Corporate responses to public pressures and price increases:Evidence from Japan's electricity crisis

Okajima, Hiroko
Okajima, Shigeharu
Takeuchi , Kenji

(Citation)
神戸大学経済学研究科 Discussion Paper,1908

(Issue Date)
2019

(Resource Type)
technical report

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/81011840

Corporate responses to public pressures and price increases:

Evidence from Japan's electricity crisis

Hiroko Okajima
Shigeharu Okajima
Kenji Takeuchi

May 2019

Discussion Paper No.1908

GRADUATE SCHOOL OF ECONOMICS

KOBE UNIVERSITY

ROKKO, KOBE, JAPAN

Corporate responses to public pressures and price increases: Evidence from Japan's electricity crisis

Hiroko Okajima [*]
Towson University

Shigeharu Okajima[†]
Osaka University
of Economics

Kenji Takeuchi [‡]
Kobe University

May 5, 2019

Abstract

Behaviors of non-residential electricity customers during power crises have been underinvestigated. This study adds to the literature by providing some empirical evidence from the analysis of Japan's electricity crisis after the 2011 earthquake using firm-level micro data. The earthquake created a natural experiment to examine the effect of public pressures and price increases on firms' electricity consumptions during a power crisis. Using a DID model, we show that firms' electricity consumption as a whole was elastic to public pressures in a short term but inelastic to price. On closer look, however, the power conservation during public pressures was made by only 30% of the firms. The remaining 70% of the firms were free-riders, but their electricity consumption was actually elastic to price. The result indicates that it is important for policy makers to implement both economic and non-economic incentive interventions to promptly induce conservation from as many firms as possible during power crises as firms tend to respond to either economic or non-economic incentives.

---

[*] Email: hokajima@towson.edu
[†] Email: shigeharu.okajima@gmail.com
[‡] Email: takeuchi@econ.kobe-u.ac.jp

1 Introduction

Power outages can occur anywhere at any time and are not uncommon even in well-developed countries. As electricity plays a vital role in the functioning of the society and economy, the economic loss due to electric power outages can be significant. For example, the cost of weather-related power outages in the United States is between \$18 billion and \$33 billion a year (Executive Office of the U.S. President, 2013). What's worse, the frequency of catastrophic power outages is likely to increase worldwide due to aging infrastructures, increasing numbers of natural disasters and extreme weather conditions, and the growing threat of terror attacks.

Non-residential customers account for about 80% of the world electricity use (U.S. Energy Information Administration, 2017). Therefore, it is very important for policy makers to understand how firms respond to different types of conservation strategies in order to prevent a catastrophic power outage and promptly restore power supply if it happens. There is a large body of literature dedicated to the study of electricity demand (for review, see, e.g., Taylor, 1975; Newsham and Bowker, 2010; Torriti, 2014). However, very few studies have investigated non-residential electricity customers at the firm level. As far as we know, Bjørner, Togeby and Jensen (2001) is the only study that focuses entirely on the analysis of non-residential electricity demand using firm-level micro data. They investigate the influence of various characteristics, such as size and industrial sub-sector, on price and production elasticities using a panel of 2,949 Danish companies from 1983 to 1996. Several other studies, such as Woodland (1993), Arnberg and Bjørner (2007) and Bardazzi, Oropallo and Pazienza (2015), use micro data but analyze aggregate industrial energy demand, including electricity. The other studies that use micro data include Kahn, Kok and Quigley (2014), which analyzes electricity consumptions of commercial buildings but aggregates data at the building level.

Moreover, to the best of our knowledge, there has been no research that investigates the behavior of non-residential customers during electricity crises. Yet, previous research on voluntary agreements and corporate social responsibility (CSR) provide some insights. According to Potier (1994), a voluntary agreement is a contract between industry (e.g., trade association, industrial branch and firm) and authorities (e.g., environmental ministry, municipality and local residents' association). Under a contract, industry undertakes to achieve environmental objectives, whereas government agrees not to adopt regulations while the contract remains in force. Segerson and Miceli (1998) and Schmelzer (1999) employ game theoretic approach and show that a voluntary agreement occurs if there is a credible legislative threat to introduce a standard or tax if it is not reached. A legislative threat is also one of the factors that are driving CSR, as Lyon and Maxwell (2008) state in the survey of literature on CSR. To reduce regulatory threats and enforcement pressures, many firms make environmental claims and enhance their corporate images in their CSR activities. For instance, Fortune Global 500 firms invest over $15 billions a year on CSR (Davidson, Dey and Smith, 2019). Given the prevalence of voluntary agreements and CSR, it is predicted that firms are likely to reduce electricity consumption voluntarily during an electricity crisis as they face tangible threats of extended blackouts, involuntary rolling blackouts, or stringent legislative penalties or restrictions on electricity use.

Given the gap in the literature, this study is to investigate firms' power conservation behaviors during an electricity crisis, in particular, their responses to public pressures (non-economic instruments) and price increases (economic instruments). Public pressures and price increases are commonly used as means to reduce electricity demand. However, it is difficult to distinguish the two effects in a natural experiment as they are often put into practice simultaneously during an electricity crisis. As far as we know, Reiss and White (2008) is the only study that investigates both effects during an electricity crisis. They find that residential electricity consumption was very elastic to price and fairly responsive to voluntary conservation requests as well during California's energy crisis in 2000 and 2001. To overcome the difficulty in a natural experiment, Ito, Ida and Tanaka (2018) design a field experiment to compare the effects of public pressures (called "moral suasion" in their study) and price increases using residential customers. They show that price increases induced a larger and more persistent residential electricity conservation than did public pressures. Other studies investigate the effects of either public pressures (e.g., Allcott, 2011) or price increases (e.g., Jessoe and Rapson, 2014; Ito, 2015). Overall, residential electricity consumption tends to be more elastic to price than to public pressures.

In order to investigate firm responses to public pressures and price increases, we exploit Japan's devastating earthquake in March 2011 as a natural experiment. In the wake of the earthquake, tsunami, and nuclear crisis, Japan began experiencing serious electricity shortage. In a comprehensive electricity conservation campaign by the government, non-residential customers were first exposed to public pressures to reduce peak demand and then price increases. Importantly for our analysis, public pressures and price increases were implemented separately and some regions were exposed to neither public pressures nor price increases. These together provide us with a unique opportunity to compare the effects of public pressures and price increases on non-residential customers using a difference in difference (DID) model.

The natural experiment also provides us with a rare opportunity to investigate free-rider problem that is common in public goods provision. During Japan's electricity shortage, the government first used public pressures and then price increases to reduce electricity consumption. This sequence of events allows us to identify possible free-riding firms that did not respond to public pressures first but responded to price increases later. Free-riding problems have been extensively studied in experimental economics (see, for example, Andreoni, 1988; Ledyard, 1995). Some empirical studies have estimated the proportion of free riders to be as high as 80% to 90% in energy conservation subsidy programs and tax credit systems (e.g., Joskow and Marron, 1992; Grösche and Vance, 2009; Nauleau, 2014; Boomhower and Davis, 2014). Reiss and White (2008) state that despite the free-riding problem, the collective conservation of residential customers during California's energy crisis was significant, owing to the tangibility and high public awareness of the costs of collective-action failures (i.e., involuntary blackouts). Nevertheless, research on free-ridership among non-residential customers during electricity crises is premature.

Our analysis provides some empirical evidence on the behaviors of non-residential customers. We find that non-residential customers respond to public pressures and price increases differently from residential customers reported in Ito, Ida and Tanaka (2018). As a whole, public pressures work better than price increases for non-residential customers. Firms in Tokyo and Kansai regions reduced electricity consumption by 4.6% and 3.1%, respectively, in response to public pressures, whereas they did not reduce electricity consumption when electricity price increased. However, detailed analyses find that only 32% of the firms contributed to the reduction in electricity consumption during public pressures. In other words, 68% of the firms were free-riders. Moreover, these free-riders did reduce electricity consumption when electricity price increased, whereas non-free-riders did not. This may imply that different policy instruments should be combined to achieve the target of electricity saving.

