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Using Economic Incentives to Reduce Electricity Consumption: A field Experiment in Matsuyama, Japan

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ABSTRACT: This study examines the effectiveness of economic incentives in promoting electricity-conservation behavior among Japanese households. Fifty-three Japanese households participated in a field experiment and were offered monetary rewards depending on their rate of reduction in electricity consumption. To avoid bias in sample selection, which is typically present in previous studies, we adopted a request-based approach for recruiting participants. Results showed that only 34% of the participants succeeded in reducing their electricity consumption, and the average reduction rate was –4.8%. Econometric analysis confirmed that monetary rewards had a positive influence on the electricity conservation behavior, especially of family members who typically stay at home on weekdays. Responses to the questionnaires administered before and after the experiment suggest that participants may have underestimated the marginal costs of the electricity conservation behavior. The efficacy of economic incentives, established in our study, offers a potential measure for encouraging electricity-conservation behavior among Japanese households.

Keywords: Economic incentive; Electricity conservation; Household behavior
JEL Classifications: Q38; Q48

1. Introduction

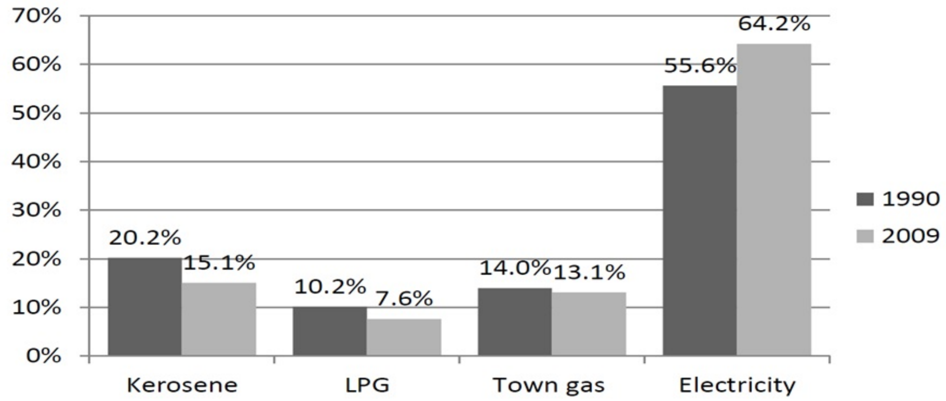
In 2009, Japan succeeded in curtailing its total annual CO_2 emissions to 1.145 billion tons, only marginally above its total annual emission figure in 1990, the base year of the Kyoto Protocol (about 1.144 billion tons). While Japan's sustained efforts at reducing emissions in the industrial and transportation sectors are commendable, a cause for concern is the steadily rising levels of emissions in the household sector. A reason for this could be the government's decision to use a voluntary energy conservation approach in the household sector instead of a regulatory one. In 2009, emission levels from the household sector were 26.9% higher than those in 1990[1]. In other words, the household sector accounted for 14% of the total CO_2 emissions in Japan[2], making it a prime candidate for targeted measures at reducing emissions.

Electricity represents the most commonly used form of energy within a household. Figure 1 shows the percentage of CO_2 emissions from different household energy sources in Japan for the years 1990 and 2009. It is clear from the figure that electricity contributes the maximum to CO_2 emissions. Moreover, while the usage of other energy sources have decreased from 1990 to 2009, that of electricity has increased by 8.6%. Rising levels of income in Japan have led to increased ownership of

[1] The difference between 1990 and 2007 levels was 41.1%.
[2] The contribution of the household sector to CO_2 emissions in Japan increased from 11% to 14% between 1990 and 2009, while that of industrial and transportation sectors decreased (from 46% to 36%) or remained constant (at 21%) (the Greenhouse Gas Inventory Office of Japan).

electronic goods, which in turn may have led to increased use of electricity (Cohen et al., 2005; Pachauri, 2004; Weber and Perrels, 2000). For example, the ownership ratios of television sets and air-conditioners in Japan have grown from 2.01 and 1.27 in 1990 to 2.43 and 2.63 in 2009, respectively. Greater adoption rates have also been observed for IT equipment and luxury products such as personal computers (from 0.13 in 1990 to 1.18 in 2009) and warm water bidets (from 0.16 in 1990 to 0.97 in 2009). Given these statistics, it is reasonable to state controlling electricity consumption is the key to reducing CO_2 emissions in the household sector.

Figure 1. The CO2 emission shares from each energy sources of Household sector (1990 and 2009)



Data source: Greenhouse Gas Inventory Office

According to the Kyoto Protocol Target Achievement Plan, formulated by the Japanese Ministry of the Environment, the target emission level of CO_2 for the household sector is between 138 million tons and 141 million tons. However, the total household emission in 2009 was 162 million tons, more than 15% above the target level. To achieve the target, the consumption of electricity, which accounted for 64% of the CO_2 emission share of the household, has to be reduced by 10%.

The Kyoto Protocol Target Achievement Plan recommends two measures to reduce CO2 emissions in the household sector: (1) promoting environmental education and awareness and (2) promoting the diffusion of energy-efficient electrical home appliances. However, these measures have not been very effective because it takes a relatively long time to realize their effects. Promoting environmental education and awareness can enhance individuals' consciousness for energy saving but the impact on household behavior is usually a gradual process. The latter measure—promoting the purchase of energy-saving appliances—runs the risk of producing a rebound effect (Sorrell and Dimitropoulos, 2008; Mizobuchi, 2008). That is, increased energy efficiency lowers the cost of consumption, and hence increases the level of consumption. For example, if the hours of operation and the preset temperature are kept constant, a new air conditioner will consume a lower amount of energy than an old one. However, this technological improvement will also reduce the operating costs, resulting in additional demand for air-conditioning. From May 2008 to March 2011, the Japanese government offered subsidies for purchasing energy-saving electric appliances, such as TV, air conditioner, refrigerator, that assured a certain level of energy efficiency. However, it did not introduce any measures to discourage additional purchasing, which, in turn, may have led to increased electricity demand. As a result, technological improvements did not lead to the expected electricity saving.

