The Influences of Economic and Psychological Factors on Energy-Saving Behavior: A Field Experiment in Matsuyama, Japan

Kenichi Mizobuchi[1] : Department of Economics, Matsuyama University, 4-2, Bunkyo, Matsuyama, Ehime, 790-8578, Japan, E-mail: kmizobuc@cc.matsuyama-u.ac.jp

Kenji Takeuchi : Graduate School of Economics, Kobe University, 2-1, Rokkodai, Nada, Kobe, Hyogo 657-8501, Japan, E-mail: takeuchi@econ.kobe-u.ac.jp

Abstract

This study examines the influences of economic and psychological factors on electricity conservation behavior. A random selection of 236 Japanese households participated in the field experiment, and they were offered two interventions, such as monetary rewards depending on their reduction in electricity consumption and comparative feedback. The average saving rates of the (i) economic incentive group (5.9%) and (ii) economic incentive with comparative feedback group (8.2%) are statistically larger than those of the (iii) control group (1.6%). Our econometric analysis confirmed that economic and psychological factors have a positive influence on the decision concerning *whether to save electricity*, and a reward combined with comparative feedback is most effective. Psychological factors also affect the decision about *how much to save electricity*, while economic incentive factors do not influence this decision. In particular, social norms, which are psychological factors, have a consistent effect on both the *whether* and *how* decisions. Responses to the questionnaire before and after the experiment suggest that participants may have underestimated the marginal costs of the electricity saving.

Keywords: Comparative feedback; Economic incentive; Electricity saving; Field experiment; Household energy use; Social norm;

[1] Corresponding author. Tel.: +81 89 926 7140.
E-mail address: kmizobuc@cc.matsuyama-u.ac.jp

1. Introduction

The Great East Japan Earthquake in March 2011 and subsequent radiation leak from the Fukushima nuclear plant have triggered widespread concerns about the safety of nuclear plants. Since then, most of the nuclear power reactors in Japan have been shut down.[2] However, replacing nuclear power with an alternative source of electricity in the short term presents great difficulty. Thus, massive attempts have already been implemented to cut the peak demand for electricity. The household sector will need to play a key role in these attempts, but significant energy saving has been less than successful in this sector.[3]

Many studies have examined effective intervention for encouraging household energy saving behavior, such as information provision, public campaigns, goal setting, feedback, comparative feedback, and reward (Winett et al., 1978; Becker, 1978; McClelland and Cook, 1980; Midden et al., 1983; Brandon and Lewis, 1999; Abrahamse et al., 2005; Abrahamse et al., 2007; Petersen et al., 2007; Allcott, 2011). Abrahamse et al. (2005) reviewed thirty-eight field studies in social and environmental psychology, and evaluated the effectiveness of these interventions. However, it is not clear from these studies which form of intervention is most effective or which has the most enduring effect. One of the main reasons for this fact is that each study focused on only a few factors. In order to learn about policies that can effectively and efficiently reduce energy consumption, various data and insights need to be integrated. In particular, one needs to understand, first, the motivations of consumers in implementing

[2] In the interests of safety, as of April 2012, 53 out of Japan's 54 nuclear power reactors had been shut down. In fact, by May 2012, the remaining one nuclear power reactor is also expected to be shut down.

[3] In 2011, electricity-saving rates of large and small customers of industrial sector are 29% and 19% higher than the rates of the previous year. However, the rate of electricity-saving among households is only 6% (Tokyo Electric Power Company, 2011).

certain types of energy-saving behavior. Second, a careful analysis is required of the various factors that influence household behavior, for leaving out crucial factors will lead to biases in the assessment of a particular factor's contribution to household behavior (van den Bergh, 2008). Therefore, an extension to the broadest possible range of policy instruments would require considering a great many factors, such as economic, psychological, and demographic.

Traditionally, economic and psychological approaches differ, so research efforts tend to be confined only to each academic area. Economists tend to examine the influence of external conditions—such as price, income, and other socio-economic characteristics—upon pro-environmental behavior. Thus, econometric studies of pro-environmental household behavior that include psychological variables relating to attitudes, knowledge, perceptions, and values are rare. On the other hand, studies by psychologists that include these variables exclude economic variables. A few studies have considered both economic and psychological factors in analyzing households' pro-environmental behavior (Clark et al., 2003; Kotchen and Moore, 2007).

Within traditional economic theory, individuals maximize their own utility, subject to budget constraints, and they have little incentive to strive toward a public good—i.e., pro-environmental behavior—so they will choose a "free ride" instead. However, this theoretical prediction is rarely shown empirically. Thus, economists have started to consider the role of psychological factors, such as warm-glow altruism (Andreoni, 1990) and paternalistic altruism (McConnell, 1997), in motivating individuals to make contributions to public goods. In the psychological discipline, Fransson and Garling (1999) have reviewed many studies examining the relationship between psychological variables and pro-environmental behavior. The influence of some psychological factors, such as attitudes, knowledge, perceptions, and values, has been demonstrated in terms of pro-environmental behavior. By means of a natural experiment, Guagnano et al. (1995) proved the hypothesis that attitudinal factors and external conditions act in combination to influence pro-environmental behavior. They also showed, specifically, that external conditions affect the strength of attitude-behavior relationships. Thus, strong positive external conditions increase the likelihood of attitudes that give rise to pro-environmental behaviors.

As a result, recent developments in economics (psychology) emphasize the need to consider internal (external) influences. However, as we mention above, what is lacking is a systematic integrated analysis of interventions or instruments: psychological (internal) factors—such as attitude, knowledge, motivation, and perception—and economic (external) factors, such as prices (subsidy or tax) and incomes.

This study aims to evaluate the influences of both economic and psychological factors on encouraging electricity conservation behavior. We conducted a field experiment based on an intervention study from October to November of 2011 in randomly selected Japanese households. As far as we know, this is the first study that examines the influence of both factors on electricity-saving behavior based on behavioral data (van den Bergh, 2008). Moreover, we divide the decision of electricity saving behavior into *whether to save* and *how much to save*, and reveal the main contributing factors to each type of decision-making.

This paper is organized as follows: section 2 discusses previous studies on household energy-saving behavior. In section 3, we describe our field experiment, in which we used subsidies as an economic incentive for electricity conservation behavior within households, and section 4 discusses the empirical analysis. Section 5 analyzes the marginal costs of electricity conservation behavior and discusses some limitations of our study, and section 6 is the conclusion.

2. Factors of influence on household energy saving behavior

Over the past several decades, many scholars have emphasized the importance of economic or psychological factors for encouraging household energy conservation behavior (Stern, 1992; Dwyer et al., 1993; Abrahamse et al., 2005; van den Bergh, 2008). This section gives a brief overview of relevant studies that have used economic and psychological factors—such as reward, comparative feedback, social norms, environmental concerns, goal setting, and some socio-economic variables—with a specific focus on these factors' influence on households' energy-saving behavior.

