perceived innovativeness and how this condition is perceived to be important for the cases (subjects) in these two configurations. But, they differ in social influence and perceived cost, while *solution 4* indicates the negation of both conditions leads to outcome, *solution 5* indicates that the presence of these two conditions leads to outcome. Thus, it can be argued that, while the outcome is the same for all cases within these two configurations, but different conditions (receipts) separately lead to the outcome.

Table 3: Intermediate solution for intention to use smart home technology.

| Solution | PN | CPINNO | PCOST | SI | ATT | Raw Coverage | Unique Coverage | Consistency |
|----------|----|--------|-------|----|-----|--------------|-----------------|-------------|
| 1 | | | | | ● | 0.924 | 0.163 | 0.888 |
| 2 | ○ | ○ | ● | | | 0.382 | 0.000 | 0.943 |
| 3 | ● | ○ | ● | | | 0.520 | 0.001 | 0.932 |
| 4 | ● | ● | ○ | ○ | | 0.325 | 0.000 | 0.955 |
| 5 | | ● | ● | ● | | 0.715 | 0.001 | 0.914 |

In the next step, two other conditions (i.e., gender and experience) were included in the analysis and seven interesting configurations were obtained. These configurations show that gender of the respondents and their previous experience with smart home technology play important roles and how these two conditions influence the intention to use technology. However, in two configurations (*solution 1* and *3*) gender does not play any role, whereas in other five configurations, four of them are geared towards females and only one solution is for males. With regard to experience, only three configurations show the importance of this condition (see *Table 4*).

Table 4: Intermediate solution for intention to use smart home technology (with gender and experience included).

| Solution | GEN | EXP | PN | CPINNO | PCOST | SI | ATT | Raw Coverage | Unique Coverage | Consistency |
|----------|-----|-----|----|--------|-------|----|-----|--------------|-----------------|-------------|
| 1 | | | | | ● | | | 0.444 | 0.009 | 0.922 |
| 2 | ○ | ○ | ● | | | | ● | 0.715 | 0.069 | 0.755 |
| 3 | | ○ | | ● | | | | 0.781 | 0.001 | 0.962 |
| 4 | ● | | | | | ● | ● | 0.714 | 0.014 | 0.864 |
| 5 | ● | ● | | | | ● | | 0.655 | 0.000 | 0.878 |
| 6 | ● | | | ● | | ● | | 0.764 | 0.000 | 0.913 |
| 7 | ● | | ● | | | ● | | 0.753 | 0.000 | 0.916 |

Solution 1 indicates that the presence of perceived cost is the only condition for the outcome of interest to occur, regardless of the respondents' gender and previous experience with the technology. *Solution 2* indicates the presence of perceived newness and attitude toward using the technology lead to the outcome of interest, this solution only applies to males who indicated that they have used and

experienced the smart home technology before. *Solution 3* shows a configuration that the presence of consumer perceived innovativeness is the only condition for those who indicated that they have used and experienced the technology before, in this solution the gender of respondents does not play any role. According to the coverage value (0.781) it is the most important solution. *Solution 4* indicates a configuration for females, for whom the presence of attitude toward using the technology and social influence affect their intention to use smart home technology. *Solution 5* indicates a configuration applicable only to females who did not use or experience the smart home technology before. For them the presence of social influence is the only condition that impacts their intention to use the technology. *Solution 6* shows a configuration for females that the presence of consumer perceived innovativeness and social influence lead to the outcome of interest. Finally, *solution 7* indicates a configuration that applies only to female and for them the presence of perceived newness and social influence lead to the outcome of interest. From consistency value perspective, solution 7 is the second most important configuration. The overall consistency is 0.833 and the overall solution coverage value is 0.906, indicating that these seven solutions cover almost 91% of the cases (respondents).

