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家計のエネルギー選好と原発に関する意識調査

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Keio University

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Institute for Economic Studies, Keio University
2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan
ies-office@adst.keio.ac.jp
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【要旨】

慶應家計調査パネルを用いて、個人のエネルギーミックス(再生可能エネルギー、化石燃料、原子力)、とくに原子力発電への考え方や選好を研究した。概ね、原子力発電は今後低減させるべきであると考える個人は多い。人々の選好は家計や個人特性のみならず、幸福度や心理状態、道徳心など、さらには東日本大震災時点での被害や心理状況や原発からの距離が影響していることが分かった。

大久保敏弘
慶應義塾大学経済学部
〒108-8345
東京都港区三田2-15-45
okubo@econ.keio.ac.jp

成田大樹
東京大学大学院総合文化研究科・教養学部
〒153-8902
東京都目黒区駒場3-8-1
daiju.narita@global.c.u-tokyo.ac.jp

Katrin Rehdanz
Department of Economics, University of Kiel
Christian-Albrechts-Universität zu Kiel Institut für
Volkswirtschaftslehre Olshausenstr. 40, 24098 Kiel
rehdanz@economics.uni-kiel.de

Carsten Schroeder
DIW Berlin and Freie Universitaet Berlin
DIW Berlin 10108 Berlin
CSchroeder@diw.de

Preferences for nuclear power in post-Fukushima Japan: Evidence from a large nationwide household survey

Toshihiro Okubo, Daiju Narita, Katrin Rehdanz and Carsten Schroeder[1]

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Abstract

Utilizing data of a large nationwide household survey, we investigate determinants of public preferences on nuclear power in Japan after the Fukushima nuclear accident. The comprehensive household survey data we use allow us to examine the roles of 1) household/individual socioeconomic characteristics, 2) psychological status, 3) geographical aspects, and 4) Fukushima accident-related experiences. We find that male, elderly, unmarried, less educated, high-income people, and government party supporters prefer nuclear power, except if they live near nuclear power plants. The experience of blackout and aversion to nuclear power during the Great East Japan Earthquake of 2011 reinforce people's negative feelings toward nuclear power nowadays.

Keywords: Energy mix, Nuclear power plant, Proximity, Household survey

JEL Classification: Q40

[1] Okubo: Faculty of Economics, Keio University (corresponding) okubo@econ.keio.ac.jp, 2-15-45 Mita Minato-ku Tokyo Japan. Narita: Graduate School of Arts and Sciences, University of Tokyo, Rehdanz: Department of Economics, University of Kiel, Schroeder: DIW Berlin and Freie Universitaet Berlin

1. Introduction

On March 11, 2011, the Great East Japan Earthquake was followed by a devastating tsunami, causing a series of accidents at the Fukushima Dai-ichi Nuclear Power Plant. After this disaster, there was great controversy in Japan and elsewhere about the role of nuclear energy and the future energy mix (Cabinet Office, Japan, 2012). For instance, German Chancellor Angela Merkel reversed her energy policy and announced that all nuclear reactors would close by 2022. Subsequently, Switzerland, Belgium, and Taiwan decided to stop nuclear power generation by 2025. In Japan, public opinion is mixed. Many people are afraid of the huge risks involved in nuclear power generation, and this concern is shared particularly by residents close to nuclear power plants (Institute of Applied Energy, 2013, 2014). People are also concerned about a high dependency on imported oil and gas for thermal power generation, and about the (presumed) high costs of renewable energy techniques (Cabinet Office, Japan, 2012; Kitada, 2015; NHK Bunken, 2016).

This paper studies public preferences in Japan for three different fuels in the energy mix: renewables, fossil, and nuclear. The Keio Household Panel Survey (KHPS) and data on regional subsidies for energy development serve as our empirical basis. In particular, we make use of a novel question included in KHPS's energy module in 2014. The question reads as follows: "*Suppose you could decide about the fuel mix in Japan. What would the mix look like?*", and respondents reported their preferred shares of fossil, nuclear, and renewable fuels in the fuel mix. We use the responses to describe the optimal fuel mix, and how preferences vary along four sets of control variables: (a) individual/household characteristics, (b) individual's psychological status and social views (political stance and belief), (c) past experiences of the Great East Japan Earthquake of 2011, (d) regional/geographical factors (locations of nuclear/thermal power plants). Our study finds several interesting results. First, many individual/household socioeconomic characteristics such as gender, age, income, financial assets, education, and energy costs largely affect an individual's preference on energy mix. Male, elderly, unmarried, less educated, high-income people prefer nuclear power. Second, psychological status, political stance, and attitude to risk are also critical. For instance, government party supporters and those who prefer liberty to equality like nuclear power. Third, past experiences of the 2011 earthquake affect present opinions on energy mix. In particular, experiences of blackouts and aversion to nuclear power during the Great East Japan Earthquake in 2011 reinforce people's current negative feeling toward nuclear power. Fourth, regional characteristics affect people's preferences on energy, e.g. the location of power plants. Those who live near nuclear power plants prefer renewables over nuclear. Our contribution is that these four sets of characteristics are investigated simultaneously whereas previous studies investigated these characteristics separately.