To evaluate the effects of taxes and subsidies for household energy usage, many previous studies have focused on the behavioral impacts of energy prices by a degree of price elasticity with time-series, cross-section, and panel data (Silk and Joutz, 1997; Vaage, 2000; Halvorsen and Larsen, 2001). Most of these studies showed statistically significant price elasticities. However, the degree of elasticity fluctuates, depending on the data and estimation method (Espey and Espey, 2004). In addition, some field studies are based on an intervention through economic rewards (e.g., money or prizes) to examine household energy-saving behavior (Winett et al., 1978; Midden et al., 1983; McClelland and Cook, 1980; Petersen et al., 2007). These studies indicate that economic rewards have been successful in reducing household energy consumption. For example, Winett et al. (1978) studied the effect of certain energy-saving interventions, including an economic incentive (i.e., a reward for reducing electricity consumption), involving 107 single-family households in Texas. The electricity conservation by the group with an economic incentive was significantly higher than that by other intervention groups and the control group. Moreover, if households were in competition with each other, the influence of the rewards was more effective (McClelland and Cook, 1980; Petersen et al., 2007). These results support the use of an economic incentive; however, two problems remain in these previous studies. One is the low statistical reliability because of the small number of households involved in the experimental groups (fewer than 20). Another is an identification problem—that is, the effects of rewards could not be isolated since a combination of other interventions, such as information, and individual and comparative feedback, was used in the study. Our field experiment provides a solution for these problems.

Feedback is widely used to encourage energy conservation (Abrahamse et al., 2005). In general, feedback is given in terms of a household's own energy savings in order to confirm the effectiveness of the effort to save energy; feedback becomes more effective, in particular, if its frequency is increased. Another type of feedback, which gives participants information about the energy savings of the other people in the study, is referred to as comparative feedback (Midden et al., 1983; Siero et al., 1996). This type of feedback has been found to be more effective than individual feedback in promoting energy conservation (Brandon and Lewis, 1999). Comparative feedback may be more effective because of the sense of competition or because people derive satisfaction from conforming to social norms. In the former case, when participants can compare their savings levels among themselves, they may try to reduce energy more than other participants. Such competition may be especially effective when the contest is also accompanied by a reward. The latter condition is also important; if households are uncertain about some part of their production function, the social comparisons may facilitate social learning about their optimal level of energy use, as documented in other contexts by Cai et al. (2009) and Munshi and Myaux (2006). Comparative feedback demonstrates relevant social norms in favor of energy conservation—that is, it becomes clear that others are actively engaged in energy conservation as well. Some academic work has shown that providing social norm information induces people to conserve energy (Schultz et al., 2007; Nolan et al., 2008; Allcott, 2011). For example, Allcott (2011) examined non-price energy conservation programs using data from randomized natural field experiments in 600,000 households across the United States, run by a company called OPOWER. This company mails Home Energy Report letters that compare a household's energy use to that of similar neighbors and provide energy conservation tips. Allcott showed that average energy reduction was 2.0%. In our empirical study, we deal with comparative feedback as evoking a sense of competition. At the same time, separate from a sense of competition, we employ another variable that relates to a social norm (see sections 3 and 4).

Environmental concern is also considered as one of the psychological motivating factors on pro-environmental behavior. For assessing the degree of environmental concern, the New Ecological Paradigm (NEP) scale has been developed as an instrument in the social and behavioral sciences for measuring attitude about the environment (Dunlap et al., 2000). The NEP scale has also been used in the economic literature on households' green electricity participation program (Kotchen and Moore, 2007).

Goal setting, which is sometimes used to promote energy saving, sets energy-saving targets that households can strive for, such as saving 10% (Abrahamse et al., 2007). The efficacy of goal setting is strengthened if combined with a promise to save (Katzev and

Johnson, 1983) or with feedback (McCalley and Midden, 2002). Moreover, in the case wherein goal setting was combined with feedback, a high-level goal appeared to be more effective in reducing energy demand than a low-level goal (Becker, 1978).

Other variables typically included in previous studies are household income, age, and education level of household members; house size; a measure of outside temperature; and ownership of certain appliances (e.g., electric appliances). The statistical significance of these variables is not completely consistent with some review studies (Espey and Espey, 2004; Abrahamse et al., 2005), but it is appropriate to consider that these variables also influence household energy-saving behavior.

This study integrates factors from economics and psychology to identify key internal and external variables that determine household electricity-saving behavior. Moreover, we focus on two energy-saving behaviors, *whether to save* and *how much to save*, and analyze households' specific motives for these two behaviors. Our analysis uses data from 236 randomly selected households in a field experiment. Economic variables consist of reward, household income, and standard socio-demographic elements. Psychological variables consist of comparative feedback, social norm, a modified version of the New Ecological Paradigm (NEP) scale to measure environmental concerns, and goal setting. In the next section, we present our research strategy in greater detail.

3. Field Experiment

3.1. Design

Our field experiment lasted for 8 weeks, from October to November 2011. Each enrolled household was entitled to receive a reward for reducing its electricity consumption to a level below their previous year's consumption for the same period. Electricity consumption was measured in kWh to ensure comparability across households, regardless of the energy fuels used. The reduction of electricity consumption (*Reduction*) was calculated as follows:

$$Reduction(\%) = \frac{(C_p - C_x)}{C_p} \times 100, \quad (1)$$

where C_x and C_p represent the electricity consumption during the experiment and during the same period of the previous year. If *Reduction* was larger than 1% ($Reduction \geq 1$), households could receive a reward (economic incentive). The amount of the reward was 200 yen (about \$2.50) per 1% of electricity consumption reduction (We have assumed the following exchange rate: \$1 = 80 yen). For example, if actual *Reduction* was 10%, households were given 2,000 yen (200 yen × 10).

On the other hand, we also examined the effectiveness of comparative feedback, in which each household received information about the average amount of electricity saving by other households (e.g., the value of *Reduction*). We conducted the comparative feedback twice: the first one informed households of the target levels of electricity saving by means of pre-experiment questionnaires in late September, and the second one provided information on the values of *Reduction* from the first month (i.e., October) in early November.[4]

Households were assigned randomly to three groups—(1) Reward, (2) Reward with Comparative Feedback, and (3) Control—to examine the effectiveness of

[4] The first comparative feedback is not a real value of *Reduction*, and there may be a difference between the value of the target and real values. However, participants can compare others' target reduction levels with their own. Therefore, in terms of comparison with other participants, we deal with it as the first comparative feedback.

economic incentives and of comparative feedback. We use a non-parametric approach to compare the three groups in section 3.3. Because we wanted to avoid a small sample problem like the previous studies, we set the sample size of every group as larger than 50. Moreover, we also use a parametric approach—i.e., a regression analysis—taking *Reduction* as the dependent variable to examine the influences of economic factors and psychological factors on electricity conservation behavior (see section 4 for details).

We administered two questionnaires, one before and one after the field experiment. The responses from the subjects offer valuable information on the factors that play a key role in reducing energy use. In the pre-experiment questionnaire, we asked participants about the following aspects: their attitude toward environmental issues, their level of environmental concern,[5] attitudes toward electricity conservation, their intended target level of electricity saving as well as their level of confidence in meeting this target, and the types of home electrical appliances in the household. Finally, we elicited social norm, socio-economic, and demographic details. Here, in our study, the degree of social norm is measured by the question “Do you think consider how often people close to you are attempting electricity-saving behavior?” Comparison with neighbors or other close persons will construct people’s social norms and will induce people to conserve energy (Nolan et al., 2008 and Allcott, 2011). Responses were made on a 5-point Likert scale (always = 5, usually = 4, sometimes = 3, rarely = 2, never = 1), and high score responses mean a high level of attention to social norms (and vice versa).

