Concern of Uncertainty and Willingness to Pay for Adopting PSS: Example of Solar Power System Leasing

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Abstract

Conjoint analysis has been widely used to find consumers' preference and direction of improvement in new product development. It can also be used in product service system development and marketing as long as attributes and attribute levels are carefully selected. This study focuses on consumers' preference and willingness to pay (WTP) of product service system taking photovoltaic system as an example. Leasing is considered as a type of product service that consumers could choose. In addition, consumers' concerns on several uncertainties are measured in order to find the effect of uncertainty on preference of different lease times. The results show that the concern of uncertainties on government subsidy, electricity price, reliability, and rise of new generation solar power system would significantly affect the additional willingness-to-pay for shorter lease time. The relation between gap of WTP between lease times and uncertainty scores that measure consumers' concern are presented. Cluster analysis is used to find two groups with high and low concern of uncertainty. People with higher concern on uncertainty tend to pay more for adopting PSS with shorter lease time.

Keywords

Conjoint analysis, Lease time, Photovoltaic System, Uncertainty

1 INTRODUCTION

Conjoint analysis has been used to find consumers' preference for new product development and marketing. It can also be used in product service system (PSS) development and marketing as long as attributes and attribute levels are carefully selected. Since PSS is a combination of product and service, attribute selection needs to consider both ends to reflect characteristics of PSS and get adequate responses from customers. Defining attributes in conjoint analysis is essential and should be carefully conducted in a case by case basis. This study works on PSS of photovoltaic system with leasing service and finds consumers' preference and willingness to pay (WTP) for various service types, i.e. lease time. Preference of purchase and leasing are presented and compared while gaps of WTP between service types are estimated.

Since photovoltaic electricity system is considered clean and sustainable transforming solar energy directly to electricity, many countries have announced that photovoltaic energy is going to play essential role in electricity generation in near future. EPIA [1] estimated that overall annual installation of photovoltaic systems will increase more than three times by 2013. In fact, overall installation has grown 15 times from 1998 to 2008. For example, Taiwan's installed capacity has increased from 3KW to 2060KW from 2000 to 2007. Recently, local government also announced that electricity from renewable energy will be more than 11% of the total electricity generation by 2015. Among the capacity, solar power capacity would stand 6.25%.

As an emerging energy supplier, there are several competing solar energy technologies such as c-Si technology, thin film technology and new concepts technology. According to technology forecast [2], the cost and efficiency of solar energy technology will greatly improve in next 20 years. Among the technologies, thin film technology could have more improvement (up to 30% cost reduction) than silicon based technology. Efficiency improvement of both technologies is also expected to be 15% to 40%. Hoffmann et al [3] estimated that market share of thin film technology will increase from 5% (2005) to 35% (2030) while new concept technology such as chemical compound technology might also increase from 0%(2005) to 35% (2030). These technology forecast pointed out tremendous growth potential of solar power system, but also revealed that there would be dramatic change and competition among various solar power technologies.

In light of the technology uncertainty as well as policy uncertainty, this study considers effect of uncertainty in solar power system diffusion. Since photovoltaic technology is still an emerging technology, consumers are often concerned about uncertainty factors like inconsistent government incentive policy, changing price of electricity, reliability and maintainability, product lifetime, energy efficiency, and phase-out speed. It is essential to deal with these uncertainty concerns in order to expedite the growing speed and volume of solar power system market.

In summary, this study shows the use of conjoint analysis for finding consumers' preference and willingness to pay for new product service system, taking photovoltaic system leasing as an example. On the other hand, concern of uncertainty, including policy and technology uncertainty, is investigated to see its effect on adoption of photovoltaic systems with different types of PSS.

2 CONSUMERS' PREFERENCE AND ESTIMATION OF WILLINGNESS-TO-PAY VIA CONJOINT ANALYSIS

Conjoint model has been widely used in new product development (Krieger et al [4]; Green and Srinivasan [5]) to estimate consumers' utility function and find the preference structure. The part worth utility estimation of multiple attributes could be helpful in detecting

consumers' responses to the new product and provide feed-back to product development process for further improvement. Recently, conjoint analysis is also used in new service design evaluation. Good examples include Danielis et al [6], Lockshin et al [7], and Enneking et al [8].