The remainder of this paper is organized as follows. We explain the background of Japan's electricity shortage and corresponding governmental conservation campaign in Section 2. Section 3 describes our dataset, treatments in our natural experiment, and hypothesis tested in our analysis. Section 4 reports our findings. Finally, Section 5 concludes the paper.

2 Background

2.1 The Great East Japan Earthquake

The Great East Japan Earthquake on March 11, 2011, became the largest earthquake ever recorded in Japan. The magnitude 9.0 earthquake struck off the northeast Pacific coast of Japan and triggered tsunami waves as high as 40 meters (131 feet). About 19,500 people were dead, 2,500 people were missing, and more than 400,000 buildings were destroyed or partially collapsed. The direct financial damage of the disaster is estimated to be about 16.9 trillion Japanese yen (about 150 billion US dollars) (Cabinet Office, 2013). The situation was compounded by the crisis of the Fukushima Daiichi nuclear power station when the cooling system failure caused the meltdown of fuel rods and the corresponding leakage of radioactive materials.

2.2 Electricity Shortage

Electricity shortage became a serious problem after the earthquake. Historically, Japan is divided into ten regions, each of which is served by a single electric company[1]. Figure 1 shows the supply capacity in each region before and after the earthquake. Two regions had direct damages of the earthquake: Tokyo region whose electric company operates the Fukushima Daiichi nuclear power station and Tohoku region that is the closest to the epicenter. Immediately after the earthquake, the two regions lost about 40% of power supply (Soda, 2015). Power outages reached a peak of 4.05 million (14%) customers in Tokyo (Tokyo Electric Power Company, 2013) and 4.86 million (66%) customers in Tohoku (Tohoku Electric Power Company, 2011). Tokyo had to implement involuntary rolling blackouts for 10 weekdays following the earthquake to prevent further major power outages.

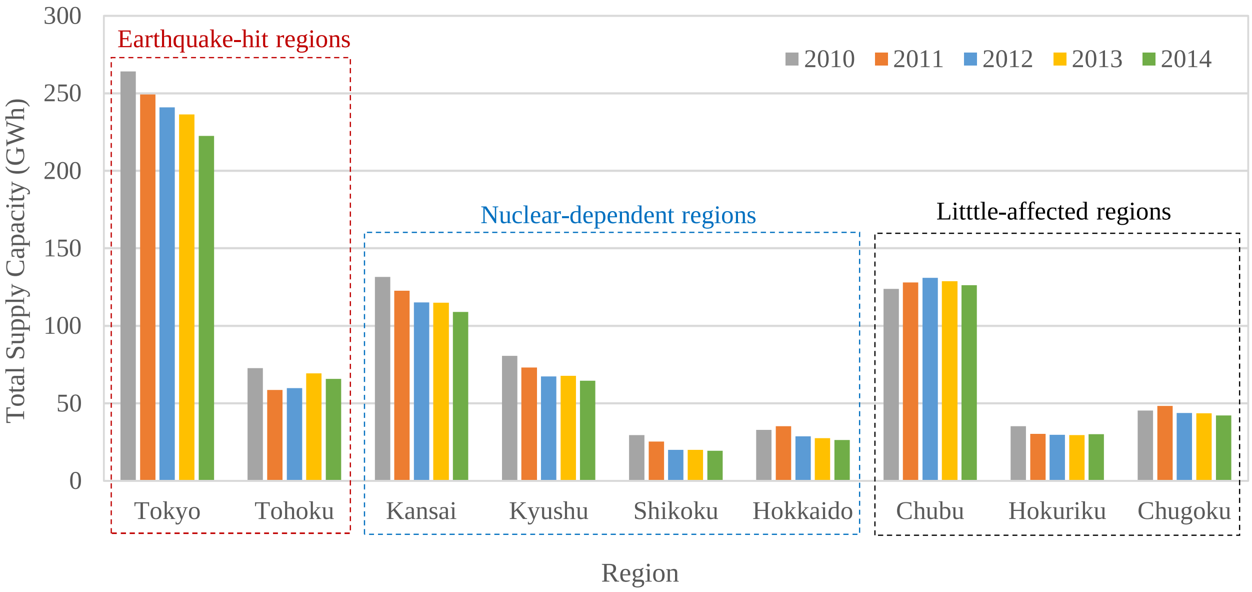

Figure 1: Supply capacity by regions before and after the earthquake

Source: Federation of Electric Power Companies of Japan (2016)

Even worse, all nuclear power stations in the nation were suspended due to safety and public concerns. Japan has 54 nuclear reactors, accounting for 26% of the power sources before the earthquake (Agency for Natural Resources and Energy, 2017). When the earthquake occurred, 36 reactors were operating, of which 10 were stopped immediately, and the remaining 18 reactors were offline for regular inspections (Japan Nuclear Safety Institute, 2017). Due to the public mistrust after the Fukushima Daiichi nuclear crisis, nuclear reactors that remained intact in the earthquake also went offline indefinitely after regular inspections. Only

---

[1] Okinawa, one of the ten regions, is excluded from any analyses in this study due to its peculiarity. Okinawa is much smaller than other regions and its electricity usage patterns are very different from other regions because it is located at the far south of Japan.

six reactors were in operation at the end of 2011 and all reactors went offline by September 2013 (Japan Nuclear Safety Institute, 2017)[2]. As shown in Figure 1, some regions that did not have direct damages of the earthquake but relied heavily on nuclear power, such as Kansai region, suffered declines in supply capacity after the earthquake.

2.3 Energy Saving Campaigns

The Japanese government undertook comprehensive campaigns to make electricity saving as a national movement. While rolling blackouts were cancelled when the cold weather started to ease up at the end of March 2011, the possibility of major power outage returned in some regions during summer and winter months. Accordingly, the government set peak clipping targets region by region.

Table 1 summarizes the peak-clipping targets. Tokyo and Tohoku, which are the earthquake-hit regions, were requested to reduce peak demand by 15% from the 2010 levels during the three-month period between July and September of 2011. The compliance was voluntary, except for large businesses with contract demand of 500 kW or more. These large businesses were subject to penalties of up to one million Japanese yen (about 9,000 US dollars) per hour for violation under Article 27 of Japan's Electric Business Act. During the summer of 2011, the government also set a voluntary peak clipping target of 10% reduction for Kansai, which is a nuclear-dependent region. The other regions did not have numerical targets but were requested to reduce electricity usage "within the range that would not hinder people's daily lives and economic activities (e.g., adjusting lighting and air conditioners)." The government sent licensed electricians to individual firms and held local information events on how to save electricity to encourage them to formulate and publish voluntary action plans (Japanese Ministry of Economy, Industry and Trade, 2012). In addition, an information campaign was conducted using a variety of media, including newspapers, TV, and the Internet, to raise awareness among people about electricity saving.

Owing to these conservation efforts, power outage was avoided and the numerical targets were achieved. Similar energy saving campaigns were undertaken in the following winters and summers. While some regions continued to have numerical targets until the winter of 2013-2014, such targets were removed in Tokyo and Tohoku regions after the summer of 2011.

2.4 Electricity Price Increases

As ten electric companies dominate electricity supplies in each region, price increases are regulated by the government. Due to concerns about negative impacts on the nation's disaster recovery efforts, electricity

---

[2] As of April 2019, nine nuclear reactors resumed operation.

			(Earthquake-hit)		(Nuclear-dependent)				(Little-affected)		
			Tokyo	Tohoku	Kansai	Kyushu	Shikoku	Hokkaido	Chubu	Hokuriku	Chugoku
Target	2011	Summer	-15%*	-15%*	-10%	-	-	-	-	-	-
		Winter	-	-	-10%	-5%	-	-	-	-	-
	2012	Summer	-	-	-10%	-10%	-5%	-7%	-	-	-
		Winter	-	-	-	-	-	-7%	-	-	-
	2013	Sumer	-	-	-	-	-	-	-	-	-
		Winter	-	-	-	-	-	-6%	-	-	-
Price Increase			9/2012	9/2013	5/2013	5/2013	9/2013	9/2013	-	-	-

Note: Numbers show percentage changes in peak demand from the 2010 levels. * indicates a mandatory target. - indicates no target or price increase. Source: Institute for Sustainable Energy Policies (2012); Japanese Ministry of Economy, Industry and Trade (2017); Agency for Natural Resources and Energy (2013).

