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Customers' Adoption Factors and Willingness to Pay for Home Energy Information Management System in Taiwan

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Abstract. Home Energy Information Management Systems (HEIMS) in advanced countries are a new trend for energy-saving in residential sector, as the pre-stage of smart grid. Taiwan Power Company (TPC) has begun to deploy the Advanced Metering Infrastructure (AMI) for low-voltage customers since 2012. TPC plans to complete the installation of 10,000 AMI by the end of 2013.
In general, the household has three options to choose at the time of AMI installation, i.e., deluxe option (smart meter, in-home display (IHD), HEIMS); standard option (smart meter, IHD); basic option (smart meter). The purpose of this paper is to conduct a market survey for investigating the residential customers' preferences and willingness to pay when they are facing these three options.
In order to achieve this objective, we utilized technology acceptance model (TAM), derived from theory of reasoned action (TRA) as a research methodology. Then, we designed a questionnaire based on the following subjects: willingness to pay, switching cost, usefulness, attitude toward, subject norm, and switching intentions. Next, we conducted internet surveys through "Mysurvy" (www.mysurvy.com). In addition, we utilized LISREL8.70 and SPSS12.0 to analyze the surveyed results. The major findings of this study showed that switching costs would not positively affect actual behavior, subject norm would not positively affect attitude, but the perceived usefulness and attitudes would positively affect actual behavior.

Keywords: Home Energy Information Management System (HEIMS), advanced metering infrastructure (AMI), technology acceptance model (TAM), theory of reasoned action (TRA), willingness to pay (WTP), switching costs, subject norm.

1. Introduction

With the evolution of civilization all around the world, human beings have been pursuing a more convenient life. However, the limited resources of the earth have been deteriorated. According to the "Energy Statistics Monthly Report" published by Taiwan Bureau of Energy , the total 2011 annual electricity consumption of the residential sector (8.06 million customers) in Taiwan was about 42.21 billion kilowatt hours. If each residential customer could save 1 kilowatt hour per day, we could save a total of 29.41 billion kilowatt hours which is equivalent to 70.48 billion NTD (2.4NT/kWh), and also reduced 188.24 tons of carbon dioxide emissions (0.64KG/kWh). Therefore, it is important that, through a real-time electricity monitoring system, one can control the usage of all electric appliances in order to save electricity expenditures and mitigate carbon dioxide emissions. Under this circumstance, the total demand for electricity can be reduced while the power plant investment cost can be lowered (Hsu et al, 2011).

To implement energy saving and carbon reduction, AMI plays an important role. Customer automation is a significant infrastructure next to the feeder automation. HEIMS for residential and commercial buildings, will be complementary with the AMI, to strengthen the energy saving and carbon reduction (Energy White Paper in Taiwan, 2010). In TPC's AMI programming, TPC started to develop high-voltage AMI and by the end of 2012 TPC will complete 23,000 high-voltage customers' smart meter installations.

With the information mentioned above, we could see that Taiwan's government and TPC have promoted AMI and smart grid development with a timeframe. However, the consumer's level of acceptance and willingness to adopt such kind of systems still remained an unknown question. Actually, there are some

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factors that are worth discussing. One of the principal subjects is the consumers' adaptation. It is very important to find out the key factor which will affect the adaptation of AMI and HEIMS. Such factors can provide useful information on further development strategy and AMI promotion policy. Accordingly, the objectives of this study are: (1) understanding the adoption factors and acceptance of the consumers, when they are facing three options (i.e., deluxe option, standard option, or basic option) for installing AMI, (2) finding out the price range that the consumers are willing to pay for the deluxe and standard options (the basic option is free of charge). In order to achieve these objectives, we first conducted a market survey focusing on the population who paid for electricity bills as the sample group. Second, we utilized TAM and contingent valuation method as our research models. Third, we analyzed the collected data through the structural equation modeling (SEM) softwares of LISREL8.70 and SPSS12.0.

The rest of the paper is organized as follows. Section 2 presents the literature review discussing TRA, TAM, willingness to pay, switching costs and AMI. Based on the literature review, methodology and empirical results of this paper and is shown in Section 3.

2. Literature Review

2.1. Theory of Reasoned Action (TRA)

In 1975, Fishbein and Ajzen established "Theory of Reasoned Action (TRA)" which the researcher used for studies regarding consumers' adoption to innovative technology theory. Social psychology expressed TRA as universal explanations of different human behaviors, and stated that behaviour was defined by two typical factors, "attitude and subject norm" (Ajzen and Fishbein, 1980). The factors of belief and evaluation mainly affected the attitude, while the norm belief and the motivation to obey shaped the subject norm. Figure 1 illustrates the theory of reasoned action (Fishbein and Ajzen, 1975).

