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Estimation of household's preference for energy sources by conjoint analysis in Japan

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Estimation of household's preference for energy sources by conjoint analysis in Japan[1]

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Abstract

Aftermath the great East Japan earthquake on March 11th, 2011, nuclear power plants ceased operations. We need other energy sources instead of nuclear power. Thermal power sources such as oil and coal increase emissions of greenhouse gases which compromises their viability and acceptability. Thus, here, we specifically focus on renewable energy sources such as solar and wind power. We estimate household preferences for energy sources by conjoint analysis, and calculate willingness to pay (WTP) after estimation by a random parameter logit model. We find that households negatively value nuclear power, while positively value renewable energy sources. Further, the stability of electricity supply is valued highly. We posit a future, post-earthquake, post-deregulation electricity supply system.

Keywords

conjoint analysis, random parameter logit model, WTP, renewables, deregulation

JEL classification

C25, L51, L94, L95, Q42

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1. Introduction

Aftermath the great East Japan earthquake in March 2011, Japan has faced drastic energy and environmental changes and many problems. After the earthquake, the Fukushima nuclear facility ceased operation due to serious accidents. Other nuclear power plants also stopped operation and were subjected to inspections. Though the Kyushu electric power company's Sendai nuclear power plant recommenced operations in 2015, the bulk of the country's nuclear power plants remain out of action. We urgently need alternative energy sources instead of nuclear power. Since the earthquake, Japan has relied on thermal power generated by natural gas (LNG), importing more LNG as a consequence. However, the price of LNG is too volatile and too vulnerable to exchange rate dynamics. Higher costs thereof are shifted to households via tariff rates.

After the earthquake, people who live in the Kanto area around Tokyo experienced planned outages because nuclear power plants had ceased operations. Electricity shortages are particularly pertinent in the context of peak demand in the summer and winter. We have been requested to save electricity use in case of a sudden outage.

Climate change is another serious problem which is clearly relevant in this context. Relying on thermal power begets emissions of greenhouse gases such as CO_2. Japan faces difficulties in reducing CO_2 emissions in spite of the promise of the Kyoto Protocol to other countries in the world. Renewable energy sources such as solar and wind power are needed instead of nuclear and thermal power. However, renewable energy sources have not prevailed as principal energy sources even though many solar panels have been constructed and fitted. In July 2012, the Japanese government introduced a feed-in-tariff system to promote renewable energy sources. Many companies construct solar panels and sell electricity. However, tariffs offered by the existing major electric power companies are relatively highly priced, particularly solar power tariffs.

The deregulation of the electric power industry, which started in 2000, is also an important and pertinent topic. Consumers can purchase electricity from all electric power companies including newcomers and electric power companies based in other areas, as well as the electric power company in their area. At the beginning, the target was only large demand consumers. After 2003, the target was gradually expanded to encompass smaller demand consumers. At last, from April 2016, all households can now purchase electricity from any company including new companies from other industries such as telecommunication. Deregulation of the gas industry will start in April 2017.

The environment around energy markets and energy sources has been changing dramatically in Japan, not least since the Fukushima disaster. To explore and quantify this it is pertinent to estimate households' preferences for energy sources and discuss energy policies which accord with those preferences. In order to estimate households' preferences, we adopt conjoint analysis. We focus on preferences for nuclear power and renewable energy sources such as solar and wind power. We evaluate preferences in terms of willingness to pay (WTP). If WTP for renewable energy sources is positive and substantial and WTP for nuclear power is small or negative, this provides support for policy interventions that reduce the share of nuclear power and promote renewable energy sources. Some households would purchase electricity generated by renewable energy sources even if the electricity tariff rate was higher. Given that deregulation was fully completed in April 2016, there is now good scope for providers to generate electricity using renewable energy sources. Accordingly, this study could provide useful insights into future energy policies from the viewpoint of consumer preferences.

This paper consists of the following sections. In section 2, energy and environmental problems in the Japanese context are presented. In section 3, related studies are introduced. In section 4, the conjoint analysis methodology is explained. In section 5, econometric methods are elaborated upon. In section 6, estimation results are delineated. Finally, in section 7, we conclude, with a focus on the policy implications emanating from this study.

2. Energy and environmental problems in Japan

We have many energy problems in Japan, including supply-demand mismatch issues. In terms of climate change, through the 1997 Kyoto Protocol, Japan agreed to reduce its emissions of greenhouse gases by 6% from 2008 to 2012, compared to a 1990 baseline. However the total amount of greenhouse gases had increased to 10 billion 343 million tons; this represents a 6.9% increase compared with levels at the 2010 fiscal year[3]. This increase was caused by electricity generated using fossil fuels such as natural gas, coal, and oil.