---

[5] Respondents were asked to what extent they agreed or disagreed with 15 statements known as the modified new ecological paradigm (NEP) scale (Dunlap and Liere, 1978; Dunlap et al., 2000). The modified NEP scale is commonly used in the psychology literature; it aims to capture the following five facets of environmental concern: limits to growth, anti-anthropocentrism, the fragility of the balance of nature, rejection of the idea that humans are exempt from the constraints of nature, and the possibility of an eco-crisis or ecological catastrophe.

In the post-experiment questionnaire, we asked participants, *inter alia*, about changes in their attitudes toward electricity conservation, the challenges in conserving electricity, and the appropriateness of economic incentives. Table 1 represents the schedule of our field experiment for three groups.

[**Insert Table 1 here**]

3.2. Respondents and Procedure

We conducted the study in Matsuyama, a city in Ehime Prefecture that has approximately 516,000 inhabitants in western Japan. In August 2011, 1,800 households in Matsuyama city were randomly selected and were sent letters informing them about the study and inviting them to participate in our field experiment. Aside from a broad description—i.e., that the study was about an experiment in energy saving—we did not divulge any details about the field experiment in the initial invitation letter. Of the households invited to participate in this study, 236 (13.1%) returned a completed pre-experiment questionnaire. All respondents were older than 20 years (81 was the oldest). Compared to a national sample (Population Statistics, 2009), male respondents were overrepresented,[6] and respondents in the category of 55 through 69 years were slightly underrepresented. In field-experiment or questionnaire survey studies about environmental problems, a tendency exists toward overrepresentation from high-income households and underrepresentation from low-income households—i.e., the studies are biased for high incomes (Poortinga et al., 2003). Figure 1 represents a comparison of the

[6] Most respondents were the householders. This might be the reason for male overrepresentation.

income distributions in our study and a national sample.[7] Figure 1 shows that both high incomes (over 6 million yen) and low incomes (under 4 million yen) are slightly underrepresented, and that incomes of 4-6 million yen are overrepresented. The average income of Japan is about 5.5 million yen. Therefore, the households in our study are not biased toward high incomes, but have a slight tendency toward a higher concentration of average incomes.

[**Insert Figure 1 here**]

As described earlier, participating households were entitled to receive subsidies based on their *Reduction*, which was calculated according to equation (1). Shikoku Electric Power Co. was the electricity supplier for all participating households. Participants could access their historical data on electricity consumption per month by logging onto the Shikoku Electric Power website, using their unique identification numbers. We collected these consumption data for the previous year from the households (printed Web page) and used them as the measurement criteria. Additionally, for tracking ongoing consumption, every household was asked to send a copy of its monthly electricity consumption record from Shikoku Electric Power Co.

3.3. Results and non-parametric analysis

Figure 2 shows the results of electricity conservation, in terms of *Reduction*, in the sampled households at the end of 8 weeks.[8] About 70% of the households successfully reduced their electricity consumption. There are some possibilities as causes for this result: the households showed a high response to economic incentives or

[7] Ministry of Health, Labor and Welfare: National Livelihood Survey 2009. http://www.mhlw.go.jp/index.shtml

[8] Because of an inadequacy or a lack of electricity consumption data, 28 participants dropped out of the field experiment, reducing the total number of households to 208.

comparative feedback; the economic incentives offered in this experiment were perhaps higher than the marginal cost of the electricity-saving behavior; or the temperature of the target year may have been cooler than that of the previous year.[9] As Figure 2 shows, in particular, the greatest percentage of households (19.2%) was in the 10%–15% *Reduction* bracket, followed by the 5%–10% bracket (17.8%), and the 1%–5% (13.9%). However, the percentage of households that saved more than 15% was small, and it decreased as the values of *Reduction* increased. Additionally, about 29.8% of the households did not conserve electricity, so we can confirm that a certain percentage of households did not respond well to economic incentives and comparative feedback.

[**Insert Figure 2 here**]

The average *Reduction* of the households in this experiment is 5.4%, indicating a decrease in energy consumption compared to the previous year. Here, we investigate the effects of interventions—i.e., economic incentive and comparative feedback—statistically.

[Insert Table 2 about here.]

Table 2 shows the average electricity saving rate (i.e., average *Reduction*) of the three groups: (i) Reward, (ii) Reward with Feedback, and (iii) Control. The average saving rate is highest in the Reward with Feedback group (8.2%), followed by the Reward group (5.9%), and the Control group (1.6%). Our study investigates the effects of intervention, so we test the following null hypothesis.

[9] One probable reason is a rise in the awareness of the need to save electricity after the Great East Japan Earthquake in March 2011. Because most of the nuclear power reactors have been shut down in the interest of safety (51 of Japan's 54 by January 2012), massive electricity-saving measures have been implemented in Japan. From the pre-experiment questionnaire survey, 63.9% of households perceived a change in their awareness of interest in electricity saving (high interest + interest). From this result, we can conclude that the awareness for electricity saving has become high in general and that it may slightly affect the electricity-saving behavior of our experimental households.

$$H_0 : \gamma_i - \gamma_j = 0 \qquad i \neq j, \quad i, j = \text{(i), (ii), (iii)},$$

where γ_i indicates the average *Reduction* of *i*th groups. Table 2 shows the t-statistics of three hypotheses—that is, Reward vs. Control, Reward with Feedback vs. Control, and Reward vs. Reward with Feedback. From the t-statistics of the first hypothesis, Reward vs. Control, the null hypothesis was rejected at the 10% significance level (1.74 > 1.65, p = 0.1), so the effect of the economic incentive could be found statistically. Moreover, from the t-statistics of the second hypothesis, Reward with Feedback vs. Control, the null hypothesis was also rejected at the 5% significance level (2.59 > 1.98, p = 0.05), so this result enhances the effect of the economic incentive. However, the intrinsic effect of comparative feedback was obscure, because the null hypothesis was not rejected (1.10 < 1.66, p = 0.1) for the third hypothesis, Reward vs. Reward with Feedback. This result is inconsistent with those of Midden et al. (1983) and Brandon and Lewis (1999), which supported the effectiveness of only comparative feedback, but is consistent with those of McClelland and Cook (1980) and Petersen et al. (2007), which supported the effectiveness of comparative feedback with reward. In the next section, we use the parametric approach to investigate the economic and psychological factors in saving electricity consumption, and we also examine the effect of comparative feedback.

4. Parametric Analysis (regression analysis)

This section presents the results of a parametric analysis (i.e., regression analysis) undertaken to examine whether economic and psychological factors affect the decisions about electricity-saving behavior within households.

