Chapter 6
An Empirical Study of the Tokyo Emissions Trading Scheme: An Ex Post Analysis of Emissions from University Buildings

Tatsuya Abe and Toshi H. Arimura

Abstract The Tokyo Emissions Trading Scheme (ETS) is the first cap -and-trade program of CO_2 emissions in Asia, and it is unique in regulating commercial and service sectors. We examine the impacts of the Tokyo ETS on CO_2 emissions and energy consumption by universities in the first phase. Focusing on universities allows us to estimate the effects of the Tokyo ETS separately from the economic stagnation Japan experienced after the Great East Japan Earthquake in 2011 because universities are less likely to be affected by economic fluctuations compared to other sectors. In addition to the ETS, other factors may have achieved CO_2 emissions reductions in Tokyo in this phase due to the influence of the earthquake. To deal with the shortage of electricity supply after the Fukushima disaster, several measures were undertaken, such as rolling blackouts and power-saving orders, particularly in the Tokyo Electricity Power Company's jurisdiction. To capture the characteristics for each university at the campus level and their experience with being regulation targets of the policies mentioned above, we conducted a mail survey for universities in Japan and obtained panel data that contain information about both regulated and unregulated universities over 5 years (2009–2013). The difference-in-differences approach reveals that the Tokyo ETS caused regulated universities to reduce their CO_2 emissions and energy consumption by approximately 3–5% relative to unregulated universities in the first phase. In addition, we find that the quantitative regulations, such as rolling blackouts and power-saving orders, also had an impact on the universities' behavior.

Keywords Emissions trading scheme · Tokyo ETS · Universities · Policy effects · Rolling blackouts · Power-saving orders

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1 Introduction

Previous chapters explained the carbon mitigation policy by sections in Japan. In most countries, however, carbon pricing, such as carbon tax or emissions trading schemes (ETSs), has been the major policy instrument. This chapter and the following two chapters introduce and quantitatively examine the two regional ETSs in Japan, i.e., the Tokyo ETS and the Saitama ETS. As of 2020, Japan has introduced a small carbon tax, 289 JPY per ton of carbon dioxide (CO_2), a carbon tax of less than US$3, which is not large enough to achieve the long-term target of an 80% reduction by 2050 (Chap. 1). Japan has not introduced a national ETS, although it has discussed introducing such a scheme intensively in the past (Arimura 2015).

The Tokyo metropolitan government introduced a regional ETS in 2010. This ETS was the first cap -and-trade scheme of greenhouse gas (GHG) emissions in Asia. Compared to ETSs in other countries, the Tokyo ETS has several notable features. In particular, it is characterized by the inclusion of the commercial sector and universities as well as the manufacturing sector in the regulation target. This feature is a distinctive characteristic of the Tokyo ETS, which is different from earlier ETSs, such as the EU Emissions Trading Schemes (EU ETS) or the Regional Greenhouse Gas Initiatives (RGGI) in US.

Tokyo has been known as a leader of environmental regulations in Japan because of a number of factors. For example, to tackle PM 10 emissions from diesel trucks, the Tokyo metropolitan government took a leadership role in implementing regulations together with the surrounding three prefectures, including Saitama (Arimura and Iwata 2015). Moreover, the Japanese national government respects a voluntary approach by the industry association (Arimura et al. 2020) and has been reluctant to introduce ETSs at the national level. Consequently, the Tokyo metropolitan government took a lead and decided to introduce an ETS. Saitama joined this movement by adopting an ETS in their prefecture one year after Tokyo (Chap. 7). Tokyo and Saitama are collaborating on the design and the implementation of their ETSs. In fact, Saitama primarily uses the design of the Tokyo ETS and their markets are linked as explained later. The other two prefectures, Kanagawa and Chiba, have not adopted ETSs, which is possibly because the two prefectures host large energy-insensitive facilities, such as steel plants or fossil fuel power plants; hence, achieving a consensus with their industry stakeholders was difficult.

At the end of the first compliance period (phase I), 2010–2014, the Tokyo metropolitan government announced the actual reduction of CO_2 emissions. According to the report, the regulated facilities reduced their CO_2 emissions by approximately 25% compared with the reference year level. During phase I, however, the Great East Japan Earthquake occurred on March 11, 2011, and caused economic stagnation in many sectors. In addition, the earthquake affected power plant facilities throughout Japan and led to an electricity supply shortage. To deal with this power shortage, the government implemented a quantity regulation of electricity in 2011, especially in the Kanto and Tohoku regions. Two quantity regulations were implemented, i.e., rolling blackouts and power-saving orders, and these two regulations may have partially contributed to the emission reductions. Thus, some people are skeptical about attributing an observed reduction in CO_2 emissions in Tokyo to the achievement of the Tokyo ETS. It is important to evaluate whether the ETSs have worked effectively by conducting a quantitative analysis. In this chapter, we estimate the causal effect of the Tokyo ETS in phase I on the energy consumption of the regulation targets, especially focusing on universities.

Why do we focus on universities? The regulation targets of the Tokyo ETS are facilities with over a certain level of annual energy consumption, and universities are included among such facilities. GHG emissions are likely to be influenced by economic fluctuations. However, compared to other sectors, the GHG emissions from universities are less likely to be impacted by the economic situation. Therefore, universities are a suitable target for quantitative analysis. To estimate the policy effect of the Tokyo ETS, it is necessary to remove factors other than the Tokyo ETS. For this reason, we focus on universities in this study.

