Energy for Sustainable Development 25 (2015) 27–33

Contents lists available at ScienceDirect

Energy for Sustainable Development

Do households misperceive the benefits of energy-saving actions? Evidence from a Japanese household survey

Kazuyuki Iwata [a,*], Hajime Katayama [b], Toshi H. Arimura [c]

[a] Faculty of Regional Policy, Takasaki City University of Economics, Japan
[b] Faculty of Commerce, Waseda University, Japan
[c] Faculty of Political Science and Economics, Waseda University, Japan

ARTICLE INFO

Article history:
Received 30 April 2014
Revised 5 November 2014
Accepted 16 December 2014
Available online xxxx

Keywords:
Household
Perception
Energy-saving actions

ABSTRACT

Using a household survey conducted in a suburb of Tokyo, we examine whether individuals properly perceive the benefits of energy-saving actions. A bivariate regression shows that, on average, individuals overestimate the benefits. The tendency to overestimate is robust to controlling for individual and home characteristics. Our results are contrary to those of Attari et al. (2011), who found that individuals in the U.S. tended to underestimate the benefits of energy-saving activities. The difference in our results suggests that the provision of information about the benefits of energy saving may be an effective policy to address global warming issues in one country but not necessarily in all countries. We also find that the magnitude of overestimation is greatest among young single males, whereas the benefits perceived by older married females are the smallest. This result suggests that the provision of tailored information (i.e., highly personalized and specific information) can be an effective intervention even in Japan.

Introduction

Global warming is one of the most serious problems that our society must address. The average global temperature has increased by approximately 0.8 degrees Celsius since 1880, and with the current level of greenhouse gas (GHG) emissions, each successive decade is expected to be warmer than the previous one (U.S. global change research program, 2014). An increase in global temperature may have negative effects on water supplies, agriculture, power and transportation systems, the natural environment, and our health and safety among other critical systems and resources (EPA, 2014). To avoid such consequences, a reduction of energy consumption is urgently needed.

One promising strategy may be to change household energy-consumption behavior (Truelove and Parks, 2012; Yue et al., 2013). Households are responsible for a large portion of global GHG emissions; specifically, 11% of global emissions are attributable to the household sector (Ecofys, 2013). In addition, the potential for reduction in this sector appears to be large. For example, it is estimated that the energy consumption of U.S. households could be reduced 20–30 percent by changing the selection and use of household and motor vehicle technologies (Dietz et al., 2009; Gardner and Stern, 2008). Similar, though smaller, potentials have been estimated for other countries (Carlsson-Kanyama et al., 2005; Alfredsson, 2004; Benders et al., 2006; Vringer and Blok, 1995). Furthermore, because there is high variance in household GHG emissions a significant reduction in GHG emissions appears possible by shifting individual to more climate friendly consumption patterns (Griod and de Haan, 2009). For these reasons, households are an important target group for intervention (Arbrahamse et al., 2005, 2007; Steg et al., 2006).

In response to both global warming and the energy crisis of the 1970s, a number of studies have examined intervention strategies aimed at household energy conservation. For an excellent review, see Arbrahamse et al. (2005). One of the most common strategies is to provide information through workshops (Geller, 1981) or mass media campaigns (Hutton and McNeill, 1981; Luyben, 1982; Staats et al., 1996). The information may be general (e.g., information on the causes of global warming) or specific (e.g., information on ways to reduce household energy use). In some interventions, tailored (i.e., highly personalized and specific) information is provided (Gonzales et al., 1988; Hirst and Grady, 1982–1983; Winett et al., 1982–1983; McMakin et al., 2002).

The provision of general information is intended to make individuals aware of and concerned about problems related to household energy consumption, thereby influencing individuals' energy use. This approach is based on evidence that environmental awareness and concern for the environment have significant effects on various energy-saving behaviors (e.g., Barr et al., 2005; Scherbaum et al., 2008; Urban and Scasny, 2012; Whitmarsh and O'Neill, 2010). It seems, however, that there is little room for general information to reduce individuals' energy use because an increasing number of individuals have already become

* Corresponding author at: Kaminamie-cho 1300, Takasaki, Gunma, 370-0801, Japan. Tel.: +81 27 343 5417.
E-mail address: iwata.kazuyu@gmail.com (K. Iwata).

http://dx.doi.org/10.1016/j.esd.2014.12.005
0973-0826/

concerned about global warming. For example, approximately 90% of individuals are concerned about climate change in a majority of EU countries (Eurobarometer, 2007).

The provision of specific information is based on the assumption that individuals may not be aware of a variety of possible activities, devices and technologies for energy conservation.[1] Perhaps more plausibly, even though they are aware, they may misperceive the potential energy savings. For this reason, the extent of misperception is of particular interest because it provides insight into possible changes in individuals' energy conservation when their perceptions are corrected via information provision.

Baird and Brier (1981) found that individuals tend to think of larger appliances as consuming more energy, even when the opposite is true. Larrick and Soll (2008) provided evidence that individuals tend to underestimate the value of taking the most fuel-inefficient vehicles off the road. More comprehensive evidence was provided by Attari et al. (2011). Using data on individuals in the U.S., they examined public perceptions of energy use and potential energy savings for 15 activities, including turning off lights, driving less, and installing more efficient light bulbs and appliances. Their results show that individuals, on average, underestimate energy use and savings, suggesting that information on the energy use and potential energy savings may have positive influences on household energy conservation.

Using survey data on individuals living in a suburb of Tokyo, this study attempts to provide further evidence on whether and the extent to which individuals misperceive the potential energy savings (monetary benefits) of energy-saving actions. In particular, we examine a wide variety of simple actions recommended by the Energy Conservation Center Japan (ECCJ), most of which are curtailment actions (i.e., actions that involve repetitive efforts to reduce energy use).

