Measuring Barriers to the Widely Implementation of Energy-efficient Appliances: An Estimation of Subjective Discount Function

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1. Introduction

Current evidence showed a high possibility that the temperature will rise 1.5°C by the end of 2030. More active energy saving, and emission reduction behaviors should be conducted. The residential sector has great potential in cutting emissions. Counting for one-fourth of world emissions, residential energy use can vary greatly depending on the individual's behaviors and the using appliances. The latest household appliances can achieve more than 30% of energy saving[1]. Reform of dwellings improved the indoor thermal insulation performance, and the implementation of residential photovoltaic systems provide a safe energy supply to the house. Facing sustainable pressure after the Tohoku earthquake in 2011, Japan aimed to reduce 40% of residential emission[2]. China, with its fast-speed development, produced the most emissions in the world and had great potential for emission reductions.

However, the adoption speed of energy-saving appliances in both countries was slow, indicating that such long-term benefits are not favored by people. A major obstacle to the large implementation of energy-efficient appliances is that these appliances usually cost high initial payment and take long terms to payback, refraining people from buying these appliances. To get rid of initial payment, a special loan called "pay as you save (PAYS)" was introduced to allow people to pay loans with energy bills they saved. Also, if taking the non-energy benefit (NEB), for example, the health effect of thermal insulation retrofit into account, people might be more willing to adopt this appliances[3].

The subjective discount rate represents the present value of a future reward. It revealed peoples' preference between current and future values and was used to explain peoples' purchase behaviors. Previous studies tried to measure variables that affect the subjective discount rate or tried to estimate subjective discount rates by generating discount functions. Few studies have considered using the subjective discount rate and discount functions to estimate the utility function of purchase decisions.

Table 1 Overview of Questionnaire Surveys

Questionnaire Survey		
Survey Method:	Internet Survey	
Executing Agency	NTTCom Online Marketing Solutions Corporation	
Valid Sample	China: 1124	Japan: 1053
Survey Period	China: 2019/09/06～2019/09/07	Japan: 2019/08/29 ~ 2019/09/02
Survey Area	All prefectures in China	All prefectures in Japan
Exclusion	Respondents under 20 years old / Students	

Table 2 Sample size for each group in China and in Japan.

	China			Japan		
	Male	Female	Sum	Male	Female	Sum
Group1	67	64	131	54	55	109
Group2	61	65	126	55	53	108
Group3	210	218	428	209	208	417
Group4	219	220	439	209	210	419
Total	557	567	1124	527	526	1053

In this study, questionnaire surveys were used in China and Japan for data collection. Observations of respondents' subjective discount rates and parameters of discount functions were conducted. Another observation of respondents' purchase decision on energy-efficient appliances with different given conditions was conducted independently. The main purpose of this study is to analyze the correlation between subjective discounting and purchase behaviors. Additionally, the effects of PAYS and NEB on respondents' purchase decisions will be measured. This study assumes that peoples' purchase decisions on energy-efficient appliances can be predicted through their subjective discount rate and parameters of discount functions. Buying appliances with additional NEB by PAYS is assumed to increase respondents' purchase willingness.

2. Method

Internet survey through a research company collected over 1000 valid samples in China and Japan respectively, from late August to early September. Table 1 is a summary of the questionnaire surveys' conditions.

There were 64 questions in the questionnaire. Questions were designed to collect:

a) Subjective discount rate
b) Purchase decisions on energy-efficient appliances
c) Demographic data

In each country, respondents were divided into 4 different groups (Table 2), each group will answer questions based on different conditions.

2.1 Subjective discount rate & Discount function

Respondents were asked to choose between a near term reward with less money and a delayed reward with more money. 6 sub-questions in each set (Figure 1), and 5 sets of delayed time were asked. For respondents in different groups, the baseline of rewards, and the source of rewards were

different (Table 3). A hyperboloid discount function proposed by Green et al.[4] was used to estimate respondents' subjective discount rates (Equation 1)

$$F(t) \cdot P = (1 + \alpha \cdot t)^{-\frac{\beta}{\alpha}} \cdot P \qquad (1)$$

$F(t)$ is respondents discount rate, calculated by delayed time t, parameter $\frac{\beta}{\alpha}$ and α that indicate the sensitivity of delay. P is the baseline reward.

