Preference Characteristics and EE investment: Focusing on Time, Risk, and Social Preferences

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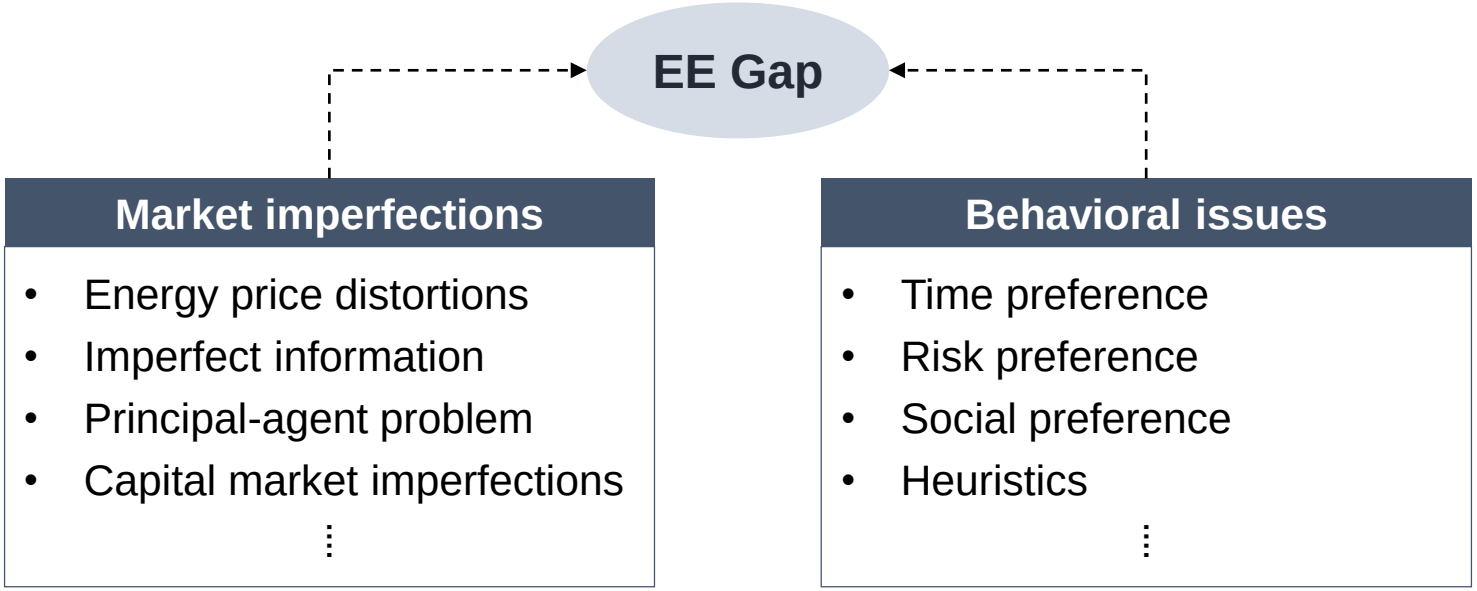
Contents

I. Introduction

1 Motivation

Energy efficiency (EE) gap

- Why do consumers **fail to adopt EE technologies** that are even economically superior? **(Gerarden et al., 2014)**
- **Sources of EE gap:** Market imperfections & behavioral issues
  (Hirst and Brown, 1990; Gillingham et al., 2009; Kim and Shim, 2015)



I. Introduction

1 Motivation

Role of the behavioral issues in narrowing EE gap

- Explain why **some people invest in EE but others do not** under the same condition
- Understand **people's actual decisions on EE**, which **deviates from the ideal decisions** **(DellaVigna, 2009)**

EE investment & preference characteristics

- EE investment can be converted into a decision on how much **pay more upfront capital costs for reducing energy costs** over a long period of time **(Hausman, 1979)**.
- **Individually heterogeneous preference characteristics** could influence the perceived value of tradeoffs between capital and energy costs.

I. Introduction

2 Summary

Research question

- What is the influence of time, risk, and social preferences on a home energy retrofit decision?

My answer

- Preference characteristics play a significant role in home energy retrofit decision.