2. Literature Review

A number of studies have studied public preferences on nuclear/renewable power generation. First, public acceptance is determined by characteristics of individuals and households, such as gender, age, income, and education. According to previous survey studies (e.g. Eurobarometer, 2010; Corner et al., 2011; Kim et al., 2014), male, elderly, and less educated people tend to have a positive attitude toward nuclear power generation. Furthermore, an individual's psychological status and social views such as belief, and perspective on liberty, equality, and trust, also matter. Trust (de Groot and Steg, 2010) and fairness (Visschers and Siegrist, 2013) influence acceptance of nuclear power and renewables.

Second, past experience matters. Nuclear power accidents have a tremendously negative social impact. The regions affected by the Chernobyl accident became largely negative to nuclear power (Drottz-Sjoberg and Sjoberg, 1990), although this might only be a short-term phenomenon (Renn, 1990).[2]

Third, geographical distance from nuclear power stations influences public acceptance. Proximity to a nuclear power station negatively influences public acceptance of nuclear power.[3] For example, after the Fukushima nuclear power plant accident, land prices close to the nuclear power stations fell substantially (e.g. Kawaguchi and Yukutake, 2017). In contrast, when people live far away from a nuclear power station, they have less information about and knowledge of nuclear power and less fear; thus, they are more willing to accommodate nuclear power generation (Stoutenborough et al., 2013). Furthermore, regional subsidies from government to compensate for the disadvantage of living near a nuclear power station would mitigate negative public opinion and result in their reluctant acceptance. In the case of Japan, local governments hosting nuclear power plants receive subsidy programs, under the Three Power Source Development Laws, as mentioned below (Lesbirel, 1998).

Finally, the literature on the not-in-my-backyard (NIMBY) effect is relevant to our paper. The conventional view on NIMBY is that people are in favor of nuclear power, but are opposed to nuclear power plants located in their own area (e.g. Burningham et al., 2006). Although our paper does not directly test NIMBY effects in the construction of power plants, understanding why people close to nuclear power stations tend to prefer renewables might be intuitive.

As far as we know, no previous studies simultaneously tested all of these four aspects, i.e. individual/household characteristics, people's psychological status, regional aspects, and past experience. Japan is a centralized nation and homogeneous in terms of institutions, education, and economic situation. However, climate and topology vary across regions, which fosters

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[2] Renn (1990) pointed out the possibility of intensifying public concern by mass media. Indeed, mass media and stigma have a negative impact on public opinion (Gamson and Modigliani, 1989). Sufficient knowledge on nuclear power is most effective in creating public acceptance on nuclear power generation, and trust is most effective in creating reluctant acceptance (Kim et al., 2013, 2014).

[3] See e.g. Wolsink (2000) and Van der Horst (2007) for energy power plant issues.

heterogeneity in culture, lifestyle, and social views. In addition, the Great East Japan Earthquake seriously damaged the coastal area of East Japan, but damage was not nationwide. Since many factors would affect public preferences on energy, our paper investigates all four of these factors. Furthermore, most previous studies used simple, one-shot survey questions without requesting details about individual background/characteristics/experience/belief and residential place. By contrast, our interest is in covering conventional aspects of the individual, household, and region. The Keio Household Panel Survey (KHPS) enables us to estimate what factors affect people's energy preference. The data include individual characteristics (e.g. household location, income, gender, number of family members, financial assets), political stance, attitude to risk, behavior, and experiences just after the Fukushima earthquake, and noncognitive aspects. KHPS 2014 includes energy preference.

Many researchers conducted empirical analyses on public preferences on energy sources. Most found that people tend to prefer renewable energy (Wustenhagen et al., 2007; Komarek et al., 2011; Groesche and Schroeder, 2011; Cicia et al., 2012).[4] After the Fukushima nuclear accident, as some previous studies suggested, the public's view on the reliability of nuclear energy decreased, and it increased for renewable energy, drawing the attention of the world (e.g. Siegrist and Visschers, 2013; Chen et al., 2014; Siegrist et al., 2014; Kim et al., 2014; Bird et al., 2014; Jacksohn et al., 2019).[5] In Japan, public support for and trust in nuclear power have definitely collapsed after the Fukushima accident (Kato et al., 2013; Poortinga et al., 2013). Thus, renewable energy is considered the most favorable while nuclear energy is the least in Japan (Itaoka et al., 2006; Ida et al., 2015; Murakami et al., 2015; Rehdanz et al., 2017).[6] These previous studies

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[4] According to Reiner (2006), solar power is perceived most favorably in the UK; in general, renewables are perceived as more secure than coal, oil, and nuclear.

[5] Chen et al.(2014) compare Japan, Taiwan, and Korea. Siegrist and Visschers (2013) and Siegrist et al. (2014) study the impact of the Fukushima accident on Switzerland. Bird et al. (2014) study the case of Australia. Kim et al. (2014) find that the acceptance of renewable energy increased in Korea.

[6] Itaoka et al. (2006), Ida et al. (2015), Murakami et al. (2015), and Rehdanz et al. (2017) study the

mainly focus on public energy preference, and some of them conducted cross-country comparisons. In many studies, spatial variations within a country are not taken into account sufficiently.[7] Since our household data include the location information for households and our data on regional subsidies from government for energy generation are at the municipality level, the data allow us to test the effect of location of power plants and regional factors. Our paper studies the factors relating to public preferences on energy sources—in particular, who prefers renewable energy, who accommodates nuclear power, and what factors affect their preference—by taking into account several aspects such as geographical location of households, regional factors, and individual characteristics.