Table 1: Numerical targets and electricity price increases during three years after the earthquake

price was not raised during the first one and half years after the earthquake. However, electric companies experienced soaring operating costs after the earthquake owing to damaged power plants, nuclear reactor shutdowns, and restarting inefficient old power plants to make up for lost supplies. At last, the electric company in Tokyo filed an application for a price increase in May 2012. After ten meetings of the Expert Committee on Reviewing Electricity Rates, the application was approved in July 2012 and implemented on September 1, 2012 (Agency for Natural Resources and Energy, 2013). Following Tokyo, electricity price was raised in other earthquake-hit region and nuclear-dependent regions (Table 1). Note that Chubu, Hokuriku and Chugoku regions, which had little impact of the earthquake, did not have price increases for three years after the earthquake.

Electricity price for non-residential customers is not publicly available as different firms receive different prices depending on contracts. Yet, we can still estimate the average electricity price for non-residential customers using other publicly available data (the details are described later in Section 3.1). Figure 2 shows the trend of the average electricity price for industrial customers based on our calculation. It shows that the estimated price sharply increased in Tokyo in September 2012 and in Kansai in May 2013.

3 Data, Treatments and Hypotheses

3.1 Data

The primary data for this study come from the panel data of monthly electricity consumptions of 620 offices of manufacturing firms in Japan from 2008 to 2013 provided by the Agency for Natural Resources and Energy (ANRE) under a confidentiality agreement. ANRE has been conducting the Current Survey of Energy Consumption every month since 1981 and keeps the complete electricity consumption history of

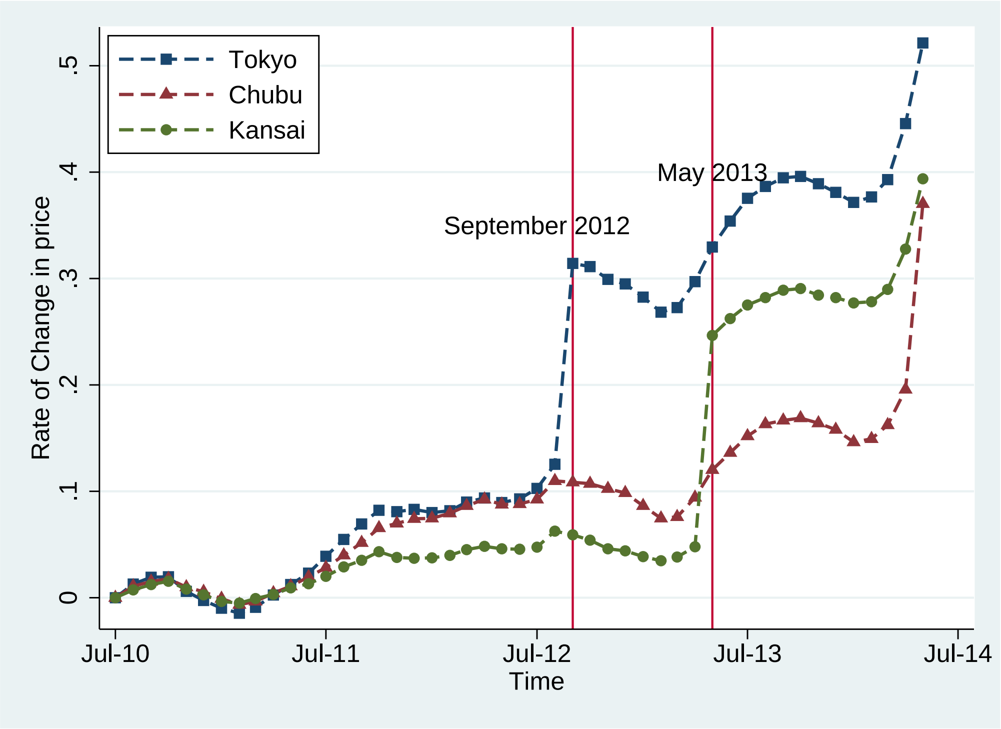

Figure 2: Electricity price changes for non-residential customers

Note: Electricity price for non-residential customers was calculated by dividing electricity sales by electricity consumption in the industrial sector, which were obtained from the Federation of Electric Power Companies of Japan (Federation of Electric Power Companies of Japan, 2016).

nine manufacturing industries surveyed: (1) pulp, paper and paperboards, (2) chemicals, (3) chemical fibers, (4) petroleum products, (5) ceramic, clay and stone products, (6) glass products, (7) iron and steel, (8) non-ferrous metals, and (9) machinery. Since regional electricity price for non-residential customers is not publicly available, we estimated it by dividing electricity sales by electricity consumptions in the industrial sector obtained from the Federation of Electric Power Companies of Japan (Federation of Electric Power Companies of Japan, 2016) and then converted them to real values, using prefectural consumer price indices obtained from the Statistics Bureau of Japan (Statistics Bureau, 2014). To control for the level of economic activity, prefectural industrial production indexes were obtained from Ministry of Economy, Trade and Industry (Japanese Ministry of Economy, Industry and Trade, 2017). Heating degree days (hereafter HDD) and cooling degree days (hereafter CDD) were calculated from the historical weather data provided by the Japan Meteorological Agency (Japan Meteorological Agency, 2013). Descriptive statistics are provided in Table 2.

	(Earthquake-hit)	(Nuclear-dependent)	(Little-affected)		
Variable	(1) Tokyo	(2) Kansai	(3) Chubu	(4) Hokuriku	(5) Chugoku
$\ln(EC)$	7.76	7.52	7.78	7.75	8.35
	(1.833)	(2.055)	(1.766)	(1.69)	(1.915)
$\ln(EP)$	3.25	3.31	3.19	3.15	3.38
	(0.120)	(0.0841)	(0.0607)	(0.035)	(0.041)
EI	99.50	102.50	102.85	103.38	100.40
	(11.72)	(8.799)	(13.24)	(10.77)	(10.54)
HDD	72.90	85.44	76.60	66.81	80.19
	(101.9)	(115.5)	(105.8)	(100.06)	(111.4)
CDD	147.18	143.02	155.68	183.71	154.22
	(151.7)	(151.3)	(160.7)	(179.11)	(160.54)
Observations	29,370	18,690	25,810	4,183	12,727

Note: All columns show the sample means and standard deviations of observables. Standard deviations are in parentheses in all columns. EC is the electricity consumption in gigajoule. EP is the average real electricity price in Japanese yen per kilowatt hour. EI is the prefectural industrial production indices. HDD and CDD are the sum of the daily heating degree days and cooling degree days of a year with a base temperature of 65 F (18.3 C), respectively.

Table 2: Descriptive statistics

3.2 Treatments

The treatments in our natural experiment are public pressures and price increases. For public pressures, we focus on the government imposition of numerical targets for peak clipping after the earthquake. While the government requested voluntary electricity conservation in all regions, it took a further step and set numerical targets for peak clipping in some regions where electricity supply was especially tight (see Table 1). Focusing on these targets allows us to clearly specify the periods of public pressures as these targets were effective only for a limited time. One potential drawback is that although these targets were for peak clipping, we only have data on total electricity consumption. We admit that our data cannot isolate the conservation efforts towards peak clipping. For instance, if production was simply shifted from peak hours to off-peak hours, our data do not show any change in the total electricity consumption. However, it is likely that firms also adopted energy efficient behaviors, such as reducing the usage of electricity consuming equipments. Indeed, previous studies have shown that residential electricity customers tend to adopt energy efficient lifestyles in face of high peak hour electricity prices, which leads to the reduction of total electricity consumption (Holland and Mansur, 2008; Wolak, 2011). Therefore, we expect that our data can reasonably capture firms' conservation efforts in response to peak clipping requests.