Since July 2012, the feed-in-tariff system has started to promote renewable energy sources such as solar and wind power. The prevalence of renewable energy sources has the potential to reduce emissions of greenhouse gases. All companies which generate

[3] "The white paper on energy usage in 2013"(2014) from the Agency for Natural Resources and Energy in the Ministry of Economy, Trade and Industry

electricity by renewable energy sources can sell electricity to nine major electric power companies, including the Kansai electric power company[4]. The major electric power companies are required to purchase electricity from these companies. However, the bid price associated with these nine major electric power companies is relatively high. Importantly, these high prices are then shifted to households via electricity tariff rates. The bid price was over 650 JPY (6.5 US$) per month in the 2016 fiscal year. This price is ten times the price in the 2012 fiscal year[5].

In July 2015, the Japanese government tabled an energy plan in which it put forward what it considered to be an optimal composition of energy sources –the so-called “best-mix” –for the fiscal year 2030. The share of nuclear power will be raised to around 20%-22% assuming nuclear power plants recommence operations. This share was only 1% in the fiscal year 2013. However the share was 30% in December 2010 before the earthquake. While the share of renewable energy sources such as solar and wind power will be raised to around 22%–24%, from 2% in the fiscal year 2013. The notable point of this plan is to expand the share of renewable energy sources. The share of coal will be reduced to 26%, from 30% in 2013, and the share of LNG will be reduced to 27%, from 43% in 2013.

Lastly, we mention the deregulation of the electric power industry vis-à-vis retail sales. Deregulation started in 2000 for large scale consumers such as factories, office buildings, and commercial facilities. These consumers can purchase electricity from all electric power companies including Power Producer and Supplier(PPS) which are newcomers in the electric industry, as well as the existing electric power company in their area. The target consumers of deregulation have been expanded to smaller scale consumers since 2000. Since April 2016 general households have become the target consumers of deregulation. Households can purchase electricity freely from all electric power companies including newcomer companies and major electric power companies in other areas. Some electric power companies do not have any nuclear power plants and provide electricity generated only by renewable energy resources. Some households might object to nuclear power and support renewable energy resources; such households could thus purchase electricity from a company which does not have any nuclear power

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[4] In Japan there are nine major electric power companies; Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Chugoku, Shikoku and Kyushu electric power companies. These companies have monopoly power in their respective regions.

[5] This calculation is from the Agency for Natural Resources and Energy in the Ministry of Economy, Trade and Industry (2016), "Concerning the determination of bid prices and charges for renewable energy sources in the fiscal year 2016".
http://www.meti.go.jp/press/2015/03/20160318003/20160318003.html

plants and generates electricity only by renewable energy sources. Some telecommunication companies now provide electricity; discounted prices are offered if households purchase electricity along with smartphones, internet, or CATV.

3. Related literature

In this section, certain studies focusing on household energy choices are introduced. Nakajima, Ida, and Kinoshita (2006) estimate household preferences for electricity and gas using conjoint analysis. They estimate relevant parameters using a conditional logit model. In 2006, the competition between electric power companies and gas companies was intense in urban areas. This study estimated preferences for an all-electric service, gas cogeneration, and fuel batteries. Morita and Managi (2013) estimated preferences for energy sources, particularly renewables, after the earthquake in 2011, by conjoint analysis. They estimate WTP for each energy source and suggest policy implications vis-à-vis the energy mix of the Japanese government. They obtained negative WTP for nuclear power, while positive WTP for renewable energy sources.

Murakami et al. (2015) estimate consumers' WTP for renewable energy and nuclear energy in the US and Japan. They use a choice experiment methodology and consumers in both countries showed negative preferences for nuclear power and positive preferences for renewable energy in both countries. Ida, Takemura, and Sato (2015) explore conflicts between nuclear power and electricity rates in Japan wherein a trade-off can occur between low rates with nuclear or high rates without it.

In terms of preferences for renewable energy sources, Roe et al. (2001) estimate WTP for green energies among consumers in the US. This study uses hedonic analysis and the dependent variable is the price premium. Bordhers, Duke, and Parsons (2007) also estimate WTP for green energies among consumers. Those authors adopted a choice experiment approach with a nested logit model for estimation purposes; at the first stage consumers choose to join a green program or not. At the second stage consumers choose the best program among several green options. Importantly, they evaluate only renewable energy sources whereas this study evaluates renewable energy sources compared with other energy sources including nuclear power. Scarpa and Willis (2010) estimate preferences of UK households for renewable energy sources, again using a choice experiment approach. Banfi et al. (2008) estimate WTP for energy saving methods using a choice experiment approach in the context of Swiss households.

The novelty of this study compared with previous studies is the estimation of household preferences for energy sources in Japan after households have experienced an unprecedented disaster. As such, this study could provide useful insights vis-à-vis energy policies in countries which frequently experience substantive natural disasters. Moreover, this study also focuses on the deregulation of the electric power industry as already discussed.

