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Abstract

Aftermath the great earthquake in the east part of Japan on March 11th, 2011, nuclear power plants stopped operation. We need another energy sources instead of the nuclear power. Thermal power such as oil and coal increases the emission of global warming gases such as CO2. Especially I focus on renewable energy sources such as solar and wind power. I estimate household's preference for each energy source by conjoint analysis and calculate willingness to pay (WTP). I find that they have negative evaluation for nuclear power, while have high evaluation for renewable energy sources. And they have high evaluation for the stability of electricity supply.

Keywords

conjoint analysis, renewable energy sources, deregulation of electric power industry

JEL classification

C25,L51,L94,L95,Q28

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1. Introduction[2]

Aftermath the great east Japan earthquake in March 2011, Japan faces the drastic changes in energy environment and has many difficult energy problems. After the earthquake the Fukushima nuclear power plants stopped operation due to serious accident. Other nuclear power plants stopped operation for inspection. Though the Sendai nuclear power plant of Kyushu electric power company restarts in 2015, almost all nuclear power plants haven't been operated yet. We need alternative energy sources instead of nuclear power urgently. After the earthquake, we have relied on thermal power generated by natural gas (LNG). Japan has imported more natural gas (LNG). However, the price of LNG is too volatile and the imported price of LNG soars due to weak yen. The higher cost is shifted to electricity rate for households.

After the earthquake, we experienced planed outage because nuclear power plants stopped operation. We have concerned about the shortage of electricity at the peak of demand in summer and winter. We have been requested to save electricity use in case of a sudden outage.

The global warming is also one of the serious problems to solve. We have relied on thermal power. But it emits the greenhouse warming effect gases such as CO2. Japan faces difficulty to reduce the emission of CO2 in spite of the promise of the Kyoto Protocol to other countries in the world. In fact, the emission of CO2 is reported to increase in 2012 compared with in 2010[3]. On the other hand, renewable energy sources such as solar and wind power are needed instead of nuclear power and thermal power. However, renewable energy sources are far from one of the main energy resources even though many solar panels have been built. Since July 2012, the feed-in-tariff system has started to promote renewable energy sources. Many companies build solar panels and sell electricity. However, the tariff for the existing major electric power companies is relatively expensive and it is shifted to higher electricity rate for consumers such as households. Especially, the tariff of solar power is more expensive.

The deregulation of electric power industry for a retail market is also remarkable as one of the recent energy problems. The deregulation has started since 2000. Consumers

[2] This study uses the research fund(500,000 yen) of " the workshop about regulation and competition" hosted by Osaka Gas Co. Ltd. I presented this paper in the academic meeting of the Japanese Economic Association and the Japan Economic Policy Association in May 2015. All errors are mine. I thank for members of the workshop of Osaka Gas Co. Ltd and discussants of academic meeting: Prof. Takahiro Tsuge, Prof. Shinichi Hanada and Prof. Chiharu Kobayashi.

[3] This is according to "The white paper about energy in fiscal year 2013" [2014] from the agency for natural resources and energy in the ministry of economy, trade and industry.

can purchase electricity from all electric power companies including newcomers or electric power companies of other area as well as the electric power company in their area. At the beginning, the target was only large demand consumers. After 2003, the target has been expanded to smaller demand consumers gradually. At last, from April 2016, all the consumers including general households become the target of deregulation. All households can purchase electricity from all the companies including newcomers like telecommunication companies as well as the existing major electric power company of consumers' area. At the same time, the deregulation of gas industry will start in 2017.

The environment around energy markets has been changing dramatically. In the future the composition of energy sources will change in Japan. Our interest for energy sources has changed after the earthquake. We should consider suitable energy sources for our future. We need to estimate the households' preference for energy sources and discuss energy policies from their preferences. In order to estimate the households' preference, I use conjoint analysis. Especially I focus on the preference for renewable energy sources such as solar and wind power because we can't rely on fossil and nuclear power in the future for above reasons. I evaluate renewable energy sources by the willingness to pay (WTP). We should reduce the share of fossil and nuclear power and promote renewable energy sources. If the WTP for renewable energy sources is positive and large and the WTP for nuclear power is too small or negative, we support the policy that reduces the share of nuclear power and promotes renewable energy sources. Some households would purchase electricity generated by renewable energy sources even if the electricity rate is higher. After the deregulation in April 2016, some new providers of electricity would generate electricity by renewable energy sources. Some households would purchase electricity from such providers if they support renewable energy sources. This study might give a useful material to consider future energy policies from the view of consumer preference.

This paper consists of the following sections. In section 2, I show the environment and problems around energy sources in Japan. In section 3, I introduce related studies. In section 4, I explain conjoint analysis and its profile. In section 5, I explain econometric methods. In section 6, I show the estimation results. In section 7, I compare the preference between in Kanto and Kansai area. In section 8, I suggest some future energy policies.

2. The environment and problems around energy sources in Japan

Aftermath the great east Japan earthquake in March 2011, nuclear power plants in

Fukushima prefecture caused serious accident and other nuclear power plants in Japan have stopped operation for inspection. Though the Sendai nuclear power plant of Kyushu electric power company restarts in 2015, almost all nuclear power plants haven't been operated yet. As a result, we have relied on thermal power by coal and LNG and its share has become higher. However, the price of LNG is too volatile and the imported price of LNG soars due to weak yen. The higher cost is shifted to electricity rate for consumers. Moreover thermal power increases the emission of CO2. Due to the shortage of electricity, we have been requested to save electricity use at the peak of electricity demand in summer and winter in case of a sudden outage. Sometimes we experienced the planed outage and the possibility of outage still remains.