Energy prices play an important role in electricity conservation. The benefit of reducing household electricity consumption is composed of savings in the electricity bill and economic incentives provided by policy intervention. On the other hand, the cost of saving electricity is composed of various activities from not using the air conditioner to purchasing more efficient home appliances. While we focus on the impact of the economic incentives in this paper, a full-fledged analysis of household electricity consumption should consider all the different components. For instance, at the supply end, it is more important to generate renewable energy, such as through photovoltaic cells, wind, biomass, etc., because decarbonization of electricity generation can lead to decrease in greenhouse gases (GHG). However, currently, renewable energy accounts for less under

1% of the total energy generated in Japan (about 10% if hydropower is included). This is because the costs of generating renewable energy are much higher than that of using fossil fuel. Thus, given that currently, supplying renewable energy is not cost-effective, electricity conservation at the demand end is necessary and probably the most efficient solution in the short run.

This study evaluates the effectiveness of introducing an economic incentive to encourage electricity conservation behavior among Japanese households. For this, a field experiment was conducted from November 2010 to January 2011. The salient features of this study are as follows. While previous studies used a sampling method that could have introduced a sample selection bias, we mitigated its effects by using a request-based approach for recruiting participants. Further, as part of this study, we administered two questionnaire surveys, before and after the experiment, and used the responses from the subjects to examine the characteristics that contribute to successful reduction in energy use. Survey participants or household members were grouped into two categories—those who stay at home on weekdays and those who do not—to analyze the difference in the effect of the economic incentive on each group, by regression analysis. Lastly, it must be noted that this study was conducted before the Great East Japan earthquake in March 2011. Hence, the electricity-saving behavior of households was not influenced by massive energy conservation measures introduced in Japan after the nuclear disaster and the subsequent shutting down of nuclear power plants.

The paper is organized as follows: Section 2 discusses previous studies on household energy-saving behavior. In Section 3, we describe our field experiment, which uses a subsidy as an economic incentive for electricity conservation behavior within households. Section 4 presents the empirical analysis. Section 5 analyses the marginal costs of electricity conservation behavior and discusses some limitations of our study. Section 6 presents the conclusions.

2. Previous Studies

Promoting energy conservation behavior among households is a challenging task. Studies on behavioral science show that most individuals prefer to maintain the status quo, especially when the costs and the benefits of engaging in a particular behavior are unknown, as in the case of energy conservation (Samuelson and Zeckhauser, 1988). The effectiveness of interventions in promoting household energy conservation behavior has been studied under various academic disciplines, including behavioral science, psychology, and economics (see Abrahamse et al., 2005 for a comprehensive review). Such interventions have met with varying degrees of success.

Providing general information on energy saving decreases the electricity demand at least in the short-run (Dulleck and Kaufmann, 2004), although little is known about the effects of mass media campaigns on actual energy use. Environmental education and generating awareness have been viewed as effective interventions (Sardianou, 2007, Linden et al., 2006, Brandon and Lewis, 1999). Feedback on the actual energy consumption within the household has also been effective; in fact, increasing the frequency of such feedback is known to enhance its efficacy (Abrahamse et al., 2005). In addition to the above feedback, Brandon and Lewis (1999) examined the positive effects of financial feedback, which refers to monetary savings earned from energy conservation, and comparative feedback, which refers to sharing energy consumption information of other households. Information on energy-saving techniques (i.e., tailored information) and setting unforced conservation target for households (i.e., goal setting) have also been effective according to some studies. Recent studies recommend the use of a combination of multiple interventions instead of a single one (Benders et al, 2006, Abrahamse et al., 2005, Abrahamse et al., 2007, Steg, 2008).

While many studies have evaluated the effectiveness of different kinds of interventions, they have failed to shed light on three key issues: (1) reliability of the data collection measures, (2) capability of the research design to adequately evaluate the effect of economic incentives, and (3) sample selection bias in recruiting subjects for the study. Data on energy saving found in many studies are based on self-reported changes in energy-related behaviors shared by the study participants. However, behavioral changes do not necessarily result in energy savings; therefore, self-reported data should be compared against actual energy consumption (Abrahamse et al., 2005, Benders et al., 2006, Abrahamse et al., 2007, Ek and Söderholm, 2010). Further, it is likely that self-reported behaviors are influenced by social desirability. For example, Luyben (1982) found that self-reported thermostat settings were significantly lower than those observed by interviewers. Benders et al. (2006) examined the effect of interventions, such as general information, tailored information, and feedback, on the actual energy consumption on 190 households in Netherlands and reported that energy consumption in the experimental groups was significantly lower than that in the control groups. However, in this study, changes in energy consumption were tracked through self-reported data via a website instead of an electric master meter. Ek and Söderholm (2010) divided 536 Swedish households into three groups on the basis of the energy-saving information shared with them. The participants reported the changes in their energy-related behavior by responding to a questionnaire. Results showed that more detailed information on energy saving led to greater willingness to save energy. Again, the data captured stated intention and not the realized behavior. Since there is a difference between stated intention to pay and actual behavior (List and Gallet, 2001; Murphy et al., 2005), observable measures, such as a master meter, are more suitable for validating the effects of an energy-saving intervention.