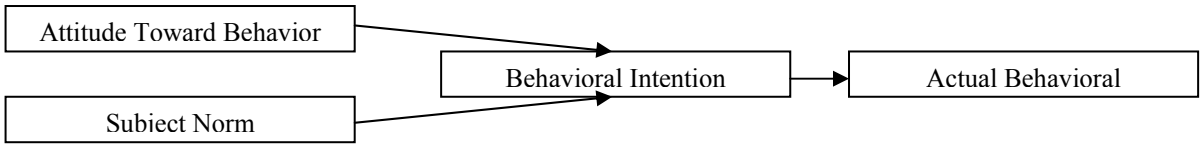

Fig. 1: Theory of Reasoned Action (TRA)

2.2. Technology Acceptance Model (TAM)

TAM, which was a revision of TRA, was introduced by Davis (1989). Figure 2 illustrates the original technology acceptance model (Wu et al., 2011). TAM was used widely to predict customer's acceptance and usage of an investigated technological product or service. In order to examine the explanatory power of the TAM, researchers performed empirical studies on TAM. The results of the empirical studies were relatively consistent on the acceptance or using behavior of IT end customers (Lee et al., 2011; Lin Shin, 2007; Keil et al., 1995; Adams et al., 1992). Several studies and researches proved the efficiency and the legitimacy of the TAM, supported the theory of TAM, and expanded the applicability of the TAM (Lee et al., 2011; Lin, et al., 2011; Shin, 2007; El-Gayar and Moran, 2007; Legris et al., 2003; Chau, 2001; Horton et al., 2001; Lederer et al., 2000; Adams et al., 1992; Davis et al., 1989).

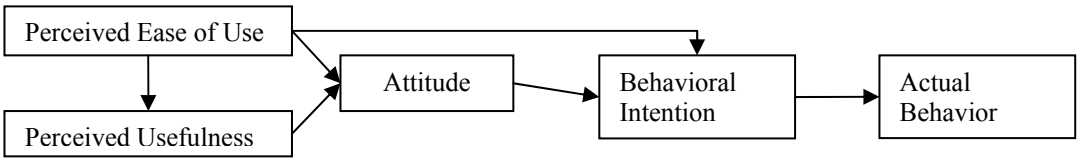

Fig. 2: Technology Acceptance Model (TAM)

2.3. Willingness to Pay (WTP)

The concept of willingness to pay is often used as one of the criteria for measuring the benefit to the consumer of a change in the price or quality of a good. According to Perman and Mcilvray (1996), willingness to pay means the amount a person would be willing to pay to "secure a welfare improvement." There are two methods, indirect and direct, that can be used to determine how much people are willing to pay for a welfare improvement. The idea that, if a person want to know the willingness to pay of people, he can simply ask them, formed contingent valuation which is a direct method (Field, 1994). The method is called

contingent valuation because it simply asks people how they feel or how they will act when they are placed in contingent situations (Field, 1994). Many environmental impact studies have been done by using contingent value method. For our research, we utilized this method to design our survey questions to elicit willingness to pay response from people. In other words, we endeavored to know the maximum amount consumers would be willing to pay (Ozanne and Vlosky, 1997).

2.4. Switching Costs

According to Porter (1980), switching costs are the one-time costs that consumers pay for the process of switching from one provider to another (Burnham et al., 2003). Switching costs are not limited to objective, "economic" costs. When the consumers are not willing to switch providers merely because it's not worth it. They may comprehend obstacles such as search costs, transaction costs, learning costs, loyal customer discounts, customer habit, emotional coast and cognitive effort, coupled with financial, social, and psychological risk on the part of the buyer (Fornell, 1992). Burnham et al., (2003) provided a detail typology by examining the relationships between the eight switching costs aspects. The eight switching costs could be reorganized as three higher-order switching costs types: procedural switching costs, financial switching costs, and relational switching costs.

3. Research Design and Methodology

3.1. Framework

When the new technology comes to replace the old ones, switching cost is one of the most important factors that will affect consumers' willingness to switch. Therefore, we combined technology acceptance model (TAM) and theory of reasoned action (TRA), switching costs based on Burnham's (2003) three higher-order switching costs. Then, we simulated switching costs for two alternatives: switching costs of deluxe option (SCD) and standard option (SCS).The following Figure 3 shows the relationship between the customers' willingness to pay and switching costs.

