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Voluntary electricity conservation of households after the Great East Japan Earthquake: A stated preference analysis

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ABSTRACT

This paper examines the voluntary electricity-saving awareness of households after the Great East Japan Earthquake and the subsequent accident at the Fukushima nuclear power station. We conduct a conjoint analysis of consumer stated preferences for the settings of air conditioners, refrigerators, and the standby power of electrical appliances, based on a web questionnaire survey administered in the areas supplied by the Tokyo Electric Power Company (TEPCO) and Kansai Electric Power Company (KEPCO). The main findings of this paper are as follows. First, we observe awareness of voluntary electricity conservation among the households in both the TEPCO and KEPCO areas after the disasters. Second, awareness of voluntary power saving is higher in the TEPCO area, which has been directly affected by the electric power shortages, in comparison with the KEPCO area, where there was no such direct impact. Third, if power prices are to be further raised, the consumer responses to the price changes would be small in both areas. Furthermore, we show that the potential voluntary reduction in electric power consumption of a household in the TEPCO area is 26% more than that in the KEPCO area during the summer peak periods.

1. Introduction

The Great East Japan Earthquake on March 11, 2011, led to the severe accident of the Fukushima nuclear power station. TEPCO had to suspend the electric power supply from the Fukushima Dai-ichi (No. 1) and Dai-ni (No. 2) nuclear power plants, totaling 9000 MW. Moreover, some of the thermal power plants located around Tokyo Bay also suffered significant damage due to the earthquake. As a result, the power supply to the Tokyo metropolitan area was initially expected to be reduced to 50,000 MW during the summer peak of 2011 against an estimated demand of 55,000 MW to 60,000 MW. Thus, the power shortages in the TEPCO area were expected at the peak hour of the day (typically, 2:00–3:00 pm) in the summer of 2011, although the power supply was estimated to be sufficient to meet a much lower demand in the nighttime. Note that it is critical to induce "peak-time" conservation rather than general daily or monthly energy savings, which include night-time conservation, in order to avoid power outage in this situation.

To manage the power shortages in the daytime in the TEPCO area, the central government decided to mandate large-scale customers in industrial and commercial sectors (contract demand of 500 kW or more) to reduce their power consumption during peak times by 15% as compared to the summer of 2010, under the Electric Utility Law.[1] On the other hand, the government requested household consumers to voluntarily reduce their power consumption by 15%. The major reasons for merely requesting households to voluntarily conserve electricity are the lack of rules governing household consumption under the law and also the lack of real-time power meters for household consumers. Unfortunately, the real-time meters that enable hourly or half-hourly metering of electricity consumption have not been installed for residential customers, while those meters have already been introduced to the industrial and commercial sectors in Japan. Hence, the government and even the electric power companies cannot measure the actual hourly consumption of electricity by individual households during peak hours of the day.

However, it should be emphasized that peak-time conservation by households is important for overcoming power shortages since household demand is estimated to constitute one-third of all electric power consumption during peak times in Japan. Therefore, a question arises about the degree of potential voluntary conservation at the peak time by households in the TEPCO area. We investigate the

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[1] The same rule was also applied in the area supplied by Tohoku Electric Power Company in northern Japan, where the huge earthquake hit.

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electricity-saving awareness of households confronted with this recent power crisis. Specifically, this paper presents a conjoint analysis of consumers' stated preferences for power conservation during peak periods, using double-sided censored regression models. The analysis is based on a web questionnaire survey administered in both the TEPCO and KEPCO areas in April, 2011, soon after the earthquake disaster. We compare the results for the TEPCO area, which has been directly affected by the power shortages, with those for the KEPCO area, which has the second largest electricity demand in Japan but which was not directly impacted by power shortages.[2] The KEPCO area is suitable for comparison because it has a big city, Osaka, and the surrounding suburban and rural districts as in the TEPCO area.[3]

The majority of power consumption in Japanese households is for air conditioners, which contributes to rising electricity demand during peak periods in summer. Air conditioners constitute 58% of the power consumption in households (with people present) during peak times in summer, followed by refrigerators that constitute 17% of consumption (ANRE, 2011). The standby power used by many electrical appliances also contributes to the electricity consumption of households. In this paper, we focus on consumers' stated preferences for the temperature settings of air conditioners, the cooling intensity of refrigerators, and the frequency of suppressing standby power consumption of electrical appliances.

Previous studies using stated preference analysis of household power usage include papers that examine the purchase selection of electrical appliances such as air conditioners (Dubin and McFadden, 1984; Hausman, 1979; Revelt and Train, 1998). Some papers present stated preference analysis of the selection of optional Time-of-Use (TOU) or peak load tariffs (Hausman and Trimble, 1984; Matsukawa, 2001; Train and Mehrez, 1994). Other studies examine the selection of consumption blocks under a block tariff scheme (Herriges and King, 1994). To the best of our knowledge, however, consumer preferences for the settings of electrical appliances have not been fully investigated. Hence, our results contribute to the literature.

