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Consumers' willingness to pay for renewable and nuclear energy: A comparative analysis between the US and Japan

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ABSTRACT

This paper examines consumers' willingness to pay for nuclear and renewable electricity as two alternatives to fossil fuels for the reduction of greenhouse gas emissions. We conduct a choice experiment of consumer-stated preferences on the basis of an online survey in four US states and Japan after the Fukushima nuclear plant accident. First, the results suggest that US consumers' willingness to pay for a 1% decrease in greenhouse gas emissions is $0.31 per month, which is similar to the results for the US a decade ago. Japanese consumers show a slightly lower willingness to pay of $0.26 per month. Second, the average consumer in both countries expresses a negative preference for increases in nuclear power in the fuel mix (to a greater extent in Japan). Third, renewable energy sources were endorsed by both US and Japanese consumers, who show a willingness to pay $0.71 and $0.31 per month for a 1% increase in the use of renewable source energy. This study also examines the differences in respondents' characteristics. Approximately 60% of the US respondents who did not change their perception concerning the use of nuclear energy subsequent to the Fukushima nuclear crisis have almost no preference for variation in nuclear power, which is in stark contrast to the Japanese respondents' opposition to nuclear energy.

1. Introduction

Increasing awareness of global environmental problems and the requirements for greenhouse gas (GHG) emissions reduction is the motivation for this study. The Great East Japan Earthquake of March 2011 and the subsequent accident at the Fukushima nuclear plant raised concerns about the trade-offs involved in replacing fossil fuels with renewable sources and nuclear power to meet climate change goals.

Changing power sources present advantages and disadvantages that add to a complex process. For example, nuclear power has the potential to meet emissions reduction targets; however, it also brings nuclear power generation risks such as the environmental impact of radioactive waste and damage to the health of populations in the event of a catastrophe. Renewable energy also has the potential to drastically reduce GHG emissions and, as is the case with nuclear energy, it may have additional benefits such as decreasing the need for imported energy sources. The pursuit of renewable energy entails substantial investment, intermittent supply, and associated negative local externalities, such as altered landscapes, noise, and potential harm to birds. Therefore, consumer opinion should be sought concerning the benefits and drawbacks of each power source.

According to previous social survey findings, substantial public opposition to nuclear energy exists in conjunction with the endorsement of renewable energy investment (Ertor-Akyazi et al., 2012; Greenberg, 2009).[1] Moreover, the extent to which people are willing to pay a price premium for green electricity is examined in numerous empirical studies. These studies find that people prefer renewable energy (Goett and Hudson, 2000; Menges et al., 2005; Grösche and Schröder, 2011; for a comprehensive review of recent literature, see Menegaki, 2008; 2012 and Zoric and Hrovatin, 2012). Consumers prefer to avoid the risks related to nuclear power generation and prefer the implementation of future renewable energy generation systems. However, recent evidence concerning relative consumer willingness to pay (WTP) for emissions reduction through changing electricity sources, particularly nuclear relative to renewable sources, is insufficient. The extent to which WTP differs according to the source type, and according to the characteristics of the consumer, is unknown. The Fukushima nuclear crisis revealed evidence of change in consumer attitudes toward the

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[1] Extensive literature addresses public preference for different energy sources. Ertor-Akyazi et al. (2012) provide a comprehensive review of previous social surveys and results concerning the endorsement of and opposition to renewables and nuclear power. Greenberg (2009) reports the recent preferences of US households.

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electric power source mix that includes nuclear and other alternative energy (Hartmann et al., 2013; Kato et al., 2013; Kim et al., 2013; Siegrist et al., 2014; Stoutenborough et al., 2013).[2] The extent to which this affects relative WTP is a key issue and lends support to the further investigation of consumer preferences.

Roe et al. (2001) were the first to evaluate consumers' WTP for green electricity using a choice experimental design that included a mix of fuels. The research finds that a higher level of WTP for emissions reduction stems from increased reliance on renewable resources, and a lower level of WTP for emissions reduction stems from a reliance on nuclear power (for questionnaire details, see Winneg et al., 1998). Based on this, Borchers et al. (2007) estimate the WTP for each renewable energy source such as wind, solar, farm methane, and biomass, individually, and find that solar energy is the first preference for US households, although nuclear energy was not considered.

The results of Roe et al. (2001) also suggest that US consumers' WTP varies depending on the population segment. For certain segments only, larger premiums can be obtained for emissions reduction that is accompanied by increased reliance on renewable fuels. Recent studies such as Komarek et al. (2011) and Cicia et al. (2012) investigate those who prefer each energy source in the context of market segmentation and public decision making.[3] The study for the US by Komarek et al. (2011), and that for Italy by Cicia et al. (2012), showed that consumer WTP varies according to socio-economic characteristics and environmental awareness. Yoo and Ready (2014) is the most recent paper investigating consumers' attitudes toward multiple renewable energies in Pennsylvania using choice experiments. The paper addresses preference heterogeneity concerning different renewable technologies. Nuclear energy was not included for consideration.[4]

This paper addresses consumer preference for two alternative fuels, nuclear and renewable sources, as replacements for fossil fuels. We estimate the trade-off involved in replacing fossil fuels with renewable sources and nuclear power with the aim of reducing GHG emissions. This study expands the work of Roe et al. (2001) in terms of sample size and estimation model and compares the results from four US states and Japan. This is the first comparative study of US and Japanese preferences for renewable and nuclear energy, and the first to use a choice experiment method and the same questionnaire. The trade-offs with respect to different renewable sources are dependent on local geographical characteristics (e.g., the amount of sunlight or wind), whereas the priorities for renewable sources relative to nuclear and fossil fuels are dependent on broader social or political choices. The latter are of primary interest in this study and narrow the scope of the survey. Additionally, the results of this study have policy implications concerning future decisions to adopt renewable portfolio standards and target levels. For more details on these policies, see Schmalensee (2012).