Theoretical model

- Modification of Allcott and Greenstone (2012)'s model of EE investments
- Formulation of 6 research hypotheses

Empirical study

- Well-designed survey on Korean people's decisions on home energy retrofit and their time, risk, and social preferences
- Significant effects of preference characteristics on home energy retrofit decisions

II. Research Background

1 Theoretical Model

Model of EE investments

- Modification of **Allcott and Greenstone (2012)**'s model
- Decisions of home energy retrofit, i.e. increasing the EE of HVAC system
- **Option A : Do home energy retrofit** / Option B : Maintain the status quo

Assumptions

- Period 0 : Pay for capital investments / Period 1 : Pay for energy costs
- Incremental upfront capital cost of A : $c > 0$
- Energy intensity : $e_A < e_B$ (Option A is more energy efficient)

II. Research Background

1 Theoretical Outline

- **Agent i will choose the option A if**

Net present cost of A | **Net present cost of B**

$$D_i(p \cdot m_i \cdot e_A) + \varphi_i D_i(m_i \cdot e_A) + \mathrm{c} + \xi_i < D_i(p \cdot m_i \cdot e_B) + \varphi_i D_i(m_i \cdot e_B) \quad \text{Eq. (1)}$$

Discounted energy cost | Internalized negative externalities | Discounted energy costs | Internalized negative externalities

$$\Leftrightarrow \quad (p + \boldsymbol{\varphi_i}) m_i (e_B - e_A) \boldsymbol{D_i} - \boldsymbol{\xi_i} > c \quad \text{Eq. (2)}$$

- Discounting factor of the energy costs: $0 < D_i \leq 1$
- Unobserved incremental cost **(Greene, 2011)**: ξ_i ($\xi_i > 0$: cost, $\xi_i < 0$: benefit)
- Degree of internalizing negative externalities **(Di Maria et al., 2010)** : $\varphi_i \geq 0$
- Energy price in the period 1 : $\mathrm{p} > 0$
- Taste for usage of HVAC system in the period 1: m_i

II. Research Background

2 Research Hypotheses

Time preference

- ***HP1a.*** **If an agent's time preference is present biased ($\beta_i < 1$), the possibility of investing in home energy retrofit will decrease.**
- ***HP1b.*** **The greater adjusted discounting factor ($\delta_i \uparrow$), the greater possibility of investing in home energy retrofit.**

Risk preference

- ***HP2.*** **The more risk averse, the lower possibility of investing in home energy retrofit.**

Social preference

- ***HP3a.*** **The more seriously concern the influence of environmental pollution and climate change, the greater possibility of investing in home energy retrofit.**
- ***H3b.*** **The stronger personal norm, the greater possibility of investing in home energy retrofit.**
- ***H3c.*** **The more sensitive toward social comparison, the greater possibility of investing in home energy retrofit.**

II. Research Background

3 Literature

Time preference

- Di Maria *et al*.(2010), Newell and Siikamäki (2013), Richard and Gareth (2015), Fischbacher *et al*.(2015)

Risk preference

- Farsi (2010), Allcott(2011), Alberini *et al.*(2013), Qiu *et al*.(2014), Fischbacher *et al*.(2015)

Social preference

- Di Maria *et al*.(2010), Choi (2011), Alberini *et al.*(2013), List and Price(2013), Kim and Jung (2014), Fischbacher *et al*.(2015), Ramos et al.(2016)

Contributions

- Provide empirical results consistent with theoretical explanation
- Provide a reliable result by excluding respondents' subjective judgements when eliciting preference characteristics

III.Survey Design

1 Survey Outline

Survey purpose

- **Collect data** for analyzing the effects of Korean people's time, risk, social preference on decisions of home energy retrofit

Sample

- **Target population :** Household head or spouse aged from 20 to 65 living in detached house, apartment, and multi-family houses in 16 regions across the country
- Quota sampling by housing type, region, gender, and age in 2010 Census (KOSIS, 2010)

Survey process : Online survey

- 1st pilot survey at May 31, 2016 : 230 responses
- 2nd pilot survey on June 22-23, 2016 : 305 responses
- Final survey on July 18-26, 2016 : **1,856 responses**
  - Sent an e-mail 27,872 individuals and received a total 1,856 completed responses (6.7%)

III.Survey Design

2 Questionnaire Contents

A. Time preference
(lottery choice experiment)
⇨ **Discounting factor, Present Bias**
(Coller and Williams, 1999; Laibson, 1997)

B. Risk preference
(WTP for a gamble)
⇨ **Risk aversion coefficient**
(Holt and Laury, 2002; Park and MacLachlan, 2013)

C. Social preference
⇨ **Attitude toward environmental issue,**
Moral obligation, Social comparison, & etc.
(Diekmann and Preisendörf, 1998, 2003; Kim et al, 2009)