4. Conjoint analysis

In this paper preferences for energy sources among Japanese households are estimated by conjoint analysis. Conjoint analysis is a stated preference methodology; more specifically it is a type of choice experiment which estimates the preferences of individuals for hypothetical goods or services that have several attributes, each of which can be evaluated by WTP. Households choose an option out of a set of alternatives which may exist or may be hypothetical, representing possible future options. Contingent Valuation Method (CVM) is another popular stated preference method, but it is not a choice experiment. In conjoint analysis, profiles of goods or services which have several attributes are presented to respondents. A profile which has only few attributes may not be realistic, whereas a profile which has too many attributes can place undue cognitive burdens on respondents. In general, five or six attributes tend to be adopted. Profiles were created using the orthogonal planning method to avoid multicollinearity between attributes (Louviere, Hensher, and Swait, 2000; Kuriyama and Shoji , 2005; Tsuge, Kuriyama, and Mitani, 2011; Kuriyama, Tsuge, and Shoji, 2013).

In this choice experiment, households choose one electric power company which has several attributes and generates electricity by particular energy sources, as attributes. This choice construct is consistent with household options, post-deregulation, in Japan. Goett, Hudson, and Train (2000) examined customers' choice for retail energy suppliers by conjoint analysis; they included the ratio of renewable energy sources as an attribute of energy suppliers as well as other attributes such as a fixed price. From the analysis herein we can simulate the behavior of households and potentially avail of useful information to promote renewable energy sources in the post-deregulation era. We suppose the following alternatives:

Alternative 1: an electric power company which has nuclear power plants and generates electricity by nuclear and thermal power such as LNG and coal.
Alternative 2: an electric power company which has zero nuclear power plants and generates electricity by thermal power such as LNG and coal. This electric power company purchases electricity from other electric power companies which generate

electricity by renewable energy sources such as solar and wind power through a feed-in-tariff system.

Alternative 3: an electric power company including newcomer companies which has zero nuclear power plants and generates electricity by renewable energy sources such as solar and wind power or thermal power such as LNG and coal.

Alternative 1 assumes that households purchased electricity from electric power companies before the earthquake in March 2011. Alternative 2 assumes that households purchase electricity from the current electric power companies after the earthquake. Alternative 3 assumes that households purchase electricity from electric power companies after deregulation was completed in April 2016.

The attributes and the levels of each alternative are as follows.

1. Electricity rate (per month):

Electricity rate per month increases or decreases compared with the current rate. There are several assumptions. If households purchase electricity from nine major electric power companies such as Kansai electric power company, sometimes the electricity rate might be cheaper if nuclear power plants start operation again. Sometimes the electricity rate might be higher if it is thermal power because the prices of oil and LNG are volatile. The electricity rate might be higher in the context of renewable energy sources because the electric power companies purchase electricity through the feed-in-tariff system. If households purchase electricity from a new electric power company, such as a telecommunications company, they may purchase electricity at discounted prices when they make simultaneous telephone, internet, or CATV purchases.

2. CO_2 emissions:

CO_2 emissions will increase or decrease in 2030 compared to 2014. There are some assumptions. When nuclear power plants start operation again, CO_2 emissions will decrease. When thermal power is used to a greater extent, CO_2 emissions will increase; while increasing the use of renewable energy sources, CO_2 emissions will decrease.

3. The stability of electricity supply or the possibility of outages:

If nuclear power plants start operation again, electricity will be supplied constantly. If households purchase electricity from a power company which generated electricity by thermal power, sometimes, electricity will not be supplied constantly due to planned outages stemming from electricity shortages. If households purchase electricity from a power company which generated electricity by renewable energy sources, sometimes electricity supply might not be stable due to weather conditions. When electricity is constantly supplied, there are no outages in a year. When electricity is not constantly supplied, short-term outages may occur a few times a year or the lights in the houses become dimmer. A dummy variable is used which equals 1 where there is stable electricity, else 0.

4. The main energy source:

We suppose an energy supply source set consisting of nuclear power, thermal power (LNG), solar power, and wind power. A dummy variable is used for each energy source where thermal power is the base category.

In Table 1, the levels of each variable are summarized.

[Table 1 near here]

We construct profiles using the orthogonal planning method in SPSS conjoint version 17.0, to avoid multicollinearity between attributes. From the various cards which were produced, cards and combinations were selected to construct profiles; unrealistic and dominant cards and combinations were removed. In alternative 1, only nuclear power and thermal power (LNG) are included. In alternative 2 and 3, only thermal power (LNG), solar power, and wind power are included. The levels of other attributes (ex. electricity rate) depend on these energy sources. However, we use all levels of attributes in each alternative. Table 2 is an example profile; households answer with respect to eight choice questions like in this profile. Through a pretest, we identify issues with the questionnaire and correct profiles to maximize understanding and minimize ambiguity for respondents.

