Economics, Law, and Institutions in Asia Pacific

Toshi H. Arimura
Shigeru Matsumoto *Editors*

Carbon Pricing in Japan

OPEN ACCESS

Springer

Economics, Law, and Institutions in Asia Pacific

Series Editor

Makoto Yano, Research Institute of Economy, Trade and Industry (RIETI), Tokyo, Japan

The Asia Pacific region is expected to steadily enhance its economic and political presence in the world during the twenty-first century. At the same time, many serious economic and political issues remain unresolved in the region. To further academic enquiry and enhance readers' understanding about this vibrant region, the present series, Economics, Law, and Institutions in Asia Pacific, aims to present cutting-edge research on the Asia Pacific region and its relationship with the rest of the world. For countries in this region to achieve robust economic growth, it is of foremost importance that they improve the quality of their markets, as history shows that healthy economic growth cannot be achieved without high-quality markets. High-quality markets can be established and maintained only under a well-designed set of rules and laws, without which competition will not flourish. Based on these principles, this series places a special focus on economic, business, legal, and institutional issues geared towards the healthy development of Asia Pacific markets. The series considers book proposals for scientific research, either theoretical or empirical, that is related to the theme of improving market quality and has policy implications for the Asia Pacific region. The types of books that will be considered for publication include research monographs as well as relevant proceedings. The series show-cases work by Asia-Pacific based researchers but also encourages the work of social scientists not limited to the Asia Pacific region. Each proposal and final manuscript is subject to evaluation by the editorial board and experts in the field.

All books and chapters in the Economics, Law and Institutions in Asia Pacific book series are indexed in Scopus.

More information about this series at http://www.springer.com/series/13451

Toshi H. Arimura · Shigeru Matsumoto
Editors

Carbon Pricing in Japan

Springer

Editors
Toshi H. Arimura
Faculty of Political Science and Economics
Waseda University
Shinjuku-ku, Tokyo, Japan

Shigeru Matsumoto
Department of Economics
Aoyama Gakuin University
Shibuya-ku, Tokyo, Japan

ISSN 2199-8620 ISSN 2199-8639 (electronic)
Economics, Law, and Institutions in Asia Pacific
ISBN 978-981-15-6963-0 ISBN 978-981-15-6964-7 (eBook)
https://doi.org/10.1007/978-981-15-6964-7

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Carbon pricing (CP), in the form of, for example, an emissions trading scheme (ETS) or a carbon tax, has reentered the global spotlight since the Paris Agreement entered into force. In Japan, the government has set a long-term reduction target for greenhouse gas (GHG) emissions, and consequently, the importance of CP has been reaffirmed as a tool of effective mitigation measures. However, Japan has failed to adopt carbon pricing at a level that can substantially reduce GHGs: The carbon tax introduced in 2012 was set at a very low level, and a nationwide emission trading program has not been introduced. In contrast, two local governments, Tokyo and Saitama, have introduced ETSs. The initiatives of these two local governments are little known to the rest of the world.

The research project underlying this book is "*An ex post analysis of carbon pricing and the proposal of policy options to achieve the Japanese long-term GHG emissions reduction* target (Principal Investigator: Toshi H. Arimura)." Seven research groups at six universities/institutes in Japan joined this project under the Research Institute for Environmental Economics and Management (RIEEM) at Waseda University. The project was a three-year endeavor from April 2017 to March 2020 and was supported by the Environmental Research and Technology Development Fund (2-1707) of the Environmental Restoration and Conservation Agency. Without this generous financial support, we could not have completed this book.

This research project conducted an empirical study of Japanese mitigation policy with a focus on CP by examining the impacts on firms and households. Furthermore, we proposed possible policy options by using a newly constructed economic model. The project consists of the following two teams: the Empirical Analysis Team (four subthemes) and the Economic Modeling Team (three subthemes) and aims to contribute to Japanese environmental policy and institutional design for achieving the long-term emission reduction target.

The aim of this book is to evaluate various measures introduced in Japan to mitigate carbon emissions from an economic perspective. Although countries have created several such policies in response to pressing climate change issues, the effectiveness of those programs has not been sufficiently analyzed or compared.

In particular, policy evaluations in the Asian region lag far behind those in North America and Europe due to data limitations and political reasons. We offer a series of empirical analyses of Japanese mitigation policies to satisfy research needs.

Moreover, the domestic policies implemented in Asia are less known to the rest of the world. The second aim of this book is to introduce various mitigation policies in various Japanese sectors to the world. The book covers mitigation policies targeting the sectors of manufacturing, electric power, services, households, and transport. This aspect of the book will be useful for academics and policy makers in emerging countries seeking to design carbon mitigation policies in corresponding sectors.

Finally, we intend to offer policy options for the Japanese economy. Although the Japanese government set a long-term emission reduction target of 80% by 2050, it has not specified policy measures to achieve this target. We offer a carbon pricing option for the long-term target and assess the economic burden at both the firm and household levels.

The book consists of three parts. In the first part of the book, Japanese climate mitigation policies are summarized by sector, and their progress is assessed. Although emissions trading and carbon taxation have been used in Japan, there are few studies that have assessed their impacts. The second part of the book shows how those policies have changed the behavior of firms and households. In addition, macroeconomic simulations are offered that account for the potential of renewable energy. Given these comprehensive assessments, the effectiveness of measures to prevent climate change is compared between Japan and Western countries. Each chapter is written independently, and the contents are related across each chapter. Therefore, readers can start from any chapter following their own interest.

Part I addresses policy issues and reviews Japanese climate policies in various sectors. Chapter 1 is the introductory chapter for the entire book and provides an overall assessment of current carbon pricing in Japan. Based on the concept of effective carbon rates proposed by the OECD, this chapter illustrates that Japan's nationwide average effective carbon rate is lower than the average effective carbon rates of OECD countries and rejects the claim that Japan has already introduced sufficiently high-carbon prices through energy taxes.

Chapter 2 focuses on the commercial sector, which faces the highest reduction targets among all sectors. After explaining the carbon policies in the commercial sector, the chapter summarizes the results of a survey on the implementation of energy efficiency measures in office buildings. The results show that Tokyo leads the other regions of Japan in the implementation of energy efficiency measures.

Chapter 3 studies energy consumption in the household sector, where energy conservation measures are slow to progress. The Japanese government has introduced various energy conservation measures to reduce household energy usage for the past several decades. The chapter selects several major energy conservation measures and evaluates their cost effectiveness.

Chapter 4 addresses the transport sector, which faces high effective carbon rates but accounts for a high share of greenhouse gas emissions. Japanese vehicle users need to pay acquisition, ownership, and gasoline taxes to use their vehicles. In the first half of the chapter, the authors combine those taxes and estimate the effective carbon rate. The Japanese government has promoted electric vehicles (EVs). In the latter half of the chapter, the authors conduct a cost–benefit analysis of EVs.

Chapter 5 uses oligopoly models to analyze two policies that have actually been implemented in Japan. The first policy is to improve the efficiency of fossil fuel power generation, and it is shown that efficiency improvement does not necessarily lead to a reduction in CO_2 emissions. The second policy is a combination of feed-in tariffs and carbon taxes, and the analysis shows that social welfare can be enhanced by combining the two policies.

Part II assesses the impact of two local ETSs currently implemented in Japan, i.e., the Tokyo ETS and Saitama ETS. Chapter 6 illustrates the design of the Tokyo ETS and evaluates its impact on energy consumption by universities. The authors collect the data from a mail survey administered to universities in Japan and conduct a difference-in-differences analysis before and after the implementation of the Tokyo ETS. The empirical results demonstrate that the Tokyo ETS has decreased CO_2 emissions by 3–5%.

Chapter 7 investigates whether the Target-Setting Emissions Trading (TSET) Program (Saitama ETS) in Saitama Prefecture has reduced CO_2 emissions. The author finds that the TSET program was successful in reducing emissions even though the program includes no penalty for facilities that do not meet emission goals. The analysis also revealed that the program functioned as an incentive for facilities that are not covered by the program to lower their energy consumption.

Chapter 8 uses nationwide facility-level data to compare CO_2 reductions in the manufacturing sector between the Tokyo ETS and Saitama ETS. The authors find that the Tokyo ETS reduced electricity consumption by 16 percent, but the Saitama ETS did not reduce it in a statistically meaningful way. The authors further examine whether manufacturers switched from dirty fuels to clean fuels after ETS implementation.

Part III conducts a top-down model analysis to assess the macro-level impact of carbon pricing. Chapter 9 develops input–output tables for the analysis of the next generation energy systems (IONGES) to analyze the ripple effects of CO_2 emissions from the introduction of renewable energy power plants and to analyze the three types of carbon tax: upstream, midstream, and downstream. The authors revealed that the taxation effects of one unit of carbon tax differ depending on the type of carbon tax. Their empirical results also have implications for changes in household energy consumption attitudes according to carbon tax types.

Chapter 10 conducts a computable general equilibrium (CGE) analysis, which is the most commonly used approach for the assessment of tax impacts and examines how carbon pricing affects the international competitiveness of the Japanese economy. The CGE simulation shows that the CO_2 reduction planned by the Japanese government generates large negative impacts on the Japanese economy in the absence of preventive measures. Border adjustments can only slightly mitigate the negative macroeconomic impact.

Chapter 11 focuses on the effective carbon rate and estimates the effects of carbon policies that increase the effective carbon rate to a 30 euro threshold. The findings indicate that the short-term effect of a carbon tax that raises the effective carbon rate for all industries above 30 euros will affect not only energy-intensive industries but also downstream industries that already have high effective carbon rates. Furthermore, the analysis shows that the carbon tax implemented in 2012 increased the difference between taxed emitters and non-taxed emitters. Thus, tax exemptions for energy-intensive industries reduce economic efficiency.

Chapter 12 compares the impact of carbon pricing across various households. The chapter shows that there is significant heterogeneity in the tax burden across geographical regions and income classes. In particular, low-income households living in cold regions are expected to be seriously affected by carbon pricing. The chapter proposes redistribution policies to avoid damaging the living standards of vulnerable people.

Chapter 13 addresses the issue of double dividends. To obtain public support for carbon pricing, several countries use revenue from a carbon tax to reduce existing distortionary taxes. The authors first show that the Japanese long-term emissions reduction target can be achieved through a carbon tax with revenue recycling. Then, the authors assess two types of tax revenue recycling (RR): reductions in corporate taxes and social security payments. Their simulation results demonstrate that RR can increase public support for a carbon tax.

The knowledge offered by this book is valuable for various readers. First, we expect it will be useful to academic and non-academic researchers who work on environmental economics and environmental policy. Another group of target readers consists of graduate students in economics or public policy. We also believe that the contents of this book will help inform government officials and policy makers who seek cost-effective measures to mitigate carbon emissions in developing and emerging economies.

We are indebted to a number of colleagues and researchers for insightful comments and feedback on our research. We are grateful to the formal advisors of the project: Akira Yokoyama (Chyuo University), Kanemi Ban (Osaka University), Toru Morotomi (Kyoto University), and Kyoshi Fujikawa (Nagoya University). Most of the chapters were presented at the annual meetings of the Society for Environmental Economics and Policy Studies, where we received useful comments for the revision. We also hosted three annual symposiums at Waseda Neo in Tokyo by inviting David Brown (University of Alberta), Yukari Takamura (University of Tokyo), and Hyungna Oh (Kyung Hee University) as keynote speakers. All the speakers helped us improve our research. We also appreciate administrative support from Mriduchhanda Chattopadhyay, Yukie Iwatuska, and Yuki Mikami.

Many of the chapters have been presented at international workshops and conferences. We benefitted from comments from Jian Zhou, Alun Gu, and Bin Liu, who generously hosted a workshop at Tsinghua University in Beijing. Several chapters of this book were presented at the annual meeting of East Asian Association of Environmental and Resource Economics, Beijing 2019. We appreciate Maosheng Duan (Tsinghua University) for his useful comments in the thematic session that we organized jointly with Hyungna Oh. Moreover, we were fortunate to have presented several chapters at workshops at Resources for the Future in the USA and the University of Manheim/Center for European Economic Research in Germany. We benefited from comments from Dick Morgenstern, Karen Palmer, Dallas Burtaw, Alan Krupnick, Joshua Linn, Ulrich Wagner, and other participants in the workshops.

With respect and gratitude, we want to dedicate this book to Prof. Kanemi Ban, who supported the project from the outset and attended our first symposium at the annual meeting of the Society for Environmental Economics and Policy Studies, Kochi University of Technology. Unfortunately, he passed away in 2018 without seeing the completion of the project. Without his encouragement and support, we could not have completed this project or the book.

Tokyo, Japan — Toshi H. Arimura
Tokyo, Japan — Shigeru Matsumoto

Contents

About the Editors

Dr. Toshi H. Arimura Director, Research Institute for Environmental Economics and Management; Professor, School of Political Science and Economics, Waseda University.

Dr. Toshi H. Arimura is a professor of Political Science and Economics and a director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Prior to joining Waseda, he was a professor at Sophia University in Tokyo and was a visiting scholar with George Mason University and Resources for the future as a recipient of the Abe Fellowship. His research interests include climate change, energy policies, air pollution regulations, and voluntary environmental actions. He has published his research in academic journals such as *Journal Environmental Economics and Management, Journal of Association of Environmental and Resources Economics, Environmental and Resource Economics, Ecological Economics*, or *Energy Policy*. He is a co-author of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach from Environmental Economics* (Springer 2015). He holds a Ph.D. in economics from the University of Minnesota, an MSc in environmental sciences from the University of Tsukuba, and a BA in history of science from the University of Tokyo. He has served on a number of Japanese government committees on environmental issues including the committees on carbon pricing (2018) and emission trading scheme (2010) of the environmental council under Ministry of the Environment. He is also a member of the Tokyo

Metropolitan Environmental Council. He has served on advisory committees of local governments for emission trading schemes of Tokyo and Saitama. He has also been on editorial boards of academic journals such as *Review of Environmental Economics and Policy, Agricultural and Resource Economics Review, Economics of Energy and Environmental Policy*, or *Environmental Economics and Policy Studies*. Since 2018, Waseda University has chosen him as one of the ten next generation core researchers. He is a recipient of SEEPS Outstanding Publication Award from Society for Environmental Economics and Policy Studies (Japanese Association of Environmental Economics and Policy) and the academic award from Society of Environmental Science, Japan.

Shigeru Matsumoto joined the Aoyama Gakuin University faculty in 2008. He studied on Heiwa Nakajima Foundation Scholarship at North Carolina State University, where he earned his Ph.D. in economics. He also holds his Masters of Environmental Science from Tsukuba University. Before coming to Aoyama Gakuin University, he spent seven years on the faculty of Kansai University.

His research interest lies in applied welfare economics, with particular focus on consumer behavior analysis. In recent years, he studies households' pro-environmental behaviors such as recycling and energy-saving practices as well as consumers' valuation on food attributes such as organic farming.

http://shigeruykr.wixsite.com/happy-environment.

Chapter 1
Expectations for Carbon Pricing in Japan in the Global Climate Policy Context

Satoshi Kojima and Kenji Asakawa

Abstract Realizing a decarbonized society in consistent with the Paris Agreement, a fundamental transformation of the entire economic and social system is needed, and not only carbon intensive sectors but also all sectors and all stakeholders including households must be decarbonized. This chapter demonstrates increasing expectations for carbon pricing in Japan in this global policy context. After the review of the global trend of carbon pricing, historical progress of carbon pricing in Japan and the existing nation-wide carbon tax, i.e. the Global Warming Countermeasure Tax, is explained. There are also two sub-national carbon pricing schemes in Japan, Tokyo ETS and Saitama ETS, which are explained in Chaps. 6 and 7 respectively, and not focused in this chapter. We examine the claim that Japan has already implemented high level carbon pricing in terms of various forms of energy taxes. Based on the effective carbon rate which is defined by OECD as the sum of explicit carbon prices and fossil fuel taxes per carbon emission, the nationwide average effective carbon rate of Japan is lower than the average effective carbon rates of OECD countries and its key partner countries. The current carbon pricing schemes in Japan are too modest to realize decarbonization transition and there is a room to upgrade them to exploit full potential of carbon pricing. This chapter discusses adequate levels of carbon prices in compatible with decarbonization transition.

Keywords Paris agreement · Decarbonization · Transition · Carbon pricing · Effective carbon rates

1 Introduction

The Paris Agreement adopted in December 2015 sets out the trend toward decarbonization, which calls for net zero GHG emissions by the latter half of this century. Along with this trend not a few countries have set ambitious emission reduction targets to address it, and among them Japan officially set an 80% reduction target for

S. Kojima (✉) · K. Asakawa
Institute for Global Environmental Strategies (IGES), Hayama, Japan
e-mail: kojima@iges.or.jp

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_1

greenhouse gas (GHG) emissions by 2050 in the Plan for Global Warming Countermeasures adopted by the Cabinet in May 2016. The IPCC 1.5°C Special Report (IPCC 2018) published in November 2018 further corroborates this trend, and now international society seriously discusses decarbonization measures to reduce CO_2 emissions to net zero around 2050. In order to realize such a decarbonized society, a fundamental transformation of the entire economic and social system is needed and not only carbon intensive sectors such as the power generation sector and the iron and steel sector but also all sectors and all stakeholders including households must be decarbonized.

How to realize such a fundamental transformation is apparently an extremely difficult question, but there are number of existing studies tackling this daunting task to answer this question and there seems to be a general agreement that carbon pricing is necessary to realize a fundamental systemic change toward a decarbonized society.

The Deep Decarbonization Pathways Project (DDPP), an international research project that aimed to chart a pathway to reach the 2050 reduction target using backcasting methods to be consistent with the Paris Agreement, placed carbon pricing as a key element in all policy packages (DDPP 2015). It is explained that the realization of decarbonization assumes that a large number of discrete (decentralized) actors will make the right choices, and carbon pricing is essential to harmonize such discrete decisions (DDPP 2015). Rockström et al. (2017), in their "Roadmap for Rapid Decarbonization" to achieve net zero CO_2 emissions by 2050, stated that carbon pricing of at least USD 50/t-CO_2 in 2020 for all CO_2 emissions needs to be introduced, and that it needs to be raised to a level above USD 400/t-CO_2 by 2050.

There are strong calls for carbon pricing from several influential stakeholders at the global level. At COP21 in December 2015, the Carbon Pricing Leadership Coalition (CPLC) was officially launched. As of 2019 CPLC brings together more than 33 national and sub-national governments, 162 private sector organizations, and 80 strategic partners representing NGOs, business organizations, and universities, aiming at promoting carbon pricing towards the long-term objective of introducing carbon pricing all over the world (World Bank 2019a). Actually it was not by chance that the launch of CPLC and the adoption of the Paris Agreement happened simultaneously at COP21. There was a strong synergy between these two events. The call for ambitious climate actions, through carbon pricing, by both heads of governments and CEOs of leading companies gave momentum to raise the level of ambition of the Paris Agreement, and ambitious climate goals stipulated in the Paris Agreement built momentum to introduce carbon pricing as a key instrument to attain the climate goals. From the business sector, the World Business Council for Sustainable Development (WBCSD) stated in their 2019 report that "carbon pricing mechanisms are critical to support the urgent efforts required to drive the transition towards a low carbon future and achieving the 1.5 °C goal" (WBCSD 2019, p. 6). As WBCSD (2019) declared, the time for debating the need for carbon pricing was over and it is time to strongly call for the need of carbon pricing as long-term polices towards decarbonized society.

Carbon pricing is expected to contribute to decarbonization through several functions. Two key functions are price signalling and revenue generation functions. The price signalling function means that carbon pricing improves economic efficiency by reflecting the cost of carbon emissions, i.e. the damage costs of climate change. Ideally carbon prices should be set at the true cost of carbon emissions, but in reality any level of carbon pricing will raise the relative prices of carbon intensive commodities and can contribute to mitigation. This function is common across all forms of explicit carbon pricing, including both carbon tax and cap-and-trade (emission trading system), and it makes low-carbon products relatively cheaper than carbon-intensive alternatives, which results in steering consumers to make low-carbon choices, as well as making low-carbon business profitable and creating business opportunities. The revenue generation function means that revenues from the carbon pricing schemes can be utilised to finance climate actions. This function is limited to carbon taxes or cap-and-trade mechanisms with auction of emission allowances. This function may enable low-carbon and decarbonization investment, including infrastructure development, without which systemic changes towards decarbonized society cannot be materialised. In addition, a carbon tax with a clearly announced future price schedule may serve to inform the general public the strong commitment of governments to achieve climate goals and enable them to accommodate expected levels of carbon prices in their decision making, which is termed as an announcement effect. Through these functions, carbon pricing is expected to provide enabling conditions of a systemic transformation towards decarbonized society.

On the other hand, existing research on carbon pricing has advanced around either theoretical studies supporting that carbon pricing is the most cost-effective emission reduction measure (e.g., Pearce 1991; Schneider and Goulder 1997; Morotomi 2000; Nordhaus 2010) or research on the double dividend hypothesis (e.g., Fullerton and Metcalf 1997; De Mooij 2000; Arimura et al. 2018), which argues that emissions reductions and positive economic impacts can be achieved simultaneously by appropriating revenues from carbon pricing to reduce market-distorting taxes such as income tax and corporate tax. Tvinnereim and Mehling (2018) review empirical studies on carbon pricing, including examples of ex-post evaluations by econometric analysis, and point out that although the emission reduction effect of carbon pricing was empirically supported, the reduction effects were only in the range of a few percent to 10% even in countries that have introduced expensive carbon pricing, including Sweden, and does not support that carbon pricing is effective for the large emission reductions needed for decarbonization. Patt and Lilliestam (2018) claim that most of the existing theoretical studies on carbon pricing are based on the short-term and static demand-supply curves of neoclassical economics, but in order to handle system transitions such as decarbonization, a theoretical framework of transition theory from a long-term and dynamic perspective is needed, such as a decrease in supply price due to an increase in supply due to learning effects and a product value that is determined by regimes such as infrastructure, social networks and institutions.

This chapter demonstrates increasing expectations for carbon pricing in Japan in the context of global climate policy corresponding to the Paris Agreement, in particular the 1.5 °C goal, with keeping mind of the abovementioned research gap. The following Sect. 2 explains the global trend of carbon pricing with introducing advanced cases of carbon pricing across the world. Section 3 explains historical progress of carbon pricing discussion in Japan and outlines the current nation-wide carbon pricing scheme, i.e. *Global Warming Countermeasure Tax*. There are also sub-national carbon pricing schemes in Japan, that is, ETSs in Tokyo and Saitama, of which explanation are provided in Chaps. 6 and 7 respectively, and this chapter focuses on carbon tax including the currently implemented *Global Warming Countermeasure Tax*. Section 4 argues that the current carbon pricing schemes in Japan are too modest and there is a room to upgrade them to exploit full potential of carbon pricing, with arguing expected price ranges in compatible with decarbonization transition, and Sect. 5 concludes this chapter.

2 Global Trend of Carbon Pricing

2.1 Carbon Pricing Initiatives in the World

Since the first carbon tax was introduced by Finland in 1990, only a limited number of European countries implemented carbon tax and the emissions covered by these schemes were very small until the early 2000s. In 2005 EU-ETS was started and the emissions covered by carbon pricing significantly increased, around 4% of global emissions (World Bank 2019b). In 2007 the number of carbon pricing initiatives reached 10, and 4 years later the number of initiatives exceeded 20. Since then the number of initiatives have steadily increased, and as of April 2019, 46 countries and 28 cities/states/regions, which represent 56% of global greenhouse gas (GHG) emissions, have introduced carbon pricing initiatives, according to World Bank (2019b). The levels of carbon prices vary significantly across countries/schemes as shown in Fig. 1.

Currently three Nordic countries (Sweden, Norway and Finland), Switzerland, Liechtenstein and France set high carbon prices above USD 50/t-CO_2, with Sweden implementing the highest carbon price of USD 127/t-CO_2. 18 initiatives employ moderate carbon prices between USD 10/t-CO_2 and USD 50/t-CO_2, and the remaining initiatives employ low carbon prices less than USD 10/t-CO_2. Japan's carbon tax (*Global Warming Countermeasure Tax*) is JPY 289/t-CO_2 (around USD 2.6/t-CO_2), which is among the lowest carbon prices.

2.2 Lessons Learned from Advanced Carbon Pricing Initiatives

In order to make the debate over carbon pricing in Japan more productive and proactive towards decarbonization transition, advanced cases of carbon pricing in

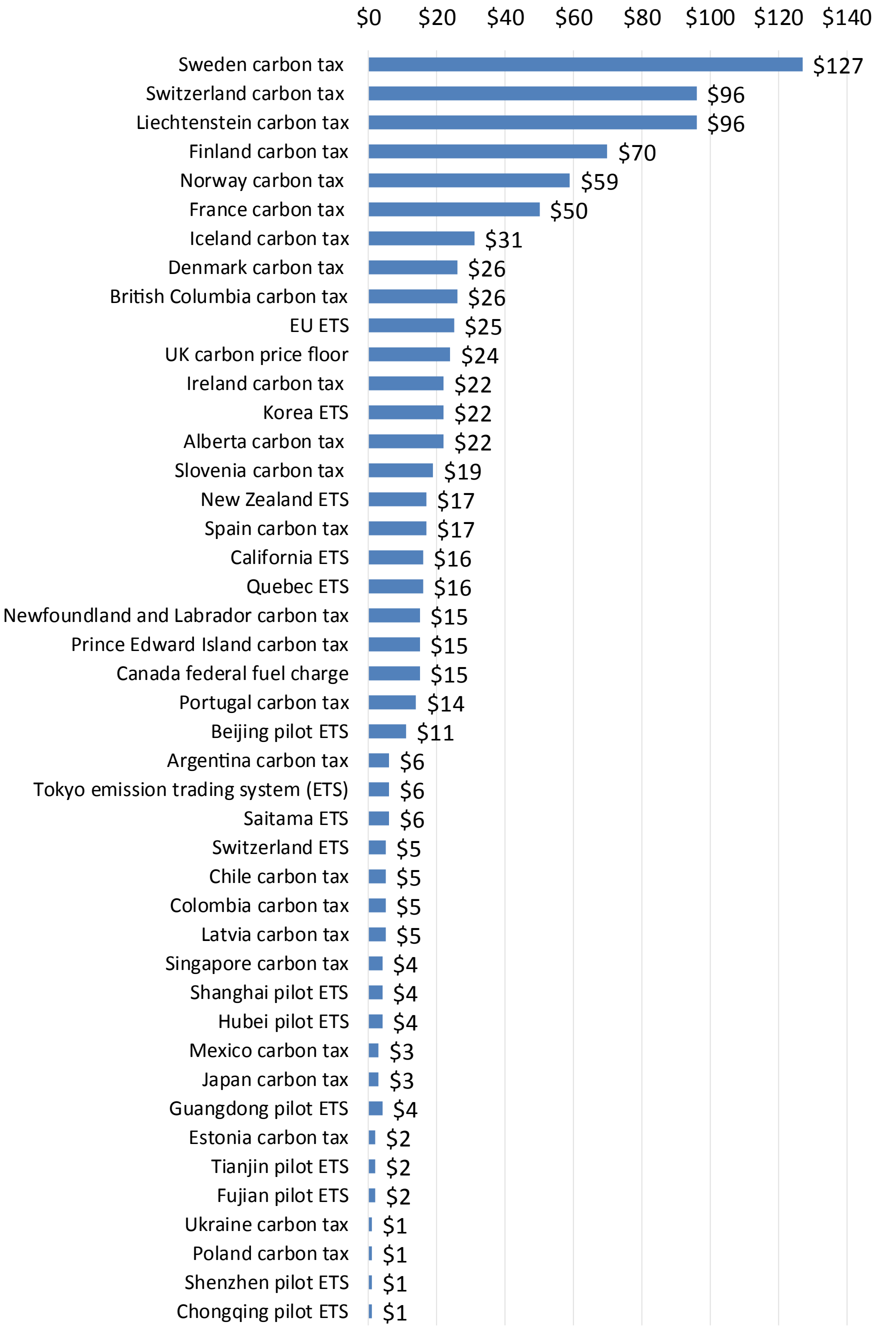


Fig. 1 Prices in existing carbon pricing initiatives. *Source* World Bank (2019b), adopted by the authors

Europe, which were often introduced after intense debate with opponents, provide good reference cases.

In Germany, compared to Japan, ecological tax reform itself has become a political point of contention and has been elevated to a national debate through the election campaign. The lesson to be learned from this is that the larger the national debate became, the more each stakeholder's "real opinions" (the real points of contention) came up for discussion, rather than superficially contesting theoretical and academic points of contention (Kreiser et al. 2015). As a result, it was decided to focus on individual benefits, such as the international competitiveness, performance, and employment issues of the stakeholders affected by the carbon tax, particularly the manufacturing industry, rather than the macro and general discussion such as impacts on GDP growth rates. In this way, we believe that the political contentiousness has stimulated a wide range of stakeholders to discuss their "true feelings" and, because the issues were thoroughly addressed, it was possible to design the system for a carbon tax and other measures accordingly, and relatively quickly consensus was formed.

France was more concerned about the international competitiveness of its own industry, and discussion of border tax adjustment in cooperation with other countries was rendered in parallel with the introduction of a carbon tax and other measures (Asakawa et al. 2016). In EU, many countries have already traded emissions credits through EU-ETS and many countries have also introduced carbon taxes. Therefore, at least a fairer competitive market in terms of carbon pricing has been developed than in the other regions. Nevertheless, the fact that border tax adjustments were being considered suggests that international competitiveness is an issue that should be handled with caution.

In the United Kingdom, from the beginning of policy process the priority is given to stakeholder consultation in order to reflect the opinions of citizens and industry in the design of the system, including consideration for the energy poor (Force 1998). In response to industry concerns, the government exempted energy-intensive industries from taxation, but instead forced them to sign a climate change agreement with the government with voluntary reduction targets. This active adoption of a policy mix of agreements and carbon taxes is also instructive in designing carbon pricing in Japan.

In Sweden, the success factor of early introduction of carbon tax was the fact that tax on fossil fuels was sought as an alternative revenue source to income taxes that had been a high tax burden (Asakawa et al. 2016). This suggests that in addition to the importance of revenue neutrality, the choice of alternative taxes also contributes to public support. In addition, the abundance of biomass, which became an alternative heat source for local heat supply with the introduction of the carbon tax, could be another important factor in increasing public support.

2.3 The Current Status of Effective Carbon Rates

There is an argument that energy taxes also function as carbon pricing instruments. For example, taxation on fossil fuels provides incentives to reduce fossil fuels consumption and consequently has the same effect as a carbon tax, if we just focus on one type of fossil fuel. The important difference between carbon tax and energy tax is that the former tax rates per carbon content are identical across different types of fossil fuels while those of the latter differ between different fossil fuels, and in the worst case the latter could give incentive to increase carbon emissions through lowering relative price of high carbon content fossil fuel such as coal comparing with that of low carbon content fossil fuel such as natural gas. Bearing this caveat in mind, energy tax can be regarded as an extension of carbon pricing. Following this line of argument, OECD defines effective carbon rates (ECR) as the sum of explicit carbon prices (carbon taxes and ETS) and fossil fuel taxes per carbon emission, and estimates the effective carbon rates of OECD countries and its key partner countries as shown in Table 1 (OECD 2016).

Switzerland records the highest national average effective carbon rate at EUR 104.4/t-CO_2, followed by Luxemburg (EUR 95.3/t-CO_2) and Norway (EUR 93.0/t-CO_2). Interestingly the national average effective carbon rate of Sweden (EUR 69.3/t-CO_2) is significantly lower than its carbon tax rate (USD 127/t-CO_2), which means that substantial portion of carbon emissions are exempted from carbon tax.

The effective carbon rates vary greatly across sectors. In many countries including Japan, road transport energy is heavily taxed and is associated with much higher effective carbon rates than those of remaining energy usages, as shown in Table 1. For example, in Japan, the average effective carbon rate of road transport energy is high at EUR 188.3/t-CO_2 while that of other energies is much low at EUR 7.7/t-CO_2, which result in the country's average effective carbon rate at EUR 34.8/t-CO_2.

3 The Current Status of Carbon Pricing in Japan

3.1 The Current Carbon Pricing Initiatives in Japan

Currently there are three carbon pricing initiatives in Japan, Tokyo ETS started in 2010, Saitama ETS started in 2011 and linked to Tokyo ETS, and the *Global Warming Countermeasure Tax*, a national carbon tax, started in 2012. As two local ETSs are addressed in the following Chap. 6 (Tokyo ETS) and Chap. 7 (Saitama ETS), this section focuses on the *Global Warming Countermeasure Tax*.

Japan introduced the *Global Warming Countermeasure Tax* in April 2012 after long discussion at the Central Environment Council. In particular, the Special Committee on Global Warming Countermeasures and Taxation, which was established under the Joint Committee of Comprehensive Policy and Global Environment, the Central Environment Council, from 2001 to 2003, carried out intensive discussions on carbon taxes with the aim of creating a basis for public debate on carbon taxes as a part of evaluation and review of the Charter of Countermeasures against Global Warming in 2004. Based on these discussions the Ministry of the Environment (MOE) submitted a series of tax proposals based on the examination of the

Table 1 Effective Carbon Rates (ECR) of OECD Countries and Key Partner Countries

	Overall average ECR (EUR/t-CO_2)	All energy excluding road transport energy		Road transport energy	
		Share of emissions (%)	Average ECR (EUR/t-CO_2)	Share of emissions (%)	Average ECR (EUR/t-CO_2)
Australia	21.2	82	2.4	18	106.6
Austria	56.2	75	20.2	25	164.4
Belgium	40.6	79	7.4	21	165.7
Canada	10.7	73	3.4	27	30.6
Chile	12.5	84	0.0	16	78.2
Czech	33.2	84	6.7	16	172.3
Denmark	80.3	77	47.4	23	190.4
Estonia	29.1	87	9.5	13	160.4
Finland	48.7	87	23.7	13	216.1
France	65.8	67	9.7	33	179.9
Germany	58.7	82	23.4	18	219.5
Greece	60.4	82	20.7	18	241.4
Hungary	35.4	77	5.0	23	137.4
Iceland	80.1	58	18.1	42	165.6
Ireland	71.9	73	20.6	27	210.6
Israel	79.6	75	26.3	25	239.4
Italy	60.4	82	20.4	18	242.7
Japan	34.8	85	7.7	15	188.3
Rep. Korea	28.4	87	9.8	13	153.3
Luxemburg	95.3	31	5.8	69	135.5
Mexico	2.7	69	0.2	31	8.1
Netherlands	88.7	80	54.6	20	224.8
New Zealand	30.5	67	1.2	33	90.2
Norway	93.0	76	46.7	24	239.3
Poland	28.6	85	10.6	15	130.6
Portugal	48.4	72	6.6	28	156.1
Slovakia	40.0	83	16.3	17	155.7
Slovenia	67.8	62	16.6	38	151.5
Spain	43.4	74	11.1	26	135.1
Sweden	69.3	78	30.7	22	206.5
Switzerland	104.4	64	21.5	36	251.7
Turkey	39.2	85	7.6	15	218.6
UK	75.5	77	14.3	23	280.6

(continued)

Table 1 (continued)

	Overall average ECR (EUR/t-CO_2)	All energy excluding road transport energy		Road transport energy	
		Share of emissions (%)	Average ECR (EUR/t-CO_2)	Share of emissions (%)	Average ECR (EUR/t-CO_2)
USA	5.7	72	0.8	28	18.4
Argentina	33.0	77	3.7	23	130.9
Brazil	3.8	72	1.8	28	9.1
China	4.0	94	1.6	6	42.0
India	2.9	93	1.0	7	29.1
Indonesia	2.4	83	0.0	17	13.9
Russia	0.0	92	0.0	8	0.1
South Africa	13.7	91	3.0	9	122.1

Source OECD (2016), adopted by the authors

characteristics of carbon taxes, institutional issues as taxes, the use of tax revenues, and preliminary estimation of the effects of carbon taxes. Table 2 shows changes in proposals made by MOE and the Central Environment Council until the introduction of the *Global Warming Countermeasure Tax*.

It is observed that basic features of the implemented *Global Warming Countermeasure Tax* as well as most proposals, except for those in 2003, 2004 and 2009, are low tax rate with spending tax revenue for global warming countermeasures. Kawakatsu et al. (2017) reported that the study group on possible tax system reform established by the Environmental Agency (the current MOE) already suggested in 1998 that a possible Japanese carbon tax should have a low tax rate and that the revenues should be solely used for GHG reduction, according to Environmental Agency (1997). In many countries carbon intensive sectors such as the fossil fuel industry, the iron and steel industry and the paper industry strongly oppose carbon pricing that significantly increases production costs if other conditions remain the same, and Japanese business community strongly opposed introducing the carbon tax, which was one of the factors explaining why the realized tax rate (JPY 289/t-CO_2) was much lower than the originally proposed rates (JPY 655/t-CO_2 in the proposals during 2004–2008, and JPY 1,064/t-CO_2 in the 2009 proposal).

Another interesting feature of carbon tax debate in Japan and the implemented *Global Warming Countermeasure Tax* is lack of double dividend perspective, which has been intensively discussed associated with carbon pricing and has provided orientation of green tax reform in many countries. The double dividend hypothesis claims that the reduction of externality by a carbon tax (the first dividend) and the effect of reducing market distortions caused by taxation (the second dividend) can be achieved simultaneously by using carbon tax revenues to reduce other taxes (Goulder 1995; Schob 2003). The original double-dividend hypothesis is that the tax revenue from the optimal solution for the first dividend, which is the Pigouvian tax,

Table 2 Contents of tax proposals towards the *Global Warming Countermeasure Tax*

Proposal date	Description	Tax rate (JPY per t-CO_2)	Expected mitigation effects	Tax revenue (JPY billion per year)	Use of tax revenue
August 2003	Preliminary estimation by the special committee on taxation for global warming countermeasure	927 for all fossil fuels	Kyoto protocol target of 6% reduction from 1990	950	Subsidy for global warming countermeasures
		12,273 for all fossil fuels		12,574 (estimated by the authors)	No use (only price incentive)
November 2004	FY2005 tax reform proposal by MOE	655 for all fossil fuels	4% reduction from 1990	490	General revenue: JPY 340 billion for global warming countermeasures and JPY150 billion for reduction of social insurance cost
November 2005	FY2006 tax reform proposal by MOE	655 for all fossil fuels, with temporal exemption for gasoline, diesel, jet fuels	3.5% reduction from 1990	370	General revenue: JPY 370 billion for global warming countermeasures, with partial concession to local municipalities
November 2006	FY2007 tax reform proposal by MOE	655 for all fossil fuels, with temporal exemption for gasoline, diesel, jet fuels	No description	360	General revenue: JPY 360 billion for global warming countermeasures, with partial concession to local municipalities
November 2007	FY2008 tax reform proposal by MOE	655 for all fossil fuels, with temporal exemption for gasoline, diesel, jet fuels	No description	360	General revenue: JPY 360 billion for global warming countermeasures, with partial concession to municipalities

(continued)

Table 2 (continued)

Proposal date	Description	Tax rate (JPY per t-CO_2)	Expected mitigation effects	Tax revenue (JPY billion per year)	Use of tax revenue
November 2008	FY2009 tax reform proposal by MOE	655 for all fossil fuels, with temporal exemption for gasoline, diesel, jet fuels	No description	360	General revenue: revenue neutral by reducing other environmental tax revenue
November 2009	FY2010 tax reform request by MOE	For importers and extractors of fossil fuels • 1,174 for coal • 1,064 for non-coal For gasoline producers • 7,467 for gasoline	No description (a part of the Challenge 25 that will achieve 25% reduction from 1990 by 2020)	2,000	General revenue: priority is given to expenditures for global warming countermeasures and tax cut included in the challenge 25
November 2010	FY2011 tax reform proposal by MOE	300 for all fossil fuels	1% reduction from 1990 in 2020	240	Use for mitigation measures of energy-derived CO_2
November 2011	FY2012 tax reform proposal by MOE (implemented from FY2012)	289 for all fossil fuels, starting from 1/3 of 289, raised to 2/3 of 289 in April 2014 and raised to 289 in April 2016	No description	262 (normal years)	Use for mitigation measures of energy-derived CO_2

Source MOE, 'Greening taxation', accessed 15 January 2020 at https://www.env.go.jp/policy/tax/kento.html, adopted by the authors

can be used to reduce other taxes that have the effect of distorting the market, in order to attain additional benefit of further improvement in resource allocation efficiency by correcting market distortions (the second dividend). For this form of the double dividend hypothesis, partial equilibrium model analyses by Nichols (1984), Terkla (1984), and Lee and Misiolek (1986) in the 1980s provided results supporting the hypothesis (Schob 2003). There are various variations in the double dividend hypothesis in terms of the definition of the second dividend such as an increase in employment rather than general GDP growth (e.g., Bovenberg and van der Ploeg 1998) or in the effect of correcting inequality in the income distribution (e.g., Klenert et al. 2016). In either case the possibility of double dividend from carbon tax can contribute to improve social and political acceptability of carbon tax. In Japan, however, the possibility of double dividend through revenue recycling to reduce other taxes or social insurance cost was reflected only in the MOE's tax proposals in 2004 and 2009, and the implemented *Global Warming Countermeasure Tax* does not have this possibility. Replacing existing taxes, such as corporate tax and income tax, with carbon tax in order to pursue double dividend would have financial implications to related ministries, not only MOE and the Ministry of Finance but also the Ministry of Economy, Trade and Industry, the Ministry of Health, Labor and Welfare, and so on. Consequently, incorporation of double dividend feature into carbon tax very likely requires inter-ministerial coordination, which might have hindered active discussion on double dividend issues in Japan.

3.2 The Current Sectoral Effective Carbon Rates in Japan

Broadly, there are three types of energy taxes in Japan, that is, upstream fossil fuel tax (the Petroleum and Coal Tax), downstream fossil fuel taxes (the Gasoline Tax, the Light Fuel Oil Tax, and the Aviation Fuel Tax), and electricity tax (the Electric Power Development Promotion Tax). The tax rates of downstream fossil fuel taxes are in general high, e.g. that of the Gasoline Tax is around USD 200/t-CO_2 and that of the Light Fuel Oil Tax is around USD 100/t-CO_2, but only selected types of fossil fuels are covered (Kawakatsu et al. 2017). Upstream fossil fuel tax, i.e. the Petroleum and Coal Tax, is levied on the import or extraction of all types of fossil fuels including natural gas, and the Global Warming Countermeasure Tax is implemented as an additional tax on the Petroleum and Coal Tax (Arimura and Iwata 2015). It should be noted that tax rates of the Petroleum and Coal Tax vary across different types of fossil fuels, i.e., around USD 7/t-CO_2 for crude oil, USD 4/t-CO_2 for natural gas, and USD 2.7/t-CO_2 for coal, which would give price advantage to coal against other cleaner fossil fuels.

Some opponents to carbon pricing often claim that Japan has already implemented quite high carbon pricing through the abovementioned energy taxes. The effective carbon rates estimated by OECD (2016) shed light on this claim. As shown in Table 1, Japan's effective carbon rate of road transportation energy is EUR 188.8/t-CO_2, which is higher than the average of listed countries in Table 1 (EUR 146.6/t-CO_2) but not extremely high among OECD countries. In terms of national average effective carbon rates, Japan is EUR 34.8/t-CO_2, which is lower than the average of listed countries in Table 1 (EUR 43.9/t-CO_2).

In order to identify potential of carbon pricing in Japan further, we estimated Japan's sectoral average effective carbon rates of 6 sectors, that is, the road transportation, the offroad transportation, the industry, the agriculture and fishing, the residential and commercial, and the electricity sectors, as shown in Table 3.

Table 3 Sectoral effective carbon rates of Japan

Sector	Average ECR (EUR/t-CO_2)	Emission (1000 t-CO_2)	Emission share (%)
Road transport	188.3	196,028	14.7
Offroad transport	56.7	20,719	1.6
Industry	3.3	451,225	33.8
Agriculture and fishing	0.8	10,237	0.8
Residential and commercial	5.5	150,165	11.2
Electricity	10.4	508,103	38.0

Source OECD (2016), adopted by the authors

It is striking that the average effective carbon rate of the industrial sector, which emit 33.8% of total carbon emissions, is EUR 3.3/t-CO_2, which is only marginally above the rate of *Global Warming Countermeasure Tax*. In terms of effective carbon rate it is clear that only transportation sectors (road transportation and offroad transportation) bear disproportionally heavy burden, which may result in sub-optimal mitigation outcome as a whole country.

4 Expectations for Carbon Pricing in Japan

4.1 Discussion on Required Price Level

As we discussed in the previous section, the current carbon pricing schemes in Japan are modest and there is a room to upgrade them to exploit full potential of carbon pricing in the context of decarbonization transition. The first key issue is adequate level of carbon pricing. In order to get ideas from the existing literature, it seems important to distinguish two approaches in estimating the carbon price corresponding to the given reduction target. One is the marginal abatement cost approach, which assumes that the carbon price to achieve the given reduction target is equal to the marginal abatement cost corresponding to that target, and the other is explicit carbon pricing approach in which the reduction target is achieved as a result of stakeholders response to explicit carbon pricing. In hypothetical first best world two approaches result in the same carbon price, but this does not hold in the real world as explained below.

The marginal abatement cost is the cost to reduce one unit in addition to the current amount of abatement. Since the cost to reduce one unit differs depending on abatement technologies and the amount of abatement, and since it is used from less expensive abatement technologies to achieve the required abatement, the marginal abatement cost increases as the required amount of emission reduction increases

(Fig. 2). When the marginal abatement cost corresponding to the given reduction target is collected as a carbon price, the reduction target is achieved as a result of the emitter's rational action of cost minimization. In this case, the marginal abatement cost corresponding to the given reduction target is equal to the carbon price to achieve the target (Fig. 2). IPCC (2018) reports the marginal abatement costs in the scenarios corresponding to the 1.5°C and 2°C targets as the prices of carbon emissions.

On the other hand, Kesicki and Ekins (2012) point out that an approach in which reduction targets are achieved through the introduction of a carbon price equal to the marginal abatement cost corresponding to the reduction target does not reflect the various interactions associated with the dynamic processes, and it is necessary to consider marginal abatement costs separately from explicit carbon prices such as carbon taxes and ETS. Bataille et al. (2016) point out that prior to COP 15, majority of research focused on the marginal abatement cost curve for discussing economically efficient emission reductions since the main challenge there was partial emission reductions, but when addressing the challenge of full decarbonization, such as the DDPP, the marginal abatement cost approach is not useful because it may lead to lock-into carbon-intensive infrastructure and technologies or solutions that are inconsistent with social and economic priorities. For utilizing carbon pricing to realize a decarbonized society, it is important to go beyond the framework of the statistic equilibrium analysis of the marginal abatement cost approach and to conduct a dynamic analysis of the processes that significantly change the marginal abatement cost curve itself and the possibility of lowering total emissions and target reductions through a reduction of emitting activities as a result of influencing decision-making of all actors such as producers, consumers, and investors.

For example, the introduction of carbon pricing gives renewable energy a price advantage over fossil fuels, while the introduction of renewable energy in large quantities as a result of this price advantage makes renewable energy technologies

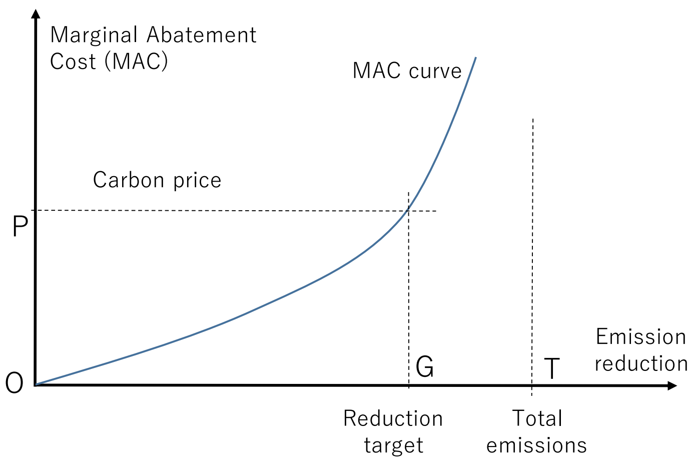


Fig. 2 Marginal abatement cost curve and carbon price. *Source* The authors

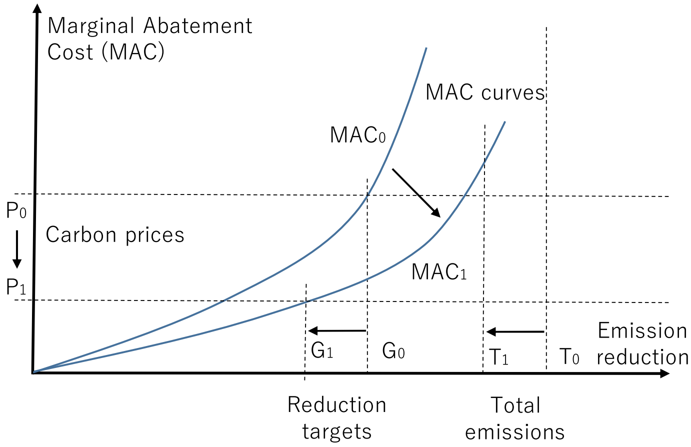


Fig. 3 Possibility of lowering carbon price through various dynamic effects. *Source* The authors

cheaper due to economies of scale, and this virtuous cycle will lead to substantial emission reduction. Taking these dynamic effects into account, the explicit carbon price required to achieve the reduction target is expected to be substantially lower than the corresponding marginal abatement cost for achieving the reduction target in the statics framework, as illustrated in Fig. 3.