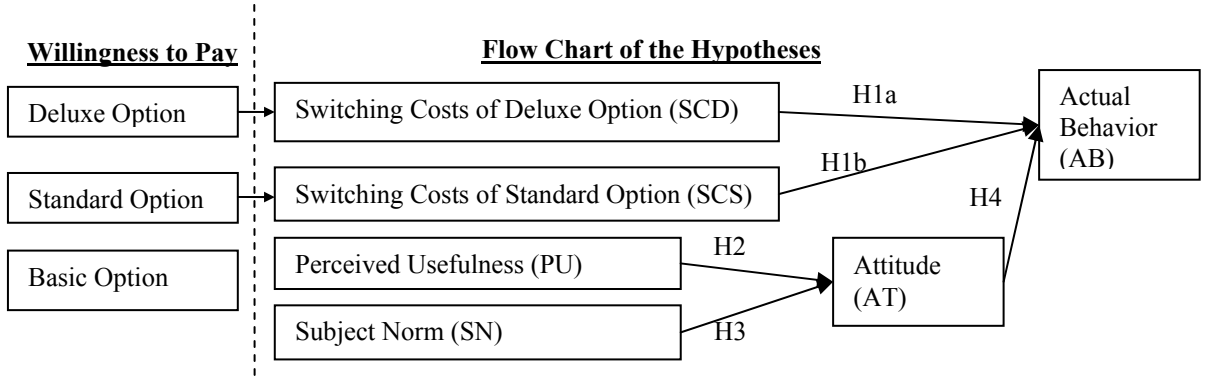

Fig. 3: Theory of Reasoned Action

Based on the above theoretical grounds, we then set up the following hypotheses to be test.

H1a: SCD would positively affect actual behavior (AB); H1b: SCS would positively AB; H2: perceived usefulness (PU) would positively affect attitude (AT); H3: subject norm (SN) would positively affect AT; H4: AT would positively affect AB.

3.2. Research Methods

First, we designed a questionnaire asking the consumers adoption factors of HEIMS, including: willingness to pay, switching cost, usefulness, attitude, subject norm, and actual behavior. Second, we constructed our questionnaire on "Mysurvy", an internet platform. After that, we sent out our questionnaire to residential customers. Over the period of a month, starting on February 17, 2012 till March 18, 2012, we had collected 163 completed questionnaires. 22 of the questionnaires were regarded as invalid questionnaires. As a result, we had 141 valid questionnaires. Respondents clicked their answers for each statement of items by a five-point Likert-scale: ranged from 1 to 5, reflecting strongly disagree, disagree, neutral, agree, and strongly agree. Then, we used LISREL8.70 and SPSS12.0 to analyze the surveyed contents. According to the demographic information of valid questionnaire respondents, there are 44% males and 56% female. Age of

most respondents are under 39(88%), and most of respondents have a bachelor's degree or above (93.7%). Most respondents are in the commerce and service industry (70.29%). Majority of respondents live in townhouses and apartment complexes with elevators (82.3%) and have a household size of 3-5 people (73.7%). Most of the respondents have an average electricity bill under $3000NT (73.2%).

3.3. Willingness to Pay

We asked the consumers to choose one of the three options as the willingness to pay. The results showed that the willingness to pay for the deluxe option: Below 5000 NT(66.9%), 5001~6000 NT(23.94%), 6001~7000 NT(7.75%), 7001~8000 NT (1.41%); standard option: 0 NT(9.86%), 1~1000 NT(28.7%), 1001~2000 NT(28.7%), 2001~3000 NT(26.06%), 3001~4000 NT(6.34%); and the willingness of adoption for basic option: option accepted (96.48%), option rejected (3.52%).

3.4. Analysis of the Hypotheses

3.4.1. Reliability Analysis

We utilized LISREL8.70 and SPSS12.0 to analyze the results of our market survey, the major findings showed that χ^2/d.f. =0.59. According to Bollen(1989), if χ^2/d.f is less than 5, the surveyed results are acceptable. In addition, Henson (2001) proposed that if the value of the Cronbach's α is between 0.50~0.60, then the reliability of the result is acceptable. This study has a Cronbach's α value of 0.675 which is grater than the minimum standards 0.50. Therefore, this market survey has a good reliability and validity. In addition, Henson (2001) proposed that if the value of the Cronbach's α between is 0.50~0.60, then the reliability of the results is acceptable. This study's Cronbach's α= 0.675, which is greater than the minimum standards 0.50. Therefore, this study has good reliability and validity.

3.4.2. Model Fitness

Table 2 shows the obtained values and recommended values of our goodness-of-fit statistics. We could clearly tell that other than NFI, all other statistics were good. Hoelter (1983) stated that when CN is greater than 200, then the model could be utilized to reflection sample data. These results suggested that the model was acceptable because fit indices satisfied the thresholds of recommended cutoffs. In table 3, the diagonal is equal to the square root of AVE, and the data should be larger than the variables' correlation coefficient (Chin, 1998). This will show the differences between each value of all variable, and this indicates that our survey results have distinguished validity.