We use a DID model to investigate the treatment effects, with Tokyo and Kansai as a treated region and Chubu, as a control region. As shown in Table 1, the government set numerical targets in Tokyo (from July 1, 2011 to September 9, 2011) and Kansai (from July 1, 2011 to September 22, 2011) during the first summer after the earthquake. Tohoku also had a numerical target in summer 2011, but it is excluded from the treated region as the earthquake so severely damaged the region that the firm activities and electricity consumption considerably dropped. Chubu was selected as a control region because it had neither numerical targets nor price increases during our analysis period. In addition, unlike the other little-affected regions by the earthquake (i.e., Hokuriku and Chugoku), Chubu is reasonably comparable to Tokyo and Kansai in the magnitude of electricity demand (see Figure 1)[3].

In order to test the parallel trend assumption for a DID model, Figures 3 and 4 compare electricity consumption in summer (July) and winter (January), respectively, in the treated and control regions. The parallel trend assumption is satisfied because both figures show similar trends in both treated and control regions before the earthquake in March 2011.

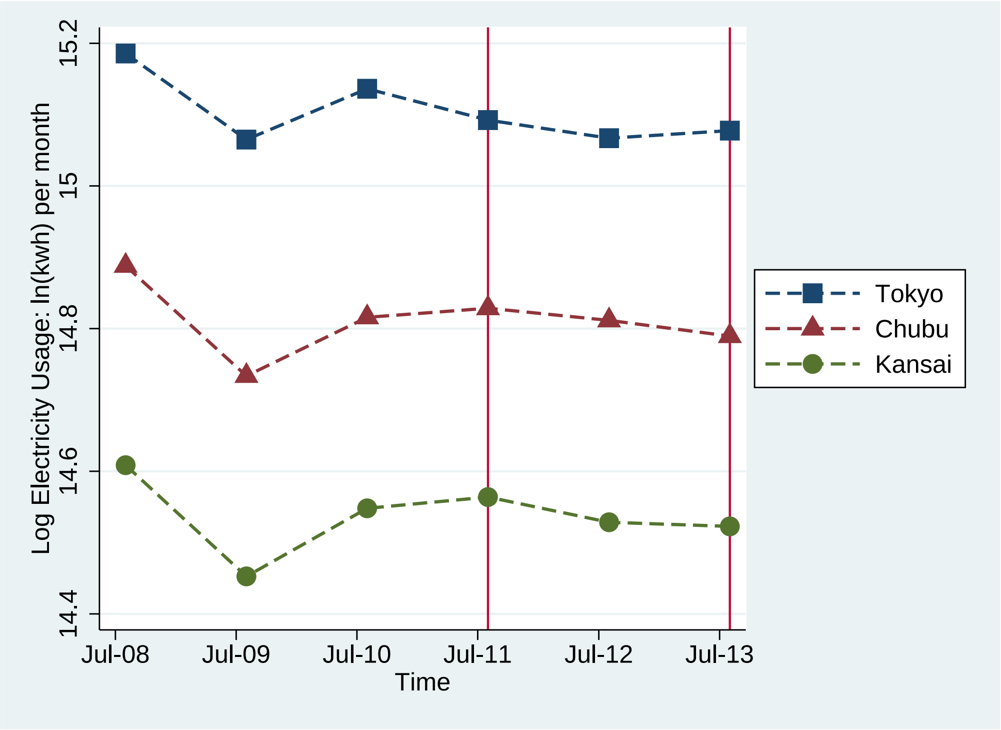

Figure 3: Summer electricity consumption in the treated and control regions

3.3 Hypothesis

3.3.1 Non-economic Incentive: Public Pressures

Although it is difficult to speculate how firms' responses will change with the intervention, findings on residential customers offer an insight that helps our hypothesis development. Previous studies have shown that public pressures are effective in reducing residential electricity consumption (Reiss and White, 2008; Allcott, 2011; Ito, Ida and Tanaka, 2018). Specifically, Ito, Ida and Tanaka (2018) find three characteristics.

---

[3] In Section 4, Hokuriku and Chugoku are excluded from the control region in the original model. Then, they are added to the control region to test the robustness of the original model.

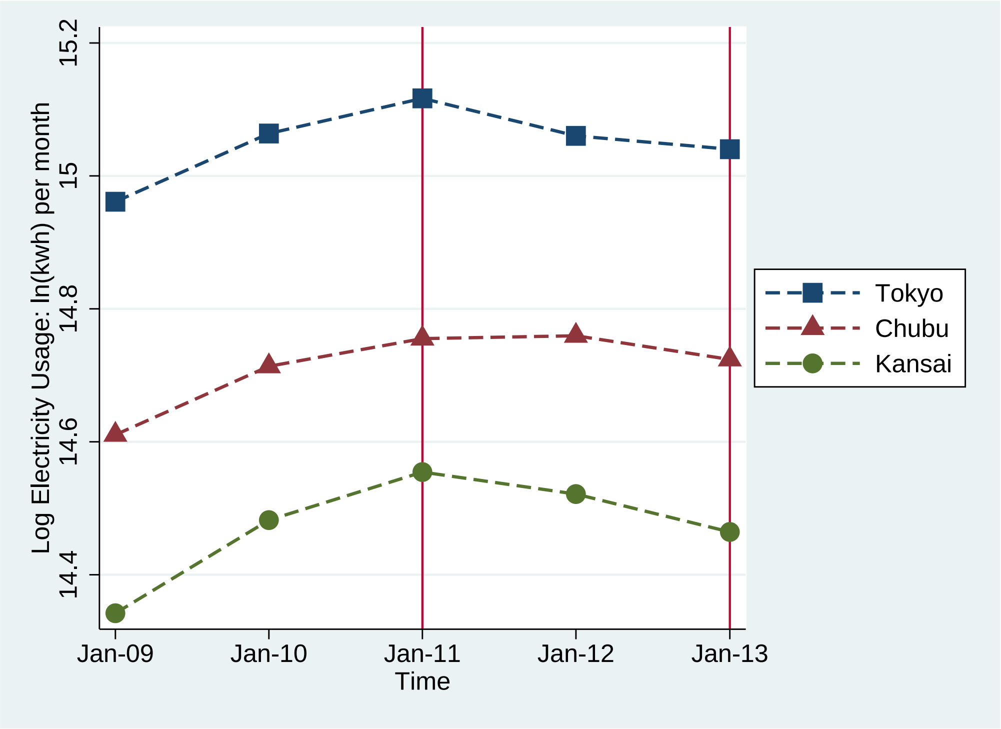

Figure 4: Winter electricity consumption in the treated and control regions

First, while residential customers reduce electricity consumption in response to public pressures, the effect diminishes very quickly week by week (known as *habituation* in psychology). Second, when residential customers are exposed again to public pressures after several months of a long interval, they restore the original levels of electricity savings (known as *dishabituation* in psychology). Third, residential customers are not likely to adopt energy-efficient lifestyle due to public pressures and thus, there is no electricity saving after public pressures are withdrawn (i.e., no *habit-formation* often studied in economics). Based on their findings, we examine whether firms possess similar characteristics, in particular, dishabituation and habit-formation, toward public pressures. We do not examine habituation as our electricity consumption data are only monthly and cannot trace short-term (daily or weekly) changes.

Before examining dishabituation and habit-formation, we must check that firms do respond to public pressures to begin with. Therefore, we first estimate the changes in monthly electricity consumption in the treated region (Tokyo and Kansai) in the months of July and August in 2011, in which numerical targets for peak clipping were set for the first time in the region[4].