Furthermore, the downward shift in the marginal reduction cost curve and the reduction in total emissions can also be caused by systemic changes such as the transition to a digital economy or a circular economy, which are not necessarily caused by the introduction of carbon pricing. Obviously the above argument still applies in this case. Regardless of the impact of carbon pricing, the dynamic analysis of system conversions that significantly change the marginal abatement cost curve itself and the possibility of lowering total emissions and the reduction target through a reduction in emitting activities is important to support actual implementation of carbon pricing.

In addition to the above arguments, the fact that individual bounded rationality plays a major role in real-world decision-making can also be a factor in the discrepancy between the marginal abatement cost estimates and the carbon price. It is known that there are negative marginal abatement costs, i.e., technologies that benefit from the implementation of reduction measures, when a marginal abatement cost curve is drawn by ordering the reduction cost per unit and the amount that can be reduced for each reduction measure technology from the one with the lowest reduction cost per unit. The fact that not all of these technologies with negative marginal abatement costs have been introduced shows that in the real world, the assumption that all measures with marginal abatement costs lower than the carbon price will be implemented is not necessarily valid. Therefore, a distinction needs to be made between estimating the marginal abatement cost corresponding to a given reduction target and how much is reduced through each stakeholder's responses when that marginal abatement cost is introduced as an explicit carbon price.

As the above discussion suggests, estimated carbon prices in consistent with decarbonization transition significantly vary between two approaches. In general, the marginal abatement cost approach resulted in much higher carbon prices than the explicit carbon pricing approach.

IPCC (2018) estimates global marginal abatement costs for emission pathways meeting the 2°C target to be USD 15-220/t-CO_2eq (2010 prices) in 2030 and USD 45-1,050/t-CO_2eq (2010 prices) in 2050, while marginal abatement costs for emission pathways meeting the 1.5°C target to be USD 135-6,050/t-CO_2eq (2010 prices) in 2030 and USD 245-14,300/t-CO_2eq (2010 prices) in 2050. Oshiro et al. (2017) estimated marginal abatement costs using the AIM/Enduse [Japan] model, a sequential dynamic bottom-up energy model, for seven different scenarios for Japan's decarbonization paths corresponding to the 2°C and 1.5°C targets, with and without utilizing carbon sequestration through nuclear power and bioenergy CCS (BECCS), and with and without making early abatement efforts in 2030 that exceed the NDC reduction target. It is also argued that without the use of BECCS, the 1.5°C target cannot be achieved and the marginal reduction cost in 2050 under the 2°C target achievement scenario rises to USD 860/t-CO_2. Sugiyama et al. (2019) analyzed the decarbonization paths of achieving the 2030 NDC and 80% reduction in 2050 using 7 different models with different characteristics, including sequential and full dynamics, global model and Japan single country model, general equilibrium model and partial equilibrium model, and estimated the marginal abatement cost in 2030 as USD 44-346/t-CO_2 (median USD 150/t-CO_2) and the marginal abatement cost in 2050 as USD 273-7,730/t-CO_2 (median USD 2,818/t-CO_2).

On the other hand, the studies in explicit carbon pricing approach estimate relatively moderate carbon price to achieve decarbonization transition. DDPP (2015) identifies carbon pricing as an important element in all policy packages, but Canada and France are the only countries to place explicit carbon pricing in their policy packages in the DDPP country reports (Bataille et al. 2015; Criqui et al. 2015). As part of its policy to reduce GHG emissions by 90% from 2005 levels by 2050, Canada assumes to introduce carbon pricing at CAD 50/t-CO_2 in 2020 and raise it by CAD 10/t-CO_2 each year thereafter until it reaches CAD 350/t-CO_2 in 2050 through a combination of an ETS for heavy industry and a flexible carbon pricing system with an upstream ETS or carbon tax option for other stakeholders. Revenues from carbon pricing are assumed to be used to reduce income taxes for individuals and corporations (Bataille et al. 2015). In France, as part of the policy to reduce GHG emissions by 75% of 1990 levels by 2050, a carbon tax of EUR 90/t-CO_2 in 2030 and EUR 280/t-CO_2 in 2050 is introduced for all sectors under the scenario of 50% share of nuclear power and 40% share of renewable energy in the power supply mix in 2050, and a carbon tax of EUR 120/t-CO_2 in 2030 and EUR 360/t-CO_2 in 2050 is introduced for all sectors under the scenario of 25% share of nuclear power and 70% share of renewable energy in the power supply mix in 2050, and the carbon tax revenue is returned equally to households (Criqui et al. 2015). Rockström et al. (2017) argue that in an effort to achieve a "roadmap for rapid decarbonization" to achieve net zero CO_2 emissions globally by 2050, they would eliminate all fossil fuel subsidies by 2020, which currently amount to USD 500–600 billion per year, and introduce an explicit carbon price of at least USD 50/t-CO_2 for all CO_2 emissions in 2020 through international ETS scheme and a carbon tax on air and sea transport, gradually increasing to a level above USD 400/t-CO_2 by 2050. This roadmap assumes that all CO_2 emissions, estimated to be around 5 Gt by 2050, will be captured by BECCS to achieve net zero CO_2 emissions. To realize a decarbonized society in Japan, Kojima et al. (2018) propose a policy package consisting of carbon tax and a tax recycling scheme in which a portion of the carbon tax revenues is allocated to energy efficiency investments in order to achieve the 2030 NDC target and the long-term goal of the Global Warming Action Plan, an 80% reduction by 2050. Based on E3ME macro-measurement model analysis, Kojima et al. (2018) propose a carbon tax of JPY 11,400/t-CO_2 (around USD 100/t-CO_2) in 2030 and JPY 57,300/t-CO_2 (around USD 500/t-CO_2) in 2050 in a phased manner from 2021 to 2050, with allocating 2–4% of the carbon tax revenue to energy efficiency investments and returning the remainder of the tax revenue to households in a lump-sum manner. More recently, Kobayashi et al. (2019) incorporate an assumption of a full transition to a digital economy and estimate the carbon tax rate to achieve 80% reduction in CO_2 emissions in 2050 (compared to 2013), which corresponds to the 2°C target, and zero CO_2 emissions in 2050, which corresponds to the 1.5°C target, using the static computable general equilibrium (CGE) model. Their assumption of a full transition to a digital economy include widespread use of artificial intelligence (AI), the Internet of Things (IoT), and big data. In introducing the carbon tax, the existing energy tax portion of the tax is reduced so as not to be double taxed with the existing energy tax. It is also assumed that all carbon tax revenues will be returned to households. This study assumes that CO_2 emissions in 2050 will be reduced by 61% in comparison with 2013 even without carbon pricing, because the transition to the digital economy will result in a reduction in manufacturing and a shift to an industrial structure dominated by the service industry along with a decline in the population and an aging of the population. Furthermore, this study assumes a structural change accompanying the transition to the digital economy, such as the use of plastic as a substitute for steel in automobile manufacturing due to the improved safety of automobile traffic caused by the spread of automated driving, or an 80% reduction in the number of automobiles due to the development of the sharing economy, and the elimination of automobile purchases by ordinary households. Based on these assumptions, Kobayashi et al. (2019) conclude that a carbon tax of JPY 9,700/t-CO_2 (around USD 90/t-CO_2) would be necessary to achieve 80% reduction, which means additional 19% reduction on the baseline reduction of 61%, with an additional assumption that carbon pricing triggers the introduction of CCS and additional renewable energy. Without assuming carbon pricing-induced CCS and additional renewable energy deployment, the carbon tax rate required to achieve an 80% reduction in 2050 will jump to more than JPY 30,000/t-CO_2 (around USD 270/t-CO_2). In order to further reduce emissions and achieve zero emissions in 2050, Kobayashi et al. (2019) estimate that a carbon tax of JPY 21,400/t-CO_2 (around USD 200/t-CO_2) will be required, assuming the introduction of CCS and additional renewable energy through carbon pricing.

4.2 Careful Consideration for Revenue Recycling

The revenue generation function of carbon pricing is associated with both potential and challenges and it must be carefully considered.

In terms of potential, there are various options of spending of the revenue of carbon pricing. In case of the *Global Warming Countermeasure Tax* its revenue is solely spent for global warming countermeasures. However as explained in Sect. 3, wisely designed revenue recycling may be able to achieve double dividend in some forms (Chap. 13). Considering the problems Japan is facing now, such as low birthrate and aging population, declining local population, in addition to various challenges associated with decarbonization transition including infrastructure investment, revenue recycling for solving these problems may generate double dividend or even multiple dividend. When the level of carbon price will be as high as discussed in 4.1, the expected revenue could be very large and appropriate revenue recycling could have huge positive impacts.

On the other hand, there is a potential conflict between the mitigation function and the revenue generating functions of carbon pricing (Morotomi 2000). This concern is particularly important when carbon pricing is introduced in order to achieve major emissions reduction. For example, if Japan could achieve an 80% emissions reduction by 2050 with carbon tax as one of key policy instruments for this purpose, the tax base of the carbon tax would fall by 80%. Some may argue that no tax can escape revenue fluctuations, but the point here is not just revenue fluctuations but also implications for policy design. If, for example, a carbon tax is intended to generate stable revenue, either a sufficiently low tax rate should be chosen or a gradually increasing tax schedule would be needed to compensate for the reduction in the tax base. In the former case, the mitigation effect is sacrificed. The latter case, starting with an initial low rate may be reasonable as in any case, but a very high rate of carbon tax would be politically infeasible and keeping a certain revenue level would become very difficult.

5 Conclusion

This chapter reviewed the current carbon pricing in Japan, in terms of not only explicit carbon pricing but also effective carbon rates, along with the current status of carbon pricing worldwide, in the context of global climate policy after the Paris Agreement and the IPCC 1.5°C Special Report (IPCC 2018).

There seems a general agreement among the literature addressing decarbonization pathways corresponding to post Paris Agreement climate policy that carbon pricing with high price level plays indispensable roles to realize systemic transition towards decarbonized society. The rationale is that high level of carbon pricing can provide effective and consistent signals to all stakeholders which is essential to harmonize their decentralized decision making towards decarbonization.

In this context, there is a large potential of improvement in Japan's carbon pricing schemes. Japan has implemented nationwide carbon tax, i.e. the *Global Warming Countermeasure Tax*, since April 2012. The tax rate of this carbon tax is JPY 289/t-CO_2 (around USD 2.6/t-CO_2), which is one of the lowest among carbon pricing initiatives in the world. There are also two municipality level ETS schemes in Tokyo (since 2010) and in Saitama (since 2011), which will be addressed in Chaps. 6 and 7, respectively. There is an argument that Japan has already implemented high level carbon pricing in terms of various forms of energy taxes. However, the nationwide average effective carbon rate of Japan is EUR 34.8/t-CO_2 according to OECD (2016), which is lower than the average effective carbon rates of OECD countries and its key partner countries (EUR 43.9/t-CO_2). Our estimates of Japan's sectoral average effective carbon rates based on OECD (2016) highlight that only the transportation sectors are associated with high effective carbon rates. In Japan the sectoral average effective carbon rates of two large emitters, i.e. the industrial sector and the electricity sector, are EUR 3.3/t-CO_2 and EUR 10.4/t-CO_2, respectively. For improving mitigation efficiency of carbon pricing, one candidate option is energy tax reform based on carbon content of energy carriers, which is discussed in Chap. 11.

In order to exploit full potential of carbon pricing in materializing decarbonization transition, much higher carbon price than the current *Global Warming Countermeasure Tax* is needed. In order to get ideas about adequate level of carbon pricing from the existing literature, we distinguished two approaches in estimating carbon price corresponding to the given reduction target, that is, the marginal abatement cost approach that assumes carbon price to achieve the given reduction target is equal to the marginal abatement cost corresponding to the target, and the explicit carbon pricing approach in which the reduction target is achieved as a result of stakeholders response to explicit carbon pricing. In general the former is associated with much higher carbon prices than the latter due to lack of dynamic interactions between carbon pricing and marginal abatement cost curves, such as downward shift of marginal abatement cost curves due to innovation induced by carbon pricing. The literature based on the explicit carbon pricing approach tend to estimate carbon prices corresponding to decarbonization paths at around USD 100-500/t-CO_2 (c.f. DDPP 2015; Rockström et al. 2017; Kojima et al. 2018; Kobayashi et al. 2019).

Another important issue of carbon pricing is the revenue recycling design. As in many European cases green tax reform in which revenue of carbon tax is spent to reduce other forms of taxes or social insurance costs may result in double dividend (Chap. 13), or even multiple dividend. While careful consideration of revenue recycling design is necessary because of potential conflict between the mitigation function and the revenue generating functions of carbon pricing, carbon pricing with adequate price level with wisely designed revenue recycling is expected to play important roles to materialize decarbonization transition.

References

Arimura TH, Iwata K (2015) Economic impacts of the GHG tax on the Japanese economy: short-term analysis. An evaluation of Japanese environmental regulations. Springer, Dordrecht, pp 145–173

Arimura T, Takeda S, Onuma H (2018) Double dividend of carbon pricing. Rev Environ Econ Policy Stud 11(2):73–76 (in Japanese)

Asakawa K, Matsuo Y, Sunhee S, Rocamora AR (2016) Case studies on analysis of political debate on carbon pricing, especially carbon-tax, in Japan and the other countries. In: Society for environmental economics and policy studies, 10 Sept 2016 (in Japanese)

Bataille C, Sawyer D, Melton N (2015) Pathways to deep decarbonization in Canada, SDSN-IDDRI

Bataille C, Waisman H, Colombier M, Segafredo L, Williams J (2016) The deep decarbonization pathways project (DDPP): insights and emerging issues. Clim Policy 16(sup1):S1–S6

Bovenberg AL, van der Ploeg F (1998) Consequences of environmental tax reform for unemployment and welfare. Environ Resource Econ 12:137–150

Criqui P, Mathy S, Hourcade JC (2015) Pathways to deep decarbonization in France, SDSN-IDDRI

DDPP (2015) Pathways to deep decarbonization 2015 Report, SDSN-IDDRI

De Mooij RA (2000) Environmental taxation and the double dividend. North-Holland, Amsterdam

Environmental Agency (1997) Measures for climate change mitigation and environmental taxation, Gyousei (in Japanese)

Force MT (1998) Economic instruments and the business use of energy: conclusions. Marshall Task Force on the Industrial Use of Energy, HM Treasury, London

Fullerton D, Metcalf GE (1997) Environmental taxes and the double-dividend hypothesis: did you really expect something for nothing? National Bureau of Economic Research, Cambridge, MA

Goulder LH (1995) Environmental taxation and the 'double dividend': a reader's guide. Int Tax Publ Finance 2:157–184

IPCC (2018) Global warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Intergovernmental Panel on Climate Change, Geneva

Kawakatsu T, Lee SC, Rudolph S (2017) The Japanese carbon tax and the challenges to low-carbon policy cooperation in East Asia. Kyoto University Graduate School of Economics Discussion Paper Series No. E-17-009

Kesicki F, Ekins P (2012) Marginal abatement cost curves: a call for caution. Clim Policy 12(2):219–236

Klenert D, Schwerhoff G, Edenhofer O, Mattauch L (2016) Environmental taxation, inequality and engel's law: the double dividend of redistribution. Environ Resource Econ 71(3):605–624

Kobayashi T, Tahara K, Kawasaki Y, Ochiai K, Suzuki T, Kobayashi H, Sayama S, Iwata K (2019) Transition to digital economy: 60% reduction of greenhouse gases—environmental tax of JPY 10,000 in order to achieve 80% reduction in 2050. Japan Centre for Economic Research, 7 May 2019 (in Japanese)

Kojima S, Asakawa K, Lee SC, Chewpreecha U, Suk S (2018) Green tax reform proposal towards realisation of long-term low carbon vision. Rev Environ Econ Policy Stud 11(2):82–86 (in Japanese)

Kreiser L, Andersen M, Olsen B, Speck S, Milne J, Ashiabor H (2015) Carbon pricing: design, experiences and issues. Edward Elgar, Cheltenham

Lee DR, Misiolek WS (1986) Substituting pollution taxation for general taxation: some implications for efficiency in pollution taxation. J Environ Econ Manage 13:338–347

Morotomi T (2000) Theory and practice of environmental tax. Yuhikaku, Tokyo (in Japanese)

Nichols AL (1984) Targeting economic incentives for environmental protection. MIT Press, Cambridge

Nordhaus WD (2010) Economic aspects of global warming in a post-Copenhagen environment. Proc Natl Acad Sci 107(26):11721–11726
OECD (2016) Effective carbon rates: pricing CO_2 through taxes and emissions trading systems. OECD Publishing, Paris
Oshiro K, Masui T, Kainuma M (2017) Transformation of Japan's energy system to attain net-zero emission by 2050. Carbon Manage. https://doi.org/10.1080/17583004.2017.1396842
Patt A, Lilliestam J (2018) The case against carbon prices. Joule 2(12):2494–2498
Pearce D (1991) The role of carbon taxes in adjusting to global warming. Econ J 101(407):938–948
Rockström J, Gaffney O, Rogelj J, Meinshausen M, Nakicenovic N, Schellnhuber HJ (2017) A roadmap for rapid decarbonization. Science 355(6331):1269–1271
Schneider S, Goulder LH (1997) Achieving low-cost emissions targets. Nature 389(6646):13
Schob R (2003) The double dividend hypothesis of environmental taxes: a survey. Nota di Lavoro, Fondazione Eni Enrico Mattei, no 60
Sugiyama M, Fujimori S, Wada K, Endo S, Fujii Y, Komiyama R, Kato E, Kurosawa A, Matsuo Y, Oshiro K, Sano F, Shiraki H (2019) Japan's long-term climate mitigation policy: multi-model assessment and sectoral challenges. Energy 167:1120–1131
Terkla D (1984) The efficiency value of effluent tax revenues. J Environ Econ Manage 11:107–123
Tvinnereim E, Mehling M (2018) Carbon pricing and deep decarbonisation. Energy Policy 121:185–189
WBCSD (2019) Carbon pricing, WBCSD policy paper
World Bank (2019a) Carbon pricing leadership report 2018/19. World Bank, Washington, D.C.
World Bank (2019b) State and trends of carbon pricing 2019. World Bank, Washington, D.C.

Dr. Satoshi Kojima is a principal coordinator at the Institute for Global Environmental Strategies (IGES). He has conducted various quantitative policy impact assessments using computable general equilibrium models and he has led research projects on sustainable development policy including sustainable resource management and sustainable ecosystem use. He studied environmental economics at the University of York in UK and received a Ph.D. in 2005.

Dr. Kenji Asakawa completed a Master of Urban Environment Engineering in Architectural Engineering at the Waseda University Faculty of Science and Engineering. While working at a consulting company on environmental preservation projects based on ODA and being involved in environmental impact assessment both in Japan and overseas, he obtained a class-1 certification as an Architect and as a Professional Engineer. Subsequently, after working in the development of global warming mitigation, including CDM projects, and climate policy, he obtained his Juris Doctor from Omiya Law School and passed the National Bar Examination.

Chapter 2
Climate Policy in the Commercial Sector: A Survey of Commercial Buildings in Japan

Hiroki Onuma and Toshi H. Arimura

Abstract In Japan, the government has set a target for a reduction in greenhouse gas (GHG) emissions by 26% from 2013 levels by 2030. The commercial sector has the highest reduction target—39.8%—among all Japanese sectors. This chapter first presents the current GHG situation in Japan and Japanese climate policy in the commercial sector. Second, we introduce a nationwide survey that we conducted on the implementation of energy efficiency measures (EEMs) in office buildings with large-scale emissions in Japan. The survey results show that energy-saving technology adoption is more advanced in Tokyo than in other prefectures and that there is more space for the adoption of energy-efficient technologies nationwide. To accelerate EEM adoption to achieve the 2030 target, regulatory agencies must improve the way they promote energy audits and subsidies and provide information on energy savings.

Keywords Energy efficiency measures · Office building · Emissions trading scheme · Energy conservation act · Energy audit

1 Commercial Sector's Position in Japan's NDC

To accomplish the Paris Agreement goals of holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels, countries all over the world have set their targets for post-2020 climate actions. In Japan, the government has set a target for a reduction in greenhouse gas (GHG) emissions by 26% from 2013 levels by 2030 (see Table 1).

H. Onuma (✉)
Research Institute of Economy, Trade and Industry (RIETI), 1125 (11th floor), Annex, Ministry of Economy, Trade and Industry (METI), 1-3-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8901, Japan
e-mail: h.onuma.ac@gmail.com

H. Onuma · T. H. Arimura
Waseda University, Tokyo, Japan

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_2

Table 1 Japan's GHG emissions target (by 2030)

Unit: million t-CO_2	Estimated emissions in FY 2030	Actual emissions in FY 2013	Compared to FY 2013 (%)	Percentage of total (%)
Energy-originated CO_2	927	1235	−25.0	−21.9
Industry sector	401	429	−6.5	−2.0
Commercial and other sectors	168	279	−39.8	−7.9
Residential sector	122	201	−39.3	−5.6
Transport sector	163	226	−27.6	−4.5
Energy conversion sector	73	101	−27.7	−2.0
Other GHGs	152.4	173	−11.9	−1.5
Non-energy-originated CO_2	70.8	75.9	−6.7	−0.4
Methane (CCH_4)	31.6	36.0	−12.3	−0.3
Nitrous oxide (N_2O)	21.1	22.5	−6.1	−0.1
Fluorinated gases (HFCs, PFCs, SF_6, NF_3)	28.9	38.6	−25.1	−0.7
Carbon sink (LULUCF[a] sector)	−37.0			−2.6
Total	1042.4	1408.0	−26.0	−26.0

[a]LULUCF stands for land use, land use change and forestry

Within this national emission reduction target, the government has set different emission target levels for each sector. The reduction target for the industrial sector is 6.9%, and the target for the transportation sector is 26.9%. The commercial sector has the highest reduction target—39.8%—among all Japanese sectors.

Japan's GHG emissions had not declined below 1990 levels since statistics started being collected in 1990 (excluding 2009 due to the bankruptcy of Lehman Brothers) before finally doing so in 2018 (MOE 2019). In 2018, the emission level was 1244 million tons of carbon dioxide (CO_2) equivalent, representing a decrease of 3.6% (47 million tons) from the previous year, after decreasing for five consecutive years. Although the main contributor to emission reductions relative to 1990 levels is the industrial sector, emissions over the past five years in other sectors, such as the commercial, residential, and transportation sectors, have also declined (see Fig. 1). However, the commercial and residential sectors have not reduced their emissions enough compared to 1990 levels. The reasons for the higher emissions in these two sectors are the increase in fossil fuel power generation after the Great East Japan Earthquake on March 11, 2011; the expansion of building floor areas; and the increase in the number of households, which has led to a growth in energy use.

To achieve Japan's emissions target under the Paris Agreement, it is crucial to accelerate the adoption of energy efficiency measures (EEMs) for the reduction of GHGs. In 2010 and 2011, respectively, Tokyo and its neighboring prefecture Saitama

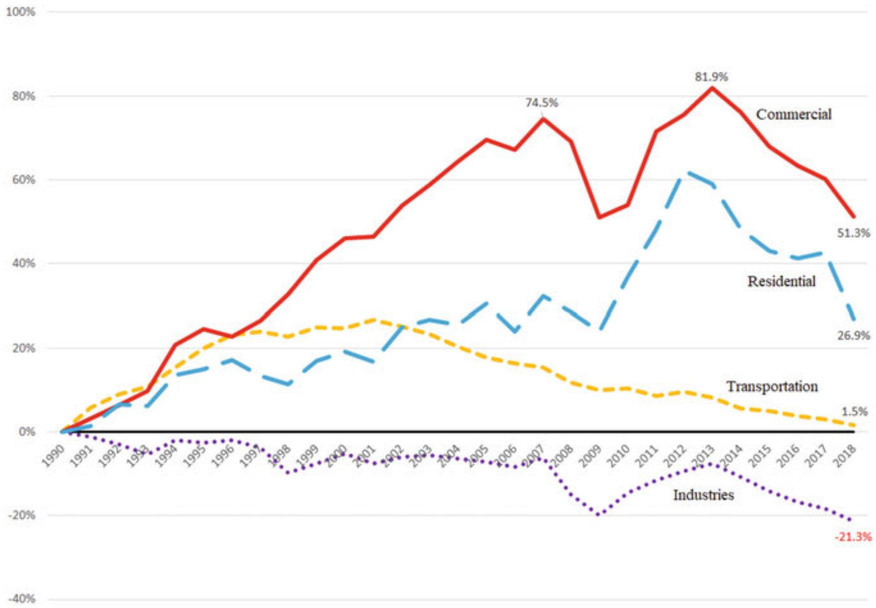


Fig. 1 CO_2 emissions change by sector since 1990

introduced an emissions trading scheme (ETS), which is a policy tool involving effective mitigation measures for the commercial sector.[1] These schemes seem to have led to a reduction in GHGs in both prefectures (Arimura and Abe 2020), although it is unclear how the reduction was achieved.

Based on this background, we conducted a nationwide survey of EEM implementation in 906 commercial buildings with large-scale emissions to clarify how GHGs were reduced. This chapter explains the outline of the survey and compares the EEMs and technology adoption status of commercial buildings in Tokyo, where an ETS is implemented, with those of commercial buildings in areas where there is no ETS. Based on the survey results, we discuss the possibility of EEM diffusion among commercial buildings by introducing ETSs.

The remainder of this chapter is organized as follows. The next section describes Japan's current energy and climate change policies in the commercial sector. Section 3 presents how office buildings can conserve the energy consumption and GHG emissions. Section 4 provides an overview of our survey and the survey results. Section 5 concludes the chapter.

[1] See Chap. 6 for the Tokyo ETS and Chap. 7 for the Saitama ETS in this book.

2 Japan's Energy and Climate Change Policies in the Commercial Sector

This section provides an overview of Japan's energy and climate change policies in the commercial sector (based on the Ministry of Economy, Trade and Industry (METI) 2018; Arimura and Iwata 2015).

Japan's energy consumption efficiency (final energy consumption amount/real GDP) has improved by approximately 40% since the oil crises in the 1970s due to the combined efforts of the public and private sectors.

After the first oil crisis in 1973, an act on the rational use of energy (known as the "Energy Conservation Act"; ECA) was enacted in 1979 (enforced in October 1979) with the goal of efficient energy use in the context of energy security. The act obligates plants and offices with a large amount of energy consumption (crude oil equivalent of 1500 kl/year) to report the state of their EEMs and improvements in energy consumption efficiency every year and to develop medium- and long-term plans for energy efficiency.[2] It also establishes a target of a 1% reduction in energy intensity annually. In addition, regulated facilities must appoint qualified energy managers to promote energy management at plants and offices.

The initial objective of the ECA was to reduce energy consumption rather than GHG emissions, but reducing energy consumption results in a decline in fossil fuel consumption. Therefore, the goal of the ECA was aligned with reducing GHG emissions even before climate change was recognized as a major policy issue.

In the first commitment period of the Kyoto Protocol, energy conservation in Japan had two purposes. The first purpose was energy conservation to address energy security issues motivated by the oil shocks in the 1970s. Now, the purpose of energy conservation is to reduce GHG emissions.

Naturally, when the first commitment period began, the act was viewed as a measure to combat climate change and to contribute to achieving the Kyoto Protocol target plan published by the Cabinet Public Relations Office (2005). This plan emphasized that the objective of the ECA included reducing GHG emissions. The plan projected a 3 million ton reduction in emissions in the commercial and residential sectors.

In 2016, METI introduced a new system, *the evaluation system for business operator classification*. In this system, METI refers to facilities or a group of facilities as "business operators", which is a unit of regulation. Business operators that submit periodic reports are categorized into four classes. If the performance of a business operator is superior, the operator is ranked as Class S[3] and is publicized as "superior in energy conservation efforts" on METI's homepage. If the performance is average, the operator is categorized as Class A and recognized as a "general business operator". If the energy conservation efforts are not progressing as expected, the operator is ranked as Class B. Class B business operators receive a written notice that their

[2] In 2002, the ECA was revised to require the commercial sector to submit regular reports.

[3] In 2016, 56.7% of firms were categorized as Class S. Class A composed 29.2%, and Class B accounted for 14.0% of the total. No firms were categorized as Class C (METI website).

energy conservation efforts are not progressing, and they may face various levels of intervention, such as on-site inspections or collection of reports by the regulatory organization. A business operator can be classified as Class C after inspection if its efforts toward energy conservation are poor. If an operator is ranked as Class C, it must receive administrative guidance (*shido*). If the performance is still poor even after receiving guidance, the operator is required to make a plan for energy conservation. If it does not follow the directions, the business operator's name is published as a penalty, and it faces an order from the regulatory agency. In 2016, no business operator was classified as Class C.

Among policy measures under the act, the Top Runner Program, which includes fuel efficiency standards, is well known. The Top Runner Program was introduced by an amendment to the ECA in 1998. This measure designates products with distinctions such as appliances and cars, indicates numerical criteria based on the best products in energy efficiency at that time, and requires manufacturers and importers to make their products comply with the threshold by a target year. Until now, energy-saving efforts in the commercial and residential sectors have progressed under the Top Runner Program. For example, as of FY2016, compared to FY2001 levels, the efficiency of air conditioners improved by 28%, that of TV sets improved by 71%, and that of household electric refrigerators improved by 252%.

In the commercial and residential sectors, energy efficiency improvements in buildings and houses are expected to be the most effective way to conserve energy. Using high-performance construction materials for openings and walls in which heat dissipates is especially effective. However, these materials were not originally included in the items of the Top Runner Program, which sets the standards for the energy consumption efficiency of machines and instruments in Japan.

To promote EEMs in the building and housing sector as above, the government of Japan added products that contribute to the improvement of the energy efficiency of buildings, houses, and other products in the scope of the Top Runner Program. For that purpose, the ECA was revised in 2013, and as a result, construction materials were added to the scope of the program.

The Top Runner Program for building insulation materials now includes building materials that contribute to the prevention of heat loss in buildings and/or houses. More specifically, "insulation used in envelope" and "glass and frames used in windows" are now included in the program. The program includes the following three types of building materials: extruded polystyrene foam, glass wool, and rock wool. The following three categories of materials are excluded from the scope of building materials covered by the new Top Runner Program: (1) building materials used for special applications, (2) building materials for which no technical measurement or assessment methods have been established, and (3) building materials whose share of use in the market is exceedingly small. The insulation standards for insulation materials, windows, and sashes are specified.

Setting energy efficiency standards can be expected to reduce energy consumption through technological innovation. Using data from seven European countries, Noailly (2012) investigates the impact of environmental policy instruments such as regulatory energy standards in building codes on technological innovations aiming to improve energy efficiency in buildings. The study finds that strengthening the minimum insulation standards for walls by 10% would increase the likelihood of additional patent filings for specific technologies related to energy efficiency in buildings by approximately 3%.

In addition, energy-consuming equipment such as commercial electric refrigerators and freezers, multifunction devices, printers, electric water heaters (heat pump water heaters) and light-emitting diode (LED) lamps were newly added to the items of the Top Runner Program in 2013. The Japanese government has positioned LED lighting as an important measure against global warming and plans to replace all conventional (incandescent and fluorescent) lamps and lighting in homes, offices, and factories with LED lamps and lighting on a flow basis by 2020 and on a stock basis by 2030. To that end, in April 2019, the energy consumption efficiency target, which had been set separately for conventional lamps and lighting and LED lamps and lighting, was unified into a common target.

Furthermore, the government of Japan has promoted the renovation and rebuilding of existing buildings and houses with high energy efficiency performance. In addition, the government has encouraged the adoption of energy-efficient technologies such as high thermal insulation in new buildings and houses. As of the end of FY2017, the government had supported approximately 28,000 projects as measures to achieve net zero energy[4] by introducing the abovementioned energy-efficient technologies in public and commercial buildings, houses and hospitals across the nation.

The Japanese government also aims to achieve net zero energy buildings (ZEBs) on average in newly constructed nonresidential buildings by 2020 and newly constructed public buildings by 2030 nationwide. For this goal, the government utilizes the Top Runner Program for building materials and coordinates with measures pertaining to the promotion of the introduction of renewable energy, which is essential for ZEBs. Moreover, in promoting ZEBs, it is important to demonstrate how the prices of high-energy performance building materials can be reduced.

With the aim of achieving ZEBs, the government of Japan has also decided to phase in an obligation for newly constructed buildings and houses to meet the energy efficiency standards by 2020, with due consideration given to the need for and degree of regulation. The obligation to meet the standards has started to be phased in for large-scale nonresidential buildings based on the Act for the Improvement of Energy Consumption Performance of Buildings (Building Energy Efficiency Act) established in 2015. The act was revised in 2019 and will be expanded to small and medium-sized buildings starting in April 2021.

The realization of a low-carbon society will be advanced by implementing various policy measures, such as the Top Runner Program based on the ECA and the Building Energy Efficiency Act. These policy measures have contributed to the progress of energy-efficient technological innovation. However, the extent to which new energy-efficient technologies have been adopted in society remains an open question.

---

[4]"Net zero" means zero by subtracting energy production from energy consumption. This can be achieved if energy demands such as electricity and heat can be met with energy that does not emit GHGs. For more details, please see Chap. 3.

As a policy measure aiming to spread technology use in society, carbon pricing (CP), such as an ETS or carbon tax, has come under the global spotlight after the Paris Agreement entered into force. In Japan, the government has set a long-term target for the reduction of GHG emissions, and the importance of CP has been reaffirmed as an effective mitigation tool. At the national level, however, Japan has failed to adopt CP at a level that can substantially reduce GHGs: only two prefectures, Tokyo and Saitama, have introduced an ETS. Additionally, a carbon tax was set in 2012, but the price level is insufficient compared with that of other countries that have set a carbon tax. The Tokyo ETS is the first ETS in the world adopted for the commercial sector. For more details about the Tokyo ETS, please see Chap. 6 and Arimura and Abe (2020). One year after the introduction of the Tokyo ETS, Saitama launched the Target Setting Emissions Trading System. This system is similar in many respects to the Tokyo ETS but differs from the Tokyo ETS in that there are no penalties if the target facility does not meet its emissions targets. For more details about the Saitama ETS, please see Chap. 7 and Hamamoto (2020).

In addition to the lack of an appropriate CP level, there are other barriers to the adoption of energy-efficient technologies. For example, facilities do not adopt such technologies even though the savings from the installation of the technologies exceed the costs. This is known as the energy efficiency gap (Gillingham and Palmer 2014). There are several reasons for this gap. First, facility managers may not have accurate information on energy-efficient technologies. Second, facilities may face liquidity constraints and hence be unable to invest in expensive technologies even though the net benefit of the investment is positive. Finally, it may be difficult for stakeholders to reach a consensus on investment due to the complexity of organizations (DeCanio 1998).

The Japanese government is implementing policy measures to overcome these barriers in energy. For example, the Ministry of the Environment Japan implements energy audits[5] called the "Assessment of CO_2 Emission Reduction Potential (*CO_2 sakugen potensharu shindan*)",[6] and METI implements the "Energy-saving Diagnostic (*sho-ene shindan*)".[7] These two types of diagnostics by the MOE and METI often come with subsidies for energy-efficient technologies or appliances, often in compliance with the Top Runner Program (MOE website). They also provide reduced-rate loans for investments in energy-efficient technologies (DBJ website). Furthermore, they often implement demonstrations of new innovative technologies such as ZEBs. Through these various programs, the national government and local

[5]According to Babatunde et al. (2019), an energy audit is effective as an energy management tool that helps in the identification and implementation of strategies for achieving energy efficiency and conservation. It can also help extend the equipment/system lifespan, which, in the long run, translates into savings in terms of capital and reductions in emissions.

[6]In 2014 (2015), CO_2 emission reduction potential was assessed at 362 (138) facilities. Among them, 238 (26) facilities belonged to service centers including commercial buildings (MRI 2016).

[7]For example, with funding from METI and the MOE, Energy Conservation Center Japan has conducted more than 10,000 audits (https://www.asiaeec-col.eccj.or.jp/energy-audit-program/, accessed on March 15, 2020).

governments in Japan are engaged in the promotion of low carbon or decarbonization in commercial buildings.

The next section introduces a survey that tried to clarify the effect of CP, especially in the Tokyo ETS, on technology adoption in office buildings. The results of the survey are presented.

3 How Can Energy Efficiency Be Promoted in Office Buildings?

How can we promote energy conservation in office buildings? There are two channels to that end. First, buildings can adopt energy-efficient technologies. Olsthoorn et al. (2017) present some examples of energy-efficient technologies related to the energy use of buildings in the commerce and service sectors. These examples include replacing lighting with more efficient alternatives, such as LED bulbs; applying insulating materials to the outer faces of a building, such as the roof or the outer walls; installing better insulating windows; substituting older, less efficient heating systems with more efficient ones, such as new condensing boilers; and adopting add-on digital technology for the optimization of heating system operations, which involves energetic optimization of the heating system, such as through hydraulic adjustments, nighttime turndown, dynamic control, or thermostat lowering. We refer to these methods of energy efficiency improvement as technological measures (TMs).

Second, improvement in energy efficiency can be achieved through non-technological measures (NTMs). For example, buildings can reduce their energy consumption by appropriately setting the temperatures of air conditioners. The MOE recommends air conditioner temperatures of 28 °C in summer and 20 °C in winter. Other examples are turning off lights or PCs when unused, operating existing equipment in a highly efficient way and encouraging equipment users to perform energy-saving actions.

4 Survey of Office Buildings in Japan

4.1 Overview of the Survey

This section first explains the survey sampling period and method. Then, it introduces the main questions about EEMs and basic building information.

4.1.1 Survey Period and Target Buildings

We conducted a nationwide survey in Japan of buildings whose main usage was for offices. We sent questionnaires and collected responses from October to December 2018. The surveyed office buildings were so-called large-scale GHG emission buildings, which consumed 1500 kl or more of crude oil equivalent of energy (electricity, gas, fuel, etc.) per year in FY2015. As of 2006, these buildings are obligated to report their GHG emissions annually under the Greenhouse Gas Emissions Accounting, Reporting, and Disclosure System, in accordance with the Act on Promotion of Global Warming Countermeasures. We surveyed 906 commercial buildings. The respondents were qualified energy managers (energy experts, facility managers) in the buildings of the surveyed facilities. The questionnaire was answered in paper-based or electronic form. We received responses from 167 buildings, for a response rate of 18.4%.

The questionnaire inquired about the implementation status of EEMs, including CO_2 emissions reduction measures; basic physical and operational information on the buildings; and investments in energy savings. The next subsection explains the question items.

4.1.2 Survey Questions

The survey consisted of three parts. The first part asked questions regarding the general characteristics of buildings. The second part included questions about EEMs implemented in the buildings. The third part asked EEM adoption-related questions.

Buildings' Physical and Operational Characteristics

The buildings' physical characteristics included the year of construction of the building, gross floor area, and number of gross floors by use. The building operational characteristics included the number of workers and visitors on workdays, vacancy rates, building operating time (hours per day) by use, operating frequency ("every day" or "weekday") by use, and experience of large-scale repairs/renovations for energy savings after the completion of the building construction.

EEMs in a Building

Regarding the implementation status of EEMs, we asked about the following categories: (1) lighting, (2) thermal insulation, (3) building energy management system (BEMS), (4) elevators, air conditioning (AC) and heat source, and (5) miscellaneous. In comprehensively selecting EEM items, we referred to the energy-saving measures of the ZEB Roadmap Follow-up Committee (2018). We elaborate on each category below.

First, six items were related to lighting-related EEMs: lighting fixtures with an automatic brightness adjustment function by sensor, scheduled switching (time scheduling), initial illumination correction, motion sensors, adjusting illuminance to less than 500 lx on the work plane in the office, and thinning out unnecessary lights.

The first five EEMs are TMs, which require investment in expensive technology. The last EEM is an NTM, which does not require much extra cost.

Second, we selected three thermal insulation-related EEMs. First, the most basic measures of thermal insulation are blinds, eaves and sunshades. In the summer, closing blinds can keep direct sunlight out of the office and reduce unwanted solar heat gain. In the winter, closing window blinds can save energy by preserving heat even on cold days.[8] Second, we inquired about the adoption of highly efficient thermal insulation materials. Finally, we asked about highly efficient thermal insulation windows.

Third, we asked about the BEMS, which is a management system that reduces energy consumption in buildings "while maintaining occupants' comfort" (Manic et al. 2016). There are three levels of BEMS implementation. First, buildings are engaged in monitoring and storing historical data on energy consumption. Second, buildings use the stored data to make a plan of energy savings. Finally, buildings use a demand control system, e.g., alerts when electricity demand is expected to be higher than the upper limit of the electricity supply.

Fourth, regarding elevator-related EEMs, we asked whether buildings had adopted a "reduction in the number of elevators operating outside regular hours" as operationally feasible in the existing facilities. We also asked if they had installed energy-efficient elevators, i.e., elevators with variable voltage variable frequency (VVVF) inverters. The former measure is an NTM, and the latter is a TM.

Finally, we asked whether the buildings had installed automatic water taps or solar panels. We inquired whether they had set temperatures in an environmentally friendly manner (28 °C for cooling, 20 °C for heating) as recommended by the MOE.

Other Questions Related to Energy Efficiency

We also asked three questions related to EEM adoption. First, we asked whether the buildings had received energy audits and, if so, what types of energy audits they had received. There are various types of energy audits in Japan. First, internal audits by experts inside the firm itself are easiest to implement. Second, external experts can conduct energy audits by visiting facilities on site. For instance, energy service companies (ESCOs)[9] provide services for energy audits. Alternatively, suppliers and manufacturers of energy-efficient appliances conduct energy audits as part of sales. Further, power companies and gas companies conduct energy audits for their customers. Moreover, local governments and municipalities have energy audit support services, which have increased in recent decades due to growing interest in global warming. Other public organizations, such as the MOE and the Energy Conservation Center, Japan (ECCJ), offer similar services, but these energy audits have been implemented for medium- and small-sized enterprises as well as factories and buildings with annual energy consumption (crude oil equivalent) of 100 kl or

[8] However, there is an energy use trade-off between light and heating and cooling.

[9] An ESCO is a company that offers energy services, usually design, retrofitting and implementation of energy efficiency projects, after identifying energy-saving opportunities through energy audits of existing facilities. As payment, the ESCO can receive part of the return from the energy savings realized by their advice.

more and less than 1500 kl in principle. Therefore, our surveyed buildings do not focus on these public energy audits.

Second, we asked about the types of energy subsidies, if any, that the buildings had received. In Japan, regulatory agencies under national and local governments offer subsidies for investment in energy savings. For example, the ECCJ implemented several schemes for subsidy provision under both the MOE and METI.

Third, we obtained information on past investment in energy efficiency. We asked how the buildings had acquired information on energy efficiency. For example, persons in charge such as energy managers may ask vendors or search for information by themselves. Alternatively, they may receive information from energy audits or obtain information from industrial associations.

4.2 Survey Results

The breakdown of the prefectural distribution of the responding facilities is as follows. Of the 167 responding buildings, 65 were in Tokyo and seven were in Saitama.[10] These two prefectures have implemented ETSs. The 95 facilities located in other prefectures are further divided into two groups. We refer to the first group as *the five major prefectures*, which include Aichi, Fukuoka, and Osaka, which have major metropolitan cities, and Chiba and Kanagawa, which are adjacent to Tokyo and the Greater Tokyo area. The rest of the facilities located in other prefectures compose the second group, *the rest of the prefectures*. We compare the implementation rate of each EEM in Tokyo with that in the above two groups to identify differences in technology adoption between areas with implementation and non-implementation of ETSs. Note that the samples of each question for basic building information and EEM implementation status contain only facilities from which we obtained responses.

4.2.1 Basic Building Information

Before explaining the results of EEM adoption, we present the basic information of the buildings for which responses were obtained. In this chapter, we gather key information on the basic building information questions. Table 2 shows summary statistics of this information.

First, we explain the physical characteristics of the buildings. The years of construction are, on average, 1993 in Tokyo and 1991 in *the five major prefectures*. In *the rest of the prefectures*, the average year of construction is 1986. Thus, buildings in metropolitan areas, including Tokyo, tend to be newer than those elsewhere. There are also regional differences in the number of floors. Buildings in Tokyo are, on average, 6.7 stories higher than those in *the five major prefectures*. Moreover,

[10] We focus only on Tokyo as an implementation prefecture in this chapter due to the small sample in Saitama.

Table 2 Basic information on surveyed buildings by group

	Tokyo	Five major prefectures	Rest of the prefectures
Physical characteristics			
Year of construction	1993.5	1991.2	1986.4
	(64)	(64)	(28)
Number of floors	25.8	19.1	11.6
	(65)	(63)	(29)
Total floor area (m^2)	85,205.0	59,794.0	36,106.8
	(64)	(64)	(23)
Floor area by office use (m^2)	61,660.2	33,328.9	14,278.4
	(48)	(41)	(20)
Operation characteristics			
Average number of workers and visitors on workdays	6828.9	2951.8	943.3
	(60)	(47)	(22)
Vacancy rate (%)	4.0	4.1	4.2
	(58)	(54)	(21)
Experience of large-scale repairs/renovations with energy savings (%)	25.4	35.0	7.4
	(58)	(54)	(21)

Note Numbers in parentheses indicate number of samples

buildings in Tokyo are much taller than those in other regions. The average number of floors in buildings in Tokyo is more than twice that in other prefectures, excluding *the five major prefectures*. Consequently, the total floor area of buildings is largest in Tokyo. The share of office usage in buildings is higher in Tokyo than in other prefectures. Offices compose 72.4% of the total office floors in Tokyo, 55.7% in *the five major prefectures*, and 39.5% in *the rest of the prefectures*.

Next, we present the building operational characteristics. The number of workers and visitors in the buildings on workdays is 6828.9 in Tokyo. This number is more than twice that in *the five major prefectures* and more than seven times that in *the rest of the prefectures*. The vacancy rate does not differ greatly between the prefecture groups and is approximately 4%. The share of the buildings that have carried out large-scale repairs and renovations with energy savings is largest in *the five major prefectures*, at 35%. This proportion is 25% in Tokyo, which is approximately 10% lower than that in *the five major prefectures*, and 7.4% in *the rest of the prefectures*, which represents a large difference from that in the other prefecture groups.

4.2.2 Implementation Status of Energy Efficiency Measures

In the questionnaire, we asked about the implementation status of each EEM. It should be mentioned that implementation is not a binary choice. In some cases, buildings may install new equipment on all floors, and in other cases, they may adopt new technology on only a limited number of floors, such as in the main entrance of the building. Therefore, we asked respondents to answer regarding the degree of the implementation of each EEM by its percentage. To enable respondents to answer easily, we asked them to choose from seven categorical answers, i.e., (1) not implemented at all (0%), (2) 0–20%, (3) 20–39%, (4) 40–59%, (5) 60–79%, (6) 80–99% and (7) fully implemented (100%).