6. Discussion

In this paper, an application of Internet of Things (IoT), i.e., smart home technology was investigated from two different methodological approaches to identify antecedent factor of intention to use the smart home technology. First, the data was analysed thorough Structural Equation Modelling and then the same dataset was used for the fuzzy-set Qualitative Comparative Analysis. While the SEM analysis provided important results, the fsQCA results while reinforcing the SEM findings, provided us additional insights to help understand better individuals' intention to use smart home technology. The SEM results show that social influence, perceived newness and consumer perceived innovativeness positively influence the attitude toward using technology and consequently intention to use. Moreover, it was found the perceived cost has a significant impact on the intention to use smart home technology, but its affect is negative. This means that the higher the asking prices for smart home devices and appliances will be, the less likely the intention to use the technology will be. Moreover, the SEM results reveal that the positive attitude toward using technology has a significant effect on the intention to use smart home technology. All of these findings indicate that five hypotheses developed to assess the path relationships in the model are accepted. With regard to fsQCA results, we found out that perceived cost is an important condition for the outcome of interest to be realized. Moreover, without including control variables (i.e., gender and experience) in the analysis, the results show that perceived cost, social influence and consumer perceived innovativeness have mixed impacts (see Table 3). Such that, in one solution, the presence of perceived cost and social

influence in addition to presence of consumer perceived innovativeness lead to the outcome (solution 5), and in another solution (solution 4) the negation of perceived cost and social influence in addition to presence of consumer perceived innovativeness are considered to be important for the occurrence of the outcome. As expected, when gender and previous experience with smart home technology were included in the analysis, interesting findings were revealed. For instance, we found that in five of configurations (out of seven) gender plays important role, and in four of them females dominate the configurations (see Table 4, solutions 4-7). Moreover, it was found that for females the presence of social influence is the most important condition to lead the intention to use the technology (see Table 4, solution 5-7). FsQCA analysis revealed only one configuration for males, indicating how males' decisions and intentions to use the new innovations are made. Solution 2 shows that the presence of attitude toward using technology and presence of perceived newness are enough conditions for males with prior experience of using smart home technology to use technology.

7. Conclusion

This paper investigates the antecedent factors of intention to use smart home technology. The results of this paper theoretically contribute to the literature by showing that in consumers' use of smart home technology, the influence of perceived newness and social influence, in addition to consumer perceived innovativeness are equally important to form a positive attitude and consequently using smart home technology. In addition to above findings, the results show that perceived cost has a direct, but negative, impacts on individual's intention to use smart home technology. The impact of perceived newness and consumer perceived innovativeness to attitude toward using a technology is moderated by demographic variables, i.e., gender and prior experience of smart home technology. The results of fuzzy-set Qualitative Comparative Analysis reveal very important observations. For instance, the fsQCA result shows that for female, the impact of social influence is considerably higher than other factors. All in all, the fsQCA findings show that there are multiple ways (configurations) that lead to the outcome of interest (intention to use smart home technology) and not only one pattern for all. In other words, the fsQCA results show that while interdependencies between variables exists, there are multiple conjunctive paths and causal relationships between antecedent factors of intention to use smart home technology.

7.1. Implications.

Our findings show that the perceived cost has a direct negative effect on individual's intention to use technology. This has a direct implication to smart home technology vendors and service providers and how they define their pricing strategy. Particularly, our finding suggests that perceived costs over

perceived benefits of smart home technology can influence individuals' usage intention. Moreover, technology suppliers, service providers and policymakers are advised to take a broad view and be sensitive to individual's concerns about the cost of the technology. While, smart home technology is gaining massive popularity and its significance is growing rapidly, the pricing strategy has a direct impact on total business revenue. Such that the more affordable the cost of smart home technology will be, the higher will be the willingness to use the technology. Another practical implication of the findings is that emphasis should be placed on females' needs and their perceptions toward the smart home technology, as their intentions toward using the technology is greatly affected by the influence of others (social influence).

7.2. Limitations and future research

The first limitation concerns generalizability of the findings. As our study was conducted in Finland, a country in the Northern Europe with high penetration of advanced technology users, thus the findings may not apply to the countries that are less technologically advanced. Moreover, as our sample prior knowledge and experience with smart home technology is somewhat skewed, 52 out of 155 respondents, the findings may not apply to those who are more experienced with smart home technology. Also, we have investigated smart home technology in general and in the context of Finnish households, future research can build on our study by testing the proposed model in different countries focusing for example on one particular smart home technology. Finally, prior studies have shown that hedonic motivation plays an important role in determining technology acceptance and use (Venkatesh, Thong and Xu, 2016). Hedonic motivation, a construct often labelled as perceived enjoyment in Information Systems research, can be added to the model in future studies to determine its effect on smart home technology acceptance.

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