[Table 2 near here]

The data were collected via a web-based questionnaire, utilizing the services of the Rakuten Research company. The sample size is 250 households in each (Kanto[6] and Kansai[7]) area, thus 500 households in total. Data were collected in August 2014 before the deregulation for general households in April 2016. Table 3 presents the attributes of households in the sample. The percentages of not employed in occupation and less than 2,000 thousand JPY (20 thousand US$) in household income are larger, caused by

[6] Kanto area is in East Japan around Tokyo. It includes Saitama, Chiba, Tokyo and Kanagawa prefectures.

[7] Kansai area is in West Japan around Osaka. It includes Shiga, Kyoto, Osaka, Nara, Hyogo and Wakayama prefectures.

housewives and retirees.

[Table 3 near here]

5. Econometric analysis

In a choice experiment the dependent variable is discrete. In order to estimate this choice model, we, thus, need to employ a discrete choice econometric model. The conditional logit model is a popular choice model in this context. However, this model assumes Independent and Identical Distribution (IID) and this assumption derives from the Independence of Irrelevant Alternatives(IIA). This assumption is restricted and easily violated in many cases. Consequently, we adopt a random parameter logit model (mixed logit model). This model allows the random variation of individual preferences, unrestricted substitution patterns and correlation in unobserved factors over time.

The random parameter logit model assumes that each parameter has a distribution. The utility is specified as:

$$U_{nj} = \alpha' x_{nj} + \beta_n' z_{nj} + \varepsilon_{nj}$$

This function specifies that individual n chooses alternative j. α is a non-random parameter and β_n is a random parameter which represents the preference of each individual and varies over individuals. In this paper constant terms and the parameter of electricity rate which is a price parameter, are non-random parameters. x_{nj} is a variable vector which includes electricity rate. On the other hand, the parameters of CO_2 emissions, the stability of electricity supply and the main energy sources are random parameters. z_{nj} is a variable vector which includes CO_2 emissions, the stability of electricity supply, and the main energy sources. ε_{nj} is a random error term and has an IID extreme value.

The probability conditional on β_n is

$$L_{ni}(\beta_n) = \frac{\exp(\beta_n' x_{ni})}{\sum_j \exp(\beta_n' x_{nj})}$$

The random parameter logit probability is

$$P_{ni} = \int \left(\frac{\exp(\beta' x_{ni})}{\sum_j \exp(\beta' x_{nj})} \right) f(\beta) d\beta$$

This probability is the unconditional choice probability calculated as the integral of $L_{ni}(\beta_n)$ over all β_n.

We should assume the distribution of β_n. Usually we assume normal, lognormal triangular distribution etc. In this paper, the normal distribution is assumed.

We use simulation methods for estimation. The simulated probability is

$$\widetilde{P_{ni}} = \frac{1}{R} \sum_{r=1}^{R} L_{ni}(\beta^r)$$

R is the number of draws. This simulated probability is an unbiased estimator of P_{ni}. The simulated log likelihood is

$$SSL = \sum_{n=1}^{N} \sum_{j=1}^{J} d_{nj} \ln \widetilde{P_{nj}}$$

d_{nj} is an indicator. It equals 1 if individual n chooses alternative j, else 0. We maximize SSL to capture the maximum simulated likelihood estimator. We use 100 times Halton draws for simulation (Train, 2003, 138-154; Hensher, Rose, and Greene, 2005, 605-694). For estimation we use Limdep NLOGIT 5.

After estimation, the WTP for each attribute including each energy source, is calculated. If the utility function is linear, it is expressed as:

$$V_{nj} = \alpha' x_{nj} + \beta_n' z_{nj}$$

V_{nj} is the deterministic term of the utility function. The total differentiation of the V_{nj} formula is:

$$dV_{nj} = \frac{\partial V_{nj}}{\partial x_{nj}} dx_{nj} + \frac{\partial V_{nj}}{\partial z_{nj}} dz_{nj}$$

Now we obtain the WTP of z_1 which is one of the attributes, such as solar power. If the utility level does not change ($dV_{nj} = 0$) and other variables, except z_1, are unchanged, we can obtain the marginal WTP (MWTP) as follows:

$$MWTP = -\frac{\partial V_{nj}}{\partial z_{nj1}} \Big/ \frac{\partial V_{nj}}{\partial x_{njm}}$$

x_m is a monetary variable such as a price. We can also write MWTP by invoking parameters as follows:

$$MWTP = -\beta_i / \beta_m$$

β_i is the coefficient of each attribute and β_m denotes a monetary coefficient such as an electricity rate. We can obtain WTP by dividing the coefficient of each attribute by a monetary coefficient.

6. Estimation results

First, descriptive statistics are presented followed by the estimation results from the random parameter logit model.

6.1 Descriptive statistics

Table 4 shows the number of choices and the ratio of choices.