A brief summary of the present study follows. A bivariate regression shows that on average, individuals overestimate the benefits of energy-saving actions. The tendency for overestimation is robust to controlling for individual and home characteristics as well as for potential nonlinearity between actual and perceived benefits. These results are in sharp contrast to those of Attari et al. (2011), suggesting the presence of heterogeneity in how individuals from different countries perceive the monetary benefits of energy-saving actions.

Background and data

Background on Japanese energy conservation policies

Several policies have been implemented to promote energy conservation in Japanese households. One major policy initiative aims to promote the diffusion of energy efficient home appliances. To accelerate the diffusion of energy efficient products, the Ministry of Economy, Trade and Industry (METI) mandated under the *Energy Conservation Act* that product labels include energy consumption information. The first labeling system, however, did not allow consumers to easily compare products across different manufacturers. In 2000, METI launched a second program, the voluntary Energy-Saving Labeling program, which informs consumers of the energy consumption of a product relative to the most efficient products in the same class. By the 2008, 16 products were covered under this new labeling program, including air conditioners and electric refrigerators.

These programs provided consumers with information on the energy efficiency of electric appliances. They did not, however, inform consumers of strategies for saving energy when using those appliances or potential cost savings from various energy saving practices.

Other national campaigns, however, specifically promoted energy saving practices. In 2005, the Ministry of the Environment (MOE) launched a national campaign called *Team Minus 6 Percent*. The goal of the campaign was to raise the awareness of the country's GHG emission target, a 6% reduction relative to 1990 emissions, and to contribute to emissions reduction by promoting energy saving practices. The campaign promoted six specific energy saving actions: 1) “Set air conditioners to 28 degrees Celsius (or higher) in summer and 20 degrees Celsius (or lower) in winter,” 2) “Turn off the faucet when unnecessary,” 3) “Drive car your more efficiently,” 4) “Choose eco-friendly products,” 5) “Say no to excessive packaging,” and 6) “Unplug electric appliances when not in use.” By June 2008, more than two million people and 21,975 organizations declared themselves team members.[2]

To reinforce the *Team Minus 6 Percent* campaign, the MOE launched another campaign, *Cool Biz,* in the summer of 2005. *Cool Biz* promoted casual dress codes, including in formal settings such as the workplace, to help people feel comfortable with the air conditioning set at 28 degrees Celsius.

In Japanese business culture prior to the campaign, every businessman was implicitly required to wear a jacket and tie. Consequently, office temperatures had to be cold enough that businessmen could feel comfortable with a jacket in summer. Once the government endorsed more casual attire in the summer, businessmen began to wear “business causal” or even more relaxed styles, which allowed offices to be kept at warmer temperatures. The MOE hoped that this campaign on the business attire would help people set the temperature to 28 degree Celsius or higher in the summer.

The *Cool Biz* campaign was quite successful and has drastically changed Japanese summer business attire. According to a survey conducted by MOE, more than 90% of the respondents were aware of the *Cool Biz* campaign and 32.7% of offices set their air condition to 28 degrees. The MOE estimated that the campaign contributed to a reduction of 460 thousand tons of CO_2, which is equal to the consumption of one million households.[3]

Despite the success of the *Cool Biz* campaign, it was unclear whether people understood the cost savings that resulted from the new temperature settings. The campaign did not inform people of the monetary savings associated with energy efficiency practices such as setting air conditioners to a higher temperature.

In another effort, ECCJ promoted energy saving practices in households through their brochure, titled *Dictionary of energy savings in households* (ECCJ, 2010),[4] and through their webpages. ECCJ listed specific energy saving practices such as “Set air conditioner to 28 degrees Celsius in summer” or “Turn off televisions when unnecessary.” ECCJ listed both monetary savings and the amount of electricity saved from each action. ECCJ (2010) resources, however, were not used in the *Cool Biz* or *Team Minus 6 Percent* campaigns, possibly because ECCJ is funded and supported by METI while the Cool Biz campaign was run by MOE.

Survey description

To examine the relationship between the actual and perceived benefits of energy-saving activities, we conducted a household survey in Soka City, a suburb of Tokyo (25 km away from Tokyo). The population of the city is approximately 240,000, with a population density of 8.9 thousand persons per square kilometer. Although the population is not large, the density is relatively high in comparison to the average for Japan, which is approximately 0.3 thousand persons per square kilometer.

[1] For example, Yohanis (2012) provided evidence that a majority of households surveyed in Northern Ireland are unaware of the presence of thermostatic controls on hot water tanks, with which they can reduce energy consumption resulting from water heating.

[2] http://www.team-6.jp/english/about.html (accessed on August 9th, 2014).

[3] http://www.env.go.jp/press/press.php?serial=6491 (accessed on August 6th, 2014).

[4] http://www.eccj.or.jp/dict/pdf/dict_all.pdf (accessed on August 6th, 2014).

The survey was implemented following the methods described below. From a dataset of all households in Soka City, 1200 households were randomly selected. Data collectors visited each of the selected households between January 7 and February 7, 2011. The data collectors provided a questionnaire to one member of each household with an explanation that they would receive a coupon book worth approximately 6.3 US dollars (500 Japanese yen) [5] for participating in the survey. At a later date, the data collectors revisited the households to collect the questionnaires. The survey response rate was high (59.5% or 714 households), most likely a result of the door-to-door survey method. However, 464 of the respondents did not answer all of the questions required for analysis and were discarded from the sample. Therefore, our analysis is based on 250 respondents.