Confirming that firms respond to public pressures, we then investigate the possibility of dishabituation. If

---

[4] Numerical targets were set from the beginning of July to the middle of September in 2011 in the treated region. However, we exclude September from the analysis because our electricity consumption data are monthly and cannot capture the effects of target setting in September correctly. We apply the same rule when dealing with numerical targets set during winter months and limit our analysis to the months of January and February.

firms possess the characteristic of dishabituation toward public pressures, the magnitude of electricity saving during the first and second periods of public pressures should be similar. As shown in Table 1, Kansai had a numerical target of 10% in the winter of 2011-2012 as well as in the summer of 2011, while Tokyo did not. Thus, we limit the treated region to Kansai and compare the changes in monthly electricity consumption between July-August, 2011, and January-February, 2012.

Finally, we investigate whether firms form energy-saving habits when exposed to public pressures. For this purpose, we limit the treated region to Tokyo as Tokyo had a numerical target only once. That is, if firms in Tokyo formed energy-saving habits when they were exposed to public pressures in the summer of 2011, they must have kept reducing electricity consumption in the winter of 2011-2012 without any public pressures. Thus, we compare the changes in monthly electricity consumption in Tokyo between July-August, 2011, and January-February, 2012.

3.3.2 Economic Incentive: Price Increases

It has been a common assumption that price elasticity of electricity demand is very low as electricity is a necessity good. However, previous studies have shown that residential electricity consumption becomes elastic to price during electricity crises (Reiss and White, 2008) as well as under some conditions during non-crisis periods (Jessoe and Rapson, 2014; Ito, 2015; Ito, Ida and Tanaka, 2018). Since little has been investigated on whether this also applies to non-residential customers, we estimate the changes in monthly electricity consumptions in the treated region (Tokyo and Kansai) when electricity price sharply increased in September 2012 in Tokyo and in May 2013 in Kansai.

3.3.3 Free Ridership

Requests for voluntary conservation during electricity crises create a situation of public goods game. Customers are required to reduce electricity consumption to stabilize power supply, which often accompanies a significant reduction in utility. They receive rewards (e.g., averted further blackouts, involuntary rolling blackouts, and price hikes) only if aggregate conservation efforts become greater than a threshold. Because the rewards are enjoyed by all customers regardless of individual contribution levels, it causes a free-riding problem.

It is challenging to investigate free-ridership during electricity crises. Firstly, data availability is limited as large-scale electricity crises occur only occasionally. Secondly, electricity price increases often precede voluntary conservation requests during electricity crises. Some energy-conservation efforts, such as adopting energy-saving behaviors and installing energy-efficient equipments, have prolonged effects. Therefore, if price increases occur before public pressures, it is difficult to identify free-riders that made conservation efforts in response to the price increases, but not to the conservation requests. Indeed, Reiss and White (2008) mention the possibility of free-ridership during the electricity crisis in California, but the order of the intervention, public pressures coming after price increases, prevents them from investigating the issue further.

Japan's electricity crisis after the earthquake provides us with a unique opportunity to examine free-ridership during electricity crises as conservation requests preceded price increases. First, we divide firms in the treated region (Tokyo and Kansai) into two groups: the firms that reduced electricity consumption in the months of July and August in 2011 when numerical targets were set, and the firms that did not reduce electricity consumption during the same period. Then, we examine whether two groups respond to a price increase differently. If firms are free-riders, they will not respond to the target setting, but will reduce electricity consumption after the price increase. Table 3 summarizes the hypotheses tested in this study.

Hypothesis	Method			
Non-economic Incentive (Public Pressures)		(Treated)	(Control)	(Period)
(1) Overall Effect of Public Pressures	DID	Tokyo, Kansai	Chubu	Jul-Aug 2011
(2) Dishabituation	DID	Kansai	Chubu	Jul-Aug 2011 (1st public pressures) vs. Jan-Feb 2012 (2nd public pressures)
(3) Habit-formation	DID	Tokyo	Chubu	Jul-Aug 2011 (public pressures) vs. Jan-Feb 2012 (no public pressures)
Economic Incentive		(Treatment)	(Control)	(Period)
(4) Price Increase	DID	Tokyo, Kansai	Chubu	Sep 2012 for Tokyo May 2013 for Kansai
(5) Free Ridership	OLS	Free-riders* vs. non-free-riders** in Sep 2012 for Tokyo and May 2013 for Kansai *Firms in Tokyo and Kansai that did not reduce electricity consumption during public pressures in Jul-Aug 2011 **Firms in Tokyo and Kansai that reduced electricity consumption in Jul-Aug 2011		

Table 3: Hypotheses tested in the study

4 Empirical Analysis and Results

4.1 Identification Strategy

In order to examine firm responses to public pressures and price increases, we estimate the effects of these policy instruments on electricity consumption in the Tokyo and Kansai regions. First, we estimate a simple model that allows possible level shifts in electricity consumption in the treated region by using ordinary least squares (OLS):

$$\ln EC_{irt} = \gamma_r + \lambda_t + \phi_i + \lambda_t D_t + X'_{irt}\beta + u_{irt}. \tag{4.1}$$

The dependent variable, $\ln EC_{irt}$, is the natural log of electricity consumption ($\ln EC$) at office i in region r in month t. γ_r is a regional fixed effect, λ_t is a time fixed effect, and ϕ_i is an individual fixed effect. D_t equals one if a numerical target was set in month t and zero otherwise. X_{irt} denotes three exogenous variables and one endogenous variable. The exogenous variables are prefectural industrial production index (EI), HDD and CDD for office i in region r in month t. The endogenous variable is the natural log of lagged electricity price ($\ln EP$) for office i in region r in month t as an instrumental variable for electricity price. u_{irt} is an error term. The standard errors are clustered at the office level to adjust for serial correlation. While the inclusion of time dummy variables (D_t) allows us to see the change in electricity consumption during the treatments, as a limitation of this model, the change can also include other time trends in electricity consumption. Therefore, we next estimate a DID model that computes the difference in electricity consumption between the treated and control regions pre- and post- treatment. We estimate the following equation:

$$\ln EC_{irt} = \gamma_r + \lambda_t + \phi_i + \delta D_{rt} + X'_{irt}\beta + u_{irt}. \tag{4.2}$$

D_{rt} is defined as $D_r \times D_t$, where D_r equals one for data points from the treated region and zero otherwise. Other variables are defined as before. The standard errors are clustered at the office level to adjust for serial correlation.

Three robustness tests are conducted to investigate the sensitivity of the results of Eq.(4.2) to changes in the DID specifications. Firstly, we relax the common trend assumption in Eq.(4.2) by adding regional-specific time trends, such as interaction terms between regional dummies and time trends (Besley and Burgess, 2004). Then, the DID model with regional-specific time trends is given by

$$\ln EC_{irt} = \gamma_{0r} + \gamma_{1r}t + \lambda_t + \phi_i + \delta D_{rt} + X'_{irt}\beta + u_{irt}, \tag{4.3}$$

where γ_{0r} is a regional-specific intercept, γ_{1r} is a regional-specific trend coefficient multiplied by a time trend variable t, and other variables are defined as before. Secondly, the common trend assumptions can be investigated as our dataset has several years of data before the treatments. To test the common trend assumptions, we produce DID model estimates for the years before the treatments, called anticipatory effects. If the leads of the treatments are economically or statistically insignificant, there is no evidence for anticipatory effects. The DID model with anticipatory effects is given by

$$\ln EC_{irt} = \gamma_r + \lambda_t + \phi_i + \sum_{\tau=0}^{m} \delta_\tau D_{rt-\tau} + X'_{irt}\beta + u_{irt}, \tag{4.4}$$

where the sum on the right-hand side allows for m lead effects. Finally, another important robustness test is to produce a DID model with other control regions. In addition to Chubu (the original control region), we include Hokuriku and Chugoku into the control region and re-estimate Eq.(4.2). Columns (1)-(4) correspond to Eqs.(4.1)-(4.4) and Column (5), to the DID model with other control regions, respectively, in Tables 4 and 5 in the following sections.