The empirical studies presented in this chapter use a questionnaire survey conducted by the authors in 2015. This data set includes data for five years from 2009, before the start of the Tokyo ETS, to 2013, one year before the end of phase I. By using this data set, it is possible to analyze the extent of the energy reduction by the regulated universities.

The results of the quantitative analysis using our survey of universities in Japan confirmed that the regulated universities reduced their energy consumption compared to the unregulated universities during phase I. In addition, we found that the effects of the power-saving orders and rolling blackouts implemented after the earthquake were very large.

The rest of this chapter is organized as follows. Section 2 provides a review of the literature on this research field, especially focusing on the EU ETS. Section 3 describes in detail the system of the Tokyo ETS. Section 4 presents explanations for the power-saving orders and rolling blackouts. Section 5 outlines the data sources used in our analysis. Section 6 presents our approach to estimating the causal effect of the Tokyo ETS and interprets the estimation results. Section 7 discusses the national development of the regional ETS in Japan.

2 ETS Literature Review

2.1 Impact on Emission Reductions

This subsection introduces the existing literature that has conducted empirical analysis to verify the effects of ETSs on GHG emission reductions. We review studies on the EU ETS, followed by those on the Tokyo ETS. Since the EU ETS is now in phase III, some findings up to phase II have thus far been obtained. The description of the EU ETS is largely based on Martin et al. (2015).

For phase I, 2005–2007, some papers have confirmed a GHG emission reduction due to the EU ETS. Ellerman and Buchner (2008) used a data set including all countries complying with the EU ETS for the first two years of phase I. To assess the effects of the EU ETS on CO_2 emission reduction, they compared the actual amount of emissions with the hypothetical amount had the EU ETS not been introduced. They concluded that EU ETS countries as a whole reduced their CO_2 emissions by 50–100 Mt annually from 2005 to 2006. In addition, Ellerman et al. (2010) and Anderson and Di Maria (2011) supported this finding, reporting annual reductions of 70 Mt and 58 Mt during phase I, respectively.

Other papers have focused on the GHG emission reduction effect in a single country. For example, Ellerman and Feilhauer (2008) estimated this effect, focusing on Germany. They found that in phase I, the EU ETS reduced CO_2 emissions by 28.5 Mt in all ETS industries and by 11.7 Mt in the manufacturing sector.

For phase II, 2008–2012, Egenhofer et al. (2011) showed an average improvement of 3.4% in CO_2 emissions intensity over the first two years of phase II. On the other hand, Cooper (2010) and Kettner et al. (2015) were skeptical about the effect of the EU ETS during this period, particularly the economic downturn from 2007 to 2008.

The number of papers that use firm-level panel data has recently increased. Petrick and Wagner (2014) and Colmer et al. (2018) analyzed the causal effects of the EU ETS using firm-level panel data in Germany and France, respectively. These studies used a matching method to estimate the causal effect of the EU ETS. Petrick and Wagner (2014) showed that the EU ETS caused the regulated manufacturing firms in Germany to reduce their CO_2 emissions by 25–28% over the first three years of phase II, from 2008 to 2010. Colmer et al. (2018) confirmed that French manufacturing firms under the EU ETS reduced their CO_2 emissions by 13.5% in phase II compared with the 2000 level.

To our knowledge, few empirical papers have investigated the policy effect of the Tokyo ETS on the emissions from regulation targets. Wakabayashi and Kimura (2018) and Arimura and Abe (2020) estimated the impact on the commercial sector using a facility-level data set. Wakabayashi and Kimura (2018) concluded that the Tokyo ETS did not cause regulated facilities to reduce their CO_2 emissions during phase I (2010–2014) and that the energy saving behaviors after the Great East Japan Earthquake in 2011 were the main drivers for the observed emissions reduction. However, they did not control for the electricity power prices or consider drastic increases in the power prices after the earthquake. Arimura and Abe (2020) controlled for the electricity power price to estimate the causal effect of the Tokyo ETS and then derived different conclusions from those of Wakabayashi and Kimura (2018). Arimura and Abe (2020) showed that the Tokyo ETS had an impact on the CO_2 emissions from regulated facilities to the same extent as more than a 10% increase in the electricity power price.

2.2 Economic Impacts

There are concerns that the introduction of carbon pricing may reduce the international competitiveness of regulated firms. In this subsection, we focus on empirical papers that consider the issue of competitiveness in the case of the EU ETS.

In phase I, we found no evidence that the EU ETS has negative impacts on the economic performance of regulated firms. For example, Abrell et al. (2011) analyzed the impact of the introduction of the EU ETS on value added, employment, and profits in phase I. Using firm-level panel data from 2005 to 2008, they concluded that the EU ETS had no negative impact on any of these outcomes. Additionally, Commins et al. (2011) found no impact on employment using firm-level data for 1996–2007.

The size of impacts on economic activities such as production and employment are different by country, industry and compliance period. Focusing on manufacturing firms in Germany, Petrick and Wagner (2014) found that there was no negative impact on employment in phase I or phase II and that only phase II had some positive impacts of 4–7% and 7–18% on the amount of production and exports, respectively. Similarly, using data on German manufacturers, Löschel et al. (2019) examined whether regulated firms run efficient production processes by estimating a stochastic production frontier model. They found no statistically significant effect on the efficiency of production processes.

Moreover, Colmer et al. (2018) examined the effect of the EU ETS using manufacturing firm data in France. They confirmed that the value added, employment, and tangible assets of regulated firms did not decline from the announcement period to phase II compared with the 2000 level.

3 Tokyo ETS

3.1 Targets, Caps, and Compliance Periods

In this section, we first explain the history of the introduction of the ETS by the Tokyo metropolitan government. Then, the outline of the system is described.