[Table 4 near here]

Alternative 3 is the most popular. Households prefer new electric power companies which do not have any nuclear power plants and generate electricity by renewable energy sources and LNG. Table 5 presents descriptive statistics.

[Table 5 near here]

Electricity rate in alternative 2 is the highest and it in alternative 1 is the lowest.

6.2 Random parameter logit model estimation results

Table 6 illustrates the estimation results from the inferential model.

[Table 6 near here]

The electricity rate coefficient has a negative sign and is significant at the 1% level. If the electricity rate is lower, the probability of choosing that alternative increases. The CO_2 coefficient has a negative sign and is significant at the 1% level. If CO_2 emissions decrease, the probability of choosing that alternative increases. The coefficient associated with the stability of the electricity supply has a positive sign and is significant at the 1% significance level. If the possibility of outages is zero, the probability of choosing that alternative increases. Next, the estimation results pertinent to the main energy sources are explained. Dummy variables for each energy source have been used, where thermal power is the base category. The nuclear power coefficient has a negative sign and is significant at the 1% level. If the main energy source is nuclear power instead of thermal power, the probability of choosing that alternative decreases. On the other hand, the coefficient associated with renewable energy sources such as solar and wind power has a positive sign and is significant at the 1% level. If the main energy source is renewable instead of thermal power, the probability of choosing that alternative increases.

6.3 WTP

WTP for each attribute is calculated. WTP is obtained by dividing the parameter of each attribute by the parameter of electricity rate which is a price parameter. Table 7 shows the WTP for each attribute.

[Table 7 near here]

WTP for stable electricity supply is 731.04. Thus, households will pay an additional 731.04 JPY (7.3104 US$) per month for a stable supply of electricity. Households positively value a stable supply of electricity. WTP for CO_2 emissions is −57.84. Thus, if the electricity rate is cheaper by 57.84 JPY (-0.5784 US$), households will allow an increase in CO_2 emissions. WTP for nuclear, solar and wind power is −5239.06, 1414.01 and 610.79 respectively. Households will, thus, pay an additional 1414.01 JPY (14.1401 US$) per month for solar power and an additional 610.79 JPY (6.1079 US$) per month for wind power instead of thermal power. Households therefore positively value renewable energy sources. On the other hand, households negatively evaluate nuclear power. Specifically, households will only satisfice with nuclear power if the electricity rate is cheaper by 5239.06 JPY (-52.3906 US$) per month.

6.4 Elasticities

We calculate the elasticities of price and other attributes. Table 8 shows price elasticities. Price elasticities indicate how the choice probability for each alternative increases or decreases when the price changes by 1%. Own-elasticities measure the direct effect of percentage changes on the same alternative. By contrast, cross-elasticities measure the effect of percentage changes of an alternative on the other alternatives. Own-elasticities of alternatives 1, 2 and 3 are −0.04795, −0.29334 and 0.00096 respectively. Clearly, the own-elasticities of alternatives 1 and 2 are negative; thus, if the price decreases by 1%, the choice probability of alternatives 1 and 2 increases. For alternative 1 the choice probability increases by 0.04795%; for alternative 2 the choice probability increases by 0.29334% Thus, households are relatively more responsive with respect to alternative 2. Own-elasticities of alternatives 3 is not significant. Some cross-elasticities are positive, while others are negative. When the price increases with respect to alternative 1, the choice probability of alternatives 2 decreases and that of alternatives 3 increases. When the price increases with respect to alternative 2, the choice probability of alternatives 1 and 3 increase. When the price increases with respect to alternative 3, the choice probability of alternatives 1 and 2 decrease.

[Table 8 near here]

Next, we discuss elasticities of other attributes (Tables 9–13). Almost all own-elasticities are positive. Regarding the stability of the electricity supply, if there are no outages the choice probabilities in all alternatives increase. In terms of energy resources, if the main energy source is solar or wind power the choice probabilities increase in the alternatives. On the other hand, the own-elasticity of nuclear power is negative. Thus, if the main energy source is nuclear power, the choice probability decreases in the alternative. Cross-elasticities are negative. If there are no outages in an alternative, the choice probabilities in the other alternatives decreases. If the main energy source is solar or wind power in an alternative, the choice probabilities in the other alternatives decrease.

[Table 9 near here]

[Table 10 near here]

[Table 11 near here]

[Table 12 near here]

[Table 13 near here]

6.5 Comparison of households' preferences between Kanto and Kansai areas

After the great earthquake, households who live in the Kanto are suffered from damages. Moreover they experienced planned outages. We suppose that there will be a difference in households' preferences over nuclear power, renewable energy sources, and the stability of electricity supply. Households' WTP for nuclear power will be more negative and their WTP for renewable energy sources and stability of electricity supply will be more positive in Kanto, compared to Kansai. Tables 14 and 15 present relevant estimation results and Table 16 shows WTP of households in the Kanto and Kansai areas.

