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Replacement or additional purchase: The impact of energy-efficient appliances on household electricity saving under public pressures

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HIGHLIGHTS

- Energy efficient air conditioner purchases affect household power savings.
- Additional air conditioner purchase led to significant energy savings.
- Replacement units did not produce more savings than non-purchase.
- "Electricity conservation directives" amount had a significant power-saving effect.
- Altruistic households were more likely to cooperate with power-saving requests.

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ABSTRACT

This study examined the influence of additional and replacement purchases of energy-efficient air-conditioners on power savings. We used a questionnaire survey and measured electricity use data from 339 Japanese households, collected from two city areas with different level of government-requested electricity-saving rates, namely, Osaka (10%) and Matsuyama (5%). The main findings of our study are as follows: (1) Households that purchased energy-efficient air-conditioners saved more electricity than those that did not. (2) "Additional-purchase households" showed significant energy savings, whereas "replacement households" did not. The rebound effect may negate the energy-saving effects of a new air-conditioner. (3) Altruistic attitude is associated with more active participation in power saving. (4) Households in Osaka saved more electricity than those in Matsuyama, probably because the government call to save electricity was more forceful.

1. Introduction

Unlike in Europe and the United States, where central heating and air-conditioning are predominant, houses and apartments in Japan usually use unit cooling and heating in each room.[1] Therefore, Japanese households make frequent purchase and replacement decisions for air-conditioners. Consequently, people in Japan have more energy-efficient investment opportunities (i.e., chances to purchase energy-efficient air-conditioners for replacement or additional use) than those in European countries and United States. These investments have important implications not only for cooling and heating costs but also for total energy demand and the risk of climate change. In Japan, air-conditioners account for 60% of household electricity consumption during peak summer and winter hours (Ministry of Economy, Trade and Industry, 2013).

Several scholars have investigated the relationship between energy-efficient investment and actual energy saving. Halvorsen and Larsen (2001), for example, analyzed the influence of electricity appliance possession on power demand, using Norwegian household panel data. Berkhout et al. (2004) analyzed electricity and gas demand in the Netherlands based on possession of several electric appliances. Davis et al. (2014) evaluated the effect of a large-scale electric appliance replacement program in Mexico, using data on 1.9 million households. Rehdanz (2007) analyzed the factors that contributed to space-heating expenditure, using panel data on 12,000 German households. The results of these studies suggest that high-income, owner-occupier households invest in energy-efficient equipment but tend to not engage in energy-

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[1] According to EDMC (2015), room air-conditioners have a diffusion rate of 90.6% in Japan and their average number per household is 2.76 based on 2013 data.

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saving behavior.

Extending the scope of previous works, this study compares two modes of energy-efficient equipment investment: replacement and additional purchases. While both investment types may contribute to energy saving, we need to perform an empirical analysis to understand how these different appliance-purchase motives actually affect energy-saving behavior. Generally, we can expect that an energy-efficient appliance that has replaced an old appliance contributes to power saving. On the other hand, an energy-efficient appliance purchased additionally would increase power consumption. However, these expectations might not be always right. For example, an energy-efficient appliance that has replaced an old appliance might not contribute to power saving when a rebound effect occurs (Sorrell and Dimitropoulos, 2008). Moreover, the degrees of the response to the government energy-saving policies (as we will discuss below) might be different between two investment types: replacement and additional purchases.

Until the closure of nuclear power plants in Japan after the Great East Japan Earthquake of March 2011 due to safety concerns, approximately 25% of the power supply in Japan was generated by nuclear power (EDMC, 2014).[2] Thus, the shutdown of the nuclear plants caused power shortage, especially in the summer and winter seasons when electricity demand is high. Therefore, power saving was required in all sectors after 2011. In summer 2012, the Japanese government issued an "electricity conservation directive" for seven of the ten regions of Japan (from 1 July to 30 September, 9:00 to 20:00 on weekdays), depending on the expected power shortage.[3] Fig. 1 shows the service areas of the 10 major electric power companies in Japan.[4]

This study targeted households in two cities (Osaka city area in Kansai region and Matsuyama city in Shikoku region) with different electricity-saving goals: a reduction of 10% for Osaka and 5% for Matsuyama from the 2010 level. Therefore, our study can investigate the effect of this policy on household electricity-saving behavior. Moreover, if power demand exceeds power supply, large-scale power failure would occur. Therefore, people might cooperate with each other, saving electricity for themselves and for others. This altruism mirrors the power-saving behavior that aims to mitigate climate change. Thus, we can consider an altruistic attitude as an important determinant of household decisions on saving electricity. We measure the extent of altruism from the responses to five questions and investigate their relationship to electricity-saving behavior (Clark et al., 2003).