In general, conjoint analysis consist of five steps, including determining attributes and levels, constructing model, building profiles, conducting survey and data collection, and conducting statistical analysis. For PSS application, attribute selection is the most essential part since it should cover both product and service concerns from customer's point of view. A good combination of attributes and attribute levels could reflect faithfully the preference structure of customers and hence obtain better estimate of WTP. In this study, conjoint analysis is conducted as follows:

- **Select important attributes and attribute levels of PSS**

Since number of attributes in conjoint analysis is recommended less than eight, attributes representing characteristics of PSS must be carefully selected. The attributes should cover aspects that targeted customers would consider in adopting a PSS to faithfully reflect the utility structure. Attributes should be representing characteristics for both product and service so that difference between product and PSS can be detected. It is better if attribute levels could stand for different types of PSS. A good selection of attributes would make conjoint analysis to have better explaining ability and useful results.

- **Construct preference model**

Several types of conjoint models have been proposed since the method was first proposed in 1970s. The mathematical form of multiple attribute utility function could be additive, multiplicative, and nonlinear. Evaluation collected from respondents could be ranking, rating, and comparison. This study presents a conventional conjoint model, where addition of main effects is adopted and rating scores on PSS profiles are collected in a survey. For the ensuing discussion, some notations are introduced herein.

m denotes the index for attribute. Assume there are M attributes, i.e., m = 1, 2, …, M.

l is the level for an attribute, for example, l = 1, 2, …, L_m denoting the levels of m^{th} attribute.

s_r^i is the evaluation rating obtained for the rth full profile received by respondent i.

r is the index for full profile, where r = 1,…, R, R is the total number of PSS profiles.

The preference model is in regression model form:

$$s_r^i = a + \sum_{m=1}^{M}\sum_{l=1}^{Lm} B_{ml}\, I_{rml}^i + e_r^i \qquad (1)$$

where I_{rml}^i equals to 1 when the rth full profile matches the level l at the m^{th} attribute; otherwise, I_{rml}^i equals to 0. In regressing the data, s_r^i and I_{rml}^i are adopted from the ratings from the respondents. It should be noted that **a** and B_{ml} are regression parameters in expression (1) while e_r^i is an error term. The parameter B_{ml} eventually is the part worth value at the level l of the mth attribute.

- **Build PSS profiles with factorial design**

In conjoint analysis, combinations of PSS profiles are presented to potential customers and ask for their rating and willingness to adopt the products that match the profile. Profiles of PSS are made according to combinations of all attributes levels. When the number of profiles is too large, fractional factorial design is used to reduce number of profiles in questionnaire design. Respondent would give rating of willingness to adopt for each product profile and the ratings from respondents are used in regression analysis in order to estimate part worth utility of attributes. The hypothetical product profile was presented verbally, as a list of attributes and levels.

- **Questionnaire survey and data collection**

PSS profiles are presented in a questionnaire to collect respondents' rating on willingness to adopt. A combination of attribute levels is showed as a profile to respondents. Number of profiles should be reduced to an acceptable level to avoid lengthy questionnaire and ineffective responses. In addition, personal data of respondents is collected to conduct marketing research such as finding market segment using cluster analysis. In this study, respondents' concern on uncertainty is measured using Likert scale. Six questions regarding six major uncertainties are included in the questionnaire.

- **Conduct statistical analysis and result analysis**

Conjoint analysis provides estimates of the part worth utilities of all attributes. As indicated in expression (1), part worth utilities are estimated using coefficients of the regression model. Commercial software like SPSS can well be used to conduct the regression analysis and present the part worth utilities. Since utility corresponding to each attribute level can be estimated, the shape of utility function for each attribute (i.e. part worth utility, PWU) can be obtained. Furthermore, Green and Wind [9] suggested that the range of part worth utility of an attribute represent the relative importance of this attribute.

Conjoint analysis can also be used to estimate willingness-to-pay (WTP) on certain attributes provided that price is selected as one of the attributes. Many recent literatures have used the method such as Hurlimann et al [10], Espino et al [11] and Longo [12]. The willingness to pay can be calculated using equation (2) where difference of part worth utility (PWU) between any pair of selected attribute levels is used to multiply the price coefficient. The price coefficient can be obtained using the price difference and the PWU difference of price attribute.

$$\beta_p = \frac{\beta_{highp} - \beta_{lowp}}{High\,\mathrm{Pr}\,ice - Low\,\mathrm{Pr}\,ice} \qquad (2)$$

$$WTP_{pair} = -\frac{\Delta\beta_{selected}}{\beta_p}$$

β_p: price coefficient

β_{highp}: PWU of the higher level of price attribute

β_{lowp}: PWU of the lower level of price attribute

HighPrice: higher level of price

LowPrice: lower level of price

WTP_{pair}: gap of WTP between the selected pair of attribute levels.