4.1. Model and Data

We begin with a Tobit model for analyzing the variables with *Reduction* as the dependent variable because there are a large number of households that achieve no electricity-saving:

$$\begin{aligned} Y_i^* &= \alpha + \beta X_i + \varepsilon_i \\ Y_i &= \max(0, Y_i^*) \qquad i = 1,2,....,N \end{aligned} \tag{2}$$

The dependent variable Y_i indicates the *Reduction* of the *i*th household and is censored at zero. Households with a negative value of *Reduction* in our experiment are treated as households "not saving electricity right from the beginning" or "having abandoned electricity conservation sometime during the experiment." X is a vector of the independent variables: a comparative feedback dummy, a reward (i.e., economic incentive) dummy, an anticipation of the electricity-saving behavior of persons close to the household (i.e., social norm), the NEP score, the target level of *Reduction* shown in the pre-questionnaire, the gender and age of the household representative, the income level, the family size, type of home ownership, size of home (area), and cooling degree days[10] (previous year – target year). Data on the independent variables were obtained from the pre- and post-study questionnaires. Table 3 presents a statistical summary of the above and dependent variables.

[Insert Table 3 about here.]

4.2. Estimation results

Eviews (version 7.0), which is an econometric software package, was used to

[10] The difference between an average temperature higher than 24 °C and 22 °C. The day of meter reading by the electric company is different for each household. Therefore, we summed up the differences for the experimental term and set an independent variable.

estimate equation (2). The test of heteroskedasticity was conducted based on a Lagrange multiplier statistic. The statistic was 32.55, and this statistic has a limiting chi-squared distribution with 12 degrees of freedom. The sample value exceeds the critical value of 21.03 (p = 0.95, d = 12), so the null hypothesis of homoscedasticity could be rejected. To adjust for heteroskedasticity, we use White's covariance matrix.

[Insert Table 4 about here.]

The estimation results from the Tobit model are reported in the first column of Table 4. The *comparative feedback* and *reward* have a positive effect on electricity-saving behavior; both variables have coefficients that are positive and statistically significant. In the previous section, we showed the efficacy of economic incentives and comparative feedback against the control group by a non-parametric approach. Here, both the values of the estimation coefficient were statistically significant; therefore, we confirmed also by the parametric approach that reward and comparative feedback (with reward) have an effect by way of encouraging electricity-saving behavior. However, the comparison of estimated coefficients between the *comparative feedback* and *reward* is not statistically significant. Thus, similar to the result in section 3.3, the efficacy of comparative feedback (without reward) is obscure.

The coefficient of the social norm is positive and statistically significant, thereby showing that others' behavior does have an impact on one's own electricity-saving behavior. This impact could stem from two sources. First, overall household behavior in electricity saving may influence people's views concerning personal responsibility. Specifically, if others participate in electricity saving, the individual may experience a loss in his or her self-image as a morally responsible person if he or she does not do so.

Second, there is also the presence of explicit prescriptive social norms stemming from, for instance, family members and close friends. This influence may well constitute a complement to the above perceptions of others' contributions. If close friends and family stress the importance of saving electricity, the individual may deduce that others also believe it is important. Nyborg et al. (2006) presented a theoretical framework in which individual responsibility for pro-environmental behavior depends on beliefs about others' behavior. Using household survey data, Ek and Soderholm (2008) showed the positive influence of social norms on participating in the Swedish green-electricity market, and Nolan et al. (2008) and Allcott (2011) also showed the positive influence of it on U.S. household energy-saving behavior.

Two other psychological factors, such as NEP score and target, have no influence on electricity conservation behavior; both coefficients are statistically insignificant. The positive effect of the NEP score has manifested in other pro-environmental behaviors, such as participation in the green-electricity market, in some previous studies (Clark et al., 2003; Kotchen and Moore, 2007; Ek and Soderholm, 2008). However, electricity-saving behavior has not only an aspect of public good—i.e., being pro-environmental—but also has a private good aspect, such as saving one's own money. This consideration may be the cause of the insignificant effect of the NEP score. Another possible reason is the *Motivation Crowding Theory*, or the *crowding-out effect*, which suggests that external intervention via monetary incentives may undermine intrinsic motivation (Deci, 1971). This effect is presented widely in the economy and society (Deci et al., 1999; Frey and Jegen, 2001). If the individuals affected perceive external interventions to be *controlling*, both self-determination and self-esteem suffer, and such individuals react by reducing their intrinsic motivation in the activity controlled. From this effect, participants who save electricity because of motivation from intrinsically high environmental concern might experience reduced motivation to save electricity if monetary rewards are introduced, and this influence might be presented as statistically insignificant regarding the NEP parameter.

The coefficient on income is statistically insignificant, and this result is a little different than was expected. In the theoretical model of public goods, the coefficient of household income will become positive, and this outcome has been supported empirically (Kotchen and Moore, 2007), as pro-environmental behaviors do, in fact, increase with income. However, like the result of the NEP score above, electricity-saving behavior does not have the nature of a pure public good, thus perhaps causing this result. Family size and homeownership have a negative and statistically significant effect on electricity saving, suggesting the importance of considering disposable income. The size of home is positive and statistically significant. This result may indicate the possibility that there is large electricity-saving potential in a house that has many rooms. Finally, the coefficient of the cooling degree day (previous year – target year) is statistically significant, and the positive sign indicates that if the target year becomes cooler than the previous year, the amount of time the air-conditioner is used decreases, a situation conducive to electricity savings. Actually, the average temperature within the experimental term was lower by 0.9 °C than it was the previous year.[11]

A feature of the Tobit model is the restriction that explanatory variables are assumed

[11] In the post-study questionnaire, we asked participants to indicate a factor that was important for electricity saving. Thirty-five percent of households felt that *cooperation from family members* was the most important factor. *Willingness to act* was identified as an important factor by 31%, while 15% of households believed that it was *temperature*. Only a small percentage of respondents identified *information on energy saving* (4%) as an important factor.

to influence the extensive and intensive margins of electricity-saving behavior in the same way. That is, an implicit assumption is made that the decision of *whether to save electricity* is the same as the decision of *how much to save*. However, it is possible that the explanatory variables influence electricity-saving on the extensive and intensive margins in different ways. Smith et al. (1995) and Kotchen and Moore (2007) make this observation and find empirical support for it in a study of charitable contributions to a rural health care facility and a green-electricity program. We explore the same possibility here by decomposing the Tobit model into a probit model for the decision of *whether to save electricity*, and a truncated regression model for the decision of *how much to conserve*.[12]

We report the results of these two models in the second and third columns of Table 4. The qualitative results of the probit model are similar to those of the Tobit model; most of the coefficients have the same sign except for NEP score and target. However, the levels of statistical significance are substantially different. Thus, the variables that influence only the extensive margin of electricity-saving (*whether to save electricity*) are different from those that jointly influence the extensive and intensive margins (*how much to save*). Comparative feedback, social norm, and size of home have a positive and statistically significant effect on the decision of *whether to save electricity*, whereas home ownership has a negative and statistically significant effect. Here, the marginal effect of comparative feedback is statistically larger than that of reward. Thus, under the existing economic incentives, if households know the amount of other households' electricity saving and can compare energy-saving levels under the

[12] Similar to Kotchen and Moore (2007), our sample includes all households that participated in our field experiment; therefore, the analysis of the intensive margin needs no correcting for sample-selection bias. For such cases, Greene (2008) notes that the appropriate decomposition of a Tobit model is into a probit model and a truncated regression model.

economic incentives, they may be motivated to compete and may conserve electricity consumption more than without the comparative feedback (McClelland and Cook, 1980; Petersen et al., 2007).