We show the results of EEM implementation by prefecture groups, *Tokyo*, *the five major prefectures*, and *the rest of the prefectures*, in Figs. 2 and 3. The number

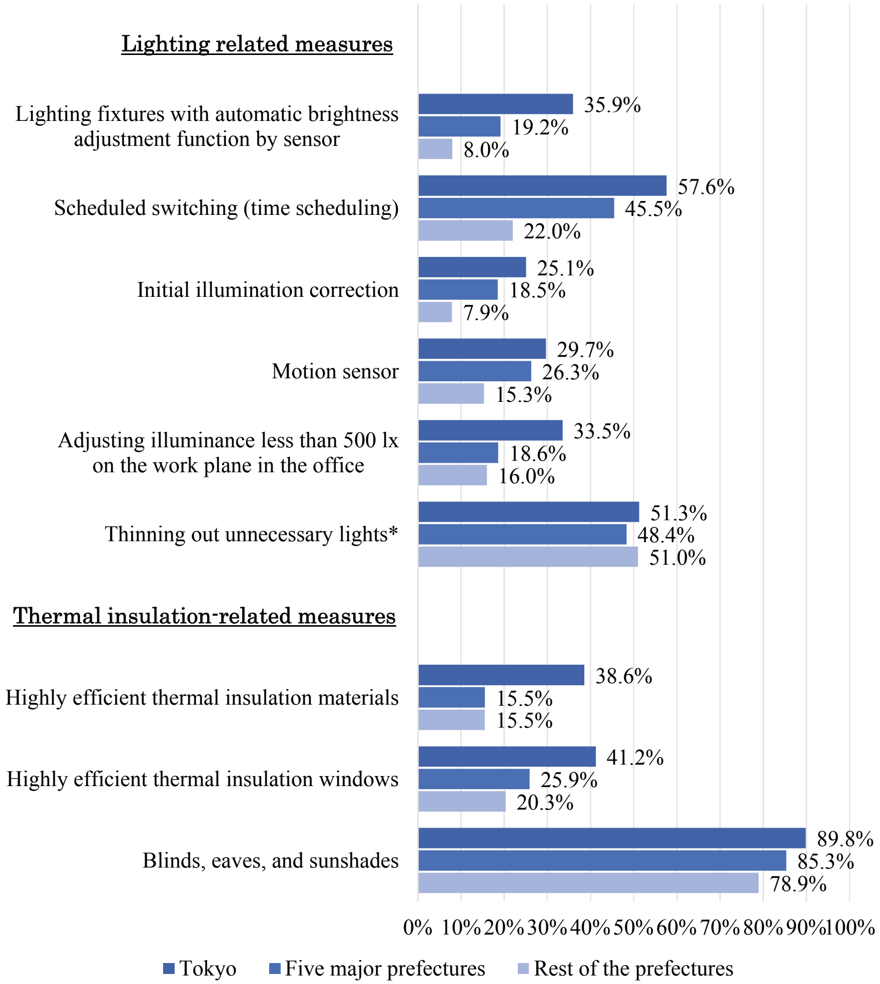


Fig. 2 Implementation status of lighting-related EEMs. *Note* Saitama prefecture is excluded from this aggregation because of the Saitama ETS effect. * indicates non-technological measures (NTM)

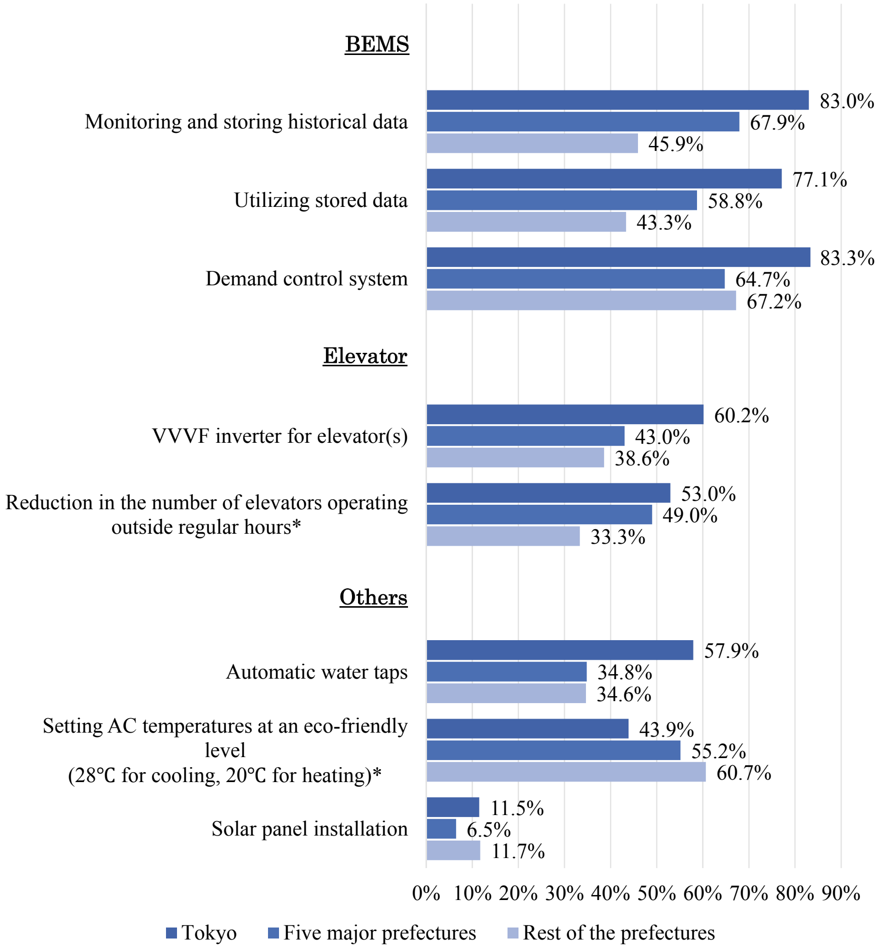


Fig. 3 Implementation status of BEMS, elevator, and other related EEMs. *Note* Saitama prefecture is excluded from this aggregation because of the Saitama ETS effect. * indicates non-technological measures (NTM). VVVF stands for variable voltage variable frequency

of responses for each EEM implementation status ranged from 56 to 64 buildings in Tokyo, from 54 to 62 buildings in *the five major prefectures*, and from 24 to 30 buildings in *the rest of the prefectures*.

Figure 2 illustrates the adoption of lighting-related EEMs and thermal insulation-related EEMs. The top five lighting-related EEMs, defined as TMs, in the figure are most advanced in Tokyo, followed by *the five major prefectures* and *the rest of the prefectures*. The implementation rate of thinning out unnecessary lights, defined as an NTM, is approximately 50% in all groups.

For thermal insulation-related measures, the adoption of highly efficient materials and windows is most advanced in Tokyo among all groups. The adoption ratio of the conventional measures “blinds, eaves and sunshades” is high in all groups. It seems that this is basically standard equipment of building facilities even without the consideration of energy savings. For this reason, the implementation rates in all prefecture groups are quite high compared to the implementation rates of other measures.

Figure 3 shows the implementation status of BEMSs, elevators, and other related EEMs by prefecture group. For BEMS-related measures, Tokyo leads the other regions in every aspect. In particular, the implementation ratio of a “demand control system” in Tokyo is greater than that in the two other groups by at least 16%. The adoption of “monitoring and storing historical data” and “utilizing stored data” is scarce in *the rest of the prefectures.*

Next, we examine the elevator-related EEMs. For TMs, the adoption of VVVF inverters in Tokyo is advanced compared to that in *the five major prefectures* and *the rest of the prefectures.* For NTMs, there is also a difference between Tokyo and the other two groups. The difference in a “reduction in the number of elevators operating outside regular hours” between Tokyo and *the five major prefectures* is approximately four percent and thus not significant. In contrast, a “reduction in the number of elevators operating outside regular hours” is not implemented as much in *the rest of the prefectures.* Among other EEMs, there is a clear difference between Tokyo and the two other groups in the adoption of “automatic water taps”, which is also a TM. Interestingly, the practice of setting AC temperatures at an eco-friendly level is less common in Tokyo than in the two other groups. In particular, *the rest of the prefectures* has the highest implementation rate. In all groups, solar panel installation is low compared to the other EEMs discussed above.

To summarize these results, the ranking patterns for most of the EEMs appear similar. Regarding most EEMs, the adoption of TMs is higher in Tokyo than those in the other two groups. One plausible reason for this observation is the Tokyo ETS. Under the Tokyo ETS, the CO_2 emissions from Tokyo must be reduced compared to their baseline (Chap. 6). In contrast, there is not much difference in the implementation of NTMs among the three groups. In fact, for some NTMs, the implementation rate is higher in *the rest of the prefectures* than in Tokyo.

4.2.3 Energy Audits, Energy-Related Subsidies, and Information on Energy Savings

Figure 4 shows the results regarding the implementation status of energy audits. In-house, subsidiary, or affiliated company technicians’ energy audits compose 17.2% (26 facilities) of the total responses. More than half of those facilities (16 cases) are in Tokyo. External company energy audits have the same implementation rate as the rate of in-house, subsidiary, and affiliated company audits. Of all energy audits, 28 were performed by external companies, eight of which were performed by ESCOs. The rest of the cases were audits by private companies, such as equipment manufacturers/vendors, general contractors, and energy companies. Fifteen facilities (10.3%) had experienced an ECCJ energy audit. As mentioned in Chap. 4, Sect. 1.2,

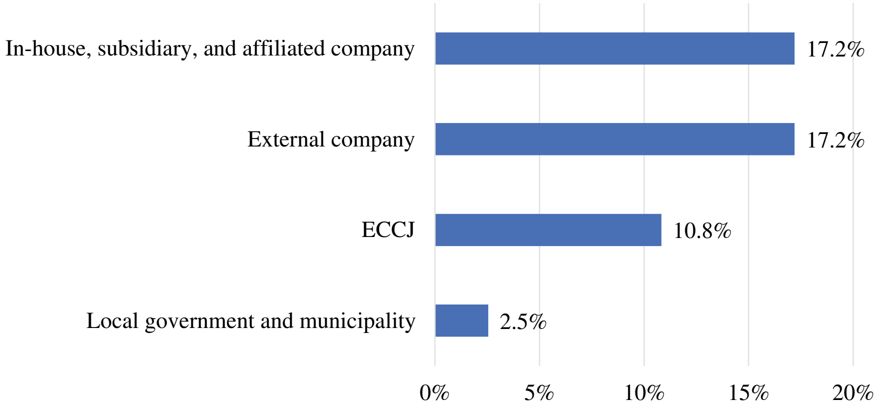


Fig. 4 Proportion of facilities with energy audits. *Note* Examples of external companies are ESCO, equipment manufacturer, general contractor, energy company, etc.

the ECCJ is currently implementing energy audits only for small and medium-sized enterprises and facilities with an annual energy consumption (crude oil equivalent) of 100 kl or more and less than 1500 kl in principle. However, before 2017, the ECCJ conducted energy audits in large-scale facilities as well. The facilities in our survey had experienced these energy audits before 2017. Finally, four energy audits were conducted by local governments and municipalities, and this number is much smaller than the number of audits conducted by other organizations.

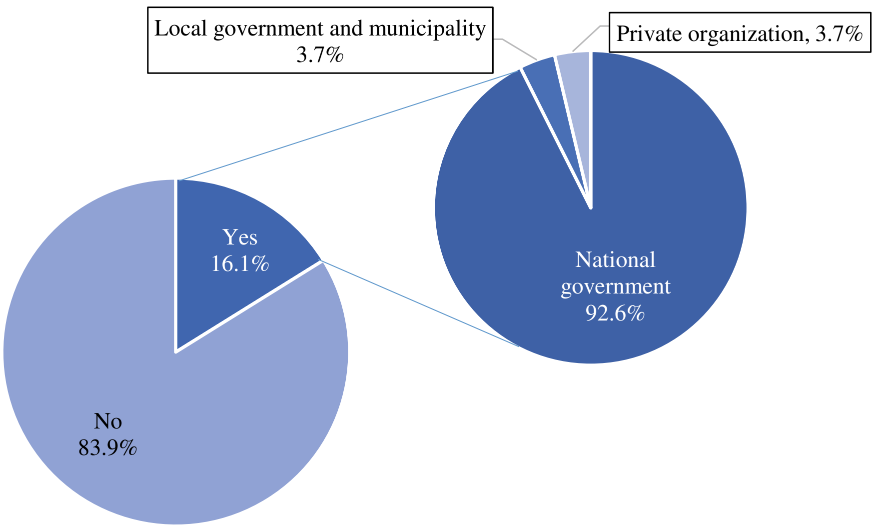


Fig. 5 Usage rate and breakdown of energy subsidies

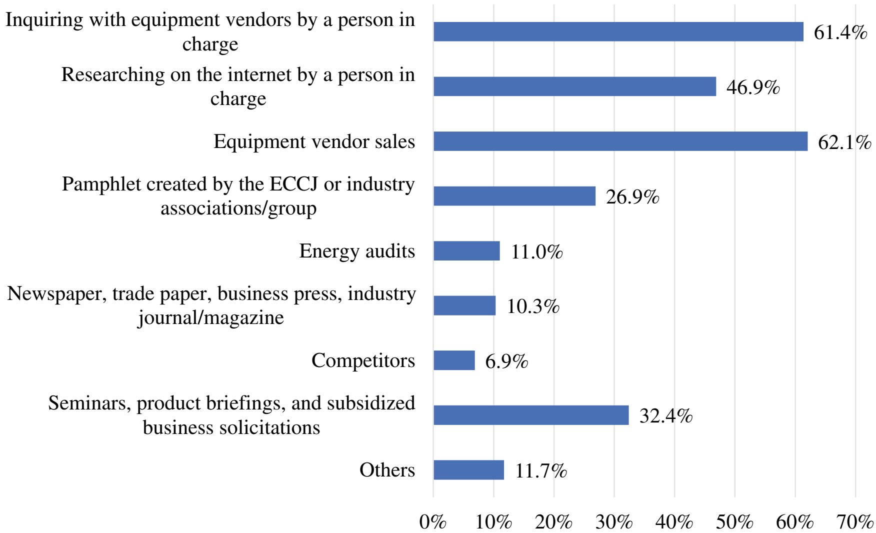


Fig. 6 Proportion of facilities how they acquired information on energy efficiency

Figure 5 illustrates whether the buildings had used subsidies when investing in energy-saving equipment. Of the 161 valid responses, 26 facilities (16.1%) responded that they had used subsidies. Of these 26 facilities, the number of facilities using subsidies was the largest in Tokyo, at 13. In addition, we asked about the types of subsidies the buildings had used. Among 24 facilities that responded to this question, a few had used subsidies several times. Buildings that used national government subsidies accounted for 25 examples (92.6%). There was only one case each of local government and private organization subsidies.

Figure 6 shows how information on energy conservation investments was obtained. The most common source of information was an inquiry from the person in charge of energy conservation, followed by sales from vendors/manufacturers of energy-efficient equipment. Eleven percent of facilities had obtained information from energy auditors. In other categories, there were multiple information sources, such as building design companies, the head office, and building management contractors.

5 Conclusions

This chapter has mainly aimed to review Japanese climate and energy conservation policies in the commercial sector and the current EEM implementation status in large-scale commercial buildings in Japan.

The first section explains the current GHG emissions in Japan and the long-term reduction goal. We observe that emission reduction in the commercial sector is urgently needed to achieve the Japanese NDC. Section 2 describes the mitigation policies implemented in Japan. In Sect. 3, we explain the current situations of energy-saving technologies and practices in office buildings using the results of the survey we conducted in 2018.

In our survey, we found that there is potential for energy savings in office buildings. Recent research by Arimura and Abe (2020) and Chap. 7 show that ETSs have reduced GHG emissions in Japan. This chapter indicates that emission reduction was achieved by the adoption of energy-efficient technologies. Thus, CP such as an ETS or carbon tax may be useful in promoting energy-efficient technologies. However, the identification of a causal relationship between ETSs and the adoption of technologies needs more rigorous analysis.

Our survey reveals that some relatively expensive EEMs have been adopted in Tokyo but not as much in other parts of Japan. In contrast, the implementation rate of relatively inexpensive measures does not differ across regions. These observations are consistent with the interviews that we conducted with energy managers of office buildings. In general, they have started to implement relatively inexpensive measures to save energy consumption. According to Thollander et al. (2015), as of 2007, energy audits in Japan were provided for firms in non-energy-intensive industries that did not have enough expertise in energy management in-house. The authors point out that most of the recommendations from the results of energy audits are operational improvement that requires no investment but also include investment measures with short payback periods (usually less than three years). This observation was especially true in buildings outside Tokyo. Typical examples are "turning off lights when unnecessary" and "installing LED lights". As explained in Sect. 2, policy measures adopted by the government seem to have been effective in some aspects to certain degrees. However, our survey results indicate that these policy measures were not effective in promoting TMs. CP, such as the Tokyo ETS, is expected to play a crucial role in promoting TMs that have not been adopted outside Tokyo. Therefore, CP can be expected to contribute to the spread of relatively expensive energy-efficient technologies.

We also found that the usage of energy audits or subsidies for energy-efficient technologies is limited among office buildings. To remove barriers to the adoption of EEMs, the provision of proper information can be helpful for the promotion of energy efficiency in office buildings. According to our survey, more than half of energy audits have been implemented in Tokyo. By looking at the office buildings in Tokyo, we found that the buildings that experienced energy audits are more likely to adopt energy-efficient technologies than those without energy audit experience. This observation hints that energy audits may make managers or decision makers of office buildings aware of the benefits of energy-saving technologies under the CP of the Tokyo ETS. Thus, in addition to CP, policy measures promoting awareness of the merits of energy savings, such as energy audits, seem to be effective for the diffusion of these technologies.

Finally, energy-saving efforts in buildings are strongly dependent on the capacity and awareness of energy managers. Unless energy managers exert great effort to obtain proper information on energy savings, they will lack this information. The government should work harder so that managers of buildings can have more access to energy audits and subsidies.

Acknowledgements The survey of commercial buildings presented in this chapter was supported by the Environment Research and Technology Development Fund (JPMEERF20172007) of the Environmental Restoration and Conservation Agency.

References

Arimura TH, Abe T (2020) The impact of Tokyo emission trading scheme on office buildings: what factor contributed the emission reduction? Forthcoming in Environmental Economics and Policy Studies

Arimura TH, Iwata K (2015) The evaluation of "comprehensive management under the act on the rational use of energy" as a measure to combat climate change for the hotel industry. In: An evaluation of Japanese environmental regulations. Springer, Dordrecht

Babatunde OM, Oluseyi PO, Denwigwe IH, Akin-Adeniyi TJ (2019) Establishment of electrical energy benchmarking protocol for the assessment of the carbon emissions in hotel industry. In: Muthu SS (ed) Energy footprints of the bio-refinery, hotel, and building sectors. Springer, Singapore, pp 83–128

DeCanio SJ (1998) The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. Energy Policy 26(5):441–454

Development Bank of Japan (DBJ) website. DBJ Environmentally Rated Loan Program. Accessed 17 Mar 2020. https://www.dbj-sustainability-rating.jp/en/enviro/

Gillingham K, Palmer K (2014) Bridging the energy efficiency gap: policy insights from economic theory and empirical evidence. Rev Environ Econ Policy 8(1):18–38

Hamamoto M (2020) Impact of the Saitama prefecture target-setting emissions trading program on the adoption of low-carbon technology. Environ Econ Policy Stud. https://doi.org/10.1007/s10018-020-00270-x

Manic M, Wijayasekara D, Amarasinghe K, Rodriguez-Andina JJ (2016) Building energy management systems: the age of intelligent and adaptive buildings. IEEE Ind Electron Mag 10(1):25–39

METI website. Jigyosya kurasuwake hyokaseido ni tsuite. p 3. Accessed 18 Mar 2020. https://www.enecho.meti.go.jp/category/saving_and_new/saving/classify/pdf/h29-classify.pdf (in Japanese)

Ministry of Economy, Trade, and Industry (METI) (2018) The fifth strategic energy plan. July 2018. Accessed 12 Feb 2020. https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf

Ministry of the Environment (MOE) (2019) Japan's national greenhouse gas emissions in fiscal year 2018 (Preliminary Figures), 29 Nov 2019. Accessed 7 Jan 2020. https://www.env.go.jp/en/headline/2420.html

Mitsubishi Research Institute (MRI) (2016) FY2015 report on the verification and evaluation of *Assistance programs of* CO_2 *emission reduction potential* under the special account for energy measures (in Japanese)

MOE website. FY 2019 Calls for *Assistance programs of* CO_2 *emission reduction potential*. Accessed 6 Apr 2020. https://www.env.go.jp/press/106710.html (in Japanese)

Noailly J (2012) Improving the energy efficiency of buildings: the impact of environmental policy on technological innovation. Energy Econ 34:795–806

Olsthoorn M, Schleich J, Hirzel S (2017) Adoption of energy efficiency measures for non-residential buildings: technological and organizational heterogeneity in the trade. Commer Serv Sector Ecol Econ 136:240–254

Thollander P, Kimura O, Wakabayashi M, Rohdin P (2015) A review of industrial energy and climate policies in Japan and Sweden with emphasis towards SMEs. Renew Sustain Energy Rev 50:504–512

ZEB (Net Zero Energy Building) Roadmap Follow-up Committee (2018) ZEB Design Guideline: Medium-sized office edition

Dr. Hiroki Onuma is a fellow of the Research Institute of Economy, Trade and Industry (RIETI), Tokyo, Japan. He received his B.A. in Economics from Soka University in 2011, his M.A. in Environmental Studies from Tohoku University in 2013, and his Ph.D. in Engineering from Kyushu University in 2017. Prior to joining RIETI, he was a junior researcher (assistant professor) of the Research Institute for Environmental Economics and Management at Waseda University. His research focuses on environmental and energy economics and disaster management including climate change policies. He currently works to examine the impact of carbon pricing mechanisms on firms' environmental performance and residential energy consumption in Japan.

Dr. Toshi H. Arimura is a Professor of Political Science and Economics and Director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Prior to joining Waseda, he was a Professor at Sophia University in Tokyo and was a visiting scholar with George Mason University and Resources for the Future as a recipient of the Abe Fellowship. His research interests include climate change, energy policies, air pollution regulations and voluntary environmental actions. He has published his research in academic journals such as *Journal Environmental Economics and Management, Journal of Association of Environmental and Resources Economics, Environmental and Resource Economics, Ecological Economics* or *Energy Policy*. He is a coauthor of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach from Environmental Economics* (Springer 2015). Dr. Arimura holds a Ph.D. in economics from the University of Minnesota, an M.Sc. in environmental sciences from the University of Tsukuba and a B.A. in history of science from the University of Tokyo. He has served on a number of Japanese government committees on environmental issues including the committees on carbon pricing (2018) and emission trading scheme (2010) of the environmental council under Ministry of the Environment. He is also a member of the Tokyo Metropolitan environmental council. He has served on advisory committees of local governments for emission trading schemes of Tokyo and Saitama. He has also been on editorial boards of academic journals such as *Review of Environmental Economics and Policy, Agricultural and Resource Economics Review, Economics of Energy and Environmental Policy* or *Environmental Economics and Policy Studies*. Since 2018, Waseda University has choses him as one of 10 next generation core researchers. He is a recipient of SEEPS Outstanding Publication Award from Society for Environmental Economics and Policy Studies (Japanese Association of Environmental Economics and Policy) and the academic award from Society of Environmental Science, Japan.

Chapter 3
Climate Policy in Household Sector

Jiaxing Wang and Shigeru Matsumoto

Abstract Compared to the industry sector, the progress of energy conservation of the household sector is very slow. It is because the household sector is more diverse than the industrial sector, and regulatory enforcement is much more difficult. The government can stop firms' operation if their environmental burden is too heavy but cannot stop household's activities. Therefore, the government needs to find energy conservation policies that are supported by the public. Like other countries, the Japanese government has introduced various energy conservation measures to reduce the energy usage from households for the past several decades. It has introduced energy efficiency standards for energy-consuming durables and provided subsidies to promote energy-efficient products in recent years. At the same time, it has raised the price of energy in order to provide households with an appropriate incentive to conserve. In addition, it has promoted renewable energy usage in the household sector. Facing climate change, the Japanese government has not introduced energy conservation measures systematically but rather on an ad hoc basis. In this chapter, we review energy conservation measures implemented in the household sector in Japan. We then make policy recommendations to enhance the effectiveness of energy conservation measures in the household sector.

Keywords Cost effectiveness · Energy conservation measures · Household sector

This work was supported by JSPS KAKENHI Grant Numbers 18H00837 and Institute of Economic Research of Aoyama Gakuin University.

J. Wang · S. Matsumoto (✉)
Faculty of Economics, Aoyama Gakuin University, Room 828, Building 8, 4-4-25 Shibuya, Shibuya, Tokyo 150-8366, Japan
e-mail: shmatsumoto@aoyamagakuin.jp

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_3

1 Introduction

Households use energy for transport and housing. Excluding fuel consumption for passenger vehicles, household energy consumption accounts for about one-fifth of global energy consumption. However, the share exceeds one-third if the fuel consumption is included (International Energy Agency (IEA) 2016). For the past several decades, countries have implemented various energy saving measures to reduce household energy consumption. However, energy saving in the household sector has not been so successful, vis-à-vis other sectors. For example, in EU countries, while industry energy consumption decreased by 16.4% from 2005 to 2016, household energy consumption decreased only by 8.0% (European Environment Agency 2019). This trend is also visible in Japan: industrial energy consumption decreased by 17.9% from 1990 to 2017, while household energy consumption increased by 42.0% (National Institute for Environmental Studies 2019).

The Japanese government's mid-term target is a 26.0% reduction in greenhouse gas (GHG) emissions from their 2013 level by the year 2030[1] and to reduce household GHG emissions by 39.3% during this period (Ministry of the Environment 2020). Although household energy consumption began decreasing in 2012, the reduction over the past five years is only 12.3%, which is obviously too slow to achieve mid-term target.

Japan has had another difficult energy policy problem since 2011: The Fukushima accident increased awareness of the risks of nuclear power, while decreasing its public support. The share of nuclear power in the Japan's electricity supply before the accident was about 30%, and decreased to 1% in 2017 (Agency for Natural Resources and Energy 2017). Although the government states that the desirable share of nuclear power in 2030 is approximately 20–22%, there is strong objection to this plan (nippon.com 2015). On the other hand, Japan lags other developed nations in introducing renewable energy (see Chap. 4).

Slow progress in energy conservation measures and the difficulty in shifting toward alternative energy highlight the importance of household energy conservation measures. The objectives of this chapter are to investigate Japanese household energy conservation measures, and to propose policies to achieve the 2030 target.

This chapter is structured as follows. In the next section, we examine energy usage among Japanese households.[2] We review major energy conservation measures implemented in Japan and summarize their distinguishable features in Sect. 3. We conclude with policy recommendations to enhance the effectiveness of household energy conservation measures.

[1]The long-term target is an 80.0% reduction by the year 2050. Chapter 1 discusses the long-term target in detail with its context.

[2]We exclude the energy consumption for vehicle usage from the analysis and focus on the energy consumption inside the household.

2 Energy Consumption Among Japanese Households

2.1 Characteristics of Japanese Households: International Comparison

Japan's energy consumption is characterized by a high share in the industrial sector and a low share in the household sector. Although its market share has declined in recent year, the industrial sector still has the greatest share of 46% in 2016. In contrast, the Japanese share of household to total energy consumption was 14% (Agency Natural Resources for Energy 2017). This share is much lower than that of the EU, 26%, (Euro Stat 2016), or the US, 21% (US Energy Information Administration (EIA) 2018).

Although US household energy consumption differs widely among the states, the annual energy consumption of the average American household was 81.3 GJ (EIA 2015). Similarly, although there is a wide variation in energy consumption between countries, that of the average EU household was 54.0 GJ, according to the Eurostat (2016). In contrast, the average Japanese household consumed only 33.5 GJ (Ministry of the Environment of Japan 2016). The energy consumption per household in Japan is about the level of Spain and Bulgaria.

Japanese shares of electricity, natural gas, propane gas, and kerosene of total energy sources were 52%, 19%, 11%, and 18%, respectively (Survey on Carbon Dioxide Emission from Households (SCDEH) by Ministry of the Environment (2016)). In contrast, those in the US were 47%, 44%, 4%, and 5%, respectively (Residential Energy Consumption Survey (RECS) by US Energy Information Administration (2015)). In the EU, natural gas accounted for 36% of household energy consumption, electricity 24%, renewables 18%, and petroleum products for 11%, according to Eurostat (2016). Pertaining to CO_2 emissions, the shares of electricity, natural gas, propane gas, and kerosene, are 70%, 13%, 5%, and 12%, respectively in Japan. These statistics indicate that Japanese households heavily rely on electricity.

Table 1 compares energy use purpose across several countries, and indicates that Japanese households use less energy for space heating, but more for lighting and appliances. It is interesting to know that Japanese households use more energy also

Table 1 Final energy consumption by purpose (%)

	Japan	US	EU
Space heating	22.4	44.1	64.1
Space cooling	2.6	8.9	0.3
Water heating	23.8	18.5	14.8
Cooking, Lighting, Appliances etc.	51.0	28.6	21.0

Source Japan (SCDEH 2016) , US (RECS 2015), EU (Eurostat 2016) for water heating. Perhaps, this result reflects Japanese habit having a bath instead of taking a shower.[3]

2.2 Historical Change in Household Energy Consumption

The National Survey of Family Income and Expenditure by Statistical Bureau of Japan (1980–2014) (NSFE) is a nationwide cross-sectional survey initiated in year 1959, and conducted every five years. It collects data on households' socioeconomic characteristics, such as income/expenditure, savings/liabilities, and ownership of durables, as well as housing information such as dwelling characteristics and site area. Using household micro data from NSFE, we report the change in household energy consumption from 1989 to 2014 below.

The NSFE data pose two major drawbacks. First, the data do not report the actual energy consumption; rather, only the average monthly expenditure. We calculated the average monthly energy consumption from the monthly electricity energy expenditure, which contains measurement errors, since the price of energy varies across regions and depends on the type of contract held by the household. Second the NSFE's sampling period is limited to between September and November, that corresponds to the fall season and require less energy for room temperature control. Therefore, the estimation based on the NSFE data may underestimate household energy consumption.

Although it is preferable to analyze the annual data to take account of the seasonal variation in energy consumption, we focus on energy usage in autumn due to the above-mentioned data limitation. Figure 1 shows the change in monthly energy consumption of Japanese households from 1989 to 2014. Electricity consumption increased until 2004 while natural gas and kerosene consumption decreased steadily; consequently, the overall energy consumption decreased from 4.70 to 3.61 GJ.

The share of energy sources varies between regions. Warmer urban regions use electricity mainly, while cold suburban regions use kerosene more intensively. More specifically, the share of kerosene in Hokkaido, the coldest prefecture in Japan, was 60.4% in 2014, while in Tokyo it was 19.6%; and the share of electricity in Hokkaido was 24.7% while in Tokyo it was 40.6% (NSFE 2014).

2.3 Electric Appliance Ownership

As explained so far, Japanese households depend on electricity for much of their energy consumption. Households use home electric appliances. Here, we report how the ownership of home electric appliances has changed among Japanese households since 1980s. Given that approximately 60% of the electricity is consumed for

[3]More than 50% of Japanese household take bath every day during the winter (SCDEH 2016).

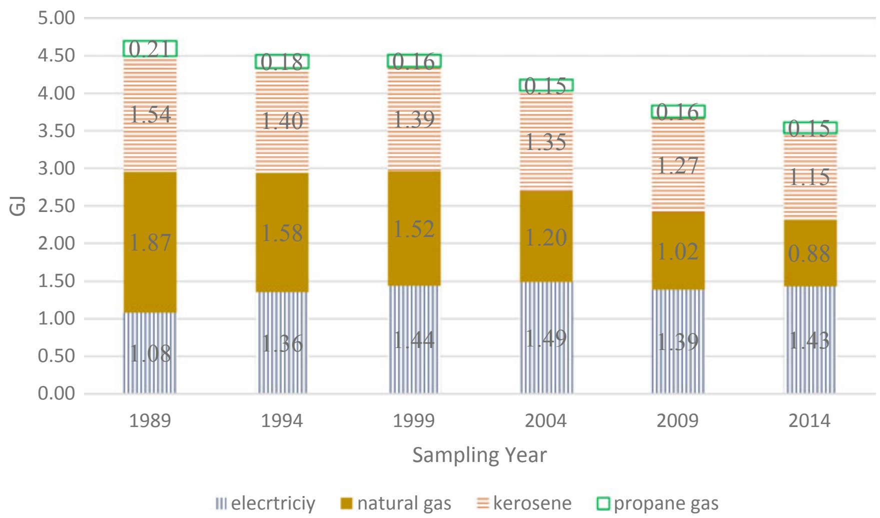


Fig. 1 Change in household energy consumption. *Source* NSFE (1989–2014)

air-conditioning (AC), television (TV), refrigerators (REF) and lighting (Bureau of Environment Tokyo Metropolitan Government (BETMG) 2018), we focus on the ownership of these four electric appliances in this sub-section.

The 2014 NSFE reports that 98.9% of households own REF, 98.3% own a TV, and 89.12% own an AC. The penetration of these electric appliances has completed and Japanese households have increased the number of TVs or ACs for the past 30 years. The 2014 NSFE reports that 79.87% of households own multiple TVs, and 79.87% own multiple ACs.

The 2014 NSFE asked respondents whether they were using light-emitting diode (LED), which is more energy efficient than conventional fluorescent lamps, and found that only 31.42% of households installed LEDs, suggesting a significant energy saving potential.

The ownership of home electric appliances is associated with households' characteristics. Table 2 shows the number of AC/LED/TV/REF used in the average Japanese

Table 2 AC/LED/TV/REF used in the average Japanese household

	Household size		Dwelling characteristics		Average
	Single-person households	Multi-person households	Detached house	The other types	
AC	1.83	2.74	2.96	1.57	2.66
LED	0.48	0.80	0.83	0.57	0.77
TV	1.50	2.21	2.33	1.47	2.15
REF	1.10	1.25	1.30	1.02	1.24

Source NSFE (2014)

household. The average household owns 2.66 ACs, 0.77 LEDs, 2.15 TVs, and 1.24 REF. Single-person households tend to own fewer appliances than multi-person households. For example, the average multi-person household owns 2.74 ACs while the average single-person household owns only 1.83 ACs. However, multi-person households more likely tend to install LEDs than single households, suggesting that multi-person households may be more energy saving.

Pertaining to the relationship between appliance ownership and housing characteristics, Table 2 indicates that households living in a detached house tend to own more appliances than those living in apartments; whereas the former uses LEDs more frequently than the latter.

In the Tokyo metropolitan area, the number of households increased from about 429 million to about 670 million from 1980 to 2015. However, the ownership of ACs per 100 households increased from 95 units to 301 units between 1982 and 2015 (BETMG 2018). Therefore, the growth rate of ACs is substantially higher than that of households. This is because Japanese households began purchasing additional air conditioners in order to make spending time at home more comfortable. This comparison growth rate suggests that the reduction of energy consumption is not an easy task even in a society with a declining population.

2.4 Electric Appliance Usage

Household appliance ownership is not directly associated with energy consumption and it is necessary to know how intensively households use appliances, in order to understand household energy consumption. Here, we report the intensity of appliance use from the SCEDH (2016).

Table 3 indicates a large variation in the time of TV and AC use across households. The median time of TV use is around 4–8 h. However, about 8% of households do not watch TVs on weekdays, and about 7.5% of households keep TVs on for more

Table 3 Intensity of appliance daily use

		Not use (%)	<2 h (%)	2–4 h (%)	4–8 h (%)	8–12 h (%)	12–16 h (%)	>16 h (%)
Time of TV watch on weekdays	Japan	4.5	8.0	27.0	38.8	14.3	5.4	2.1
	Tokyo	1.3	5.6	21.9	39.8	17.9	8.8	4.7
	Osaka	1.7	6.9	23.4	39.5	17.9	6.9	3.8
Time of the main AC use on summer weekdays	Japan	13.7	16.9	31.6	18.2	9.9	4.3	5.4
	Tokyo	4.9	9.2	28.3	20.0	15.1	9.8	12.6
	Osaka	4.5	15.7	31.0	22.3	14.6	6.6	5.2

Source SCDEH (2016)

than 12 h. Similarly, the median time of AC use on summer weekdays is around 4–8 h. However, about 13.7% of households do not use AC on weekdays, and about 9.7% of households keep AC on for more than 12 h.

Table 3 compares time of TV and AC use across regions. It shows that people living in Tokyo and Osaka (the second largest city) use both TVs and ACs more intensively than those in other regions. The average household in Japan owns 2.32 ACs. The average household in Tokyo owns 2.84 ACs while the average household in Osaka owns 2.91 ACs. This data suggests that households living in large cities own more ACs and use them more heavily.

3 Energy Conservation Measures

3.1 Energy Price and Carbon Pricing

Japan imports almost all energy from abroad and thus the energy prices have been set at a high level for both household and industrial uses. Considering that further energy price increases would lower the international competitiveness and impact economic growth negatively, introducing the carbon tax in Japan has been long debated; after two decades Japan finally introduced the carbon tax in October 2012 to mitigate warming mitigation.[4]

Carbon pricing is now considered as one of the most cost-effective measures to reduce CO_2 emissions, especially under the long-term target of de-carbonization. In this sub-section, we compare energy prices between Japan and other countries, especially the relative size of carbon taxes among the household sector. We focus on electricity, natural gas, and kerosene, which comprise almost 90% of Japanese energy usage (see Sect. 2.1).

Energy price[5] data in Table 4 were collected from Energy Prices and Taxes of IEA (2018). The table indicates that energy prices in Japan are higher than other countries: the prices of natural gas and electricity for Japan are 107.4 USD/MWh and 226.6 USD/MWh, respectively, the average prices in OECD countries are 53.9 USD/MWh for natural gas and 166 USD/MWh for electricity.

Table 4 indicates the size of energy taxes to energy prices; and that the sizes of taxes in Japan are lower than those in France or Germany. The tax size of natural gas for Japan, France, and Germany are 7.4%, 24.5%, and 24.3%, respectively, and electricity: 8.9%, 36.2%, and 54.5%, respectively. By removing tax payment, we can calculate each country's prior-tax base energy prices. The base price of natural gas for Japan is 99.5 USD/MWh, while for France and Germany, 59.3 USD/MWh and 56.6 USD/MWh. Similarly, the base price of electricity in Japan, France, and

[4]Presently, the tax rate is set at very low rate (0.76 yen/litter for Gasoline, 0.76 kWh yen/litter, 0.11 yen/kWh) (Ministry of Environment 2020).

[5]According to the IEA (2018), the energy price is defined as the ratio of the total amount of money spent on purchasing an energy and the total sales volume of the same energy over one year.

Table 4 Energy end-use prices in 2017 (converted using exchange rates)

	Kerosene (USD/1000 L)		Natural gas (USD/MWh)		Electricity (USD/MWh)	
		Total taxes (%)		Total taxes (%)		Total taxes (%)
Japan	695.8	11	107.4	7.4	226.6	8.9
US	694.7	4.7	36.1	na	129	na
UK	649.8	26.8	55.3	4.8	205.7	4.8
France	832.6	32.7	78.5	24.5	187.3	36.2
Germany	642.8	26.7	74.8	24.3	343.6	54.5
OECD Europe	765.2		68.1		222.4	
OECD Total	738.5		53.9		166	

Notes na means data is not available
Total taxes mean the percentage of the energy end-use prices
Source Energy Prices and Taxes of IEA (2018)

Germany are 206.4 USD/MWh, 119.5 USD/MWh, and 156.3 USD/MWh, respectively. The price-differences between Japan and the other countries are substantial on the base price level.

Pertaining to kerosene, its price in Japan is lower than the average OECD countries. The prior-tax base price in Japan is about 619.3 USD/1000 L, which is the second highest price among the five countries listed in Table 3.

Thus, the base energy prices are relatively high in Japan but carbon taxes are relatively small. Indeed, the effective carbon price of residential and commercial use in Japan was 5 EUR/ton, while that of UK, Germany, and France was 23 EUR/ton, 26 EUR/ton, and 19 EUR/ton, respectively (Ministry of the Environment 2018).

3.2 Policy Measures to Improve Appliance Energy Efficiency

Energy consumption per service is reduced via energy efficiency improvement. Households might choose an energy-efficient product even without any policy intervention since they can save money. Manufacturers will develop an energy-efficient product to increase demand for their products. However, it is often difficult to achieve the sufficient energy efficient improvement necessary for the society when simply relying on household's voluntary product selection and manufacturers' voluntary investment,[6] and thus the government has introduced policies to forcibly improve the energy efficiency of durable consumer goods. While policies for improving electricity

[6] Arimura et al. (2019) compared environmental policies between Japan and other developed countries and discussed the conditions for the voluntary approaches.

usage of home appliances have been widely implemented, the Japanese government has adopted similar strategies.

The government introduced the Top Runner Program to improve the efficiency of energy-consuming durables in 1998. It set the energy efficiency of the products with the highest efficiency as the energy efficiency standard and requested manufacturers to achieve it before the specified target year. Although only 11 items were covered at the beginning of the program, seven items were added in 2002, two items were added in 2009, and five in 2013. Presently, a total of 31 items are subject to the Top Runner Program, resulting in significant improvement in the energy efficiency of energy-consuming durables. The energy saving of several electric appliances has improved twice or more than the target. For example, the energy efficiency of REFs has improved by 43% from 2005 to 2010, while its target was 21%. Similarly, the energy efficiency of TVs has improved by 73.6% from 2008 to 2012, while its target was 37%.

Households cannot examine the energy efficiency of products at the time of purchase. In 1995, to effectively inform consumers of product energy efficiency, the Japanese government introduced the Energy Star Program jointly with the US. In 2000, the Japanese government introduced the Energy Saving Labeling program based on the Japanese Industrial Standards. A green mark is placed if a product achieves the top runner standard, while the orange mark indicates that it did not. Manufacturers further provide consumers with detailed information including an energy-saving mark of the target year, an achievement rate of energy-saving standard, and an annual electricity consumption.

A strength of these programs is that they do not significant consumer effort. The Top Runner Program improves energy efficiency of the products sold, and the Energy Saving Labeling Program enables consumers to choose an energy-efficient product at the time of product replacement by reporting its energy saving benefit. To further promote the selection of energy-efficient products by consumers, the Japanese government started the Unified Energy Saving Labeling Program in 2006, in which the government requests retailers to indicate the energy efficiency of products with the number of stars, as well as the annual estimated electricity bills from using the products. Consumers require less cognitive skills to identify the energy efficiency of products since they can identify product energy efficiency by simply counting the number of the stars. Presently, six varieties of home electric appliances including AC, REF, and TV are covered under this program.

CO_2 emissions per household reached approximately 4520 kg CO_2 in 2016, about 50.9% was due to electricity. Pertaining to electricity usage, the shares of usage from REF, lighting, TV, AC were 14.2%, 13.4%, 8.9%, and 7.4%, respectively in 2009 (Ministry of the Environment 2019). This data suggests that improvements in energy efficiency of electric appliances are closely related to the reduction of the CO_2 emissions from households. However, households tend to not choose an energy-efficient durable even if they are informed of the detailed information about product energy efficiency (Allocott 2011; Jaffe and Stavins 1994). Moreover, not all households would equally react to such programs: for example, wealthy households with many family members are more likely to purchase an inefficient REF (Wang et al. 2019). Households living in rented houses are less likely to choose LED lamps

(Onuma and Matsumoto 2019). Since the energy-efficiency of appliances has been greatly improved through the implementation of the programs mentioned above, the next challenge is how to encourage households to purchase an energy-efficient appliance.

3.3 Policy Measures to Improve Housing Energy Efficiency

Households can reduce energy consumption by installing energy-efficient durables. Similarly, households can reduce energy consumption by improving the energy efficiency of their houses. Although both the purchase of energy-efficient durables and the renovation of old houses are energy-saving investments, previous studies have found that households respond differently to these two types of energy-saving investments. Ramos et al. (2016), and Trotta (2018) confirm that the environmental attitude can explain the purchase of energy-efficient appliances, but not for home renovation. This data suggests a different policy for improving the energy efficiency of houses vis-à-vis that of other energy-consuming durables.

In order to improve the energy-efficiency of houses, the Japanese government has introduced various measures including subsidies and a long-term tax reduction, and the most ambitious measure: the subsidy for net zero energy houses (ZEHs).[7] These are houses whose annual primary net energy consumption is set at around zero (or less). Under the ZEH program, houses are constructed to save energy as much as possible, while maintaining a comfortable living environment. In the fourth Energy Basic Plan introduced in 2014, the Japanese government targeted make more than half of newly-constructed detached houses ZEHs by 2020, and the average newly-constructed house ZEH by 2030 (Agency for Natural Resources and Energy 2014).

In recent years, a series of subsidy programs have been introduced to promote ZEHs. The first, "ZEH support program", started in 2015, which targets newly-constructed detached houses with more than 20% reduction rate of primary energy consumption as well as high thermal insulation performance. In the first program period, 1.3 million JPY would be provided for households constructing a ZEH, with 1.5 million JPY for households in cold regions. In 2016, 6146 subsidies were issued, the average reduction rate of the primary energy consumption including solar power among these houses reached to 120.7%, and with excluding solar power reached to 43.9%. With the success of the first ZEH program, the government continued it but reduced the amount of subsidies: 1.25 million JPY in 2016, 0.75 million JPY in 2017, and 0.7 million JPY in 2018 and 2019, although the number of issued subsidies has increased to 7100 in 2018 (Sustainable Open Innovation Initiative, SII 2019).

The Japanese government introduced "ZEH + program" in 2018 and "ZEH + R program" in 2019. The ZEH + program requires ZEHs' average reduction rate of primary energy consumption to be 25%. The ZEH + R program asks sufficient energy

[7]Zero Energy Buildings (ZEBs) is discussed in Chap. 2.

provision during a power failure as well as the resilience strengthening option, in addition to the requirement of the ZEH+ program. The subsidy amount of the ZEH+ program is 1.15 million JPY/house, and that of ZEH + R program is 1.25 million JPY/house. The number of subsidies provided under three types of programs (ZEH, ZEH + , and ZEH + R) were 9172 in 2018 and 7345 in 2019.

Subsidies for companies began 2018 with "Detached-sale ZEH program. Aiming to support building companies to construct ZEHs, the program provides 0.7 million JPY (or 1.15 million JPY) per house to the building company (SII 2018). In 2018, the first subsidy program targeted at housing complexes (including apartments), "High building ZEH-M program" started, whereby projects with six floors or higher ZEH apartment can obtain a subsidy two-thirds of the total subsidized cost.

In addition, the ZEH builder mark and the ZEH planer mark have been implemented to increase the recognition of ZEHs among households as well as building companies. However, despite such efforts, only 15.3% of newly-constructed detached houses were ZEHs in 2017 (Agency for Natural Resources and Energy 2019), far below the 2020 target of 50%. Given the high housing construction, it seems difficult to achieve the target solely thorough the ZEH subsidy programs: with the average price of a new house in Japan of 34 million JPY (Japan Housing Finance Agency 2019), the subsidy amount to less than 4% of the construction cost.

3.4 *Support for Solar Panel Installation*

Solar panel, an important renewable energy, has been universally used in the household sector. In Japan, the first solar panel for residential use was installed in 1993. Given the expensive price of solar panels, the Japanese government introduced a subsidy program in 1994. The size amounted to 50% of the installation cost. Nevertheless, solar panels are unpopular, with only 3.14% of Japanese households installing them in 2005 (NSFE 2014).

The promotion of solar panels in the household sector was proposed again when formulating the Action Plan for Creating a Low-Carbon Society in 2008 (Ministry of the Environment 2008) and the revival of the subsidy program since 2009. Owing to this new program, the installation cost of the solar-panel system was lowered substantially. When introduced in 2009, households purchasing a solar-panel system with a unit price less than 700,000 JPY could receive a subsidy of 70,000 JPY/kW initially. However, the amount of subsidy kept decreasing continually to 15,000 JPY/kW when the program ended in 2013. This subsidy targeted households that purchased a relatively low-price solar-panel system. For example, in 2012, the subsidy for a system priced lower than 475,000 JPY was 35,000 JPY/kW, while that for a system priced lower than 550,000 JPY was only 30,000 JPY/kW (Eco life 2019).

In addition to the subsidy program, the government started a 10-year Feed-in Tariff (FIT)[8] in 2009, promising that the surplus electricity produced by solar panels

[8]The detail of Feed-in Tariff is explained in Chap. 5.

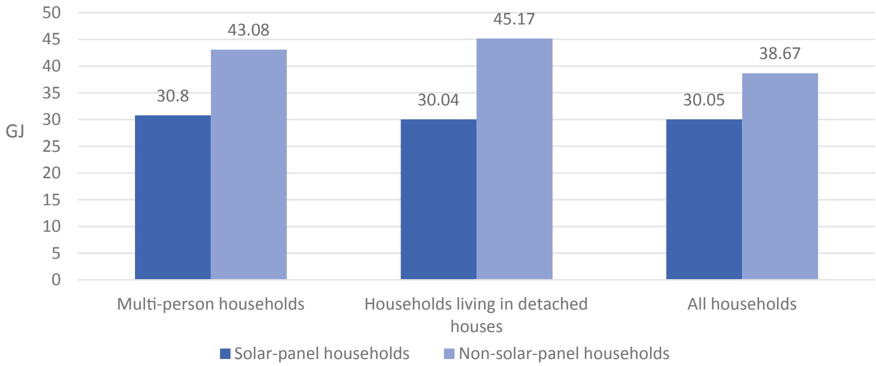


Fig. 2 Households' annual energy consumptions on average. *Source* SCDEH (2016)

would be purchased by the power company in a fixed price in 10 years (Agency for Natural Resources and Energy 2009). The FIT made solar-panel investment more attractive, as households not only pay lower electricity bills but also make a profit by selling surplus electricity. The average solar-panel households earn approximately 153,755 JPY annually by selling surplus electricity (SCDEH 2016).

The new subsidy and the FIT positively affected the promotion of solar panel. According to the 2014 NSFE, approximately 60.12% of solar-panel households installed a solar panel system during the new subsidy program period, whereas only about 28.7% of the installed before 2009. Furthermore, the 2014 NSFE shows that solar panels have been promoted especially among multi-person households, as well as households living in detached houses. Among all solar-panel households, about 97.35% are multi-person households, while about 98.13% live in detached houses.

Figure 2 indicates the differences in annual energy consumption (the sum of electricity, natural gas, propane gas, and kerosene consumption) between solar-panel households and non-solar-panel households (SCDEH 2016). (The energy produced by solar panel is not included.) Figure 2 shows that solar-panel households use less energy than households without solar panels, a propensity more palpable among multi-person households and households living in detached houses. The annual energy consumption of non-solar-panel households is 43.08 GJ while that of solar-panel households is only 30.8 GJ. As for households living in detached houses, the annual energy consumption of solar-panel households is 30.04 GJ, and that of non-solar-panel households is about 45.17 GJ.