The rest of this paper is organized as follows. Section 2 explains the online stated preference survey method and the experimental design. Section 3 describes the discrete choice model used for estimation. Section 4 contains details of the estimation results and compares the WTP values of the mixture of electric energy sources. Section 5 extends the analysis to differences in respondents' characteristics, the expected acceptability for several future energy services, and several policy implications. Section 6 presents the conclusions.

2. Survey and design

Approximately 1 year after the Fukushima disaster, in February 2012, we randomly drew a sample from 4202 US households from four US states (web survey)—California, Michigan, New York, and Texas.[5] These states were chosen to reflect the diversity of circumstances and attitudes that exist across the US. The selected states differ from one another and from other areas of the country and use different electricity management systems.[6] However, the survey responses were similar in each of the four states. Thus, this study will sometimes refer to the average as the US result. For comparison, we conducted a similar survey in Japan, which randomly drew a sample of 4000 Japanese households 1 year later in February 2013 (approximately 2 years after Fukushima).[7] In contrast to some of the US states, Japanese consumers cannot choose their electricity provider and energy sources, but public interest in the ability to do so has been increasing since the Fukushima nuclear crisis.[8]

The respondent demographic profiles are presented in Table 1. No remarkable differences are observed between the four US states and Japanese households with respect to age. However, the percentage of female respondents in the US and Japan is in the range of 55% to 67% (US) and 50% (Japan), respectively. Additionally, there are a greater number of respondents with no bachelor's degree and lower household income in the Michigan state sample. There are differences in monthly electricity expenses between the US and Japan. Over half of US respondents pay at least $100 for electricity each month, whereas many Japanese

[2] Kato et al. (2013) report the negative shift of attitudes toward the advantages and disadvantages of hosting nuclear power plants by comparing local citizens' response data from 2010 and 2011. The authors explain change in consumers' attitudes and safety perceptions concerning nuclear power plants based on public sector knowledge and information (Stoutenborough et al., 2013) and the perception of risk and emotional fear (Hartmann et al., 2013; Siegrist et al., 2014). For a review of changes in consumers' attitudes toward the mixture of electric sources, see Kim et al. (2013). The authors examine the effect of the Fukushima disaster on global public acceptance of nuclear energy using extensive Global Snap Poll data, which was conducted by WIN–Gallup International in 42 countries.

[3] Komarek et al. (2011) compare different preferences for campus energy strategies with respect to fuel portfolios including nuclear power among three types of members of a large university campus community in the US. Cicia et al. (2012) estimate preferences for wind, solar, biomass, and nuclear energy using a latent class model in Italy. The authors utilize choice experiments to investigate the WTP for different shares and types of renewable energy sources.

[4] Shin et al. (2014) is another recent study that investigates consumers' preferences concerning renewable policy using choice data. The authors focus on specific attributes of the renewable portfolio standard policy such as employment, length of electricity shortage, and damage to forest areas in Korea.

[5] The US sample was randomly drawn from the panel. Participants were aged between 18 and 79 years and pre-recruited by the US research company, Lightspeed GMI (http://www.lightspeedgmi.com/). From a total of 11,740 individuals who had visited the survey site, 4637 questionnaires were submitted (a gross response rate of 39.5%). Of those, 435 were unusable because of unreasonably rapid response times. This led to a net response rate of 35.8%. This observed response rate was higher than the traditional mail survey reported by previous studies (cf. 24% (Mannesto and Loomis, 1991), 30% (Bateman et al., 1997)). For the definition and discussion of response rates for web-based surveys, see Fleming and Bowden (2009) and Morrison et al. (2013).

[6] California is in the west, Michigan the mid-west, New York the northeast, and Texas the south. Texas has by far the greatest amount of competition at both wholesale and retail levels (where customers can choose from competing power suppliers), followed by New York, which has substantially less retail competition for residential customers. California is next and has substantial wholesale competition but almost no retail competition for residences, followed by Michigan, which has limited power supply options.

[7] The Japanese sample was randomly drawn from the panel aged between 20 and 79 years and pre-recruited by the Japanese Internet research company, MyVoice (http://www.myvoice.co.jp/). From a total of 5289 individuals who had visited the survey site, 4673 questionnaires were submitted (a gross response rate of 88.4%), of which 673 were unusable because of unreasonably rapid response times. This led to a net response rate of 75.6%.

[8] With the rapid growth of the application of web-based surveys in stated preference studies, the sample representativeness and hypothetical bias of Internet users are examined by recent literature. Although there are some mixed results in recent studies on survey mode effect on WTP, several studies found Internet-based CV surveys to provide similar results to telephone surveys (Berrens et al., 2003; Li et al., 2009), traditional mail surveys (Banzhaf et al., 2006; Fleming and Bowden, 2009), and face-to-face surveys (Nielsen, 2011). In a choice experiment study, Olsen (2009) reported no significant differences in the unconditional WTP estimates in spite of differences in demographics between Internet and traditional mail survey modes. Olsen also found that Internet surveys have an advantage over traditional mail surveys in terms of receiving valid replies, leading to higher effective response rates. These findings suggest that the Internet has the potential to become a valuable tool for non-market valuation. Mozumder et al. (2011), which is a recent study using an online sample in a context of energy policy, reported WTP highly adjusted for sampling bias and hypothetical bias. For a very recent and comprehensive study, see Meyerhoff et al. (2014), which explores the effects of respondent and survey characteristics and Internet survey mode effects through a meta-study based on datasets from previous stated preference studies including choice experiments.