Second, only a few studies have examined the effectiveness of using economic incentives as an energy-saving intervention, and most of them suffer from sample selection bias and low statistical reliability. For example, Winett et al. (1978) studied the effect of some energy-saving interventions, including an economic incentive (i.e., reward for reducing electricity consumption) with the help of a field experiment involving 107 single-family households in Texas. The electricity conservation by the group receiving an economic incentive was significantly higher than that by other intervention groups and the control groups. While these results support the use of an economic incentive, the findings are not statistically reliable because of the small number of households that were included in the experimental groups (less than 20). Similarly, a study by Midden et al. (1983) examining the effects of some interventions, including economic incentives, among 91 Dutch households living in the same neighborhood confirmed the positive influence of economic incentives, but lacked statistical reliability. McClelland and Cook (1980) organized an energy-saving contest among four groups of apartments in the University of Colorado in the U.S. They offered rewards to individuals who reduced their consumption of gas. The study included about 500 apartments located in the same neighborhood. The reduction in gas consumption achieved by the intervention group, which received rewards, was statistically significant and lower than that of the control groups. However, the effects of the economic incentive could not be isolated since a combination of interventions, including information feedback and comparative feedback, was used in the study. Petersen et al. (2007) also offered rewards for the hostel saving the maximum electricity and water from among 22 student hostels in Oberlin College in the U.S. They observed 32% decrease in electricity consumption and a 3% reduction in water usage, on an average. However, these findings could not be attributed to economic incentives alone because the researchers had combined economic incentives with feedback, and the experiment did not include a control group. The limited sample size (22) added to the problems. Thus, the efficacy of economic incentives in promoting energy-saving behavior has not been adequately established because of the limited sample size of the previous studies and the use of combined interventions.

Another shortcoming of the earlier studies is the possible sample selection bias in recruiting subjects for field experiments and questionnaire surveys. Most of the previous studies recruited participants for experiments and surveys by posting mailers to randomly selected households. Even though the selection of the households was random, 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 possibly viewed the experiments and/or the survey as encouragement to conserve energy. Ek and Söderholm (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 have low levels of awareness incur higher opportunity cost (of time) and may not participate in the experiment or survey. Sardianou (2007) surveyed the energy consumption patterns of Greek households and showed that individuals with thorough knowledge of environmental problems, high environmental awareness, and relatively high incomes tend to greatly reduce their energy consumption. If most of the subjects in an experiment have high environmental awareness, generalization of the results is difficult. Thus, it is likely that a number of previous studies have a sample selection bias, and the bias is, in fact, greater when the sample size is small.

In addition to academic investigations, social experiments aimed at promoting energy-saving behavior have also been conducted. Table 1 presents an overview of the five experiments carried out by the local municipalities in Japan, in the following regions: (i) Ehime prefecture, (ii) Masaki town of Ehime, (iii) Tobe town of Ehime, (iv) Hiroshima city of Hiroshima, and (v) Saitama prefecture[3]. Participants in the experiments were asked to reduce their levels of electricity or gas consumption to below those of the previous year (shown in second and third rows) and were rewarded for decreasing their consumption (shown in fourth row). These experiments were conducted in the summer and winter seasons from 2009 to 2010 (shown in fifth and sixth rows). The last row in Table 1 shows the average rate of reduction in electricity consumption (i.e., average reduction of each experiment). The first three experiments ((i), (ii), and (iii)) succeeded in achieving a reduction rate between 11.7% and 15.5%, indicating that the economic incentive had a positive influence on the electricity-saving behavior. However, these three experiments only report the result of households that successfully reduced electricity consumption (see the second and third rows from the bottom); therefore, these results possibly overestimate the effectiveness of the incentives. Moreover, the recipients of the incentives in these experiments were selected by lottery. Therefore, despite various attempts, the impact of economic incentives has not been evaluated using a clear framework.

Table 1. Comparison from other anecdotal reports (Economic incentive)

study area	i. Ehime Prefecture	ii. Masaki Town, Ehime	iii. Tobe Town, Ehime	iv. Hiroshima City, Hiroshima	v. Saitama Prefecture
target	Electricity	Electricity・Gas	Electricity・Gas	Electricity・Gas	Electricity
provision of reward	decrease from previous year	decrease from previous year	decrease from previous year	depending on the CO2 emission reduction rate	decrease from previous year
incentive	1．gift product 2．lot drawing(10,000yen)	lot drawing (10,000, 5,000, 1,000yen)	lot drawing (10,000, 5,000, 1,000yen)	200yen per 10%	1. gift product for decreasing 2. gift product for increasing(lot drawing)
target year	2009	2010	2010	2010	2010
target month	Oct. - Jan.	Summer：Jul. - Sep. Winter：Nov. - Jan.	Summer：Jul. - Sep. Winter：Nov. - Jan.	Nov. and Dec.	Aug.
participants	residents of Ehime prefecture	residents of Masaki town	residents of Tobe town	citizens of Hiroshima City	residents of Saitama prefecture
way of subscription	public offering	public offering	public offering	public offering	public offering
pre-registration	no	no	no	yes	no
number of participation	713	146 (winter)	42 (winter)	1018	1247
households with successful reduction (%)	100	100	100	42	22
average rate of electricity reduction (%)	13.9	15.5	11.7	no data	-11.1 (12.3)*

* the rate omitting participants who failed in reduction

[3] Data for (i), (ii), (iii), and (v) were obtained by interviewing the authors. Results of (iv) were obtained from the website.