For this study, we consider the 18 energy-saving actions presented in Table 1. These actions are recommended by the ECCJ (2010) as "simple actions for energy savings." ECCJ (2010) also provides information on actual annual savings from each action, which we hereafter refer to as the "actual benefit." Actual benefits from each action are also presented in the table. In the survey, respondents are asked how much energy (s)he thinks each action saves per year. The answer will be hereafter referred to as his/her "perceived benefit."

Perceived and actual benefits

For respondent i and energy-saving action j, we have a pair of actual and perceived benefits (ab_j, pb_{ij}), where ab_j is the actual benefit from action j and pb_{ij} is the benefit respondent i perceives for action j. We did not ask the respondent to report pb for action j if it was irrelevant to him/her. For example, if the respondent did not own a plasma TV, (s) he was not asked to answer pb for "turning it off when unnecessary." As a result, the number of observations analyzed is 2496, representing approximately 10 actions per respondent. Descriptive statistics, including mean, standard deviation, and minimum and maximum values of actual and perceived benefits are presented in Table 2. Table 2 also includes descriptive statistics for additional variables, which will be explained in Section 2.4.

To examine how the actual and perceived benefits are related, we plot (ab_j, pb_{ij}), $i = 1,\ldots, 250$ and $j = 1,\ldots, 18$, in Fig. 1, where the horizontal and vertical axes represent actual and perceived benefits, respectively. There are two images in Fig. 1. The left shows all observations, and the right shows only observations for which perceived benefits are less than 100 dollars. In both figures, we also present the fitted line obtained by regressing pb_{ij} on ab_j (i.e., $pb = 56.06 + 0.473ab$), labeled as "OLS" (Ordinary Least Squares). The estimated coefficients and their standard errors are shown in Column (1) of Table 3. Both coefficients are significant. The 45-degree dashed line is also added to the figure. If respondent i correctly recognizes the monetary benefit of action j (i.e., $pb_{ij} = ab_j$), then the data point will fall exactly on the 45-degree line.

As is evident from the fitted line, on average respondents overestimate the monetary benefits of the energy-saving actions. The fitted line intersects with the 45-degree line at more than 100 dollars per year, suggesting that respondents underestimate benefits of energy-saving actions for which actual benefits are more than 100 dollars per year. Note, however, that there is no action that can save more than 100 dollars (see Table 1).

In examining the relationship between the actual and perceived benefits, regressing pb_{ij} on ab_j may not be adequate because some respondents perceive rather high benefits as shown in Fig. 1. The histogram of perceived benefits drawn in Fig. 2 also implies that the distribution is highly skewed. To account for the skewed distribution, logarithmic transformation of pb (i.e., $\ln(pb)$) is frequently used. The transformation reduces the skewness of the distribution such that we can obtain an appropriate fitted line.

Using the log-transformed perceived benefit, however, a zero-value problem arises. There are a total of 154 observations (approximately 6%) with zero value (see Fig. 2). To avoid the zero-value problem, some researchers may add one to the perceived benefits (i.e., $pb + 1$) before performing the logarithmic transformation of $pb + 1$. However, this procedure may induce inconsistent parameter estimates (Silva and Tenreyro, 2006), and as a result, the shape of a fitted line may be incorrect. The logarithmic transformation, therefore, cannot be used in our estimation.

To account for these issues, we employ the Poisson pseudo-maximum likelihood estimation (PPML) instead of OLS. Although the PPML has been used to analyze count data, the data are not required to be nonnegative integers. In addition, the assumption that data are drawn from a Poisson distribution is not required. In running PPML, all we need to obtain consistent estimators is accurate specification of the conditional mean, $E(pb|ab) = exp(\alpha + \beta \times ab)$ where α and β are parameters (Silva and Tenreyro, 2006).

The dotted curve, "PPML," in Fig. 1 illustrates the relationship estimated by PPML (i.e., $pb = exp(4.048 + 0.006ab)$). The coefficients and standard errors obtained by PPML are presented in Column (2) of Table 3. The coefficients of both actual benefit and constant term are

Table 1
Energy-saving actions and their actual benefits (US dollars).

	Equipment	Energy-saving action	Actual benefit per year
1	Air conditioner	Set to 28 degrees in summer	8.40
2	Air conditioner	Set to 20 degrees in winter	14.66
3	Air conditioner	Turn off when unnecessary	8.21
4	Air conditioner	Clean filters	8.77
5	Gas heater	Set to 20 degrees in winter	15.79
6	Oil heater	Set to 20 degrees in winter	25.69
7	Gas heater	Turn off when unnecessary	9.77
8	Oil heater	Turn off when unnecessary	16.29
9	Electric carpet	Frequent temperature control	51.25
10	CRT TV	Turn off when unnecessary	8.77
11	Plasma TV	Turn off when unnecessary	20.55
12	Liquid crystal TV	Turn off when unnecessary	4.13
13	Refrigerator	Temperature control	14.54
14	Refrigerator	Fixed away from wall	12.40
15	Electric pot	Unplug when unnecessary	29.57
16	Water heater	Set water temperature low	17.04
17	Water heater	Refrain from reheating water	74.18
18	Water heater	Turn shower off when unnecessary	37.34

Table 2
Descriptive statistics.