D. Housing and energy-use
⇨ **Home energy retrofit decisions,**
Housing conditions, Energy expenses, & etc.

E. Socio-economic factors
⇨ **Age, Gender, Income, Education,**
Family size, & etc.

III.Survey Design

2 Questionnaire Design

Questions for eliciting time preference

- Based on the MPL (Multiple Price Listing) **(Coller and Williams, 1999)**
- Present a series of choices between two alternatives (A & B)
- Identify the parameters of a quasi-hyperbolic discounting factor **(Laibson, 1997)**

$$D_i(t) = \begin{cases} 1 & if \quad t = 0 \\ \beta_i \times \delta_i^t & if \quad t = 1, 2, \ldots \end{cases}$$

P. Bias **D.Factor**

Table 1. Payoff table for 1 and 10 year horizons

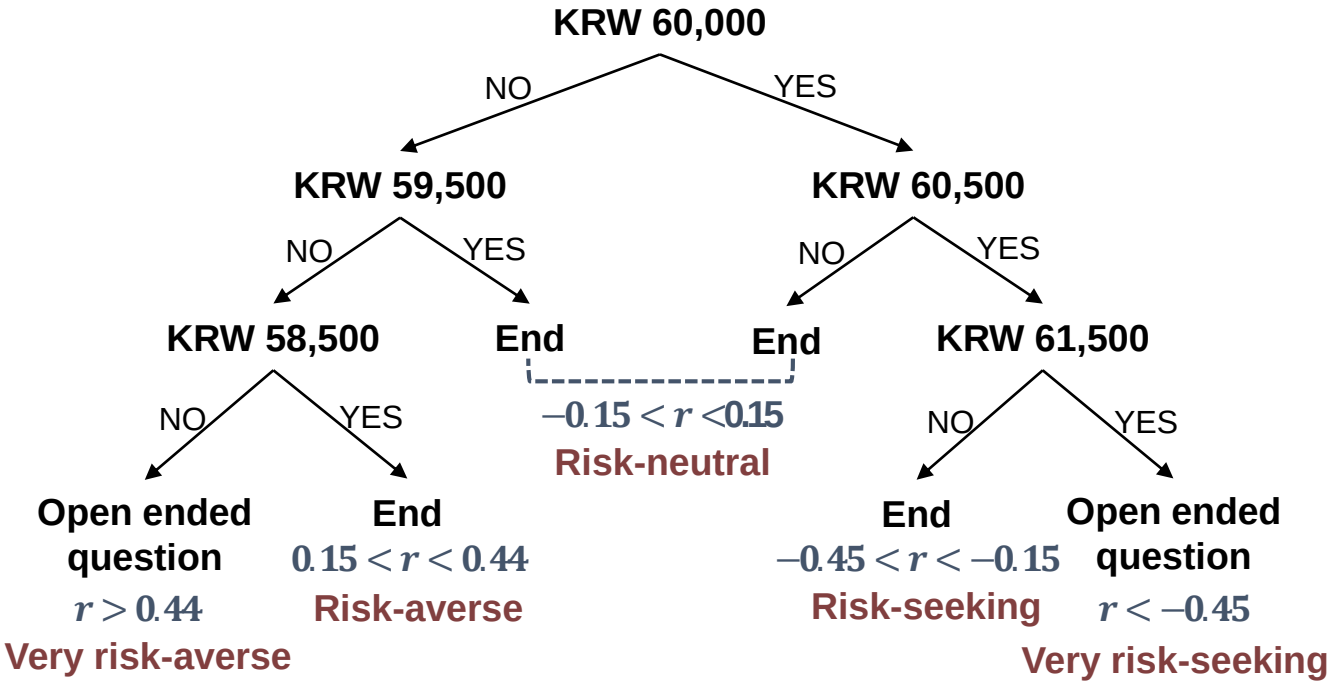
First binary choice : $D_i(1)$			Second binary choice : $D_i(10)$		
Choice A 1 month (KRW)	Choice B 1 year (KRW)	Discounting factor $D_i(1)$	Choice A 1 month (KRW)	Choice B 10 years (KRW)	Discounting factor $D_i(10)$
500,000	520,000	0.962	500,000	700,000	0.714
500,000	540,000	0.926	500,000	1,100,000	0.455
500,000	560,000	0.893	500,000	1,600,000	0.313
500,000	580,000	0.862	500,000	2,200,000	0.227
500,000	600,000	0.833	500,000	3,000,000	0.167