To address this gap, we designed our study as follows. First, we confined our focus to one intervention: the use of economic incentives in reducing household electricity consumption. Second, data for the experiment were collected from individual master meters instead of self-reported measures over a 12-week period. Third, to avoid the recruitment of only highly motivated participants, we requested select business establishments to enroll all the employees in the experiment. The next section describes our research strategy in greater detail.

3. Field Experiment—Economic Incentive

3.1. Participants

Fifty-three Japanese households from Matsuyama city, Ehime prefecture, participated in the field experiment. As mentioned earlier, despite the use of random sampling, previous studies typically attracted people who had high motivation for conservation or low opportunity cost of time, potentially leading to biased results. To prevent this, we adopted a different approach to enlisting households. We selected seven business establishments in Matsuyama city and requested them to allow their employees to participate in our field experiment. If a business establishment agreed to participate, all the employees of the firm were enrolled in the study. As a result, households were included in the experiment regardless of their environmental consciousness or motivation for energy conservation. The request-based approach avoided possible biases of random sampling by relying on organizational power and semi-compulsorily enrolling subjects. However, unintended bias may have affected this enrollment process. For example, employees who are loyal to the organization may work harder to achieve a higher level of reduction in electricity consumption. On the other hand, those who were forced to participate by their employers may achieve a lower level of reduction in electricity. Moreover, employees within the same organization could have communicated with each other during the course of the experiment, as it was difficult to control the information flow.

Table 2 compares the demographic features of the studied households with other households in Matsuyama city and across the country. Except for age, the characteristics of the sample households were similar to that of the general population. The average age of the sampled households (41.2 years) was lower than that of the general population. This is probably because the age variable for Matsuyama city and the rest of the country denotes the age of householder[4]. On the other hand, the average age in the experiment is that of the respondent who answered the questionnaire and worked in the participating firm. Therefore, the average age of the latter might be less than the former. The non-inclusion of retired individuals in our sample could have also contributed to lowering the average age.

Table 2. Demographic features of respondents and households

	Men (%)	Average Age	Average Households size	Homeownership rate (%)	Average electric bill per month (Yen) *	Unmarried (%)
Experiment	57%	41.2	3.02	71.7	10,954	32.1
Matsuyama **		56.3	2.88	79.3	9,159	
Japan ***	49%	55.9	3.1	80.1	9,423	27.1 ****

* : Nov. Dec. of 2009 and Jan, 2010
, * : Family Income and Expenditure Survey, Bureau of Statistics Japan (2011)
**** : A National Census of Japan (2010)

3.2. Design

Our field experiment was carried out for 12 weeks, from November 2010 to January 2011. Each enrolled household was entitled to receive a reward for reducing their electricity consumption to a level below the 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

[4] A "householder" refers to the head of the household in Japanese civil registration records and is typically the oldest person in the household.

reduction rate of electricity consumption (*Reduction*) was calculated as *Reduction* (%) = (Cp – Cx)/ Cp × 100, where Cx and Cp represent the electricity consumption during the experiment and during the same period in the previous year, respectively. If household the amount of electricity consumption is smaller than that of previous year, *Reduction* takes positive value (vice versa). If *Reduction* was larger than 20% (*Reduction* ≥20), households were given a reward (economic incentive) of 7,000 yen (about $87.5). If *Reduction* was between 10% and 20% (10 ≤ *Reduction* < 20), households received 2,500 yen (about $31.2), and if *Reduction* was between 0% and 10% (0 < *Reduction* < 10), households received 500 yen (about $6.3)[5].

The incentive amounts for different levels of saving were determined on the basis of previous findings on subsidies. For instance, in California, the 20/20 Rebate Program provided rebates to customers whose electricity usage levels were lower than those in the previous year. Customers received a 20 percent rebate on their electricity bills for a reduction rate of 20 percent or greater. However, Wirtshafter Associates (2006) who evaluated the effectiveness of the program, via a field survey of households and businesses, found that the program was not cost-effective and recommended that it be discontinued. Problems identified included low awareness, the existence of free riders, and high cost per unit reduction of electricity usage. In our study, we provided different amounts of incentives for different levels of saving, after considering the incremental marginal costs of each household.

The effect of subsidy and that of tax are theoretically the same in the short run. These are different at the time of entry into or exit from the market (Baumol and Oates 1988, pp. 218-20); however, this argument does not apply to electricity consumption in households where the total number of agents is relatively stable. Empirical studies found different elasticity of demand for energy changes with an increase or decrease in energy prices (Wirl, 1991; Walker and Wirl, 1993; and Haas and Schipper, 1998). Higher elasticities are observed during price increases, and lower elasticities during price decreases. This suggests that the impact of price increase of same amount as the premium in this study would attain even more reduction of electricity use.

Unlike in previous studies, we did not divide the households into three subgroups, on the basis of *Reduction*, to examine the effectiveness of the economic incentive. Doing so would lead to a subgroup sample size of less than 20, which tends to hamper the statistical validity of the results. Instead, we performed a regression analysis, with *Reduction* as the dependent variable, to examine the influence of the economic incentive on the electricity conservation behavior (see Section 4 for details)

We administered two questionnaires—before and after the field experiment. The responses from the subjects offer valuable insights into the factors that play a key role in reducing energy use. In the pre-experiment questionnaire, we asked the participants to share their views on the following aspects: attitude to environmental issues, environmental awareness, attitude to electricity conservation, intended target level of electricity saving and the confidence to meet this target, types of electrical appliances in the household, and social, economic, and demographic details. In the post-experiment questionnaire, we asked participants about the changes in their attitudes toward electricity conservation, the challenges in conserving electricity, the appropriateness of economic incentives, etc.