Our main findings on consumers' stated preferences are as follows. First, we observe awareness of voluntary electricity conservation among the households in both the TEPCO and KEPCO areas after the disasters. Second, awareness of voluntary power saving is higher in the TEPCO area, which has been affected directly by the electric power shortages, in comparison with the KEPCO area, where there was no such direct impact. Third, if power prices are to be further raised, the consumer responses to the price changes would be small in both areas.

We then apply empirical data of electrical appliances to the stated preferences that we obtain in the aforementioned analysis. Technical reports by the Energy Conservation Center of Japan (ECCJ, 2004, 2008) provide the empirical measurements of changes in power consumption due to changes in the settings of electrical appliances. We apply these empirical data provided by ECCJ to the results of the stated preferences in order to calculate the potential reductions in electric power consumption by households in both the TEPCO and KEPCO areas.

The potential voluntary reduction in power consumption by a household (with people present) during the peak time in summer is estimated to be 112.4 W (103.3 W for air conditioners, 4.9 W for refrigerators, and 4.5 W for standby power) in the TEPCO area, and 89.4 W (82.7 W for air conditioners, 3.5 W for refrigerators, and 3.2 W for standby power) in the KEPCO area. That is, the potential effect per household is 26% larger in the TEPCO area than in the KEPCO area. The overall reduction effect for all households in the TEPCO area is 2.7 times greater than that in the KEPCO area. Our results are consistent with TEPCO (2011), which reports the actual electricity demand of households for the summer of 2011.

The rest of the paper is organized as follows. Section 2 explains the survey method and experimental design of the conjoint analysis. Section 3 provides an exploratory analysis of the survey data. Section 4 presents the double-sided censored regression models used for estimations. Section 5 provides the estimation results and analysis. Section 6 calculates the potential voluntary reduction in power consumption. Section 7 discusses the results of a follow-up survey and the policy implications. Section 8 concludes.

2. Survey and study design

This section explains the survey method and experimental design of conjoint analysis. The survey was conducted online by an investigation company (MyVoice Communications, Inc.) in April 2011, one month after the Great East Japan Earthquake on March 11. The samples were randomly selected from the monitors registered with the company, ensuring that the actual population distribution, age distribution, and gender distribution among prefectures were properly reflected. A total of 1080 samples were obtained, comprising 539 and 541 households from the TEPCO and KEPCO areas, respectively.[4] The respondents received a small pecuniary remuneration for completing the questionnaire.

Conjoint analysis considers the attributes of a service or product. We focus on the primary attributes, that is, electricity tariffs and temperatures. As such, after conducting several pretests, we determined the alternatives, attributes, and levels as follows:

(1) Hypothetical peak surcharge added to the standard electricity tariff (standard rate: 30 US cents/kWh, given 10 US cents = 8 yen).[5]
Levels: none, 20%, 60% and 100%.
(2) Maximum atmospheric temperature (average maximum temperature in summer: 30 °C and 33 °C in Tokyo and Kansai, respectively).
Levels: 28 °C, 32 °C and 36 °C.[6]

There are 4 × 3 combinations of electricity tariffs and temperatures. The respondents were shown these 12 combinations (scenarios) and

[2] If we had obtained the hourly data of peak-time power consumption by individual households in both areas before and after the earthquake, we could have conducted more sophisticated and straightforward econometric analyses such as Difference-in-Difference (DID) estimates. However, as aforementioned, such revealed preferences data are not currently available due to the lack of real-time power meters for household customers. This is why we focus on the post-earthquake situation, and conduct a conjoint analysis of consumers' stated preferences for power conservation during peak periods. The respondents are asked to answer how they would react to the primary attributes levels of electricity tariffs and temperatures, given the post-earthquake condition. We can then examine the impact of the earthquake on the household behavior, by comparing the two areas with different influences of the earthquake.

[3] Chubu Electric Power Company has the third largest electricity demand in Japan but is located just next to the TEPCO area. There are three other utilities, which are more remote from the site of the earthquake than the KEPCO area. However, we do not think that these utilities are very suitable for comparison because they are relatively small-scale and the demographics are considerably different from those in the TEPCO area.

[4] Response rate calculations are not possible because of the way MyVoice Communications, Inc. administers the internet-based survey. MyVoice Communications, Inc. dispatches the online survey to its registered monitors until the agreed number of completed surveys is obtained. For example, Hidrue et al. (2011), who use a similar internet-based survey, argue that calculating response rate for this type of computer-based questionnaire would not be meaningful because one cannot know whether those who have not completed the online survey at the time it was terminated are non-responders or late responders.

[5] The most common type of an electricity tariff for ordinary households both in the TEPCO and KEPCO areas has the structure of a two-part tariff, which comprises a fixed charge and a variable (usage) charge. A variable charge is a standard inverted block rate, which is divided into three blocks so that a higher rate applies as power consumption increases. The second block (over 120 kWh to 300 kWh) is considered to be the typical usage of an average household, and the rate is approximately 30 US cents/kWh in each area. Thus, we assumed that peak surcharge would be calculated based on the second block rate of 30 US cents/kWh in this study. Note that we only took account of households with a standard electricity tariff since the proportion of a residential Time-of-Use tariff is still quite small in Japan (e.g., 4% in the TEPCO area in 2010).

[6] Note that 30 °C and 33 °C correspond to 86 °F and 91 °F, respectively.