The Tokyo metropolitan government established a mid-term emission target of a 25% reduction by 2020 compared to the 2000 level. Earlier, they tried a voluntary scheme (Roppongi et al. 2017), but such a scheme did not generate a substantial emission reduction. Consequently, the Tokyo government needed to adopt a mandatory emission reduction scheme[1] with flexibility, which is why the Tokyo ETS was introduced.

[1] Any facility that cannot attain the goal set by the Tokyo ETS faces a fine. This penalty contrasts with the Saitama ETS, which was modeled after the Tokyo ETS and was introduced in 2011. The Saitama ETS is a voluntary scheme and thus has no fines. For details on the Saitama ETS, see Chap. 7 by Hamamoto.

As of 2020, the Tokyo ETS is in the third compliance period of the system. The first phase (phase I) was from 2010 to 2014, and the second phase (phase II) ran from 2015 to 2019. The Tokyo metropolitan government has announced details on phase III, which will continue from 2020 to 2024.

The targets of the Tokyo ETS are large-scale CO_2 emitters in the commercial and manufacturing sectors.[2] The emissions from these sectors amount to approximately 40% of the CO_2 emissions from the commercial and manufacturing sectors in Tokyo. Facilities consuming crude oil equivalent energy of 1,500 kl or more per year are subject to the Tokyo ETS. Because there are small and medium-sized facilities that do not meet this threshold, the Tokyo ETS covers approximately 20% of total CO_2 emissions in Tokyo.

A unique feature of the Tokyo ETS is that it regulates buildings in the service sector as well as industrial plants. Just like other metropolitan cities in developed economies all over the world, the service sector accounts for the majority of facilities in Tokyo. The manufacturing sector accounts for a small portion of GHG emissions in Tokyo. Moreover, large-scale power plants are not located in Tokyo. Thus, to have a meaningful regulation of GHG emissions, the Tokyo metropolitan government decided to include commercial and service sectors in the ETS. Indeed, commercial and office facilities account for approximately 80% of regulated facilities.

This characteristic is unique and quite different from that of existing ETSs implemented in other countries at the time of the adoption of the Tokyo ETS in 2010. For example, when it started in 2005, the EU ETS regulated emissions from manufacturing facilities and power plants. Additionally, the RGGI is a scheme that targets power plants. The main target of the Korean ETS is manufacturing facilities (Jun et al. 2019). Therefore, in 2010, the Tokyo ETS differed from other schemes in that it regulated emissions from the service sector.

Although the Tokyo ETS is a regional ETS, there is a large number of regulated facilities. For example, in the Tokyo area, in 2013, 1,392 facilities had to comply with the Tokyo ETS. The number of facilities under the Korean ETS, which has the largest market value for a single country (World Bank 2019), is approximately 600 (Jun et al. 2019); therefore, in comparison, the Tokyo ETS has a large number of regulated facilities.

The reduction targets under the Tokyo ETS have been different across the two phases. The reduction target for phase I was relatively low, as this phase was thought to be an introductory phase. In fact, the mandatory CO_2 reduction targets were 8% for commercial buildings and 6% for manufacturing facilities compared to a base year level.[3] However, in phase II, the emission targets were tightened to 17% for office buildings and 15% for manufacturing facilities.

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[2] Specifically, facilities that consume 1,500 kl or more of crude oil equivalent energy per year are defined as large-scale facilities in this system. This typical threshold is used in energy regulation in Japan. For details, see Arimura and Iwata (2015).

[3] Facilities had the flexibility to choose their baseline emissions from the average of three consecutive years selected from 2002 to 2007.

3.2 Transition of GHG Emissions and the Calculation of Indirect Emissions

To what extent have emission reductions been achieved by facilities complying with the Tokyo ETS through phase I in total? At the end of phase I, the Tokyo metropolitan government announced the actual values of CO_2 emission reductions. The graph in Fig. 1 shows the transition of CO_2 emissions from the regulated facilities. Emissions in the base year were 13,630,000 tons of CO_2, and annual emissions decreased during this period. In 2014, the final year of phase I, emissions decreased by 10,270,000 tons of CO_2, indicating that the decrease in the amount of emissions in 2014 from Tokyo ETS facilities was approximately 25% relative to the base year level. This fact suggests that the target for phase I established under the Tokyo ETS was achieved beyond expectations. Notably, however, the influence of the 2011 earthquake also contributed to these reductions. We will reveal the effects of the Tokyo ETS purely from the total emissions reduction in later sections.

The Tokyo ETS is also unique in how it measures GHG emissions. Emissions from electricity usage, as indirect emissions, are regulated because the majority of emissions from commercial and office buildings are from their electricity usage. The regulation of these emissions is different from other ETSs, such as the EU ETS, which focuses on emissions from fossil fuel combustion.