[Table 14 near here]

[Table 15 near here]

[Table 16 near here]

WTP for stability in Kansai is larger than in Kanto, which is converse to expectation (663.18 JPY in Kanto and 928.51 JPY in Kansai). However this research was carried out in 2014, three years after the earthquake and this result therefore testifies to the effects of time on diminishing collective memory and issue importance. Moreover, WTP for renewable energy sources in Kanto is greater than in Kasai (1405.86 JPY in Kanto and 1272.8 JPY in Kansai for solar power).

Lastly, we test for parameter differences in order to quantify the extent to which preferences are heterogeneous between Kanto and Kansai. If preferences are indeed different, households in Kanto and Kansai make contrasting choices vis-à-vis electric power companies. We test for differences by the likelihood test and use the following test statistic.

$$-2[LL(A+B)-(LL(A)+LL(B))]$$

LL(A+B) is the log likelihood which is obtained after estimation by pooling data from Kansai and Kanto. LL(A) is the log likelihood for Kansai and LL(B) is the log likelihood for Kanto. The null hypothesis is that preferences or parameters between Kanto and Kansai area are equal. The alternative hypothesis is that preferences or parameters are not equal. The test statistic is chi-squared distributed with degrees of freedom equal to the number of parameters.

The calculated statistic is 0.392 and thus the null is not rejected because the critical value for the 5% significance level is 22.362 for 13 degrees of freedom. Preferences for electric power companies are, thus, not significantly different between the Kanto and Kansai areas. From these results, households in both Kanto and Kansai areas have the same preferences for electric power companies. They may prefer new electric power companies which do not have any nuclear power plants and generate electricity by renewable energy sources.

7. Conclusions and Policy Implications

We estimate preferences of Japanese households for energy sources by conjoint analysis and calculate WTP for each energy source and its attributes. WTP for nuclear power is negative. On the other hand, WTP for renewable energy sources such as solar and wind power, is positive. Further, WTP for a stable supply of electricity is positive. Japanese households positively value renewable energy sources and stability of electricity supply but do not positively value nuclear power. From this study we can support policy interventions to reduce the share of nuclear power and promote renewable energy sources. Households will pay higher electricity rates for renewable energy sources. Households will accept nuclear power if the electricity rate is lower. This study may support the feed-in-tariff system for promotion of renewable energy sources. If the stability of electricity supply associated with renewable energy sources improves, renewable energy sources will become widely used.

After the great East Japan earthquake in March 2011, nuclear power operations were largely suspended. Thermal power which has been the main energy source following the earthquake is also difficult to enlarge because of climate change concerns and rising fuel costs. Renewable energy sources such as solar and wind power are expected to prevail as future energy sources.

Various companies have started to provide electricity since the onset of deregulation, which was completed in April 2016. Some providers do not possess nuclear power plants and provide electricity generated only by renewable energy sources. Some households who object to nuclear power, thus, have the option of purchasing electricity from such providers. This study offers a post-earthquake, post-deregulation blueprint.

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References

Banfi, Silvia, Mehdi Farsi, Massimo Filippini, and Martin Jakob (2008), “Willingness to pay for energy-saving measures in residential buildings”, *Energy Economics*, 30, p503-516.

Borchers, Allison M., Joshua M. Duke, and George R. Parsons (2007), “Does willingness to pay for green energy differ by source?,” *Energy Policy*, 35, p3327-3334.

Goett, Andrew, Kathleen Hudson, and Kenneth Train (2000), “Customers' choice among retail energy suppliers: The willingness-to-pay for service attributes,” *The Energy Journal*, 21, p1-28.

Hensher, David A., John M. Rose, and William H. Greene (2005), *Applied Choice Analysis: A primer*, Cambridge University Press.

Ida, Takanori, Kousuke Takemura, and Masayuki Sato (2015), “Inner conflict between nuclear power generation and electricity rates: A Japanese case study,” *Energy*