The results also differ substantially when we focus on the intensive margin (*how much to save*). In the truncated regression model, two psychological factors, one socio-economic factor, and the weather variable are statistically significant explanatory variables in the decision of *how much to save*, and economic incentive factors have no effect. In particular, the coefficient of *target*, which was not statistically significant in both the Tobit and probit models, is statistically significant. Becker (1978) showed that setting a relatively difficult goal appeared to be more effective in reducing energy use than setting a relatively easy goal. Our result of the truncated regression model is consistent with his result.

These results provide evidence that the decision of *whether to save electricity* is not determined in the same way as the decision of *how much to save*. Specifically, we found that comparative feedback, social norm, homeownership, and size of home influence the decision about *whether to save electricity*, and social norm, target setting, family size, and cooling degree day influence the decision of *how much to save*.

4.3. The effects of economic and psychological factors

Which is more important in terms of electricity conservation behavior: economic factors or psychological factors? Our results show that both economic and psychological factors are important. As we showed in subsection 4.2, however, the effectiveness of these two factors differs based on the timing of the decisions that each factor influences in electricity-saving behavior—i.e., *whether to save electricity* and *how much to save*. From the estimation result of the probit model in the second column of Table 4, the coefficients of both comparative feedback (with reward) and social norm are positive with a statistically significant effect. Therefore, in the decision of *whether to save electricity*, both economic and psychological factors would affect electricity-saving behavior. Here, the marginal effect of comparative feedback (with a reward) is larger than that of the social norm. Therefore, in the decision of *whether to save electricity*, we might conclude that comparative feedback with a reward will become the most positive decisive factor. From the estimation result of the truncated regression model in the third column of Table 4, on the other hand, only psychological factors—i.e., *social norm* and *target*—are statistically significant. Thus, in decisions concerning *how much to save*, psychological factors would most affect electricity-saving behavior. Here, only social norm has a positive and statistically significant effect on both decisions of *whether* and *how much*, which imply that social norms do have a consistent positive impact on one's own electricity-saving behavior.

5. Discussion and Limitations

This section discusses the two major reasons for the 29.8% of participants who demonstrated negative *Reduction* in this study: (1) lack of understanding of the difficulties in electricity conservation and (2) the marginal cost of electricity saving. Figure 3 shows the participants' evaluation of the difficulties associated with electricity conservation before and after the experiment. Before the experiment, the majority of the respondents felt that the level of electricity conservation was "neither easy nor difficult." However, at the end of the experiment, 55% of the participants felt that saving electricity was "difficult" or "very difficult." This change in response indicates a limited initial understanding of the challenges associated with the conservation behavior beforehand. This result may also suggest that pre-experiment responses concerning electricity saving behavior have an upward bias, as participants expect to save more electricity before actually acting on it. In other words, using only a stated intention to evaluate household energy saving may not be appropriate, given the likelihood for overestimation.

[Insert Figure 3 about here.]

The second reason is that the marginal cost of energy saving is greater than the incentive amounts. As described earlier, most of the households underestimated the difficulties in conservation before the experiment; that is, they underestimated the marginal cost of energy saving. However, actually making efforts to reduce consumption may have helped them realize the greater marginal cost of conservation, thus resulting in cessation of conservation efforts. To the question "Would you conserve electricity if the incentive amounts were doubled?" in the post-experiment survey, nearly 71% of households that failed in reducing their consumption returned negative responses. This result also supports the notion that the marginal cost of saving electricity is quite high.

These results carry important implications for policymakers targeting energy conservation in the household sector: before introducing incentives to promote conservation, it is necessary to study the marginal cost of electricity saving and to ensure that the incentives exceed this cost. Moreover, it would be worthwhile to combine economic incentives with other interventions aimed at lowering the marginal cost. For example, as we showed in section 4, the comparative feedback under economic incentives is very effective in the decision of whether to save electricity.

Although these findings offer important insights, a few limitations to this study must be acknowledged and possibly overcome in future works. The first consists of possible sample selection bias. Most of the previous studies recruited participants for field experiments and surveys by mailing randomly selected households. Even if the selection of the households is random, however, it is highly likely that participants who expressed a desire to enroll in the experiment or survey had high levels of environmental awareness and were inherently motivated to save energy. They may have viewed the experiments and/or the survey as encouragement to conserve energy. Ek and Soderholm (2010) confirm that participants who voluntarily enroll in energy-saving experiments typically have high levels of environmental awareness and are inherently motivated. On the other hand, households that are not interested in saving energy or that have low levels of awareness may not participate in the experiment or survey. In other words, it is likely that a number of previous studies have a sample selection bias. Sardianou (2007) surveyed the energy consumption patterns of Greek households and showed that individuals with a thorough knowledge of environmental problems and high environmental awareness tend to reduce their energy consumption greatly. When most of the subjects in an experiment have a high awareness of the environment, the generalization of the results becomes questionable. In fact, the bias is greater when the sample size is small. Randomization is essential in an experimental study, but we could not exclude the possibility that participants had a bias toward high motivation in our field experiment.

Second, the sample size of our study (236 participants) is obviously larger than that of previous studies, which enhances the statistical reliability of the results. However, even this sample size is not sufficient for deriving policy implications from these findings. One of the chief reasons for limitation in the sample size was the use of an observable measure (i.e., a master meter) for validating the effects of an energy-saving intervention. While an observable measure can ensure objectivity in measurement, it poses considerable difficulties if the sample size is large or if the experimental period is long. However, if an electric company is willing to cooperate strongly in an experiment for saving electricity, it is possible to obtain a large enough sample size (Allcott, 2011). In fact, very few field experiments that use observable measures have a sample size of more than 300 (Abrahamse et al., 2005).

Third, because our study implemented comparative feedback that was collected twice for two months, the frequency of the comparative feedback might be a little low. This might be a reason why we were unable to obtain a result showing that comparative feedback is effective in both a non-parametric and a parametric approach. In previous studies, the effectiveness of the feedback rises if the frequency of the feedback increases (Abrahamse et al., 2005). Thus, verification and comparison are needed when the frequency changes. These limitations should be addressed in future work.

6. Conclusion

Through an 8-week field experiment, this study investigated the influences of economic and psychological factors on electricity-conservation behavior among Japanese households. A few studies have examined the influence of two factors on pro-environmental behavior (Clark et al., 2003; van den Bergh, 2008; Kotchen and Moore, 2007), but no studies focus in particular on electricity-saving behavior with revealed data. From the results detailed in sections 3 and 4, we have shown the effectiveness of both economic and psychological factors for encouraging electricity conservation. However, the effectiveness of these two factors is divided, based on the timing of the decisions, in terms of the influence of each factor on electricity-saving behavior—i.e., *whether to save electricity* and *how much to save*. Economic incentives are more effective than such psychological factors as social norms, environmental concerns, and target setting regarding decisions about *whether to save electricity*, especially under comparative feedback. On the other hand, in decisions about *how much to save electricity*, such psychological factors as social norms and target setting are effective. Only social norm has a consistent positive effect on both *whether to save* and *how much to save*. The effectiveness of economic incentives on electricity saving is in agreement with that of previous studies (Midden et al., 1983; Petersen et al., 2007; Winett et al., 1978). The effects of psychological factors—such as comparative feedback, social norm, and target setting—are also consistent with results from previous studies (Becker, 1978; Midden et al., 1983; Brandon and Lewis, 1999; Ek and Soderholm, 2008; Nolan et al., 2008; Allcott, 2011). Nor does this study suffer from the drawback identified in some earlier works: sampling problem and small sample size. Our experimental households were randomly selected, and the sample size of 236 households is higher than that of previous studies, ensuring high statistical reliability.