Table 2: Goodness-of-Fit Statistics

Goodness-of-Fit Statistics (GFS)	Recommended value	Obtained value
Goodness of Fit Index(GFI)	≧0.9	0.93 *
Adjusted Goodness of Fit Index (AGFI)	≧0.9	0.91*
Parsimonious Goodness of Fit Index (PGFI)	≧0.5	0.71*
root mean square residual (RMSEA)	≦0.05	0.00*
Normed Fit Index (NFI)	**≧0.9**	**0.79** (Not significant)
Non-Normed Fit Index (NNFI)	≧0.9	1.35*
Parsimonious Normed Fit Index (PNFI)	≧0.5	0.67*
Comparative Fit Index (CFI)	≧0.9	1.00*
Incremental Fix Index (IFI)	≧0.9	1.26*
Hoelter's Critical N (CN)	>200	287.4*

*: significant

Table 3: Correlation Coefficient Matrix

Variable	AT	AB	SCD	SCS	PU	SN
AT	0.278*					
AB	0.179*	0.283*				
SCD	0.002	-0.113	0.401**			
SCS	-0.045	-0.087	0.617**	0.387**		
PU	0.376**	0.182*	-0.015	-0.063	0.483**	
SN	0.281*	0.199*	-0.090	-0.015	0.123	0.449**

**: When the significance level of 0.001, significant.
*: When the significance level of 0.05, significant.

3.4.3. Structural Paths

To test the structural relationships, the hypothesized causal paths were estimated; 5 hypotheses were accepted and 3 hypotheses were rejected. PU has a significant influence on AT (H2, β = 0.78, t = 3.25); AT slightly affects AB (H4, β = 0.85, t = 1.99). Oppositely, H1a (SCA to AB), H1b (SCB to AB), and H3 (NO to AT), were rejected. Finally, the model explains 75 % of the variance in AT and 73 % of the variance of AB.

4. Major Findings

PU and AT has a strong explanatory power (H2: β = 0.78; H4: β = 0.85) in explaining consumers' intention to adopt the HEIMS, the result points out when the consumers consider whether to adopt the HEIMS, PU would always be their priority. When HEIMS has a greater usefulness, and the consumers attitudes are moving toward more positive, and consumers' intentions to adopt HEIMS are becoming higher. SN would not positively affect AT (H3: β =0.24), we proposed the possible explanation: First, HEIMS is a new technology, it has not attracted consumers attention yet. Second, when respondents were completing the questionnaires, they would be given basic information about HEIMS. However, they did not realize whether people with influences on his (or her) decision would know about new technology of HEIMS. These factors have greatly reduced the effectiveness of SN.

SCD and SCS would not positively affect AB (H1a: β =-0.29; H1b: β =0.12), In order to find the major factors of switching costs, we conducted an analysis within the group for SCD (H1a) and SCS (H1b). The results are showed in Table 5, which could be explained as the followings: H1a (Q2+Q3) would positively affect AB, because most of respondents have high educational background (93.7% have bachelor's degrees or above) and are more familiar with 3C products. They are supposed quite familiar with computers and smart phones, which are similar to IHD. Therefore, when consumers are choosing deluxe option, Q1 is not a concern for switching costs. For this reason, SCD (H1a) would not positively affect AB. As to H1b(Q4+Q5), a possible reason might be that consumers feel that with only smart meter and IHD installed, their relationships with TPC will keep unchanged. As a result, when consumers are choosing standard option, Q6 is not a concern for switching costs. In sum, these factors have greatly reduced the effect of SCS (H1b).

Table 5: The Results of Analysis within the Group

Hypotheses	Analysis within the Group	
H1a: **Q1: procedural switching costs** **Q2: financial switching costs** **Q3: relational switching costs**	Q1+Q2	β = -0.09, t = -0.87
	Q2+Q3	β = 0.30, t = 2.27**
	Q1+Q3	β = -0.32, t = -1.73
H1b: **Q4: procedural switching costs** **Q5: financial switching costs** **Q6: relational switching costs**	Q4 +Q5	β = -0.26, t = -2.20**
	Q5+Q6	β =0. 20, t = 1.57
	Q4+Q6	β = 0.22, t = 1.72

**: The absolute value>1.94

5. Conclusion:

This paper had several theoretical and practical contributions. In theoretical grounds, we were investigated adoption factors and willingness to pay for HEIMS. Since H1a and H1b were rejected, we discovered that switching costs did not affect AB. These results have subverted conventional impression on switching cost being the obstacle of AB (Shapiro & Varian, 1999). In practical findings, the results of this market survey provide HEIMS suppliers a meaningful implication, i.e., HEIMS usefulness. Because it is the only factor that greatly affects AB. For example, a friendly display, tailor-made programming, information security, etc. are all very important. According to our research results, these PUs would greatly enhance consumers' AT on HEIMS and thus, increase their AB.

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