III. Survey Design

2 Questionnaire Design

Questions for eliciting risk preference

- **Measure of risk aversion :** CRRA coefficient r **(Holt and Laury, 2002)**
- **Calculation of CRRA coefficient :** Willingness pay for a gamble where tossing a coin, a player is paid KRW 80,000 if the head is upside, or KRW 40,000 otherwise **(Park and MacLachlan, 2013)**



III.Survey Design

2 Questionnaire Design

Questions for eliciting social preference

- **Attitudes toward environment / climate change issue**
  - 9 items developed by **Diekmann and Preisendörf (2003)**
  - Measure the attitudes from the affective, cognitive, and conactive aspects
- **Personal norm : Moral obligation**
  - Experiences of donations and volunteers **(Kim et al, 2009)**
- **Social comparison**
  - Perceived level of energy cost in comparison with similar household
  - Based on the idea of Home Energy Report by **Opower**

IV. Model Specification and Data Description

1 Model Specification

Relationship among variables of interest

Model 1 : $y_1^* = \boldsymbol{X}\boldsymbol{\beta}_1 + u_1$, where $y_1 = \begin{cases} 1 & if \quad y_1^* > 0 \\ 0 & otherwise \end{cases}$ Eq. (3)

- y_1^* : Latent utility function determining whether or not to invest in energy retrofit in the past
- y_1 : 1 if one has experiences of home energy retrofit, or 0 otherwise
- $\boldsymbol{X}$: set of covariates $(1 \times k)$ – including preference characteristics, socio-economic factors, housing conditions, etc.

Model 2 : $y_2^* = \boldsymbol{X}\boldsymbol{\beta}_2 + u_2$, where $y_2 = \begin{cases} 1 & if \quad y_2^* > 0 \\ 0 & otherwise \end{cases}$ Eq. (4)

- y_2^* : Latent utility function determining whether or not to invest in energy retrofits in the future
- y_2 : 1 if one has a plan of home energy retrofit in 3 years, or 0 otherwise

IV. Model Specification and Data Description

1 Model Specification

Probit model

$$\begin{aligned}\Pr(y_1 = 1|\boldsymbol{X}) &= \Pr(\boldsymbol{X\beta}_1 + u_1 > 0) \\ &= \Pr(u_1 > -\boldsymbol{X\beta}_1) \\ &= F(\boldsymbol{X\beta}_1) \\ &= \Phi(\boldsymbol{X\beta}_1)\end{aligned} \qquad \text{Eq. (5)}$$

Partial effects (for continuous and discrete regressor, respectively)

$$\begin{aligned}PE_j(\boldsymbol{X}) &= \frac{\partial E[y_1|\boldsymbol{X}]}{\partial x_j} \\ &= \frac{\partial \Pr[y_1=1|\boldsymbol{X}]}{\partial x_j} \\ &= \beta_j \phi(\boldsymbol{X}\beta_1)\end{aligned} \qquad \text{Eq. (6)}$$

$$\begin{aligned}PE_j(\boldsymbol{X}) &= E\left[y_1\middle|\boldsymbol{X}_{(j)}, x_j = 1\right] - E\left[y_1\middle|\boldsymbol{X}_{(j)}, x_j = 0\right] \\ &= Pr\left[y_1 = 1\middle|\boldsymbol{X}_{(j)}, x_j = 1\right] - Pr\left[y_1 = 1\middle|\boldsymbol{X}_{(j)}, x_j = 1\right] \\ &= \Phi\left(\boldsymbol{X}_{(j)}\boldsymbol{\beta}_1 + \beta_{1,j}\right) - \Phi\left(\boldsymbol{X}_{(j)}\boldsymbol{\beta}_{1,j}\right)\end{aligned} \qquad \text{Eq. (7)}$$

IV. Model Specification and Data Description

2 Data Description

1,609 observations

- Excludes inappropriate responses

Dependent variables

- y_1 : Experience (whether or not experienced home energy retrofits in the past)
- y_2 : Plan (whether or not has a plan of home energy retrofits in the near future)

Independent variables (X)