4 Conclusion

In this chapter, we reported the characteristics of the energy consumption of Japanese households, and then reviewed the policy measures implemented in Japan for residential energy conservation. Like other developed countries, the Japanese government has introduced various programs to improve energy efficiencies of energy-consuming durables. Among them, the most effective policy is probably the top runner program: the energy efficiency of appliances has greatly improved for the last several decades. According to a survey by Ministry of Economy, Trade and Industry (METI) (2007), during the period 1997–2004, the energy efficiencies of televisions (TVs), air conditioners (ACs), and refrigerators (REFs) improved by 25.7%, 67.8%, and 55.2%, respectively. Nevertheless, much of energy saving effects has been lost due to stock and size increase (Inoue and Matsumoto 2019). The fact tells that it is difficult to reduce residential electricity consumption merely through technological innovation.

Even if it reliably reported that energy investment is beneficial, many households will not invest in energy efficiency. In recent years, many studies have been conducted worldwide in order to find effective programs to induce households to choose energy-efficient durables. Although many interesting findings have been reported in recent studies, it is expected that the effectiveness of incentive programs would vary across countries. Thus, it is necessary to find effective programs for Japanese households. However, at present, it is not well-known what types of households do not invest in energy efficiency and what type of information households are likely to respond to. Further research is clearly needed.

Although various subsidy programs have been introduced for the last several decades, those programs primarily focus on the purchase of new products. Such subsidy programs would be effective for durables with a short replacement cycle, and less effective for the durables whose replacement cycle is slow. And given that the amount of subsidy is small compared to the purchase price, the subsidy program for energy-efficient houses seems less successful currently (Matsumoto 2016). Given that household energy efficiency improvement will substantially impact carbon mitigation, it is important to find more effective programs for penetrating energy-efficient houses. Although a system to display the total energy performance of houses has been introduced in Japan (Housing Performance Evaluation and Display Association 2019), its usage is low, and will (as in other developed nations) be necessary to popularize it in the future.

A palpable weakness of the subsidy programs is regressivity: Almost all subsidy programs, including for solar power and new appliances, support the purchase of durables, but households obviously must purchase them to receive subsidies. The households using such a subsidy program lived in detached houses where solar panels could be installed, or were those who had an additional deposit to replace electric appliances during the specified subsidy period. Therefore, in past subsidy programs the poor supported the rich to enable him or her to use energy services at low cost. Perhaps, such regressive policies will not be able to retain public support. A publicly acceptable policy, must not only account for energy consumption, but also energy consumption purposes.

Japan introduced the carbon tax in October 2012 to mitigate global warming, which was simply added to the old energy taxes (Chap. 1). As we mentioned before, the tax rate is low presently but is expected to increase in near future. The distinguishing feature of this new carbon tax is that it is uniformly applied on a CO_2 basis regardless of the purpose of energy use. In contrast, the conventional energy taxes were adjusted by the energy use purpose. Although the new carbon tax effectively mitigates carbon, it is regressive. In particular, the new carbon tax is more stringent for low-income households living in cold regions. Thus, the government should introduce redistribution policies when it increases the carbon tax.

The rapid spread of renewable energies is essential for significant energy savings in the household sector. Households with a strong interest in environmental problems installed a renewable energy system initially, and subsequently households with sufficient financial asset installed it by using subsidies. However, the system penetration is still low, and more households will need to use renewable energy equipment in the future. Even if various policy options for renewable energies are introduced, it will be difficult to achieve the energy conservation target. It is, therefore, necessary to investigate energy use purpose in order to judge whether a household is using essential energy for life or is wasting energy. Without that knowledge, it is impossible to speculate how much energy can be reduced.

References

Agency for Natural Resources and Energy (2009) The feed-in tariff. https://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/surcharge.html. Accessed on 20 Dec 2019

Agency for Natural Resources and Energy (2014) The fourth energy basic plan. https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/140411.pdf. Accessed on 9 Dec 2019

Agency for Natural Resources and Energy (2017) Power survey statistics. https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2. Accessed on 13 Feb 2020

Agency for Natural Resources and Energy (2019) For the promotion of ZEH: the policy trends and budget plan. https://www.enecho.meti.go.jp/category/saving_and_new/saving/assets/pdf/general/housing/zeh3shourenkei_setsumeikai.pdf. Accessed on 13 Dec 2019

Allcott H (2011) Consumers' perceptions and misperceptions of energy costs. Am Econ Rev 101:98–104

Arimura TH, Kaneko S, Managi S, Shinkuma T, Yamamoto M, Yoshida Y (2019) Political economy of voluntary approaches: a lesson from environmental policies in Japan. Econ Anal Policy 64:41–53. https://doi.org/10.1016/j.eap.2019.07.003

Bureau of Environment Tokyo Metropolitan Government (2018) Household usage of energy. https://www.kankyo.metro.tokyo.lg.jp/climate/home/energy.html. Accessed on 11 July 2020

Eco life.com (2019) Subsidy programs for solar panel. http://standard-project.net/solar/hojokin.html. Accessed on 19 Dec 2019

EURO Stat (2016) Final energy consumption by sector. https://ec.europa.eu/eurostat/databrowser/view/ten00124/default/table?lang=en. Accessed on 11 July 2020

European Environment Agency (2019) Final energy consumption by sector and fuel. https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-9/assessment-4. Accessed on 25 Sep 2019

Housing Performance Evaluation and Display Association (2019) https://www.hyoukakyoukai.or.jp/. Accessed on 31 Dec 2019

Inoue N, Matsumoto S (2019) An examination of losses in energy savings after the Japanese Top Runner Program? Energy Policy 124:312–319. https://doi.org/10.1016/j.enpol.2018.09.040

International Energy Agency (2016) Energy efficiency indicators

International Energy Agency (2018) Energy prices and taxes, vol 2018(3). Third Quarter 2018, IEA, Paris. 10.1787/energy_tax-v2018-3-en

Jaffe AB, Stavins RB (1994) The energy paradox and the diffusion of conservation technology. Resour Energy Econ 16:91–122
Japan Housing Finance Agency (2019) https://ie-daiku.org/saisin-souba.html. Accessed on 27 Jan 2020
Matsumoto S (ed) (2016) Environmental subsidies as a policy instrument: how did they work in the Japanese market?. Routledge, London, New York
Ministry of Economy, Trade and Industry (2007) Present condition and evaluation of the Top Runner Program. Report to General Resources and Energy Research Committee. http://www.meti.go.jp/committee/materials/downloadfiles/g70305a05j.pdf. Accessed on 25 May 2017
Ministry of the Environment (2008) Action plan for creating a low-carbon society. https://www.env.go.jp/press/file_view.php?serial=11912&hou_id=10025. Accessed on 19 Dec 2019
Ministry of the Environment (2016) Survey on carbon dioxide emission from households. http://www.env.go.jp/earth/ondanka/ghg/kateiCO2tokei.html. Accessed on 11 July 2020.
Ministry of the Environment (2019) Energy-saving product replacement navigation. https://ondankataisaku.env.go.jp/shinkyusan/. Accessed on 09 Nov 2019
Ministry of the Environment (2019) Significance, effects and issues of carbon pricing. https://www.env.go.jp/council/06earth/y0619-03/mat02.pdf. Accessed on 05 Dec 2019
Ministry of the Environment (2019) Survey on carbon dioxide emission from households. http://www.env.go.jp/earth/ondanka/ghg/kateiCO2tokei.html. Accessed on 11 July 2020.
Ministry of the Environment (2020) Japan's draft proposal (New greenhouse gas emission reduction target after 2020) https://www.env.go.jp/earth/ondanka/ghg/2020.html. Accessed on 25 Oct 2019
National Institute for Environmental Studies (2019) Greenhouse gas inventory office of Japan. http://www-gio.nies.go.jp/aboutghg/nir/nir-e.html. Accessed on 25 Sep 2019
nippon.com (2015) Japan's power mix: 20–30% nuclear power generation ratio to 20–22%. https://www.nippon.com/ja/features/h00114. Accessed on 25 Sep 2019
Onuma H, Matsumoto S (2019) Measuring household ability to adopt new technology: The case of the light-emitting diode (LED) Paper BECC JAPAN 2019. Tokyo, Japan. Presented on 22 Aug 2019
Ramos A, Labandeira X, Loschel A (2016) Pro-environmental households and energy efficiency in Spain. Environ Resource Econ 63:367–393. https://doi.org/10.1007/s10640-015-9899-8
Statistical Bureau of Japan (1980–2014) The national survey of family income and expenditure. http://www.stat.go.jp/english/index.html. Accessed on 11 July 2020.
Sustainable open Innovation Initiative (2019) Net zero energy house subsidy program. https://sii.or.jp/meti_zeh31/uploads/ZEH_conference_2019.pdf. Accessed on 13 Dec 2019
Trotta G (2018) Factors affecting energy-saving behaviours and energy efficiency investments in British households. Energy Policy 114:529–539. https://doi.org/10.1016/j.enpol.2017.12.042
US Energy Information Administration (2015) Residential energy consumption survey. https://www.eia.gov/consumption/residential. Accessed on 25 Sep 2019
US Energy Information Administration (2018). https://www.eia.gov/energyexplained/use-of-energy. Accessed on 12 Jan 2020
Wang J, Sugino M, Matsumoto S (2019) Determinants of household energy efficiency investment: analysis of refrigerator purchasing behavior. Int J Econ Policy Stud 13:389–402

Jiaxing Wang is a doctoral program's student at Aoyama Gakuin University, major in economics. She also earned a Master's Degree in Economics from Aoyama Gakuin University in 2018. She comes from Shanghai, China. She earned her Bachelor's Degree in Management at Shanghai Normal University in 2015. In addition, she has an experience of studying as an exchange student at Yokohama City University during 2013–2014.

Her research interest lies in environmental economics, particularly focuses on energy problems among household sector. She studies the mechanism of the energy consumption of households and consumers' valuation on energy-saving practices.

Shigeru Matsumoto joined the Aoyama Gakuin University faculty in 2008. He studied on Heiwa Nakajima Foundation Scholarship at North Carolina State University, where he earned his Ph.D. in economics. He also holds his Masters of Environmental Science from Tsukuba University. Before coming to Aoyama Gakuin University, he spent seven years on the faculty of Kansai University.

His research interest lies in the applied welfare economics, with particular focus on consumer behavior analysis. In recent years, he studies households' pro-environmental behaviors such as recycling and energy-saving practices as well as consumers' valuation on food attributes such as organic farming.

http://shigeruykr.wixsite.com/happy-environment.

Chapter 4
Climate Policy in Transportation Sector: Role of Carbon Pricing

Kazuyuki Iwata

Abstract This chapter focuses on climate countermeasures in the Japanese transport sector. We introduce the Japanese complexed automobile tax system and then calculate the Japanese effective carbon rate (ECR) on automobiles. In addition to the discussion of the ECR, this chapter offers a simple examination of the efficiency of electric vehicles (EVs) from the viewpoint of cost-benefit because it is expected that EVs will become the most popular eco-friendly vehicle in the future. Two remarks are found in our analysis. First, although the carbon tax rate on fuel consumption is small in Japan, compared to the European countries, the ECR is rather high. For further improvement of climate policy, the Japanese government should shift its attention to vehicle usage from vehicle purchase and possession. Second, under the basic assumption (i.e., representative owners do not recharge their EVs at home but at outdoor fast chargers), the diffusion of EVs is not an efficient measure for reducing GHG emissions. If owners recharge their EVs at home once of every two charges, the net benefit becomes positive Therefore, the opportunity cost of waiting for recharges is a key factor in whether EVs can play a role in mitigating climate change.

Keywords Automobiles · Carbon tax · Effective carbon rate · Life cycle assessment · Electric vehicles · Fast chargers

1 Introduction

Automobiles are one of the most important sources of greenhouse gases (GHG) emissions. In Japan, the amount of total GHG emissions was 1.19 billion t-CO_2 in 2017 (Ministry of the Environment, 2019). Of that amount, 0.21 billion t-CO_2 (i.e., 17.9%) was attributable to the transport sector. Automobiles, including passenger vehicles and trucks, accounted for 86.2% of the GHG emissions from the transport

K. Iwata (✉)
Faculty of Economics, Matsuyama University, 4-2 Bunkyo-cho, Matsuyama, Ehime 790-8578, Japan
e-mail: iwata.kazuyu@gmail.com

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_4

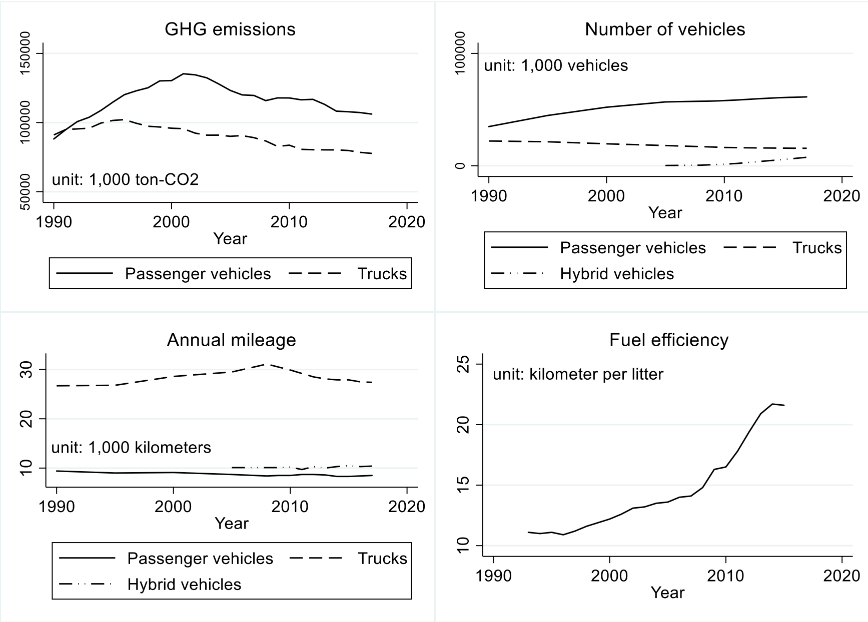


Fig. 1 Trends in GHG emissions and indicators related to vehicles in Japan (The data of the GHG emissions (the top-left panel), number of vehicles (the top-right panel), annual mileage (the bottom-left panel) and fuel efficiency (the bottom-right panel) are obtained from the websites of the Greenhouse Gas Inventory Office of Japan (http://www-gio.nies.go.jp/aboutghg/nir/nir-e.html), the Automobile Inspection and Registration Information Association (https://www.airia.or.jp/publish/statistics/trend.html), the Survey on Motor Vehicle Transport (https://www.mlit.go.jp/k-toukei/jidousya.html) and the Ministry of Land, Infrastructure, Transport and Tourism (https://www.mlit.go.jp/common/001178377.pdf), respectively (accessed on December 10, 2019).)

sector.[1] Therefore, 0.18 billion t-CO_2 (15.4%) of the total GHG emissions were generated by automobiles. Although automobiles emit not only the GHG but also air pollutants, this chapter focuses on the GHG only.

Although automobiles are responsible for a large share of GHG emissions, the total amount of emissions has been continuously decreasing since approximately 2000. The top-left panel in Fig. 1 shows the trends in GHG emissions from passenger vehicles and trucks. The emissions peaked in 2002 and 1995 for passenger vehicles and trucks, respectively, and then started decreasing.

What led to the decreased in emissions? There are three potential drivers of the reductions: the total number of vehicles, annual mileage per vehicle and fuel efficiency. The first, the total number of passenger vehicles and trucks (including buses), is presented in the top-right panel in Fig. 1. The numbers of passenger vehicles and trucks have been gradually increasing and decreasing, respectively. The reason why

[1]Refer to the following website of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLITT): https://www.mlit.go.jp/sogoseisaku/environment/sosei_environment_tk_000007.html (accessed on December 10, 2019).

the total number of passenger vehicles has increased is the popularity of hybrid vehicles such as the Prius.[2] In tandem with the increase in hybrid vehicles, the number of traditional gasoline and diesel passenger vehicles has been decreasing, suggesting that passenger vehicles have been shifting from gasoline and diesel vehicles to eco-friendly hybrid vehicles. Meanwhile, the total number of trucks has continuously decreased since 1990.

The kilometers travelled by passenger vehicles and trucks are shown in the bottom-left panel in Fig. 1. The annual mileage for gasoline passenger vehicles is likely to decrease over time. The decrease may come from increase of aging population because older drivers voluntary limit vehicle usage (Baldock et al. 2006). For diesel trucks, the annual mileage increased until 2008 and then started decreasing. It is thought that this trend may be correlated with Japanese economic conditions. The economic boom lasted until approximately 2009, when the financial crisis happened due to the collapse of Lehman Brothers. After that, the recession started.

The Ministry of Land, Infrastructure, Transport and Tourism shows that the average fuel efficiency of gasoline passenger vehicles is improving over time, suggesting that this improvement has helped to reduce GHG emissions (see the bottom-right panel in Fig. 1). For example, average fuel efficiency in 2015 increased to 21.6 km/liter compared with 11.1 km/liter, 12.2 km/liter, 13.6 km/liter and 16.5 km/liter in 1995, 2000, 2005 and 2010, respectively. Therefore, in the last 30 years, fuel efficiency has improved approximately twice over. This consistent increase is mainly due to the diffusion of hybrid vehicles.

GHG emissions from vehicles reached a peak in 2001 (see Fig. 1). Although the total amount of emissions has continuously decreased over time, 0.18 billion t-CO_2 in 2017 was still caused by vehicles. To cost-efficiently reduce GHG emissions from vehicles, economic instruments such as emission trading schemes or Pigouvian taxes are the best countermeasures (Kolstad 2010).

For automobiles, it is cost-efficient to impose a Pigouvian carbon tax on gasoline and diesel according to their CO_2 coefficients. In 1990, the first carbon tax in the world was implemented in Finland. Then, Sweden introduced a similar tax in 1991. Of course, the two taxes cover gasoline consumption. The World Bank reports that there were 28 countries and regions[3] where carbon taxes had already been implemented as a carbon pricing initiative by 2019.[4] In Japan, a carbon tax was introduced in October 2012. The initial tax rates were 250 yen (US$2.3)[5] per kiloliter, 260 yen (US$ 2.4) per ton and 220 yen (US$2) per ton for petroleum, liquefied natural gas (LNG) and coal, respectively. The government had originally planned to raise the tax rates. Eventually, in 2016, these rates increased by approximately triple, that is, to 760 yen (US$6.9) per kiloliter, 780 yen (US$7.1) per ton and 670 yen (US$6.1) per

[2]The Prius was released in 1997 by Toyota as first hybrid vehicle in the world.

[3]Alberta in Canada will abolish its carbon tax in 2020.

[4]Refer to the following website of the World Bank: https://carbonpricingdashboard.worldbank.org/ (accessed on December 10, 2019).

[5]US$1 roughly equals to 110 yen.

ton. Automobiles are indirectly affected by this carbon tax because the tax covers petroleum.

The current Japanese carbon tax rates are equivalent to 289 yen (US$2.6) per t-$CO_2$.[6] Viewing the carbon tax rates among 28 countries and regions, the highest rate is US$121.3 per t-$CO_2$ in Sweden. The next highest rate is US$96.6 per t-$CO_2$ in Liechtenstein and Switzerland. Therefore, the carbon tax rate in Japan is relatively low compared with such countries. Another efficient economic instrument is an emission trading scheme (ETS); the carbon prices in the EU ETS and Korea ETS are US$32.5 and US$24.2 per t-CO_2 in 2019, respectively, whereas the price in the Japanese Tokyo ETS[7] is only US$6.0. In addition, firms located outside of Tokyo are not affected by the Tokyo ETS. We observe that the carbon price of the ETS in Japan is also low.

To efficiently reduce GHG emissions and achieve a balance between economic development and implementation of countermeasures against climate change, it is necessary to set appropriate carbon prices using economic instruments such as a carbon tax or an ETS. The efficient carbon price should be set to be equal to the social cost of carbon (SCC). Although many studies have estimated the SCC, there are large differences among them. In a recent study, Wang et al. (2019) reviewed 578 estimates of the SCC from 58 studies (the range is between US$-13.38 and US$2386.91 per t-CO_2) and concluded that the SCC is US$54.7 per t-$CO_2$, on average. As mentioned above, the Japanese total carbon price is US$8.6, which sums the US$2.6 for the carbon tax and US$6.0 for the Tokyo ETS. The value is obviously lower than the SCC of Wang et al. (2019). Therefore, it may appear that the Japanese government should raise its carbon price to mitigate climate change.

However, several types of taxes besides carbon taxes and ETS costs are already imposed on most goods. For example, many counties impose a value-added tax (VAT) as a consumption tax, and a gasoline tax is often levied on the usage of vehicles. Although the purpose of such taxes is not to prevent climate change but to secure governmental financial resources, such taxes indirectly play the same role as a carbon tax or ETS. The expanded carbon price, which is the sum of carbon taxes, ETS costs and such indirect taxes, is called the effective carbon rate (ECR) (OECD 2016).

In Japan, the ECR for automobiles is complicated because the automobile tax system is not simple. Therefore, this chapter will introduce the Japanese automobile tax system and then calculate the Japanese ECR on automobiles. In addition to the discussion of the ECR, this chapter offers a simple examination of the efficiency of electric vehicles (EVs) because it is expected that EVs will become the most popular eco-friendly vehicle in the future. The IEA (2019) reports that EVs are developing at a rapid pace. For example, the number of EVs was more than 5.1 million in 2018, compared to 3 million in 2017. The report concludes that the market share of EVs

[6]Refer to the following website of the Japanese Ministry of the Environment: https://www.env.go.jp/policy/tax/about.html (accessed on December 10, 2019).

[7]The Tokyo ETS does not cover automobiles but covers facilities including office buildings and industrial plants.

Table 1 Automobile tax system in Japan

Behavior	Tax	Frequency	Note	Rate (%)
Purchase	Vehicle acquisition tax[a]	Only once		0–3
	VAT on vehicle purchase	Only once		10
Possession	Vehicle tax	Every year	For vehicle with displacement over 661	
	Light vehicle tax	Every year	For vehicle with displacement under 660	
	Vehicle weight tax	Once every two years		
Usage	Gasoline tax	Each time	For gasoline vehicle	
	Diesel oil tax	Each time	For diesel vehicle	
	VAT on fuel purchase	Each time		
	Carbon tax	Each time		
	Petroleum coal tax	Each time		

[a]The vehicle acquisition tax was greatly revised on October 2019. Before the revision, the tax rate was fixed at 3%

will be 30% by 2030. In addition, Japan Post Holdings stated in a press release that it will introduce 1200 EVs for use in delivery service by 2020, implying that 30% of delivery vehicles in Tokyo will be EVs.[8]

2 ECR on Automobiles in Japan

2.1 Automobile Tax System

Before calculating the ECR in Japan, this section provides an overview of the automobile tax system. A summary of the tax system is shown in Table 1. In October 2019, the tax system for vehicles drastically changed. Briefly, the tax rate for eco-friendly vehicles decreased.

The tax system for vehicles in Japan consists of taxes on three behaviors: purchase, possession and usage. Suppose that people buy a new or an old vehicle and use it. They must pay various taxes in addition to the vehicle and fuel costs. First, they

[8]Refer to the following newspaper website of Asahi Shimbun: https://www.asahi.com/articles/ASMCF4RRPMCFULFA016.html (accessed on December 10, 2019).

must pay two types of taxes on vehicle purchase: *vehicle acquisition tax* and *VAT*. These taxes are imposed only once. The *vehicle acquisition tax* rate is set to 0%, 1%, 2% or 3%, according to vehicle environmental performance characteristics such as fuel efficiency. The tax rate for EVs is set at the lowest rate of 0% because their environmental performance is better than those of conventional vehicles. Vehicles with low performance face higher tax rates. The *VAT* rate was fixed at 10% after October 2019.[9] When a person purchases a new vehicle at a price of 1 million yen (US$9091) and the *vehicle acquisition tax* rate is 2%, (s)he needs to pay 20,000 yen (US$182) and 100,000 yen (US$909) for the *vehicle acquisition tax* and *VAT*, respectively.

The second type of tax is on vehicle possession. Vehicle owners have an obligation to have a legal inspection of their vehicles carried out once every two years to use them on the road. If vehicles do not pass inspection, they cannot be used on the road. Owners must pay *vehicle taxes* or *light vehicle taxes* every year for their vehicles to be considered eligible for inspection. If they forget to make the payment, the vehicles cannot be inspected, meaning that they cannot travel on the road. Which tax is applied depends on the displacement of the vehicle. When the displacement is more than 661 cc, the *vehicle tax* is applied. Otherwise, the *light vehicle tax* is applied. Even when vehicle owners do not use their vehicle at all, they are required to pay this tax because it is on vehicle possession. The greater the vehicle displacement is, the higher the annual amount of the *vehicle tax*.[10] The tax amount increases for every 500 cc of displacement. For example, the tax amount for passenger vehicles with a displacement of 1000 cc is 25,000 yen (US$227) a year, whereas the amount for passenger vehicles with a displacement of 3000 cc is 50,000 yen (US$455) a year. Different from the *vehicle tax*, the amount of the *light vehicle tax* is fixed at 7200 yen (US$65) a year.[11]

In addition to the *vehicle tax* or *light vehicle tax*, all vehicle owners must pay the *vehicle weight tax* when a legal inspection is carried out. The first inspection occurs 3 years after a new vehicle is purchased, and then the following inspections occur every 2 years. Therefore, vehicles will undergo inspections and owners will pay the *vehicle weight tax* at 3, 5, 7 and so on years thereafter. As the name suggests, the tax rate depends on the vehicle weight. The greater the vehicle weight, the higher the tax rate is. For example, the standard tax amounts for passenger vehicles with weights of 1000 and 2000 kg are set to 16,400 yen (US$149) and 32,800 yen (US$298), respectively. In addition to the weight, the tax rates change according to the environmental performance and vehicle age. For the case of a passenger vehicle with a weight of 1000 kg and high environmental performance, the tax amount decreases from 16,400 yen (US$149) to 10,000 yen (US$91). In contrast, for a passenger vehicle with the same weight and age of 18 (i.e., a very old vehicle), the tax amount increases from

[9]The VAT rate was 8% before September 2019.

[10]The *vehicle tax* amount varies across vehicle type and purpose of use. The tax amount shown here is for passenger vehicles for personal use.

[11]The *light vehicle tax* amount also depends on vehicle type and purpose of use. The tax amount shown here is for passenger vehicles for personal use.

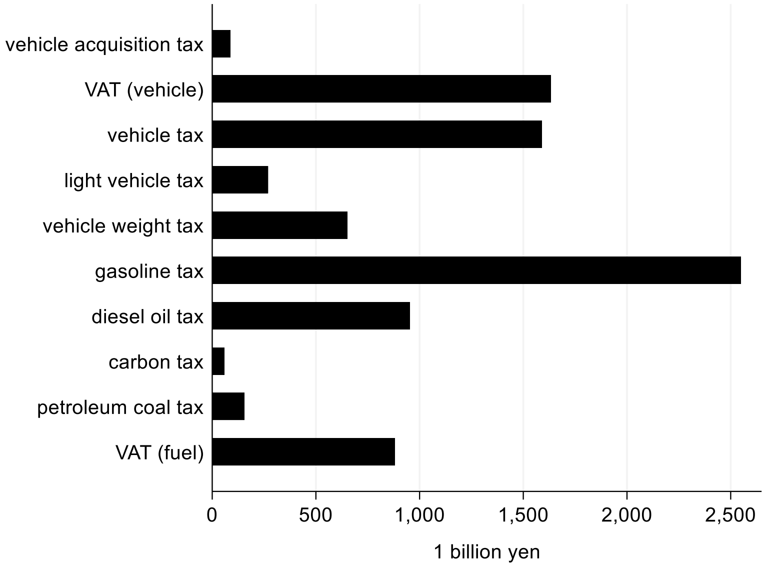


Fig. 2 Tax revenues from each tax related to automobiles in 2018

16,400 yen (US$149) to 25,200 yen (US$229). The *vehicle tax* and *light vehicle tax* are local tax, whereas the *vehicle weight tax* is a national tax.

Gasoline or diesel is necessary to use vehicles. The third type of tax is on fuel consumption. The retail price for gasoline includes the *gasoline tax*, *petroleum coal tax* and *carbon tax*. In addition to these three taxes, vehicle users pay *VAT* when purchasing gasoline, meaning that they pay 4 taxes when using gasoline vehicles. For diesel vehicles, users pay *diesel oil tax* instead of *gasoline tax*. The *gasoline tax* and *diesel tax* rates are 53.8 yen (US$0.49) and 32.1 yen (US$0.29) per liter, respectively. The *petroleum coal tax* and *carbon tax* are imposed on all oil and coal products, including gasoline and diesel oil. The *petroleum coal tax* is 2.04 yen (US$0.02) per liter, and the *carbon tax* is 0.74 yen (US$0.01) per liter, implying that these tax rates are relatively smaller than the *gasoline tax* and *diesel oil tax* rates. In particular, the carbon tax rate is much smaller than the other conventional fuel taxes.

Figure 2 presents the revenue from each tax in 2018.[12] The tax revenues of the *carbon tax* and *petroleum coal tax* are calculated from the tax rates and consumption data. The data are obtained from the Survey on Motor Vehicle Fuel Consumption. The other revenues are quoted from the website of the Japan Automobile Manufacturers Association.[13] The total amount of tax revenue was approximately 8829 billion yen (US$80.3 billion). The revenue from the carbon tax was only 58 billion yen (US$0.52 billion), which indicates that the *carbon tax* is of less importance from the viewpoint

[12]For the tax revenues from the *petroleum coal tax* and *carbon tax*, the 2017 values are used.
[13]http://www.jama.or.jp/tax/outline/image_01.html (accessed on December 10, 2019).

of tax revenue. The most important revenue source is the *gasoline tax*, followed by the *VAT* on vehicle purchase and the *vehicle tax*.

2.2 Actual ECR After Consideration of the Tax System

The described 10 types of taxes are levied on vehicle possession and usage in Japan. In this subsection, we simulate and discuss how much GHG emissions vehicle owners generate and pay taxes on from the perspective of a life cycle assessment. For the simulation, we assume that Japanese drivers are average passenger vehicle owners.

Each car owner drove 6300 km in 2018 (Sony Assurance, 2018). The average fuel economy of gasoline passenger vehicles is 21.9 km per liter (MLITT 2017). Therefore, the average car consumes 287.7 L of gasoline per year. Using the CO_2 emission coefficient of 2.348 kg-CO_2 per gasoline liter presented by the IEA (2011) yields an equivalence of approximately 676 kg-CO_2 per year. The Automobile Inspection & Registration Information Association (AIRIA) reports that the average number of years of passenger vehicle usage in 2018 was 13.24.[14] Therefore, the lifetime total amount of GHG emissions is approximately 8943 kg-CO_2 (=676 kg-CO_2 per year $\times$ 13.24 years). With a social discount rate of 4% (MLITT 2018) on the total amount of the emission, the present discounted emission is 7112 kg-CO_2. After 13.24 years, we assume that the owners scrap their vehicles.

The average gasoline retail price in 2018, 149.9 yen per liter, was obtained from the Survey on Petroleum Product Price by the Agency for National Resources and Energy. The average owner annually spends approximately 43 thousand yen on gasoline. Over the long term, the total amount of gasoline consumption costs approximately 571 thousand yen.

The average vehicle price is assumed to be 2525 thousand yen (US$23.0 thousand), which is the average value of the prices of the Note (2131 thousand yen; US$19.4 thousand), Aqua (2314 thousand yen; US$21.0 thousand) and Prius (3132 thousand yen; US$28.5 thousand) car models. These were the top three best selling cars in 2018.[15] In the same manner, the weight and displacement of the average vehicle are set to 1212 kg and 1497 cc, which are the averages of the weights and displacements, respectively, of these three described vehicles. The characteristics of the assumed average vehicle are shown in Table 2.

Hereafter, we calculate how much owners of the average vehicle pay for the various taxes over the 13.24-year life cycle. We ignore scrapping cost in the calculation. The calculation results are presented in Table 3. The rows in the table denote the vehicle age, so row 14 indicates the final year, when vehicles are scrapped. The owners,

[14] https://www.airia.or.jp/publish/file/r5c6pv000000m20m-att/r5c6pv000000m211.pdf (accessed on December 10, 2019).

[15] In 2018, the best-selling vehicle was the Note, produced by Nissan; 136,324 vehicles were sold. The next best sellers were the Aqua and Prius, manufactured by Toyota. The sales volumes of the Aqua and Prius were 126,561 and 115,462, respectively.

Table 2 Features of the assumed average vehicle

Terms	Value	Unit	References
Annual mileage	6300	km/year	Sony Assurance (2018)
Fuel efficiency	21.9	km/litter	MLITT (2017)
CO_2 coefficient	2.348	kg-CO_2/litter	IEA (2011)
Vehicle price	2525	thousand yen	Average retail price among Note, Aqua and Prius
Vehicle weight	1212	kg	Average weight among Note, Aqua and Prius
Vehicle displacement	1497	cc	Average displacement among Note, Aqua and Prius
Years of vehicle usage	13.24	years	AIRIA website
Gasoline price	149.9	yen/litter	The survey on petroleum product price

Table 3 Amount of tax payments until vehicle scrapping (unit: thousand yen)

Year	Purchase		Possession		Usage			
	Vehicle acquisition tax	VAT on vehicle purchase	Vehicle tax	Vehicle weight tax	Gasoline tax	VAT on fuel purchase	Carbon tax	Petroleum coal tax
1	25.3	252.5	34.5	11.2	15.5	4.3	0.2	0.6
2	0.0	0.0	33.2	0.0	14.9	4.1	0.2	0.6
3	0.0	0.0	31.9	0.0	14.3	4.0	0.2	0.5
4	0.0	0.0	30.7	13.3	13.8	3.8	0.2	0.5
5	0.0	0.0	29.5	0.0	13.2	3.7	0.2	0.5
6	0.0	0.0	28.4	12.3	12.7	3.5	0.2	0.5
7	0.0	0.0	27.3	0.0	12.2	3.4	0.2	0.5
8	0.0	0.0	26.2	11.4	11.8	3.3	0.2	0.4
9	0.0	0.0	25.2	0.0	11.3	3.2	0.2	0.4
10	0.0	0.0	24.2	10.5	10.9	3.0	0.2	0.4
11	0.0	0.0	23.3	0.0	10.5	2.9	0.1	0.4
12	0.0	0.0	22.4	9.7	10.1	2.8	0.1	0.4
13	0.0	0.0	21.5	0.0	9.7	2.7	0.1	0.4
14	0.0	0.0	6.9	3.0	2.2	0.6	0.0	0.1
Total	25.3	252.5	365.2	71.5	163.0	45.4	2.3	6.2

Note Tax rates of the *vehicle acquisition tax*, *vehicle tax* and *vehicle weight tax* are discounted for designated eco-friendly vehicles such as plug-in hybrid vehicles and EVs. The tax rates for eco-friendly vehicles are applied for the calculation therefore, pay only a quarter of each tax in the final year because they hold their vehicles for only 0.24 years (approximately 3 months). With a social discount rate of 4%, the present discounted value of the tax payment is 931.4 thousand yen in total. Considering the total discounted emission volume described above, the ECR from the viewpoint of life cycle assessment is 131.0 thousand yen (US$1.19 thousand) per t-$CO_2$, implying that the ECR in Japan is considerably higher than the SCC of US$54.7 per t-$CO_2$ determined by Wang et al. (2019). It is concluded that the Japanese government should reduce the tax rate on automobiles because the ECR is too high.

Of the total payment, 365.2 thousand yen (US$3.32 thousand), the highest tax payment, is attributable to the *vehicle tax*. The tax with next highest payment is the *VAT* on vehicle purchase and then the *gasoline tax*. When aggregating tax payments by behavior, the tax payments for purchase, possession and usage are 277.8, 436.7 and 216.8 thousand yen (US$2.07 thousand, US$3.97 thousand and US$1.97 thousand), respectively. Therefore, the tax payment for usage is lowest, implying that the Japanese automobile tax system emphasizes taxes on vehicle purchase and possession.

Assuming that the average vehicle features are as shown in Table 2, we calculate the long-term ECR as the total tax payment divided by GHG emissions. If vehicles are assumed to be fuel inefficient, ceteris paribus, the ECR decreases because the denominator becomes larger. If vehicles are assumed to be more expensive, the ECR increases because the numerator becomes larger. These changes are due to the features of the Japanese automobile tax system, where the main tax target is not fuel consumption but vehicle purchase and possession.

GHG emission is not generated from vehicle purchase and possession but usage (i.e., fuel combustion). Therefore, a Pigouvian carbon tax should be imposed on vehicle usage to attain cost efficiency. According to economic theory, the extent of the Pigouvian carbon tax should equal the SCC. Therefore, the Japanese government should shift its attention in the automobile tax system from purchase and possession to usage. At the same time, it should reduce the tax rates on vehicle usage to cost-effectively reduce GHG emissions.

Table 4 shows the ECR for an average vehicle. In general, the ECR is calculated by summing taxes on fuel consumption only (OECD 2018), that is, the 4 types of taxes on usage. In this case, the ECR is 30.5 thousand yen (US$ 277) per t-CO_2. The OECD (2016) reports that the Japanese ECR on road vehicles in 2012 was approximately 22.6 thousand yen (US$205) per t-$CO_2$. Considering that the estimated ECR depends on vehicle characteristics (as in Table 2), our calculated ECR is not greatly different from that of the OECD (2016). Additionally, the difference may come from the

Table 4 The ECR for an average vehicle

	Purchase	Possession	Usage	Total
Tax payment (thousand yen)	277.8	436.7	216.8	931.4
Tax payment/GHG emissions (thousand yen/ t-CO_2)	39.1	61.4	30.5	131.0

different benchmark years. The benchmark years of this chapter and the OECD (2016) report are 2018 and 2012, respectively.

The OECD (2016) also shows the ECRs for 40 countries, including Japan. The highest ECR, 33.7 thousand yen (US$307) per t-$CO_2$, is implemented in the UK. Of the 40 countries, Japan has the 14th highest ECR on road vehicles. That is, although the carbon prices of the *carbon tax* and the Tokyo ETS in Japan are smaller than those in other countries, it is confirmed that the ECR is sufficiently high compared to the SCC.

3 Cost-Benefit of EVs in Japan

3.1 Construction Cost for Fast Chargers

After the consideration of the ECR on automobiles in Japan in the previous section, this section conducts a cost-benefit analysis of the diffusion of EVs. Different from previous studies examining the effects of EVs, this chapter explicitly considers the recharging time of EVs, which is a social loss, similar to congestion. The basic concept of the analysis follows the method of Ito and Managi (2015). In this cost-benefit analysis, we assume that all vehicles in Japan are substituted by EVs, that is, that there are no conventional gasoline or diesel vehicles. The AIRIA shows that there are approximately 62.1 million vehicles in Japan.[16] Therefore, our analysis assumes that there are same number of EVs.

Similar to refuelling stations for conventional gasoline vehicles, EVs require fast chargers outside of homes. Of course, frequently charging EVs at home may eliminate the demand for fast charging them elsewhere. However, when EVs travel long distances, fast chargers are always required. Therefore, considering the diffusion of EVs, many new fast chargers must be constructed.

We calculate the required number of fast chargers and their construction costs. The required number of fast chargers can be obtained from the total yearly electric power consumption divided by the yearly electric power supply per charger [Eq. (1)]. In the equation, the term in parentheses denotes the unit. The value of the yearly electric power supply per charger is set to approximately 140,160 kWh/unit/year, obtained from Mitsubishi UFJ Research and Consulting (2014). The report shows that the fast charger takes 30 min to charge 8 kWh. In other words, the charger takes one year to charge 140,160 kWh.

The total yearly electric power consumption is calculated by multiplying the total number of EVs (i.e., 62.1 million vehicles) and the required electric power consumption per EV [Eq. (2)]. On the assumption that drivers' behaviors are not changed by the use of EVs, the required electric power consumption per EV is obtained from the annual mileage (i.e., 6300 km in Table 2) divided by the EV

[16] https://www.airia.or.jp/publish/statistics/ub83el00000000wo-att/01.pdf (accessed on December 10, 2019).

driving distance per kWh [Eq. (3)]. We use approximately 9.3 km/kWh as the driving distance of the EV, which is equal to the performance of the Leaf model produced by Nissan.[17] According to the three equations, the required number of fast chargers is 299,069. In the calculation, we assume that all EV owners do not recharge their EVs at home but at fast chargers outdoors. Therefore, the required number can be regarded as the maximum.

$$\begin{aligned} &Number\ of\ fast\ chargers(units) \\ &= \frac{Total\ yearly\ electric\ power\ consumption(kWh/year)}{Yearly\ electric\ power\ supply\ per\ charger\left(\frac{kWh}{unit\cdot year}\right)} \end{aligned} \tag{1}$$

$$\begin{aligned} &Total\ yearly\ electric\ power\ consumption(kWh/year) \\ &= Total\ number\ of\ EVs(vehicles) \\ &\quad \times Required\ electric\ power\ consumption\ per\ EV\left(\frac{kWh}{vehicle\cdot year}\right) \end{aligned} \tag{2}$$

$$\begin{aligned} &Required\ electric\ power\ consumption\ per\ EV\left(\frac{kWh}{vehicle\cdot year}\right) \\ &= \frac{Annual\ mileage\left(\frac{km}{vehicle\cdot year}\right)}{driving\ distance\ of\ EV\ per\ kWh(km/kWh)} \end{aligned} \tag{3}$$

The construction cost of the fast charger is set to 2.25 million yen (US\$20.5 thousand) (Mitsubishi UFJ Research and Consulting, 2014). The statutory useful life for a fast charger is 8 years.[18] Therefore, ignoring a discount rate, the annual cost per charger is approximately 281 thousand yen (US\$2.26 thousand). The total annual cost for constructing fast chargers is 84.1 billion yen per year (US\$0.76 billion). The values and data sources in the calculation are shown in Table 5.

3.2 GHG Emission Reduction

As mentioned earlier, the amount of GHG emissions from automobiles is 0.18 billion t-CO_2. In the case that all conventional gasoline and diesel vehicles are replaced with EVs, the amount of GHG emissions from fuel consumption becomes zero. Therefore, the direct emission reduction effect of EVs is 0.18 billion t-CO_2.

On the other hand, EVs need electric power. The total yearly electric power consumption of EVs is already calculated in Eq. (2): approximately 42.9 GWh per

[17]The Leaf with a 30 kWh battery can travel 280 km on a full charge; http://history.nissan.co.jp/LEAF/ZE0/1211/charge.html (accessed on December 10, 219).

[18]Refer to the Next Generation Vehicle Promotion Center website: http://www.cev-pc.or.jp/hojo/pdf/h31/H23-H24_kouhukitei_saisoku.pdf (accessed on December 10, 2019).

Table 5 Data sources for calculating construction cost

Term	Value	Unit	Source
Yearly electric power supply per charger	140,160	kWh/unit/year	Mitsubishi UFJ Research and Consulting (2014)
Total number of EVs	62.1	million vehicles	AIRIA website
Annual mileage	6200	km/year	Sony Assurance (2018)
Driving distance of EV per kWh	9.3	km/kWh	Nissan website
Construction cost of fast charger	2.25	million yen/unit	Mitsubishi UFJ Research and Consulting (2014)
Statutory useful life for fast charger	8	years	Next Generation Vehicle Promotion Center website

year. Therefore, that amount of electric power must be newly generated for the use of EVs. Here, the additional electric power is assumed to be generated by thermal power generation (i.e., coal, oil and LNG). Viewing the breakdown of thermal power generation, coal, oil and LNG account for 40.4%, 10.8% and 48.8%, respectively (Agency for Natural Resources and Energy 2018). Therefore, when the power generation amount is apportioned at these rates, 16.9, 4.5 and 20.5 GWh are generated by coal, oil and LNG thermal generation. Since the CO_2 coefficients for each type of power generation are 943, 738 and 599 gram-CO_2 per kWh, respectively (Imamura et al. 2016), the additional annual total amount of GHG emissions is 31.5 million t-CO_2.

Therefore, the amount of net GHG emission reduction is approximately 0.15 billion t-CO_2 because the reduction in emissions from replacement of other vehicles with EVs exceeds the increase in emissions from the related power generation. When the reduction is converted into monetary value with the SCC at 6017 yen (US$54.7) per t-$CO_2$ in line with Wang et al. (2019), the annual benefit of reducing GHG emissions from diffusion of EVs is approximately 916.4 billion yen (US$ 8.33 billion).

3.3 Opportunity Cost of Recharging Time

The EV owner must wait for the vehicle to recharge at the charging station. They may do something to work during the recharging time (e.g., input work using a laptop). However, for simplicity, we ignore this possibility. That is, we consider the recharge wait time to be an opportunity cost. Although the charging time has become shorter, Mitsubishi UFJ Research and Consulting (2014) reports that it takes 30 min to fully recharge an EV.

EV owners annually drive 6300 km, and an EV can travel 280 km on a single charge (see the previous Sect. 3.2). Owners thus recharge their EVs at charging stations 22.5 times a year. The time value of driving is presented in MLITT (2018) at 39.6 yen per minute. Following Eq. (4), the annual opportunity cost per EV is 26,730 yen (US$243).

$$
\begin{aligned}
&Opportunity\, cost\ for\ EV\left(\frac{yen}{vehicle}\right) = recharging\, time\left(\frac{minute}{time}\right)\\
&\quad \times number\ of\ recharges(time)\\
&\quad \times time\, value\, of\ driving\left(\frac{yen}{vehicle \cdot minute}\right)
\end{aligned} \tag{4}
$$

When using conventional gasoline vehicles, owners must refill fuel at refuelling stations. The Fire and Disaster Management Agency reports that the refuelling amount is on average 30.6 L.[19] The refuelling speed of the refuelling machine is legally set to between 30 and 35 L per minute by the Fire Service Act. Using the average speed of 32.5 L per minute and the average refuelling amount, we can calculate the refuelling time for each refuel as approximately 0.94 min.

Since gasoline vehicle owners consume 287.7 L of gasoline per year, calculated by the annual mileage (i.e., 6300 km) divided by the fuel efficiency (i.e., 21.9 km per liter), they refuel their vehicles approximately 9.4 times for a year (=287.7 L per year/ 30.6 L). Therefore, the opportunity cost for conventional gasoline vehicles is approximately 350 yen (US$3.2), calculated as in Eq. (5). The opportunity cost of refuelling conventional vehicles is quite small compared to that of recharging EVs.

$$
\begin{aligned}
&Opportunity\, cost\ for\ conventional\ vehicles\left(\frac{yen}{vehicle}\right)\\
&= refuelling\, time\left(\frac{minute}{time}\right)\\
&\quad \times number\ of\ refuels(time)\\
&\quad \times time\, value\, of\ driving\left(\frac{yen}{vehicle \cdot minute}\right)
\end{aligned} \tag{5}
$$

The net opportunity cost of replacing conventional vehicles with EVs is 26,379 yen (US$239.8). Considering that the number of vehicles is 62.1 million, the total opportunity cost is 1638.2 billion yen (US$14.9 billion). The data sources for calculating the costs are described in Table 6.

3.4 Total Net Benefit of EVs

Three components of EV net benefit have been calculated: the construction cost, the benefit from the GHG reduction and the net opportunity cost. The amounts of those components are annually 84.1 billion yen, 916.4 billion yen and 1638.2 billion

[19] Refer to the Fire and Disaster Management Agency website: https://www8.cao.go.jp/kisei-kaikaku/kaigi/meeting/2013/wg/ene/130508/item2-2.pdf (accessed on December 10, 2019).

Table 6 Data sources for calculating opportunity costs

Term	Value	Unit	Source
Recharging time	30	minute	Mitsubishi UFJ Research and Consulting (2014)
Annual mileage	6200	km/year	Sony Assurance (2018)
Travel distance on a single charge	280	km	Leaf with 30kWh battery
Time value of driving	39.6	yen/minute	MLITT (2018)
Refuelling amount	30.6	litter	Fire and Disaster Management Agency website
Refuelling speed	32.5	litter/minute	Fire Service Act
Fuel efficiency	21.9	km/liter	MLITT (2017)

yen, respectively. Therefore, the total net benefit is negative, −805.9 billion yen (−US$73.3 billion), implying that the Japanese government should not promote the diffusion and usage of EVs. This conclusion mainly comes from the fact that the opportunity cost of waiting for EVs to recharge is remarkably large.

The upper bound value of the opportunity cost is calculated in the simulation as mentioned before because all EV owners are assumed not to recharge their EVs at home but at outdoor fast chargers 22.5 times per year. Therefore, we reduce the number of recharges at outdoor fast chargers (i.e., increase the number of recharges at home) and recalculate the cost and benefit. When owners recharge their EVs at home, the opportunity cost of waiting for EVs to recharge is assumed to be zero. For example, this could be because the recharge is performed overnight.