Variables	Mean	S.D.	Min	Max
Perceived benefits (US dollar)	66.9	96.2	0	902.2
Actual benefits (US dollar)	22.9	18.8	4.1	74.2
Income (scale variable)	4.58	1.82	1	8
Age	53.56	13.64	22	84
Male	0.3	0.46	0	1
Education (Bachelor's degree or higher)	0.25	0.43	0	1
Environmental concerns	0.27	0.44	0	1
Importance of energy expenses when saving	2.77	1.67	1	9
Married	0.92	0.27	0	1
Number of family members	3.48	1.3	1	7
Own house	0.85	0.36	0	1
House size (number of rooms)	5.08	1.43	1	10
House age	17.83	11.02	1	50
Number of electrical equipment for each action	1.72	1.12	0	9
Comfortable temperature in summer	25.71	2.01	18	30
Comfortable temperature in winter	23.49	2.5	15	30
Electric water heating	0.16	0.37	0	1
Oil water heating	0.04	0.2	0	1

Note: The number of observations is 2496.

[5] The annual average exchange rate in 2011, 1 US dollar = 79.807 Japanese yen, is used in this paper.

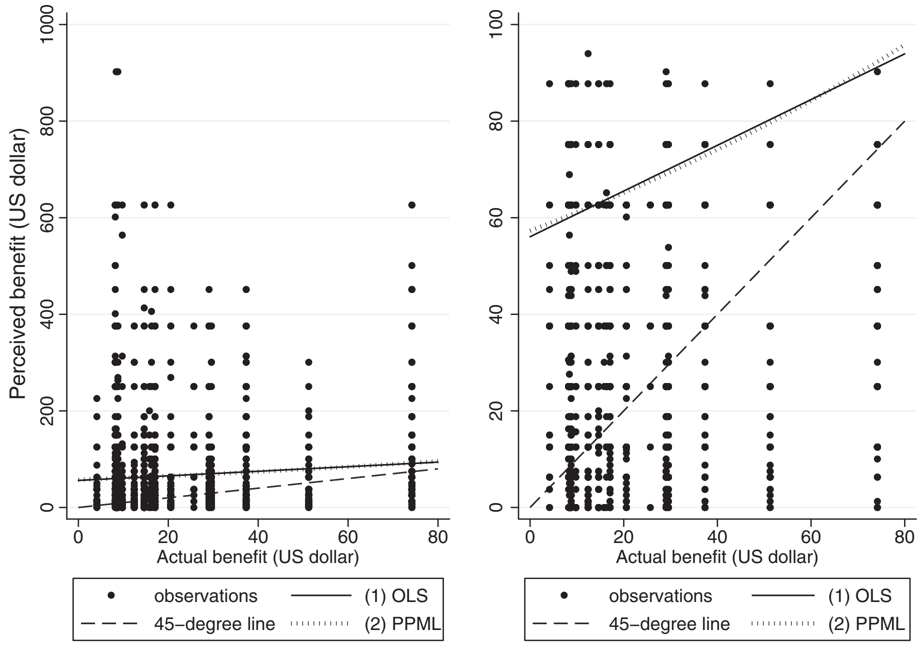

Fig. 1. Actual (X-axis) and perceived (Y-axis) benefits: Note: The number of observations is 2496. The scales of X-axis and Y-axis are different from each other. The left figure is drawn with all observations. The right figure is illustrated with observations for which perceived benefits are less than 100 US dollars.

significant at the 1% level. The dotted curve is located above the 45-degree dashed line. The features of the curve are quite similar to that of the OLS; even accounting for two features of the perceived benefits data, i.e., skewed distribution and zero-value observations, households are found to always overestimate the benefits of energy-saving actions.

Variable descriptions

As illustrated in Fig. 1, there is much variability around the regression line. To examine what factors contribute to the variability of the perceived benefits among the respondents, we extend the previous regression models to include individual as well as home characteristics.

Table 3
Estimation results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	PPML	OLS	PPML	PPML-Q	OLS-Q	PL
Variables	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Actual benefits	0.473 (0.113) ***	0.006 (0.001) ***	0.516 (0.123) ***	0.007 (0.002) ***	−0.015 (0.006) **	−1.129 (0.435) ***	
Square of actual benefits					0.0003 (0.00007) ***	0.021 (0.005) ***	
Income			−0.122 (1.186)	−0.001 (0.018)	0.001 (0.018)	0.042 (1.185)	2.585 (5.832)
Age			−0.688 (0.197) ***	−0.011 (0.003) ***	−0.010 (0.003) ***	−0.659 (0.196) ***	0.054 (0.345)
Male			16.60 (5.115) ***	0.232 (0.069) ***	0.231 (0.068) ***	16.59 (5.098) ***	16.41 (5.544) ***
Education			4.072 (5.106)	0.057 (0.071)	0.059 (0.070)	4.222 (5.082)	1.833 (5.752)
Environmental concerns			1.030 (4.628)	0.016 (0.067)	0.021 (0.067)	1.395 (4.603)	−6.312 (5.530)
Importance of energy expenses when saving			3.247 (1.451) **	0.048 (0.020) **	0.049 (0.020) **	3.315 (1.455) **	1.484 (1.410)
Married			−20.54 (10.17) **	−0.241 (0.115) **	−0.240 (0.115) **	−20.57 (10.13) **	−22.66 (10.77) **
Number of family members			−5.978 (1.663) ***	−0.097 (0.027) ***	−0.095 (0.027) ***	−5.806 (1.659) ***	−4.708 (2.260) **
Own house			15.54 (6.095) **	0.268 (0.100) ***	0.265 (0.100) ***	15.47 (6.091) **	21.68 (8.027) ***
House size			−1.335 (1.862)	−0.019 (0.027)	−0.015 (0.027)	−1.000 (1.858)	−4.125 (2.036) **
House age			0.058 (0.214)	0.001 (0.003)	0.001 (0.003)	0.033 (0.213)	0.097 (0.267)
Number of electrical equipment for each action			2.848 (2.100)	0.041 (0.032)	0.012 (0.034)	0.728 (2.188)	−3.902 (2.694)
Comfortable temperature in summer			−2.312 (0.931) **	−0.035 (0.013) ***	−0.034 (0.013) ***	−2.264 (0.931) **	−2.493 (1.196) **
Comfortable temperature in winter			0.730 (0.742)	0.009 (0.011)	0.010 (0.011)	0.790 (0.740)	−0.090 (0.948)
Electric water heating			0.634 (5.927)	0.007 (0.086)	0.006 (0.085)	0.485 (5.917)	−6.995 (6.783)
Gas water heating			−1.446 (9.819)	−0.002 (0.145)	−0.003 (0.144)	−1.536 (9.749)	−4.033 (12.53)
Constant	56.056 (3.245) ***	4.048 (0.488) ***	147.08 (35.25) ***	5.371 (0.500) ***	5.582 (0.502) ***	163.28 (35.42) ***	
Pseudo/adjusted R-squared	0.01	0.01	0.04	0.06	0.06	0.04	0.03
Wald/F value	17.48***	20.65***	4.97***	111.42***	130.57***	4.97***	4.70***
Significance of actual benefit							2.64***