3. Background: Energy Mix and Energy Policies in Japan

Energy supply has always posed a dilemma for modern Japan. As in many other countries, the Japanese public has been anxious about the safety of nuclear power generation. The general awareness of limited domestic energy sources, however, yielded the majority view that while nuclear power is not desirable, it is necessary (e.g. Kitada, 2013). Reflecting this public attitude, major opposition parties in Japanese politics that are challengers of the dominant Liberal Democratic Party (LDP) (which promotes nuclear power), did not take a stance of outright rejection of nuclear power, but one of cautious acceptance. The Atomic Energy Basic Law 1955, which determines the principle of use of nuclear technologies for civilian purposes, was proposed by Diet members including those of the Japan Socialist Party, whose offshoots constitute the main opposition parties to the governing LDP in Japanese politics.

During economic growth periods in the 1960s and 1970s, the Japanese government shifted more

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willingness to pay for renewable and nuclear power energy.

[7] Exceptionally, Rehdanz et al. (2017) use information on the geographical distance from the Fukushima power plant.

toward nuclear power. On the one hand, high population density and intensive industrial activities imply high energy demand. On the other hand, Japan's resource base of fossil fuels is seriously limited. As the switching of fuel from expensive domestic coal to imported oil had taken place in the 1960s, the country had an increased dependence of energy supply on oil imports, but this resulted in a series of domestic energy shortages during the 1970s as a consequence of the global oil crises. Since then, the Japanese government has attempted to diversify energy sources, and the use of nuclear power has been promoted in that context.

Nuclear power plants have been constructed under the initiatives of private entities, and the role of the national government in promoting nuclear power has mostly been financial support for hosting local governments, particularly in the form of subsidies under the Three Power Source Development Laws established in 1974.[8] For instance, construction of the Fukushima Dai-ichi power plant was also in private hands, with the Tokyo Electric Power Company (TEPCO) as the owner and operator of the plant. In contrast, hosting by local government attracts a subsidy. The subsidy scheme is aimed at reducing high dependency on thermal power generation and is applied to local governments engaged in, not only nuclear power generation, but also any energy generation other than thermal power, as discussed below. Besides the subsidies, the hosting local municipalities also enjoy large amounts of corporate and property tax revenues, and the prospect of these financial incentives has been an easing factor for the siting of nuclear power plants, which are mostly located in remote areas without any strong industrial base.[9]

After the 2011 accident, public opinion about nuclear power has naturally shifted negatively. However, due to the unchanging dilemma of Japanese energy demand, the policy stance on the

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8 Electricity is mostly supplied by 10 regional vertically integrated monopolies, which are private companies under governmental oversight based on the Electricity Business Act. For example, one of these firms, the Tokyo Electric Power Company (TEPCO) has service areas covering the Kanto region (7 prefectures), Yamanashi prefecture, and some municipalities of Shizuoka prefecture (east side of the Fuji River).

9 See Lesbirel (1998) for example.

energy mix after the accident is still ambiguous. On the one hand, the government has leaned toward renewable energies. The feed-in-tariff system was introduced in July 2012 and expansion of the share of renewable resources was put on the political agenda. On the other hand, the LDP has sought to operate nuclear power plants under the new safety standard. In July 2013, the Diet in fact passed legal amendments to restructure the regulatory system, now with significantly tighter safety standards for nuclear power plants (Nuclear Regulation Authority, Japan, 2016).

Before the 2011 accident, there were 54 commercial nuclear power reactors in operation in the country (Agency for Natural Resources and Energy, 2010).[10] While it was decided to decommission 24 nuclear reactors, the other existing reactors are planned to restart after safety reviews; 9 of these are already in operation as of July 2019. As for the role of nuclear power in the long run, the Strategic Energy Plan approved by the Cabinet in 2018, which is a long-term governmental plan of energy policy being reviewed and updated about every 3 years, states "lower reliance on nuclear power as much as possible" (The Agency for Natural Resources and Energy, 2018, p. 47). More specifically, it sets the target for an energy mix of 20–22% of nuclear power and 22–24% of renewable resources in 2030.

Another feature characterizing the Japanese electricity market today is an ongoing process of liberalization, which will weaken the monopoly status of the 10 regional companies. Since April 2016, the electricity retail market has become fully liberalized, and a breakup of the regional utilities into separate companies for power generation and transmission/distribution will take place in 2020 (The Agency for Natural Resources and Energy, 2018).

4. Data

[10] In 2009, nuclear power energy accounted for 29.2% in total power generation. Japan had the third largest capacity for nuclear power generation in the world.

Our main data are taken from KHPS. KHPS is a two-stage, stratified, random, representative household panel survey conducted by Keio University.[11] KHPS started from 2004 in the form of an annual panel survey, covering around 4,000 households. The location of households can be identified at the municipality level. The basic questions include an individual's basic characteristics, and economic factors such as gender, age, income, education, family member, expense, saving, financial assets, occupation, job status, housing, as well as psychological status, and social views such as moral and social stances. In addition to the basic questions, KHPS includes some year-specific modules.