We have many problems around energy in Japan as well as the shortage of electricity. One of the problems is the global warming gas problem. Japan promised to reduce the amount of emission of global warming gases by 6% from 2008 to 2012 fiscal year compared with in 1990, at the Kyoto protocol in 1997. However, according to the " white paper on energies" in 2013, the total amount of global warming gases like CO2 had increased to 10 billion 343 million tons , which was 6.9% increase compared with in 2010 fiscal year. It was caused by the electricity generated by 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 will reduce the emission of global heating gas such as CO2. All companies which generate electricity by renewable energy sources can sell electricity to nine major electric power companies such as Kansai electric power company. The major electric power companies are required to purchase the electricity from these companies. However the bid price for nine major electric power companies is relatively high. As a result, the high bid price is shifted to electricity rate for households. The bid price is over 650 yen per month in fiscal year 2016. This price is ten times compared with in fiscal year 2012[4]. Table 1 shows the bid price of each renewable energy source in fiscal year 2016.

Table 1 The procurement cost and period in fiscal year 2016[5]

[4] This calculation is from the agency for natural resources and energy in the ministry of economy, trade and industry [2016]. "About the determination of bid price and charge of renewable energy sources in fiscal year 2016" http://www.meti.go.jp/press/2015/03/20160318003/20160318003.html

[5] The source is from the agency for natural resources and energy in the ministry of economy, trade and industry [2016] " The guidebook about the feed-in-tariff system in fiscal year 2016"

energy sources	procurement classification	procurement cost per 1 kWh	procurement period
solar power	more than 10 kW	24 yen (+tax)	20 years
	less than 10 kW (surplus purchase)	31 yen (+tax)	10 years
	less than 10 kW (double generation, surplus purchase)	25 yen (+tax)	
wind power	more than 20kW	22 yen (+tax)	20 years
	less than 20kW	55 yen (+tax)	
wind power on the ocean	more than 20kW	36 yen (+tax)	
geothermal power	more than 15,000kW	26 yen (+tax)	15 years
	less than 15,000kW	40 yen (+tax)	
hydraulic power	from 1,000kW to 30,000kW	24 yen (+tax)	20 years
	from 200kW to 1000kW	29 yen (+tax)	
	less than 200kW	34 yen (+tax)	
biomass	methane gas	39 yen (+tax)	20 years
	woody biomass by timber from forest thinnings (less than 2,000 kW)	40 yen (+tax)	
	general woody and crop biomass	24 yen (+tax)	
	waste from construction material	13 yen (+tax)	
	general waste and other biomass	17 yen (+tax)	

In July 2015, The Japanese Government published the suitable composition of energy sources what is called " best-mix" in fiscal year 2030 as the energy plan[6]. The share of

[6] The source is from the agency for natural resources and energy in the ministry of economy, trade and industry [2016] "The long term outlook of energy demand and supply".

nuclear power will be raised to around 20-22% from 1% in fiscal year 2013[7] assuming some nuclear power plants start operation again. On the other hand, the share of renewable energy sources such as solar and wind power will be raised to around 22-24% from 2% in fiscal year 2013. The notable point of this plan is to promote renewable energy sources instead of nuclear power and fossil fuels such as natural gas, oil and coal. The share of coal will be reduced to 26% from 30% and the share of LNG will be reduced to 27% from 43% in fiscal year 2013.

Lastly I mention the deregulation of electric power industry for retail sales. The 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 PPS (Power Producer and Supplier) which is newcomers in 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. At last in April 2016 general households have become the target consumers of the deregulation. Households can purchase electricity freely from all electric power companies including new coming companies and other major electric power companies in other areas. Some electric power companies don't have any nuclear power plants and provide electricity generated only by renewable energy resources such as solar and wind power. Some households might object nuclear power and support renewable energy resources. Such households would purchase electricity from a company which doesn't have any nuclear power plants and generates electricity only by renewable energy sources. Some telecommunication companies provide electricity. They provide electricity at discounted prices if households purchase electricity with smart phone, internet or CATV. After the deregulation households get chance to purchase electricity from various types of providers. The deregulation might change the behavior of households. The deregulation of electric power industry is important for energy policies. In 2017 the deregulation in the gas industry will start. We should consider all energy markets including electricity and gas.

From these environments around energy in Japan, we have to consider several points. Firstly, under these environments that operation of nuclear power plants is difficult and the share of nuclear power is reduced, we should consider another suitable energy source in Japan. Also we have to consider energy sources to solve the global heating problem. In this paper I estimate the preference of households for several energy

[7] Before the earthquake in December 2010 the share of nuclear power was about 30%.(the agency for natural resources and energy in the ministry of economy, trade and industry [2014] " On the situation of energy")

sources by conjoint analysis and calculate willingness to pay (WTP). Especially I focus on renewable energy resources such as solar and wind power. From the households' preference, I consider suitable energy sources and the condition that promotes these energy sources.