$\Delta\beta_{selcted}$: PWU difference between levels of selected attribute

3 UNCERTAINTY FACTORS IN ADOPTING PHOTOVOLTAIC ELECTRICITY SYSTEM

Not only solar power systems, uncertainty factors could cause resistance in adopting many innovative products. Ram and Sheth [13] stated that there are three major barriers in adopting innovation including value barrier, usage barrier and risk barrier. Value barrier means

innovation's inability to produce economic-or performance-based benefits while use barrier means innovation may not be compatible with existing workflows, practices and habits. The third barrier for consumers adopting innovative products is risk barrier which includes physical risk, functional risk, economic risk and social risk. Customers, aware of the risks, could postpone adopting the innovation until they could learn more about it or avoid the risks. Cox et al [14] mentioned that consumers are cautious about accepting novel technologies because of perceived risk and lack of benefits. They used conjoint model to study consumers' perceived risk, benefits, need, unnaturalness and safety of the technologies. Participants were segmented by the sum of their beliefs on the novel technologies.

Since photovoltaic technologies are still in a fast changing stage, consumers are also very cautious in adopting the technology. Uncertainty of payment for innovative products could increase the value barrier. They include government policy on subsidy, selling price and the price of electricity which heavily depends on changing fossil fuel prices. On the other hand, the risk barrier could be caused by several uncertainty factors such as product lifetime, reliability and maintainability, replacement by new generation technology. This study focuses on value and risk barriers in adopting solar power systems.

Before actually designing the questionnaire, field interview was conducted to verify the uncertainty factors that are concerned by customers. Questions about whether respondents are concerned about the uncertainty factors while considering adopting solar energy system are included in the questionnaire. Five point Likert scale was used to collect degree of concern on the particular uncertainty. Each respondent was asked to choose between "very agree" and "very disagree" on the statement concerning each of the six uncertainty factors. These responses reflecting respondents' concern would be used to find their relationship to the adoption and willingness to pay later.

4 CONJOINT ANALYSYS FOR SOLAR POWER SYSTEM ADOPTION CONSIDERING LEASING

Leasing is considered an option of PSS in promoting photovoltaic systems. Instead of purchase, leasing may reduce consumers' worry on these uncertainty factors, especially for an expensive new product. By leasing a solar system, consumers can get electricity without actually owning it. The risk due to uncertainty factors of new products is taken by the service providers. Currently, there are some leasing service providers in the US. Consumers can choose lease term for one, five, ten or fifteen years. Service providers would take care of installation, maintenance, and repair of the system. The rent may be fixed or adjustable following local electricity price at the time. Service providers generally do not charge rent if the system is broken or under maintenance. When the lease term is up and extension is of interest, the companies can upgrade the system for free.

In light of the existing lease service of photovoltaic power system, this study works on consumers' preference and willingness-to-pay for the leasing service using conjoint analysis. Multiple attribute utilities of consumers' preference are estimated. Gaps of willingness-to-pay from one attribute level to another level are estimated. Time period for leasing is intentionally set as one of the attributes to investigate the willingness to pay between various leasing time. On the other hand, consumers' concerns on several uncertainty factors are measured. The main research question is how much consumers are willing to pay (WTP) to reduce the aforementioned uncertainty by adopting leasing instead of purchase.

When consumers consider a solar energy system, many attributes could be considered. Besides price, capacity, reliability, maintenance, and efficiency are some examples. They could reflect economical as well as functional aspect on the consumer side. In this study, lease time is included to find out the utility of leasing duration. The levels of leasing time are selected as 5, 15, and 20 years while 20 years is looked as purchase. Payment per month for leasing is selected as one attribute so that gap of WTP could be calculated for comparison. Other attributes selected include monthly payment, capacity, and frequency of break down. Table 1 shows the attribute and attributes levels. The attribute levels of capacity and monthly payment are defined based on the ranges of actual electricity usage. As to reliability concern, Goett et al [15] suggested that when a solar energy system breaks down more than three times, the reliability would be considered a serious problem.

attribute	levels
Capacity	（1） 300 KW hr
	（2） 700 KW hr
	（3） 1100 KW hr
Payment per month	（1）2500 NT dollars per month*
	（2）6000 NT dollars per month
	（3）9500 NT dollars per month
Lease time	（1）5 year
	（2）10 years
	（3）20 years (equivalent to purchase)
Frequency of break down	（1）high
	（2）low

*Note: 1 US dollar is approximately 32 NT dollars

Table 1: Attributes and attribute levels.