The CO_2 emissions from the electricity usage of a facility are measured by multiplying its electricity consumption by the CO_2 intensity. The CO_2 emission intensity

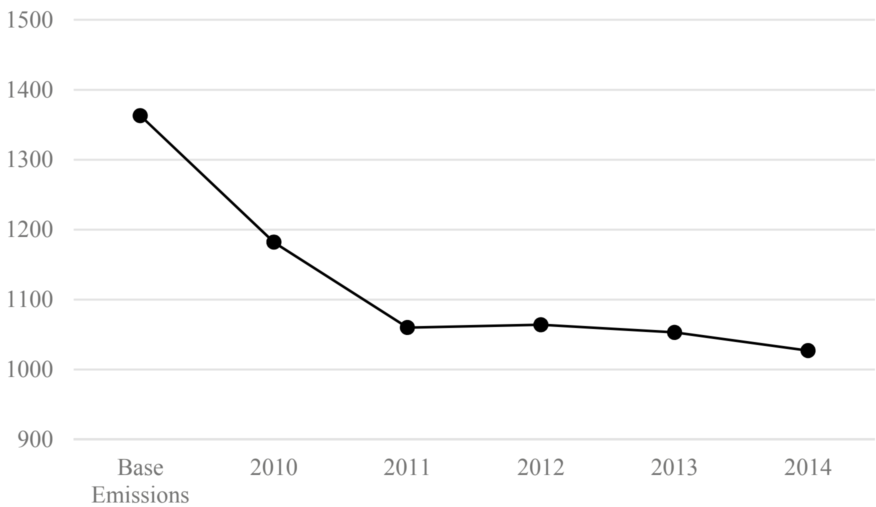

Fig. 1 Transition of Total CO_2 Emissions from Tokyo ETS Facilities. *Source* Tokyo Metropolitan Government Bureau of Environment (2016), https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/data/index.files/candtpuresusiryouhonnbun.pdf (last access date: 08/04/2020)

of electricity was 0.382 kg CO_2 per kWh[4] and was fixed for the compliance period of the Tokyo ETS. According to this method, in 2010, total emissions under the Tokyo ETS were approximately 11.8 million CO_2 tons.

3.3 Credits and Compliance Methods

To ease the burden of compliance and to provide several options for achieving targets, the Tokyo metropolitan government permits the regulated facilities to use several types of credits. All facilities receiving permit allocations can participate in trading, and the transactions are conducted by *emission reduction credits*. Such credits can be issued to facilities only after they have already reduced their emissions.

Additionally, the Tokyo ETS has three offset credits: *small and medium-sized installation credits within the Tokyo area*, *renewable energy certificates,* and *outside Tokyo credits*. These offset credits offer options to the regulated facilities to count emission reductions by small and medium-sized facilities that do not comply with the Tokyo ETS or facilities outside Tokyo as their own reductions. Facilities can also earn credits by investing in renewable energy.[5]

In addition, the Tokyo ETS has *Saitama credits,* as the Tokyo ETS is linked with the Saitama ETS, which was introduced in 2011. The Saitama ETS was modeled after the Tokyo ETS; thus, the features of the two systems are similar, and the credits from the two systems are exchangeable.

Table 1 presents the aggregate amounts of credit issues between 2011 and 2016.[6] A total of 9.51 million tons of CO_2 was issued during this period. Regarding the

Table 1 Amount of credit issues (unit: tons of CO_2)

Emission reduction credits	Small and nedium-sized installation credits	Renewable energy cerfiticates	Outside Tokyo credits	Saitama credits	Total
9,062,832 (1,272)	56,421 (1,051)	289,615 (119)	92,030 (8)	5,557 (6)	9,506,455 (2,456)

Source Tokyo Metropolitan Government Bureau of Environment (2017) https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/trade/past_information.files/jukyuryosuikei20170602.pdf (last access date: 07/02/2020)
Note These values represent aggregate amounts of credit issued from 2011 to 2016 in terms of tons of CO_2 (left) and the number of facilities (right, in parentheses)

[4]This amount is the average CO_2 intensity from 2005 to 2007. Under the Tokyo ETS, the coefficient is fixed through all periods even when the emission intensity changes as power companies change the fuel mix. This fuel mix is hardly impacted by the Tokyo ETS because most power plants are located outside Tokyo or Saitama and do not have to deal with an ETS.

[5]For details, see the Tokyo Metropolitan Government Bureau of Environment (2015).

[6]Tokyo ETS set an adjustment period for regulated facilities; for phase I, it was between 2015 and September 2016.

Table 2 Compliance methods

	Emissions trading	Internal reduction measures
Number of facilities	124 (9%)	1,262 (91%)
Emission reductions (unit: 1,000 t-CO_2)	192.7 (1.9%)	10,080 (98.1%)

Source Tokyo Metropolitan Government Bureau of Environment (2017) https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/trade/past_information.files/jukyuryosuikei20170602.pdf (last access date: 07/02/2020)
Note The numbers in parentheses show the ratios for each row

emission reduction credits, which were the most frequently issued among all credits, 9.06 million tons of CO_2 were issued. The emission reduction credits are bankable up to the next phase. Therefore, credits from phase I were carried over into phase II, although they cannot be used in phase III.

Facilities under the Tokyo ETS can achieve their targets through several methods. Table 2 shows the compliance methods by entity. First, they can reduce emissions: according to the Tokyo metropolitan government, 91% of facilities reduced their emissions beyond the target. Alternatively, they can achieve their target by obtaining additional credits: approximately 9% of facilities achieved their target through the acquisition of credits.

The Tokyo ETS is also unique in the way regulated facilities engage in trading. In designing the Tokyo ETS, the Tokyo government faced the criticism that permit trading under an ETS could create a "casino" (Roppongi et al. 2017). Stakeholders close to the manufacturing sector were afraid that the ETS might invite speculation by the financial sector and that the ETS would thus be ineffective as a means of environmental regulation. In dealing with this criticism, the Tokyo government introduced "reduction credits" and not "emission credits". The introduction of this type of credit means that regulated facilities can earn credits only after they reduce their emissions. In addition, the Tokyo government has not introduced permit auctions. Only emitting entities can participate in trading, and the financial sector is excluded from permit trading. As a result, most trades have been bilateral, and compared to other markets, permit trading has not been very active. The Tokyo government examines the price through private interviews and publicizes the permit price; Fig. 2 depicts the trajectory of permit prices. In 2011, the price was initially approximately 10,000 JPY ($125) per CO_2 ton, but in 2015, it fell to approximately 4,500 JPY ($37) per CO_2 ton for reduction credits. These numbers are close to the findings by Arimura and Abe (2020), who estimated the implicit price of permits from their empirical analysis. Figure 2 shows that renewable credits are more expensive than reduction credits. The reason is that one can use renewable credit permits for other compliance purposes.