3. Related literature

In this section, I introduce some studies about energy choice of households. Nakajima, Ida and Kinoshita[2006] estimates the preference of households for electric and gas applicants by conjoint analysis. They estimate the parameters by conditional logit model. In 2006 the competition between electric power companies and gas companies was severe in urban areas. This study estimates the preference for all-electric service, gas cogeneration and fuel battery which are called electric equipment for future generation. This study also describes the image of degeneration of electric industry for households. My study is similar as this study. Morita and Managi[2013] also focuses on energy choice of households. This study estimates the preference for energy sources after the earthquake in Tohoku area by conjoint analysis. Especially they estimate the preference for renewable energy sources such as solar and wind power because people have much interest in renewable energy sources after the earthquake. They estimate willingness to pay (WTP) for each energy source and propose policy implications for "energy mix" of Japanese government. My study focuses on the preference for renewable energy sources. But especially I focus on the deregulation for general households in April 2016.

Murakami, Ida, Tanaka and Friedman[2015] estimates consumers' WTP for renewable and nuclear energy. They compare between US and Japan. They use choice experiment. Consumers in both countries show negative preference for nuclear power and positive preference for renewable energy. Ida, Takemura and Sato[2015] estimates inner conflict between nuclear power and electricity rates in Japan. Some households avoid nuclear power and an increase of electricity rate. However generally if electricity supply by nuclear power is stopped, electricity rate will increase. Some Japanese households face such a trade-off. They estimate such an inner conflict of households by choice experiment.

I show some studies about energy choice for renewable energy sources in foreign countries. Roe, Teisl, Levy and Russel[2001] estimates WTP for green energies among consumers in America. This study uses hedonic analysis and the dependent variable is price premium. They don't use conjoint analysis. Bordhers, Duke and Parsons[2007] also estimates WTP for green energies among consumers. They use choice experiment. 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 programs. They use nested logit model for estimation. They evaluate only renewable energy sources but my study evaluates renewable energy sources compared with other energy sources including nuclear power. Scarpa and Willis[2010] estimates the preference of households in UK for the generation technologies using renewable energy sources by choice experiment. Banfi, Farsi, Filippini and Jakob[2008] estimates WTP for energy saving methods of residences in Switzerland by choice experiment.

The remarkable point of my study compared with previous studies is to estimate the preference of households for energy sources in Japan after households experienced unprecedented disaster. This study might provide some useful suggestions for energy policies in countries which experience a big earthquake. Moreover I focus on the deregulation of electric power industry for general households in April 2016. I will show the image of electricity supply after the deregulation.

4. Conjoint analysis

4.1 Conjoint analysis

In this section I estimate the preference for energy sources among Japanese households by conjoint analysis[8]. Conjoint analysis is one of the stated preference methods. It estimates the preference of individuals for hypothetical goods or services which have several attributes. Households choose one of the alternatives about goods or services. Sometimes the goods or services haven't prevailed yet. It is often used in the marketing research. I adopt this method because I estimate the preference for energy sources in the future and hypothetical situation. CVM(Contingent Valuation Method) is another popular stated preference method. To evaluate each attribute by WTP I adopt conjoint analysis. In conjoint analysis, we provide profiles of goods or services which have several attributes to households. We consider the number of attributes we adopt. A profile which has only few attributes is not enough as goods, while a profile which has too many attributes makes us difficult to choose. In general, we adopt five or six attributes. We make profiles by the orthogonal planning method to avoid multicolineality where some attributes have correlation. I select attributes and their

[8] I refer to Louviere etc. [2000], Kuriyama and Shoji [2005], Tsuge, Kuriyama and Mitani [2011], Kuriyama, Tsuge and Shoji [2013] for conjoint analysis.

levels to avoid this problem. I make profiles after I delete unrealistic and dominated cards. I use SPSS conjoint version 17.0 for the orthogonal planning method.

4.2 Preference for energy sources :Conjoint A

The purpose of this study is to estimate the preference of households for energy sources. I suppose three alternatives.

Alternative 1: nuclear power.
Alternative 2: thermal power (LNG and coal)
Alternative 3: renewable energy sources (solar and wind power)

Energy sources in each alternative are main energy sources. I suppose the share of each energy source.

Alternative 1: nuclear power: 50%, thermal power: 40%, hydraulic power and others: 10%
Alternative 2: nuclear power: 10%, thermal power: 80%, hydraulic power and others: 10%
Alternative 3: nuclear power: 0%, thermal power: 60%, renewable energy sources: 30%, hydraulic power and others: 10%

I present this share to households. The share in alternative 1 is similar to the share of Kansai electric power company before the earthquake in March 2011. Under the various conditions households choose one of the alternatives.

Next, I assume the attributes and their levels of each alternative.

1. electricity rate (per month):
Electricity rate per month increases or decreases compared with current rate ; -2000 yen, -1500 yen, -1000 yen, -500 yen, 0 yen (unchanged), +500 yen, +1000 yen, +1500 yen and +2000 yen.

I have some assumptions in the levels of electricity rate. When nuclear power plants start operation again, the rate will be lower. When thermal power is main energy source, sometimes the rate may be higher because oil and LNG prices are volatile. When renewable energy sources are main energy source, sometimes the rate will be higher due to the feed-in-tariff system.

2. the emission of CO_2:
The emission of CO_2 increases or decreases in 2030 compared with in 2014 ; -20%, -10%, 0% (unchanged), +10% and +20%.