- Time preference : P.Bias (-), D.Factor (+)
- Risk preference : Risk.1 (+), Risk.2 (+), Risk.4 (-), Risk.5 (-)
- Social preference : Attitude (+), Donation (+), Volunteer (+), Comparison (+)
- Socio-economic factor : Edu (+, -), Child (+), Senior (+), Inc.2~Inc.5 (+)
- Housing condition : Apart (+, -), H.age1 (+), H.age3 (-), Homeowner (+), MP2 (-, +)
- Energy-use : Expense (+), Prospect (+)

IV. Model Specification and Data Description

2 Data Description

Table 2. Data description and sample statistics

Variable	Description	Type	Mean (S. D.)
Experience	1 if one has experienced home energy retrofit in the past, or 0 otherwise.	1/0	0.749 (0.434)
Plan	1 if one has a plan of home energy retrofit in 3 years, or 0 otherwise.	1/0	0.672 (0.469)
P.Bias	1 if $\beta_i < 1$ where $D_i(t) = \beta_i \delta_i^t,\ t \geq 1$, or 0 otherwise.	1/0	0.659 (0.474)
D.Factor	δ_i where $D_i(t) = \beta_i \delta_i^t,\ t \geq 1$	Conti.	0.877 (0.069)
Risk.1	1 if one is very risk seeking, or 0 otherwise.	1/0	0.149 (0.356)
Risk.2	1 if one is risk seeking, or 0 otherwise.	1/0	0.028 (0.165)
Risk.3	1 if one is risk neutral, or 0 otherwise (base).	1/0	0.080 (0.272)
Risk.4	1 if one is risk averse, or 0 otherwise.	1/0	0.009 (0.093)
Risk.5	1 if one is very risk averse, or 0 otherwise.	1/0	0.735 (0.442)
Attitude	Attitudes toward environmental & climate change issues (standardized)	Conti.	0.000 (3.047)
Donation	1 if has donated ever, or 0 otherwise.	1/0	0.622 (0.485)
Volunteer	Degree of participation in unpaid volunteer activities (standardized)	Conti.	0.000 (3.285)
Comparison	Relative degree of energy costs compared to similar households (standardized)	Conti.	0.000 (0.889)
Edu	1 if entered or graduated a college, or 0 otherwise	1/0	0.843 (0.364)
Child	1 if there is any preschool child in one's family, or 0 otherwise.	1/0	0.204 (0.403)

IV. Model Specification and Data Description

2 Data Description

Table 2. Data description and sample statistics (Continued)

Variable	Description	Type	Mean (S. D.)
Senior	1 if there is any senior in his/her family, or 0 otherwise.	1/0	0.221 (0.415)
Inc.1	Avg. monthly household income: below KRW 2 million (base)	1/0	0.085 (0.279)
Inc.2	Avg. monthly household income: KRW 2-4 million	1/0	0.307 (0.461)
Inc.3	Avg. monthly household income: KRW 4-6 million	1/0	0.365 (0.482)
Inc.4	Avg. monthly household income: KRW 6-8 million	1/0	0.152 (0.359)
Inc.5	Avg. monthly household income: over KRW 8 million	1/0	0.091 (0.287)
Apart	1 if living in an apartment, or 0 if living in other types of house	1/0	0.643 (0.479)
H.age1	1 if living in a house built before 2000, or 0 otherwise.	1/0	0.514 (0.500)
H.age2	1 if living in a house built between 2000 and 2010, or 0 otherwise (base).	1/0	0.318 (0.466)
H.age3	1 if living in a house built after 2010, or 0 otherwise	1/0	0.168 (0.374)
Homeowner	1 if living in a house owned by oneself, or 0 otherwise	1/0	0.468 (0.499)
MP2	1 if there is a possibility of moving within 2 years, or 0 otherwise	1/0	0.690 (0.463)
Expense	Expense for heating and electricity-using (standardized)	Conti.	0.000 (1.122)
Prospect	Prospects for energy price changes in the future (standardized)	Conti.	0.000 (0.873)

V. Estimation Results

1 Model 1 (Dep. Var. : Experience)

Table 3. Estimation results of model 1 (Dependent variable: Experience)