Most importantly, for our purposes, KHPS 2014 involved a module with energy-related questions (see Rehdanz et al., 2017 for more details). In particular, this module posed the following question to each household:

> *"Suppose you could decide about the fuel mix in Japan. What would the mix look like? ____% renewable; _____% fossil; _____% nuclear. Make sure that the percentages add up to 100."*

This question represents a person's preference on energy mix and is the focal variable in our estimations.

The left panel of Table 1 reports the basic statistics on energy mix. The mean of energy mix

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[11] KHPS uses a two-stage stratified random sampling strategy (see Kimura, 2005). In the first sampling stage, Japan is stratified into 24 regions by regional classification. The number of samples for a region is determined by the population ratio. The number of areas to be surveyed within each region is determined so that around 10 samples are taken for each survey area, which is defined by districts according to the Population Census (Ministry of Internal Affairs and Telecommunication), and a random sampling of the designated number of survey areas is implemented. In terms of survey areas, Population Census survey districts are employed as sampling units. In the second sampling stage, basic resident registers for the selected survey areas are utilized as sampling registers, and approximately 10 respondents for each survey area are drawn from the population. Unlike other surveys, it is difficult to measure response rates in KHPS. When it is not possible to meet and/or survey an officially selected survey subject because they have moved residence, they are absent for an extended period, or their address is unknown, a pre-selected reserve survey subject will be surveyed instead, thereby maintaining the planned sample size. Reserve survey subjects are randomly selected from candidate subjects living in the same survey district, and are the same gender and age group as the official survey subject to be replaced.

variables (0 to 1) is 0.59 for renewables, 0.29 for fossil fuels, and 0.12 for nuclear. In nuclear, the median value is 0 and p90 is 0.4; thus, variation is larger than for other energies. The right panel of Table 1 reports correlations. Renewables are negatively correlated with fossil fuels (–0.68) and nuclear (–0.62). The correlation between nuclear and fossil fuels is weakly negative (–0.15).

Next, Figure 1 plots energy mix preference three-dimensionally. A small number of points are close to a high percentage of nuclear power, while many points are located in the area of higher renewables. Overall, many people prefer less dependency on nuclear and more on renewables and/or fossil fuels.

Appendix Table A1 reports further descriptive statistics and definitions of variables. Household income in our sample amounts to 6,629 thousand yen (5,760 thousand yen in median), whereas it is 5,289 thousand yen (4,150 thousand yen in median) according to the Comprehensive Survey of Living Conditions (Ministry of Health, Labour and Welfare, 2014). Total household saving amounts to 9,010 thousand yen (10,315 thousand yen, Comprehensive Survey of Living Conditions (Ministry of Health, Labour and Welfare, 2016)). Household-level monthly energy expense in our sample amounts to 29,803 yen (20,129 yen (Household Survey, 2014)), financial assets, defined as total security assets, amount to 2,162 thousand yen, average house area is 116 square meters (94.42 square meters (Ministry of Land Infrastructure, 2013)). Average family size is 3.16 persons per household (2.49 persons, Comprehensive Survey of Living Conditions (Ministry of Health, Labour and Welfare, 2014)). Note that we omitted some observations due to missing information. Our working sample includes 4,122 observations.

5. Estimation and Results

5.1 Estimation strategy

Our dependent variable is the reported optimal shares by the KHPS respondents. Each of the following equations are estimated by seemingly unrelated regressions (SUR):

$$(1)\quad Energy\_Renewable_i = \beta_{R1}X_i + \beta_{R2}P_i + \beta_{R3}R_i + \beta_{R4}PX_i + FE_{pref,i} + FE_{occu,i} + \varepsilon_i$$

$$(2)\quad Energy\_Nuclear_i = \beta_{N1}X_i + \beta_{N2}P_i + \beta_{N3}R_i + \beta_{N4}PX_i + FE_{pref,i} + FE_{occu,i} + \varepsilon_i$$

$$(3)\quad Energy\_Fossil_i = \beta_{F1}X_i + \beta_{F2}P_i + \beta_{F3}R_i + \beta_{F4}PX_i + FE_{pref,i} + FE_{occu,i} + \varepsilon_i$$

Importantly, since our energy mix variables are required to satisfy $Energy\_Renewable_i + Energy\_Fossil_i + Energy\_Nuclear_i = 1$, one of the three equations must be omitted due to collinearity. In our regression, we omitted equation (3) *Energy_Fossil*.

Parameter *i* denotes respondents, *X* is a set of variables for household and individual characteristics, *P* represents a set of variables for personal social views and political stance, and *R* is a set of variables for regional characteristics. *PX* is 'past experience' just after the earthquake of 2011. The dependent variable, preferred energy percentage for each energy source for individual *i*, *Energy_Renewable*, *Energy_Nuclear*, takes from 0 to 1. *FE_pref* is a prefectural fixed-effect dummy and *FE_occu* is an occupation fixed-effect dummy.[12] There are 47 prefectures in Japan.

In the first set of regressions, our independent variables are household and individual characteristics ("*X"*), which are taken from KHPS 2014. The variables are basic characteristics and economic factors such as gender, age, the number of family members, income, savings, financial assets, university degree, and energy cost share. All of these independent variables are

[12] The occupation classifications are agriculture, fishery, mining, construction, manufacturing, wholesale and retail, restaurants and hotels, finance and insurance, real estate, transportation, information services, IT, electricity/gas/water/heat supply, medical services, education, public services/government, and others.

often included in social surveys on energy issues and are thought of as crucial factors for Japanese public energy preference (e.g. Cabinet Office, Japan, 2012).