I have some assumptions. When nuclear power is main energy source, CO_2 will decrease. When thermal power, CO_2 will increase. When renewable energy sources, CO_2 will decrease.

3. the stability of electricity supply or the possibility of outage:

I suppose that electricity is always supplied constantly; no outage in a year or sometimes electricity isn't supplied constantly; short time outage happens a few times in a year or lights in our house get dark a little. I use a dummy variable which assigns 1 for the stability of electricity and 0 for the instability of electricity. If nuclear power is main energy source, electricity will be always supplied constantly. If thermal power, sometimes electricity will not be supplied constantly due to planed outage from the shortage of electricity. If renewable energy sources, sometimes electricity supply will not be stable due to weather conditions.

I suppose these alternatives, attributes and levels and make profiles by the orthogonal planning method. Through a pretest I make clear problems of questionnaire and correct profiles for households to answer easily. Table 2 is an example of profile. Households answer eight questions like this profile.

Table 2 An example of profile

Attribute	Alternative 1 (nuclear power)	Alternative 2 (thermal power)	Alternative 3 (renewable energy)
electricity rate (per month)	-2000 yen	+2000 yen	unchanged
CO_2	-10%	+10%	-10%
outage (per year)	No	No	Yes

After estimation I calculate WTP for each attribute and consider conditions households choose each energy source. WTP is calculated by dividing coefficient parameter of each attribute by price coefficient parameter. That is

$$\mathrm{WTP} = \frac{\beta_i}{\beta_m}$$

β_i is coefficient parameter of each attribute and β_m is price coefficient parameter which is electricity rate. This is marginal WTP.

This profile is simple and easy to understand for households in that they only choose an energy source which they support. However I want to calculate WTP for each energy source to estimate the preference of households for energy sources. In next subsection, I include main energy sources as an attribute and calculate WTP by dividing coefficient parameter of each energy source by price coefficient parameter.

4.3 Preference for electric power companies with an energy source: Conjoint B

In order to estimate the preference of households for energy sources, I include energy sources as an attribute. Each alternative is an electric power company with some attributes. In this conjoint analysis households choose an electric power company which generates electricity by some energy sources. This choice is similar to households' behavior after the deregulation in April 2016. Each household chooses an electric power company which they like. From this analysis we can simulate the behavior of households and might get some useful information to promote renewable energy sources after the deregulation. I 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 doesn't have any 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 feed-in-tariff system.
Alternative 3: an electric power company including new coming companies which doesn't have any nuclear power plants and generates electricity by renewable energy sources such as solar and wind power or thermal power such as LNG.

Alternative 1 assumes that households purchase 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 the deregulation in April 2016.

The attributes and their levels of each alternative are following. I imagine the electricity supply system after the deregulation in April 2016.

1. Electricity rate (per month):

The level is same as former conjoint analysis. The electricity rate increases or decreases compared with current rate; -2000 yen, -1500 yen, -1000 yen, -500 yen, 0 yen (unchanged),+500 yen, +1000 yen, +1500 yen and +2000 yen.

I have several assumptions. If households purchase electricity from nine major electric power companies such as Kansai electric power company, sometimes the electricity rate will be cheaper if the main energy source is nuclear power. Sometimes the electricity rate will be higher if thermal power because the prices of oil and LNG is volatile. The electricity rate will be higher if 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 telecommunication companies, they may purchase electricity by the discounted prices when they purchase telephone, internet or CATV at the same time.

2. the emission of CO2:

The level is same as former conjoint analysis. The emission of CO2 increases or decreases by 2030 compared with 2014 ; -20%, -10%, 0% (unchanged), +10% and +20%.

If the main energy source is nuclear power, CO2 will decrease. If it is thermal power, CO2 will increase. If it is renewable energy sources, CO2 will decrease.

3. the stability of electricity supply or the possibility of outage:

The level is same as former conjoint analysis. I suppose that electricity is always supplied constantly; no outage in a year or sometimes electricity isn't always supplied constantly; short time outage happens a few times in a year and lights in our house get dark a little. I use a dummy variable which assigns 1 for the stability of electricity and 0 for instability of electricity. If nuclear power is main energy source, electricity is always supplied constantly. If thermal power is main energy source, sometimes electricity isn't always supplied constantly due to planed outage from the shortage of electricity. If renewable energy sources are main energy source, sometimes electricity supply is not stable due to weather conditions.

4. the main energy source:

I suppose nuclear power, thermal power (LNG), solar power and wind power. I use a dummy variable for each energy source. Thermal power is the base category.

I calculate WTP for each energy source. We get WTP by dividing the parameter of each energy source by the parameter of electricity rate which is a price parameter.

Table 3 shows an example of profile.

Table 3 An example of profile

attribute	Alternative 1	Alternative 2	Alternative 3
electricity rate (per month)	-2000 yen	+1000 yen	-1000 yen
CO2	-10%	+10%	-20%
outage (per year)	no	yes	yes
main energy source	nuclear power	thermal power	solar power

I collect sample by web questionnaire of Rakuten research. The sample size is 250 households in each Kanto[9] and Kansai[10] area so the total sample size is 500 households. I collect the sample through on Thursday August 28 and Friday 29 in 2014.

In next section I show the results of this questionnaire.