4.2 Model Validation and Overall Effect of Public Pressures

Tables 4 and 5 show firm responses to public pressures (i.e., target settings) in the moths of July and August in 2011 in Tokyo and Kansai, respectively. It is found that the imposition of numerical targets indeed reduced electricity consumption during this period. The estimated electricity saving effects in Column (2) are 0.46 log points (4.6%) in Tokyo and 0.31 log points (3.1%) in Kansai. Note that these results are slightly different from the result in Column (1). Column (2) provides more accurate estimates as it separates the effects of numerical targets from the other time trends.

Variables	(1) OLS	(2) DID	(3) DID Robust test 1	(4) DID Robust test 2	(5) DID Robust test 3
$\ln EP$	-0.206**	-0.168**	-0.171**	-0.162**	-0.156**
	(0.047)	(0.050)	(0.050)	(0.055)	(0.053)
$D(Tokyo)$		-0.001	-0.582**	0.006	-0.003
		(0.144)	(0.221)	(0.144)	(0.144)
$D(Summer2011)$	**-0.037****	0.006	0.006	0.010	0.009
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)
$D(Tokyo) * D(Summer2011)$		**-0.046****	**-0.046****	**-0.053****	**-0.048****
		(0.013)	**(0.013)**	**(0.015)**	**(0.014)**
$D(Tokyo) * D(Summer2009)$				0.008	
				(0.023)	
$D(Tokyo) * D(Summer2008)$				-0.013	
				(0.021)	
$D(Tokyo) * D(Summer2007)$				-0.036	
				(0.024)	
HDD	-0.000	0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EI	0.006**	0.005**	0.005**	0.005**	0.004**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$D(Tokyo) * Year$			0.000**		
			(0.000)		
Constant	7.866**	7.873**	7.878**	7.831**	7.879**
	(0.143)	(0.188)	(0.188)	(0.197)	(0.215)
Observations	8,677	8,677	8,677	8,677	11,335
Number of companies	620	620	620	620	810

Note: Columns (1)-(4) show the estimation results for Eqs.(4.1)-(4.4) and Column (5) shows the estimation result to the DID model with other control regions, respectively. The dependent variable is the natural log of the office-level monthly electricity consumption. $D(Tokyo)$ is a dummy for the firms in Tokyo. $D(Summer2007)$, $D(Summer2008)$, $D(Summer2009)$ and $D(Summer2011)$ are dummies for the months of July and August in 2007, 2008, 2009 and 2011, respectively. The other independent variables are defined in Section 3.1. Fixed effects are included. The standard errors are clustered at the office level to adjust for serial correlation. Standard deviations are in parentheses in all columns. The individual coefficient is statically significant at 5% level (**) or 10% level (*).

Table 4: Effects of target setting in Tokyo in July-August 2011

Columns (3)-(5) in Tables 4 and 5 test the sensitivity of the DID model for Column (2) to various changes in the DID specifications. The results show that the model for Column (2) is robust because the estimated

Variables	(1) OLS	(2) DID	(3) DID Robust test 1	(4) DID Robust test 2	(5) DID Robust test 3
$\ln EP$	-0.420**	-0.269**	-0.273**	-0.275**	-0.219**
	(0.060)	(0.058)	(0.058)	(0.056)	(0.066)
$D(Kansai)$		-0.222	-0.927**	-0.225	-0.226
		(0.176)	(0.343)	(0.177)	(0.176)
$D(Summer2011)$	**-0.034****	0.006	0.007	0.006	0.010
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)
$D(Kansai) * D(Summer2011)$		**-0.031****	**-0.031****	**-0.029****	**-0.030***
		(0.015)	**(0.015)**	**(0.013)**	**(0.015)**
$D(Kansai) * D(Summer2009)$				0.014	
				(0.026)	
$D(Kansai) * D(Summer2008)$				0.013	
				(0.022)	
$D(Kansai) * D(Summer2007)$				-0.012	
				(0.023)	
HDD	0.000*	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EI	0.007**	0.005**	0.005**	0.005**	0.004**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$D(Kansai) * Year$			0.000**		
			(0.000)		
Constant	8.343**	8.162**	8.172**	8.160**	8.078**
	(0.197)	(0.211)	(0.211)	(0.211)	(0.256)
Observations	7,000	7,000	7,000	7,000	9,658
Number of companies	500	500	500	500	690

Note: Columns (1)-(4) show the estimation results for Eqs.(4.1)-(4.4) and Column (5) shows the estimation result to the DID model with other control regions, respectively. The dependent variable is the natural log of the office-level monthly electricity consumption. $D(Kansai)$ is a dummy for the firms in Kansai. $D(Summer2007)$, $D(Summer2008)$, $D(Summer2009)$ and $D(Summer2011)$ are dummies for the months of July and August in 2007, 2008, 2009 and 2011, respectively. The other independent variables are defined in Section 3.1. Fixed effects are included. The standard errors are clustered at the office level to adjust for serial correlation. Standard deviations are in parentheses in all columns. The individual coefficient is statically significant at 5% level (**) or 10% level (*).

Table 5: Effects of target setting in Kansai in July-August 2011

electricity savings in Column (2) are essentially the same as those in Columns (3)-(5) in both Tokyo and Kansai. The savings in Columns (2)-(5) are 4.6%, 4.6%, 5.3%, and 4.8%, respectively, in Tokyo and 3.1%, 3.1%, 2.9%, and 3.0%, respectively, in Kansai. Note that no anticipatory effect is found in Column (4) because all the interaction terms are statistically insignificant except for $D(Tokyo) * D(Summer2011)$ in Table 4 and $D(Kansai) * D(Summer2011)$ in Table 5, which are the interaction terms between the treated regions and the the months of July and August in 2011. That is, electricity consumption in the months of July and August in 2007, 2008 and 2009 were not affected by the future policy to impose numerical targets on electricity consumption in summer 2011.

Based on the results of the robustness tests, we use the DID model in Eq.(4.2) to examine firm responses in Sections 4.3 and 4.4.

4.3 Dishabituation

Table 6 summarizes the changes in electricity consumption in the treated regions in the months of January and February in 2012. During this period, the government set a numerical target in Kansai second time but removed a target from Tokyo.

We first look at the result in Column (1) to examine the possibility of dishabituation. It shows that imposing a numerical target second time in Kansai had no significant effects on electricity savings. Although Ito, Ida and Tanaka (2018) find dishabituation toward public pressures among residential customers, our result finds no such effect on non-residential customers. Unlike residential customers, non-residential customers must maintain their production while saving electricity. Because of the hurdle, non-residential customers may be reluctant to take conservation measures unless they are at an imminent risk. They might have felt that an imminent crisis had lessened by the time a numerical target was set second time and thus made little conservation efforts.

Another implication of the result is that electricity conservation efforts made during the first period of target setting did not last for more than a several months. As the conservation request in the summer of 2011 was on relatively short notice, firms may have had little time to fundamentally change their operations or equipments and relied on only tentative measures.

Variables	(1) Dishabituation Treated Region: Kansai	(2) Habit-formation Treated Region: Tokyo
$D(Kansai)$	-0.207 (0.173)	
$D(Kansai) * D(Winter2012)$	**-0.023** **(0.014)**	
$D(Tokyo)$		0.023 (0.143)
$D(Tokyo) * D(Winter2012)$		**0.014** **(0.013)**
$D(Winter2012)$	0.012 (0.008)	0.005 (0.008)
Constant	7.885** (0.246)	7.633** (0.204)
Other controls	Yes	Yes
Observations	7,986	9,906
Number of companies	500	620

Note: Two columns show the estimation results for Eq.(4.2) in each region. The dependent variable is the log of office-level monthly electricity consumption. $D(Kansai)$ and $D(Tokyo)$ are dummies for the firms in Kansai and Tokyo, respectively. $D(Winter2012)$ is a dummy for the months of January and February in 2012. The other independent variables are $\ln EP$, EI and CDD defined in Section 3.1. Fixed effects are included. The standard errors are clustered at the office level to adjust for serial correlation. Standard deviations are in parentheses in all columns. The individual coefficient is statically significant at 5% level (**) or 10% level (*).