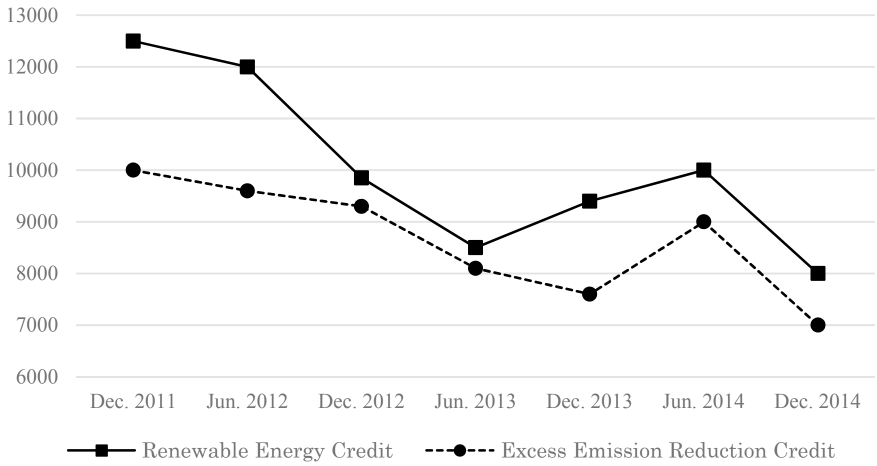

Fig. 2 Permit Price (JPY/CO_2 ton). *Source* Mizuho Information & Research Institute, Inc. (2019), https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/trade/index.files/sateikakaku.pdf (last access date: 08/04/2020)

4 Rolling Blackouts and Power-Saving Orders

In addition to the regulation of the Tokyo ETS, one can consider other factors as having influenced GHG emissions in Tokyo. On March 11, 2011, the Great East Japan Earthquake occurred, with its epicenter off the coast of Miyagi Prefecture in the Tohoku region. This disaster caused tremendous damage to the Kanto[7] and Tohoku regions near the epicenter. One example of such damage was the accident at the Fukushima nuclear power plant. After the accident, electric power supply shortages became a serious problem because all nuclear power plants in Japan were shut down for safety inspections, and other electric power facilities had also been damaged. To address this problem the Japanese government decided to implement quantity regulations of electric power as a countermeasure, and these regulations consisted of rolling blackouts and power-saving orders.

Rolling blackouts were the first regulation introduced. In a rolling blackout, the electric power supply in a certain area is stopped and restarted in a structured manner to avoid large-scale blackouts caused by excess demand. Rolling blackouts were implemented only within the service area of the Tokyo Electric Power Company (TEPCO) from March 14 to 28, 2011, right after the earthquake. To choose the target area, the damage from the earthquake disaster had to be comparatively small, and negative spillover effects from the blackouts to other regions had to be limited. The location and time of an actual blackout were announced the day before.

[7] In general, the Tokyo, Kanagawa, Saitama, Chiba, Ibaraki, and Tochigi Prefectures are included in the Kanto region.

In the service area of the TEPCO and the Tohoku Electric Power Company, where the damage was especially severe, power-saving orders were issued to address the electricity shortages anticipated for the summer. These orders required a consumption reduction of 15% or more compared with the previous year during peak weekday hours for large-lot users whose contracted electric power was over 500 kW. In the case of a violation, large-lot users had to pay a fine of less than one million JPY. This regulation was enforced in the service area of the TEPCO and the Tohoku Electric Power Company from July 1 to September 9, 2011.

These regulations may have had some impacts on the conservation of electricity consumption, and they may have promoted energy saving investments among universities. Moreover, the activities at universities may have changed due to these regulations. In Sect. 6, we control for these factors when estimating the causal effect of the Tokyo ETS.

5 Data

5.1 Mail Survey of Universities in Japan

We conducted a mail survey of universities in 2015 to capture their yearly energy consumption and their GHG emissions. As of 2015, there were 779 universities in Japan. Among them, 137 universities were in Tokyo, accounting for 17.6% of the population. The targets of this survey were chosen from the GHG Emissions Accounting, Reporting, and Disclosure System under the Act on the Promotion of Global Warming Countermeasures, which requires facilities in Japan to report their GHG emissions if they consume 1,500 kl crude oil equivalent energy or more. Consequently, we sent questionnaires to the 340 universities across Japan that met these criteria. We received responses from 271 universities, for a response rate of 79.7%. In our sample, the number of universities located in Tokyo is 52, which is consistent with the population rate.

The universities were requested to provide their CO_2 emissions, electricity consumption and energy consumption over the five years between 2009 and 2013.[8] To capture their characteristics, the universities were also asked to provide information regarding the number of students, the percentage of science and engineering students, and the floor space of their buildings. In addition, we included items in the questionnaire regarding the universities' experiences with the rolling blackouts and the power-saving orders from the power companies.