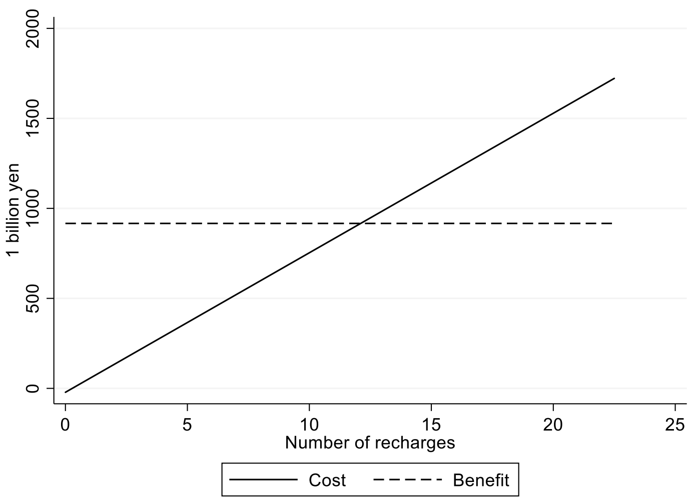


Fig. 3 Cost and benefit of EVs by number of outdoor recharges

The recalculated costs and benefits are depicted in Fig. 3. The x- and y-axes represent the number of recharges and monetary value of the cost or benefit, respectively. In the basic simulation, the number of outdoor recharges is set to 22.5. As shown in Fig. 3, we observe that the cost (i.e., sum of the construction cost and opportunity cost of recharge wait time) decreases as the number of outdoor recharges decreases. When the number of recharges decreases to 12, the benefit is greater than the cost, implying that the promotion of EVs improves social welfare. Twelve is approximately half of 22.5, so if less than one of every two recharges is done outdoors, the spread of EVs will be an efficient countermeasure against climate change. Since charging EVs takes longer than refuelling gasoline or diesel vehicles, it is necessary to examine in particular how many times EV owners will use outdoor fast chargers. In addition, to improve social welfare further, it is important for policymakers and manufacturers to develop high-performance fast chargers.

4 Concluding Remarks

Since automobiles greatly contribute to GHG emissions in Japan (i.e., 15.4% of the total), it is important to examine how to efficiently reduce emissions from automobile. A carbon tax on fuel consumption was implemented in Japan in 2012 to reduce GHG emissions from vehicles. However, the tax rate, 289 yen (US$2.6) per t-$CO_2$, has been criticized as being too low compared to the rates of other countries and the SCC determined by Wang et al. (2019). However, multiple taxes are already imposed on vehicles in Japan. Considering taxes such as the *vehicle acquisition tax* and *VAT*, the entire tax rate on carbon, that is, the ECR, may not be small. Focusing on automobiles in Japan, this chapter first gave an overview of the complicated vehicle tax system and examined the entire ECR on vehicles.

Different from the OECD (2016) and OECD (2018), when calculating the ECR on vehicles in Japan, we consider the entire vehicle tax system, including taxes on vehicle purchase and possession, from the perspective of life cycle assessment. The final ECR on vehicles in Japan is estimated to be 128.9 thousand yen (US$1.17 thousand) per t-$CO_2$, suggesting that the ECR is quite large. This is because the tax rates for vehicle purchase and possession are high compared to the rate for vehicle usage under the vehicle tax system in Japan. Therefore, although the carbon tax rate on fuel consumption is small in Japan, the ECR is rather high. For further improvement of countermeasures against climate change, the Japanese government should shift its attention to vehicle usage from vehicle purchase and possession.

Second, we completed a cost-benefit analysis of EVs, which are projected to become a main type of vehicle in the future (IEA 2019). The benefit of EVs is calculated as the monetary value of GHG emissions reduction when all vehicles are replaced with EVs. The cost is the sum of the construction cost of fast chargers and the opportunity cost of the EV recharge wait time. For the basic calculation, we assume that EV owners do not recharge their EVs at home but at outdoor fast chargers. In that case, the cost and benefit are estimated to be 1722 and 916 billion yen (US$15.7 and 8.3 billion), respectively. That is, the diffusion of EVs is not an efficient measure for reducing GHG emissions. However, if owners recharge their EVs at home once of every two charges, the net benefit becomes positive, suggesting that the opportunity cost of waiting for recharges is a key factor in whether EVs can play a role in mitigating climate change. Therefore, it is important for policymakers to examine how often EV owners use outdoor fast chargers as well as to develop higher performance fast chargers. Additionally, to make effective use of the waiting time for recharging, it is desirable to construct fast chargers. This chapter introduces strong assumptions for estimating the ECR and the cost-benefit analysis. Future research needs to relax the assumptions to examine them precisely.

Acknowledgements This chapter was supported by JSPS KAKENHI Grant Numbers 16K13371 and 18H03433.

References

Agency for Natural Resources and Energy (2018) Japanese energy 2018: 10 questions to know energy today. https://www.enecho.meti.go.jp/about/pamphlet/pdf/energy_in_japan2018.pdf. Accessed on 10 Dec 2019

Baldock MRJ, Mathias JL, McLean AJ, Berndt A (2006) Self-regulation of driving and its relationship to driving ability among older adults. Accid Anal Prev 38(5):1038–1045

IEA (2011) Carbon dioxide emissions coefficients detail factors. https://www.eia.gov/environment/emissions/archive/coefficients.php. Accessed on 10 Dec 2019

IEA (2019) Global EV Outlook 2019. https://www.iea.org/reports/global-ev-outlook-2019. Accessed on 10 Dec 2019

Imamura E, Iuchi M, Bando S (2016) Comprehensive assessment of life cycle CO_2 emissions from power generation technologies in Japan, Socio-economic Research Center Rep., No.Y06

Ito Y, Managi S (2015) The potential of alternative fuel vehicles: A cost-benefit analysis. Res Trans Econ 50:39–50

Kolstad CD (2010) Environmental economics. Oxford University Press, Oxford

Ministry of Land, Infrastructure, Transport and Tourism (2017) Average fuel economy for gasoline passenger vehicles by JC08 mode. http://www.mlit.go.jp/common/001225518.pdf. Accessed on 10 Dec 2019

Ministry of Land, Infrastructure, Transport and Tourism (2018) Cost-benefit analysis manual. http://www.mlit.go.jp/road/ir/hyouka/plcy/kijun/ben-eki_h30_2.pdf. Accessed on 10 Dec 2019

Ministry of the Environment (2019) National greenhouse gas inventory report of JAPAN. http://www-gio.nies.go.jp/aboutghg/nir/2019/NIR-JPN-2019-v3.0_GIOweb.pdf. Accessed on 10 Dec 2019

Mitsubishi UFJ Research and Consulting (2014) Survey on profitability of charging infrastructure development. http://www.cev-pc.or.jp/chosa/pdf/H25_chosa_1_honpen.pdf. Accessed on 10 Dec 2019

OECD (2016) Effective carbon rates: pricing CO_2 through taxes and emissions trading systems. OECD Publishing

OECD (2018) Effective carbon rates 2018: pricing carbon emissions through taxes and emissions trading, OECD Publishing

Sony Assurance (2018) Survey on car life in 2018. https://from.sonysonpo.co.jp/topics/pr/research20181203.pdf. Accessed on 10 Dec 2019

Wang P, Deng X, Zhou H, Yu S (2019) Estimates of the social cost of carbon: A review based on meta-analysis. J Cleaner Production 209:1494–1507

Kazuyuki Iwata is a Professor of Faculty of Economics at Matsuyama University in Ehime, Japan. He is a Ph.D., MA and BA in economics from Sophia university in Tokyo. After the graduation, he has worked as a researcher of Graduate School of Environmental Studies at Tohoku University and then an associated professor of Faculty of Regional Studies at Takasaki City University of Economics. His major is environmental economics and applied economics, and he is particularly interested in empirically evaluating urban and transport policies related to the environment such as air pollution and global warming issues. His research papers have been published in international academic journals such as *Transportation Research Part D*, *Journal of Economic Behavior and Organization*, *Applied Energy*, and *Energy for Sustainable Development*. He is also a coauthor of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach from Environmental Economics* (Springer 2015, coauthored with Dr. Toshi H. Arimura).

Chapter 5
Climate Policy in Power Sector: Feed-in Tariff and Carbon Pricing

Yukihide Kurakawa

Abstract The purpose of this chapter is to investigate the effects of some mainstream policy schemes in the power sector on the reduction of CO_2 emissions. The first part of this chapter is the analysis on the effects of promoting generation (fuel) efficiency of fossil-fuel power generation, specifically assuming more efficient coal-fired power plants that recently indicates increased presence in the Japanese power sector. Improvement in generation efficiency of fossil-fuel power plants is expected to reduce emissions of carbon dioxide mainly from a technological aspect. However, overall effects on carbon reduction in the whole industry would be ambiguous since it also depends on market structure. The increased efficiency in generation leads to an improvement in cost conditions of fossil-fuel power producers relative to their rivals. It enables them to expand their generation and market share. Analyzing the Cournot oligopoly model, it is shown that an improvement in fossil-fuel power generations produces two effects: the 'saving effect' and the 'rebound effect'. The total CO_2 emission in the whole industry decrease if the former effect exceeds the other, and vice versa. In addition, it is indicated that a rise in the generation efficiency would increase a difficulty of implementing carbon tax. In the second part of this chapter, I study the combination of feed-in tariff and carbon tax; that would be worthy to investigate since they could possibly complement each other. FIT policy could be financed by the revenue of carbon tax, and a reduction in electricity supply by the carbon tax would be lessen by supporting renewable power generations under FIT. It is demonstrated that FIT had the combined effects: it fosters a competitive environment in addition to indirectly reduces CO_2 emissions. The result indicates that the combination of these policies would produce potential welfare gains.

Keywords Generation (fuel) efficiency · Carbon tax · Feed-in tariff

Y. Kurakawa (✉)
Faculty of Economics, Kanazawa Seiryo University, 10-1 Ushi, Gosho-machi, Kanazawa, Ishikawa 920-8620, Japan
e-mail: kurakawa@seiryo-u.ac.jp

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_5

1 Introduction

1.1 Background

There are several turning points in the history of energy use. The invention of the Watt steam engine in the late eighteenth century driven the industrial revolution and led to a rapid growth in coal consumption. In the 1950s, successive discovery of oilfields in the Middle East and Africa brought about a shift from coal to oil as a major source of energy. Since then, economies in various countries had become more dependent on political and diplomatic situations of oil-producing nations. That poses potential risks associated with social and economic stability in various countries. The oil crises in the 1970s revealed the risk from energy use highly dependent on petroleum. That triggered a promotion of usage of alternative energy sources like natural gas and nuclear power as well as energy conservation policies in order to improve energy security. After the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, there has been a growing recognition of the global warming as a problem of global issue.

Nuclear power has occupied an important position not only as a major energy source but also as a low-carbon power source which plays a substantial role in reducing CO_2 emissions as well as increasing energy security; uranium is distributed in countries with relatively stable political conditions and is able to release greater thermal energy with smaller amount than fossil fuels. On the other hand, the issue of securing a final disposal site for radioactive waste still remains unsettled. In addition, the costs for safety measures at nuclear power generation facilities has increased after the Fukushima Daiichi Nuclear Power Station accident in 2011, that has been increasing the difficulty of constructing new nuclear power plants nowadays.

In that context, promoting renewable energies has become an increasingly more important policy issue to tackle the problems of global warming and energy security in recent years. Accordingly, many countries have implemented support schemes to promote renewable power generations.

Feed-in tariff (FIT) is the mainstream policy scheme that is particularly effective in promoting renewable energies. Despite its effectiveness, it usually causes an operational difficulty of making delicate adjustment in quantities of renewable energies, since it is a kind of price regulation under which the government sets a price for renewable electricity leaving the quantities to the market; practically it is difficult for the government to grasp precise cost conditions of the renewable power producers. The main purpose of the FIT policy is to reduce renewable power generation costs to the competitive level by encouraging technological developments and producing efficiency gains from mass production (e.g., the learning effect). Indeed, many countries adopting FIT policy are aiming at transition to a support schemes that are more relevant to the market mechanism such as feed-in premiums (FIP) and bidding systems when the FIT policy successfully creates competitive cost conditions of renewable power generations.

Additionally, there exist the financing problem with FIT which tend to receive public attentions since it would be partly passed on to consumers. On the other hand, it is noteworthy to say that supporting renewable energy generations would partially overlaps with fostering the competitive environment in the industry that is formerly characterized by high market concentrations and entry barriers, because the new entrants would be heavily subsidized by the FIT; eventually it would has the effect of decreasing the consumer price. The analysis of the later part of this chapter primarily focuses on this aspect of FIT in addition to its effects as a climate policy in the power sector.

1.2 Outline

The major instruments for carbon reduction in the power sector typically involves the environmental and regulatory policy schemes which can be classified as the following categories,

1. Improving energy efficiencies
2. Carbon pricing
3. Promoting non-fossil fuel energy sources.

The first category covers approaches to both the supply-side and demand-side efficiencies: efficiencies of producing and using energies, respectively. The second category contains carbon tax and cap and trade schemes. The third category mainly represented by support schemes for promoting renewable energy sources, e.g., feed-in tariff (FIT), feed-in premium (FIP), and renewable portfolio standard (RPS). As for Japanese power sector, FIT has been implemented since 2012, and partly combined with the bidding system for large-scale photovoltaics from 2017.

In the first part of this chapter, I will be examining a linear model to investigate the effects of generation efficiency and carbon tax. I will also be focusing on the interrelationship between these factors. In the next part, I will analyze a model with quadratic cost functions to examine the effects of feed-in tariff, as well as combination with feed-in tariff and carbon tax.

2 Generation Efficiency and Carbon Tax

I will begin the analysis by considering a linear model in which the cost functions and the demand function of the market are all linear to examine the overall effect of generation efficiency of the fossil-fuel power plants (specifically suppose coal fired power plants here) on carbon reduction. Following previous works such as Tamás et al. (2010) and Böhringer and Rosendahl (2010), I consider a liberalized[1] Cournot

[1] Armstrong et al. (1994) states a distinction between "deregulation" and "liberalization"; the former would represent the removal of regulations such as price control as well as the removal of restrictions

oligopoly market which is consisted of n identical fossil-fuel power producers and m identical renewable power producers.[2] The inverse demand function is assumed to be as follows,

$$P(Q) := A - BQ,$$

where $P = P(Q)$ is the consumer price and Q is the total electricity supplied by both fossil-fuel and renewable power producers.

The profit of each fossil-fuel power producer is given by,

$$\pi_F^i := (P - c_F - a)y_i - k_F, i = 1, \cdots, n \tag{1}$$

where y_i is the amount of electricity supply, c_F is the constant marginal cost, and k_F is the fixed cost. Let a denote the access charge for each unit of electricity which is paid to the network operator in order to access the transmission network. The marginal cost of fossil-fuel power generation c_F is composed of fuel cost and carbon tax:

$$c_F := p_F\theta + t(\eta\theta), \tag{2}$$

where $\theta(\text{kg/kWh})$ represents the amount of fuel needed to produce 1 kWh of electricity, it is equivalent to the generation efficiency of power plants,[3] p_F is the fuel price (yen/kg), and t is the carbon price (equivalent to a tax for each unit of emissions of carbon dioxide). Let $\eta(\text{kg} - CO_2/\text{kg})$ denote the carbon intensity of fuel; that represents the amount of CO_2 emissions generated from burning 1kg of fossil-fuel.[4] Substituting Eq. (2), Eq. (1) can be rewritten as follows,

$$\pi_F^i := (P - p_F\theta - a)y_i - t(\eta\theta y_i) - k_F, i = 1, \cdots, n. \tag{3}$$

where $\eta\theta y_i$ is the emission of the i-th fossil-fuel power producer, which is represented as $e_i = \eta\theta y_i$. Accordingly, the total emission in the electric power sector is,

$$E := \eta\theta \sum_i y_i.$$

Similarly, the profit of the renewable producer j is written as,

$$\pi_R^j := (P - c_R - a)x_j - k_R, j = 1, \cdots, m, \tag{4}$$

on competition. For clarity, they use "liberalization" to mean the removal of restrictions on competition. Following them, I use "liberalized market" here to represent the competitive environment under environmental regulations such as FIT.

[2]As Tamás et al. (2010) pointed out, market concentration in the electricity markets often high despite liberalization.

[3]Note that lower (higher) θ corresponds to higher (lower) generation efficiency.

[4]The amount of emission by producer i is given by $\eta\theta y_i(\text{kg} - CO_2)$.

where x_j is the amount of electricity supply, c_R is the constant marginal cost, and k_R is the fixed cost.

By solving the profit maximization problems, the first order conditions for fossil-fuel and renewable power producers are obtained as follows,

$$\frac{\partial \pi_F^i}{\partial y_i} = \{A - BQ - p_F\theta - a\} - By_i - t(\eta\theta) = 0 \tag{5}$$

$$\frac{\partial \pi_R^j}{\partial x_j} = \{A - BQ - c_R - a\} - Bx_j = 0 \tag{6}$$

Assuming the symmetry ($y_i = y$for all i, and $x_j = x$ for all j) in the equilibrium, the equilibrium outcomes can be obtained as follows,

$$y = \frac{A - (m+1)(p_F\theta + t\theta\eta) + mc_N - a}{(n+m+1)B}, \tag{7}$$

$$x = \frac{A - (n+1)c_N + n(p_F\theta + t\theta\eta) - a}{(n+m+1)B}, \tag{8}$$

$$Q = \frac{(n+m)(A-a) - n(p_F\theta + t\theta\eta) - mc_N}{(n+m+1)B}. \tag{9}$$

In order to secure positive outputs of the fossil-fuel and renewable power producers, it is assumed in the following analysis that $A - (n+1)c_N - a > 0$ and $\theta < \bar{\theta}$, where

$$\bar{\theta} := \frac{A + mc_N - a}{(m+1)(p_F + t\eta)}.$$

2.1 Generation Efficiency

Contrary to the worldwide trend toward restrictions or 'divestment' on coal-related projects in recent years, the Japanese Ministry of Economy, Trade and Industry (METI), as well as former monopolists in the electric power industry are positive about promoting coal-fired power generations. They rather place emphasis on technological measures for carbon reductions, i.e., developing low emission technologies that would reduce emissions of carbon dioxide such as higher-efficient power plants, CCS (Carbon dioxide Capture and Storage) and CCU (Carbon dioxide Capture and Utilization).

Japanese electric power companies shut down nuclear power plants in May 2011 after Fukushima Daiichi Nuclear Power Station Accident. METI and the former monopolists in the power sector regard coal fired power generation as a good alternative to nuclear power. They have become more enthusiastic to promote coal fired power generation after the accident. In addition, the Japanese government aims to export high efficiency coal fired power plants to the developing countries.

Improvement in generation efficiency of fossil-fuel power plants is expected to reduce emissions of carbon dioxide mainly from a technological aspect; more efficient power plants are able to produce the same amount of electricity with less fuel input. Consequently, it enables cutting fuel consumption and carbon emissions maintaining the electricity output. However, overall effects on carbon reduction in the whole industry would be ambiguous since it also depends on market structure. The increased efficiency in generation leads to an improvement in cost conditions of fossil-fuel power producers relative to their rivals. It enables them to expand their generation and market share. It may cause a net increase in total CO_2 emission in the industry. We need to take this factor related to the market structure into account when we consider to what extent does promoting more efficient power plants contribute to carbon reduction in the whole industry.

To examine the impact of changes in generation efficiency of fossil-fuel power plants, the derivatives of the equilibrium outcomes with respect to θ are calculated as follows,

$$\frac{dy}{d\theta} = -\frac{(m+1)(p_F + t\eta)}{(n+m+1)B} < 0, \tag{10}$$

$$\frac{dx}{d\theta} = \frac{n(p_F + t\eta)}{(n+m+1)B} > 0, \tag{11}$$

$$\frac{dQ}{d\theta} = \frac{-n(p_F + t\eta)}{(n+m+1)B} < 0. \tag{12}$$

Note that $dy/d\theta < 0$. This means that an improvement (reduction) in generation efficiency, which is equivalent to a decrease (increase) in θ, leads to a lager (smaller) output of fossil-fuel power producers. A higher generation efficiency improves cost conditions of fossil-fuel generators. This gives them a competitive advantage relative to their rivals: renewable electricity producers. To sum up, improvement in generation efficiency leads to an increase in output of fossil-fuel power producers and reduces output of renewable power producers, and vise-versa. The total output rises with higher generation efficiency.

The effect on the overall CO_2 emission is given by,

$$\frac{dE}{d\theta} = n\eta\left(y + \theta\frac{dy}{d\theta}\right). \tag{13}$$

The first term in the bracket indicates the direct effect of fuel conservation. A higher generation efficiency (lower θ) can cut carbon emissions due to fuel conservation. The second term indicates the indirect effect through the market in which the fossil-fuel power producers expand their production with improved cost conditions relative to their rivals. It causes the adverse effect through changing in the market equilibrium.[5] Improvement in generation efficiency reduces total emission of the power sector if the direct effect outweighs the indirect effect, and vice versa. Note that a reduction in θ increases the former effect but decreases the latter. Substituting Eqs. (7) and (10) into Eq. (13) yields,

$$\frac{dE}{d\theta} = n\eta\left(\frac{A - 2\theta(m+1)(p_F + t\eta) + mc_N - a}{(n+m+1)B}\right). \tag{14}$$

The sign of Eq. (14) depends only on the sign of numerator of fraction in the bracket. We can obtain a threshold,[6]

$$\hat{\theta} := \frac{A + mc_N - a}{2(m+1)(p_F + t\eta)},$$

such that,

$$\frac{dE}{d\theta}\begin{cases} > 0 \; if 0 < \theta < \hat{\theta} \\ = 0 \; if \theta = \hat{\theta} \\ < 0 \; if \hat{\theta} < \theta < \bar{\theta} \end{cases} \tag{15}$$

Note that a lower θ corresponds to more efficient power plant. The above equation indicates that an improvement in generation efficiency increases total emission of the industry if the fuel efficiency is lower than a threshold,[7] and vice versa.

Concerning a combination with carbon tax, a higher tax level increases the threshold of generation efficiency. In other words, a higher tax level reduces $\hat{\theta}$; $d\hat{\theta}/dt < 0$. This is because in a market where carbon tax is implemented, the direct effect of higher efficiency gets smaller with a reduction in the output of fossil-fuel power producers by the tax, which is represented by the first term in the bracket of Eq. (13), while the impact of the indirect effect, which is represented by the second term in the bracket of Eq. (13), increases with the rise in the carbon tax. Consequently, the required level of generation efficiency which enables total emission reduction goes up with an increase in the tax level. This means that the situation in which generation efficiency leads total emission expansion is more likely to occur as

[5]It can be interpreted as a form of the 'rebound effect'. In Sorrel (2009), the 'rebound effect' is described as "an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency."

[6]Note that $\hat{\theta} = \bar{\theta}/2$.

[7]It can be seen as a kind of 'Jevons' Paradox' suggested by William Stanly Jevons in 1865, that claims an improvement in energy efficiency will increase the overall energy consumption (Alcott 2005; Sorrel 2009). That is not the case under the cap and trade policy scheme in which the total emission is controlled by the cap that is set by the government. Under the cap and trade scheme, the gains in fuel efficiency does not affect the total emission. Instead, it would increase the price for the allowances by raising the marginal abatement costs of the fossil-fuel power producers.

environmental tax increases. Similarly, a higher fuel price raises the threshold efficiency level. The fossil-fuel power producers reduce their outputs with an increase in fuel price. This diminishes the relative impact of the direct effect relative to the indirect effect. As a result, the required level of generation efficiency gets higher.

2.2 Effect of Carbon Tax

Next, I will be examining the effect of carbon tax. Differentiate Eqs. (7)–(9) with respect to t yeilds,

$$\frac{dy}{dt} = -\frac{(m+1)\theta\eta}{(n+m+1)B} < 0, \tag{16}$$

$$\frac{dx}{dt} = \frac{n\theta\eta}{(n+m+1)B} > 0, \tag{17}$$

$$\frac{dQ}{dt} = -\frac{n\theta\eta}{(n+m+1)B} < 0. \tag{18}$$

The above equations suggest that a reduction in carbon emission by the carbon tax leads a reduction in the total output Q, with a production shift from fossil-fuel power producers y to the renewable power producers x.

The effect on the total emission is given by,

$$\frac{dE}{dt} = -\frac{(m+1)n(\theta\eta)^2}{(n+m+1)B} < 0. \tag{19}$$

In order to reduce a certain amount of emission ΔE,[8] the level of tax must be,

$$t(\Delta E;\theta) = t_0 + \frac{(n+m+1)B}{(m+1)n(\theta\eta)^2}\Delta E,$$

where t_0 denotes the initial tax level.[9] We can see from the above equation that a gain in fuel efficiency (a reduction in θ) raises the required tax level to reduce the equivalent amount of total emission;

---

[8]Suppose that ΔE corresponds to a reduction target set by the government. The analysis of this section focuses on the cost efficiency in achieving a certain level of reduction target. The major factor relevant to the cost efficiency would be the effect on consumer price and the external cost of CO_2 emissions are offset each other when compared with the other level of the reduction target.

[9]ΔE can be represented as,

$$\Delta E = \int_{t_0}^{t_1} \frac{dE}{dt} dt,$$

where $t_1 = t(\Delta E;\theta)$.

$$-\frac{\partial t(\Delta E;\theta)}{\partial \theta} > 0. \tag{20}$$

Additionally, if $\theta > \hat{\theta}$, a gain in fuel efficiency increases the overall emission. It leads to a counterintuitive implication. The tax level must be raised with an improvement in fuel efficiency to achieve the equivalent target of carbon reduction, especially when the fuel efficiency is lower than the threshold ($\theta > \hat{\theta}$).

We can examine the relationship between the carbon reduction and the total output as follows,

$$\frac{dQ}{dE} = \frac{dQ/dt}{dE/dt} = \frac{1}{(m+1)\theta\eta}.$$

The above equation indicates that a 1kg reduction in CO_2 emission involves $1/(m+1)\theta\eta$(kWh) decrease in the total output. The reduction rate rises with an improvement in generation efficiency (corresponds with an increase in θ). A decrease of ΔE in total emission brings about the corresponding decline in the total output:

$$\Delta Q(\Delta E;\theta) = \frac{\Delta E}{(m+1)\theta\eta}.$$

It results in a rise in the consumer price and a welfare loss derived from the decreased total consumption. The corresponding reduction in the benefit of the demand side electricity consumption can be calculated as follows,[10]

$$\Delta W^D = \frac{\Delta E}{(m+1)\theta\eta}\left\{A - \frac{B}{2}\left(2Q_0 + \frac{\Delta E}{(m+1)\theta\eta}\right)\right\},$$

where Q_0 is the initial level of total output which is represented as Eq. (9).

In the same way, we can derive the effect of carbon reduction on the output of fossil-fuel power producers from Eqs. (16) to (19),

$$\frac{d(ny)}{dE} = \frac{d(ny)/dt}{dE/dt} = \frac{1}{\theta\eta}.$$

We can easily see that with a fuel-efficient power plant, a unit reduction of CO_2 involves a greater reduction in the electricity output. A decrease of ΔE in CO_2 emission involves a reduction of $\Delta E/\theta\eta$ in the output of fossil-fuel power producers, which increases with an improvement in the fuel efficiency (a lower θ).

[10] Note that the reduction in total benefit can be written as follows,

$$\Delta W^D = -\int_{Q_0}^{Q_1} P(q)dq,$$

where $Q_1 = Q_0 - \Delta E/(m+1)\theta\eta$.

Finally, it is useful to investigate the impact of carbon tax on the profit of fossil fuel power producers, since it would be relevant to political feasibility of the tax.[11] The impact of the carbon tax on the profit can be written as follows,

$$\frac{d\pi_F}{dt} = \frac{\partial \pi_F}{\partial y}\frac{dy}{dt} + \frac{\partial \pi_F}{\partial t}. \tag{21}$$

Since $\partial \pi_F / \partial y = 0$ from Eq. (5), the above equation can be rewritten as follows,

$$\frac{d\pi_F}{dt} = \frac{\partial \pi_F}{\partial t} = -\eta\theta y. \tag{22}$$

In the similar way with the above discussion, we can write the impact of a carbon reduction as follows,

$$\frac{d(n\pi_F)}{dE} = \frac{d(n\pi_F)/dt}{dE/dt} = \frac{(n+m+1)B}{(m+1)\eta\theta}y. \tag{23}$$

Since $dy/d\theta > 0$ from Eq. (10), and the denominator of Eq. (21) decreases with a reduction in θ, we can easily see that the marginal profit loss derived from the carbon reduction increases with an improvement in fuel efficiency. That is,

$$\frac{d}{d\theta}\left[\frac{d(n\pi_F)}{dE}\right] < 0. \tag{24}$$

2.3 *Summary: Generation Efficiency and Carbon Tax*

Table 1 summarizes the main results of this section. Case 1 describes a notable situation where an improvement in generation efficiency leads the overall CO_2 emission expansion (Statement (1)) and the increase in the potential profit loss of fossil-fuel power producers by the carbon tax (Statements 3 and 4). It would be the case in which the tax increase provokes a fierce opposition from the fossil-fuel power producers.

In Case 2 at Table 1, the efficiency gain would contribute to the overall CO_2 reduction. A comparative advantage of promoting fuel-efficient power plants relative to the carbon tax is that an improvement in fuel efficiency possibly increases a total electricity output [Eq. (12)] while it reduces the overall CO_2 emission; in other words, it could decouple a carbon reduction from a decrease in the total electricity output. On the other hand, a carbon reduction by the carbon tax involves a decrease

[11] Resistance from the producers or the consumers could become a significant obstacle to introducing environmental taxes. In the policy proposal on long-term growth strategy of Japan under the Paris agreement (issued at March 19, 2019), Japan Business Federation expressed their opposition to promoting carbon pricing such that carbon tax and emissions trading scheme.

Table 1 Impact of improvement in fuel efficiency

Case 1: $\theta > \hat{\theta}$ (lower efficiency)	Case 2: $\theta < \hat{\theta}$ (higher efficiency)
(1) The overall emission increases. Equation (15)	(2) The overall emission decreases. Equation (15)
(3) The marginal profit loss of the fossil-fuel power producers by the tax increases. Equation (24)	
(4) The required tax level to reduce a certain amount of CO_2 emission increases. Equation (20)	

in the total electricity output. The notable point is that an efficiency standard (which corresponds to $\hat{\theta}$ in the model of this section) is necessary in order to achieve an effective CO_2 reduction by the efficiency improvement. An incorrect estimation of the critical threshold or irrelevant setting of the standard could cause the adverse effect. In addition, statements (3) and (4) in Table 1 still valid in Case 2, which would make it difficult to complement the effect of carbon reduction with the carbon tax.

Taking these factors into consideration, the results of this section indicate that promoting generation efficiency of fossil-fuel power plants is not a reliable way to reduce overall CO_2 emission relative to the carbon tax. In other words, it is not a substitute of the tax; rather it would increase the political difficulty of implementation of the carbon tax, which is more reliable measure to reduce the overall emissions.

3 Feed-in Tariff and Carbon Tax

In this section, I consider a policy that simultaneously use feed-in tariff and carbon tax. The combination of these policies is worthy to investigate since they could possibly complement each other; FIT policy may be financed by the revenue of carbon tax, and a reduction in electricity supply by the carbon tax may be lessen by supporting renewable power generations under FIT.

Under feed-in tariff, the price of electricity generated from renewable power producers is fixed at P_R which is set by the government. A third party network operator is obliged to purchase the electricity from renewable power producers at this fixed price. Assuming a quadratic cost function, the profit of the renewable electricity producers is given by,

$$\pi_R^j := P_R x_j - \frac{1}{2} c_R x_j^2 - a x_j - k_R, \quad j = 1, \cdots, m. \tag{25}$$

Differentiating the profit function of the renewable power producers with respect to y_i yields the first order condition for profit maximization as follows,

$$P_R - a = c_R x_j, \quad j = 1, \cdots, m.$$

Solving the first order condition, we obtain the output;

$$x_j = x = \frac{P_R - a}{c_R}, j = 1, \cdots, m, \tag{26}$$

where $P_R > a$ is assumed to secure positive outputs of renewable power producers. Accordingly, the total output of the renewable electricity producers X can be obtained as follows,

$$X(P_R) = m\left(\frac{P_R - a}{c_R}\right). \tag{27}$$

The profit of the fossil-fuel power producers is given by,

$$\pi_F^i := (P - a)y_i - \frac{1}{2}c_F y_i^2 - tc_e y_i - k_F, \quad i = 1, \cdots, n. \tag{28}$$

where $c_e(\mathrm{kg} - \mathrm{CO_2/kWh})$ represents the carbon intensity of the electricity output. They go into Cournot competition taking the outputs of the renewable power producers (and corresponding residual demand) as given; that is determined by the price for renewable electricity set by the government as Eq. (27). The first order condition of profit maximization is,

$$(A - BQ - a) - By_i - c_F y_i - c_e t = 0, i = 1, \cdots, n. \tag{29}$$

Assuming the symmetry in the equilibrium ($y_i = y$for all i), the equilibrium output is obtained as follows,

$$y(P_R, t) = \frac{c_R\{A - (a + c_e t)\} - Bm(P_R - a)}{\{(n+1)B + c_F\}c_R}. \tag{30}$$

The total output of the whole industry is,

$$Q(P_R, t) = \frac{nc_R(A - a - c_e t) + Bm(P_R - a) + c_R c_F}{\{(n+1)B + c_F\}c_R}. \tag{31}$$

3.1 Feed-in Tariff

To examine the effect of feed-in tariff, partially differentiating Eqs. (26), (30) and (31) with respect to P_R yields,

$$\frac{\partial y}{\partial P_R} = \frac{-Bm}{\{(n+1)B + c_F\}c_R} < 0, \tag{32}$$

$$\frac{\partial x}{\partial P_R} = \frac{1}{c_R} > 0, \tag{33}$$

$$\frac{\partial Q}{\partial P_R} = \frac{Bm}{\{(n+1)B + c_F\}c_R} > 0. \tag{34}$$

An increase in the feed-in tariff raises the marginal revenue of the renewable power producers. As a result, it increases their outputs. It also creates a production shift from the fossil-fuel power producers to the renewable power producers in the market. Consequently, it indirectly reduces the carbon emissions in the whole industry. In contrast with the carbon tax, a rise in the policy variable, i.e., feed-in tariff, leads to an increase in the total output of the industry and involves a reduction in consumer price. Consequently, a rise in the feed-in tariff would reduce the welfare loss generated from the market power in the oligopoly.[12]

The effect on total emission is written as follows,

$$\frac{\partial E}{\partial P_R} = \frac{-nc_e Bm}{\{(n+1)B + c_F\}c_R} < 0. \tag{35}$$

where $E := nc_e y$ denotes the total amount of CO_2 emission. An increase in the fixed price creates a production shift from the fossil-fuel power producers to the renewable power producers. As a result, it creates an indirect effect of reducing the industry-wide carbon emissions.

A sharp difference between the feed-in tariff and the carbon tax is that the feed-in tariff involves an increase in the total electricity output (which corresponds to a lower consumer price) when it indirectly reduces the output of the fossil-fuel power producers. The relationship between the effects of feed-in tariff on the carbon reduction and the total output is represented as follows,

$$\frac{dQ}{dE} = \frac{\partial Q/\partial P_R}{\partial E/\partial P_R} = -\frac{1}{nc_e} < 0. \tag{36}$$

We can see from the above equation that a 1kg reduction in the carbon emission by the feed-in tariff involves a $1/nc_e$(kWh) increase in the total output. In contrast with the case of carbon tax, feed-in tariff is able to reduce the carbon emissions without decreasing the total output; rather it increases with a rise in the feed-in tariff.

[12] In an imperfectly competitive market, policy effects of correcting distortions caused by the market power play an influential role (Hibiki and Kurakawa 2013).

3.2 Carbon Tax

The effect of carbon tax is straightforward. The partial derivatives of market outcomes with respect to t is obtained as follows,

$$\frac{\partial y}{\partial t} = \frac{-c_e}{\{(n+1)B + c_F\}c_R} < 0, \tag{37}$$

$$\frac{\partial x}{\partial t} = 0, \tag{38}$$

$$\frac{\partial Q}{\partial t} = \frac{-nc_e}{\{(n+1)B + c_F\}c_R} < 0. \tag{39}$$

When the carbon tax is implemented together with feed-in tariff, the outputs of renewable power producers are solely determined by the feed-in tariff and are not affected by the carbon tax. In other words, a change in the tax level does not create production shift caused by the strategic interrelationship in the market, because the marginal revenues of the renewable power producers are fixed by the feed-in tariff. It merely reduces the output of fossil-fuel power producers and consequently decreases the total output of the power sector. A reduction in CO_2 emission by the carbon tax involves a decrease in the total output and a rise in the consumer price.

The effect on carbon reduction can be represented as,

$$\frac{\partial E}{\partial t} = \frac{-n(c_e)^2}{\{(n+1)B + c_F\}c_R} < 0.$$

The impact of carbon reduction by the tax on the total output can be written as follows,

$$\frac{\partial Q}{\partial E} = \frac{\partial Q/\partial t}{\partial E/\partial t} = \frac{1}{c_e} > 0. \tag{40}$$

This equation indicates that a 1kg reduction in the carbon emission by the tax involves a $1/c_e$(kWh) reduction in the total output.

3.3 Combination of Feed-in Tariff and Carbon Tax

Combination of the feed-in tariff and the carbon tax enables a policymaker to choose a pair of the emission level and the total output from the feasible region which is illustrated in Fig. 1. The lines L_0 and L_1 correspond to the lower limit and the upper limit of the feed-in tariff respectively, which would be determined by multiple factors (e.g., the break-even point of the renewable power producers). The slope of these

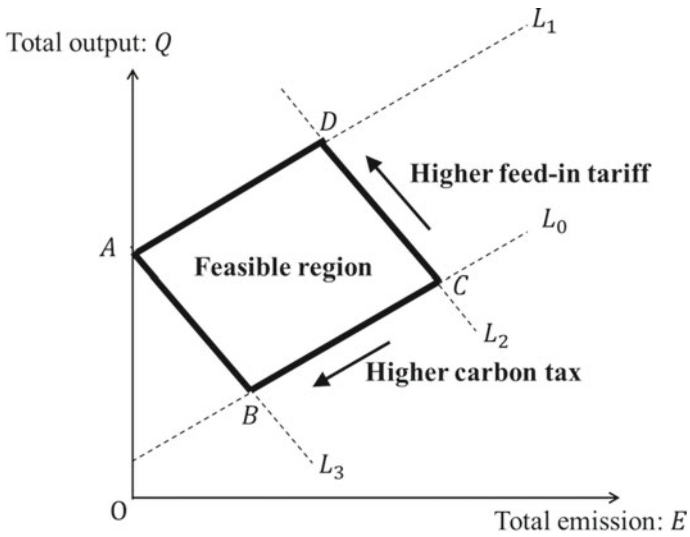


Fig. 1 The combined effect of the feed-in tariff and the carbon tax

lines is $1/c_e$ as represented in Eq. (40). Similarly, the lines L_2 and L_3 respectively correspond to the lower limit and the upper limit of the carbon tax. The slope of L_2 and L_3 is $-1/nc_e$ as Eq. (36) indicates.

As illustrated in Fig. 1, the carbon tax has a negative impact on the total output. When the carbon tax is implemented separately from the feed-in tariff,[13] there is a trade-off between the carbon reduction and a fall in the total electricity output, that results in a rise in the consumer price. The feed-in tariff introduces a positive element of the total output, that greatly extend the range of possible choice for the policy maker.[14] In other words, these policy instruments complement each other; the combination of these policies produce a potential welfare gain in the industry.

4 Summary and Conclusion

The analysis of Sect. 2 investigated the effects of generation efficiency gains in fossil fuel power plants (mainly supposing coal-fired power generation). It was shown that an improvement in generation efficiency of fossil-fuel power plants produced the following two effects:

[13]The possible range is segment BC in Fig. 1 in this case.

[14]When the feed-in tariff is introduced separately from the carbon tax, the possible range is segment CD in Fig. 1.

1. The effect of reducing the fuel required to obtain the same amount of electricity
2. The effect of increasing the cost efficiency of the fossil-fuel power generation (reducing the marginal costs of fossil-fuel power producers), that gives them an advantage in competition relative to their rivals, the renewable power producers, and enables them to increase the market shares.

   The latter effect (2) can be interpreted as a kind of the 'rebound effect', and the former can be referred as a 'saving effect'. The overall emission decreases if the 'saving effect' exceeds the 'rebound effect', and vice versa. The analysis in Sect. 2 demonstrated that
3. There exists a threshold level of fuel efficiency such that the 'conservation effect' exceeds the 'rebound effect' if the fuel efficiency is higher than the threshold. That is, the efficiency gains lead to a reduction in the total emission.
4. Conversely, if it is lower than the threshold, the "rebound effect" exceeds the "saving effect". That is, the efficiency gains lead to an increase in the total emission.

In order for an improvement in fuel efficiency to reduce total CO_2 emission of the whole industry, it is necessary to achieve a certain level of technical standard. Efficiency gains in the lower levels will result in an increase in the total emission. In order to avoid such adverse effects, it is required that (1) accurately estimate the threshold level, (2) set the regulation level on the technical standard to an appropriate level that exceeds the threshold, and (3) clear the technical standard. If these conditions are not achieved, on the contrary, the total emission will increase. In addition, it was shown that the gains in the generation efficiency would increase political difficulty of introducing the carbon tax. Overall, these results indicate that improving generation efficiency of fossil-fuel power plants is not necessarily a reliable measure to reduce CO_2 emissions.

In Sect. 3, I investigated the combination of FIT and carbon tax. It was demonstrated that FIT had the combined effect:

5. Supporting renewable power generations by FIT indirectly reduces CO_2 emissions by causing production shifts from fossil-fuels power producers to the renewable power producers.
6. FIT has the effect of fostering competitive environment in which the consumer price falls with decreasing market power.

The effects (5) and (6), together with the possibility that FIT could be financed by revenue of carbon tax, indicate that combination of these policies produce potential welfare gain.

References

Alcott B (2005) Jevons' paradox. Ecol Econ 54:9–21

Armstrong M, Cowan S, Vickers J (1994) Regulatory reform. MIT Press, Cambridge, Massachusetts, pp 148–159

Böhringer C, Rosendahl KE (2010) Green promotes the dirtiest: on the interaction between black and green quotas in energy markets. J Regul Econ 37:316–215

Hihiki A, Kurakawa Y (2013) Which is a better second best policy, the feed-in tariff scheme or the renewable portfolio standard scheme? Research Institute of Economy, Trade and Industry, Discussion paper 13-J-070, 2013 (written in Japanese)

Sorrel S (2009) Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. Energy Policy 37:1456–1469

Tamás MM, Shrestha SOB, Zhou H (2010) Feed-in tariff and tradable green certificate in oligopoly. Energy Policy 38:4040–4047

Yukihide Kurakawa is a tenured lecturer of Faculty of Economics at Kanazawa Seiryo University in Japan. He obtained Ph.D. from Tokyo Institute of Technology. He manly conducts microeconomic analyses on policy issues concerning environmental and energy problems. His recent research focuses on effective and efficient policy measures to promote renewable energy sources (RESs), as well as emerging problems arising from increasing shares of RESs.

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

T. Abe
Graduate School of Economics, Waseda University, 1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo 169-8050, Japan
e-mail: tatsuya.abe149@gmail.com

T. H. Arimura (✉)
Faculty of Political Science and Economics, Waseda University, 1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo 169-8050, Japan
e-mail: toshi.arimura@gmail.com

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_6

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.

[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

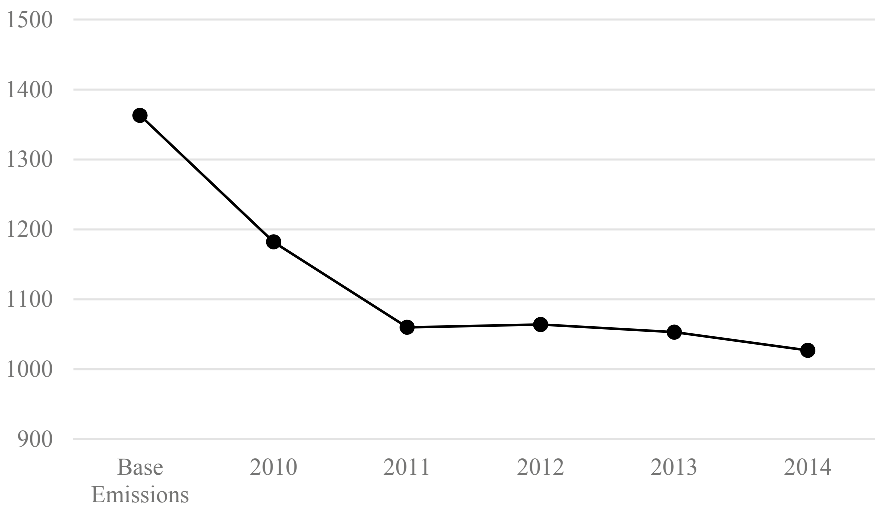


Fig. 1 Transition of Total CO_2 Emissions from Tokyo ETS Facilities. *Source* Tokyo Metropolitan Government Bureau of Environment (2016), https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/data/index.files/candtpuresusiryouhonnbun.pdf (last access date: 08/04/2020)

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.

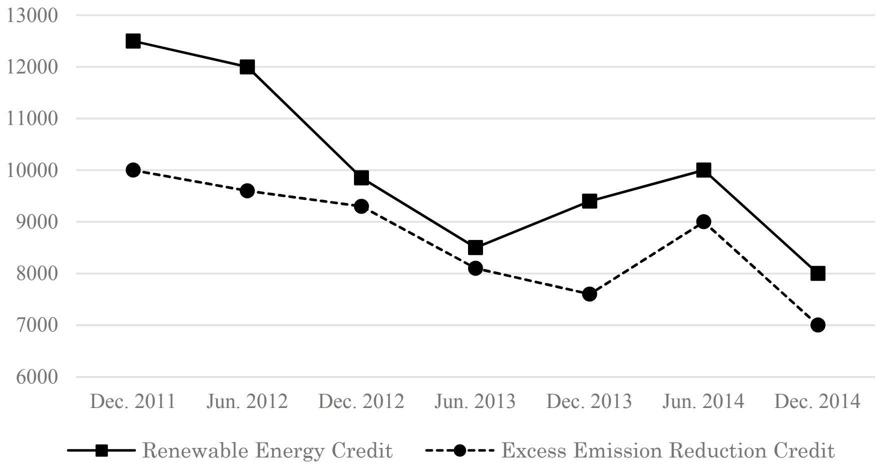


Fig. 2 Permit Price (JPY/CO_2 ton). *Source* Mizuho Information & Research Institute, Inc. (2019), https://www.kankyo.metro.tokyo.lg.jp/climate/large_scale/trade/index.files/sateikakaku.pdf (last access date: 08/04/2020)

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

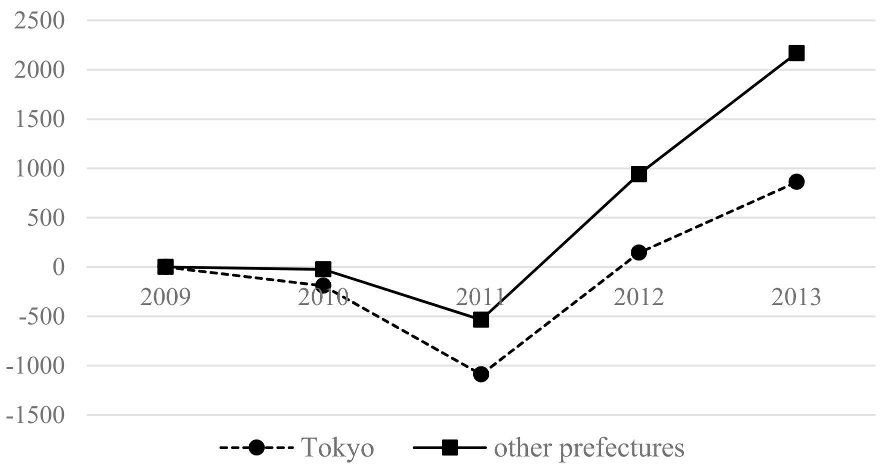


Fig. 3 Changes in CO_2 emissions. *Note* For each region, the lines show changes between CO_2 emissions in each year (2010–2013) and those in 2009, which is a reference year for our analysis

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.

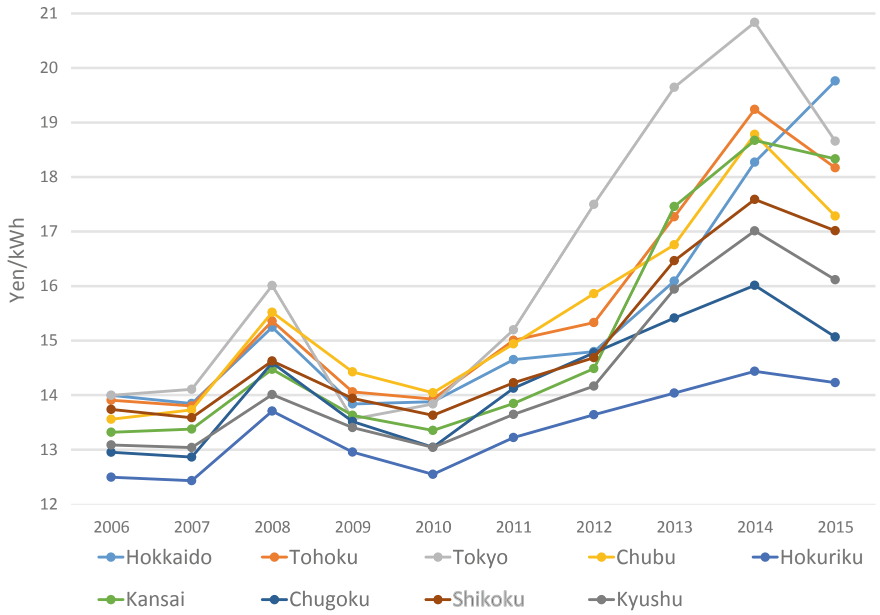


Fig. 4 Trends of electric power prices. *Source* Database from the Federation of Electric Power Companies of Japan. *Note* Each line shows trends of electric power prices for the nine electric power companies in Japan

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:

$$
\begin{aligned}
y_{itg} = \tau_g \cdot Tokyo_i \cdot I(t \geq 2010) + \alpha_{1g} Tokyo_i \\
+ \alpha_{2g} I(t \geq 2010) + x_{itg}^{'} \beta_g + \eta_t + \mu_i + \varepsilon_{itg}
\end{aligned}
$$

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.