5. Econometric analysis

I adopt a choice model in conjoint analysis. So the dependent variable is discrete. In order to estimate this choice model, I use a discrete choice model as an econometric model. The conditional logit model is one of the popular discrete choice models. However, this model assumes Independent and Identical Distribution (IID) and this assumption derives Independence of Irrelevant Alternatives (IIA). This assumption is restricted and this assumption is easily violated in many cases. As a result, I adopt the random parameter logit model (mixed logit model) . This model allows the random variation of individual preference , unrestricted substitution patterns and correlation in unobserved factors over time[11].

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 means 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 term and the parameter

9 Kanto area includes Saitama, Chiba, Tokyo and Kanagawa prefecture.
10 Kansai area includes Shiga, Kyoto, Osaka, Nara, Hyogo and Wakayama prefecture.
11 The explanation of the random parameter logit model is from Train[2003]and Louviere , Hensher and Swait[2000].

of electricity rate which is price parameter are non-random parameter. On the other hand the parameters of the emission of CO2 and the stability of electricity supply are random parameter. ε_{nj} is a random term that is 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 and 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 I assume normal distribution.

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=1 if individual n chose alternative j and 0 otherwise. We maximize SSL to get the maximum simulated likelihood estimator. I use 100 times Halton draws for simulation.

6. Estimation results

In this section, I show estimation results. Firstly I show the results of descriptive statistics. Next I explain the estimation results of random parameter logit model.

6.1 Descriptive statistics

I adopt two types of conjoint analysis: Conjoint A and B. Firstly I explain the results of Conjoint A. Table 4 shows the number and the ratio of choice for each alternative.

Table 4 Choice probability (Conjoint A)

	number	ratio
Alternative 1	1334	0.334
Alternative 2	595	0.149
Alternative 3	2071	0.518

About half households choose alternative 3. Households tend to prefer renewable energy sources. On the other hand, The number and the ratio of alternative 2 is few. They are not satisfied with the current energy sources because the main energy source is thermal power and its electricity rate is relatively high. In the ratio of choice, the total sample size is 4,000 because 500 households answer eight questions. Table 5 shows the descriptive statistics of attributes of each alternative which is chosen by households.

Table 5 Descriptive statistics (Conjoint A)

		electricity rate	CO2	stability
Alternative 1	mean	-1326.087	-12.53	1
	median	-1500	-10	1
	mode	-2000	-10	1
	standard deviation	605.15	6.75	0
	variance	366205.68	45.6	0
	minimum	-2000	-20	1
	maximum	-500	0	1
	sample size	1334	1334	1334
Alternative 2	mean	1057.983	8.319	0.652
	median	1000	10	1
	mode	500	0	1
	standard deviation	691.762	8.218	0.477
	variance	478534.6	67.541	0.227

	minimum	0	0	0
	maximum	2000	20	1
	sample size	595	595	595
Alternative 3	mean	961.854	-15.91	0.491
	median	1000	-20	0
	mode	1000	-20	0
	standard deviation	605.325	4.918	0.5
	variance	366418.589	24.183	0.25
	minimum	0	-20	0
	maximum	2000	-10	1
	sample size	2071	2071	2071

Next I show the descriptive statistics of Conjoint B. Table 6 shows the number of choice and the ratio of choice.

Table 6 Choice probability (Conjoint B)

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

Alternative 3 is the most popular. Households prefer new electric power companies which don't have any nuclear power plants and generate electricity by renewable energy sources and LNG. Table 7 shows the descriptive statistics.

Table 7 Descriptive statistics (Conjoint B)

		electricity rate	CO2	stability	nuclear power	thermal power	solar power	wind power
Alternative 1	mean	-589.722	-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	1327.709	14.043	0	0.473	0.473	0	0
	variance	1762811.6	197.195	0	0.224	0.224	0	0

	minimum	-2000	-20	1	0	0	0	0
	maximum	2000	20	1	1	1	0	0
	sample size	1187	1187	1187	1187	1187	1187	1187
Alternative 2	mean	1074.55	-11.868	0.626	0	0.167	0.661	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	0.474	0.378
	variance	433545.57	97.365	0.234	0	0.139	0.224	0.143
	minimum	-500	-20	0	0	0	0	0
	maximum	2000	10	1	0	1	1	1
	sample size	1167	1167	1167	1167	1167	1167	1167
Alternative 3	mean	-388.518	-10.043	0.437	0	0.175	0.333	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	0.471	0.5
	variance	615679.63	70.454	0.246	0	0.144	0.222	0.25
	minimum	-1000	-20	0	0	0	0	0
	maximum	2000	20	1	0	1	1	1
	sample size	1646	1646	1646	1646	1646	1646	1646

6.2 Estimation results of random parameter logit model

Next I show the estimation results of random parameter logit model. Firstly I explain the estimation results of Conjoint A. Table 8 shows the estimation results.

Table 8 Estimation results (Conjoint A)

variables	coefficient	standard error	z value	p value
random parameters(mean)				
CO2	-0.05572	0.00808	-6.89	0

stability	0.48551	0.1477	3.29	0.001
nonrandom parameters				
electricity rate	-0.00041	0.00005689	-7.15	0
constant 1	-1.44552	0.1536	-9.41	0
constant 2	-1.26028	0.16207	-7.78	0
standard deviation				
CO2	0.10047	0.00594	16.92	0
stability	2.6255	0.14887	17.64	0

log likelihood -3289.66878

McFadden R^2 0.2514036

The coefficient parameter of electricity rate has negative sign and is significant at 1% significant level. If electricity rate is lower, the probability to choose the alternative increases. The coefficient parameter of CO2 has negative sign and is significant at 1% significant level. If the emission of CO2 decreases, the probability to choose the alternative increases. The coefficient parameter of stability has positive sign and is significant at 1% significant level. If the possibility of outage is zero, the probability to choose the alternative increases. These results are consistent with my hypotheses.