Table 3 presents the summary statistics for 2009, a period before the implementation of the Tokyo ETS. For all variables in the sample, both the top and bottom one percentile of each distribution were regarded as outliers, and they were removed

[8]In our survey, we asked the universities to report their energy usage and characteristics based on campuses that they own because in the case of universities, the unit of the regulation target under the Tokyo ETS is campus.

Table 3 Summary statistics

	N	Mean	Std. Dev.	Min.	Max.
A. Full sample (mid-98%)					
Energy consumption [kl]	239	4,803.2	4,045.1	1,456.0	21,394.0
CO_2 emissions [t-CO_2]	239	8,805.1	7,724.7	2,353.0	39,400.0
Electricity consumption [GJ]	239	140,418.0	113,481.2	34,117.0	721,991.0
Floor space [m^2]	235	111,582.2	64,476.1	14,429.0	417,561.0
# of students	223	5,479.7	4,416.7	197.0	21,674.0
Percentage of Science & Eng. Students [%]	207	56.5	41.3	0.0	100.0
B. Tokyo					
Energy consumption [kl]	52	3,928.8	3,404.3	1,639.0	19,729.0
CO_2 emissions [t-CO_2]	52	6,748.0	6,001.6	2,840.0	35,029.0
Electricity consumption [GJ]	52	123,907.9	107,446.1	35,413.0	605,435.0
Floor space [m^2]	51	99,571.7	50,575.8	14,429.0	265,414.0
# of students	50	7,124.0	4,731.7	621.0	19,663.0
Percentage of Science & Eng. Students [%]	47	42.8	45.6	0.0	100.0
C. Other regions (excluded Saitama)					
Energy consumption [kl]	175	5,150.0	4,269.4	1,456.0	21,394.0
CO_2 emissions [t-CO_2]	175	9,598.2	8,232.5	2,353.0	39,400.0
Electricity consumption [GJ]	175	147,836.8	117,417.0	34,117.0	721,991.0
Floor space [m^2]	172	116,970.3	68,858.2	19,193.0	417,561.0
# of students	163	4,998.6	4,297.2	197.0	21,674.0
Percentage of Science & Eng. Students [%]	150	62.1	38.3	0.0	100.0

from the data set used for analysis. The table has three panels: the first panel shows the summary statistics for all universities in our sample, the second panel shows the statistics for the universities in Tokyo, and the third panel shows the statistics for the universities in the other prefectures.

There are clear differences in the characteristics of the universities in Tokyo and those in the other prefectures. In 2009, the annual CO_2 emissions from the universities in Tokyo were relatively low compared to those from the universities in the other prefectures, e.g., an average of 6,748 tons of CO_2 and 9,583 tons of CO_2, respectively. Regarding the scale of universities, while the universities in Tokyo have a smaller floor space than those in other regions, the number of students in Tokyo is larger.

The transitions in average CO_2 emissions over time are illustrated in Fig. 3. In this figure, the values on the vertical axis represent the differences between the 2009 level and each year, and the dashed and solid lines show the changes in CO_2 emissions

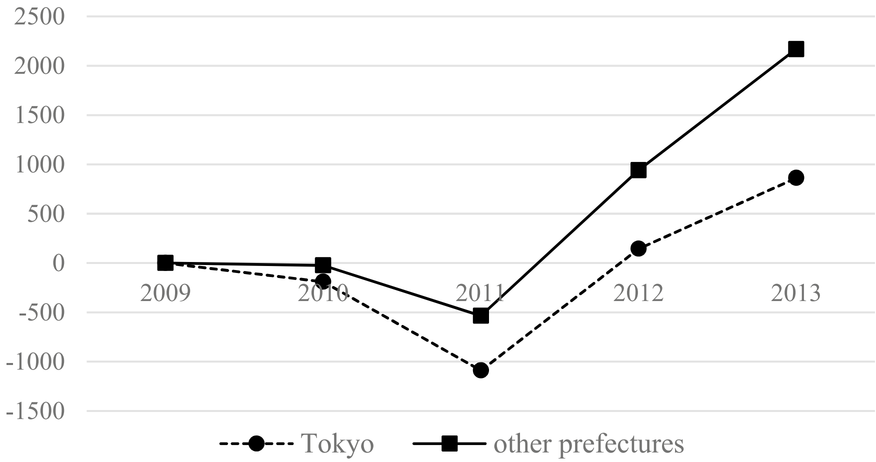

Fig. 3 Changes in CO_2 emissions. *Note* For each region, the lines show changes between CO_2 emissions in each year (2010–2013) and those in 2009, which is a reference year for our analysis

for Tokyo and the other prefectures, respectively.[9] The CO_2 emission reductions in 2011 were large in Tokyo and the other prefectures. Although the CO_2 emissions in all areas have increased since 2011, the degree of increase in Tokyo was smaller than that in the other prefectures.

5.2 *Electricity Price Data*

Electricity prices are likely to play an important role in GHG emission reductions because most GHG emissions come from electricity consumption. Specifically, there was a rise in electricity prices during phase I in the Tokyo region. We obtain electricity prices from the Federation of Electric Power Companies (FEPC) of Japan. The data set contains the volumes of electric power demand for nine regions in Japan and the associated charge revenues. Before the recent deregulation of the retail market in 2016, the Japanese power market was divided into nine regions.[10] The electricity price for each region was calculated by dividing the charge revenue by the volume of power demand.

Figure 4 depicts the transitions of electricity prices by region. The power price in Japan rose over the 10 years from 2006 to 2015. Before the Great East Japan Earthquake in 2011, the power prices were somewhat similar across the nine regions. After the earthquake, however, the price in the jurisdiction of the TEPCO increased greatly. In particular, the industrial and commercial sectors in the TEPCO market

[9] Since Saitama Prefecture has its own ETS, it is excluded from this figure.