References

Abrell J, Ndoye A, Zachmann G (2011) Assessing the impact of the EU ETS using firm level data. Bruegel Working Paper

Anderson B, Di Maria C (2011) Abatement and allocation in the pilot phase of the EU ETS. Environ Resour Econ 48(1):83–103

Arimura TH (2015) Japanese domestic environmental policy: with a focus on climate change and air pollution policy. In: The Routledge handbook of environmental economics in Asia, pp 538–553

Arimura TH, Abe T (2020) The impact of the Tokyo emissions trading scheme on office buildings: what factor contributed to the emission reduction? forthcoming in Environ Econ Policy Stud

Arimura TH, Iwata K (2015) The evaluation of "comprehensive management under the act on the rational use of energy" as a measure to combat climate change for the hotel industry, in an evaluation of Japanese environmental regulations. Springer, Dordrecht

Arimura TH, Kaneko S, Managi S, Shinkuma T, Yamamoto M, Yoshida Y (2020) Political economy of voluntary approaches: a lesson from environmental policies in Japan. Econ Anal Policy 64:41–53

Colmer J, Martin R, Muûls M, Wagner UJ (2018) Emissions trading, firm behavior, and the environment: evidence from French manufacturing firms. Working Paper

Commins N, Lyons S, Schiffbauer M, Tol NC (2011) Climate policy and corporate behavior. Energy J 32(4):51–68

Cooper R (2010) Europe's emissions trading system. In: Harvard project on international climate agreements discussion paper, Cambridge, MA

Egenhofer C, Alessi M, Georgiev A, Fujiwara N (2011) The EU emissions trading system and climate policy towards 2050: real incentives to reduce emissions and drive innovation?. CEPS Special Report, Centre for European Policy Studies

Ellerman AD, Buchner BK (2008) Over-allocation or abatement? A preliminary analysis of the EU ETS based on the 2005–06 emissions data. Environ Resour Econ 41(2):267–287

Ellerman AD, Feilhauer SM (2008) A top-down and bottom-up look at emissions abatement in Germany in response to the EU ETS. MIT Center for Energy and Environmental Policy Research Working Papers

Ellerman AD, Convery FJ, De Perthuis C (2010) Pricing carbon: the european union emissions trading scheme. Cambridge University Press, Cambridge

Gillingham K, Palmer K (2014) Bridging the energy efficiency gap: policy insights from economic theory and empirical evidence. Rev Environ Econ Policy 8(1):18–38

Jun SH, Kim JY, Oh H (2019) Evaluation mitigation performance of phase I of the KETS. Working Paper

Kettner C, Kletzan-Slamanig D, Köppl A (2015) The EU emission trading scheme: sectoral allocation and factors determining emission changes. J Environ Econ Policy 4(1):1–14

Löschel A, Lutz BJ, Managi S (2019) The impacts of the EU ETS on efficiency and economic performance–an empirical analyses for german manufacturing firms. Resour Energy Econ 56:71–95

Martin R, Muûls M, Wagner UJ (2015) The impact of the European union emissions trading scheme on regulated firms: what is the evidence after ten years? Rev Environ Econ Policy 10(1):129–148

Petrick S, Wagner UJ (2014) The impact of carbon trading on industry: evidence from german manufacturing firms. Kiel Working Paper, 1912

Roppongi H, Suwa A, Puppim De Oliveira JA (2017) Innovating in sub-national climate policy: the mandatory emissions reduction scheme in Tokyo. Clim Policy 17(4):516–532

Tokyo Metropolitan Government Bureau of Environment (2015) Case studies of the emissions trading scheme (*Haishutsuryou Torihiki Zireishuu* in Japanese), 1–27

Wakabayashi M, Kimura O (2018) The impact of the Tokyo metropolitan emissions trading scheme on reducing greenhouse gas emissions: findings from a facility-based study. Clim Policy 18(8):1028–1043

World Bank Group (2019) State and trends of carbon pricing 2019. World Bank, Washington, DC

Tatsuya Abe is a Ph.D. student at Graduate School of Economics, Waseda University. He received B.A. and M.A. in Economics from the same school of Waseda University. His research interests include the applied econometrics for environmental and energy issues. He has been currently working on empirical study that examines how the Tokyo emissions trading scheme affected the amounts of emissions from commercial buildings as well as university buildings. He was awarded a paper prize from Society of Environmental Science in 2018 for his empirical study that demonstrates differences of the rebound effect for passenger vehicles between urban and rural regions. He is a member of Society for Environmental Economics and Policy Studies.

Toshi H. Arimura is a Professor of Political Science and Economics and Director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Prior to joining Waseda, he was a Professor at Sophia University in Tokyo and was a visiting scholar with George Mason University and Resources for the Future as a recipient of the Abe Fellowship. His research interests include climate change, energy policies, air pollution regulations and voluntary environmental actions. He has published his research in academic journals such as *Journal Environmental Economics and Management, Journal of Association of Environmental and Resources Economics, Environmental and Resource Economics, Ecological Economics* or *Energy Policy*. He is a coauthor of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach from Environmental Economics* (Springer 2015). Dr. Arimura holds a Ph.D. in economics from the University of Minnesota, an M.Sc in environmental sciences from the University of Tsukuba and a B.A. in history of science from the University of Tokyo. He has served on a number of Japanese government committees on environmental issues including the committees on carbon pricing (2018) and emission trading scheme (2010) of the environmental council under Ministry of the Environment. He is also a member of the Tokyo Metropolitan environmental council. He has served on advisory committees of local governments for emission trading schemes of Tokyo

and Saitama. He has also been on editorial boards of academic journals such as *Review of Environmental Economics and Policy, Agricultural and Resource Economics Review, Economics of Energy and Environmental Policy* or *Environmental Economics and Policy Studies.* Since 2018, Waseda University has chooses him as one of 10 next generation core researchers. He is a recipient of SEEPS Outstanding Publication Award from Society for Environmental Economics and Policy Studies (Japanese Association of Environmental Economics and Policy) and the academic award from Society of Environmental Science, Japan.

Chapter 7
Target-Setting Emissions Trading Program in Saitama Prefecture: Impact on CO_2 Emissions in the First Compliance Period

Mitsutsugu Hamamoto

Abstract This chapter investigates whether the Target-Setting Emissions Trading (TSET) Program launched in 2011 by Saitama Prefecture in Japan had an impact on CO_2 emissions during the first compliance period. Facility-level data are used to estimate the causal relationship between implementation of the program and changes in CO_2 emissions. The results indicate that the TSET Program spurred emission reduction efforts. In addition, this chapter shows that the TSET Program also functioned as an incentive for facilities that are not covered by the program to lower their energy consumption. These findings indicate that the TSET Program succeeded in encouraging emission reduction efforts by the facilities, even though the program includes no penalty for facilities that do not meet emission goals.

Keywords Emissions trading · Climate policy · Treatment effect estimation

1 Introduction

In 2005, the European Union (EU) launched the EU Emissions Trading Scheme (EU ETS), which was the world's first international mandatory cap-and-trade program. Since then, emission trading has drawn attention as a policy instrument for the efficient reduction of carbon dioxide (CO_2) emissions. In the US, the Regional Greenhouse Gas Initiative was established in 2005 in order to reduce CO_2 emissions from power plants in northeastern states by utilizing emissions trading. Outside Europe and North America, many emissions trading systems have recently emerged in Asia and the Pacific region at the regional, national, and local levels.[1]

[1] A number of studies have attempted to estimate the impact of emissions trading programs on emissions, economic performance, and innovation. Martin et al. (2016) summarize and evaluate the existing literature on the impact of the EU ETS.

M. Hamamoto (✉)
Faculty of Economics, Dokkyo University, 1-1 Gakuen-cho, Soka-shi, Saitama 340-0042, Japan
e-mail: hmitutug@dokkyo.ac.jp

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_7

Although Japan has not yet implemented a nationwide mandatory emissions trading program, the Tokyo metropolitan government started a mandatory CO_2 cap-and-trade program (hereinafter, the Tokyo ETS) in 2010 in order to cut CO_2 emissions from large emitters. The Tokyo ETS differs from the EU ETS in that it covers office buildings as well as factories.

One year after the Tokyo ETS was launched, Saitama Prefecture started the Target-Setting Emissions Trading (TSET) Program.[2] This program is very similar to the Tokyo ETS in many aspects. However, unlike the Tokyo ETS, the TSET Program has no penalty even when covered facilities are in non-compliance with the emissions reduction targets. It is an important research question to explore whether cap-and-trade schemes without enforcement measures like the TSET Program can provide incentives for emission reductions, and the aim of this chapter is to address this issue. Specifically, we investigate the causal relationship between the implementation of the TSET Program and CO_2 emission reductions. Through treatment effect analysis, we examine whether the program, which is a cap-and-trade scheme without enforcement measures, incentivized covered facilities to reduce their emissions.

The remainder of this chapter is organized as follows. Section 2 provides background on the TSET Program. Section 3 describes the research design for evaluating the causal effect of the TSET Program on CO_2 emission reductions. Section 4 explains the data for this analysis. Section 5 reports the empirical results and discusses the findings of this study. Section 6 concludes the chapter.

2 Background to the TSET Program

In 2009, Saitama Prefecture formulated the "Saitama Prefecture Global Warming Strategy Action Plan," which set a target of reducing greenhouse gas (GHG) emissions by 25% below the 2005 level by 2020 (the target was revised to 21% in 2015, primarily due to the fact that the role of nuclear power was greatly diminished by the Fukushima accident in 2011). In order to achieve the reduction target, two schemes were introduced. One is the Saitama GHG Emissions Reduction Program, which requires business operators to formulate their own annual GHG reduction plans, including voluntary emission reduction targets and to report them to the Saitama Prefectural Government. This program, which started in FY 2010, covers business operators having facilities that are located in the prefecture and have total energy consumption of 1500 kiloliters or more per year in crude oil equivalent, as well as large-scale retailers whose store floor areas within the prefecture are 10,000 m^3 or more.

The other scheme is the TSET Program, which covers facilities that have total energy consumption of 1500 kiloliters or more per year in crude oil equivalent for three consecutive years. These facilities are given emission caps (i.e., emission targets) and allowed to trade allowances. The first compliance period of the TSET

[2]For the design of the Tokyo ETS, see Chap. 6.

Program is the four years from FY 2011 to FY 2014, and the second compliance period covers the five years from FY 2015 to FY 2019. The method of allowance allocation is a grandfathering approach based on historical emissions.[3] Specifically, the volume of allowances initially allocated is determined in accordance with the following formula:

$$\text{Initial Allowance Allocation } = BYE \times (1 - CF) \times YEARS, \tag{1}$$

where *BYE* denotes base year emissions, *CF* indicates a compliance factor, and *YEARS* means the number of years of a compliance period. The base year emissions are defined as the average emissions of three consecutive fiscal years between FY 2002 and FY 2007. The compliance factor in the first compliance period is set as follows: 8% ($CF = 0.08$) for office buildings, commercial facilities, educational facilities, and hospitals, and 6% ($CF = 0.06$) for factories, waste disposal and treatment facilities, and water supply and sewage facilities. In the second compliance period, the compliance factor for the former increases to 15% ($CF = 0.15$) and that for the latter to 13% ($CF = 0.13$).

Under the TSET Program, covered facilities can utilize credits from several types of offsets in order to meet their emission targets. Emission reductions from small and midsize facilities located in Saitama Prefecture and those from large facilities outside the prefecture can be used for compliance. Forest sink credits and credits originating from renewable energy such as solar, wind, geothermal, hydro, and biomass are also available. In addition, excess credits from the Tokyo ETS are formally eligible as offset credits under the TSET Program because these two cap-and-trade schemes are officially connected.

If the volume of allowances that a covered facility holds exceeds its emission cap, the surplus allowances may be banked for the next compliance period. When covered facilities fail to achieve their emission caps, the TSET Program has no enforcement measure such as the imposition of penalties. This is a major difference between the TSET Program and the Tokyo ETS; the Tokyo ETS requires non-compliant facilities to reduce emissions by the amount of the reduction shortfall multiplied by 1.3, and if non-compliant facilities fail to meet this requirement, they are subject to penalties.[4] Under the Tokyo ETS, both the setting and the achievement of targets are mandatory, whereas the setting targets is mandatory but achieving them is voluntary under the TSET Program.

The Saitama Prefectural Government published a report on the achievement status for the emission targets under the TSET Program in the first compliance period. During the period, 608 facilities were subject to the program. Of these, 599 achieved their emission targets by reducing their own emissions and/or utilizing emissions trading. Therefore, 9 facilities remained non-compliant without penalty. The number

[3] Auctioning was not adopted as the method of initial allocation in the TSET Program.

[4] The names of non-compliant facilities are made public under the TSET Program. The Tokyo ETS also publicly announces the names of non-compliant facilities if they fail to meet requirement that they must reduce emissions by the amount of the reduction shortfall multiplied by 1.3.

of facilities that utilized allowance trading for compliance is 66: approximately 11% of the covered facilities.[5] This is slightly larger than the proportion of facilities that utilized emissions trading under the Tokyo ETS (see Chap. 6). Total annual emissions from the 608 facilities were 6.94 million tons of CO_2 on average during the first compliance period, which were 1.95 million tons less than the total volume of the facilities' base year emissions. This means that the facilities as a whole reduced their emissions by 22% compared to their base year emissions.[6]

3 Research Design

Because the business facilities regulated by the TSET Program are also affected by the Saitama GHG Emissions Reduction Program, their decisions on reducing CO_2 emissions may be influenced by both programs. In order to disentangle such combined policy effects, we assume two states of prefecture-level climate policy, namely, one in which both the TSET Program and the Saitama GHG Emissions Reduction Program are implemented, and one in which only the Saitama GHG Emissions Reduction Program is implemented. Let D_i denote an indicator of the two states. If the ith facility is regulated by both the TSET Program and the Saitama GHG Emissions Reduction Program (that is, if the facility is treated), then $D_i = 1$. If the ith facility is only subject to the Saitama GHG Emissions Reduction Program, then $D_i = 0$. Let $Y_i(1)$ and $Y_i(0)$ denote the outcomes at facility i when the facility is treated and when the facility is not regulated by the TSET Program, respectively. The outcome variable of interest here is the change in CO_2 emissions. We estimate the average treatment effect on the treated (ATET) as follows:

$$ATET = E[Y_i(1) - Y_i(0)|D = 1], \tag{2}$$

where E is the expectation operator.

While data are available to calculate $E[Y_i(1) \mid D = 1]$ (changes in CO_2 emissions under the situation where the TSET Program is implemented), $[Y_i(0) \mid D = 1]$ cannot be observed. To deal with this missing data problem, data for the counterfactual outcomes are constructed using information about facilities that are subject to only a program similar to the Saitama GHG Emissions Reduction Program.

In recent years, an increasing number of Japanese local governments have established their own mandatory programs for reducing GHG emissions. These programs include requirements such as preparing GHG reduction plans and submitting them to the local government offices. Gunma Prefecture, which is adjacent to northern Saitama, implemented a program that requires business operators to formulate their

[5]Trading prices for allowances are not disclosed under the TSET Program.

[6]For more details on compliance status under the TSET Program, see the Saitama Prefectural Government Official Website. https://www.pref.saitama.lg.jp/a0001/news/page/2017/0516-01.html [Accessed January 22, 2019].

own annual GHG reduction plans, including voluntary absolute emission targets, and to report them to the Gunma Prefectural Government (hereinafter, the Gunma GHG Emissions Reduction Program) in FY 2010, the same year that the Saitama GHG Emissions Reduction Program also started. The Gunma GHG Emissions Reduction Program covers business operators whose facilities within the prefecture consume in total more than 1500 kiloliters of energy in crude oil equivalent annually. Market-based instruments such as emissions trading schemes and carbon taxes have not been used for addressing global warming in Gunma Prefecture. Therefore, climate policies in Saitama are notably different from those in Gunma in that a program such as the TSET Program has been established only in the former. The existence of such a difference permits a quasi-experimental research design that can fulfill the aim of this study.

We estimate the ATET using a propensity score matching (PSM) method (Wooldridge 2010; Imbens and Wooldridge 2009). The facilities subject to the Gunma GHG Emissions Reduction Program are used as the control group, and the treatment group consists of the facilities regulated by both the TSET Program and the Saitama GHG Emissions Reduction Program. The probability of being treated is estimated by a logistic regression model. Each facility in the treatment group is matched with a single facility in the control group whose propensity score is closest.

To identify the ATET, PSM estimators are used in a difference-in-differences setting. Specifically, we construct the data for the difference between CO_2 emissions in each fiscal year during the first compliance period and those in FY 2010, which are used for comparing the outcomes between treated and control units. Because we use log-transformed data, the ATET estimated in this analysis represents the difference in the rate of change in CO_2 emissions.

4 Data

The data for annual CO_2 emissions from each facility subject to the TSET Program during the first compliance period were reported by the Saitama Prefectural Government.[7] Since the data for base year emissions were also published by the government, emissions targets for the facilities can be calculated using the data. The Gunma Prefectural Government reports voluntary absolute emission targets and annual CO_2 emissions under the Gunma GHG Emissions Reduction Program, which are aggregated data for the facilities in Gunma Prefecture that are owned by the business

[7]The emissions data for facilities subject to the TSET Program during the first compliance period are available at the Saitama Prefectural Government Official Website. https://www.pref.saitama.lg.jp/a0502/sakugen.html [Accessed October 31, 2019].

operators subject to the program.[8] For our analysis, we therefore constructed aggregated data for the facilities regulated by the TSET Program; the data for the facilities subject to the TSET Program were summed for each of the business operators.

As covariates for estimating the propensity scores, emissions targets for each fiscal year and dummy variables denoting the types of business operators are used. The types of business operators are categorized as follows: waste disposal and treatment, water supply and sewage collection, education, medical services, business operators related to both education and medical services, business operators owing factories, and others.

Table 1 presents descriptive statistics for the samples. Some of the facilities regulated by the TSET Program were exempted from the program during the first compliance period because their emissions decreased enough to be excluded from being subject to the program. Therefore, the number of TSET facilities decreased during the first compliance period. This can be found even when TSET facilities are aggregated for each of the business operators, as shown in Table 1.

5 Results and Discussion

Table 2 shows the results of estimating the causal effect of the TSET Program on CO_2 emission reductions. The PSM estimate for the change in emissions between FY 2010 and FY 2011 is not statistically significant, suggesting that the TSET Program had little effect on emissions in the first fiscal year of the first compliance period. In contrast, the ATETs for the changes in emissions in fiscal years 2012, 2013 and 2014 compared with those in FY 2010 are statistically significant at the 1% level. This indicates that during the three fiscal years, the TSET Program induced the covered facilities to reduce their CO_2 emissions. Each estimated coefficient represents the difference in the rate of change in CO_2 emissions between the facilities regulated by the TSET Program and those subject to the Gunma GHG Emissions Reduction Program. In FY 2012, TSET facilities reduced CO_2 emissions on average by 11.7% points more than matched control facilities. The estimated coefficients for changes in emissions between FY 2010 and FY 2013 and between FY 2010 and FY 2014 are larger (15.9% points in FY 2013 and 18.9% points in FY 2014), indicating that TSET facilities made deeper emission reductions as the first compliance period went on.

Hamamoto (2020) investigates the impacts of the TSET Program on the adoption of low-carbon technology using facility-level data on the manufacturing sector, finding that the program promoted the adoption of high-efficiency machines and devices for the first three years of the second compliance period, whereas the program did not spur investments in high-efficiency equipment during the first compliance

[8]For emissions data for business operators subject to the Gunma GHG Emissions Reduction Program, see the Gunma Prefectural Government Official Website. https://www.pref.gunma.jp/04/e0100369.html [Accessed October 31, 2019].

Table 1 Descriptive statistics

Variable	Obs.	Mean	S.D.	Min.	Max.
A: TSET facilities					
Emissions in FY 2010	480	15,156.730	41,561.760	2252	737,334
Emissions in FY 2011	480	15,043.040	49,740.740	1884	946,355
Emissions in FY 2012	480	14,657.850	47,105.970	1093	886,457
Emissions in FY 2013	473	14,890.250	48,427.580	1113	903,533
Emissions in FY 2014	457	14,874.720	47,512.030	866	876,884
Targets in FY 2011	481	17,567.730	52,700.660	2188.3	962,305.3
Targets in FY 2012	481	17,607.790	52,736.500	2188.3	962,305.3
Targets in FY 2013	479	17,735.480	52,828.610	2188.3	962,305.3
Targets in FY 2014	479	17,806.910	52,888.850	2403.0	962,305.3
Factory	481	0.721	0.449	0	1
Water treatment	481	0.006	0.079	0	1
Waste treatment	481	0.017	0.128	0	1
Education	481	0.021	0.143	0	1
Hospital	481	0.033	0.180	0	1
Education and hospital	481	0.004	0.064	0	1
B: Facilities in Gunma					
Emissions in FY 2010	309	16,444.950	29,174.270	44	240,324
Emissions in FY 2011	309	15,477.480	28,005.210	41	238,345
Emissions in FY 2012	304	17,002.420	29,835.490	46	237,052
Emissions in FY 2013	300	18,504.140	33,254.110	46	311,101
Emissions in FY 2014	295	18,520.020	33,297.390	47	296,627
Targets in FY 2011	307	16,468.760	29,281.150	43	237,920
Targets in FY 2012	319	15,233.920	26,939.030	41	235,962
Targets in FY 2013	317	16,137.380	27,369.290	40	246,360
Targets in FY 2014	320	17,890.690	32,996.330	44	307,990
Factory	344	0.631	0.483	0	1
Water treatment	344	0.006	0.076	0	1
Waste treatment	344	0.026	0.160	0	1
Education	344	0.023	0.151	0	1
Hospital	344	0.032	0.176	0	1
Education and hospital	344	0.003	0.054	0	1

Table 2 Average treatment effect: TSET facilities versus facilities in Gunma

ATET	Number of treated	Number of controls
A: Change in CO_2 emissions between FY 2010 and FY 2011		
0.0274	480	307
(0.0141)		
B: Change in CO_2 emissions between FY 2010 and FY 2012		
−0.1167***	480	303
(0.0271)		
C: Change in CO_2 emissions between FY 2010 and FY 2013		
−0.1586***	472	299
(0.0264)		
D: Change in CO_2 emissions between FY 2010 and FY 2014		
−0.1894***	457	293
(0.0288)		

Robust Abadie-Imbens standard errors in parentheses
***Significant at the 1% level

period. These findings imply emission reduction measures that TSET facilities took to achieve their emission targets; the manufacturing facilities may have adopted relatively cheaper emissions reduction plans in the first compliance period such as improvements to equipment they already owned, whereas in the second compliance period, when the emissions targets became stricter, they allocated money and resources to introduce high-efficiency equipment (Hamamoto 2020).

Arimura and Abe (2020) examine the impact of the Tokyo ETS on emissions using a facility-level dataset for office buildings. They show that the Tokyo ETS caused a decrease of 6.9% in CO2 emissions. Jun et al. (2020) investigate the effect of the Korea Emissions Trading Scheme (KETS) on CO_2 emissions, finding that the stringency of emission caps provided incentives for participating firms in the manufacturing and building sectors to improve carbon intensity. The results shown in Table 2 indicate that the TSET Program, as well as the Tokyo ETS and the KETS, can encourage emission reduction efforts.

To check the robustness of the above-mentioned results, we estimate the ATETs for changes in CO_2 emissions using an alternative dataset that includes facilities that were regulated by the Saitama GHG Emissions Reduction Program but were not subject to the TSET Program in the first compliance period (hereinafter, non-TSET facilities) as part of the control group; data for non-TSET facilities are added to the data for the facilities subject to the Gunma GHG Emissions Reduction Program. The data for non-TSET facilities are aggregated for each business operator that does not own any TSET facilities. In addition, the method for constructing the data for the treatment group is slightly changed: If a business operator owns both TSET and non-TSET facilities, the data for both types of facilities are summed for the

Table 3 Average treatment effect: TSET facilities versus non-TSET facilities and facilities in Gunma

ATET	Number of treated	Number of controls
A: Change in CO_2 emissions between FY 2010 and FY 2011		
0.0078	479	476
(0.0134)		
B: Change in CO_2 emissions between FY 2010 and FY 2012		
−0.1001***	479	471
(0.0208)		
C: Change in CO_2 emissions between FY 2010 and FY 2013		
−0.1742***	474	467
(0.0317)		
D: Change in CO_2 emissions between FY 2010 and FY 2014		
−0.1626***	460	462
(0.0283)		

Robust Abadie-Imbens standard errors in parentheses
***Significant at the 1% level

business operator.[9] In estimating propensity scores, actual emissions in FY 2010 and dummy variables denoting the types of business operators are used as covariates. The reason for using FY 2010 emissions is that many of non-TSET facilities set emission intensity targets and thus do not have absolute emission targets.

Table 3 summarizes the results of estimating the ATETs using the alternative dataset. The PSM estimates indicate that TSET facilities reduced CO_2 emissions more than the controls during the period from FY 2012 to FY 2014. Compared to the ATET in FY 2014 shown in Table 2 (18.9% points), however, the ATET in FY 2014 estimated using the alternative dataset is somewhat smaller. This might suggest the possibility that CO_2 emissions from non-TSET facilities declined more than those from the facilities subject to the Gunma GHG Emissions Reduction Program.

To examine this point, we estimate the ATETs for changes in CO_2 emissions using non-TSET facilities belonging to the business operators that do not own any TSET facilities as the treated units and the facilities subject to the Gunma GHG Emissions Reduction Program as the control units (the data for these facilities are aggregated for each business operator). Table 4 shows the results. The ATETs for the changes in emissions during the period from FY 2012 to FY 2014 indicate that non-TSET facilities belonging to the business operators that do not own any TSET facilities also reduced CO_2 emissions more than the facilities subject to the Gunma GHG Emissions Reduction Program. A possible reason for this is that non-TSET facilities made efforts to reduce their energy consumption in order to avoid being regulated under the TSET Program. If a facility has total energy consumption of 1500 kiloliters or more per year in crude oil equivalent for three consecutive years, it

[9]For data on facilities subject to the Saitama GHG Emissions Reduction Program, see the Saitama Prefectural Government Official Website. https://www.pref.saitama.lg.jp/a0502/keikakukouhyou.html [Accessed November 1, 2019].

Table 4 Average treatment effect: non-TSET facilities versus facilities in Gunma

ATET	Number of treated	Number of controls
A: Change in CO_2 emissions between FY 2010 and FY 2011		
0.0224	167	309
(0.0298)		
B: Change in CO_2 emissions between FY 2010 and FY 2012		
−0.0925***	167	304
(0.0313)		
C: Change in CO_2 emissions between FY 2010 and FY 2013		
−0.1468***	167	300
(0.0370)		
D: Change in CO_2 emissions between FY 2010 and FY 2014		
−0.1999***	167	295
(0.0459)		

Robust Abadie-Imbens standard errors in parentheses
***Significant at the 1% level

becomes subject to the program. This provision in the TSET Program can incentivize non-TSET facilities to suppress their energy consumption so as not to be covered by the program. Thus, the TSET Program may have spurred the facilities that are not subject to the program to reduce CO_2 emissions.

6 Conclusion

This chapter investigates the causal relationship between the implementation of the TSET Program and CO_2 emissions. Using facility-level data, the impact of the program on emission reductions is estimated by using a PSM approach. The results show that the TSET Program spurred the facilities subject to the program to reduce emissions during the period from FY 2012 to FY 2014. In addition, the results of estimating the ATETs for changes in emissions using the data for non-TSET facilities and the facilities subject to the Gunma GHG Emissions Reduction Program show that the former reduced CO_2 emissions more than the latter. This implies that non-TSET facilities likely reduced their energy consumption to avoid being subject to the TSET Program.

An attempt to introduce cap-and-trade schemes will, in most cases, provoke a political backlash, mainly from the industry sector. A cap-and-trade scheme that includes no penalties for failure to meet targets may be faced with weaker political opposition compared to programs with some form of enforcement measures. Unlike the EU ETS and the Tokyo ETS, where both target-setting and the achievement of targets are mandatory, the TSET Program is a different type of emissions trading system: a mandatory target-setting and voluntary achievement approach. This paper reveals that cap-and-trade schemes based on such an approach can successfully provide incentives for covered entities to achieve their emission targets. A cap-and-trade scheme design like the TSET Program can be seen as one of the strategies in the political process of policymaking for combating climate change.

Acknowledgements This research was supported by the Environment Research and Technology Development Fund (2-1707) of the Environmental Restoration and Conservation Agency.

References

Arimura TH, Abe T (2020) The impact of the Tokyo emissions trading scheme on office buildings: what factor contributed to the emission reduction? Environ Econ Policy Stud

Hamamoto M (2020) Impact of the saitama prefecture target-setting emissions trading program on the adoption of low-carbon technology. Environ Econ Policy Stud (forthcoming)

Imbens GW, Wooldridge JM (2009) Recent developments in the econometrics of program evaluation. J Econ Lit 47:5–86

Jun SH, Kim JY, Oh H (2020) Evaluating mitigation performance of phase I of the KETS. mimeo

Martin R, Muûls M, Wagner UJ (2016) The impact of the European union emissions trading scheme on regulated firms: what is the evidence after ten years? Rev Environ Econ Policy 10(1):129–148

Wooldridge JM (2010) Econometric analysis of cross section and panel data, 2nd edn. The MIT Press, Cambridge

Mitsutsugu Hamamoto is Professor of the Faculty of Economics and Director of the Institute of Human and Environmental Symbiosis Research at Dokkyo University in Saitama Prefecture, Japan. He was a researcher at the Institute for Global Environmental Strategies before joining Dokkyo. He holds a Ph.D. in economics from Kyoto University. His research activity has been related to environmental innovation, emissions trading programs, and energy-saving behavior. His research outputs have been published in academic journals such as *Resource and Energy Economics* or *Energy Policy*. He has served on environmental councils of local governments such as Koshigaya and Yoshikawa (which are cities located in Saitama Prefecture).

Chapter 8
Energy Consumption in Transition: Evidence from Facility-Level Data

Naonari Yajima, Toshi H. Arimura, and Taisuke Sadayuki

Abstract This chapter estimated the impact of the Tokyo emissions trading scheme (ETS) and Saitama ETS on energy consumption in the manufacturing sector using a facility-level panel data set compiled from the *Current Survey of Energy Consumption*, a nationwide survey on energy consumption conducted by the Agency for Natural Resources and Energy in Japan. To our knowledge, no study has used this rich data set to perform sophisticated econometric analyses. We found that the Tokyo ETS reduced electricity consumption by 16%. On the other hand, we did not find evidences of switching from dirty fossil fuel to cleaner fuel associated with the introduction of the Tokyo ETS. The impact of the Saitama ETS on energy consumption was not statistically confirmed based on our samples. Additional studies are needed to identify the different impacts of the ETSs between Tokyo and Saitama. We also found that Japan has been experiencing long-term decreasing trends in the number of manufacturing facilities and the volume of fossil fuel consumption, which may reduce Japanese CO_2 emissions in the long run.

Keywords Emission trading schemes · Tokyo ETS · Saitama ETS · Manufacturing sector

1 Introduction

The previous two chapters investigated the impacts of the Tokyo emissions trading scheme (ETS) and the Saitama ETS based on facility-level data. Chapter 6 (Abe

N. Yajima (✉)
Waseda Institute of Political Economy, Waseda University, 1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo 169-8050, Japan
e-mail: nao.yajima@asagi.waseda.jp

T. H. Arimura
Faculty of Political Science and Economics, Waseda University, 1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo 169-8050, Japan

T. Sadayuki
Faculty of Economics, Seijo University, 6-1-20, Seijo, Setagaya-ku, Tokyo 157-8511, Japan

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_8

and Arimura) focused on university buildings and examined the impact of the Tokyo ETS by employing the difference-in-differences approach using the two-way fixed effects model. Chapter 7 (Hamamoto) targeted the facilities of all industries under the Saitama ETS and examined the impact of this ETS by comparing the facilities in Saitama Prefecture and one of its adjunct prefectures with a similar background in terms of environmental policies and industrial structures, namely, Gunma Prefecture.

Despite the similarity between the Tokyo ETS and Saitama ETS, two important distinctions should be noted. The first is the type of major industry targeted under each ETS. Because of the high land price and stringent environmental regulations in Tokyo, commercial and office buildings constitute the majority of regulated facilities under the Tokyo ETS. However, the regulated facilities under the Saitama ETS mostly belong to the manufacturing sector. Commercial and office buildings mainly use electricity, while manufacturing facilities consume various types of fossil fuels, ranging from petroleum-based fuels to non-petroleum-based fuels. Therefore, each regulated facility adopts a different reduction strategy because the cost of compliance with ETSs can differ depending on the type of industry and the type of energy used. Some facilities may reduce emissions by decreasing the usage of electricity, while others may reduce the usage of fossil fuel.

The second difference between the two ETSs is associated with the severity of compliance obligation. Compliance with the emission reduction targets under the Tokyo ETS is mandatory, and facilities that violate the regulation face fines. In contrast, compliance with the Saitama ETS is voluntary in the sense that regulated facilities that do not comply with the ETS face no monetary penalties.

This chapter focuses on the manufacturing sector and examines the impacts of both the Tokyo ETS and Saitama ETS on the consumption of energy by regulated facilities. We utilize the Current Survey of Energy Consumption (CSEC), which includes rich facility-level data from a nationwide survey on energy consumption conducted by the Agency for Natural Resources and Energy in Japan. This survey was started in 1981 with the aim of monitoring the consumption of various energy types by energy-intensive facilities and making use of the data for policy making, especially for policies concerning petroleum consumption. As of 2016, the survey covers approximately 1300 facilities (hereinafter, reporting facilities) in the manufacturing sector. Reporting facilities are required to submit monthly reports on the consumption of various energy types, such as electricity or petroleum.

The contribution of this chapter can be summarized as follows. First, although the previous two chapters investigated the impacts of ETSs on facilities in different prefectures and industries, this chapter examines two local ETSs by focusing on manufacturing facilities. To comply with the ETSs, regulated facilities can reduce their GHG emissions by decreasing their energy use. The *Current Survey of Energy Consumption* (CSES) allows us to examine this question in the manufacturing sector at the facility level in both Tokyo and Saitama and compare the effectiveness of the two local ETSs. As noted above, the Saitama ETS differs from the Tokyo ETSs because there is no financial penalty for noncompliance. We examine whether the ETS without the financial penalty in Saitama can generate the same level of GHG emission reductions as the Tokyo ETS, which has the binding obligation.

Second, we examine whether the regulated facilities reduced their emissions by changing the fuel mixture. The CSEC allows us to investigate whether the implementation of ETSs has motivated regulated facilities to shift energy consumption from dirty to cleaner energies. Previous studies on the impact of ETSs in Japan (Arimura and Abe 2020; Wakabayashi and Kimura 2018) only had access to aggregate levels of emissions and/or only the amount of electricity use. In contrast, Wagner et al. (2014) investigated the impacts of the EU ETS on the energy composition of coal, oil, gas, and steam and found that the regulated plants reduced their share of coal by approximately 2%. We follow this line of the study and provide the first empirical evidence regarding the shift in energy composition under the two local ETSs in Japan. Similar to the case of EU ETS, the regulated facilities may try to reduce fossil fuel consumptions such as coal. Another possibility is that they may comply with their target by reduction of fuels with cheaper abatement costs, for instance, electricity.

Finally, to the best of our knowledge, this study is the first to analyze the impacts of Japanese local ETSs using the facility-level data of the CSEC. Because scarce studies use these data, descriptive statistics and simple graphical illustrations can provide valuable information on the current trends of consumption of different energy types by large facilities.

We focus on the reduction of GHG emissions in this chapter. In general, under ETSs, regulated facilities can comply with the regulation either by reducing emissions or by purchasing additional allowances. However, few trades have been performed in the Tokyo and Saitama ETSs as illustrated in Chaps. 6 and 7. Compliance has primarily been achieved by reducing emissions, and many allowances have carried over to the next phase. Therefore, we can safely focus on emission reductions in our analysis.

The next section describes the CSEC data in detail and graphically demonstrates the trends in the number of reporting facilities and consumption by energy type. This data description is followed by an empirical analysis section that focuses on the impact of the Tokyo ETS and Saitama ETS on the consumption of various energy types. The final section concludes with some discussion on the direction of future work.

2 Data Description[1]

This section introduces a facility-level survey, the CSEC conducted by the Agency for Natural Resources and Energy in Japan. The survey was started in 1981 with the aim of collecting information on fuel consumption in the energy-intensive manufacturing sector, and it covers the following nine manufacturing industries: the "pulp and paper industry", "chemical industry", "chemical fiber industry", "petroleum products industry", "ceramic, clay and stone products industry", "glass product industry",

[1]This section is based on the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry (METI) (2015) "Yearly Report of the Current Survey of Energy Consumption".

"iron and steel industry", "nonferrous metals industry", and "machinery industry" (Table 1). Notably, the electric power and gas industries are not covered by the survey.

Table 1 Reported fuel types

Fuels
Petroleum-based fuels
Crude petroleum
Natural gas liquids (NGLs)・condensate
Gasoline
Naphtha
Oil produced by conversion
Kerosene
Gas oil
Heavy fuel oil A, B, and C
Hydrocarbon (by-product)
Liquefied petroleum gas (LPG)
Petroleum-based hydrocarbon gas
Petroleum coke
Asphalt
Recycled oil (oil origin)
Non-petroleum-based fuels
Coal-based fuels
Coal, coal for making coke
Coal coke
Tar
Coke oven gas
Other fuels
Blast furnace gas
Converter furnace gas
Natural gas
Liquified natural gas (LNG)
Town gas (including A and B)
Black liquor
Oxygen
Used tires
Waste plastic
Refuse plastic and paper fuel (RPF)
Electricity
Steam

Every facility with more than a designated number of employees (hereinafter, reporting facilities) is required to report its monthly consumption of various energy types. The threshold of the number of employees varies across industries. In some industries, such as the pulp and paper industry, chemical industry or petroleum products industry, all facilities are required to make reports regardless of the number of employees. All facilities in the nonferrous metals industry are also subject to the survey unless the facility produces secondary aluminum ingot. In other industries, facilities with a certain number of employees or more are targeted under the survey. For instance, a facility in the machinery industry, glass product industry or chemical fiber industry is not subject to the survey if it has less than 500 employees, 100 employees or 50 employees, respectively. Facilities with 500 employees or less fall beyond the scope of the survey.

The survey requires reporting facilities to report their consumption of petroleum-based fuels, non-petroleum-based fuels, electricity, and steam on a monthly basis (Table 1). Table 2 lists the number of reporting facilities that appear at least once between FY2004 and FY2015 and the average energy consumption by sector. The number of reporting facilities varied across sectors; for instance, there were 600 reporting facilities from the machinery industry and 50 reporting facilities from the glass product industry. The average energy consumption per facility also varied by sector. For example, the average consumption of electricity was approximately 6000 thousand kWh in the machinery industry and approximately 13,000 thousand kWh in the pulp and paper industry. On the other hand, the machinery industry consumed approximately 30 tons of liquefied petroleum gas (LPG), while the pulp and paper industry consumed approximately 9 tons of LPG.

In the following sections, we take a closer look at the consumption of several selected fuels and electricity generation by renewable energies and cogeneration.

3 Overall Trend in Energy-Intensive Sectors

The overall trends of the number of reporting facilities and the energy consumption by major prefectures are introduced in this section.

Figure 1 shows the number of reporting facilities from 2004 to 2016.[2] The total number of reporting facilities in Japan diminished from approximately 1600 in 2004

[2] For each year, we count the number of facilities that made monthly report(s) at least once during the year. Because some facilities made multiple reports for different sectors, we remove such duplicate observations to compute the number of facilities, and we handle such duplications as follows. If a facility reported the same amount of fuel consumption in two reports, then we take the average over the duplications for each month. The reason is that we do not know the fuel consumption ratio between sectors; therefore, we assume that the value is the total consumption of fuel, with each sector consuming half of the fuel. If a facility reported zero consumption or a missing value in one file and positive consumption in another, then we also take the average over the duplications, assuming that such reports of a positive number are the total consumption of fuels. Finally, if a facility reported different values for each sector, then we keep these values, assuming that they report the actual values for each sector.

Table 2 Number of reporting facilities and the energy consumption by sector

Sectors	Products (thresholds by # of employees)		# of facilities during FY2004–FY2015	Average monthly consumption per facility				
				Electricity (1000 kWh)	Heavy fuel oil (kl)	LPG (t)	Town gas (1000 m^3)	Steam (t)
Pulp and paper industry	Pulp, Paper, paperboard	(All) (≥50)	220	13,128.4	675.10	9.0	258.7	71,807.2
Chemical industry	Petrochemical products, ammonia and ammonia-derived products, soda products	(All)	238	13,696.5	698.3	2164.0	171.4	58,119.8
Chemical fiber industry	Chemical fibers	(≥50)	61	8340.4	575.60	11.7	473.9	33,742.80
Petroleum products industry	Petroleum products (except grease)	(All)	52	22,921.4	3299.4	1093.6	0.80	174,007.4
Ceramic, clay and stone products industry	Cement, sheet glass, Lime	(All) (≥50)	112	10,518.9	626.2	22.90	35.9	28,372.3
Glass product industry	Glass products	(≥100)	50	3920.9	348.1	83.60	473.3	512.5

(continued)

Table 2 (continued)

Sectors	Products (thresholds by # of employees)		# of facilities during FY2004–FY2015	Average monthly consumption per facility				
				Electricity (1000 kWh)	Heavy fuel oil (kl)	LPG (t)	Town gas (1000 m^3)	Steam (t)
Iron and steel industry	Pig iron, ferro-alloys, crude steel, semi-finished steel, steel forgings, steel castings, ordinary hot-rolled steel, special hot-rolled steel, cold-finished steel (except cold-finished steel bars and wires), coated steel (except wires), cold-rolled steel shapes, steel pipes and tubes	(All)	395	15,862.1	216.7	79.6	364.9	22,671.1
Nonferrous metals industry	Copper, lead, zinc, aluminum, Secondary aluminum, ingots	(All) (≥30)	78	7314.2	284.60	16.2	52.5	4598.4

(continued)

Table 2 (continued)

Sectors	Products (thresholds by # of employees)		# of facilities during FY2004–FY2015	Average monthly consumption per facility				
				Electricity (1000 kWh)	Heavy fuel oil (kl)	LPG (t)	Town gas (1000 m^3)	Steam (t)
Machinery industry	Civil engineering machinery, tractors, metal working and metal processing machinery, parts for electronic equipment, electron tubes, semiconductors, ICs, electronic computers and information terminals, associated electronic equipment, automobiles and parts (including motorcycles)	(≥500)	600	5632.0	43.7	29.30	300.90	6625.5

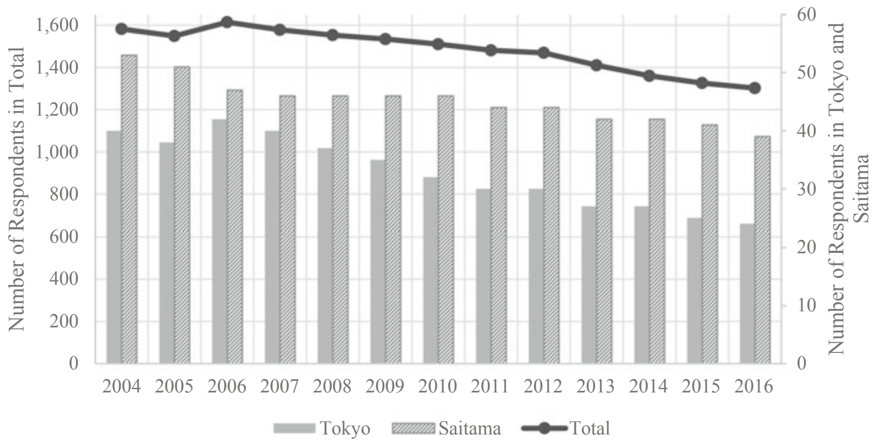


Fig. 1 Number of reporting facilities in the CSEC

to 1300 in 2016. Such a decreasing trend was also observed within Tokyo and Saitama. The closure of facilities and the integration of firms and/or facilities partially caused this trend. Such a trend implies that in Japan, the economic size of energy-intensive sectors has been diminishing over time. This finding may reflect the transition of the Japanese economy from being driven by the manufacturing sector to being driven by the service sector, as typical in many developed economies.

Figure 2 shows the trend of monthly average electricity consumption per facility, measured by thousand kWh, in five major prefectures: Saitama, Tokyo, Chiba, Kanagawa, Aichi, and Osaka. The electricity consumption in Tokyo and Saitama is shown

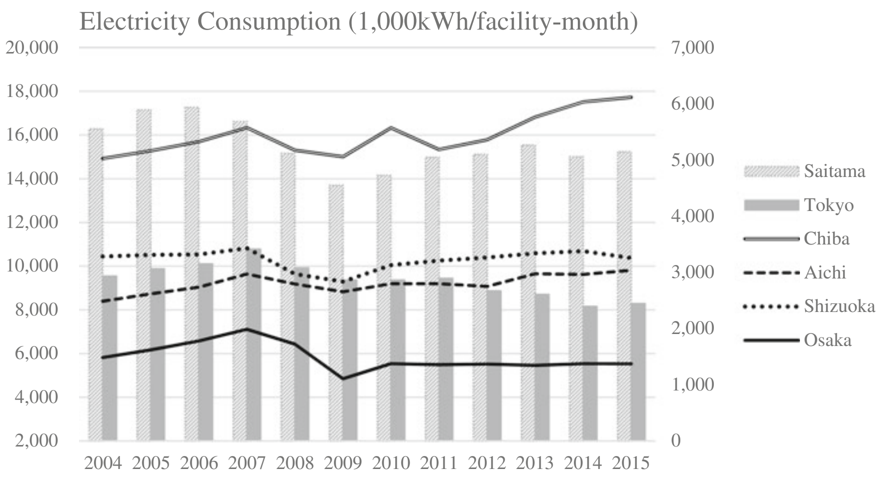


Fig. 2 Average monthly electricity consumption per facility by prefecture (the right axis is for Saitama and Tokyo and the left axis is for the other prefectures)

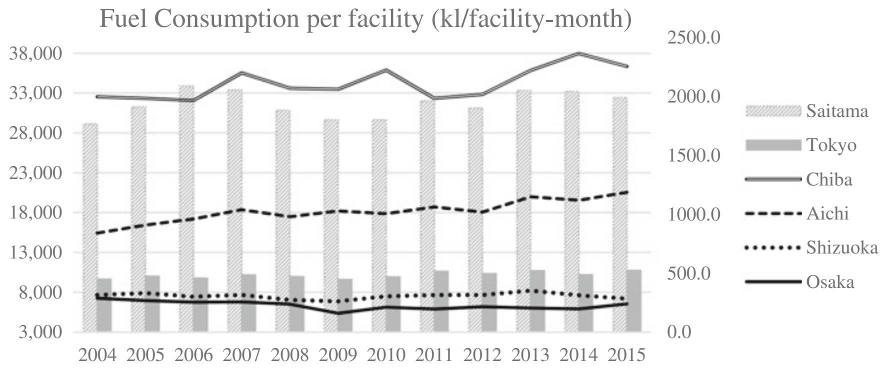


Fig. 3 Monthly average consumption of fossil fuel and steam, measured by crude oil equivalent, in transition

in bars (right axis), while that in the other prefectures is shown in line plots (left axis). The average electricity consumption peaked in 2007, the year before the financial crisis. The decline in electricity consumption between 2007 and 2009 was relatively small in Tokyo. After 2009, consumption gradually recovered in Chiba, Aichi, Shizuoka, and Saitama, where manufacturing industries are relatively active, while consumption declined or remained constant in Tokyo and Osaka. This contradictory consumption pattern between Saitama and Osaka can be explained as follows. Saitama prefecture is closer to the capital of Japan, Tokyo. Therefore, compared to other regions, it may have faced a smaller impact on its economic activities. Additionally, the difference in the industrial structures of areas may affect the impact of the Tokyo ETS and/or technological innovations on electricity consumption.