I calculate WTP to know the monetary value of each attribute. We divide coefficient parameter of each attribute such as the stability of electricity supply by coefficient parameter of a monetary variable. In this paper a monetary variable is electricity rate. Table 9 shows WTP of each attribute.

Table 9 WTP (Conjoint A)

variable	WTP
CO2	-135.90
stability	1184.17

WTP for the stability of electricity supply is 1184.17. It means that households will pay additional 1184.17 yen per month for improvement of the stability of electricity supply. Households evaluate the stability of electricity supply. WTP for the emission of CO2 is -135.9. Households have negative evaluation for increase of the emission of CO2. Or if electricity rate is cheaper by 135.9 yen, households will allow increase of the emission of CO2.

Next I calculate the marginal effect of each attribute at mean. Table 10 shows the results. I explain the marginal effect of renewable energy sources (alternative 3). If electricity rate is lower by 500 yen, the probability to choose alternative 3 decreases by 13.3%. The probability that households will purchase renewable energy sources increases by 13.3% if electricity rate is lower by 500 yen. The probability that households will purchase renewable energy sources increases by 10.8% if there is no outage.

Table 10 Marginal effects (Conjoint A)

attribute	Alternative 1		Alternative 2		Alternative 3	
electricity rate	0.2608		-0.2652		-0.1431	***
CO2	0.3538		0.1774	***	0.3283	
stability	0.5295	***	0.0826		0.1078	***

***: significance at 1% level

Next I explain the estimation results of Conjoint B. In Conjoint B households choose an electric power company. These electric power companies provides electricity generated by their own various energy resources. In Conjoint B　I imagine the electricity supply after the deregulation in April 2016. Table 11 shows the estimation results.

Table 11 Estimation results (Conjoint B)

variable	coefficient	standard error	z value	p value
random parameters(mean)				
CO2	-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
nonrandom parameters				
electricity rate	-0.00067	0.00004867	-13.78	0
constant 1	0.85603	0.11824	7.24	0
constant 2	0.03223	0.06465	0.5	0.6181
standard deviation				
CO2	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 0.249688

The coefficient parameter of electricity rate has negative sign and is significant at 1% significant level. If electricity rate is lower, the probability to choose the alternative increases. The coefficient parameter of CO2 has negative sign and is significant at 1% significant level. If the emission of CO2 decreases, the probability to choose the alternative increases. The coefficient parameter of the stability of electricity supply has positive sign and is significant at 1% significant level. If the possibility of outage is zero, the probability to choose the alternative increases. These results are same as Conjoint A. Next I explain the estimation results of main energy sources. I use dummy variables for each energy source. Thermal power is the base category. The coefficient parameter of nuclear power has negative sign and significant at 1 % significant level. If the main energy source is nuclear power instead of thermal power, the probability to choose the alternative decreases. On the other hand, the coefficient parameter of renewable energy sources such as solar and wind power has positive sign and is significant at 1 % significant level. If the main energy source is renewable energy sources instead of thermal power, the probability to choose the alternative increases.

I calculate WTP. Table 12 shows WTP of each attribute.

Table 12 WTP (Conjoint B)

variable	WTP
CO2	-57.84
stability	731.04
nuclear	-5239.06
solar	1414.01
wind	610.79

WTP for the stability of electricity supply is 731.04. It means that households will pay additional 731.04 yen per month for the stability of electricity supply. Households evaluate the stability of electricity supply. WTP for the emission of CO2 is -57.84. Households have negative evaluation for the emission of CO2. Or if electricity rate is cheaper by 57.84 yen, households will allow to increase the emission of CO2. WTP for nuclear power is -5239.06. WTP for solar power is 1414.01 and WTP for wind power is 610.79. Households will pay 1414.01 yen per month for solar power and 610.79 yen per month for wind power instead of thermal power. Households have high evaluation for renewable energy sources. On the other hand, households have negative evaluation for nuclear power. Or if electricity rate is cheaper by 5239.06 yen per month, households will allow nuclear power.

Next I calculate the marginal effects at mean. Table 13 shows the results.

Table 13 Marginal effects (Conjoint B)

attribute	Alternative 1		Alternative 2		Alternative 3	
Electricity rate	0.0821	***	-0.4558	***	0.0701	
CO2	0.0585		0.1956	***	0.1209	***
stability	0.2439		0.2154	***	0.0931	
Nuclear power	-0.2573	***	0		0	
Solar power	0		0.4023	***	0.1079	
Wind power	0		0.0360		0.0897	***

***: significance at 1% level

I focus on energy sources. If the main energy source is nuclear power, the probability to choose alternative 1 decreases by 25.73%. If the main energy source is solar power, the probability to choose alternative 2 increases by 21.43%. If the main energy source is wind power, the probability to choose alternative 3 increases by 8.97%.