Underestimation of the marginal cost of saving electricity is one of the reasons that led about 30% of the participants to cease their energy-saving efforts. This discovery presents a valuable insight for policymakers who target the household sector in reducing carbon dioxide emissions. Before offering economic incentives to promote energy conservation, the marginal costs of electricity conservation should be evaluated. If the costs are substantially high, economic incentives should be combined with other interventions, such as tailored information and goal setting, to lower the marginal costs. Comparative feedback as examined in our study might be a potentially useful intervention.

Acknowledgement

This research is supported by Japan Society for the Promotion of Science (Grant-in-Aid for Young Scientists (B) #22730217) which is acknowledged by K. Mizobuchi. K. Takeuchi would like to thank the Department of Economics at the University of Gothenburg for giving him the opportunity of visiting research.

References

Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation. J Environ Psychology 25:273–291.

Abrahamse W, Steg L, Vlek C, Rothengatter T (2007) The effect of tailored information, goal setting and tailored feedback on household energy use, energy-related behaviors and behavioral antecedents. J Environ Psychology 27:265–276.

Allcott H (2011) Social norms and energy conservation. J Public Econ 95:1082–1095.

Andreoni J (1990) Impure altruism and donations to public goods: A theory of warm-glow giving. Econ J 100:464-477.

Becker L (1978) Joint effect of feedback and goal setting on performance: A field study of residential energy conservation. J Applied Psychology 63:428–433.

Brandon G., Lewis A (1999) Reducing household energy consumption: A qualitative and quantitative field study. J Environ Psychology 19:75–85.

Cai H, Chen Y, Fang H (2009) Observational learning: Evidence from a randomized natural field experiment. Am Econ Rev 99:864–882.

Clark CF, Kotchen MJ, Moore MR (2003) Internal and external influences on pro-environmental behavior: Participation in a green electricity program. J Environ Psychology 23:237–246.

Deci EL (1971) Effects of externally mediated rewards on intrinsic motivation. Journal of Personality and Social Psychology 18:105-115.

Deci EL, Koestner R, Ryan RM (1999) A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. Psychological Bulletin 125:627-668.

Espey J, Espey M (2004) Turning on the lights: A meta-analysis of residential electricity demand elasticities. J Agric and Applied Econ 36:65–81.

Dunlap RE, Van Liere KD (1978) The "new environmental paradigm": A proposed measuring instrument and preliminary results. J Environ Education 9:10–19.

Dunlap RE, Van Liere KD, Mertig MG, Jones RE (2000) Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. J Social Issues 56 (3):425–442.

Dwyer WO, Leeming FC, Cobern MK, Porter BE, Jackson JM (1993) Critical review of behavioral interventions to preserve the environment. Research since 1980. Environ and Behavior 25:275–321.

Ek K, Soderholm P (2008) Norms and economic motivation in the Swedish green electricity market. Ecological Econ 68:169-182.

Ek K, Soderholm P (2010) The devil is in the details: Household electricity saving behavior and the role of information. Energy Policy 38:1578–1587.

Fransson M, Garling T (1999) Environmental concern: Conceptual definitions, measurement methods, and research findings. J Environ Psychology 19:369–382.

Frey BS, Jegen R (2001) Motivation crowding theory. J Econ Surveys 15:589-611.

Greene WH (2008) Econometric Analysis, sixth ed. Prentice Hall, New Jersey.

Guagnano GA, Stern PC, Dietz T (1995) Influences on attitude-behavior relationships: A natural experiment with curbside recycling. Environ and Behavior 27 (5):699–718.

Halvorsen B, Larsen BM (2001) The flexibility of household electricity demand over time. Res Energy Econ 23:1–18.

Katzev RD, Johnson TR (1983) A social-psychological analysis of residential electricity consumption: The impact of minimal justification techniques. J Econ Psychology 3:267–284.

Kotchen MJ, Moore MR (2007) Private provision of environmental public goods: Household participation in green-electricity programs. J Environ Econ and Management 53:1–16.

McCalley LT, Midden CJH (2002) Energy conservation through product-integrated feedback: The roles of goal-setting and social-orientation. J Econ Psychology 23:589–603.

McClelland L, Cook SW (1980) Promoting energy conservation in master-metered apartment through group financial incentive. J Applied Social Psychology 10 (1):20–31.

McConnell KE (1997) Does altruism undermine existence value? J Environ Econ and Management 32:22–37.

Midden CJH, Meter JE, Weenig MH, Zieverink HJA (1983) Using feedback, reinforcement and information to reduce energy consumption in households: A field-experiment. J Econ Psychology 3 (1):65–86.

Munshi K, Myaux J (2006) Social norms and the fertility transition. J Dev Econ 80:1–38.

Nolan MJ, Schultz PW, Cialdini BR, Goldstein NJ, Griskevicius V (2008) Normative social influence is underdetected. Personality and Social Psychology Bulletin 34:913–923.

Nyborg K, Howarth RB, Brekke KA (2006) Green consumers and public policy: On socially contingent moral motivation. Res Energy Econ 28:351-366.

Petersen JE, Shunturov V, Janda K, Platt G, Weinberger K (2007) Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. Inter J Sustainability in Higher Education 8:16–33.

Poortinga W, Steg L, Vlek C, Wiersma G (2003) Household preferences for energy-saving measures: A conjoint analysis. J Econ Psychology 24:49–64.

Population Statistics (2009) National Institute of Population and Social Security

Research. http://www.ipss.go.jp/index-e.asp. Cited 29 Mar 2009.

Sardianou E (2007) Estimating energy conservation patterns of Greek households. Energy Policy 25:3778–2791.

Schultz PW, Nolan MJ, Cialdini BR, Goldstein NJ, Griskevicius V (2007) The constructive, destructive, and reconstructive power of social norms. Psychological Science 18:429–434.

Siero RW, Bakker AB, Dekker GB, van den Burg MTC (1996) Changing organizational energy consumption behavior through comparative feedback. J Environ Psychology 16:235–246.

Silk JI, Joutz FL (1997) Short- and long-run elasticities in US residential electricity demand: A cointegration approach. Energy Econ 19:493–513.

Smith VH, Kehoe MR, Cremer ME (1995) The private provision of public goods: Altruism and voluntary giving. J Pub Econ 58:107–126.

Stern PC (1992) What psychology knows about energy conservation. Am Psychologist 47:1224–1232.