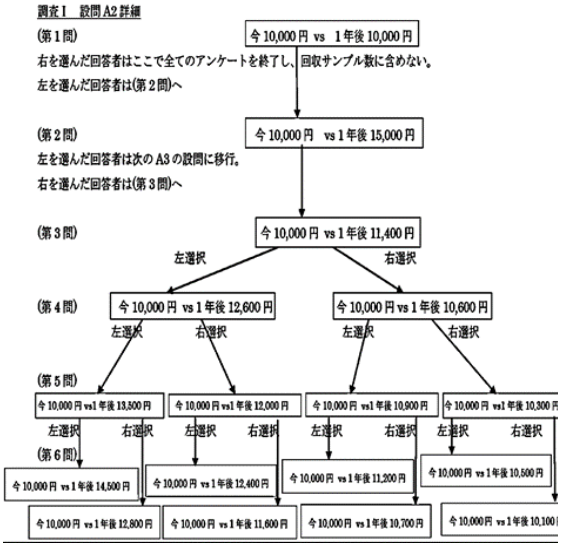

Figure 1 Example of 6 sub-questions in one given delayed time.

2.2 Purchase Decisions

Basic conditions of an energy-efficient appliance were given to each respondent. Depending on respondents' group, the price and annual energy savings varied. The annual energy savings was set to the baseline reward indicated in Table 3, and the price is 5 times of this baseline. Among 4 questions, different payment method and information about non-energy benefit was provided.

Table 3 Differences among groups by source of rewards and reward baselines.

		Baseline	Source
China	Group1	1,000 CN ¥	By wining lottery
	Group2	10,000 CN ¥	By wining lottery
	Group3	1,000 CN ¥	Investment gains
	Group4	10,000 CN ¥	Investment gains
Japan	Group1	10,000 JP ¥	By wining lottery
	Group2	100,000 JP ¥	By wining lottery
	Group3	10,000 JP ¥	Investment gains
	Group4	100,000 JP ¥	Investment gains

2.3 Binary Logistic Regression

Result of respondents' subjective discount rate, their parameter of discount functions and their demographic data will be used as independent variables. The result of purchase decisions will be used as dependent variables to measure the probability of respondents' dichotomous purchase decisions.

3. Result

Through calculation, the mean value of each respondent's subjective discount value overtime can be found. Results showed that respondents from all groups in China had higher discount rate than those in same groups in Japan (Table 4), Means the subjective value of future rewards for Chinese respondents should be lower than those of Japanese respondents. Demographic data between China and Japan had significant different, and all groups respondents in Japan had higher average income than respondents in China (Table 5).

The result of binary regression analysis (Table 6) showed that these variables has significant positive correlation with the purchase of energy-efficient appliances:

Table 4 Mean of subjective discount rate by group.

Country	Group	Mean of Subjective discount rate
China	Group1	18%
	Group2	17%
	Group3	18%
	Group4	16%
Japan	Group1	7%
	Group2	2%
	Group3	7%
	Group4	4%

Table 5 Average annual income by group.

Country	Group	Average Income (million JP ¥)
China	Group1	3.06
	Group2	3.02
	Group3	3.19
	Group4	3.25
Japan	Group1	4.68
	Group2	5.15
	Group3	4.96
	Group4	4.66

1) Subjective discount rate (represented as NPV in Table 6)
2) Parameter of discount functions ($\frac{\beta}{\alpha}$)
3) Health benefit (NEB)

Besides these positive results, we found that providing payment method "PAYS" to Japanese respondents had a significant negative correlation with the purchase willingness.

4. Conclusion

This study measured subjective discounting and purchase decision independently, which few previous studies had done. Individual's subjective discount rate and the parameter of the discount function aligned with their purchase decisions, so subjective discount rate and discount function can be used to predict purchase decisions. Information of non-energy benefit will increase respondents' willingness to purchase energy-efficient appliances, which can be a new direction for future propaganda.

Table 6 Result of binary regression analysis.

Variable	China Group3	China Group4	Japan Group3	Japan Group4
NPV-PAYS	0.37***	0.15**	0.24***	0.31***
NPV-一括払い	0.13***	-0.03	0.19***	0.26***
β/α	0.003**	0.002*	0.003**	0.004***
NEB	0.40***	0.27**	0.36***	0.35***
Payment Method	-0.06	0.27	-0.72***	-0.45**
Age	-0.04***	-0.01	0.02***	-0.01
Gender	-0.74***	0.32**	0.33**	0.85***
Income	0.05	0.03	0.02	-0.001

*** p<0.01, ** p<0.05, * p<0.1

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