3.3. Procedure

In September 2010, we requested seven business firms, employing a total of 500 employees, to participate in our field experiment. These firms were selected because they satisfied certain conditions, e.g., the employees belonged to wide range of age groups, represented different types of family structures, and had different house ownership patterns. Aside from a broad description, i.e., experiment on energy-saving, we did not divulge any details about the field experiment while asking the business firms to participate in the study. Two of the seven firms agreed to participate, and a total of 55 employees or households were enlisted. However, employees who had moved house within a year were excluded from the study owing to the potential difficulties in verifying electricity consumption data for the previous year and the problems introduced by a change in the size of the house. Thus, a total of 53 households were selected as the sample.

As described earlier, participating households were entitled to receive subsidies on the basis of their *Reduction*. Shikoku Electric Power Co. was the electricity supplier for all the participating households. Participants could access their historical data on electricity consumption by logging onto

[5] We have assumed the following exchange rate: $1 = 80 Yen.

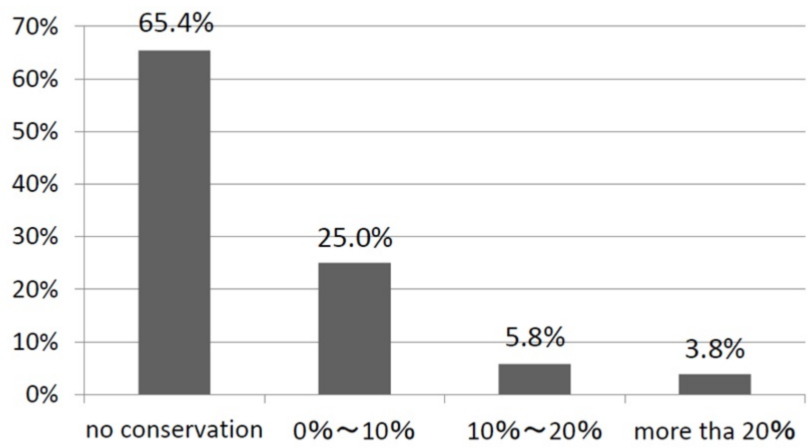
the Shikoku Electric Power website, using their unique identification number. We collected these consumption data for the previous year from the households (printed web page) and used them as the measurement criteria. Additionally, for tracking ongoing consumption, every household was asked to send a copy of the monthly electricity consumption record received from Shikoku Electric Power Co.

As the purpose of this study was to exclusively measure the effectiveness of economic incentives, other interventions for promoting electricity saving, such as feedback, were not used. Moreover, we did not request the participants to actively engage in electricity conservation. The study, thus, essentially examines changes in household energy-saving behavior in response to economic incentives.

3.4. Results and Discussion

Figure 2 shows the results of electricity conservation, in terms of *Reduction*, in the sampled households at the end of 12 weeks[6]. Thirty-four percent of the households successfully reduced their electricity consumption, and the percentage of households decreased as the values of *Reduction* increased (25.0%, 5.8%, and 3.8%, respectively). However, majority of the sampled households (65.4%) did not conserve electricity. In other words, the sampled Japanese households showed poor response to economic incentives, or the economic incentives offered in this experiment were possibly lower than the marginal cost of the electricity-saving behavior.

Figure 2. Results of electricity conservation



Rewards offered in our experiment ranged from 2,500 yen to 7,000 yen, which translated into 10.4% to 29.1% of the average electricity bill for three months in the Japanese households. That is, households with a reduction rate of 10% received 2,500 yen in electricity savings and 2,500 yen in subsidies on average. Similarly, households with a reduction rate of 20% received an average of 5,000 yen in savings and 7,000 yen in subsidies. However, even though the subsidies equaled (10%) or exceeded (20%) the earnings from electricity conservation, most of households did not respond to the economic incentives. This possibly indicates that subsidies need to be substantially high to induce electricity conservation[7].

The average *Reduction* of the households in this experiment is –4.8%, which indicates an increase in energy consumption compared to the previous year. As this study cannot be directly compared with other studies that included multiple interventions, we compared our findings with the results of the experiments shown in Table 1 of Section 2. The last row of Table 1 shows the average rate of reduction in electricity consumption (i.e., average *Reduction* of each experiment). As mentioned earlier, the first three experiments were successful but overestimate the effectiveness of the incentives because their values of *Reduction* include only those households that successfully reduced consumption. On the other hand, the number of households that conserved electricity in experiments (iv), (v), and our study is less than half the total number of participating households ((iv): 42%, (v): 22%, our study: 35%). Similar to the findings of this study, the average reduction in electricity consumption in (v) was –11.1%, which indicates an overall increase in electricity consumption. The

[6] One participant dropped out of the field experiment, reducing the total number of households to 52.
[7] The size of marginal cost of electricity conservation is discussed in Section 5.

comparison of study and sampling conditions as well as findings presented in Table 1 suggest that the results of our field experiment are unbiased and representative.