Variable	Parameter estimates ($\hat{\beta}_1$)	Partial effect ($\widehat{APE}_1$)	Variable	Parameter estimates ($\hat{\beta}_1$)	Partial effect ($\widehat{APE}_1$)
P.Bias	-0.073 (0.140)	-0.023 (0.036)	Inc.2	0.193 (0.139)	0.060 (0.044)
D.Factor	0.129 (0.991)	0.040 (0.221)	**Inc.3**	**0.424*** (0.144)**	**0.124*** (0.044)**
Risk.1	-0.041 (0.172)	-0.010 (0.040)	**Inc.4**	**0.371** (0.168)**	**0.110** (0.049)**
Risk.2	0.019 (0.273)	0.005 (0.067)	**Inc.5**	**0.512*** (0.190)**	**0.146*** (0.054)**
Risk.4	-0.063 (0.478)	-0.015 (0.085)	**Apart**	-0.132 (0.083)	**-0.036* (0.022)**
Risk.5	**-0.307** (0.144)**	**-0.080** (0.034)**	**H.age1**	**0.272*** (0.085)**	**0.072*** (0.023)**
Attitude	**0.021* (0.012)**	**0.006* (0.003)**	**H.age3**	**-0.487*** (0.104)**	**-0.157*** (0.033)**
Donation	**0.385*** (0.077)**	**0.109*** (0.022)**	MP2	-0.020 (0.077)	-0.006 (0.021)
Volunteer	**0.040*** (0.012)**	**0.011*** (0.003)**	**Homeowner**	**0.443*** (0.084)**	**0.129*** (0.025)**
Comparison	0.035 (0.051)	0.010 (0.014)	**Expense**	**0.072* (0.044)**	0.020 (0.012)
Edu	**-0.193* (0.108)**	**-0.051* (0.027)**	**Prospect**	**0.099** (0.042)**	**0.027** (0.011)**
Child	-0.003 (0.093)	-0.001 (0.026)	Constant	0.314 (0.884)	
Senior	**0.236** (0.098)**	**0.062** (0.025)**			
Log-likelihood					-781.680

i) * p<0.1, ** p<0.05, *** p<0.01; ii) The white standard errors are provided in the parentheses of the parameter estimates, iii) The partial effect estimates are calculated by the bootstrapping method; iv) We check that the results derived by the probit model are not sensitive to the probability distribution of error terms.

V. Estimation Results

1 Model 1 (Dep. Var. : Experience)

Effects of time, risk and social preferences

- **(P.Bias, D.Factor)** Insignificant effects of time and risk preferences
- **(Risk.1~Risk.5)** Very risk-averse respondents are about 8% less likely to have experienced home energy retrofit than risk-neutral respondents.
- **(Attitude, Donation, Volunteer)** Significant and positive effects of social preference

Effects of socio-economic factors

- **(Edu)** People who graduated a college are 5.1% less likely to experience home energy retrofit than those who do not **(Heo, 2010; Lee et al., 2011).**
- **(Senior)** People living with the senior are 6.2% more likely to experience home energy retrofit than those who do not **(Frederiks et al., 2015).**
- **(Inc.2~Inc.5)** Positive but nonlinear effect of income level

V. Estimation Results

1 Model 1 (Dep. Var. : Experience)

Effects of housing conditions

- **(Apart)** People living in apartments are 3.6% less likely to experience home energy retrofit than those living in other types of housing.
- **(H.age1)** People living in the houses built before 2000 are 7.2% more likely to experience home energy retrofit than those living in the houses built b/w 2000 and 2010.
- **(H.age3)** People living in the houses built after 2010 are 15.7% less likely to experience home energy retrofit than those living in the house b/w 2000 and 2010.
- **(Homeowner)** Homeowners are 12.9% more likely to experience home energy retrofit than tenants.
- **(Expense)** People paying a lot of energy costs are likely to experience home energy retrofit.
- **(Prospect)** People who expect energy price increases in the future are likely to experience home energy retrofit (Alberini et al., 2013).

V. Estimation Results

2 Model 2 (Dep. Var. : Plan)

Table 4. Estimation results of model 2 (Dependent variable: Plan)