Table 6: Dishabituation and habit-formation: Electricity consumption in Kansai and Tokyo in January-February 2012

4.4 Habit-formation

Next, we look at the result in Column (2) in Table 6 to examine the possibility of habit-formation. It is found that the change in electricity consumption was not statistically significant in the months of January and February in 2012 in Tokyo when a numerical target was removed from the region. As Ito, Ida and Tanaka (2018) show for residential customers, non-residential customers are also not likely to adopt long-lasting conservation measures, such as installing energy efficient equipments and changing energy consumption behaviors, after exposed to public pressures. The result is consistent with the finding in Section 4.3 that firms took only temporal measures to reduce electricity consumption in face of public pressures. It is likely firms were able to implement temporal conservation measures on short notice in the summer of 2011 as the risk of large-scale blackouts was tangible. However, due to the burden in terms of time and money to cut down electricity use, they lost incentives to maintain conservation efforts.

4.5 Effects of Price Increases

In order to investigate the effect of price increases on electricity consumption, we use the DID model in Eq.(4.2) to compare electricity consumption in the treated (Tokyo and Kansai) and control (Chubu) regions. Electricity price went up on September 1, 2012, in Tokyo and on May 1, 2013, in Kansai. Accordingly, the DID model compares electricity consumption between Tokyo and Chubu in September 2012 and between Kansai and Chubu in May 2013.

The result is shown in Table 7. It is found that there were no significant changes in electricity consumption in both regions when electricity price went up. That is, although residential electricity consumption is very elastic to price during power crises in previous research (Reiss and White, 2008), we find that non-residential electricity consumption was inelastic to price during the power crisis in Japan. The finding is largely consistent with the empirical evidence in Hosoe and Akiyama (2009) that price elasticities in Japanese industrial and commercial sectors during a non-crisis period are very small (less than 0.1) in Tokyo, Kansai and Chubu. As firms need to maintain high productivities and remain competitive in markets, they may keep the same operation levels for the time being even if electricity price goes up.

The result in this section shows that non-residential electricity consumptions are price inelastic. However, more detailed analysis in Section 4.6 provides a new insight into price elasticities of non-residential electricity consumption.

Variables	(1) Tokyo	(2) Kansai
$D(Tokyo)$	-0.593** (0.223)	
$D(September 2012)$	-0.028** (0.013)	
$D(Tokyo) * D(September 2012)$	**-0.004** **(0.020)**	
$D(Kansai)$		-0.935** (0.344)
$D(May 2013)$		-0.060** (0.016)
$D(Kansai) * D(May 2013)$		**-0.028** **(0.026)**
Constant	7.618** (0.145)	7.526** (0.162)
Other controls	Yes	Yes
Observations	6,198	4,999
Number of companies	620	500

Note: Two columns show the estimation results for Eq.(4.2) in each region. The dependent variable is the log of office-level monthly electricity consumption. $D(Tokyo)$ and $D(Kansai)$ are dummies for firms in Tokyo and Kansai, respectively. $D(September 2012)$ is a dummy for the month of September in 2012. $D(May 2013)$ is a dummy for the month of May in 2013. The other independent variables are $\ln EP$, HDD, CDD and EI defined in Section 3.1. Fixed effects are included and the standard errors are clustered at the office level to adjust for serial correlation. Standard deviations are in parentheses in all columns. The individual coefficient is statically significant at 5% level (**) or 10% level (*)

Table 7: Effects of price increases in Tokyo in September 2012 and Kansai in May 2013

4.6 Free Ridership

In Sections 4.2 and 4.5, we find that non-residential customers reduced electricity consumption when they were exposed to public pressures (non-economic incentives) first time but did not reduce electricity consumption when price increased (economic incentives). On closer look, 68% of the firms in the treated region actually did not reduce electricity consumption in face of public pressures in the summer of 2011. Given that a majority of the firms free-rode on others' conservation efforts, it is necessary to further investigate how these firms responded to economic incentives so that we can find a better way to control their electricity consumption. Although firms, on average, did not respond to price increases, we may find different behaviors between free-riders and non-free-riders. Thus, we divide the firms in Tokyo into (i) free-riders that did not reduce electricity consumption in face of the target setting in July-August 2011 and (ii) non-free-riders that reduced electricity consumption during the same period. Then, we examine how each group reacted to the sharp price increase that took place in Tokyo in September 2012. Similarly, we divide the firms in Kansai into free-riders and non-free-riders and then examine their reactions to the sharp price increase that took place in Kansai in May 2013. We use the OLS model in Eq.(4.1).

Table 8 summarizes the estimation result of the changes in electricity consumption in response to price increases, showing a clear difference between two groups. The changes in electricity consumption are significant for free-riders with estimated elasticities of 0.1 for Tokyo and 0.2 for Kansai, whereas they are not significant for non-free-riders. That is, free-riders are likely to take conservation actions in response to economic incentives, whereas non-free-riders are not. Interestingly, firms tend to respond to either economic incentives or non-economic incentives. The result implies the importance of using various incentives to induce conservation efforts from as many firms as possible because firms selectively respond to different incentives.

	Tokyo		Kansai	
Variables	Free-riders	Non-free-riders	Free-riders	Non-free-riders
*September*2012	**-0.101**** **(0.022)**	**0.079** **(0.085)**		
*May*2013			**-0.225**** **(0.037)**	**-0.005** **(0.026)**
Constant	7.689** (0.132)	8.074** (0.242)	6.733** (0.254)	7.520** (0.353)
Other controls	Yes	Yes	Yes	Yes
Observations	932	386	536	304
Number of companies	233	97	134	76

Note: This table shows the estimation results for Eq.(4.1). Free-riders are the firms that reduced electricity consumption during public pressures in the months of July and August in 2011, and non-free-riders are the firms that did not reduce electricity consumption during the same period. The dependent variable is the log of office-level electricity consumption. *September*2012 is a dummy for the month of September in 2012. *May*2013 is a dummy for the month of May in 2013. The other independent variables are $\ln EP$, HDD, CDD and EI defined in Section 3.1. Fixed effects are included and the standard errors are clustered at the office level to adjust for serial correlation. Standard deviations are in parentheses in all columns. The individual coefficient is statically significant at 5% level (**) or 10% level (*)

Table 8: Free-riders' Reaction to Price Increases

5 Conclusion

This study provides some empirical evidence on the behaviors of non-residential electricity customers during electricity crises. As a whole, non-residential customers responded to public pressures better than price increases under a crisis situation. The effect of public pressures, however, was tentative and disappeared when the imminent crisis lessened. On closer look, the aggregate conservation during public pressures was made by about 30% of non-residential customers. In other words, about 70% of non-residential customers free-rode on others' efforts during public pressures. Interestingly, while non-residential customers were all together inelastic to price, free-riders were actually elastic to price. This also implies that non-residential customers selectively respond to either public pressures or price increases.

Policy implications from this study are summarized as follows. First, public pressures can help non-residential customers reduce electricity consumption under a crisis situation. Supported by the prevalence of voluntary agreements and the CSR movement, some firms respond well to public pressures. Policy makers can rely on their conservation efforts to avoid the worst case scenario. However, the effect of public pressures diminishes quickly. Thus, policy makers should make effort to maintain firms' conservation behavior to avoid blackout. For example, policy makers may send specialists to individual firms to help them develop practical and customized conservation plans as did the Japanese government. Second, along with public pressures, other incentives, including economic incentives, should be used to stimulate as many firms as possible. Imposing public pressures is a relatively cost-efficient conservation strategy that policy makers can rely on. However, some firms respond to only economic incentives. Therefore, it is important to use a variety of conservation strategies to address a crisis situation. Finally, policy makers should encourage firms to make long-lasting conservation efforts during non-crisis periods. Firms make only temporal conservation efforts under a crisis situation. As serious electricity crises can occur any time due to unexpected incidences, policy makers should support firms to purchase energy-efficient equipments and adopt energy-saving behaviors during non-crisis periods in preparation for future electricity crises.

References

Agency for Natural Resources and Energy. 2013. "FY2012 annual report on energy (energy white paper 2013) outline." *http://www.meti.go.jp/english/report/downloadfiles/2013_outline.pdf*, Last accessed on March 21, 2019.