4. Econometric Analysis

This section presents the results of a regression analysis undertaken to examine whether an economic incentive encourages electricity-saving behavior within households. We used the censored regression model, i.e., the Tobit model, for analyzing the variables (see Wooldridge, 2002 and Green, 2008 in detail), with *Reduction* as the dependent variable:

$$Y_i^* = \alpha + \beta X_i + \varepsilon_i$$
$$Y_i = \max(0, Y_i^*) \qquad i = 1,2,...., 52 \tag{1}$$

The dependent variable Yi indicates the *Reduction* of ith household, and is censored at zero. Households with a negative value of *Reduction* in our experiment have been treated as households that "did not save electricity right from the beginning of the experiment" or "abandoned electricity conservation during the course of the experiment." Therefore, households that failed in electricity saving and reported negative values of *Reduction* were treated as "zero." X is a vector of the independent variables: age and gender of the respondent, his or her family size, number of children under 12 years old, living arrangements—whether living with parents or separately, the respondent's environmental awareness, change in the electricity-saving behavior of the respondent or the family, change in conservation-related motivation provided by the respondent to his/her family or by the family members to the rest, size of home (area), type of home ownership, average external temperature, dummy variable for energy-saving information, and ex post perceived difficulties of electricity conservation. Data on the independent variables were obtained from pre-and post-study questionnaires. Note that the respondent and the family play distinct roles in energy-saving behavior. The former refers to the employed person participating in the study, who works on weekdays. The latter refers to the family members of the respondent who typically stay at home on weekdays[8]. We hypothesize that electricity consumption in households critically depends on the hours spent at home. That is, the conservation behavior of the family members who stay at home relatively longer than the respondent should be strongly affected by the economic incentives. We divided the household members into two groups—respondents and family members—to examine whether and how the economic incentives have an impact on their electricity-saving behaviors. Moreover, we also classified conservation behaviors into self-motivated saving behavior and motivation provided to members in the household to induce saving.

Table 3 presents a statistical summary of the above variables[9]. Here, we discuss the effects of some other independent variables on electricity savings. A bigger *family size* (i.e., the number of people in household) may have a positive impact on electricity saving as members may discuss strategies and cooperate with each other. They may also be more conscious of the savings, given their relatively high electricity bills. Hence, the expected sign of the coefficient is positive. Households with many children may not cut down on electricity consumption, especially the use of the air-conditioner, in the interest of the children's health. Thus, the expected sign for *number of children* is negative. The variable *living with parents* was introduced to investigate the effect of incentives on electricity saving by the elderly. Since the elderly tend to stay at home longer, we expect that they contribute negatively to electricity saving. People who have high environmental awareness tend to conserve electricity more than those with low environmental awareness. Thus, we expect that the sign of *environmental awareness* is positive. People who know effective ways of saving electricity may conserve more than people who do not. Therefore, the expected sign of *energy-saving information* is positive. Lastly, in the post-experiment questionnaire, we asked participants about the difficulties of saving electricity. If they perceived conservation to be difficult, they may not succeed in reducing electricity consumption. Thus, the expected sign is negative.

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[8] The ratio of Japanese dual-income households was 44.4% in 2005 (Statistics Bureau of Japan, 2005). Thus, many households have only a single worker. Therefore, we regard the respondent of questionnaire as a worker of the household, and the other members s those who spend longer hours at home than the respondent.

[9] The before and after values of "electricity-saving behavior of respondent," "respondent's motivation to engage in electricity-saving," and "family members' motivation to engage in electricity-saving" are shown separately.

Table 3. Summary and standard statistics of the variables

Variable	Mean	Std. Dev.	Maximum	Minimum
Reduction (%)	-4.792	15.188	26.910	-63.170
Age (respondent)	41.230	11.639	62.000	22.000
Gender (respondent) (male=1, female=0)	0.577	0.499	1.000	0.000
Family size	3.000	1.188	6.000	1.000
Number of children (under 12)	0.481	0.874	3.000	0.000
Living with parents (yes=1, no=0)	0.308	0.466	1.000	0.000
Environmental awareness *	4.077	0.518	5.000	2.000
Electricity saving behavior of respondent (before) *	3.115	0.704	5.000	2.000
Electricity saving behavior of respondent (during) *	3.442	0.777	5.000	2.000
Encouragement to do electricity-saving by respondent (before) *	2.750	1.064	5.000	1.000
Encouragement to do electricity-saving by respondent (during) *	2.885	1.041	5.000	1.000
Encouragement to do electricity-saving by the family (before) *	2.015	1.471	5.000	1.000
Encouragement to do electricity-saving by the family (during) *	2.558	1.092	5.000	1.000
Electricity saving behavior of family (during) *	2.808	1.138	5.000	1.000
Size of home (seven-grade by square meter)	4.154	1.764	7.000	1.000
homeownership (yes=1, no=0)	0.717	0.457	1.000	0.000
Temperature (previous year - target year)	0.925	0.131	1.170	0.500
Energy saving information (get information=1, otherwise=0)	0.615	0.491	1.000	0.000
Ex post perceived difficulties of electricity conservation **	4.212	0.936	5.000	2.000

* : Responses to Likert Scale (always=5, ususally=4, sometimes=3, rarely=2, never=1)
**: Responses to Likert Scale (very difficult=5, difficult=4, neither easy nor difficult=3, easy=2, very easy=1)

E-views (version 7.0), an econometric software package, was used to estimate Equation (1). To adjust for heteroskedasticity, we used Whites' covariance matrix. Estimation results are shown in Table 4. First, to examine whether the incentive encouraged electricity-saving behavior among households, we tested the significance of the following estimation coefficients: change in electricity-saving behavior of the respondent, change in the motivation to save electricity offered by the respondent, and change in the motivation to save electricity saving offered by the family. If the estimated coefficients were positive and statistically significant, it would indicate that the economic incentive had a positive influence on the electricity-conservation behavior.

The estimated coefficients of the respondents were not statistically significant, indicating that the economic incentive did not introduce changes in the electricity-saving behavior of the respondent or in the motivation to save electricity offered by the respondent. On the other hand, estimated coefficients of the family members were positive and statistically significant, confirming the positive effect of the economic incentives. These results support our hypotheses that electricity consumption in households critically depends on the hours spent at home by individuals, and economic incentives encourage those who stay at home longer to save more electricity than others.