Note: The number of observations is 2,496. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Robust standard errors are in parentheses. The interaction term "Comfortable temperature in summer (winter)" and a dummy variable for the action regarding air conditioners are found to be insignificant and are not reported here.

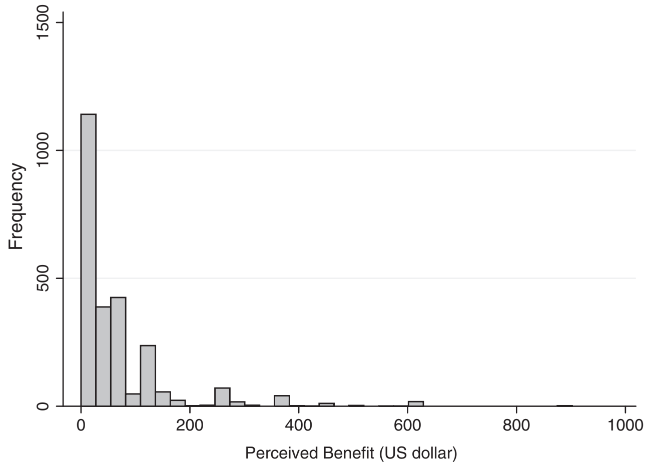

Fig. 2. Distribution of perceived benefits. Note: The number of observations is 2496. There are 154 observations for which perceived benefits are equal to zero.

The individual characteristics we consider are age, gender (=1 if the respondent is male), education (=1 if the respondent has a bachelor's or higher degree), marital status (=1 if the respondent is married), number of family members in a household, and comfortable temperatures measured in degrees Celsius in summer and winter. Annual income is also considered as a potential factor, for which we construct a scale variable; it takes a value of 1 if the income is under 25.1 thousand dollars, 2 if it is between 25.1 and 37.6 thousand dollars, 3 if between 37.6 and 50.1 thousand dollars, 4 if between 50.1 and 62.7 thousand dollars, 5 if between 62.7 and 87.7 thousand dollars, if between 87.7 and 125.3 thousand dollars, 7 if between 125.3 and 188.0 thousand dollars, and 8 if more than 188.0 thousand dollars.

To examine whether environmental concerns are associated with perceived benefits, we construct a dummy variable that takes a value of 1 if a respondent answers "very high" to the question, "To what extent are you concerned with global warming issues? (1: very high, 2: high, 3: low, 4: very low)."

We also construct a variable that captures how the respondent thinks of energy expenses in relation to other expenses. The respondents were asked: "Suppose you want to save money and cut your expenses from the following expense categories: energy, food, water, transportation and communication, housing, health care, entertainment, cultural-amusement and education. Please rank energy expenses as follows: 1 if you would cut them first among other expenses, 2 if they are your number two priority, 3 if your number three priority, and the like."

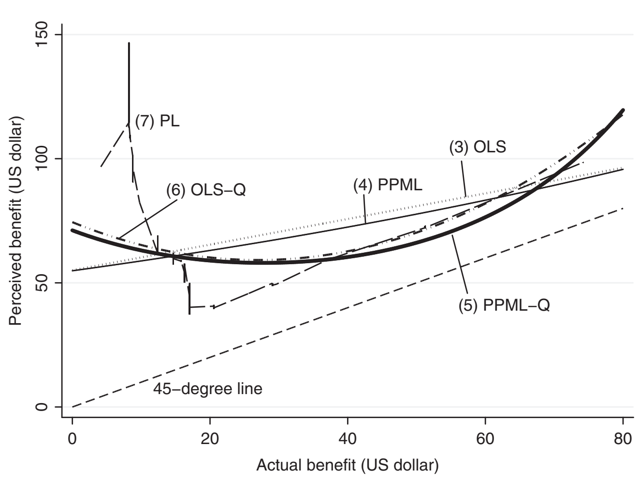

Fig. 3. Relationship between actual and perceived benefits across models. Note: The scales of X- and Y-axes differ. In illustrating each relationship, other variables (except actual benefit) are set equal to their sample means.

For home characteristics, we include home age and size (number of rooms), as well as a dummy variable that takes a value of 1 if the respondent owns his/her home. We also include a dummy variable that takes a value of 1 if the respondent's household uses an electric water heating system. Similarly, we include a dummy variable for the use of a gas water heating system. We further include, for each energy saving action, the number of associated pieces of electrical equipment that are present in the respondent's household. For example, the value of electrical equipment for "Set to 28 degrees Celsius in summer" is equal to the number of air conditioners installed in respondents' houses.