Economics, 48, p61-69.
Kuriyama, Koichi and Yasushi Shoji edited (2005) *Economic evaluation of the environment and tourism*, (in Japanese), Keisou shobou.
Kuriyama, Koichi, Takahiro Tsuge, and Yasushi Shoji (2012) *Introduction to economic evaluation of the environment for beginners*, (in Japanese), Keisou shobou.
Louviere, Jordan J., David A. Hensher, and Joffre D. Swait (2000), *Stated Choice Methods Analysis and Application*, Cambridge University Press.
McFadden (1974), “Conditional logit analysis of qualitative choice behavior,” in P. Zarembka, ed., *Frontiers in Econometrics, Academic Press*, New York, p.105-142.
Morita, Takamki and Shunsuke Managi (2013) "The energy mix after the great East Japan earthquake - demand analysis considering characteristics of each energy source”, RIETI Discussion Paper Series 13-J-066, (in Japanese), Research Institute of Economy, Trade and Industry.
Murakami, Kayo, Takanori Ida, Makoto Tanaka, and Lee Friedman (2015), “Consumers' willingness to pay for renewable and nuclear energy: A comparative analysis between the US and Japan,” *Energy Economics*, 50, p178-189.
Nakajima, Miki, Takanori Ida, and Shin Kihoshita (2006) “The conjoint analysis for energy demand of households” *Journal of Public Utility Economics* (in Japanese) 58.2, p23-33.
Roe Brian, Mario F. Teisl, Alan Levy, and Matthew Russel (2001), “US consumers' willingness to pay for green electricity,” *Energy Policy*, 29, p917-925.
Scarpa, Riccardo and Ken Willis (2010), “Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies,” *Energy Economics*, 32, p129-136.
Takahiro, Tsuge, Koichi Kuriyama, and Yohei Mitani(2011), *New techniques of environmental evaluation*, (in Japanese), Keisou shobou.
The Agency for Natural Resources and Energy in the Ministry of Economy, Trade and Industry(2014) "The white paper on energy usage in 2013" (in Japanese).
Train, Kenneth E. (2002), *Discrete Choice Methods with Simulation*, Cambridge

Table 1 The levels of each variable

Attribute	Level
Electricity rate (month, JPY)	−2000, −1500, −1000, −500, 0 (unchanged) +500, +1000, +1500, and +2000
CO_2	−20%, −10%, 0% (unchanged), +10%, and +20%
Outages (year)	Yes(0), No(1)
Energy source	nuclear power, thermal power (LNG), solar power, and wind power

Table 2 An example profile

Attribute	Alternative 1	Alternative 2	Alternative 3
Electricity rate (month, JPY)	−2000	+1000	−1000
CO_2 emissions	−10%	+10%	−20%
Outages (year)	No	Yes	Yes
Main energy source	nuclear power	thermal power	solar power

Table 3 Attributes of households

		number	%
	Total	500	100
Occupation	company worker	243	48.6
	public worker	28	5.6
	student	2	0.4
	not employed（including housewives and retirees)	135	27
	self-employed	45	9
Household income (thousand JPY)	less than 2,000	159	31.8
	2,000–3,990	116	23.2
	4,000–5,990	87	17.4
	6,000–7,990	63	12.6
	8,000–9,990	36	7.2
	more than 10,000	39	7.8
Educational background	junior high school, high school	122	24.4
	technical school, junior college	119	23.8
	university, graduate school	255	51

Family composition	single	91	18.2
	two people	131	26.2
	husband and wife (parents) and children	225	45
	two households	26	5.2
Dwelling type	detached house (including two household houses)	248	49.6
	collective housing (condominium, apartment, housing complex etc.)	241	48.2
	company housing, dormitory housing etc.	11	2.2
Area	Kanto	250	50
	Kansai	250	50
Sex	male	296	59.2
	female	204	40.8
Age (years)	Average	47.45	
	Min	21	
	Max	69	

Table 4 Choice probability

	number	ratio
Alternative 1	1187	0.297
Alternative 2	1167	0.292
Alternative 3	1646	0.412

Table 5 Descriptive statistics

		electricity rate	CO_2	stability	nuclear power	thermal power	solar power	wind power
Alternative 1	mean	−589.72	−5.712	1	0.663	0.337	0	0
	median	−1000	−10	1	1	0	0	0
	mode	−2000	−20	1	1	0	0	0
	standard deviation	1327.71	14.04	0	0.473	0.473	0	0
	minimum	−2000	−20	1	0	0	0	0
	maximum	2000	20	1	1	1	0	0
Alternative 2	mean	1074.55	−11.87	0.626	0	0.167	0.66	0.172
	median	1000	−10	1	0	0	1	0
	mode	1500	−20	1	0	0	1	0

	standard deviation	658.442	9.867	0.484	0	0.373	0.47	0.378
	minimum	−500	−20	0	0	0	0	0
	maximum	2000	10	1	0	1	1	1
Alternative 3	mean	−388.52	−10.04	0.437	0	0.175	0.33	0.492
	median	−1000	−10	0	0	0	0	0
	mode	−1000	−10	0	0	0	0	0
	standard deviation	784.653	8.394	0.496	0	0.38	0.47	0.5
	minimum	−1000	−20	0	0	0	0	0
	maximum	2000	20	1	0	1	1	1

Table 6 Estimation results

Variable	Coefficient	Standard error	z value	p value
random parameters (mean)				
CO_2	−0.03875	0.00569	−6.81	0
Stability	0.4898	0.13376	3.66	0.0003
Nuclear	−3.51017	0.30989	−11.33	0
Solar	0.94739	0.15276	6.2	0
Wind	0.40923	0.09601	4.26	0
non-random parameters				
Electricity rate	−0.00067	0.0000487	−13.78	0
Constant 1	0.85603	0.11824	7.24	0
Constant 2	0.03223	0.06465	0.5	0.6181
standard deviation				
CO_2	0.05174	0.00587	8.81	0
Stability	1.84827	0.13921	13.28	0
Nuclear	4.878	0.36084	13.52	0
Solar	1.47681	0.13304	11.1	0
Wind	0.28513	0.18274	1.56	0.1187