[10] The nine regions are as follows: Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Shikoku, Chugoku and Kyusyu.

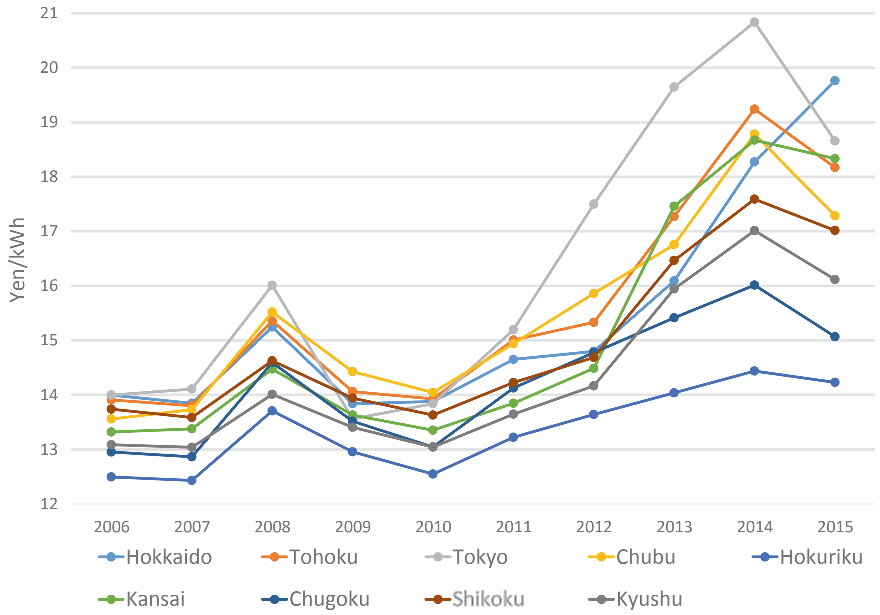

Fig. 4 Trends of electric power prices. *Source* Database from the Federation of Electric Power Companies of Japan. *Note* Each line shows trends of electric power prices for the nine electric power companies in Japan

faced an electricity price growth rate of 12.4% during the 2010–2013 period, which was the largest among the growth rates recorded in the nine regions. The TEPCO covers nine prefectures: Tokyo, Saitama, Chiba, Ibaraki, Tochigi, Gunma, Kanagawa, Yamanashi and Shizuoka. Among them, only the Tokyo and Saitama regions have an ETS in place. Therefore, we can detangle the impact of the ETS from the increase in the power price.

6 Econometric Model and Estimation Results

6.1 Econometric Model

In this subsection, we describe a method for estimating the causal effect of the Tokyo ETS on the energy usage of universities. The causal effect that we would like to estimate here is defined as the difference between the actual energy usage of a Tokyo ETS university and a counterfactual energy usage when the university was not subject to the Tokyo ETS. Therefore, we have a problem in estimating the causal effect. We are unable to observe the latter energy usage in the real world.

To solve this problem, we take the difference-in-differences (DD) approach, which is widely used in the policy evaluation context when panel data are available. Using the DD strategy, we estimate the following equation to quantify the impact of the Tokyo ETS:

$$y_{itg} = \tau_g \cdot Tokyo_i \cdot I(t \geq 2010) + \alpha_{1g} Tokyo_i \\ + \alpha_{2g} I(t \geq 2010) + x'_{itg}\beta_g + \eta_t + \mu_i + \varepsilon_{itg}$$

In this equation, y_{itg} on the left-hand side denotes the CO_2 emissions ($g = 1$), the electricity consumption ($g = 2$), and the energy consumption ($g = 3$) of university i in year t.[11] The variable $Tokyo_i$ on the right-hand side is a dummy variable that takes the value of one if university i is located in Tokyo and zero otherwise. The function $I(\cdot)$ is the indicator function, which takes the value of one if a condition in the argument is true and zero otherwise. The interaction term between $Tokyo_i$ and $I(t \geq 2010)$ represents the causal effect of the Tokyo ETS; thus, the parameter τ_g is the parameter of interest. The vector x_{itg} is composed of some explanatory variables, including the electricity price, and policy variables, including rolling blackouts and power-saving orders. In addition, the characteristics of universities, such as the floor space, the number of students, and the percentage of science and engineering students, are included in this vector. The year fixed effects and individual fixed effects are captured by η_t and μ_i, respectively. The idiosyncratic error term is represented by ε_{itg}.

6.2 *Empirical Results*

This subsection provides the implications of the estimation results obtained in the previous subsection. Table 4 reports the estimation results. We have estimated three models. Each column in the table shows these estimation results for the equation with the dependent variable being the logarithm of CO_2 emissions, electricity consumption, and energy consumption. The sample sizes for each model are different because the dependent variables have missing values for each.

As mentioned above, our value of interest is the estimate of the coefficient for the interaction term, the parameter τ_g. For each equation, the estimates are shown in the first row of Table 4: −0.036, −0.049, and −0.042. These results imply that the Tokyo ETS had an impact on the CO_2 emissions, electricity consumption, and energy consumption of regulated universities during phase I and that the size of the impact was between 3.7% and 5.0%.

In addition to the Tokyo ETS, the effect of the rolling blackouts or power-saving orders is noteworthy. The third row in Table 4 presents these estimates: −0.073, −0.049, and −0.052. From these results, we conclude that the impact of

[11] We estimated these three equations ($g = 1, 2, 3$) equation by equation. The fixed effect model was used for each estimation.