Estimation results and discussions

Estimation results

Columns (3) and (4) of Table 3 present the results obtained by OLS and PPML, respectively, where we control for both individual and home characteristics. Regardless of the estimation methods, the coefficient on actual benefits is found to be positive and significant at the 1% level. The size of the coefficient does not appear to depend considerably on whether we control for individual or home characteristics.

Fig. 3 illustrates how actual and perceived benefits are related across the models. The 45-degree dashed line represents no gap between actual and perceived benefits. "OLS" and "PPML" correspond to the fitted curves for the models in Columns (3) and (4), respectively. These curves are drawn by setting the variables (except actual benefits) to their sample means. As is evident in the figure, both curves are similarly located above the dashed 45-degree line.[6] This implies that individuals, on average, overestimate the benefits of the energy-saving actions, even when individual and home characteristics are accounted for.

Attari et al. (2011) argued that the relationship between actual and perceived benefits may be non-linear rather than linear. To account for potential non-linearity, we extend the model by including a quadratic term of actual benefits (i.e., ab^2). The results by OLS and PPML are presented in Columns (5) and (6), respectively. The coefficients on actual benefits and the square of actual benefits are both found to be significant at the 1% level. The former is negative and the latter positive, implying that the relationship between actual and perceived benefits is U-shaped.

The curves labeled as "OLS-Q" and "PPML-Q" in Fig. 3 are drawn using the estimation results in Columns (5) and (6), respectively and fixing the variables (except actual benefits) to their sample means. Both curves are always located above the 45-degree line, illustrating that the tendency to overestimate persists, at least qualitatively, when accounting for potential nonlinearity between actual and perceived benefits.

It is possible that the relationship between the actual and perceived benefits is not quadratic, even if it is nonlinear. To relax the functional form assumption, we employ a partial linear regression technique (PL) developed by Yatchew (1997). PL does not specify a function form for the actual benefit (the non-parametric part), while specifying a linear function for all other variables (the parametric part). The parametric and non-parametric parts are assumed to be additively separable; specifically, $pb = f(ab) + \boldsymbol{\beta x} + u$ where f is a smooth unknown function, $\boldsymbol{x}$ is a vector of control variables, $\boldsymbol{\beta}$ is a vector of associated parameters, and u is a disturbance term. For this estimation, we use a STATA command named "plreg" (Lokshin, 2006).

[6] It should be mentioned that both curves cross the 45-degree line at more than 100 dollars, although not shown in the figure. This does not seem to be relevant, however, as there is no action that can save more than 100 dollars in the list of energy-saving actions (see Table 1).

The estimation results for the parametric part (i.e., the individual and home variables) are presented in Column (7), while the estimated relationship between actual and perceived benefits is drawn in Fig. 4 (the curve labeled as “PL”). The shape of the curve differs from those of OLS-Q and PPML-Q especially when actual benefits reach approximately 10 dollars. In a manner similar to OLS-Q and PPML-Q, however, the curve always lies above the 45-degree line. Overall, these results suggest that individuals, on average, overestimate the benefits of energy-saving actions.

With regard to the other variables, the sign and significance for each variable do not vary substantially across the models. Among respondent characteristics, age, gender, marital status and number of family members in the household are key factors related to the perceived benefit. The coefficients of the dummy variable for male are positive and significant, suggesting that men are likely to overestimate the perceived benefit more than women. The range of magnitude of overestimation by men relative to women is approximately 15.54 (Column 5) to 16.60 dollars (Column 3), on average.[7]

The coefficients of age, marital status and number of family members are all negative and significant, suggesting that a single young person living alone is likely to greatly overestimate the benefits. The magnitude of overestimation from a single person relative to a married person is 17.07 (Column 5) to 22.66 dollars (Column 7). Similarly, marginal perceived benefits of age and number of family members are −0.64 (Column 5) to −0.69 dollars per age per year (Column 3) and −4.71 (Column7) to −5.98 dollars per number per year (Column 3), respectively.[8]

The relative importance of energy expenses when required to save money is also significantly related to the perception of benefits. This result may reflect high expectations among respondents whose priority for energy-savings is relatively high. Comfortable temperature in summer is also related to perceived benefits, whereas comfortable temperature in winter is not. That is, a person who favors temperatures below 28 degrees Celsius in summer is likely to overestimate the benefit. In contrast, the coefficients on income, education and environmental concerns are insignificant.

For home characteristics, we found that home ownership is significantly and negatively related to the perceived benefits. Compared with a renter, a homeowner overestimates the monetary benefit by 15.54 (Column 3) to 21.68 dollars per year (Column 7). In contrast, number of rooms in the house, house age, type of water heating system and number of electric appliances are not associated with perceived benefits.

Discussions

In general, information is an effective intervention when individuals have little or incorrect knowledge of energy saving activities. For example, it may be beneficial to provide information on possible actions for energy conservation if individuals are unaware of them. One might argue that informing individuals of the monetary benefits of energy-saving actions is a sensible intervention because individuals misperceive the benefits, as we illustrated in the previous section. This argument is correct if individuals underestimate the benefits of energy-saving actions. However, our results show that individuals overestimate the benefits, suggesting that it may not be possible to promote energy-saving actions with information.

Information is effective only when individuals underestimate the benefits. Suppose, for example, that an individual overestimates the benefit of energy-saving action. Then, the information may lead him/her to understand that taking the action will save less money than (s)he originally believed. If (s)he does not currently take the action, (s)he will not be affected by the information. If (s)he currently does take the action, the information may even provide an incentive to stop engaging in the energy saving activity. As a result, the information may result in no change or even an increase in household energy consumption in the Japanese context.