The behavioral difference between the respondent and the family can be explained by the fact that the respondent is a working individual who does not spend majority of his or her time at home on weekdays, unlike the other family members. Given that the unit of study is a household, the behavioral changes of the family members, who spend more time at home, are more prominently reflected in the results than those of the respondent. This is a key finding of our study. None of the earlier studies on energy conservation have grouped members of a household on the basis of their hours spent at home or focused on the difference of behavior between family members who stay at home and those who do not. Since the electricity consumption in households greatly depends on the hours spent at home, the motivation and cooperation of family members is important. Our results confirm that the change in the family member's motivation plays a significant role in attaining high electricity savings.

Table 4. Estimation results

Variable	Coefficient		Variable	Coefficient	
Age	-0.222		Size of home	-2.490	*
	(0.284)			(0.061)	
Gender	-6.857		homeownership	-4.672	
	(0.161)			(0.479)	
Family size	6.891	**	Temperature	1.618	
	(0.013)			(0.554)	
Number of children (under 12)	-10.105	***	Energy saving information (dummy)	18.541	***
	(0.001)			(0.006)	
Living with parents	-14.071	***	Perceived difficulties of electricity conservation	-8.307	***
	(0.010)			(0.000)	
Environmental awareness	-8.061	*	Constant term	46.824	**
	(0.061)			(0.027)	
Change in electricity-saving behavior of the respondent (during - before)	0.592				
	(0.745)				
Change in encouragement to engage in electricity saving offered by the	-2.938				
respondent (during - before)	(0.169)				
Change in encouragement to engage in electricity saving offered by the family	2.807	**	S.E. of regression	4.236	
(during - before)	(0.022)				
			log likelihood	-72.125	
Electricity saving behavior of family (during)	20.384	***			
	(0.000)		num. of observation	52	

1. ***, ***, * represent the statistical significance at 1%, 5%, 10% level, respectively
2. the values in the parentheses represent the p-value of the estimated parameter.

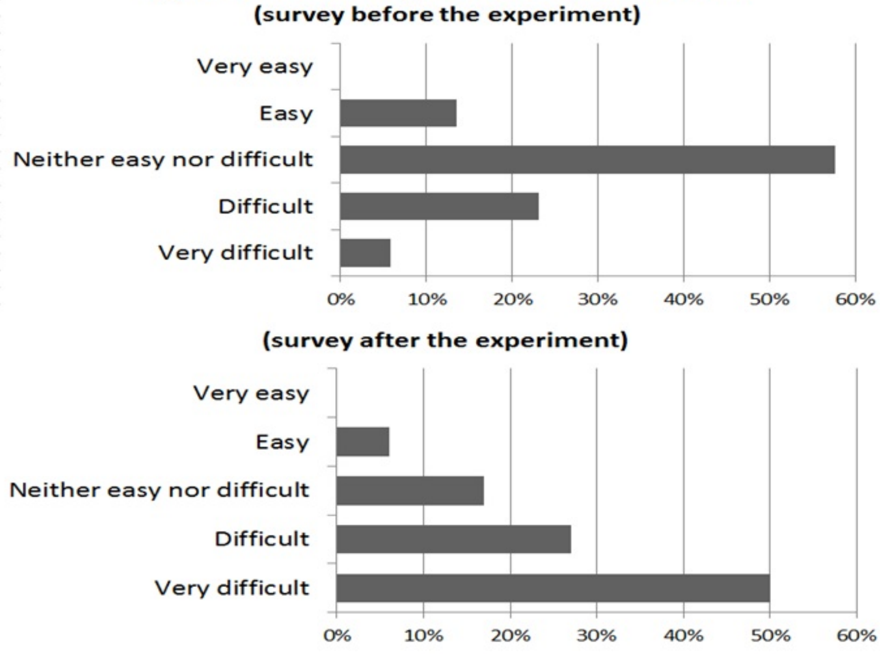
The estimated coefficient of *family size*, which was positive and significant, is consistent with our expectation that family members discuss conservation strategies and cooperate with each other. The estimated coefficients of *number of children* and *living with parents* were negative and statistically significant, which is also consistent with our expectation. It also supports our hypothesis that electricity consumption depends on the time spent at home, and the elderly tend to stay at home longer. The estimated coefficient of *environmental awareness* is negative and seemingly counterintuitive.

This is possibly because individuals with high environmental awareness have already implemented the necessary electricity-saving measures, which reduces their scope for further conservation. The coefficient of *temperature* was positive, but not statistically significant. This can be attributed to the small difference in the winter temperature between the study period and the previous year (0.6 Centigrade lower in the study period). The coefficient of *energy-saving information* was positive and significant, which is consistent with our expectation that people who know effective strategies of saving electricity can save more than those who do not. Lastly, the coefficient of *perceived difficulties of electricity conservation* is negative and significant. That is, people who experienced difficulties in reducing consumption during the experiment may have discontinued their conservation efforts. In the next section, we discuss the challenges of electricity saving in detail.

5. Discussion and Limitations

This section discusses the four major reasons for the negative average *Reduction* (–4.8%) in this study: (1) lack of understanding of the difficulties in electricity conservation, (2) the marginal cost of electricity saving, (3) lack of information about electricity-saving appliances or strategies to save electricity, and (4) the experimental period. Figure 3 shows the participants' evaluation of the difficulties associated with electricity conservation before and after the experiment. Before the experiment, majority of the respondents felt that electricity conservation was "Neither easy nor difficult." However, at the end of the experiment, most of the participants felt that saving electricity was "Very difficult." This change in response indicates a limited understanding of the challenges associated with the conservation behavior beforehand. This may also suggest that pre-experiment responses on electricity-saving behavior have an upward bias, as participants expect to save more electricity before actually acting on it. In other words, using stated intentions in a survey questionnaire to evaluate household energy saving may not be appropriate, given the likelihood for overestimation.