Table 4 Estimation results

	Dependent variable		
	ln(CO_2 emissions)	ln(electricity consumption)	ln(energy consumption)
	(1)	(2)	(3)
Independent variables:			
Tokyo ·I(t≧2010)	−0.036**	−0.049***	−0.042***
	(0.014)	(0.017)	(0.012)
ln(electricity price)	0.039	0.182**	0.129**
	(0.118)	(0.078)	(0.064)
Power-saving order or rolling blackout dummy	−0.073***	−0.049***	−0.052***
	(0.014)	(0.015)	(0.012)
Observations	982	999	1,000

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Note Standard errors robust to heteroskedasticity and serial correlation are in parentheses. Other explanatory variables, such as floor space, the number of students, and the percentage of science and engineering students, are used in the estimation, but their results are removed from the table

these electricity restrictions implemented in 2011 persisted during phase I and that the size of the impact that they had was larger than that of the Tokyo ETS. Universities may have reacted strongly to the regulatory policies issued by the government.

On the other hand, the coefficients of the electricity price for each equation do not have a negative sign. This result may suggest that universities are less likely to be sensitive to changes in the electricity price. We discuss this point in the next subsection.

6.3 Discussion

In the previous subsection, we obtained the estimate of the impact of the Tokyo ETS on CO_2 emissions at universities and found that it was approximately 3–5%. Thus, the following question arises: how did the Tokyo ETS work well not only in universities but also in other sectors? In fact, Arimura and Abe (2020) conducted an analysis for the commercial sector that was the same as that in this chapter, confirming that the Tokyo ETS made regulated commercial facilities reduce their CO_2 emissions and energy consumption by approximately 5–7%.

There may be several reasons why the effect of the Tokyo ETS for commercial facilities was larger than that for universities. One reason is that universities suffer from the principal-agent problem, as often pointed out in the literature on the energy efficiency gap (Gillingham and Palmer 2014). The managers of universities facing the Tokyo ETS want to reduce GHG emissions. However, the majority of agents consuming energy in universities are students, who have no incentive to reduce their energy consumption. Furthermore, faculty members may not listen to the requests of university managers to save energy because they, too, do not have any incentives to do so. Therefore, the impact of the ETS was weaker in universities than in office buildings.

Additionally, Arimura and Abe (2020) concluded that commercial facilities responded sensitively to changes in electric power prices. This point is largely different from the result of our empirical analysis, as we did not find that electricity consumption at universities negatively responded to the electricity price we measured. There are two possible reasons for these counterintuitive results. The first is related to the contracts with power companies. In Tokyo, universities are large consumers of electricity, and different from other commercial facilities, they might have a unique contract with the power companies. We would ideally employ the real electricity price that each university faces in our estimation. However, since these data are not available, we used the values at the regional level, which were calculated from data on charge revenues and the volumes of electricity demand as an alternative to the actual electricity price. Thus, the difference between the actual and calculated electricity prices might lead to some biases in the estimates.

Second, the principal-agent problem argued above would also apply to this issue. Students and faculty members in universities have no incentive to reduce their electricity consumption and respond to changes in electricity prices. Thus, the estimate of the coefficient for the electricity price might not become statistically significant. Moreover, we can think another possibility for this issue. When students or faculty members face a rise in electricity prices, they may tend to go to and spend time at the university to avoid consuming electricity in their homes. If this is the case, a rise in electricity prices will lead to an increase in demand for electricity in universities, making the sign of the coefficient for the electricity price positive. Of course, at this stage, this possibility is only a conjecture. Verifying it will constitute future work.

7 Conclusions

In this chapter we carried out an ex post evaluation of the Tokyo ETS in phase I, focusing on university buildings. The estimation strategy we took was to compare the CO_2 emissions and energy consumption of regulated universities with those of unregulated universities. We found that the Tokyo ETS reduced the CO_2 emissions or energy consumption of regulated universities by approximately 3–5% on average in phase I compared with the level of 2009, a year in the pretreatment period. Despite some skepticism regarding ETSs, the Tokyo ETS was effective in reducing CO_2 emissions.

Moreover, the rolling blackouts and power-saving orders in 2011 continued to have effects on subsequent energy consumption. We confirmed that these regulations had an impact of approximately 5–7% on average in phase I. On the other hand, we could not find an impact of the increase in electricity power prices in the Tokyo area; this result stands in contrast to the findings of Arimura and Abe (2020) with regard to commercial buildings.

To understand the size of these impacts from the ETS as well as the rolling blackouts and power-saving orders, we must be careful. By summing these two effects, the emissions reduction ranges from 8 to 12%, which is much smaller than the appraisal of the emissions reduction by the Tokyo government, which obtained a 25% reduction. This difference comes from the difference in the reference year. The Tokyo government uses baseline emissions, which were chosen between 2002 and 2007, a period before the announcement of the implementation of the Tokyo ETS; in contrast, our econometric analysis uses the emissions in 2009 as the reference year due to data limitations. We suspect that facilities facing the Tokyo ETS reduced their CO_2 emissions and energy consumption between the base year and 2009. Thus, our finding is not entirely inconsistent with the appraisal by the Tokyo government.

There is one limitation in our analysis. The data that we used were panel data from 2009, one year before the start of the Tokyo ETS. The analysis method used in this chapter is strongly dependent on the assumption that the energy usages of the regulation targets and nontargets have parallel trends in the period before the start of the system. However, since we have data for only one year in the pretreatment period, we cannot verify the validity of this assumption. Verifying this assumption will be the subject of future research.

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