Then, the second set of regressions adds psychological status and some social views ("*P*") such as risk attitude (time preference), preference on liberty or equality and political stance. In the risk attitude, the survey asks "Suppose that you receive 10,000 yen in one month, but instead of receiving 10,000 yen in one month, how much do you want to receive if it is in 13 months?". Higher values indicate a higher time preference. In the variable of liberty or equality, the survey asks which is more important, liberty or equality (or neutral). The value takes –1 (equality), 0 (neutral), or 1 (liberty). Political stance stands for whether the respondent is a supporter of the LDP (the right-wing government party) or a supporter of one of the left-wing parties (Democratic Party of Japan, Social Democratic Party, or Communist Party), which is taken from KHPS 2013.[13] The left-wing parties clearly insist on the abolition of nuclear power generation.

The third set of variables encompasses past experience ("*PX*"). An individual's preference on energy mix might be affected by his/her past experience. In particular, the Great East Japan Earthquake might persistently affect an individual's current preference. For this reason, we use the special survey of the KHPS, the Great East Japan Earthquake Special Survey (GEES). GEES was conducted twice after the Great East Japan Earthquake, in June and October 2011.[14] The survey asks about the experiences after the earthquake as of June 2011, i.e. the experience of nonfunctional gas, water, and telephone; blackouts; opinions for and against nuclear power; and anxiety about future big earthquakes and about Fukushima nuclear accidents. First, the variable

[13] We note that the question on political stance is not available in KHPS 2014 and appears in KHPS 2013. Other than LDP and left-wing parties, there are several parties in the KHPS questionnaire, Komei-Party, Your Party, People's Life Party, National New Party, and Japan Restoration Party.

[14] The household sample of GEES is based on KHPS. The first wave of GEES covers 2,138 households. The scope of the survey questions differs between the first and the second waves. We use some questions on earthquake experiences in GEES in the first wave. The first wave includes an individual's behaviors and feelings just after the earthquake, which is where our interest lies.

for nonfunctional public utilities is measured by counting the number of nonfunctional public services (gas, water supply, and telephone). Then we make a blackout dummy, which takes a value of 1 if the individual experienced blackout in the 2011 earthquake. The GEES survey asks people's opinions about nuclear power generation just after the earthquake, as of 2011 July. The individual chooses one answer from a list of answers to a multiple choice question: "we do not need nuclear and should reduce nuclear power generation (–1)", "we do not need nuclear but I have no opinion on and I am neutral to whether we should reduce or increase nuclear power generation" (0), "we might not need nuclear but we should sustain the current level of nuclear power generation (+1)", and "we need to increase nuclear power generation (+2)". The value is higher if the respondent is positive to nuclear power generation. In terms of anxiety, the GEES survey asks about the respondent's anxiety about 1) future big earthquakes and 2) the threat of a Fukushima nuclear accident. Higher values indicate greater anxiety. The values are taken from 0 to 1.

Finally, regional characteristics are taken into account ("*R*"). Japan has a large variety of regions. Some power plants locate in some specific municipalities, where individuals' preferences on nuclear power energy might be affected. Individuals close to nuclear/thermal power plants might dislike nuclear/thermal power generation. On the other hand, municipalities with power plants receive regional subsidies. We make dummy variables for the location of nuclear power plants and the location of thermal power plants at the city/municipality level. If a power plant is located in a municipality, the dummy takes a value of 1. In the case of nuclear power plants, there are a small number of households in the municipalities with nuclear power stations. Thus, our location dummies for nuclear plants are used as municipalities with nuclear power stations as well as within 30km of nuclear power stations. In 2012, municipalities within 30km of nuclear power stations were set as evacuation areas by the government in case of a nuclear power plant accident.

Furthermore, the government subsidy data for energy production is available. The regional subsidy data are sourced from Subsidies for Power Source Located Region Promotion (Dengen Ritti-chiiki Taisaku Kouhukin) under the Three Power Source Development Laws, as set down by the Ministry of Economy, Industry and Trade, Japan (METI). METI subsidizes some municipalities if the municipalities generate electricity. Our subsidy data are from 2012. We note that since the subsidy is granted for any kind of energy generation other than thermal power generation, the number of subsidized municipalities is much greater than the number of municipalities where nuclear power stations are located. Controlling the population size of municipalities, we use per capita subsidy in the estimation. Another variable on regional factors is the impact of TEPCO. Since electric power companies have a regional monopoly as mentioned above, the territory of TEPCO might have more intense impacts on individuals' energy preference. We make a dummy for the territory of TEPCO. If a household is located in the territory of TEPCO, the dummy takes a value of 1, and otherwise zero. Then we use interaction terms with power plant location dummies and local subsidies.

5.2 Results

Column 1 of Table 2 reports results for the basic estimation including sociodemographic and household/individual characteristics. We find that male respondents tend to prefer nuclear while female respondents tend to prefer renewables. The younger generation prefers both nuclear and renewables, whereas the older generation prefers fossil fuels. Then, larger families prefer renewables while small families or singles prefer nuclear. Higher income persons prefer nuclear, while individuals holding more financial assets prefer fossil fuels. On the other hand, individuals with lower income and smaller financial assets prefer renewables. People without a university degree tend to be positive to nuclear. If the energy expense share is higher, people prefer nuclear.