7. Comparison of households' preference between in Kanto and Kansai area

I examine the difference of households' preference between in Kanto and Kansai area. After the great earthquake households in Kanto area suffered from damage of the accident of nuclear power plants in Fukushima. Moreover they experienced planed outage. I suppose that there is a difference of households' preference 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 area than in Kansai area. Table 14 shows the estimation results of Kanto area and Table 15 shows the estimation results of Kansai area. Both table 14 and 15 show the results of Conjoint A.

Table 14 Estimation results (Kanto, Conjoint A)

variable	coefficient	standard error	z value	p value
random parameters(mean)				
CO2	-0.06255	0.01149	-5.44	0
stability	0.50828	0.21023	2.42	0.0156
nonrandom parameters				
electricity rate	-0.00044	0.00008197	-5.33	0
constant 1	-1.83752	0.2245	-8.18	0
constant 2	-1.22057	0.2308	-5.29	0
standard deviation				
CO2	0.09631	0.00886	10.87	0
stability	2.53026	0.20798	12.17	0

log likelihood -1606.53851

McFadden R^2 0.2688328

Table 15 Estimation results (Kansai, Conjoint A)

variables	coefficient	standard error	z value	p value
random parameters(mean)				
CO2	-0.04882	0.01113	-4.39	0
stability	0.72901	0.22392	3.26	0.0011
nonrandom parameters				
electricity rate	-0.00039	0.00008036	-4.89	0
constant 1	-1.13019	0.21448	-5.27	0
constant 2	-1.2816	0.23085	-5.55	0
standard deviation				
CO2	0.09778	0.00774	12.63	0
stability	2.80004	0.21871	12.8	0

log likelihood -1658.43998

McFadden R^2 0.2452114

Table 16 shows WTP of Kanto and Kansai.

Table 16 WTP (Conjoint A)

variables	Kanto	Kansai
CO_2	-142.16	-125.18
stability	1155.18	1869.26

WTP for stability in Kansai area is bigger.

Table 17 and 18 are the results of Conjoint B.

Table 17 Estimation results (Kanto, Conjoint B)

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
nonrandom 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 -1650.38316

McFadden R^2 0.2488783

Table 18 Estimation results (Kansai, Conjoint B)

variables	coefficient	standard	z value	p value

		error		
random parameters(mean)				
CO2	-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
nonrandom 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				
CO2	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 -1646.62879

McFadden R^2 0.2505869

Table 19 WTP (Conjoint B)

variables	Kanto	Kansai
CO2	-66.15	-48.49
stability	663.18	928.51
nuclear	-5135.20	-5306.07
solar	1405.86	1272.80
wind	640.46	595.51

WTP for stability in Kansai area is bigger than in Kanto area. On the other hand WTP for renewable energy sources in Kanto area is bigger than in Kasai area.

Lastly, I examine the difference of households' preference between in Kanto and Kansai area. I test the difference of parameters. If the preference is different, households in Kanto and Kansai area make different choice of energy and electric power company. I test the difference by the likelihood test and use the following test statistics.

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

LL(A+B) is log likelihood which I get after estimation by using pooling data including Kansai and Kanto area. Null hypothesis is that preference or parameter between in Kanto and Kansai area is equal. Alternative hypothesis is that preference or parameter is not equal. The test statistics is chi-squared distributed with degrees of freedom which is the number of parameters.

The calculated statistic is 49.381 in Conjoint A. Null hypothesis is rejected because the critical value for the 5% significance level is 14.067 for degrees of freedom 7. The preference is different between in Kanto and Kansai area. On the other hand, in Conjoint B the calculated statistic is 0.392. Null hypothesis is not rejected because the critical value for the 5% significance level is 22.362 for degrees of freedom 13. The preference is not different between in Kanto and Kansai area. These results are opposite. But we can conclude that when households choose energy sources households in Kanto and Kansai area have different preference but when households choose an electric power company they don't have different preference.

8. Policy implication

I estimate the preference of Japanese households for energy sources by conjoint analysis and calculate willingness to pay (WTP) for energy sources and attributes. WTP for nuclear power is negative. On the other hand WTP for renewable energy sources such as solar and wind power is positive. And WTP for the stability of electric supply is positive. Japanese households evaluate renewable energy sources and the stability of electric supply but don't evaluate nuclear power. From this study we should reduce the share of nuclear power and promote renewable energy sources. Households will pay higher electricity rate for renewable energy sources. Households will accept nuclear power if the rate is lower from WTP. This study may support the feed-in-tariff system for promotion of renewable energy sources.

Aftermath the great east Japan earthquake in March 2011, restart of nuclear power plants is difficult and we have to change the energy policy whose main energy source is nuclear power. At least it is impossible to enlarge the share of nuclear power and regain the share before the earthquake. We only should reduce the share of nuclear power. Thermal power which is the main energy source after the earthquake is difficult to enlarge because of global warming problem and rising fuel costs. Saving electricity use and planed outage have limitation. Renewable energy sources such as solar and wind power which are expected as future energy sources have many problems of instability of supply and electricity price.

Appendix　Results of questionnaire

I show the results of questionnaire. I ask attributes of households and consciousness about energy problems.