Figure 3 displays the trends of fuel consumption (i.e., the sum of fossil fuels and steam) per facility-month by prefecture, measured in crude oil equivalent.[3] Although the fuel consumption per facility in Chiba, Aichi, and Saitama moderately increased over time, the aggregate fuel consumption of all reporting facilities in each prefecture decreased (Fig. 4) due to the reduced number of facilities (Fig. 1). These observed trends may reflect the fact that small- and medium-sized facilities were more likely to close and drop out from the survey over time while large facilities remained, even with the recent stagnation in the manufacturing sector.

In addition to the drop in the number of reporting facilities, several other factors that may have driven these decreasing trends of fuel consumption. One is the effective environmental policies implemented by national and/or municipal governments. To improve energy efficiency, the manufacturing sector has been under environmental regulations since the 1970s, such as the *Energy Saving Act* (Arimura and Iwata 2015). Such regulations could reduce fuel consumption by improving energy intensity in advance of the implementation of the ETSs. Another possible factor is the increase in electricity prices. After the East Japan Great Earthquake in 2011, electricity prices

[3]For the calculation of crude oil equivalent, we use the conversion factors for each fuel and the criterion of 0.0258 kl/GJ of the Agency for Natural Resources and Energy of the METI (2015).

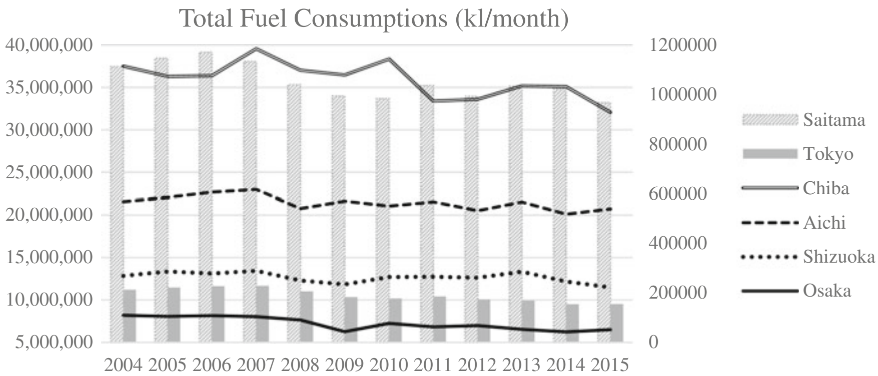


Fig. 4 Sum of the consumption of fossil fuel and steam, measured by crude oil equivalent, in transition

drastically increased in Japan due to the temporary shutdown of nuclear power plants (see Chap. 6). This sharp increase might have induced facilities in Japan to reduce their electricity consumption or substitute other fuels for electricity to manufacture. Additionally, the increase in the prices of other fuels, such as heavy fuel oil type A and natural gas, may have incentivized facilities to reduce their overall energy consumption.[4] Under such scenarios, however, the electricity consumption per facility should decrease.

These trends also indicate that it is necessary to use nationwide and facility-level data to examine the effectiveness of the Tokyo ETS and Saitama ETS. There are three main reasons. First, the difficulty in introducing new production processes and technologies to comply with the regulations may be different across sectors. If a sector can adopt such changes at a lower cost than other sectors, then the sector may have reduced more emissions due to the ETSs. Moreover, this change is a facility-level decision; therefore, the facility is a relevant unit of analysis. Second, to control for the effects of other environmental policies, it is necessary to use information on facilities located in other regions. Finally, as shown in Fig. 3, Tokyo and Saitama have relatively low fuel consumption compared with other regions, which means that the ETSs may have potentially low impacts on the facilities in their locations. Our data set can provide a relevant control group and units to examine the impacts of the ETSs.

[4]The Energy Data and Modelling Center, (2019), "Handbook of Japan's & World Energy & Economic Statistics", The Energy Conservation Center, Japan.

4 Estimation Model and Results

This section examines the causal effects of the Tokyo ETS and Saitama ETS on the energy consumption of facilities by fuel type and total energy consumption. Although Wakabayashi and Kimura (2018) and Chap. 6 find positive effects of the Tokyo ETS on the mitigation of aggregate CO_2 emissions, the effects on the consumption of each fuel are still not clear. The ETSs may have incentivized regulated facilities to change their fuel mix to reduce emissions. However, do regulated facilities actually shift their energy consumption from dirty fuels to cleaner fuels? Regarding electricity, Chap. 6 and Arimura and Abe (2020) show that the Tokyo ETS has reduced electricity consumption in university and office buildings. Because such buildings in the service sector use electricity as their main energy source, the impacts of the ETS might have been greater than those in manufacturing sectors. What is the effect on electricity consumption in manufacturing sectors where facilities use more fossil fuels? To investigate these questions, we apply the difference-in-differences approach and estimate the following equation:

$$\ln(Fuel_{ist}) = \gamma TokyoETS_{ist} + \rho SaitamaETS_{ist} + \beta X_{it} + \lambda_s + \eta_t + \mu_i + \varepsilon_{ist} \tag{1}$$

where i denotes the facility, s denotes the month and t denotes the year. Our sample period is from FY2004 to FY2014, which covers the period of Phase 1 of the ETSs.

The dependent variable, $\ln(Fuel_{ist})$, is the logarithmic value of a type of fuel consumed by facility i during month s in year t. For this analysis, we select electricity, heavy fuel oil, LPG, town gas and steam because of the relatively large amount of data on the consumption of these fuels. We also examine the aggregate consumption of energy produced from fossil fuels and steam as well as the power generation by cogeneration, waterpower, and other renewable energies. Under the ETSs, power generation from renewable energies can be excluded by calculating total CO_2 emissions. Therefore, facilities may have an incentive to generate electricity themselves.[5]

$TokyoETS_{ist}$ and $SaitamaETS_{ist}$ are the dummy variables of interest; they indicate facility i regulated under the Tokyo ETS and the Saitama ETS, respectively, during month s in year t. Because the Tokyo ETS was introduced in April 2010, $TokyoETS_{ist}$ takes the value of one if and only if the time of the data is later than March 2010 and the facility is under the Tokyo ETS. Similarly, $SaitamaETS_{ist}$ takes the value of one if and only if the time of the data is later than March 2011 and the facility is under the Saitama ETS. The parameters γ and ρ capture the impacts of the Tokyo ETS and the Saitama ETS, respectively, on the consumption of each fuel. We identify the regulated facilities under the ETSs by using official data sets

[5] For detailed information, see: A policy guideline issued by Tokyo Metropolitan Government (2015), https://www.kankyo.metro.tokyo.lg.jp/en/climate/cap_and_trade/index.files/TokyoCaT_detailed_documents.pdf (accessed 2020-07-08).

provided by the Tokyo metropolitan government and the Saitama government.[6] In our samples, there are 42 reporting facilities in Tokyo and 60 reporting facilities in Saitama, of which 24 and 34 facilities are regulated under the Tokyo ETS and the Saitama ETS, respectively, for at least one year.[7] The records of all 24 regulated facilities in Tokyo exist since the implementation of the Tokyo ETS, while the records of some of the 34 regulated facilities in Saitama appear at different periods during Phase 1. Additionally, a few regulated facilities in Saitama were exempted from the ETS during Phase 1, in which case, $SaitamaETS_{ist}$ takes the value of zero once the facility is exempted from the regulation.

Because the choice and quantity of energy consumption are not solely determined by the ETSs, we need to control for the effects of other factors that might affect energy consumption (such as the size of the facility, sector-specific production processes, temperature and the economic situation) to extract the pure effects of the ETSs. The control variables, X_{it}, include the natural log of cooling-degree days and heating-degree days to capture the effect of temperature[8] and the natural log of electricity prices by ten regions.[9] We also control for monthly fixed effects, λ_s, and yearly fixed effects, η_t, to capture the dynamic nationwide economic impact and the effect of sector-specific production processes, respectively; additionally, we control for facility fixed effects, μ_i, to capture unobservable facility-specific effects such as facility size and architectural performance. Finally, ε_{ist} is the idiosyncratic error term.

One of the disadvantages of this survey is that it does not include information on economic activities such as outputs and the number of employees. This lack of information is one of the limitations of the data set used in this chapter.

Table 3 displays the summary statistics of fuel consumption and the control variables as real values from FY2004 to FY2015. We find that there are many zero or missing values. These values imply no reporting and/or no consumption of these fuels. In our analysis, missing values are excluded, and zero values are excluded by log transformation in the estimation. Fuel consumption shows right-skewed distributions. For instance, the annual electricity consumption ranges from 0 kWh to

---

[6] Although the information has been continually revised, the lists of regulated facilities were obtained from the homepages of the local governments: https://www9.kankyo.metro.tokyo.lg.jp/koukai/koukai.html (for Tokyo) and https://translation2.j-server.com/LUCSAIPREF/ns/tl.cgi/https://www.pref.saitama.lg.jp/a0502/keikakukouhyou.html (for Saitama).

[7] We used the name of the facilities and/or their address as identifiers.

[8] Cooling degree-days (Heating degree-days) are a proxy variable of the annual energy consumption required for cooling (heading) in each prefecture, which is defined as annual sum of the difference between daily average temperature and 24° (14°) for each day in which daily average temperature is hotter than 22° (cooler than 14°) in each prefecture capital.

[9] Electricity was mostly provided to each facility by one of ten regional monopolistic power companies before the deregulation of the electric power industry in Japan in 2000. After the deregulation, it is difficult to identify the electricity supplier of each facility. We use the electricity prices of these power companies, calculated by dividing the annual profits from electricity sales by the quantities of electricity produced, as proxies for electricity prices, despite the possibility that facilities may contract with a different supplier.

Table 3 Summary statistics

Total energy consumption	Obs.	Mean	S.D.	Min	Max
Crude oil equivalent (kl)	217,734	14,001.26	64,100.16	0	1072,132
Crude oil equivalent (kl, w/o electricity)	217,734	12,984.27	61,870.95	0	1030,758
Electricity					
Electricity (consumption)	214,810	11,098.5	3,0341.5	0.0	471,615.0
Electricity (generation)	217,734	1701.6	9624.2	−251.0	335,021.0
Other Fuels					
Heavy fuel oil (A, B, and C)	217,734	428.2	1918.0	0	166,384
Liquefied petroleum gas (LPG)	217,682	355.1	3243.1	0	118,556
Town gas	217,494	267.2	1153.9	0	80,793
Steam	152,551	43,668.8	125,122.3	0	2023,363
Control variables					
Cooling-degree days	217,734	404.5	139.8	10	1042.1
Heating-degree days	217,734	1038.0	383.1	0.6	2653.9
Electricity price	217,734	17.2	2.0	14.2	23.4

Note This table shows facility-month-level summary statistics from April 2004 to March 2016. The Tokyo ETS dummy and the Saitama ETS dummy are excluded from the table. Zero values imply no reporting and/or no consumption of these fuels. We exclude missing values

471,615 thousand kWh, with a mean of 11,101 thousand kWh. Log transformation can partially overcome such skewness.

Table 4 summarizes the estimation results. Each column shows the results using a different dependent variable, i.e., $\ln(Fuel_{ist})$. We start from the impacts of the Tokyo ETS. Column [1] shows the results for electricity consumption, for which the estimate is −0.16 and statistically significant at the 5% level. This finding indicates that the Tokyo ETS reduced the electricity consumption of a facility by approximately 16%. This estimate is much greater than the impacts on electricity consumption in the service sector shown by Arimura and Abe's (2020) and Chap. 6, i.e., a 6% reduction for office buildings and a 5% reduction for university buildings.

Columns [2] to [5] show the results regarding other types of fuel, namely, steam, heavy fuel oil, LPG and town gas. We found that only steam (column 2) and LPG (column 4) were reduced by the Tokyo ETS, although the size of the impact seems rather large. On the contrary, the impacts on heavy fuel oil and town gas were not statistically significant. These results may have been caused by the small number of facilities under the ETS.

What was the aggregate impact of the Tokyo ETS? Column [6] shows the estimation results of the aggregated fuel consumption, while column [7] shows the results for all fuels except electricity. Column [6] shows that the total energy consumption was reduced by 12.3% due to the Tokyo ETS, and this result is statistically significant at the 10% level. Column [8] shows the impact of the Tokyo ETS on electricity

Table 4 Main estimation results

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Dependent variables (transformed to logarithmic value)								
	Electricity (consumption)	Steam	Heavy fuel oil (A, B, and C)	LPG	Town gas	Total energy consumption	Total energy consumption (w/o electricity)	Electricity (generation)
Independent variables								
Tokyo ETS	−0.160** (0.080)	−0.57* (0.34)	0.28 (0.26)	−0.31*** (0.09)	−0.09 (0.150)	−0.123* (0.07)	−0.09 (0.08)	0.21 (0.210)
Saitama ETS	0.01 (0.03)	−0.01 (0.16)	0.114 (0.298)	−0.198 (0.149)	−0.127 (0.100)	−0.02 (0.04)	−0.10 (0.08)	−0.02 (0.13)
ln (*HDD*)	0.07 (0.07)	−0.07** (0.03)	−0.09** (0.04)	−0.01 (0.05)	−0.749* (0.423)	0.04 (0.05)	−0.04* (0.02)	−0.62 (0.47)
ln (*CDD*)	−0.01 (0.01)	0.04 (0.03)	−0.04 (0.04)	−0.02 (0.06)	−0.040 (0.08)	−0.001 (0.02)	0.004 (0.02)	−0.08 (0.08)
ln (*Price*)	−0.07 (0.11)	0.52* (0.29)	−0.71 (0.49)	−0.20 (0.39)	−0.097 (0.42)	0.09 (0.13)	0.29 (0.19)	0.35 (0.75)
Facility FE	Y	Y	Y	Y	Y	Y	Y	Y
Yearly FE	Y	Y	Y	Y	Y	Y	Y	Y
Monthly FE	Y	Y	Y	Y	Y	Y	Y	Y
Sample size	198,023	95,150	95,400	60,436	63,259	198,472	187,849	44,606
# of id in total	1779	841	1083	663	662	1779	1714	518
# of id located in Tokyo	46	6	22	10	38	46	44	6

(continued)

Table 4 (continued)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
# of id located in Saitama	56	16	37	19	33	56	54	13

CDD denotes cooling-degree days, and HDD denotes heating-degree days. Robust standard errors clustered by facilities are in parentheses. # of id implies how many facilities are included in the estimation for the corresponding models. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

generation by renewable energies. However, we could not find evidence of the effects of promoting renewable energy usage/supply.

Our results may reveal the compliance behaviors of the regulated facilities under the Tokyo ETS. As we mentioned in the introduction, the regulated facilities have two options to comply with reduction requirements: reducing their emissions or purchasing emission allowances. Our findings imply that the regulated facilities choose the first option, with ninety percent of the regulated facilities performing emission reductions and only 10% obtaining additional permits to comply with the regulation. Thus, our estimation results are consistent with this behavior reported to the Tokyo government (Chap. 6). Notably, the facilities complied with their target by reducing electricity consumption.

Another finding from the estimation results is that reducing electricity consumption may be easier than reducing fossil fuel consumption. Reducing fossil fuel consumption may require some changes in production process technology, which requires an additional investment. For example, to reduce the consumption of fossil fuels, facilities may have to replace their overall equipment. In contrast, there are simple ways to reduce electricity consumption. For example, effective methods include the adoption of light-emitting diodes (LEDs) or the adoption of energy efficient appliances.

Our findings imply that facilities in the manufacturing sector in Tokyo achieved their target through reducing electricity consumption, such as in the case of university buildings (Chap. 6) or office buildings (Arimura and Abe 2020).

Unlike the results of the Tokyo ETS, we found no statistical evidence of impacts of the Saitama ETS on the consumption of any types of energy. However, such a result contradicts the results in Chap. 7, which identified the significant effects on CO_2 emissions in Saitama. One possible reason is that we use different samples in both the target industry and the control group. In its estimation, Chap. 7 uses information on all regulated facilities from all industries; moreover, it compares the facilities located in Saitama prefecture and Gunma prefecture. In contrast, we use only energy-intensive sectors; that is, the number of regulated facilities we cover is relatively small. Additionally, there may be some heterogeneous impacts of the Saitama ETS that depend on the characteristics of the facilities in Saitama. For instance, large facilities may face more difficulties in reducing their fuel consumption.

One hypothesis that we wanted to test with this data set was whether facilities switch fuel from dirty fuel, such as heavy fuel oil, to cleaner fuel, such as town gas or electricity. Column [4] shows the estimation results for heavy oil. Neither the Tokyo or Saitama ETS reduced the consumption of heavy oil. Therefore, we could not identify a fuel switch from dirty fuel to cleaner fuel in this analysis.

All other control variables have no impact or little impact on the selected fuels. Regarding the electricity price, although a coefficient on electricity consumption is negative, it is not statistically significant.[10] We note that the electricity price has a

[10]There are several possible reasons for this insignificant result. The first is the small number of treatments. The second is the fact that electricity is not the principal source of energy in the manufacturing sector. The third is the deregulation of the electric power industry, which leads

positive and significant effect on the consumption of steam. This finding suggests that steam and electricity are substituted in the manufacturing process.

Finally, we compare our results with those found in the literature. We select the impacts of other ETSs, such as EUETS, Korean ETS (KETS), or Chinese pilot ETSs. Several empirical studies identified statistically significant effects of the ETSs. However, the sizes of the estimated impacts are mixed. In the case of the first phase (2015–2017) of the KETS, Jun et al. (2020) concluded that the burden of emission reductions has the impact of approximately -30% on changes in carbon emissions in the manufacturing sector, however, it was not significant in the building sector, under the KETS. Moreover, Haijun et al. (2019) found that the regulated sectors reduced their carbon emissions by approximately 30% under the Chinese pilot ETSs from 2013 to 2015. Dechezleprêtre et al. (2018) also revealed that the EU ETS reduced carbon emissions by 10% from 2005 to 2012. Similarly, Wagner et al. (2014) investigated the impacts of the EU-ETS on the energy composition of coal, oil, gas, and steam and found that the regulated plants reduced their share of coal by approximately 2% In the case of the EU-ETS, Chinese pilot ETSs, KETS, and Tokyo ETS, relatively larger impacts on CO_2 reduction have been observed in the manufacturing sectors. Saitama ETS may have no effects in the manufacturing sectors. In office-buildings, the Tokyo ETS also has relatively larger impacts on carbon emissions while the KETS may have no effects. The impact of the ETSs on fuel or energy consumption varies among countries and sectors.

Moreover, in our analysis, there may be several limitations. First, we assume that the effects of the ETSs are constant over the sample period and all regulated facilities. However, such an assumption may not be realistic. Under the ETSs, regulated facilities can flexibly comply with their target. For example, if regulated facilities reduced emissions during the latter part of the compliance period, then the effects of the ETSs increased over time. Compliance behavior can also vary by industry-specific features. For instance, if replacing capital with more energy efficient capital is more difficult in one sector than in others, regulated facilities may postpone compliance with their target.

5 Conclusions

This chapter uses rich facility-level data from the CSES to analyze trends in the number of large facilities in the manufacturing sector and their energy consumption, and it also examines the impacts of the Tokyo ETS and the Saitama ETS on electricity, steam, and fossil fuel consumption.

---

to uncertainty with regard to the choice of electricity provider by each facility. The last is an equilibrium effect, where the reduction in the number of facilities in Tokyo and Saitama due to the implementation of the ETSs results in an increase in the unit cost of electricity production for power supply companies and, therefore, an increase in the electricity price.

Our findings are summarized as follows. First, the number of targeted facilities was reduced from approximately 1600 in 2004 to 1300 by 2016. This finding may reflect a shift in the industrial structure from the manufacturing sector to the service sector, which leads to closures, temporary shutdowns, and manufacturing facility integration. In addition, the total consumption of fuel, such as electricity and other fuel types, declined in Tokyo and Saitama after 2006. The reduction in the number of manufacturing sector facilities is one of the reasons for this trend. These trends will contribute to the reduction of Japanese GHG emissions in the long run.

Second, our analysis demonstrated that the Tokyo ETS led to an approximately 16% reduction in electricity consumption in the manufacturing facilities, which is larger than the reduction in office buildings found by Arimura and Abe (2020). However, we could only find weak impacts on fossil fuel consumption. The Saitama ETS had no statistically significant impacts on the consumption of any type of fuel, which may be partly due to the insufficient number of facilities in Saitama for our analysis. We could not find any statistical evidence on shifting from dirty fuels to cleaner fuels under the ETSs. In addition, we could not identify statistically significant effects of the ETSs on electricity generation by renewable energies.

We compared our results with the findings in the literature on other ETSs. The impacts of the Tokyo ETS in the manufacturing sector were larger than that of the EU-ETS but smaller than that of the Chinese pilot ETS. Moreover, the impact of the Tokyo ETS was greater than that of the Korean ETS in office buildings. The impact of the ETSs varied among countries and sectors. What can explain these variations in the impact on emissions? Is it differences in the reduction targets, external economic conditions or other regulations? Such topics represent an important area of future work.

Our analysis has policy implications. The results provided in the previous chapters indicate that both the Tokyo ETS (Chap. 6) and Saitama ETS (Chap. 7) have heterogeneous effects across sectors and fuels. Our estimation results revealed a significant impact of the ETSs only on electricity in Tokyo but not on the consumption of other types of fuels in manufacturing sector. The weak impact of the ETS in Saitama may result from the voluntary nature of the Saitama ETS and the lack of penalty for violation. On the other hand, only a limited number of observations were available for the Saitama ETS, which may have influenced our empirical results for the Saitama ETS. Further research is needed on this point.

This study has other limitations in the empirical analysis as well. First, while our data set contains detailed information on facility-level fuel consumption on a monthly basis, it has no information on economic activities. Therefore, we could not investigate the impacts of the ETSs on the adjustment of the capital stocks of facilities. In the long run, facilities can adjust their capital stock through investment, which may alter their fuel mixes or the fuel types that they can use. Second, some facilities in electricity-intensive sectors, such as the chemical and steel industries, are exempted from paying the higher electricity prices that resulted from the feed-in tariff system. Such exempted facilities pay electricity prices that are lower than those observed in our data set. However, we could not identify those facilities and thus assume that they pay the same prices as other facilities. This difference in electricity prices may have caused some bias in our estimates. In future research, we would like to consider these points to more rigorously explore the impacts of the Tokyo ETS and Saitama ETS.

In the Paris Agreement, the Japanese government set a goal of reducing greenhouse gas emissions by 80% by 2050. It looks like difficult to realize the target by ETS only. Even if the 16% reduction in Tokyo is significantly high, however, it is still not enough to achieve the goal. Moreover, the abatement cost has been increased generally, then the impacts of the ETS would decrease in the future. In a while, the Japan Center for Economic Research published a report claiming that this long-term target is feasible with a reasonable cost.[11] The declining trends in the manufacturing sector and energy consumption discussed above help reduce emissions to a great extent. Considering such trends, the long-term goal of an 80% reduction may not be an unrealistic target in the future.

References

Arimura TH, Abe T (2020) The impact of the Tokyo emissions trading scheme on office buildings: what factor contributed to the emission reduction? Environ Econ Policy Stud

Arimura TH, Iwata K (2015) The CO_2 emission reduction under the law concerning the rational use of energy: an empirical study of energy management in the Japanese hotel industry. In: Arimura TH, Iwata K (eds) An evaluation of Japanese environmental regulations: quantitative approach from environmental economics. Springer, Berlin, pp 123–143

Agency for Natural Resources and Energy Ministry of METI (2015) Yearly report of the current survey of energy consumption

Bureau of Environment (2015) Tokyo cap-and-trade program for large facilities [Detailed Documents], Tokyo Metropolitan Government. Retrieved from https://www.kankyo.metro.tokyo.lg.jp/en/climate/cap_and_trade/index.files/TokyoCaT_detailed_documents.pdf (accessed 2020-07-08)

Bureau of Environment (2019) Tokyo cap-and-trade program published information (in Japanese), Tokyo Metropolitan Government. Retrieved from https://www9.kankyo.metro.tokyo.lg.jp/koukai/koukai.html (accessed 2020-07-08)

Dechezleprêtre A, Nachtigall D, Venmans F (2018) The joint impact of the European Union emissions trading system on carbon emissions and economic performance. OECD Economic Department Working Papers

Haijun Z, Maosheng D, Peng Z (2019) Analysis of the impact of China's emissions trading scheme on reducing carbon emissions. Energy Procedia 158:3596–3601

Jun SH, Kim JY, Oh H (2020) Evaluating mitigation performance of phase 1 of KETS. mimeo

Saitama Prefecture (2019) Planning and publication of implementation status. Retreived from https://translation2.j-server.com/LUCSAIPREF/ns/tl.cgi/https://www.pref.saitama.lg.jp/a0502/keikakukouhyou.html (accessed 2020-07-08)

The Energy Data and Modelling Center (2019) Handbook of Japan's & World Energy & Economic Statistics, The Energy Conservation Center, Japan

The Japan Center for Economic Research (2019) Retrieved from https://www.jcer.or.jp/economic-forecast/long-term (accessed 2020-07-08)

[11]This is also consistent with a prediction made by the Japan Center for Economic Research. For detailed information on the long-term predictions of the Japan Center for Economic Research, see the following URL: (https://www.jcer.or.jp/economic-forecast/long-term, accessed 2020-07-08).

Wagner UJ, Muûls M, Martin R, Colmer J (2014) The causal effects of the European Union Emissions Trading Scheme: evidence from French manufacturing plants. In: Fifth world congress of environmental and resources economists. Instanbul, Turkey

Wakabayashi M, Kimura O (2018) The impact of the Tokyo Metropolitan Emissions Trading Scheme on reducing greenhouse gas emissions: findings from a facility-based study. Clim Policy 18(8):1028–1043; Economics 119(1):249–227

Naonari Yajima is a research associate at Waseda Institute of Political Economy, Waseda University in Japan. He is also a doctoral student at the Graduate School of Economics, Waseda University. He received his bachelors degree in Economics from Takasaki City University Of Economics (Valedictorian), and masters degree in Economics from Graduate School of Economics at Waseda University. He is the recipient of the Mitsubishi UFJ Trust Scholarship, 2017. His research interests are energy policy particularly focusing on voluntary environmental actions and organizational structure. He is currently working on empirical study that evaluates effects of Tokyo Emissions Trading Scheme, especially on changes in energy-saving behaviors by firms. He is a member of Society of Environmental Economics and Policy Studies, International Association for Environmental Economics and Japan Association of Political Economy.

Toshi H. Arimura is a Professor of Political Science and Economics and Director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Prior to joining Waseda, he was a Professor at Sophia University in Tokyo and was a visiting scholar with George Mason University and Resources for the Future as a recipient of the Abe Fellowship. His research interests include climate change, energy policies, air pollution regulations and voluntary environmental actions. He has published his research in academic journals such as *Journal Environmental Economics and Management, Journal of Association of Environmental and Resources Economics, Environmental and Resource Economics, Ecological Economics* or *Energy Policy*. He is a coauthor of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach from Environmental Economics* (Springer 2015). Dr. Arimura holds a Ph.D. in economics from the University of Minnesota, an MSc in environmental sciences from the University of Tsukuba and a BA in history of science from the University of Tokyo. He has served on a number of Japanese government committees on environmental issues including the committees on carbon pricing (2018) and emission trading scheme (2010) of the environmental council under Ministry of the Environment. He is also a member of the Tokyo Metropolitan environmental council. He has served on advisory committees of local governments for emission trading schemes of Tokyo and Saitama. He has also been on editorial boards of academic journals such as *Review of Environmental Economics and Policy, Agricultural and Resource Economics Review, Economics of Energy and Environmental Policy* or *Environmental Economics and Policy Studies*。Since 2018, Waseda University has choses him as one of 10 next generation core researchers. He is a recipient of SEEPS Outstanding Publication Award from Society for Environmental Economics and Policy Studies (Japanese Association of Environmental Economics and Policy) and the academic award from Society of Environmental Science, Japan.

Taisuke Sadayuki obtained Ph.D. in Economics from the University of Illinois at Urbana-Champaign in 2016 and joined the Research Institute for Environment Economics and Management (RIEEM) in 2018. Before joining Seijo University, he was an assistant professor at Waseda University. His main research interest is on empirical topics in urban and environmental economics. He proposed a new hedonic model in his paper published in Regional Science and Urban Economics.

Chapter 9
An Assessment of Carbon Taxation by Input–Output Analysis: Upstream or Downstream?

Ayu Washizu and Satoshi Nakano

Abstract To analyze the ripple effects of CO_2 emissions from the introduction of renewable energy power plants, this study developed input–output tables for analysis of next-generation energy systems (IONGES). The results revealed that the environmental benefits obtained from investing in power plants of the same capacity vary significantly depending on the type of renewable energy. Using the IONGES, under assumptions of three carbon taxation methods (upstream, midstream, and downstream), we calculated the taxable CO_2 emissions induced when producing each good or service and estimated the carbon tax burden associated with the final demand. We found that, in the upstream method, the taxation effects of one unit of carbon tax is concentrated in energy goods such as coal products and petroleum basic, while the effects are relatively dispersed in the downstream taxation method. If renewable energy is added to the government target level in 2030, taxable CO_2 emissions will decrease by 12–13.3%. Compared with the upstream taxation method, in the midstream and downstream methods, the CO_2 emissions induced by each final demand are distributed more evenly across various goods and services. Compared to the downstream taxation method, upstream taxation leads to higher CO_2 emissions from exports, but lower CO_2 emissions from household consumption. This is because energy-intensive industries such as machinery have high export ratios. We analyzed which expenditure categories contribute to the carbon tax burden associated with household consumption. In the case of upstream taxation, households mainly focus on reducing electricity consumption; in the case of downstream taxation, households reduce consumption of various energy-intensive goods and services.

A. Washizu (✉)
Faculty of Social Science, Waseda University, 1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo 169-8050, Japan
e-mail: washizu@waseda.jp

S. Nakano
Faculty of Economics, Nihon Fukushi University, 229 Otamachi Kawaminamishinden, Tokai, Aichi 477-0031, Japan

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_9

Keywords Input–output table for analysis of next generation energy system (IONGES) · Renewable energy · Structural CO_2 emissions · Upstream taxation method · Midstream taxation method · Downstream taxation method

1 Introduction

The Council of Japan's Ministry of the Environment is currently discussing a carbon tax scheme for 2050. The method of carbon taxation (upstream or downstream) is an important consideration in these discussions. Policymakers need to quantitatively understand how the tax burden on producers and consumers changes depending on the taxation method. In addition, the spread of renewable energy is expected to change the size of the carbon tax burden in various industries. To quantitatively measure how the introduction of a carbon tax affects industries under the introduction of renewable energy and how different carbon taxation methods affect producers and consumers, we developed an input–output table for analysis of next-generation energy systems (IONGES) for 2011.[1] This table follows a 2005 study of IONGES (Nakano et al. 2017) and our previously published inter-regional IONGES study (Nakano et al. 2018). IONGES is a table that incorporates renewable energy sectors into the input–output table published by the Ministry of Internal Affairs and Communications (MIC), Japan. The sectors incorporated in the IONGES are power facility construction and power generation for fifteen types of renewable energy. The purpose of this study is to describe the 2011 IONGES table and use it to analyze the ripple effects of CO_2 emissions and savings from the construction and operation of renewable-energy power plants. These results measure the potential tax reduction from each power generation technology when a carbon tax is introduced. We also examined the differences in burdens on producers or consumers caused by the three carbon taxation methods: upstream, midstream, and downstream. Detailed quantitative results obtained from the input–output analysis can provide specific ways to implement carbon pricing.

2 History of Environmental Input–Output Analysis in Japan

Input–output analysis was developed by Leontief in the 1930s as a method for assessing the consequences of technological progress on economic development through interdependences between economic agents (Leontief 1951). It can quantitatively capture the interdependences among different sectors at high levels of sectoral resolution. Interdependences emerge because sectors require each other's outputs as inputs (Nakamura and Nansai 2016). In the 1970s, Leontief argued that pollutants

[1] Waseda University Institute for Economic Analysis of Next-generation Science and Technology web page http://www.f.waseda.jp/washizu/table.html.

were inevitably emitted as a by-product of input–output relationships between sectors and applied input–output tables to the analysis of environmental (pollution) issues (Leontief 1986a, b). Based on Leontief's idea, the Ministry of International Trade and Industry (currently the Ministry of Economy, Trade and Industry) created an input–output table for pollution analysis in Japan (MITI 1971). In the 1980s, Hayami et al. (1993) developed an input–output table for environmental analysis in Japan with emission tables for air pollutants (NO_x, SO_x, CO_2) by sector. Using the table for 1985, they conducted pioneering analysis of the environmental effects that new technology development, such as energy-saving housing, exerts on the society through interdependence between economic sectors and on the environmental household account, showing direct and indirect environmental impacts of household consumption behavior (Hayami et al. 1996a, b). Researchers have provided input–output tables for environmental analysis for 1990 (Ikeda et al. 1996), 1995 (Asakura et al. 2001), 2000 (Nakano et al. 2008), and 2005 (Nakano 2009). In Europe, Statistics Netherlands developed the National Accounting Matrix including Environmental Accounts (NAMEA) at the end of the 1980s. It consists of a conventional national accounting matrix extended with environmental accounts in physical units.[2] The database was linked to input–output tables in European countries and was widely used for regional environmental studies (Marin et al. 2012).

Since the United Nations Conference on Environment and Development (Earth Summit) in 1992, input–output tables have been heavily used for environmental analysis. This increase in its use was driven by the fact that input–output analysis is useful for life cycle assessment (LCA) analysis, which evaluates the lifetime environmental impacts of products and services. LCA analysis was originally used in the engineering field, in which the physical environmental burden associated with the production of a certain product was accumulated sequentially in a bottom-up manner. Since the principle of LCA was highly compatible with that of input–output analysis (analysis of interdependency between sectors) in the social sciences field, the input–output tables of each country have been expanded for LCA analysis as environmentally extended input–output tables (EEIO) since the 1990s (Nakamura and Nansai 2016). In Japan, Hondo et al. (1996, 1998, 2002) created an input–output table for LCA analysis and considered the environmental impact of imported products abroad in their table. The National Institute for Environmental Studies published the Embodied Energy and Emission Intensity Data using input–output Tables (3EIDs) summarizing greenhouse gas (GHG) emissions by sector in the national input–output tables for 1990, 1995, 2000, 2005, 2011, and 2015.[3] Similar to Hayami's table for 1985 (Hayami et al. 1993), 3EID provides the environmental burden of each sector in the supplementary table. Meanwhile, in the waste input–output table (WIO) developed by Nakamura and Kondo (2002), waste treatment and recycling sectors (venous industries) that are not specified in the national input–output table were added. Using WIO, they

[2]European Environment Agency web page https://www.eea.europa.eu/help/glossary/eea-glossary/namea.

[3]National Institute for Environmental Studies web page https://www.cger.nies.go.jp/publications/report/d031/eng/index_e.htm.

analyzed the interdependence between sectors that produce conventional products (arterial industries) and venous industries. WIO is unique in that it describes input–output relationships of venous sectors in physical units. In 2011, the Ministry of the Environment published an input–output table for environmental analysis, which includes a supplementary table describing water resource inputs and waste emissions in addition to energy inputs and GHG emissions in physical units[4].

An input–output table based on supply and use tables is a format used in the System of National Accounts (SNA). It shows the flow of products produced by a certain industry that become inputs for another industry. This input–output table differs from Leontief's original (product based) input–output table in terms of the analytical method. An attempt is underway to develop physical supply and use tables within the framework of the SNA satellite account, the System of Environmental-Economic Accounting (SEEA) (Kovanda 2019).

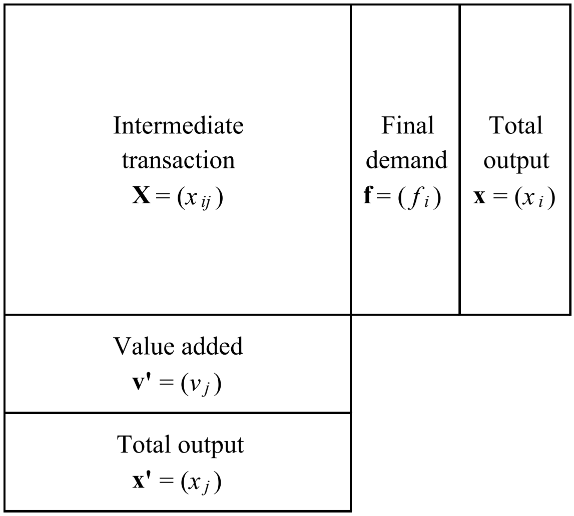
The development of multiregional input–output tables (MRIO) has intensified in recent years (Sun et al. 2019). In most cases, the developed database has a supplementary table showing the environmental burden (Nakamura and Nansai 2016). Interest in how the economic activity of one country or region (e.g., consumer activity in developed countries) exerts an environmental impact on another country or region (e.g., China) is increasing. Although it is difficult to create an MRIO due to the significant amount of information required, an attempt is ongoing to create an international platform for the tabulation (Wakiyama et al. 2020).

Considering this background, environmental research using input–output tables has been promoted through collaboration between engineering and social science researchers. However, with the advancement of research, the differences between their aims have become apparent: The purpose of engineering LCA research is to "accurately" measure the environmental impact of a certain product on (possibly) multiple regions; on the other hand, the purpose of input–output analysis in the social sciences is to analyze the effects of technological changes in a part of the economy on society and the environment as a whole. The results of such analysis can provide significant policy implications for solving economic, social, or environmental issues. Vercalsteren et al. (2020) discuss environmentally extended multi-region input–output (EE-MRIO) studies in line with policy needs.

In Japan, the introduction and use of renewable energy has attracted attention as an economic and environmental policy issue since the Great East Japan earthquake of 2011. Therefore, input–output analysis needs to be developed in the context of this new policy issue. Our IONGES fills this gap. At IONGES, renewable energy sectors have been added to the national input–output table, and the interdependences between renewable energy sectors and related sectors have been carefully described. Research using IONGES is expected to have major implications for policy to effectively build next-generation energy systems using renewable energy while simultaneously addressing other social issues (e.g., environmental damage and population aging).

[4]Ministry of the Environment web page https://www.env.go.jp/doc/toukei/renkanhyo.html.

Fig. 1 Conceptual diagram of an input–output table



Moriizumi et al. (2015) have also developed the Renewable Energy-Focused Input–Output table (REFIO)[5] as a Japanese input–output database incorporating renewable energy. REFIO aims at LCA analysis of individual renewable energy installations, while IONGES aims at comprehensive policy research, including the link between renewable energy introduction and carbon tax schemes. In these two databases, renewable energy sectors that are not specified in the national input–output table have been added. REFIO publishes the input structure (only) for each renewable energy sector based on individual information on renewable energy power generation plants, while IONGES has created renewable energy sectors based on published statistical information. The latter is an input–output table describing the supply–demand balance including renewable energy sectors and is suitable for analyzing policy issues such as carbon pricing.

3 Input–Output Model

Figure 1 provides a conceptual diagram of the input–output table. The columns in this figure shows the composition of inputs to the sector, and the rows show the composition of outputs from the sector. In Fig. 1, x_{ij} is an element of the transaction matrix **X** of the intermediate goods, and indicates the quantity of i-th goods input to the j-th sector. $\sum_i x_{ij} + v_j = x_j$ shows that the sum of intermediate inputs and the value added in the j-th sector is equal to the production value of the sector, and

[5] Yokohama National University Hondo Laboratory web page http://www.hondo.ynu.ac.jp/renewables/result/refio.html.

$\sum_j x_{ij} + f_i = x_i$ shows that the sum of intermediate demand and final demand of the i-th good is equal to the production value of the i-th sector, respectively.

The ratio of x_{ij} to x_j is called the input coefficient $a_{ij} = x_{ij}/x_j$, and is based on the following equation:

$$\sum_i a_{ij} + v_j/x_j = 1 \tag{1}$$

A, with all input coefficients as elements, is called the input coefficient matrix. Using **A**, the supply and demand balance of all sectors can be shown as follows:

$$\mathbf{Ax} + \mathbf{f} = \mathbf{x} \tag{2}$$

Here, **x** is the total production vector and **f** is the final demand vector (million JPY). The Leontief inverse matrix $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$ is obtained by solving Eq. (2) for **x**. The elements in the j-th column of **B** show the intermediate inputs required directly and indirectly throughout the supply chain to produce one unit of the j-th good. When the j-th column of the Leontief inverse matrix **B** is represented by $\mathbf{B}_\mathrm{j}$, replacing **x** in Eq. (2) with $\mathbf{B}_\mathrm{j}$ gives Eq. (3) below:

$$\mathbf{A} \cdot \mathbf{B}_j + \mathbf{I}_j = \mathbf{B}_j \tag{3}$$

Here, $\mathbf{I}_j$ is a unit vector with the j-th element as 1 and the others as zero. Here,

$$\mathbf{U}_j = \mathbf{A} \cdot \mathbf{B}_j \tag{4}$$

Ozaki (1980) defined $\mathbf{U}_j$. as the unit structure of the j-th good. The unit structure shows all intermediate goods transactions that occur directly and indirectly through the supply chain of the j-th good. Ozaki (1980) considered the unit structure to indicate the structural unit cost of producing the good.

$$\mathbf{U}_j = \begin{bmatrix} b_{1j} \\ \vdots \\ b_{jj} - 1 \\ \vdots \\ b_{\mathrm{nj}} \end{bmatrix} \tag{5}$$

Equation (5) is obtained by expanding Eq. (4). Each element of $\mathbf{U}_j$ indicates the total amount of each intermediate good required in the entire supply chain of the j-th good. Equation (4) is also expanded as follows:

$$\bar{\mathbf{U}}_j = \mathbf{A} \cdot \hat{\mathbf{B}}_j = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \cdot \begin{bmatrix} b_{1j} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & b_{nj} \end{bmatrix} = \begin{bmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{n1} & \cdots & u_{nn} \end{bmatrix} \quad (6)$$

Here, if **e** is a unit vector, the following holds:

$$\bar{\mathbf{U}}_j \cdot \mathbf{e} = \mathbf{U}_j \quad (7)$$

Equation (6) visualizes the trade structure of intermediate goods between sectors, which occurs throughout the supply chain of the j-th good. In this study, we use $\mathbf{B} = \left(\mathbf{I} - \left(\mathbf{I} - \hat{\mathbf{M}}\right)\mathbf{A}\right)^{-1}$ as a Leontief inverse matrix, taking into account the leakage effect due to imports.

4 Summary of IONGES

The IONGES has two kinds of tables, one that incorporates renewable energy sectors that existed in 2011 (2011 IONGES) and one that renewable energy sectors up to the composition ratio assumed in 2030 (2030 IONGES).

Table 1 Composition ratio in the 2030 IONGES

	Facility (%)	Operation (%)
Nuclear power	14.73	21.00
Thermal power	30.07	56.00
Water power	16.51	8.23
Solar power for homes	3.01	0.90
Solar power for businesses	12.13	6.16
Onshore wind power	2.55	1.51
Offshore wind power	0.55	0.21
Small hydropower	2.54	0.82
Flash type geothermal	1.11	0.82
Binary type geothermal	0.37	0.19
Woody biomass (30,000 kW class)	0.26	0.52
Woody biomass (5000 kW class)	2.19	2.29

(continued)

Table 1 (continued)

	Facility (%)	Operation (%)
Woody biomass (2000 kW class)	0.21	0.16
Methane fermentation (raw garbage)	0.61	0.02
Methane fermentation (sewage sludge)	0.02	0.01
Methane fermentation (livestock manure)	0.24	0.05
Waste incineration (large)	5.27	0.51
Waste incineration (medium)	7.63	0.61
Total	100.00	100.00

Based on the long-term energy supply-demand outlook (METI 2015a). Supplementary materials (METI 2015c, 2018b) were used for seven types of biomass power generation. The composition ratio of facility construction is that of facility construction cost calculated from the installed capacity and the construction unit price (METI 2015b, 2018a)

Table 1 shows the types of power and their component ratios (equipment composition, power generation composition) in 2030 IONGES. Table 2 shows the specifications of each type of power generation plants, which is basis for estimating the input coefficients.[6]

In IONGES, the average producer price (17 JPY/kWh) in the MIC input–output table is applied to existing power sources such as nuclear, thermal, and large-scale hydro, and to renewable energy power sources. This follows the single price principle adopted in the MIC input–output table. With this assumption, the value of electricity can be easily converted to a physical quantity (kWh) using the producer price.

However, electricity from renewable energy is actually purchased at a price higher than the producer price under the feed in tariff (FIT) scheme. In IONGES, the difference between the purchase price and the producer price is treated as a “subsidy”. In other words, it represents a deduction item in the value added sector.[7]

To create the input coefficient vector for the construction of each renewable energy facility or type of power generation, the total facility construction cost or total operation cost were determined based on the latest data at the time of creation. The total amount was then divided into individual input elements with reference to technical data from published papers and interviews for each type of renewable energy and created input coefficient vectors.

At the 2030 IONGES, we carefully described the biomass fuel input in woody biomass, methane fermentation gasification, and waste power generation sectors to analyze the impact of biomass power generation on the regional economy more accurately than it had been done before. For example, we described the input flow of the intermediate goods “woody biomass power generation sector → biomass

[6]For the 2011 and 2030 IONGES preparation method, see Washizu and Nakano (2019). The 2011 and 2030 IONGES are published on the Institute for Economic Analysis of Next-Generation Science and Technology, Waseda University, website (http://www.f.waseda.jp/washizu/).

[7]In the woody biomass and the methane fermentation biomass power generation sectors, it is assumed that part of the FIT subsidy is used to support fuel procurement.

Table 2 Power plant specifications used for estimation

	Capacity		Generation MWh/yr	Utilization rate	Construction unit (10 thousand JPY/kW)	Operation costs (10 thousand JPY/kW/yr)	FIT (JPY/kWh)	Service life
Solar power for homes	4	kW	*5*	0.137	32.70	0.30	26.50	30
Solar power for businesses	1200	kW	*1798*	0.171	23.85	0.50	18.00	30
Onshore wind power	20,000	kW	*43,450*	0.248	29.70	1.03	20.00	20
Offshore wind power	150,000	kW	*394,200*	0.3	56.50	2.25	36.00	20
Small hydropower	199	kW	*1046*	0.6	132.00	5.40	25.00	40
Flash type geothermal	30,000	kW	*218,124*	0.83	79.00	3.30	26.00	40
Binary type geothermal	50	kW	*394*	0.9	123.00	No specifications. Value estimated based on each source.	40.00	40
Woody biomass (30,000 kW)	30,000	kW	*217,016*	*0.826*	*29.67*		24.00	40
Woody biomass (5000 kW)	5000	kW	*34,164*	*0.780*	*53.00*		32.00	40
Woody biomass (2000 kW)	1990	kW	*13,474*	*0.773*	*71.36*		40.00	40
Methane fermentation (raw garbage)	50	t/day	*785*	0.300	*803.46*		39.00	30

(continued)

Table 2 (continued)

	Capacity		Generation MWh/yr	Utilization rate	Construction unit (10 thousand JPY/kW)	Operation costs (10 thousand JPY/kW/yr)	FIT (JPY/kWh)	Service life
Methane fermentation (sewage sludge)	161	M^3/day	*1486*	0.355	*53.58*		39.00	30
Methane fermentation (livestock manure)	95	t/day	*1977*	*0.752*	*265.00*		39.00	30
Waste incineration (large)	600	t/day	*26,685*	0.650	*474.43*		17.00	40
Waste incineration (medium)	300	t/day	*13,350*	0.650	*578.59*		17.00	40
HV	2.41	Million JPY/unit Cf. Specific price for gasoline vehicles: 1.8 million JPY/unit						
EV	3.54							

Italic indicates that the value is calculated backward fuel sector → forestry" clearly. We estimated the input of methane gas from the waste or sewage treatment sectors to the methane fermentation gasification power generation sector and the steam input from the waste treatment sector to the waste power generation sector. As a result, we were able to analyze the production spillovers that the demand for electricity from these power sectors induced in each fuel supply sector.

The effective utilization of compost or fermentation heat produced as by-products from waste treatment facilities is essential for the sustainable operation of power generation from methane fermentation of biomass (Yuyama et al. 2006; MLIT 2015). In the 2030 IONGES, we described a situation in which compost and fermentation heat are effectively used for regional agriculture, and the inputs of organic fertilizer and fuel oil used to heat greenhouses are mitigated accordingly. The value of compost and fermentation heat, which are by-products of waste treatment facilities, are not described in the MIC input–output table. Therefore, the total production values of the waste treatment sectors in 2030 IONGES became larger than that in the MIC table. We considered that this increase value added in the waste treatment sector.

Fuel wood inputs are a major cost in the woody biomass power generation sector. Therefore, it is reasonable to assume that a certain percentage of the subsidy of the power generation sector (defined as the difference between the FIT and the producer price of electricity) is spent on securing fuel wood. In the 2030 IONGES, the subsidy was allocated to the power generation sector and the fuel supply sector, and the fuel input to the power generation sector was reduced by the amount allocated to the latter.

Below, we outline the features of the IONGES by examining unit structures defined in Eq. (6) for some renewable energy sectors. Figure 2 shows the unit structure of methane fermentation gasification power (livestock manure) calculated by Eq. (6). It shows the trade structure of intermediate goods that one unit (one million JPY) of this power generation activity produces for the entire economy. A dot in the figure indicates that there is an intermediate goods transaction occurring, and the diameter of the dot indicates the relative size of the transaction volume. The order of the sectors in Fig. 2 is "order of triangularization" (Ozaki 1980).