Column 2 of Table 2 reports the results of adding psychological status, social views, and political stance. The risk variable is significantly positive for renewables, which indicates that people with high time preference prefer renewables. Urban people prefer nuclear. Those who prefer liberty to equality are significantly positive to nuclear. Furthermore, those who support the government party (LDP) are positive to nuclear and negative to renewables, whereas those who support left-wing parties are against nuclear.

Column 3 of Table 2 reports the results on past experiences of the Great East Japan Earthquake. Some past experiences have impacts on the individual's preference. The blackout dummy, "Blackout", is significantly negative in the nuclear equation, while the variable for nonfunctional gas, water supply, and telephone (stop_infra) is significantly positive to nuclear power. Variables for people's anxiety and opinions on nuclear power generation still remain and are largely influenced by their current preference on energy mix. The opinion on nuclear power generation after the Fukushima accident ("Fukushima_opinion") is highly significant and positive in nuclear but significantly negative in renewables. This indicates that an individual's opinion on nuclear just after the earthquake of 2011 still strongly remains over time and affects the current energy preferences. Turning to anxiety variables, an individual's anxiety about the threat of a Fukushima nuclear accident ("anxiety_nuclear") is significantly negative in nuclear, while their anxiety about a future earthquake ("anxiety_eq") is significantly positive.

In a nutshell, those who experienced blackouts, were anxious about the nuclear accident just after the Fukushima accident have retained strongly negative feelings about nuclear power. Therefore, the effects of past experience and anxiety have continued long after the event, and result in an ongoing negative attitude toward nuclear power.

Table 3 reports the estimation on regional characteristics. Column 1 of Table 3 reports the estimation result without interaction terms. All regional variables are not significant. However, once the regions operated by TEPCO are taken into account, the results change. Column 2 of Table 3 shows the effect of interaction with TEPCO. We use a TEPCO dummy and its interaction with power plant location dummies. The TEPCO dummy ("TEPCO") in itself is not significant. The location dummies for nuclear power station ("NPS") and neighborhood (municipalities within 30km of a power plant, "NPS_30km") interacted with the TEPCO dummy are significantly positive as regards renewable energy estimation, although the interaction term of a thermal power plant ("Thermal") is not significant. Thus, people living in municipalities close to nuclear plants in areas where TEPCO operates are positive to renewables. We note that "NPS_30km" stands for municipalities within 30km of a nuclear plant. They are neighboring municipalities but not subsidized, whereas municipalities where nuclear power plants are located are subsidized. On the other hand, "subsidy" relates to subsidized regions under the subsidy scheme by METI, where any kinds of power plants other than thermal are located.

Finally we make comparison across estimations. In all model specifications of Tables 2 and 3, the estimation including all sets of variables, Column 3 of Table 2, takes the highest values of F-statistics and R-square, implying the best model specification. Combining aspects of individual socioeconomic characteristics and past experience results in good explanatory power for the current energy mix.

6. Discussion

Our investigation uncovers the Japanese public preference on energy mix. Overall, unsurprisingly many Japanese prefer less nuclear power and more renewables or fossil fuels (Figure 1). As shown in our estimation results, female, educated, married people, and those who prefer equality to liberty and do not support the LDP tend to prefer renewable energy. Furthermore, people closer to nuclear power plants also prefer renewables. These results are consistent with results of previous social surveys in Japan (Cabinet Office, Japan, 2012) and other previous studies in other countries (e.g. Eurobarometer, 2010; Corner et al., 2011; Kim et al., 2014). In this sense, our results are not surprising.

Our results imply that if the government takes into account public opinion, it would be impossible for the existing energy policy of high dependency on nuclear power to survive. However, oil and gas for fossil fuel generation largely depend on imports while renewables are costly. Thus, various new resources and schemes for power generation might be a solution. This might include household-level or municipality-level power generation, e.g. photovoltaic power generation by household- and municipality-level hydrologic power generation (Ministry of Economy, Trade and Industry, 2016).[15] Thus, the Japanese energy policy needs to shift from nuclear power energy with some regional compensations (subsidy schemes) to the development of new energy resources and to deregulation for household-level and municipality-level energy generation.

7. Conclusion

We study individuals' preference on energy mix in Japan, using KHPS data and some regional data. Our contribution is to estimate the impact of several aspects simultaneously, i.e. an individual/household's basic characteristics, psychological status, social views, their history of Fukushima accident-related experiences, and regional factors. As a result, many individual/household characteristics such as gender, age, income, financial assets, education, and energy costs largely affect an individual's preference on the energy mix. In particular, high-income younger males with small families or who are single prefer nuclear power. Furthermore,

[15] The Ministry of Economy, Trade and Industry (2016) proposed a future plan for hydrogen power generation. Yokohama and Kawasaki cities (Kanagawa prefecture) initiated experiments on a municipality-level hydrogen power generation chain (http://www.pref.kanagawa.jp/docs/e3g/cnt/f460114/keihin.html).
Shunan city (Yamaguchi prefecture) has developed a plan for a city-level hydrogen power generation system (Shunan city, 2015).

psychological status and social views such as social stance, attitude toward risk, and political stance matter. Urban people and those who prefer liberty to equality prefer nuclear power. Past experience of the 2011 earthquake still affects the current opinion on energy mix. People's anxiety about the nuclear power accident and their opinion against nuclear power generation just after the earthquake largely affect their preferred energy mix. In addition to individual characteristics, regional factors also affect an individual's preference on energy, e.g. the location of power plants.