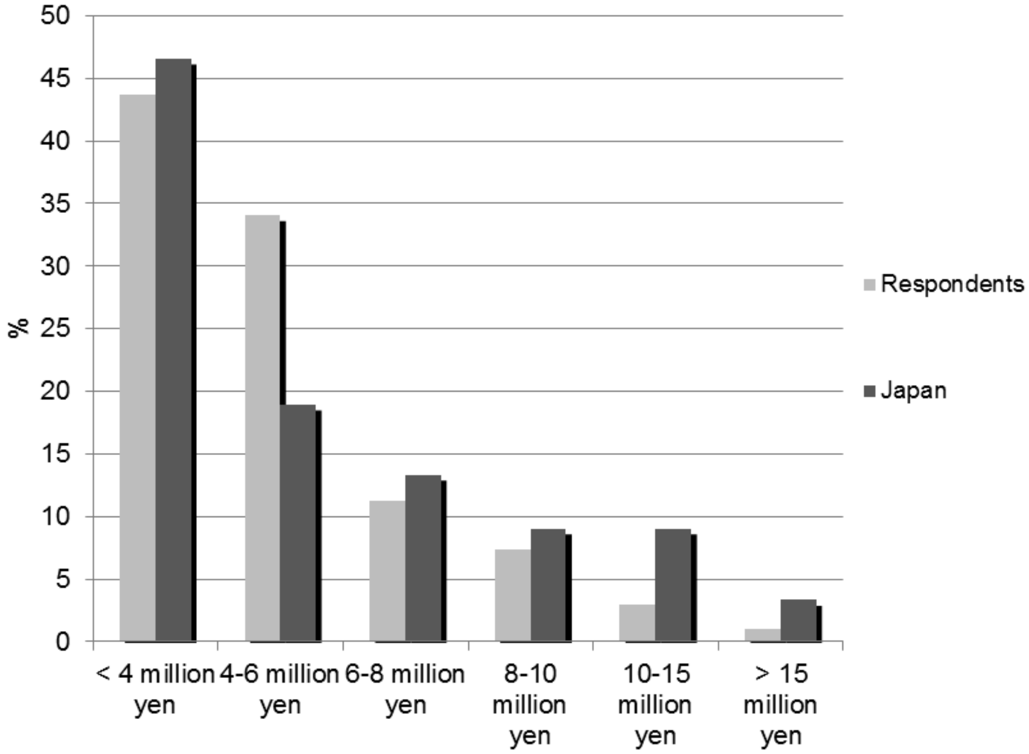
Tokyo Electric Power Company (2011) The supply and demand result for this summer. http://www.tepco.co.jp/en/press/corp-com/release/11092610-e.html. Cited 26 Sep 2011.

Vaage K (2000) Heating technology and energy use: A discrete/continuous choice approach to Norwegian household energy demand. Energy Econ 22:649–666.

van den Bergh JCJM (2008) Environmental regulation of households: An empirical review of economic and psychological factors. Ecological Econ 66:559–574.

Winett RA, Kagel JH, Battalio RC, Winkler RC (1978) Effects of monetary rebates, feedback, and information on residential electricity conservation. J Applied Psychology 63:73–80.

Figure 1. Income distribution



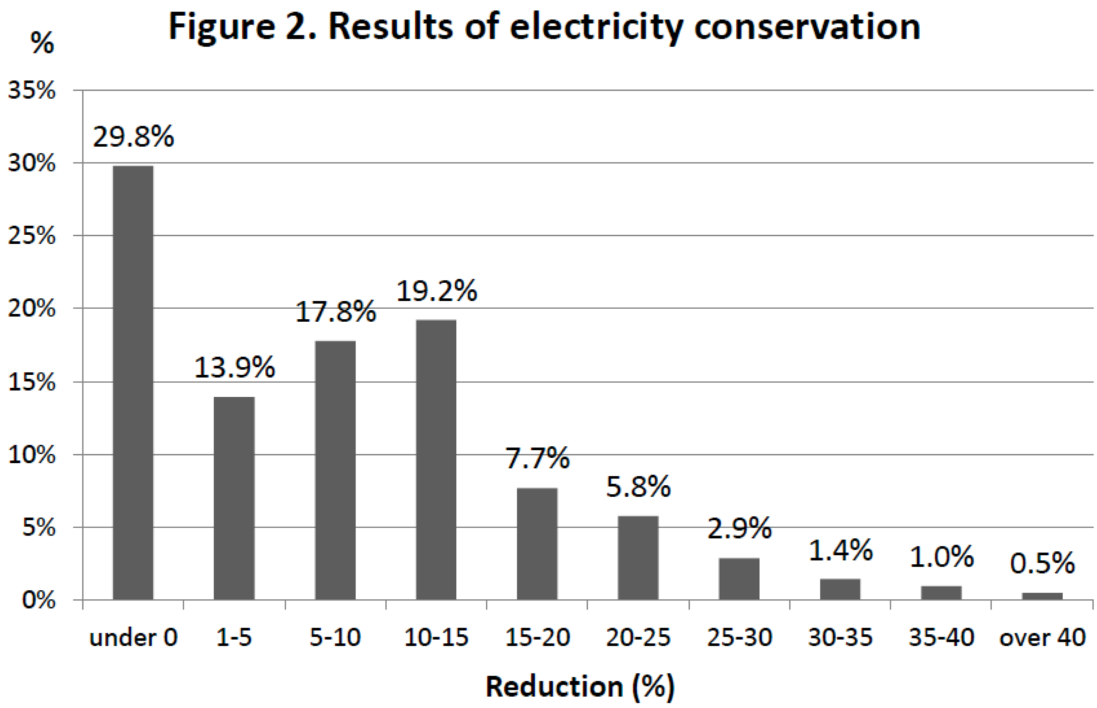
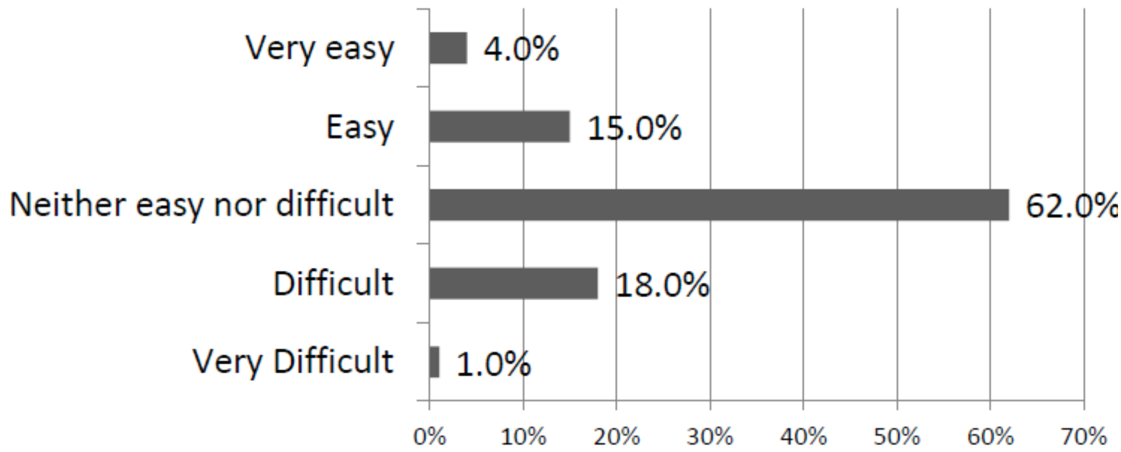