Agency for Natural Resources and Energy. 2017. "Genreal energy statistics of Japan (in Japanese)." *http://www.enecho.meti.go.jp/statistics/total_energy/results.html*, Last accessed on March 21, 2019.

Allcott, Hunt. 2011. "Social norms and energy conservation." *Journal of Public Economics*, 95: 1082–1095.

Andreoni, James. 1988. "Why free ride? Strategies and learning in public goods experiments." *Journal of Public Economics*, 37: 291–304.

Arnberg, Søren, and Thomas Bue Bjørner. 2007. "Substitution between energy, capital and labour withinindustrial companies: A micro panel data analysis." *Resource and Energy Economics*, 29: 122–136.

Bardazzi, Rossella, Filippo Oropallo, and Maria Grazia Pazienza. 2015. "Do manufacturingfirms react to energy prices? Evidence from Italy." *Energy Economics*, 49: 168–181.

Besley, Timothy, and Robin Burgess. 2004. "Can labor market regulation hinder economic performance? Evidence from India." *The Quarterly Journal of Economics*, 113: 91–134.

Bjørner, Thomas Bue, Mikael Togeby, and Henrik Holm Jensen. 2001. "Industrial companies' demand for electricity: evidence from a micropanel." *Energy Economics*, 23: 595–617.

Boomhower, Judson, and Lucas W. Davis. 2014. "A credible approach for measuring inframarginal participation in energy efficiency programs." *Journal of Public Economics*, 113: 67–79.

Cabinet Office. 2013. "White paper on disaster management 2013 (in Japanese)." *http://www.bousai.go.jp/kaigirep/hakusho/index.html*, Last accessed on March 21, 2019.

Davidson, Robert H., Aiyesha Dey, and Abbie Smith. 2019. "CEO materialism and corporate social responsibility." *The Accounting Review*, 94(1): 101–126.

Executive Office of the U.S. President. 2013. "Economic benefits of increasing electric grid resilience to weather outages." *https://www.energy.gov/sites/prod/files/2013/08/f2/Grid Resiliency Report_FINAL.pdf*, Last accessed on March 21, 2019.

Federation of Electric Power Companies of Japan. 2016. "Electric Power Statistical Information (in Japanese)." *http://www.fepc.or.jp/library/data/tokei/index.html*, Last accessed on March 21, 2019.

Grösche, Peter, and Collin Vance. 2009. "Willingness to pay for energy conservation and free-ridership on subsidization: evidence from Germany." *The Energy Journal*, 30(2): 135–153.

Holland, Stephen P., and Erin T. Mansur. 2008. "Is real-time pricing green? The environmental impacts of electricity demand variance." *The Review of Economics and Statistics*, 90(3): 550–561.

Hosoe, Nobuhiro, and Shuichi Akiyama. 2009. "Regional electric power demand elasticities of Japans industrial and commercialsectors." *Energy Policy*, 37: 4313–4319.

Institute for Sustainable Energy Policies. 2012. "Electricity supply this summer will be sufficient without reactivating nuclear power plants (in Japanese)." *http://www.cas.go.jp/jp/seisaku/npu/policy09/pdf/20120423/sanko_shiryo4.pdf*, Last accessed on March 21, 2019.

Ito, Koichiro. 2015. "Asymmetric incentives in subsidies: evidence from a large-scale electricity rebate program." *American Economic Journal: Eonomic Policy*, 7(3): 209–237.

Ito, Koichiro, Takanori Ida, and Makoto Tanaka. 2018. "Moral suasion and economic incentives: Field experimental evidence from energy demand." *Economic Policy*, 10(1): 240–267.

Japanese Ministry of Economy, Industry and Trade. 2012. "2012 white paper on small and medium enterprises in Japan." *http://www.chusho.meti.go.jp/pamflet/hakusyo/index.html*, Last accessed on March 21, 2019.

Japanese Ministry of Economy, Industry and Trade. 2017. "Indices of industrial index (in Japanese)." *http://www.meti.go.jp/statistics/tyo/iip/b2010_result-2.html*, Last accessed on March 21, 2019.

Japan Meteorological Agency. 2013. "Past weather data." *http://www.data.jma.go.jp/gmd/risk/obsdl/index.php*, Last accessed on March 21, 2019.

Japan Nuclear Safety Institute. 2017. "Operating state of nuclear power stations (in Japanese)." *http://www.genanshin.jp/facility/*, Last accessed on December 29, 2017.

Jessoe, Katrina, and David Rapson. 2014. "Knowledge is (less) power: experimental evidence from residential energy use." *American Economic Review*, 104(4): 1417–1438.

Joskow, Pauk L., and Donald B. Marron. 1992. "What Does a negawatt really cost? Evidence from utility conservation programs." *Energy Journal*, 13(4): 41–74.

Kahn, Matthew E., Niles Kok, and John M. Quigley. 2014. "Carbon emissions from the commercial building sector: The role of climate, quality ,and incentives." *Journal of Public Economics*, 113: 1–12.

Ledyard, John O. 1995. "The handbook of experimental economics." , ed. John H. Kagel and Alvin E. Roth, Chapter Public goods: A survey of experimental research, 111–194. Princeton University Press.

Lyon, Thomas P., and John W. Maxwell. 2008. "Corporate social responsibility and the environment: A theoretical perspective." *Review of Environmental Economics and Policy*, 2(2): 240–260.

Nauleau, Marie-Laure. 2014. "Free-riding on tax credits for home insulation in France: An econometric assessment using panel data." *Energy Economics*, 46: 78–92.

Newsham, Guy R., and Brent G. Bowker. 2010. "The effect of utility time-varing pricing and load control strategies on residential summer peak electricity use: A review." *Energy Policy*, 38: 3289–3296.

Potier, Michel. 1994. "Agreement on the environment." *The OECD Observer*, 189: 8–11.

Reiss, Peter C., and Matthew W. White. 2008. "What changes energy consumption? Prices and public pressures." *RAND Journal of Economics*, 39(3): 636663.

Schmelzer, Dirk. 1999. "Voluntary approaches in environmental policy." , ed. Carlo Carroro and François Lévêque, Chapter Voluntary agreements in environmental policy: negotiating emission reductions, 55–74. Springer Netherlands.

Segerson, Kathleen, and Thomas J. Miceli. 1998. "Voluntary environmental agreements: good or bad news." *Journal of Environmental Economics and Management*, 36: 109–130.

Soda, Atsushi. 2015. “Electricity demand and supply and strategies for securing stable electricity supply (in Japanese).” *Japan Foreign Trade Council Monthly Newsletter*, 738: 15–17.

Statistics Bureau. 2014. “Consumer price index (CPI) result.” Last accessed on January 4, 2018.

Taylor, Lester D. 1975. “The demand for electricity: A survey.” *The Bell Journal of Economics*, 6(1): 74–110.

Tohoku Electric Power Company. 2011. “CSR report (in Japanese).” *https://www.tohoku-epco.co.jp/csrreport/backnumber/csr2011/index.html*, Last accessed on March 21, 2019.

Tokyo Electric Power Company. 2013. “A report of recovery from power outages at electrical plants after the Great East Japan (in Japanese).” *http://www.tepco.co.jp.cache.yimg.jp/torikumi/thermal/images/teiden_hukkyuu.pdf*, Last accessed on March 21, 2019.

Torriti, Jacopo. 2014. “A review of time use models of residential electricity demand.” *Renewable and Sustainable Energy Reviews*, 37: 265–272.

U.S. Energy Information Administration. 2017. “International energy outlook 2017.” *https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf*, Last accessed on March 21, 2019.

Wolak, Frank A. 2011. “Do residential customers respond to hourly prices? Evidence from a dynamic pricing experiment.” *American Economic Review*, 101(3): 83–37.

Woodland, Alan D. 1993. “A micro-econometric analysis of the industrial demand for energy in NSW.” *The Energy Journal*, 14(2): 57–89.