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Table 1: Energy preference

stats	renewable	fossil	nuclear
mean	0.5923	0.2895	0.1182
N	4982	4982	4982
p50	0.6	0.3	0
p10	0.3	0	0
p90	1	0.5	0.4
min	0	0	0
max	1	1	1

	renewables	fossil	nuclear
renewable			
fossil	-0.68 ***		
nuclear	-0.62 ***	-0.15 ***	

***: p<0.1

Table 2: Estimation Result 1

	1		2		3	
	Renewables	Nuclear	Renewables	Nuclear	Renewables	Nuclear
male	-0.0409***	0.0440***	-0.0401***	0.0437***	-0.0359***	0.0384***
	(-5.24)	(7.52)	(-5.07)	(7.39)	(-3.62)	(5.38)
ln_age	-0.0540***	-0.0305**	-0.0505***	-0.0322***	-0.0771***	-0.0053
	(-3.37)	(-2.54)	(-3.08)	(-2.63)	(-3.55)	(-0.34)
family_num	0.0084***	-0.0058***	0.0084***	-0.0057**	0.0044	-0.0022
	(2.86)	(-2.65)	(2.83)	(-2.57)	(1.16)	(-0.81)
ln_income	-0.0086	0.0126***	-0.0091	0.0129***	-0.0058	0.0079
	(-1.40)	(2.77)	(-1.47)	(2.79)	(-0.78)	(1.47)
saving_rate	-0.0380	0.0724	-0.0295	0.0629	-0.0360	0.0414
	(-0.28)	(0.71)	(-0.21)	(0.59)	(-0.23)	(0.36)
ln_house	-0.0069	-0.0013	-0.0074	-0.0008	0.0030	-0.0009
	(-1.02)	(-0.25)	(-1.07)	(-0.15)	(0.34)	(-0.14)
ln_financial	-0.0030**	0.0004	-0.0025	-0.0002	-0.0042**	0.0005
	(-2.04)	(0.40)	(-1.64)	(-0.16)	(-2.36)	(0.40)
university	0.0008	-0.0117*	0.0029	-0.0119*	0.0051	-0.0127*
	(0.10)	(-1.94)	(0.35)	(-1.96)	(0.52)	(-1.77)
energy_cost	0.0010	0.1080**	0.0322	0.0714	-0.0002	0.0375
	(0.02)	(2.50)	(0.53)	(1.58)	(-0.00)	(0.70)
risk			0.0033*	-0.0003	0.0046**	0.0007
			(1.91)	(-0.24)	(2.13)	(0.42)
urban			-0.0177	0.0527***	0.0135	0.0289
			(-0.74)	(-2.94)	(0.46)	(1.36)
liberty			-0.0050	0.0121***	0.0004	0.0114**
			(-1.00)	(3.22)	(0.06)	(2.53)
LDP_support			-0.0164**	0.0188***	-0.0109	0.0148**
			(-1.99)	(3.05)	(-1.09)	(2.05)
Left_support			0.0240	-0.0456*	-0.0210	-0.0209
			(0.67)	(-1.71)	(-0.52)	(-0.71)
blackout					0.0216	-0.0326**
					(0.98)	(-2.06)
stop_infra					-0.0113	0.0130*
					(-1.11)	(1.78)
Fukushima opinion					-0.0313***	0.0376***
					(-9.19)	(15.31)
anxiety_eq					-0.0292	0.0302**
					(-1.49)	(2.14)
anxiety_nuclear					0.0360	-0.0359**
					(1.59)	(-2.19)
N	4122	4122	4,053	4,053	2478	2478
R-sq	0.0486	0.048	0.0507	0.0537	0.1034	0.1624
F-value	2.79	2.76	2.71	2.88	3.37	5.66