Table 20　Attributes of households

question		number	%
	total	500	100.0
1. occupation	company worker	243	48.6
	public worker	28	5.6
	student	2	0.4
	inoccupation（including housewife and retired worker）	135	27.0
	self-employed	45	9.0
	others	47	9.4
2. household income	less than 2,000,000 yen	159	31.8
	2,000,000-3,990,000 yen	116	23.2
	4,000,000-5,990,000 yen	87	17.4
	6,000,000-7,990,000 yen	63	12.6
	8,000,000-9,990,000 yen	36	7.2
	More than 10,000,000 yen	39	7.8
3. educational background	junior high school, high school	122	24.4
	technical school, junior college	119	23.8
	university, graduate school	255	51.0
	others	4	0.8
4. area	Kanto	250	50.0
	Kansai	250	50.0
5. family composition	single	91	18.2
	two persons	131	26.2
	husband and wife(parents) and children	225	45.0
	two households	26	5.2

	others	27	5.4
6. dwelling type	detached house (including two households house)	248	49.6
	collective housing (condominium, apartment, housing complex etc.)	241	48.2
	company housing, dormitory housing etc.	11	2.2
7. installation of solar panels	now install	35	7.0
	now haven't installed, but have a plan to install	6	1.2
	now haven't installed, but have an interest to install	144	28.8
	now haven't installed and don't have plan to install in the future	315	63.0
8. now using energy sources	all- electric service	54	10.8
	electricity and city gas	369	73.8
	electricity and propane gas	77	15.4

In this questionnaire, I ask households' consciousness about energy and energy saving as well as social attributes.

Do you think electricity rate becomes higher after the great east Japan earthquake? (choose 1 alternative)

	number	%
total	500	100.0
Yes, totally agree	182	36.4
Yes, slightly agree	207	41.4
Yes or no	83	16.6
No, slightly disagree	24	4.8
No, totally disagree	4	0.8

Do you become conscious of saving electricity use after the great east Japan earthquake? (choose 1 alternative)

	number	%
Yes, more conscious.	130	26.0
Yes, a little conscious.	243	48.6
Unchanged.	114	22.8
No, lesser conscious.	13	2.6

Do you have any knowledge about the deregulation of electric industry for general households? (choose 1 alternative)

	number	%
Yes, I know well.	42	8.4
Yes, I know a little.	176	35.2
Yes, but I have just heard.	212	42.4
No, I don't know at all.	52	10.4
I am not interested in at all.	18	3.6

What electric power company do you purchase electricity from? (choose 1 alternative)

	number	%
Major electric power company in the area.	81	16.2
Major electric power company in other area.	27	5.4
New coming electric power company.	56	11.2
No, not decide yet.	336	67.2

What is the most important in choice of electric power company? (choose 3 the most important alternatives in order)

	total	first	second	third	No answer
1.lower electricity rate	500 100.0	252 50.4	169 33.8	52 10.4	27 5.4
2.stability of electricity supply	500 100.0	202 40.4	216 43.2	38 7.6	44 8.8
3.eco-friendly	500 100.0	14 2.8	30 6.0	108 21.6	348 69.6
4.discounted price with telephone, internet or other electric appliances	500 100.0	2 0.4	21 4.2	82 16.4	395 79.0
5.local production for local consumption of local specific energy sources	500	1	7	15	477

	100.0	0.2	1.4	3.0	95.4
6.main energy source such as solar power	500	3	9	24	464
	100.0	0.6	1.8	4.8	92.8
7.electric power company which doesn't have any nuclear power plants	500	13	11	27	449
	100.0	2.6	2.2	5.4	89.8
8.safty of management of provider	500	13	37	154	296
	100.0	2.6	7.4	30.8	59.2

What do you think about the bid price of the feed-in-tariff system from July 2012? (choose 1 alternative)

	number	%
too high	56	11.2
slightly high	71	14.2
reasonable	104	20.8
slightly low	31	6.2
too low	16	3.2
no idea	222	44.4

What energy sources are suitable for Japan in the future? (choose 3 the most important alternatives in order)

	total	first	second	third	No answer
1. nuclear power	500	81	15	33	371
	100.0	16.2	3.0	6.6	74.2
2.thremal power(coal)	500	13	20	18	449
	100.0	2.6	4.0	3.6	89.8
3.thremal power(natural gas)	500	66	64	53	317
	100.0	13.2	12.8	10.6	63.4
4. hydraulic power	500	51	85	88	276
	100.0	10.2	17.0	17.6	55.2
5.solar power	500	172	74	79	175
	100.0	34.4	14.8	15.8	35.0
6.wind power	500	23	100	69	308

	100.0	4.6	20.0	13.8	61.6
7. geothermal power	500	34	74	77	315
	100.0	6.8	14.8	15.4	63.0
8.biomass	500	42	45	42	371
	100.0	8.4	9.0	8.4	74.2
9.wave and tidal power	500	9	21	29	441
	100.0	1.8	4.2	5.8	88.2
10.others	500	9	2	12	477
	100.0	1.8	0.4	2.4	95.4

Since the Kyoto Protocol in 1997, each country in the world is requested to reduce the emission of CO2 to avoid the global warming. Does Japan reduce the emission of CO2 more? (choose 1 alternative)

	number	%
reduce more	255	51.0
reduce a little	137	27.4
don't need to reduce	30	6.0
increase	6	1.2
no idea	72	14.4

What should we do with nuclear power in the future? (choose 1 alternative)

	number	%
Current major electric power companies should possess.	91	18.2
Countries should manage and private electric power companies should not possess.	168	33.6
abolishment	177	35.4
no idea	64	12.8

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