Log likelihood −3297.20787

McFadden R^2 0.24969

Table 7 WTP

Variable	WTP (JPY)
CO_2	−57.84
Stability	731.04
Nuclear	−5239.06
Solar	1414.01
Wind	610.79

Table 8 Price elasticities

	Choice probability					
	Alternative 1		Alternative 2		Alternative 3	
Alternative 1	−0.04795	***	0.10269	***	−0.02597	***
Alternative 2	−0.01752	***	−0.29334	***	−0.08449	***
Alternative 3	0.00276		0.14535	***	0.00096	

*** denotes significance at the 1% level.

Table 9 CO_2 elasticities

	Choice probability					
	Alternative 1		Alternative 2		Alternative 3	
Alternative 1	−0.04064	***	0.06137	***	0.06079	***
Alternative 2	0.01794	***	−0.1441	***	0.08206	***
Alternative 3	0.00457	***	0.12688	***	−0.1124	***

*** denotes significance at the 1% level.

Table 10 Stability elasticities

	Choice probability					
	Alternative 1		Alternative 2		Alternative 3	
Alternative 1	0.29601	***	−0.11446	***	−0.06498	***
Alternative 2	−0.10195	***	0.17177	***	−0.08162	***
Alternative 3	−0.13815	***	−0.05992	***	0.14915	***

*** denotes significance at the 1% level.

Table 11 Nuclear power elasticities

	Choice probability		
	Alternative 1	Alternative 2	Alternative 3

Alternative 1	−0.15977	***	0		0
Alternative 2	0.10019	***	0		0
Alternative 3	0.07034	***	0		0

*** denotes significance at the 1% level.

0 means a fixed parameter.

Table 12 Solar power elasticities

	Choice probability				
	Alternative 1	Alternative 2		Alternative 3	
Alternative 1	0	−0.10665	***	−0.04427	***
Alternative 2	0	0.19813	***	−0.03985	***
Alternative 3	0	−0.12898	***	0.038	***

*** denotes significance at the 1% level.

0 means a fixed parameter.

Table 13 Wind power elasticities

	Choice probability				
	Alternative 1	Alternative 2		Alternative 3	
Alternative 1	0	−0.01102	***	−0.04326	***
Alternative 2	0	0.02377	***	−0.06419	***
Alternative 3	0	−0.02328	***	0.08178	***

*** denotes significance at the 1% level.

0 means a fixed parameter.

Table 14 Estimation results for Kanto

variable	coefficient	standard error	z value	p value
random parameters (mean)				
CO_2	−0.043	0.00841	−5.11	0
stability	0.43107	0.18496	2.33	0.0198
nuclear	−3.33788	0.55787	−5.98	0
solar	0.91381	0.20877	4.38	0
wind	0.4163	0.13729	3.03	0.0024
non-random parameters				
electricity rate	−0.00065	0.000069	−9.38	0

constant 1	0.7561	0.16747	4.51	0
constant 2	0.02643	0.09077	0.29	0.7709
standard deviation				
CO_2	0.05713	0.00926	6.17	0
stability	1.69868	0.1834	9.26	0
nuclear	4.52963	0.46275	9.79	0
solar	1.11931	0.18096	6.19	0
wind	0.07161	0.29834	0.24	0.8103
log likelihood	−1650.38			
McFadden R^2	0.24888			

Table 15 Estimation results for Kansai

variable	coefficient	standard error	z value	p value
random parameters (mean)				
CO_2	−0.03394	0.0079	−4.3	0
stability	0.64996	0.1883	3.45	0.0006
nuclear	−3.71425	0.48689	−7.63	0
solar	0.89096	0.21529	4.14	0
wind	0.41686	0.13445	3.1	0.0019
non-random parameters				
electricity rate	−0.0007	0.00006888	−10.14	0
constant 1	0.86764	0.16614	5.22	0
constant 2	0.03168	0.09152	0.35	0.7293
standard deviation				
CO_2	0.04851	0.00775	6.26	0
stability	1.76304	0.19939	8.84	0
nuclear	5.1263	0.54034	9.49	0
solar	1.51921	0.17154	8.86	0
wind	0.33028	0.21809	1.51	0.1299
log likelihood	−1646.63			
McFadden R^2	0.25059			

Table 16 WTP (JPY)

variable	Kanto	Kansai

CO_2	−66.15	−48.49
stability	663.18	928.51
nuclear	−5135.2	−5306.07
solar	1405.86	1272.8
wind	640.46	595.51