Questionnaire survey is conducted via internet, while popular web sites and BBS are selected to spread the message. A web site was set for questionnaire and collecting responses. 317 responses were collected within a month. The respondents aged less than 21 were erased to represent the population who may purchase solar power systems. The effective sample size is then reduced to 217 (70%). Table 2 shows the statistics of the sample.

variables	number	Percentage (%)
Male	82	37.8
Female	135	62.2
21-25	89	41.0
26-30	94	43.3
31-35	24	11.1
36-40	5	2.3
41 and above	5	2.3
High school	7	3.2
College	150	69.1
Graduate school	60	27.6
30K and below	120	55.3
30-50K	77	35.5
50K and above	20	9.2

Table 2: Sample statistics.

5 RESULTS OF PART WORTH UTILITY AND CONCERN ON UNCERTAINTY FACTORS

Part worth utilities (PWU) of the four attributes are obtained using conjoint analysis. Table 3 shows the PWU and the relative importance based of the ranges of PWU. Payment per month is the most important attribute (51.7%) while electricity capacity is the least important attribute (8.8%). Leasing time ranks the third (10.8%).

attributes	level	PWU	Range of PWU	Relative importance
capacity	300 kW hr/month	0.1490	0.2980	8.8%
	700 kW hr/month	0.2980		
	1100 kW hr/month	0.4470		
Payment per month	2500 dollars	-0.8771	1.7542	51.7%
	6000 dollars	-1.7542		
	9500 dollars	-2.6313		
Lease time	5 years	0.1546	0.3656	10.8%
	10 years	0.0563		
	20 years	-0.2110		
Frequency of break down	Low	0.4869	0.9738	28.7%
	High	-0.4869		

Table 3: PWUs of four attributes and relative importance.

In the questionnaire, Likert scale of five was used to measure the concern severity of uncertainty factors. Table 4 shows the statistics on the concern on uncertainty factors including government subsidy, price, lifetime, reliability, replaced by new model and electricity price. For overall sample, replaced by new model, lifetime and price are of more concern with average score greater than 4 (5 for very concern). Concern on reliability is also high. Cluster analysis is used to see if there is significant difference between concerns on uncertainty. The bottom half of Table 4 shows two clusters with significant different opinions on uncertainty factors using analysis of variance (ANNOVA). Group 1 with higher concern scores is named “high concern group”, while group 2 is called “low concern group”.

Table 5 shows the relative importance of four attributes from the responses of the two groups. Group of higher concern ranks lease time the third while group of lower concern ranks it the fourth. The percentage of female of group 2 is higher than of group 1. The average age of the first group is slightly younger than the second group. On the other hand, Group 1 has higher income than that of group 2.

group	Sample size			
		subsidy	price	replacement of new model
All	217	3.89 (0.76)	4.08 (0.76)	4.16 (0.74)
Group 1	140	4.02	4.34	4.44
Group 2	77	3.66	3.61	3.65
ANNOVA results	F	11.65	58.56	76.36
	p value	0.001	0.000	0.000

group	Sample size			
		reliability	lifetime	Electricity price
All	217	3.97 (0.71)	4.13 (0.66)	3.77 (0.90)
Group 1	140	4.26	4.34	4.08
Group 2	77	3.44	3.77	3.61
ANNOVA results	F	93.81	44.98	14.53
	p value	0.000	0.000	0.000

Table 4: Results of uncertainty scores of all sample and two groups.(standard deviation is inside parenthesis).

attributes	level	Group 1	Group 2
		importance	importance
Capacity kW hr/month	300	8.79%	4.78%
	700		
	1100		
Monthly payment	2500	51.72%	56.12%
	6000		
	9500		
Lease time	5 years	10.78%	4.08%
	10 years		
	20 years		
Frequency of break down	Low	28.71%	35.02%
	high		
variables		Percentage (%)	Percentage (%)
Gender	Male	42.9	28.6
	Female	57.1	71.4
Age	21-30	85.0	83.2
	31-40	12.8	14.3
	41 above	2.1	2.6
Monthly income (NT dollars)	30K and below	50.7	63.6
	30-50 K	39.3	28.6
	50K and above	10.0	7.8

Table 5: PWU and relative importance of attributes in two groups.

6 GAP OF WILLINGNESS TO PAY BETWEEN LEASING AND PURCHASE

After obtaining part worth utilities of all attributes, willingness to pay for each pair of attribute levels can be calculated using equation (2). For example, Table 6 shows the utilities between different lease times as well as the gaps of willingness to pay between pairs of lease times. Consumers are willing to pay extra NT 1459 dollars on the average for choosing 5 year lease time than 20 year lease time. Please note that leasing 20 years means a long term commitment and could be interpreted the same as purchase herein. Comparing to the monthly worth of purchase, 3200 dollars, extra payment of 1459 dollars is about 45% of the purchase price. The gap of WTP implies that consumers are willing to pay 45% more to take an option of leasing the system for five years instead of purchasing it. This can also be seen as a payment to avoid the risk of holding a solar system for more than 20 years. The difference of WTP between leasing 5 years and 10 years is 392 NTD, while the difference of WTP between leasing 10 years and 20 years is 1067 NTD.