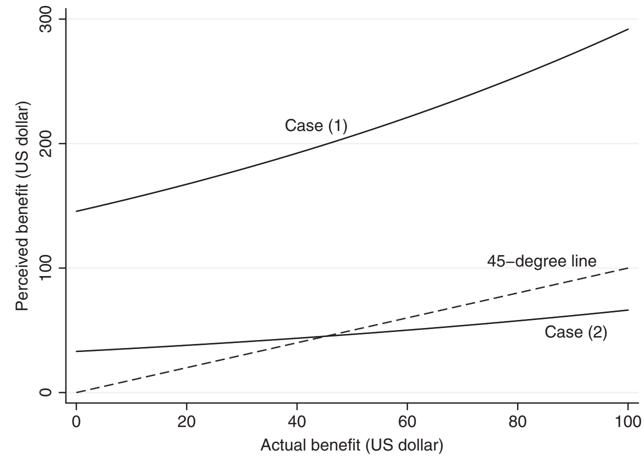

Fig. 4. Relationship between actual and perceived benefits by case. Note: Case (1) corresponds to a 20-year-old single male living alone. Case (2) corresponds to a 70-year-old married female living with five family members. Both curves are drawn using the estimation results in Column (4) of Table 3.

Our results also suggest that despite the tendency of the “average” individual to overestimate, individuals with some characteristics underestimate the benefits of energy-saving actions. To illustrate this, we consider two individuals: (1) a 20-year-old male who is not married and lives alone and (2) a 70-year-old female who is married and lives with five family members (e.g., her husband, son, daughter in law and two grandchildren). For each individual, we compute the predicted values of perceived benefits based on the estimation results of Column (4) in Table 3. For simplicity, we set the other factors to the sample means.

The results for both individuals, along with the 45-degree line, are presented in Fig. 4. For the first individual, the (predicted) perceived benefits are always located above the 45-degree line; he overestimates the monetary benefits of energy-saving actions, regardless of how much they can save. This is the same pattern as for the “average” individual that we described in the previous section. In contrast, the perceived benefits are smaller than the actual benefits for the second individual as long as the actual benefit of an action is greater than 45 dollars per year. This suggests that informing her of the benefits of two specific actions listed in Table 1 may be an effective intervention: frequent temperature control of electric carpet (no. 9) and refrain from reheating water (no. 17), both of which can save more than 45 dollars.

Several policy implications emerge from our analysis. First, it provides important insight on the types of individuals that should be targeted for outreach on energy saving activities; authorities, for example, should focus on elder married females living with a large family, rather than young single males living by themselves. This implication appears to be in line with findings of several other studies. Allcott (2011), for example, examined household energy use in a large-scale field experiment where households were provided with information about their energy consumption. The size of the reduction was found to be larger for households that consumed more energy. Examining energy consumption of space heating at apartments in Germany, Galvin (2013) also found that it is cost-effective to focus on households with heavy energy use.

Second, our results provide information on which energy-saving action authorities should focus on. In the example, when the actual benefit of an action is greater than approximately 45 dollars per year, an elder married female who lives with a large family underestimates the

[7] We set the variables (except the dummy for male) to their sample means and then calculate difference of predicted values of perceived benefits in between male and female.

[8] These values are calculated by the same procedure as in the footnote 8.

benefits; when the savings are less than 45 dollars, she overestimates the benefits (see Fig. 4). This suggests that authorities should focus on actions with relatively large benefits. Overall, our results suggest that tailored, highly personalized and specific information is more effective.

Concluding remarks

Using a survey conducted in a suburb of Tokyo, this study examined whether individuals properly perceive the monetary benefits of energy-saving actions. Our results suggest that individuals tend to overestimate the benefits, which is the opposite pattern found by Attari et al. (2011) for individuals in the United States. We also found that individual and home characteristics explain the perceived benefits to some extent.

Our results have several policy implications. First, the provision of information about the benefits of energy-saving actions may be an effective policy in one country but not necessarily in another country. This is because individuals in one country may underestimate the benefits of energy-saving actions, while those in another country may not, as suggested by the contrast found between our results and those of Attari et al. (2011). Second, the provision of information may be effective even in a country such as Japan where individuals overestimate the benefits on average. Our results showed that respondents who are married and older females tend to underestimate the benefits more than other groups. Therefore, informing this group of the actual benefits of energy-saving actions may help reduce their energy consumption.

The limitations of our study are as follows. First, we did not examine individuals' decisions on energy-saving actions. Further research should examine whether individuals initiate energy-saving actions after learning the associated actual benefits. Second, data on actual benefits may not be applicable to all households, as they are estimated by ECCJ (2010) for specific situations and for appliances with certain characteristics. Given that actual benefits depend partly on households' characteristics, including the performance of an appliance and the structure of a house, construction of detailed data on actual benefits, with help from electrical engineering researchers, may be needed to better understand the accuracy of individuals' perceptions. Third, we did not fully explore house characteristics, despite the evidence by Galvin (2013) that physical differences between apartments may influence household energy consumption. This has left unanswered questions including whether the number of external surfaces is associated with the perceived benefit of temperature control in an air-conditioner. Exploration of detailed house characteristics may help provide highly personalized and specific information. Fourth, it should be noted that the respondents in our analysis may be more environmentally conscious than the average population since we only have 250 observations out of 1200 households who received the questionnaire.