Table 3: Estimation Result 2

	1		2	
	Renewables	Nuclear	Renewables	Nuclear
male	-0.0356***	0.0383***	-0.0350***	0.0380***
	(-3.59)	(5.37)	(-3.53)	(5.32)
ln_age	-0.0763***	-0.0055	-0.0761***	-0.0060
	(-3.50)	(-0.35)	(-3.49)	(-0.39)
family_num	0.0045	-0.0023	0.0044	-0.0022
	(1.17)	(-0.84)	(1.17)	(-0.80)
ln_income	-0.0058	0.0079	-0.0059	0.0079
	(-0.77)	(1.47)	(-0.79)	(1.45)
saving_rate	-0.0327	0.0388	-0.0409	0.0431
	(-0.21)	(0.34)	(-0.26)	(0.37)
ln_house	0.0033	-0.0008	0.0038	-0.0012
	(0.37)	(-0.13)	(0.43)	(-0.19)
ln_financial	-0.0042**	0.0005	-0.0043**	0.0006
	(-2.38)	(0.41)	(-2.40)	(0.43)
university	0.0051	-0.0128*	0.0048	-0.0128*
	(0.51)	(-1.78)	(0.48)	(-1.79)
energy_cost	0.0023	0.0372	0.0087	0.0347
	(0.03)	(0.70)	(0.12)	(0.65)
risk	0.0046**	0.0007	0.0045**	0.0007
	(2.14)	(0.44)	(2.10)	(0.45)
urban	0.0130	0.0308	0.0116	0.0300
	(0.43)	(1.43)	(0.39)	(1.38)
liberty	0.0004	0.0114**	0.0004	0.0115**
	(0.06)	(2.54)	(0.07)	(2.56)
LDP_support	-0.0108	0.0147**	-0.0103	0.0145**
	(-1.07)	(2.02)	(-1.02)	(2.00)
Left_support	-0.0196	-0.0211	-0.0187	-0.0206
	(-0.48)	(-0.72)	(-0.46)	(-0.70)
Thermal	0.0057	0.0000	-0.0057	0.0057
	(0.29)	(0.00)	(-0.25)	(0.36)
NPS	-0.0493	-0.0123	-0.0992**	-0.0130
	(-1.21)	(-0.42)	(-1.97)	(-0.36)
NPS_30km	0.0012	0.0091	-0.0164	0.0123
	(0.04)	(0.44)	(-0.52)	(0.55)
subsidy_pop	-0.0010	0.0011	-0.0005	0.0000
	(-0.27)	(0.44)	(-0.14)	(0.03)
TEPCO	-0.0054	0.0225	-0.0371	0.0174
	(-0.12)	(0.73)	(-0.79)	(0.51)
NPS#TEPCO			0.2590**	-0.0582
			(2.29)	(-0.71)
NPS_30km#TEPCO			0.2450**	-0.0964
			(2.20)	(-1.20)
Thermal#TEPCO			0.0448	-0.0302
			(0.96)	(-0.90)
TEPCO#subsidy_pop			-0.0167	0.0117
			(-1.49)	(1.44)
blackout	0.0226	-0.0330**	0.0205	-0.0328**
	(1.02)	(-2.08)	(0.93)	(-2.06)
stop_infra	-0.0109	0.0130*	-0.0108	0.0131*
	(-1.07)	(1.77)	(-1.06)	(1.78)
Fukushima opinion	-0.0312***	0.0376***	-0.0310***	0.0375***
	(-9.14)	(15.29)	(-9.09)	(15.25)
anxiety_eq	-0.0295	0.0303**	-0.0287	0.0303**
	(-1.51)	(2.15)	(-1.47)	(2.14)
anxiety_nuclear	0.0364	-0.0359**	0.0385*	-0.0374**
	(1.60)	(-2.19)	(1.69)	(-2.28)
NoB	2478	2478	2,478	2,478
R-sq	0.1043	0.1627	0.1072	0.1638
F	3.2	5.34	3.15	5.14

Appendix Table: Basic Statistics

stats	mean	N	p50	min	max	Data source	Definition
male	0.5026	5008	1	0	1	KHPS2014	One if respondent is male, zero otherwise
ln_age	3.9493	5008	3.989	3.091	4.522	KHPS2014	Age of the respondent
family_num	3.1577	5008	3	1	10	KHPS2014	Number of family
ln_income	6.2916	4712	6.358	0	8.854	KHPS2014	Total income
saving_rate	0.0154	5008	0.005	0	0.443	KHPS2014	Share of saving in income
ln_house	4.5733	4427	4.605	1.099	7.272	KHPS2014	Area of respondent's house
ln_financial	1.4732	5008	0	0	9.904	KHPS2014	Total financial asset
university	0.4157	5008	0	0	1	KHPS2014	One if respondent has university degree
energy_cost	0.1178	4871	0.106	0	1.2	KHPS2014	Share of energy cost in total expense
risk	5.6824	4921	6	1	8	KHPS2014	Risk variable for time preference
urban	0.4980	5008	0	0	1	KHPS2014	One if respondent lives in Greter Tokyo, Greater Osaka and Nagoya
liberty	0.1480	4966	0	-1	1	KHPS2014	1(-1) if repondent prefers liberty (equality). Zero if neutral.
LDP_support	0.3169	5008	0	0	1	KHPS2013	One if respondent supports LDP, zero otherwise
Left_support	0.0118	5008	0	0	1	KHPS2013	One if respondent supports left-wing parties (Democratic Party, Social Democratic Party, Communist Party), zero otherwise
Thermal	0.0683	5008	0	0	1		One if respondent lives in municipalities that thermal power plants locate, zero otherwise
NPS	0.0266	5008	0	0	1		One if respondent lives in municipalities that nuclear power power plants locate, zero otherwise
NPS_30km	0.3562	5008	0	0	1		One if respondent lives within 30km from nuclear power power plants locate, zero otherwise

subsidy_pop	0.9402	5008	0	0	11.56	METI	Per-capita subsidy of energy development at municipality level
blackout	0.0639	5008	0	0	1	GEES	One if respondent experienced blackout in 2011 earthquake.
stop_infra	0.2167	5008	0	0	3	GEES	The number of stopped infrastructures respondent experienced.
Fukushima opinion	0.5583	3054	1	-1	2	GEES	Opinion on nuclear power just after the 2011 earthquake
anxiety_eq	0.5463	3168	0.6	0	1	GEES	Anxiety on future earthquake
anxiety_nuclear	0.7689	3183	0.8	0	1	GEES	Anxiety on Fukushima nuclear power accident.

Figure 1: 3D-Plot of Energy Preferences