Figure 3. the difficulty of electricity conservation



The second reason for two-thirds of the households not reducing their electricity consumption is that the incurred 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. In fact, in the post-experiment survey, 33% of the respondents who did not reduce their consumption said that that would not increase their conservation efforts even if the incentive amounts were doubled. This also supports the conclusion that the marginal cost of saving electricity is considerably large.

The third reason is that households possibly lacked information on effective electricity-saving strategies, especially the benefits of energy-efficient appliances. In the post-study questionnaire, we asked participants to indicate a factor that was important for electricity saving. Thirty-four percent households felt that "cooperation from family members" was the most important factor. "Willingness to act" was identified as the second important factor by 26%, while only a small percentage of the respondents identified energy-saving appliances (11%) and information on energy saving (6%) as important factors. Effective strategies for saving electricity include lowering the temperature of the air conditioner, reducing the use of the electric carpet, lowering the temperature of heated toilet seats, and reducing the use of TVs and PCs. However, most of households may be unaware of such measures, which possibly contributed to the negative average *Reduction* in our study.

Fourth, participants could only track electricity consumption on a monthly basis, which made it difficult for them to assess the impact of their saving measures and self-correct their behavior within the 3-month experimental period. That is, households implementing conservation measures would not learn of the benefits until at least a month later. Moreover, for the decision making to purchase energy saving devices as a conservation measure, three months might be not long enough.

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 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 such as information on effective electricity-saving strategies.

Although these findings offer important insights, there are a few limitations to the study that must be acknowledged and possibly overcome in future works. To avoid the inclusion of participants who are highly motivated to conserve energy, we did not use random the sampling method to enroll individual households. Instead, we recruited participants by requesting business establishments to enroll all their employees in the study. However, the selection of these business establishments was not random. For ease of data collection, we approached only business establishments whose employees worked in Matsuyama city and lived in houses installed with a master meter. Most of the previous studies examining the effectiveness of incentives using data from master meters have similarly selected apartments and areas, instead of opting for random selection (Midden et al., 1983, McClelland and Cook, 1980, Petersen et al., 2007). However, we believe that randomization is essential in an experimental study, and its absence, therefore, is a limitation. Second, although the sample size of our study (53 participants) is twice more than that of previous studies, which enhances the statistical reliability of the results, even this sample size is not adequate if one has to derive policy implications on the basis of these findings. One of the chief reasons for the limited 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 period of the experiment is long. In fact, very few field experiments that use observable measures have a sample size of more than 300 (Abrahamse et al., 2005). Third, the convention in experimental studies is to form a control group, which does not receive any intervention such as information, feedback, or rewards, and compare the results of the experimental groups with those of the control groups, using a nonparametric approach, such as verification of the difference of each *Reduction* size. However, our decision to not adopt this approach is linked to the second limitation, that is, forming a control group would have further reduced the sample size and lowered the statistical reliability of the results. Therefore, instead of using a nonparametric approach, we used a parametric approach, namely, Tobit specification, to examine the efficacy of the incentive. However, for comparison of our results with those of previous studies on economic incentives and other interventions such as information and feedback, setting of a control group may be necessary. We hope to address these limitations in future works.

6 . Conclusion

Through a 12-week long field experiment, this study investigated the efficacy of economic incentives in encouraging electricity-conservation behavior among Japanese households. Econometric analysis of the experiment data revealed that the economic incentives have a positive influence on the behavior of individuals who typically stay at home on weekdays. This finding is in agreement with that of previous studies (Winett et al., 1978, Midden et al., 1983, Petersen et al., 2007), which support the efficacy of the incentive. Additionally, this study does not suffer from the drawbacks identified in some of the earlier works: small sample size and biased sample selection. It does not use any interventions other than economic incentives, and the sample size of 53 households is higher than that of previous studies, ensuring high statistical reliability.

Our results suggest that economic incentive encourages electricity saving among family members who tend to spend more hours at home. In other words, the impact of economic incentives may depend on the family structure. Further research is necessary to explore how the family structure influences the degree of electricity consumption through hours spent at home and use of electricity appliances.

As explained by Abrahamse et al. (2005) and Ek and Söderholm (2010), the traditional sampling method tends to attract participants who are highly motivated to conserve energy, leading to an upward bias in the results. To prevent this, we adopted a request-based approach to sample selection. Our results showed that only 34% of the surveyed households reduced their electricity consumption, leading to a negative average *Reduction*. We believe that these results are more realistic and indicative of the attitudes of the Japanese population in general.

Underestimation of the marginal cost of saving electricity is one of the reasons that led participants to cease their energy-saving efforts. This presents a valuable insight for policymakers targeting the household sector to reduce CO_2 emissions. Before offering economic incentives to promote energy conservation, 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 feedback, to lower the marginal costs.

Apart from CO_2 emissions, the imminent electricity crisis in Japan is another reason for encouraging energy-conservation efforts. The Great East Japan earthquake in March 2011 and the subsequent radiation leak from the Fukushima nuclear plant have triggered widespread concerns about the safety of nuclear plants. In the interests of safety, many Japanese electric companies have been shutting down their nuclear power reactors. However, given that nearly 30 percent of Japan's total electricity demand is fulfilled by nuclear power, replacing it with an alternative source of fuel such as oil, coal, or LNG in the short term is highly difficult. To avert a large-scale blackout, massive electricity-saving measures have to be implemented in the future. The efficacy of economic incentives, which has been established in our study, offers a potential measure for encouraging electricity-conservation behavior among Japanese households.

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