Acknowledgments

We are grateful to the editor and reviewers for insightful comments as well as suggestions. All remaining errors are ours. This study was supported by "An economic analysis of the impact of linking domestic ETS's among on the Japanese economy: a computable general equilibrium analysis approach" by the Japanese Ministry of the Environment and Grant-in-Aid for Scientific Research (C: 24530267) by the Japan Society for the Promotion of Science.

References

Alfredsson EC. "Green" consumption—no solution for climate change. Energy 2004;29(4):513–24.

Allcott H. Social norms and energy conservation. J Public Econ 2011;95(9/10):1082–95.

Arbrahamse W, Steg L, Vlek C, Rothengatter T. A review of intervention studies aimed at household energy conservation. J Environ Psychol 2005;25(3):273–91.

Arbrahamse W, Steg L, Vlek C, Rothengatter T. The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. J Environ Psychol 2007;27(4):265–76.

Attari SZ, DeKay ML, Davidson CI, de Bruin WB. Public perceptions of energy consumption and savings. Proc Natl Acad Sci U S A (PNAS) 2011;107(37):16054–9.

Baird JC, Brier JM. Perceptual awareness of energy requirements of familiar objects. J Appl Psychol 1981;66(1):90–6.

Barr S, Gilg AW, Ford N. The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. Energy Policy 2005;33(11):1425–44.

Benders RMJ, Kok R, Moll HC, Wiersma G, Noorman KJ. New approaches for household energy conservation—in search of personal household energy budgets and energy reduction options. Energy Policy 2006;34(18):3612–22.

Carlsson-Kanyama A, Engstrom R, Kok R. Indirect and direct energy requirements of city households in Sweden—options for reduction, lessons from modeling. J Ind Ecol 2005;9(1–2):221–35.

Dietz T, Gardner GT, Gilligan J, Stern PC, Vandernbergh MP. Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. Proc Natl Acad Sci U S A 2009;106(44):18452–6.

Ecofys. World GHG emissions flow chart 2010; 2013.

EPA. http://www.epa.gov/climatechange/impacts-adaptation/, 2014. [accessed on July, 21, 2014].

Eurobarometer. Attitudes on issues related to EU energy policy—analytic report (Flash Eurobarometer 206a). Europe: European Commission; 2007.

Galvin R. Targeting 'behavers' rather than behaviours: a 'subject-oriented' approach for reducing space heating rebound effects in low energy dwellings. Energy Build 2013;67:596–607.

Gardner G, Stern P. The short list: the most effective actions U.S. households can take to curb climate change. Environ Mag 2008;50:12–24.

Geller ES. Evaluating energy conservation programs: is verbal report enough? J Consum Res 1981;8(3):331–5.

Gonzales MH, Aronson E, Costanzo MA. Using social cognition and persuasion to promote energy conservation: a quasi-experiment. J Appl Soc Psychol 1988;18(12):1049–66.

Griod B, de Haan P. GHG reduction potential of changes in consumption patterns and higher quality levels: evidence from Swiss household consumption survey. Energy Policy 2009;37(12):5650–61.

Hirst E, Grady S. Evaluation of a Wisconsin utility home energy audit program. J Environ Syst 1982–1983;12(4):303–20.

Hutton RB, McNeill DL. The value of incentives in stimulating energy conservation. J Consum Res 1981;8(3):291–8.

Larrick RP, Soll JB. The MPG illusion. Science 2008;320(5883):1593–4.

Lokshin M. Difference-based semiparametric estimation of partial linear regression models. Stata J 2006;6(3):377–83.

Luyben PD. Promoting thermostat setting behavior: public response to a presidential appeal for conservation. Environ Behav 1982;14(1):113–28.

McMakin AH, Malone EL, Lundren RE. Motivating residents to conserve energy without financial incentives. Environ Behav 2002;34(6):848–63.

Scherbaum CA, Popovich PM, Finlinson S. Exploring individual-level factors related to employee energy conservation behaviors at work. J Appl Soc Psychol 2008;38(3):818–35.

Silva JMCS, Tenreyro S. The log of gravity. Rev Econ Stat 2006;88(4):641–58.

Staats HJ, Wit AP, Midden CYH. Communicating the greenhouse effect to the public: evaluation of a mass media campaign from a social dilemma perspective. J Environ Manag 1996;46(2):189–203.

Steg L, Dreijerink L, Abrahamse W. Why are energy policies acceptable and effective? Environ Behav 2006;38(1):92–111.

The Energy Conservation Center Japan. Tokyo: Household Energy Saving Dictionary; 2010 [in japanese].

Truelove HB, Parks C. Perceptions of behaviors that cause and mitigate global warming and intentions to perform these behaviors. J Environ Psychol 2012;32(3):246–59.

U.S. global change research program. Overview: climate change impacts in the United States; 2014 [Washington, DC, USA].

Urban J, Scasny M. Exploring domestic energy-saving: the role of environmental concern and background variables. Energy Policy 2012;47:69–80.

Vringer K, Blok K. The direct and indirect energy requirements of households in the Netherland. Energy Policy 1995;23(10):893–910.

Whitmarsh L, O'Neill S. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. J Environ Psychol 2010;30(3):305–14.

Winett RA, Love SQ, Kidd C. The effectiveness of an energy specialist and extension agents in promoting summer energy conservation by home visits. J Environ Syst 1982–1983;12(1):61–70.

Yatchew A. An elementary estimator of the partial linear model. Econ Lett 1997;57(2):135–43.

Yohanis YG. Domestic energy use and householders' energy behavior. Energy Policy 2012;41:654–65.

Yue T, Long R, Chen H. Factors influencing energy-saving behavior of urban households in Jiangsu Province. Energy Policy 2013;62:665–75.