The main purpose of this study can be summarized as follows. It aims to compare the impact on electricity demand from two investment modes for energy-efficient equipment: replacement and additional purchase. Our focus is on the electricity conservation directive issued during summer 2012. The econometric analysis in this study would reveal how energy-efficient appliances helped households to comply with the power conservation directive. While analyzing power-saving behaviors, we also consider the effect of the strength of the electricity conservation directive and the role of the altruistic motive.

This paper is organized as follows: Section 2 discusses previous studies on household energy-saving behavior. In Section 3, the data and the method of empirical analysis are described. Section 4 presents the results of our empirical analysis. Section 5 discusses our findings with a focus on energy-efficient air-conditioner purchase and its effects on the level of power savings. Section 6 discusses policy implications of our study, and concludes the paper and notes some limitations of our study.

[2] All 54 nuclear power reactors in Japan were shut down by May 2012 and remain closed as of March 2015.

[3] Since many nuclear power plants in Japan were still working in summer 2011, no electricity-saving request was issued during the season, except for the Kanto and Tohoku regions, where electricity demand is heavy.

[4] The Japanese electricity market is dominated by 10 regional monopolies.

2. Literature review

2.1. Previous studies

Many scholars have studied energy-saving behaviors of households (for literature review, see Madlener (1996); Espey and Espey (2004)). These studies focus on two subjects: energy-efficient investment and energy-saving behavior. Energy-efficient investment involves introducing energy-efficient equipment such as household electric appliances, thermal insulation material, and solar panels. When these equipment are installed, households can reduce energy consumption without changing their daily behavior. On the other hand, energy-saving behavior involves decreasing energy consumption without changing equipment. Energy-saving behavior can be analyzed on a discrete-continuous or conditional demand approach. The discrete-continuous approach to estimating energy demand is based on a discrete or continuous choice analysis of energy equipment (Dubin and McFadden, 1984; Nesbakken, 2001; Halvorsen and Larsen, 2001). The conditional demand approach is based on an energy demand analysis given the features of energy equipment (Leth-Petersen and Togeby, 2001; Meier and Rehdanz, 2010).

2.2. Energy-efficient investments

Studies on energy-efficient investments have analyzed the factors (e.g., socioeconomic characteristics and government policy) that influence household investment decisions. Krumm (1983) conducted a pioneering study in this field that used micro data from 1520 American households. A multinomial logit model was estimated, which distinguished between purchase of room units and installation of central air-conditioning. Household income, housing unit characteristics, and climate conditions significantly affected investment. Cameron (1985) analyzed, also using U.S. household data, the adoption of insulated windows and double-glazed windows with a nested logit model. Cost of investment, energy price, and household income significantly influenced adoption decisions. Scott (1997) studied 1200 Irish households analyzing three types of investments. Household income, ownership form of house, amount of potential energy savings, and time and effort to find optimal equipment significantly affected energy-efficient investment. Targeting 305 households in Switzerland, Banfi et al. (2008) evaluated the willingness to pay for energy-efficient investment by conducting a choice experiment. Households placed significant value on investment benefits. Grosche and Colin (2009) also found, for German households, that the costs and benefits of energy-saving investments have a significant influence on their willingness-to-pays. Furthermore, Nair et al. (2010) showed, targeting 3000 households in Switzerland, that households with higher energy consumption tended to make energy-efficient investments. While these studies used discrete dependent variables, other studies used a Tobit model with investment expenditure as the dependent variable (Mendelsohn, 1977; Montgomery, 1992; Mahapatra and Gustavsson, 2008; Charlier, 2013). Using expenditure data, they examined not only the influencing factors but also their impact on investment. Results of these studies suggest that energy-efficient equipment is generally purchased by high-income, high-energy-spending, owner-occupier households. However, the form of purchase of energy-efficient equipment, which may affect the level of energy saving, has received relatively little attention.