Figure 2. Results of electricity conservation
%
35%
30%
25%
20%
15%
10%
5%
0%
29.8%
13.9%
17.8%
19.2%
7.7%
5.8%
2.9%
1.4%
1.0%
0.5%
under 0
1-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
over 40
Reduction (%)

Figure 3. The difficulty of electricity conservation
(survey before the experiment)　n=164



(survey after the experiment)　n=164

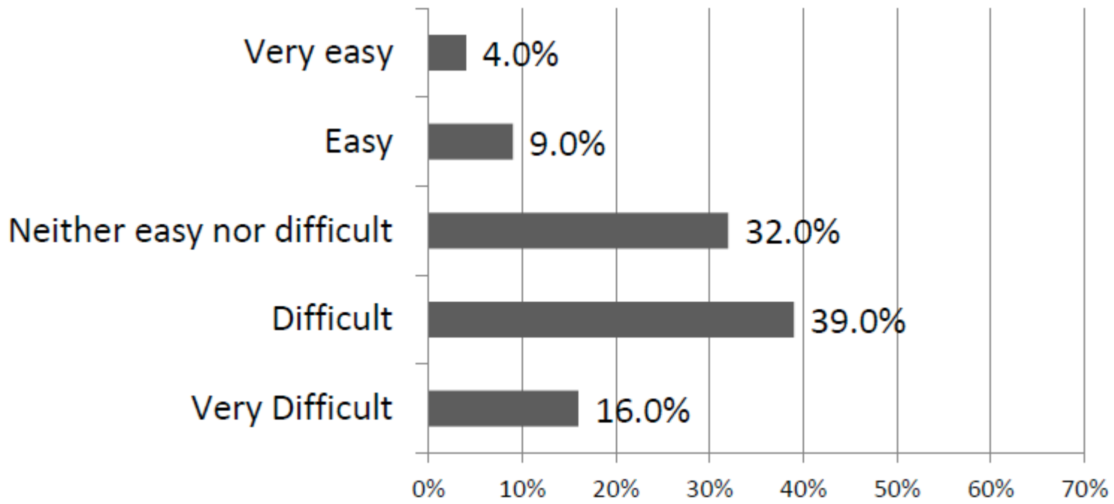


Table 1. Schedule of our field experiment

	Contents
August	Selecting the participated household (all groups)
Early September	Implementation of a pre-questionnaire (all groups)
Late September	Informing of intended target level of electricity saving (Reward and Feedback group, **first comparative feedback**)
October 1	Start the experiment (all groups)
Early November	Informing of electricity saving rate of October (Reward and Feedback group, **second comparative feedback**)
Nobember 30	End the experiment (all groups)
December	Implementation of a post-questionnaire (all groups)

"All group" represents 1) Reward, 2) Reward and Feedback, and 3) Control groups.

Table 2. Non-parametric statistical tests of each average electricity saving rate

	(i) Reward	(ii) Reward + Feedback	(iii) Control
Average	5.9	8.2	1.6
Variance	207.18	129.58	207.00
Number of obs.	103	53	52

	(i) vs (iii)	(ii) vs (iii)	(i) vs (ii)
t-value	1.7404*	2.5931**	1.0956

* and ** indicate 10% and 5% statistical significance.

Table 3. Summary and standard statistics of the variables included in the analysis

Variable	Mean	Std. Dev.	Maximum	Minimum
Dependent variable				
Reduction (%)	5.413	13.830	42.800	−69.000
Psychological factors				
Comparative feedback with Reward (yes=1)	0.255	0.437	1.000	0.000
Social norm (Persons who are close attempt electricity-saving behavior) *1	3.197	0.663	5.000	0.000
NEP-score	57.091	6.896	71.000	32.000
Target *2	3.413	1.338	8.000	1.000
Economics incentive				
Reward without feedback (yes=1)	0.495	0.501	1.000	0.000
Socio-economic variables				
Gender (household representative) (male=1)	0.654	0.477	1.000	0.000
Age (household representative)	42.639	10.802	80.000	21.000
Income *3	1.894	1.098	6.000	1.000
Family size	3.135	1.228	6.000	1.000
Homeownership (yes=1)	0.668	0.472	1.000	0.000
Size of home *4	3.740	1.448	7.000	1.000
Weather variable				
Cooling degree day (previous year − target year)	8.761	7.228	27.800	−0.700

*1 : Responses to Likert Scale (always=5, usually=4, sometimes=3, rarely=2, never=1)
*2 : Over 30%=8, 25-30%=7, 20-25%=6, 15-20%=5, 10-15%=4, 5-10%=3, 1-5%=2, under 0%=1)
*3 : Over 15million yen=6, 10-15million yen=5, 8-10million yen=4, 6-8million yen=3, 4-6million yen=2, under 4million yen=1
*4 : The number of rooms (over seven rooms=7, six rooms=6, five rooms=5, four rooms=4, three rooms=3, two rooms=2, one room=1)

Table 4. Estimation results

Variable	Model (1) Tobit		Model (2) Probit		Model (3) Truncated regressio[n]	
Psychological factors						
Comparative feedback (with Reward)	6.849	***	0.867	***	2.351	
	[2.353]		[0.288]		[2.756]	
Social norm	2.934	**	0.310	*	2.356	*
	[1.178]		[0.163]		[1.415]	
NEP-score	−0.015		0.017		−0.175	
	[0.112]		[0.015]		[0.130]	
Target (eight-grade by Reduction (%))	0.446		−0.042		1.471	**
	[0.706]		[0.074]		[0.728]	
Economics incentive						
Reward (yes=1, no=0)	3.868	*	0.342		2.227	
	[2.098]		[0.240]		[2.460]	
Socio-economic variables						
Gender	3.009		0.230		3.069	
	[1.865]		[0.230]		[2.197]	
Age (household representative)	−0.062		−0.004		−0.082	
	[0.087]		[0.010]		[0.097]	
Income (sex-grade by yen)	−0.001		−0.045		0.440	
	[0.756]		[0.097]		[0.911]	
Family size	−2.440	***	−0.090		−3.487	***
	[0.832]		[0.096]		[1.037]	
Homeownership	−5.135	**	−0.554	*	−2.656	
	[2.259]		[0.292		[2.627]	
Size of home	2.003	***	0.227	**	1.288	
	[0.731]		[0.099]		[0.901]	
Weather variable						
Cooling degree day	0.234	**	0.009		0.288	**
	[0.113]		[0.014]		[0.116]	
Constant	−5.142		−1.803		10.580	
	[8.821]		[1.148]		[10.695]	
Number of observations	208		208		146	
S.E. regression	8.388		0.450		7.629825	
Log likelihood	−606.983		−116.937		−476.116	

1. ***, ***, * represent the statistical significance at the 1%, 5%, and 10% level, respectively.
2. Standard deviation in parenthesis.