Difference of utility	10 years	20 years
5 years	0.098	0.366
10 years	-	0.267

Difference of willingness to pay (NTD)	10 years	20 years
5 years	$392	$1459
10 years	-	$1067

Table 6：Differences of utilities and willingness to pay between lease times.

Another interesting question is whether concern of the uncertainty factors is related to the WTP between short term lease and purchase. People with higher concern on uncertainty and resistance to new products are supposed to choose shorter term lease. Table 7 shows the correlation between gap of WTP and concern scores of uncertainty factors using Pearson correlation. Gap of WTP between lease times is highly correlated with most uncertainty factors like government subsidy, product lifetime, reliability, rise of new model and electricity price. The only uncertainty measure that is not significantly related to gap of WTP is product price. Among the uncertainty scores, score on reliability concern is highly correlated with gap of WTP. Concern on product lifetime has the least correlation with gap of WTP.

Gap of WTP (5 years-20 years)	Government subsidy	Product price	Product lifetime
Pearson correlation	0.168	0.077	0.143
p value	0.013**	0.257	0.035**

Gap of WTP (5 years-20 years)	reliability	Rise of new model	Electricity price
Pearson correlation	0.298	0.161	0.158
p value	0.000***	0.017**	0.020**

Table 7：Correlation between WTP gap and uncertainty score.

To compare the willingness to pay between groups of higher concern and lower concern on uncertainty factors, differences of utility and WTP between different lease times are shown in Figure 1. Group 1 has larger gap of WTP between lease times, meaning people with higher uncertainty concern prefer shorter lease time to avoid the risk. Take the comparison between 5 and 20 year lease times as an example, group 1 is willing to pay extra 1969 NT dollars for 5 year lease time than 20 year lease time. The extra payment per month is larger than that offered by group 2, 508 NT dollars. Comparing the lease times of 5 and 10 years, group 1 are willing to pay extra 537 NT dollars, which is larger than that (64 NT dollars) willingness to pay offered by Group 2. This result meets our hypothesis that short term leasing would be adopted by people who have higher concern of uncertainty factors. Higher amount of WTP for shorter leasing time by group 1 verifies the hypothesis.

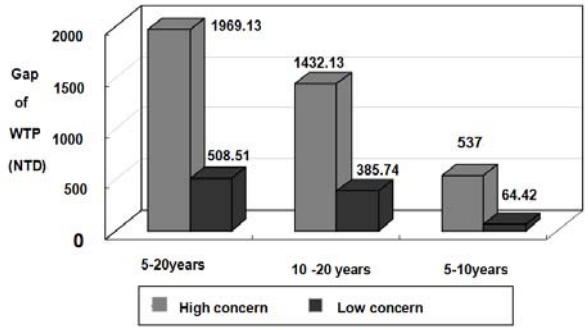

Figure 1 ：Gap of WTP between different lease times for two groups.

7 SUMMARY

This study presents application of conjoint analysis on PSS marketing and development, taking solar power system as an example. Solar power system is looked as one of the most promising renewable energy sources and novel green products adopted by consumers in the near future. But, since there are many uncertainties for the emerging technology, PSS such as leasing might be an option to help consumers reduce their risk and worry. This study finds consumers' preference of solar power systems and focuses on the willingness to pay for leasing the system comparing to purchasing. Questionnaire survey on consumers' concern on certain uncertainty factors that may affect the adoption of solar power system is conducted. Conjoint analysis is used to estimate PWU of the attributes of solar power system and the willingness to pay regarding various attributes. By including lease time as an attribute in conjoint model, the gap of WTP between various lease times can be estimated. Gaps of willingness to pay between shorter and longer leasing times could be estimated. Since leasing time equal to 20 years is interpreted as purchase, the gap of willingness to pay between shorter leasing time and purchase can be estimated.

In addition, the relation between gap of WTP between lease times and uncertainty scores that measure consumers' concern are presented. Cluster analysis is used to find two groups with high and low concern of uncertainty. Gaps of WTP for different lease time for the two groups are compared. People with higher concern on uncertainty tend to pay more for adopting shorter lease time. Characteristics of the two groups are also presented.

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