Variable	Parameter estimates ($\hat{\beta}_1$)	Partial effect ($\widehat{APE}_1$)	Variable	Parameter estimates ($\hat{\beta}_1$)	Partial effect ($\widehat{APE}_1$)
P.Bias	-0.212(0.130)	**-0.059*(0.035)**	**Inc.2**	**0.259*(0.133)**	**0.087*(0.046)**
D.Factor	1.403(0.902)	**0.393*(0.208)**	**Inc.3**	**0.364***(0.136)**	**0.120***(0.046)**
Risk.1	**0.380**(0.155)**	**0.118**(0.047)**	Inc.4	0.203(0.157)	0.069(0.052)
Risk.2	0.244(0.241)	0.078(0.080)	Inc.5	0.127(0.173)	0.044(0.060)
Risk.4	0.016(0.385)	0.005(0.135)	Apart	0.014(0.076)	0.004(0.024)
Risk.5	0.078(0.127)	0.026(0.041)	**H.age1**	**-0.148*(0.080)**	**-0.046*(0.025)**
Attitude	**0.034***(0.011)**	**0.011***(0.004)**	**H.age3**	**-0.394***(0.103)**	**-0.129***(0.035)**
Donation	**0.438***(0.073)**	**0.146***(0.025)**	**MP2**	**0.235***(0.073)**	**0.075***(0.023)**
Volunteer	**0.028**(0.011)**	**0.009**(0.004)**	**Homeowner**	**0.354***(0.080)**	**0.118***(0.029)**
Comparison	0.075(0.047)	0.024(0.015)	**Expense**	**0.071*(0.040)**	**0.023*(0.013)**
Edu	0.001(0.099)	0.000(0.031)	Prospect	0.044(0.040)	0.014(0.012)
Child	0.012(0.089)	0.004(0.028)	Constant	-1.470*(0.802)	
Senior	**0.251***(0.090)**	**0.078***(0.027)**			
Log-likelihood					-907.549

i) * p<0.1, ** p<0.05, *** p<0.01; ii) The white standard errors are provided in the parentheses of the parameter estimates, iii) The partial effect estimates are calculated by the bootstrapping method; iv) We check that the results derived by the probit model are not sensitive to the probability distribution of error terms.

V. Estimation Results

2 Model 2 (Dep. Var. : Plan)

Effects of time, risk and social preferences

- **(P.bias)** The respondents whose time preferences are present biased have a 5.9% lower possibility of planning home energy retrofit than the others
- **(D.factor)** 1% increase in adjusted discounting factor, increases the likelihood of planning home energy retrofit by 39.3%..
- **(Risk.1)** Very risk seeking respondents are 11.8% more likely to plan home energy retrofit than risk-neutral ones.
- **(Attitude)** People concerning environmental problems seriously are more likely to plan home energy retrofit.
- **(Donation)** Donors are 14.6% more likely to plan home energy retrofit in the future than those who have not.
- **(Volunteer)** Volunteers are more likely to plan for home energy retrofit.

V. Estimation Results

2 Model 2 (Dep. Var. : Plan)

Effects of socio-economic factors

- **(Senior)** People living with the senior are 7.8% more likely to plan home energy retrofit those who do not.
- **(Inc.2, Inc.3)** Positive but nonlinear effect of income level

Effects of housing conditions

- **(H.age1)** People living in the houses built before 2000 are 4.6% less likely to plan home energy retrofit than those living in the houses built b/w 2000 and 2010.
- **(H.age3)** People living in the houses built after 2011 are 12.9% less likely to plan home energy retrofit than those living in the houses built b/w 2000 and 2010.
- **(MP2)** Respondents who are planning moving in 2 years are 7.5% more likely to plan home energy retrofit than those who are not
- **(Homeowner)** Homeowners are 11.8% more likely to plan experience home energy retrofit than tenants.
- **(Expense)** People paying a lot of energy costs are likely to plan home energy retrofit

VI.Conclusion and Implications

1 Conclusions

Time preference (HP1a & HP1b)

- **The results conditionally support HP1a & HP1b.**
  - (Model 2) Partial effects of P.bias and D.factor are significantly estimated, as expected.

Risk preference (HP2)

- **The results partially support HP2.**
  - (Model 1) Very risk-averse respondents are less likely to experience home energy retrofit.
  - (Model 2) Very risk-seeking respondents are more likely to plan home energy retrofit.

Social preference (HP3a, HP3b & HP3c)

- **The results support HP3a & HP3b, but do not support HP3c.**
  - (Model 1 & 2) Both the coefficients and partial effects of Attitude, Donation, and Volunteer are significantly estimated, as expected.

VI.Conclusion and Implications

2 Implications

A tendency to discount future values and to avoid risk considerably hinders EE investments

- Need to develop a **financing program** alleviating the barriers relevant with time and risk preferences

Attitudes toward environment and moral obligations are effective in attracting EE investments.

- Need to link charity activities with energy conservation campaigns and EE programs

Homeowners and people living in houses built long before are possible consumers of EE investments.

- Need to design EE programs for tenants

Thank You.

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