Triangulation is the rearranging of input–output sectors in order of processing degree. Goods and services produced by all sectors fall into the following categories: raw materials, intermediate processing products, final products, and energy and business services used in all production processes (e.g., financial and information services). Then, sectors are rearranged in the order in which the final products are at the top. Such rearranging makes it easier to interpret the trade structure of intermediate goods. Figure 2 shows the cyclical structure of the intermediate goods transaction triggered by the following supply chain of methane fermentation gasification power; briefly, it is as follows: waste treatment sector that supplies methane gas for power generation activity → transportation sector that services the waste treatment sector → repair sector that services these sectors → other sectors supplying mechanical and chemical products to repair sectors. Figure 2 shows that intermediate transactions in information goods and services cause a new economic circulation as a result of recent digitization. Although the relative volume is small, there is also

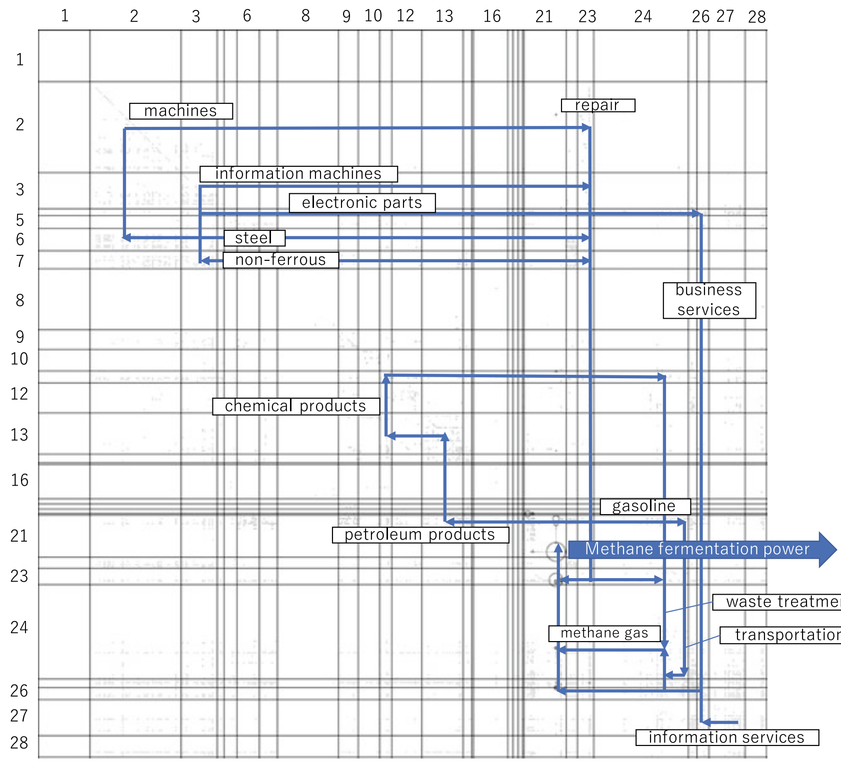


Fig. 2 Unit structure of power generation from methane fermentation (livestock manure). The sector numbers are as follows: 1. Construction, 2. Machine, 3. Information machine, 4. Primary information goods, 5. Other final industrial products, 6. Steel, 7. Non-ferrous, 8. Food, 9. Stone products, 10. Textile, 11. Rubber/Plastic/Leather goods, 12. Wood products, 13. Chemical products, 14. Inorganic chemistry, 15. Ore, 16. Agricultural products, 17. Marine products, 18. Ceramic raw materials, 19. Forestry, 20. Crude oil/Natural gas, 21. Fuel, power, 22. Metal products, 23. Repair, 24. Services, 25. Commerce/Finance/Insurance, 26. Secondary information services, 27. Primary information services, 28. Education/Research, 29. Unknown

a supply chain from the agriculture sector to waste treatment sectors via through livestock manure inputs. This chain will be important in analyzing the effects of generating power from methane fermentation gasification on the local economy.

Figures 3 and 4 show the unit structure of facility construction and power generation of offshore wind power, respectively. In Fig. 3, we can identify a large-scale triangularity structure for offshore wind power facility construction. Also, in Fig. 4, we confirmed two triangularity structures for offshore wind power generation. One of them is related to the material supply chain necessary for maintenance of facilities, and the other is related to the non-material management service for power generation activities. These two triangularity structures are closely linked through the repair sector. Recently, the New Energy and Industrial Technology Development Organization (NEDO 2019) developed a condition monitoring system (CMS) that

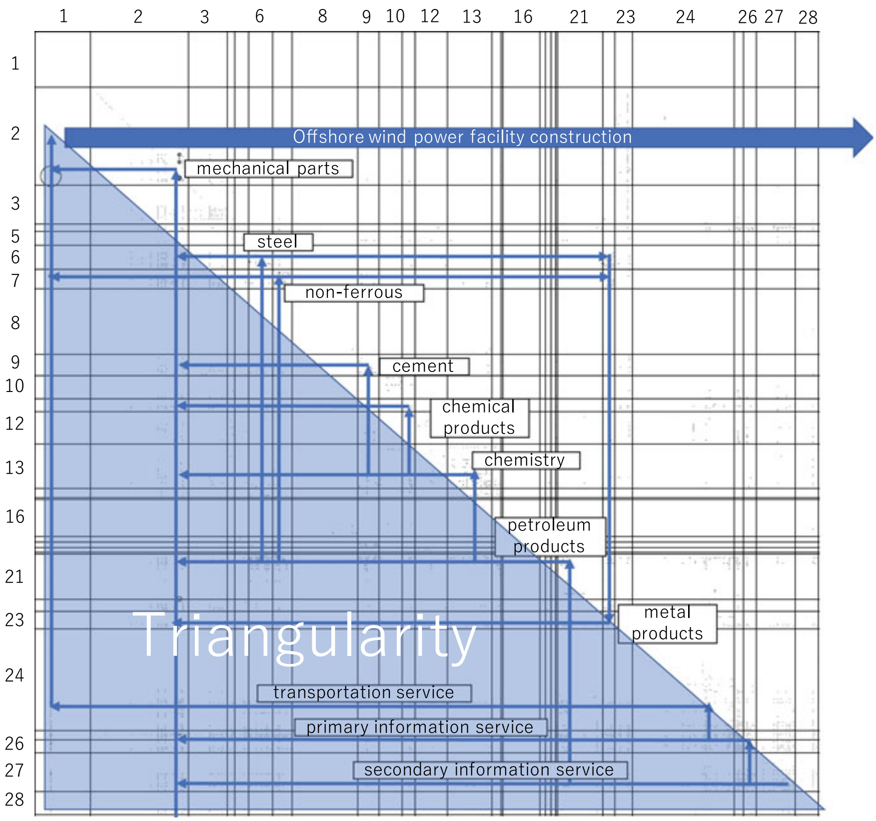


Fig. 3 Unit structure of offshore wind power facility construction. The sector name corresponding to each sector number is the same as in Fig. 2

utilizes artificial intelligence (AI) to make timely maintenance possible and streamline the operation costs of wind power generation. It is thought that, in the future, when maintenance services using CMS become widespread, the triangular structure related to management services, shown in the lower right of Fig. 4, will become more substantial than it is now, the supply chain during operation will be extended, and the ripple effect will be greater. In other words, new business opportunities in a renewable-energy society cause a new economic cycle and have a positive impact on the economy. Although the demand for facility construction is limited, the demand for facility operation is persistent, so extending the supply chain during operation is expected to have a significantly positive economic impact. It can be concluded that the spread of smart social technology in a renewable-energy society should bring about a sustainable economic cycle.

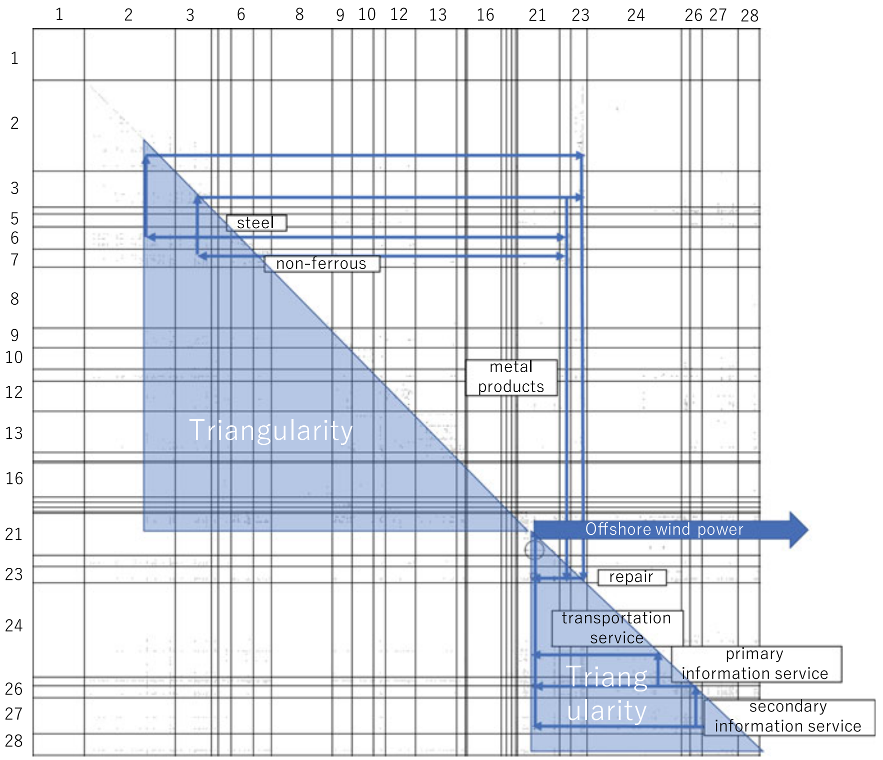


Fig. 4 Unit structure of offshore wind power generation. The sector name corresponding to each sector number is the same as in Fig. 2

5 Structural CO_2 Emissions of Renewable Energy

To confirm the ripple effects of the CO_2 emitted due to the construction and operation of renewable-energy plants, we calculated the "structural" CO_2 emissions (t-CO_2) associated with the one unit (1 million JPY) of facility construction (k_C) or generation (k_G) for renewable energy of type k.

$$SCO_{2k\_m} = \sum_i e_i \cdot b_{ik\_m}, m = C \text{ or } G, \tag{8}$$

where b_{ik_m} is an element of the Leontief inverse matrix. It shows the amount of the i-th intermediate goods needed directly or indirectly as a structural input from the economy for one unit of facility construction or renewable energy generation of type k. e_i is the CO_2 emission intensity of producing one unit of the i-th goods. Under the producer price of electricity (17 JPY/kWh), SCO_{2k_G}. (t-CO_2) represents the "structural" CO_2 emissions for electricity generation of ($1 \times 10^6 \div 17 = 5.88 \times 10^4$ kWh). The structural operating CO_2 emissions per unit of the power generation of this power plant can be calculated as follows:

$$\widehat{SCO_{2k\_G}} = SCO_{2k\_G} \cdot \frac{100}{5.88}(\mathrm{CO_2/kWh}) \tag{9}$$

With respect to the CO_2 emissions from facility construction, assuming that the unit price of facility construction of the k-th renewable energy type is α_k (10,000 JPY/kW), the equipment utilization rate is β_k, the lifetime power generation provided by one unit (1 million JPY) of the k-th renewable energy facility is as follows:

$$100 \times \frac{1}{\alpha_k} \times 8760 \times \beta_k \times \gamma_k = 8.76 \times 10^5 \times \frac{\beta_k \gamma_k}{\alpha_k} \tag{10}$$

Here, 8760 is the total number of hours in a year. By dividing the "structural" CO_2 emissions associated with one unit of facility construction of the k-th renewable energy power generation facility by Eq. (10), the CO_2 emissions from facility construction per unit of lifetime power generation is defined as follows:

$$\widehat{SCO_{2k\_C}} = SCO_{2k\_C} \times \frac{10}{8.76} \frac{\alpha_k}{\beta_k \gamma_k}(\mathrm{g - CO_2/kWh}) \tag{11}$$

The assumed construction unit price α_k (10,000 JPY/kW), the equipment utilization ratio β_k, and the useful life γ_k (years) assumed for each type of renewable energy are shown in Table 2.

Equation (12) is used to calculate the total CO_2 emissions that the power plant of the k-th renewable-energy type can reduce with respect to thermal power during its useful life.

$$\widehat{TSCO_{2k}} = \frac{8.76 \times \beta_k \gamma_k}{1000}\left(\widehat{SCO_{2Thermal\_G}} - \widehat{SCO_{2k\_G}} - \widehat{SCO_{2k\_C}}\right)(\mathrm{t - CO_2}) \tag{12}$$

$\widehat{SCO_{2Thermal\_G}}$ is the CO_2 emission induced by generating 1 kWh of thermal power. The expression in parentheses in Eq. (12) indicates the CO_2 emissions that the 1-kW renewable-energy power generation equipment can reduce per hour with respect to thermal power generation. Because the existing thermal power plant can be used, the CO_2 emissions induced by the construction of the thermal power plant are not included in this calculation.

The vertical axis in Fig. 5 indicates the structural CO_2 emissions per unit of power generated, based on Eq. (9). The horizontal axis shows the structural CO_2 emissions of constructing each type of power generation facility per unit of lifetime power it generates, as calculated using Eq. (11). The diameter of the circle indicates the relative magnitude of the power generation of each source assumed in 2030. As shown in Fig. 5, the operation and construction of methane fermentation and waste incineration power generation facilities have large structural CO_2 emissions. It should be noted, however, that these facilities perform waste treatment as well

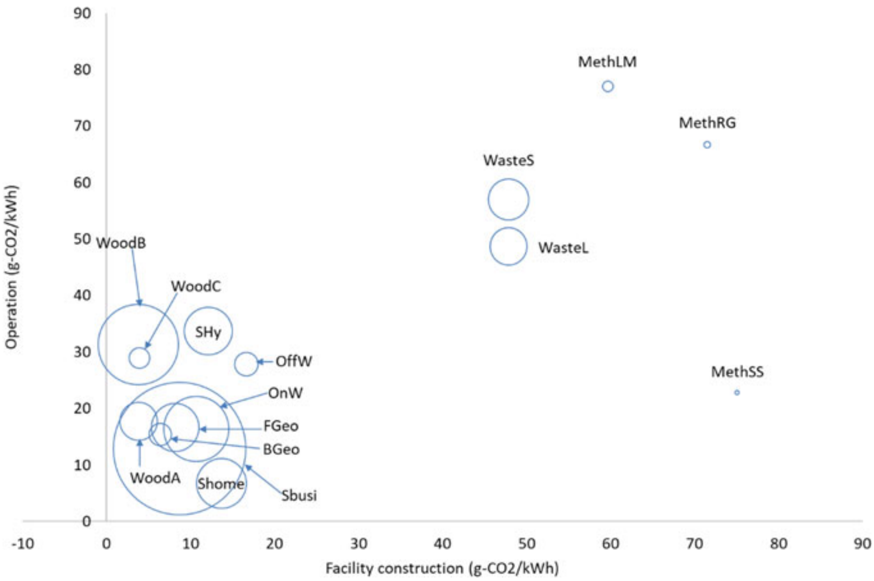


Fig. 5 Structural CO_2 emissions. Diameter of a circle indicates the magnitude of the power generation composition ratio assumed in 2030. The average CO_2 emission intensity during operation of a thermal power plant is 641 g-CO_2/kWh. Abbreviations: *Shome* solar power for homes, *Sbusi* solar power for businesses, *OnW* onshore wind power, *OffW* offshore wind power, *SHy* small hydropower, *FGeo* flash type geothermal, *BGeo* binary type geothermal, *Wood* woody biomass, *Meth* methane fermentation, *Waste* waste incineration

as power generation functions, so the total structural CO_2 emissions include those produced from waste treatment. Since the structural CO_2 emissions from thermal power generation (operation) are 641 g-CO_2/kWh, the values of renewable power generation are clearly much lower, as shown by the vertical axis.

Figure 6 shows the calculation result of Eq. (12) for each type of renewable energy. Renewable-energy types with relatively large equipment utilization rates and long useful lives, such as small and medium hydropower, geothermal, woody biomass power, and waste incineration generation, have a large total lifetime CO_2 reduction effect with respect to thermal power. The total lifetime CO_2 reduction effect from methane fermentation power generation is also large compared to solar and wind power. By multiplying the amount of CO_2 reduction shown in Fig. 6 by the projected carbon tax (JPY/CO_2-t), the total lifetime cost reduction from carbon tax per capacity (kW) of each renewable energy power generation facility can be calculated.

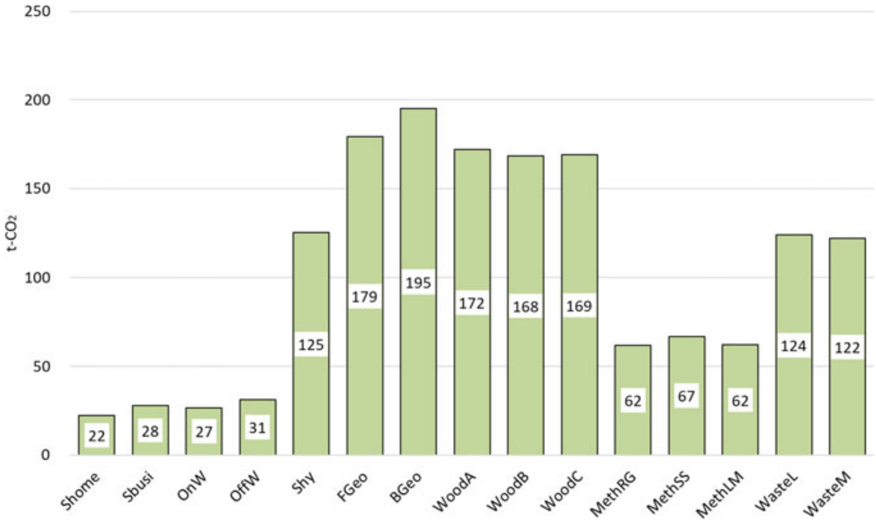


Fig. 6 Net lifetime CO_2 reductions per kW for each power plant (compared to thermal power plants). Abbreviations are same as Fig. 5

6 Analysis of the Carbon Taxation Method

Using the 2011 and 2030 IONGES data, we analyzed the effects of the following three carbon taxation methods on economic society: (i) Upstream taxation, (ii) Midstream taxation, and (iii) Downstream taxation. Upstream taxation is a method of taxing raw coal, crude oil, and LNG at the time of production or at the time of customs clearance. The carbon tax would be passed on to the price of the raw fuel. Furthermore, imported petroleum products would be taxed at the time of customs clearance. Midstream taxation is a method of taxing petroleum and coal products manufacturers, electric power companies, and gas manufacturing companies. These vendors would pass the carbon tax on the prices of petroleum and coal products, electricity and city gas they sell. In this case, the energy end-user (such as a household) indirectly pays the imputed carbon tax, as well as directly pays the tax when using kerosene, gasoline, or city gas. Downstream taxation is a method of taxing those who ultimately use petroleum and coal products, electricity, and city gas. In this case, unlike the case of midstream taxation, no carbon tax is imposed on the power producer. Moreover, end-users of energy (such as households) not only pay carbon taxes passed on to consumer goods and services, but also on fossil fuel-produced energy contained in electricity and direct use of kerosene, gasoline, and city gas. Tax collection costs are expected to increase from upstream to downstream.

For this analysis, we created three types of CO_2 emissions unit (CO_2 emissions per unit production value of each input–output sector) vectors. The 3EID database from the National Institute for Environmental Studies has estimated CO_2 emissions of each MIC Input–Output sector, and we made it correspond to our IONGES. Here, we independently estimated the CO_2 emissions of the renewable energy sectors in IONGES. By recomposing it as shown in Figs. 7, 8 and 9, we have estimated taxable CO_2 emissions allocated to each input–output sector under each upstream, midstream, and downstream taxation method.

In Fig. 7, taxable CO_2 emissions are allocated mainly to energy conversion sectors (coal/petroleum products, electricity, and city gas sectors). In Fig. 8, taxable CO_2 is allocated to sectors that ultimately consume fossil fuels and it is considered that there is no CO_2 emission associated with electricity consumption. In Figs. 7 and 8, the sum of CO_2 emissions of cells filled in the same pattern are equal to each other. The allocation method of CO_2 emissions of Fig. 8 corresponds with the framework of 3EID. In Fig. 9, all CO_2 emissions from electricity and city gas production are allocated to the final consumers of these energies. In Fig. 8a, b (which are only presented differently for convenience of explanation; the allocation of taxable CO_2 is the same in both) and Fig. 9, the sums of taxable CO_2 emissions in cells filled with the same pattern are equal to each other.

By dividing the total taxable CO_2 emissions allocated to each sector (indicated by the cells filled with dots at the bottom) in Figs. 7, 8 and 9 by the output of that sector, we have prepared three types of CO_2 emission unit vectors. Using these unit vectors and the 2011 or 2030 IONGES, taxable CO_2 emissions are ultimately induced when producing each good/service are calculated as follows.

$$\mathbf{E}^{\boldsymbol{prod}(\boldsymbol{k})} = \left(\mathbf{I} - \left(\mathbf{I} - \hat{\mathbf{M}}\right)\mathbf{A}\right)^{-1}\mathbf{E}^{(\boldsymbol{k})}, k = \text{i, ii, iii} \tag{13}$$

$\mathbf{E}^{\boldsymbol{prod}(\boldsymbol{k})}$: Vector with elements of taxable CO_2 emissions embodied in each good or service under taxation method (k)

$\mathbf{E}^{(\boldsymbol{k})}$: Vector with elements of CO_2 emission units under taxation method (k)

$\left(\mathbf{I} - \left(\mathbf{I} - \hat{\mathbf{M}}\right)\mathbf{A}\right)^{-1}$: Leontief inverse matrix of 2011 or 2030 IONGES.

Value of each element of vector $\mathbf{E}^{\boldsymbol{prod}(\boldsymbol{k})}$ is proportional to the amount of carbon tax transferred to selling price of each good or service.

	General sectors	Petroleum and coal products	Electricity	City gas	Household
Coal(direct use)					0
Coal(for processing)	0		0	0	0
Crude petroleum	0		0	0	0
LNG(direct use)					0
LNG(for processing)	0	0	0		0
Coal and petroleum products (domestic)	0	0	0	0	0
Coal and petroleum products (import)					0
Electricity	0	0	0	0	0
City gas	0	0	0	0	0
Total taxable CO_2 emissions					0

Fig. 7 (i) Upstream taxation

	General sectors	Petroleum and coal products	Electricity	City gas	Household
Coal(direct use)					0
Coal(for processing)	0	0	0	0	0
Crude petroleum	0	0	0	0	0
LNG(direct use)					0
LNG(for processing)	0	0	0	0	0
Coal and petroleum products (domestic)					
Coal and petroleum products (import)					
Electricity	0	0	0	0	0
City gas					
Total taxable CO_2 emissions					

	General sectors	Petroleum and coal products	Electricity	City gas	Household
Coal(direct use)					0
Coal(for processing)	0	0	0	0	0
Crude petroleum	0	0	0	0	0
LNG(direct use)					0
LNG(for processing)	0	0	0	0	0
Coal and petroleum products (domestic)					
Coal and petroleum products (import)					
Electricity	0	0	0	0	0
City gas					
Total taxable CO_2 emissions					

Fig. 8 **a**, **b** (ii) Midstream taxation

	General sectors	Petroleum and coal products	Electricity	City gas	Household
Coal(direct use)			0	0	0
Coal(for processing)	0	0	0	0	0
Crude petroleum	0	0	0	0	0
LNG(direct use)			0	0	0
LNG(for processing)	0	0	0	0	0
Coal and petroleum products (domestic)			0	0	
Coal and petroleum products (import)			0	0	
Electricity					
City gas					
Total taxable CO_2 emissions					

Fig. 9 (iii) Downstream taxation

The taxable CO_2 emissions induced by final demand were calculated by the following equation. This calculation results show the carbon tax burden associated with consumption of goods and services by people.

$$\mathbf{E}^{FD(k)} = \widehat{\mathbf{E}^{(k)}}\left(\mathbf{I} - \left(\mathbf{I} - \hat{\mathbf{M}}\right)\mathbf{A}\right)^{-1}\mathbf{F} + \mathbf{D}^{(k)}, k = \text{i, ii, iii} \quad (14)$$

$\mathbf{E}^{FD(k)}$: Vector with elements of taxable CO_2 emissions induced by final demand under taxation method (k)

$\widehat{\mathbf{E}^{(k)}}$: Diagonal matrix with elements of CO_2 emission units under taxation method (k)

F: Vector of final demand

$\mathbf{D}^{(k)}$: Vector with elements of taxable CO_2 emissions from final demand energy under taxation method (k).

All elements of the vector $\mathbf{E}^{prod(k)}$ are sorted in descending order and illustrated in Fig. 10. The figure is the result of using the Leontief inverse matrix of IONGES for 2030, and it shows the results under the taxation methods of upstream and downstream. Figure 10 can be interpreted as marginal carbon tax cost showing how much cost of each good or service increases by one unit of carbon taxation. In the upstream taxation method, the taxation effects of one unit of carbon tax are concentrated in energy goods such as coal products and petroleum basic, while in downstream taxation method, the effects are relatively dispersed. In upstream taxation method, the taxation effects on goods such as coal products and petroleum basic are great. Yabe and Hayashi (2020) argued that if the carbon tax exceeds 10,000 JPY/t-CO_2, coal-fired thermal power generation will be replaced by LNG thermal power generation, and CO_2 emission unit of electricity will decrease. The Japan Center for Economic Research (JCER 2019) states that under 10,000 JPY of carbon tax, CO_2 emissions can be reduced by 80% compared to 2013 in 2050. Figure 10 indicates the carbon tax burden amount (JPY) for the production of every 100 JPY worth of each product or service, when assuming carbon taxation of 10,000 JPY/t-CO_2.

Figure 11 shows the calculation results of Eq. (14) using the 2030 IONGES under three taxation method assumptions. The taxable CO_2 emissions induced by final demand are between 1.07 and 1.10 billion t-CO_2. These values are 12% (under midstream or downstream taxation method) to 13.3% (under upstream taxation method) lower than the calculation results when using 2011 IONGES. In other words, if renewable energy is introduced to the government target level in 2030, taxable CO_2 emissions will decrease by 12–13.3%. Assuming that the carbon tax is 10,000 JPY/t-CO_2, there will be a tax revenue of 10.7–11.0 trillion yen in 2030.

Under the upstream taxation method, 90% or more of those tax revenues are collected at time of sale of secondary products. On the other hand, under the midstream taxation method, about 75% of carbon tax revenue is collected at time of sale of the secondary product and about 24% is collected at the sale of the third product. Under the downstream taxation method, their values are 61 and 32% respectively. With the downstream taxation method, the carbon tax burden associated with service consumption will increase. Compared with the upstream taxation method, in the midstream and downstream taxation methods, the induced CO_2 emissions are distributed more evenly across various goods and services.

Under the upstream taxation method, the most taxable CO_2 comes from the 529 million t-CO_2 from household consumption and 293 million t-CO_2 from exports. Under the downstream taxation method, these amounts change to 544 million t-CO_2 from household consumption and 270 million t-CO_2 from exports. Compared to the downstream taxation method, upstream taxation led to higher CO_2 emissions from

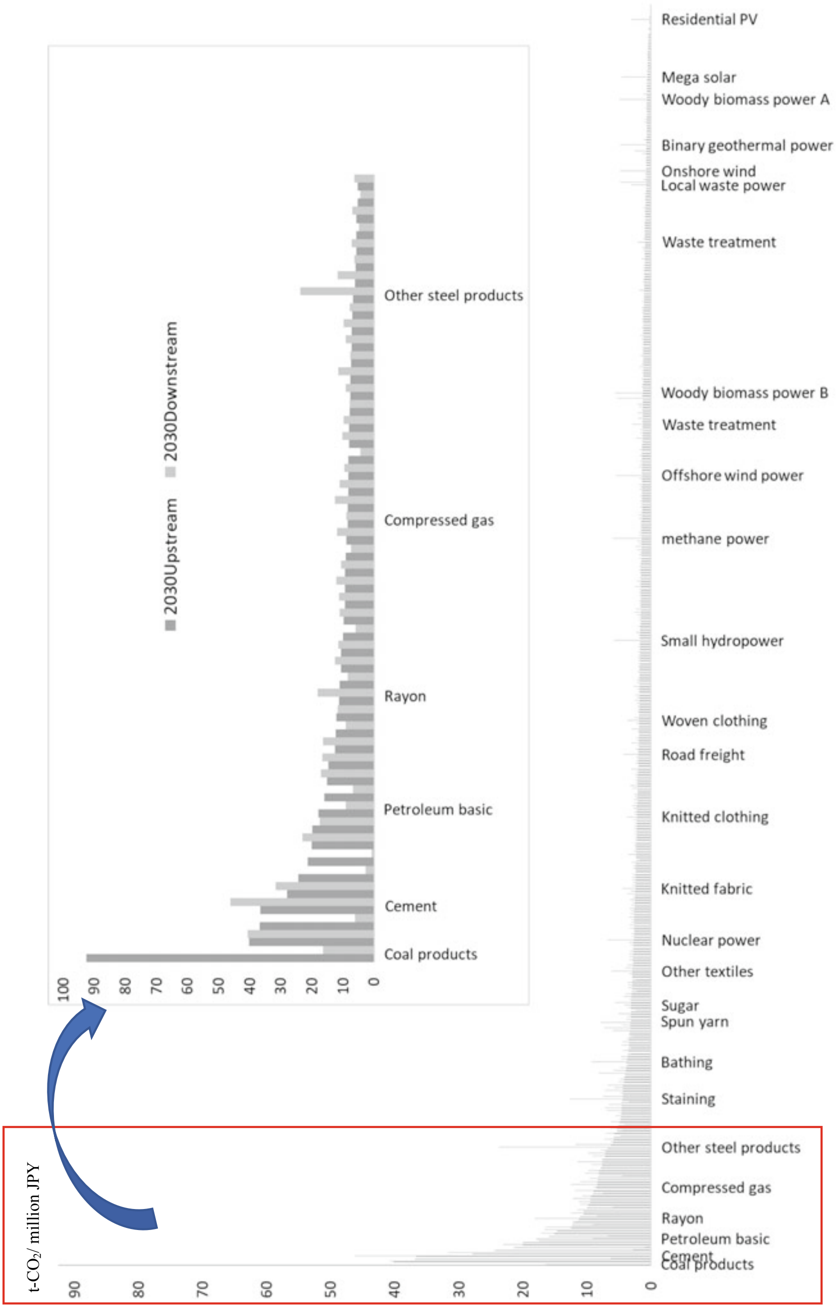


Fig. 10 Taxable CO_2 emissions embodied per million JPY of good or service

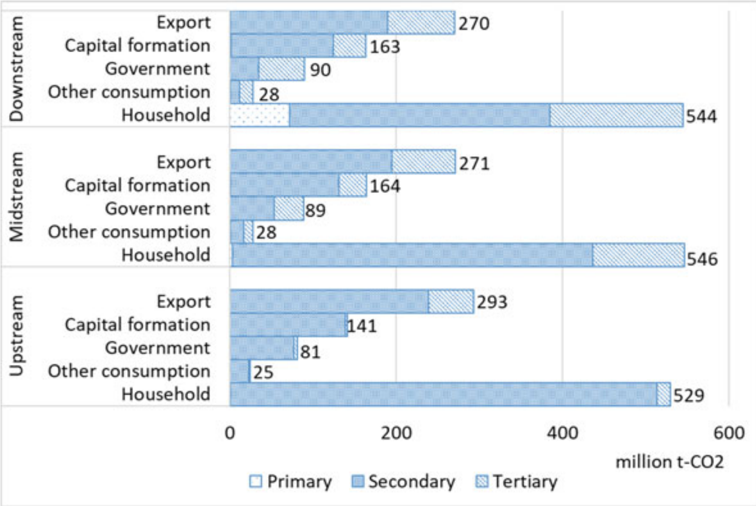


Fig. 11 Induced taxable CO_2 emissions by final demand using 2030 IONGES

exports, but lower CO_2 emissions from household consumption. This is because energy-intensive industries such as machinery have high export ratios. This suggests that the impact of a carbon tax on export competitiveness varies with the taxation method.

Figure 12 shows taxable CO_2 emissions induced by household consumption by expenditure category. This is the result of a calculation where the final demand vector **F** in Eq. (14) is replaced with $\mathbf{F}_{household}$, which indicates the final consumption in households. In the figure, the bar corresponding to "Household" in Fig. 11 is categorized as per consumption item. The calculation results of taxable CO_2 emissions induced by household consumption using Eq. (14) is 529 (in the case of downstream taxation using 2030 IONGES) to 647 (in the case of midstream taxation using 2011 IONGES) million t-CO_2. The number of Japanese households in 2011 is 53.8 million, so this corresponds to 9.8–12.0 t-CO_2 per household. Under the upstream taxation method, the ratio of induced CO_2 emissions from the energy related expenditure category is large. The ratio is 52.2% (using 2011 IONGES) and 51.7% (using 2030 IONGES) under upstream taxation, while it is around 48.0% (using 2011 IONGES) and 46.5% (using 2030 IONGES) under midstream and downstream taxation methods. Particularly under the downstream taxation method, the ratio of CO_2 emissions induced by electricity consumption is significantly small (the ratio under downstream taxation is 5.5%, whereas the ratio under upstream and midstream taxation is approximately 19.5%). Under the upstream and midstream taxation methods, consumers will pay attention mainly to saving electricity, while under the downstream taxation method, they will pay attention to saving goods and services generally produced using energy, including electricity. Especially in the case of downstream taxation, the energy used for power generation is apparently allocated

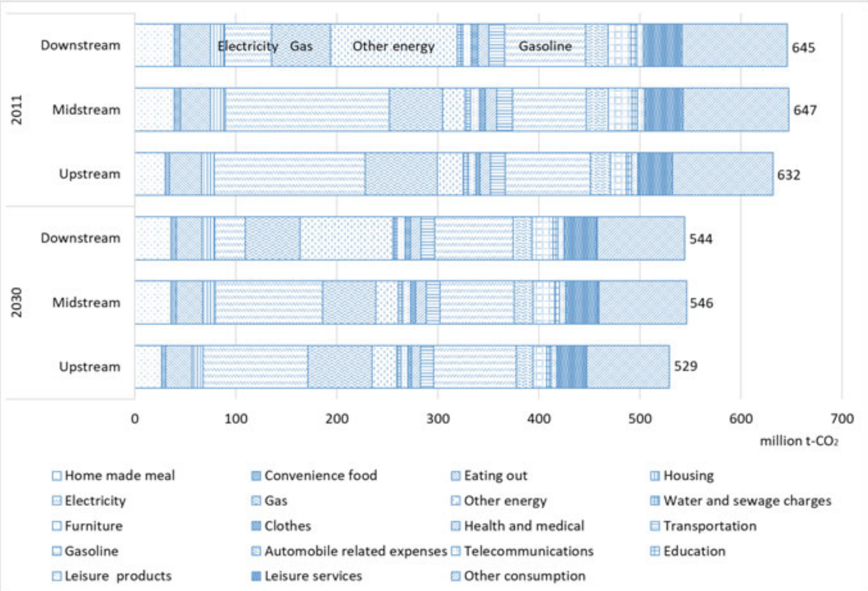


Fig. 12 Induced taxable CO_2 emissions by household expense category under 2011 and 2030 IONGES

to households. As a result, in the case of downstream taxation, households apparently consume a wide variety of energy (including energy converted to electricity), which cause households to become interested in fuels that generate electricity.

7 Discussion

The purpose of carbon taxation is summarized in Table 3. Its purpose is roughly divided into three categories, and the purpose of each category is divided into two according to the degree of innovation required to achieve the purpose. A relatively large carbon tax introduction effect can be expected for purposes in the two lightly filled cells. In order to minimize cost increase associated with introduction of carbon tax, consumers will choose goods and services with as little embodied CO_2 as possible, or introduce home solar power generators. However, careful consideration of the relationship between the carbon tax system and the system that has already been introduced is required, for example the Feed-in Tariff system.

Changes in the industrial structure, such as the transformation of economic structures into services, will promote energy saving throughout society. While progress in services is a phenomenon common to developed economies, we must also pay attention to the economic importance of heavy industries such as steel and chemicals. Ozaki (1980) clarified that the improvement in productivity of basic materials

Table 3 Purpose of carbon taxation

Need for innovation	Decarbonization	Individual energy saving	Social energy saving
Not much needed	• Renewable energy introduction	• Energy saving behavior	• Change of industrial structure
Much needed	• Advanced use of renewable energy • Hydrogen utilization	• Smart energy use • Blast furnace hydrogen reduction technology • CCS, CCU	• Building Society 5.0 • Building sharing economy and circular economy

Author created with reference to handouts of "Central Environment Council, Global Environment Division, Subcommittee on the use of carbon pricing"
CCS carbon dioxide capture and storage, *CCU* carbon dioxide capture and utilization

industries increased the productivity of the machinery industries that used them as raw materials. Furthermore, in recent years, the utilization of information and communication technology has increased the equipment ratio in service industries. As a result, the improvement in productivity of machinery industries will spread to service industries. Specifically, the energy productivity of the Japanese steel industry is the highest in the world (IEA 2014), so if the carbon tax system works effectively on a global basis, the Japanese steel industry should have international competitiveness. A single country's carbon tax system cannot be expected to reduce global energy consumption. An internationally coordinated carbon tax system is needed.

For the purposes of technological innovation, the carbon tax system alone cannot achieve the goal, and collaboration with science and technology policy is important. Since technological innovation requires a large amount of development funds, social consensus building is essential with respect to which technological development should be prioritized and which alternative technology paradigm should be chosen. These problems cannot be solved only by a carbon tax system. However, it may affect investors' decisions to fund these innovations. The scheme of a carbon tax system will differ depending on which targets in Table 3 are included in the policy targets.

8 Conclusion

In this study, we developed the 2011 and 2030 Input–output table for analysis of next generation energy system (IONGES) to analyze the ripple effects of CO_2 emissions from the construction and operation of renewable-energy power plants. Using the IONGES tables, we estimated the lifetime CO_2 reduction of each renewable energy power generation facility compared to thermal power generation. This allowed us to compare the reduction in carbon tax costs of each renewable energy power plant with respect to thermal power generation for a given capacity (kW).

According to the calculation results, the lifetime CO_2 reduction effect (from thermal power generation) per capacity for each type of renewable energy power generation facility varies significantly. In discussing the use of carbon tax revenues, Takeda (2007) revealed that replacing tax revenues with capital tax cuts would have a positive economic effect. Therefore, promoting investment in renewable energy plants by reducing the capital tax will reduce carbon emissions in the long term, and thus, it would be an economically and environmentally desirable policy. However, strategies are needed regarding which renewable energy generation plants should be invested in. Our results suggest that the environmental benefits obtained from investing in power plants of the same capacity vary significantly depending on the type of renewable energy.

Furthermore, according to the Japanese Ministry of the Environment (2018), an emission trading system has been proposed as a measure to ensure businesses that emit large amounts of CO_2 reduce their emissions. Therefore, an emission trading system should be used to promote the introduction of renewable energy to electric businesses. In doing so, the quantitative evidence in Figs. 5 and 6 for renewable energy power generation could be used to contribute to the design of these schemes.

Using the IONGES tables, we also conducted an analysis of the effects of the differences in the upstream, midstream, and downstream methods. We found that taxable CO_2 emissions are ultimately induced when producing each good or service. As a result, in the upstream taxation method, the effects of one unit of carbon tax are concentrated in energy goods such as coal products and petroleum basic, while in the downstream taxation method, the effects are relatively dispersed. In the upstream taxation method, the taxation effects on goods such as coal products and petroleum basic are significant.

We also calculated the taxable CO_2 emissions induced by each final demand. The results show the carbon tax burden associated with the final demand of goods and services. If renewable energy is added to the government target level in 2030, taxable CO_2 emissions will decrease by 12–13.3%. Compared with the upstream method, in the midstream and downstream methods, the CO_2 emissions induced by each final demand are distributed more evenly across various goods and services. Compared to the downstream taxation method, upstream taxation leads to higher CO_2 emissions from exports, but lower CO_2 emissions from household consumption. This is because energy-intensive industries such as machinery have high export ratios. This suggests that the impact of a carbon tax on export competitiveness varies with the taxation method. Generally, it is said that upstream taxation reduces taxation costs. However, the results of this study suggest that the effects of upstream taxation on Japan's export competitiveness must be carefully considered.

According to Sugino et al. (2013), to equalize the carbon tax burden among industries, an 85% carbon tax rebate ratio should be applied to energy-intensive trade-exposed (EITE) industries such as pig iron. In our analysis, the carbon tax burden on energy goods will be higher under upstream taxation, so this rebate ratio may need to be increased. Since a trade-off is expected between the magnitude of the tax rebate ratio and the emission reduction effect, it is necessary to carefully consider how upstream taxation should be implemented.

We analyzed which expenditure categories contribute to the carbon tax burden associated with household consumption. The result shows that the distribution of induced CO_2 emissions from various consumer goods and services differs greatly depending on the taxation method. In other words, each taxation method delivers a different message to households about the best energy saving behavior. In the case of upstream taxation, households mainly focus on reducing electricity consumption. In the case of downstream taxation, households reduce consumption of various energy-intensive goods and services. In that case, households are also deeply interested in the sources of their electricity. Institutional design of carbon pricing should be made considering the effect different taxation methods can have on the message to consumers.

Finally, we categorized our carbon tax targets. The carbon tax system alone cannot achieve the goal, and collaboration with science and technology policy is important for the required technological innovation. However, it may affect investors' decisions to fund these innovations. The schemes of a carbon tax system need to be carefully considered according to their purpose, especially when achieving the goal requires innovation. In this regard, analysis of the ripple effects of technological change using input–output tables would have important implications.

We believe that the detailed and quantitative results from this input–output analysis will help determine the appropriate and specific institutional design for the implementation of carbon pricing. In future research, we will use the 2011 and 2030 IONGES developed herein to quantitatively assess the social and environmental effects when different goals are achieved, taking into consideration the best combination of technological progress and economic schemes (e.g., carbon taxes).

Acknowledgements This study was supported by a MEXT Grant-in-Aid for Scientific Research (15KT0121, 16K12663, 19KT0037), a Waseda University Grant for Special Research Projects (2019C-308), and the Environment Research and Technology Development Fund (JPMEERF20172007) of the Environmental Restoration and Conservation Agency and MOE.

References

Asakura K, Hayami H, Mizoshita M, Nakamura M, Nakano S, Shinozaki M, Washizu A, Yoshioka K (2001) The input–output table for environmental analysis. Keio University Press (in Japanese)

Hayami H, Ikeda (Washizu) A, Suga M, Ching WY, Yoshioka K (1996a) A simulation analysis of the environmental effects of energy saving housing. Keio Econ Observ Rev 8:115–133

Hayami H, Ikeda (Washizu) A, Suga M, Ching WY, Yoshioka K (1996b) The CO_2 emission score table for the compilation of household accounts. Keio Econ Observ Rev 8:90–103

Hayami H, Ikeda (Washizu) A, Suga M, Yoshioka K (1993) Estimation of air pollutions and evaluating CO_2 emissions from production activities: using Japan's 1985 input-output tables. J Appl Input-Output Anal 1(2):29–45

Hondo Y, Nishimura K, Uchiyama Y (1996) Energy requirements and CO_2 emissions in production of goods and services: application of input–output table to life-cycle analysis. Central Research Institute of Electric Power Industry (CRIEPI) Research Report, Y95013 (in Japanese)

Hondo Y, Uchiyama Y, Tonooka Y (1998) Environmental burdens associated production in Japan using input–output table. Central Research Institute of Electric Power Industry (CRIEPI) Research Report, Y97017 (in Japanese)
Hondo Y, Moriizumi Y, Tonooka Y (2002) Estimation of energy and greenhouse gas intensities using 1995 Japanese input-output table: inventory data reflecting the actual conditions of overseas production activities, Central Research Institute of Electric Power Industry (CRIEPI) Research Report, Y01009 (in Japanese)
Ikeda (Washizu) A, Suga M, Shinozaki M, Hayami H, Fujiwara K, Yoshioka K (1996) The input-output table for environmental analysis. KEO Monograph Series No. 7, Keio Economic Observatory, Keio University (in Japanese)
International Energy Agency (IEA) (2014) Energy technology perspective 2014
Japan Center for Economic Research (JCER) (2019) Zero emissions under the fourth industrial revolution, https://www.jcer.or.jp/jcer_download_log.php?post_id=47122&file_post_id=47124
Kovanda J (2019) Use of physical supply and use tables for calculation of economy-wide material flow indicators. J Ind Ecol 23(4):893–905
Leontief W (1951) The structure of american economy 1919–1939. International Arts and Sciences Press, New York
Leontief W (1986a) Environmental repercussions and the economic structure: an input-output approach (1970). In: Input-output economics, 2nd edn. Oxford University Press, Oxford, pp 241–260
Leontief W (1986b) Air pollution and the economic structure: empirical results of input-output computations (1972). In: Input-output economics, 2nd edn. Oxford University Press, Oxford, pp 273–293
Marin G, Mazzanti M, Montini A (2012) Linking NAMEA and Input output for 'consumption vs. production perspective' analyses: evidence on emission efficiency and aggregation biases using the Italian and Spanish environmental accounts. Ecol Econ 74:71–84
Ministry of Economy, Trade, and Industry (METI) (2015a) long-term energy supply-demand outlook. http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/pdf/report_02.pdf. Last access: 2018.11.1
Ministry of Economy, Trade, and Industry (METI) (2015b) Specifications of each power supply, http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/pdf/cost_wg_03.pdf. Last access 2018.11.1
Ministry of Economy, Trade, and Industry (METI) (2015c) Materials from the comprehensive resource and energy research committee, long-term energy supply and demand outlook subcommittee, http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/004/. Last access 2018.11.1
Ministry of Economy, Trade, and Industry (METI) (2018a) Opinions on procurement prices, etc. after FY2018, http://www.meti.go.jp/report/whitepaper/data/pdf/20180207001_1.pdf. Last access 2018.11.1
Ministry of Economy, Trade, and Industry (METI) (2018b) Feed in tariff information website, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/statistics/index.html. Last access 2018.11.1
Ministry of International Trade and Industry (MITI) (1971) Input-output table for pollution analysis–sulfur oxide pollution analysis in the Kanto Coastal area. Gov Pollut Data 6(6):17–55 (Pollution Research Center)
Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2015) Sewage sludge energy technology guidelines, http://www.mlit.go.jp/common/001083170.pdf
Ministry of the Environment (MOE) (2018) Summary of "review committee on carbon pricing", https://www.env.go.jp/earth/cp_report.pdf. Last access 2019.12.30
Moriizumi Y, Hondo Y, Nakano S (2015) Development and application of renewable energy-focused input-output table. J Jpn Inst Energy 94:1397–1413
Nakamura S, Kondo Y (2002) Input-output analysis of waste management. J Ind Ecol 6(1):39–63

Nakamura S, Nansai K (2016) Input–output and hybrid LCA (Chap. 6). In: Special types of life cycle assessment. Springer, Berlin

Nakano S (2009) The input-output table for environmental analysis 2005: estimation and results. KEO Discussion Paper No.117, Keio Economic Observatory, Keio University (in Japanese)

Nakano S, Hayami H, Nakamura M, Suzuki M (2008) The input-output table for environmental analysis and its application. Keio University Press (in Japanese)

Nakano S, Arai S, Washizu A (2017) Economic impacts of Japan's renewable energy sector and the feed-in tariff system: using an input–output table to analyze a next-generation energy system. Environ Econ Policy Stud 19(3):555–580

Nakano S, Arai S, Washizu A (2018) Development and application of an inter-regional input-output table for analysis of a next generation energy system. Renew Sustain Energy Rev 82:2834–2842

New Energy and Industrial Technology Development Organization (NEDO) (2019) Outcome report, https://www.nedo.go.jp/library/seika/shosai_201903/20190000000059.html

Ozaki I (1980) The structure of economic development (III): a statistical determination of economic fundamental structure. Mita J Econ 73(5):66–94

Sugino M, Arimura TH, Morgenstern R (2013) The effects of alternative carbon mitigation policies on Japanese industries. Energy Policy 62:1254–1267

Sun Z, Tukker A, Behrens P (2019) Going global to local: connecting top-down accounting and local impacts, a methodological review of spatially explicit input-output approaches. Environ Sci Technol 53(3):1048–1062

Takeda S (2007) Possibility of double dividend in CO_2 emission control: evaluation by dynamic applied general equilibrium analysis, mimeo http://shirotakeda.org/ja/research-ja/dd-carbon-ja.html. Last access 2019.12.30

Vercalsteren A, Christis M, Geerken T, Van der Linden A (2020) Policy needs (to be) covered by static environmentally extended input–output analyses. Econ Syst Res 32(1):121–144

Wakiyama T, Lenzen M, Geschke A, Bamba R, Nansai K (2020) A flexible multiregional input–output database for city-level sustainability footprint analysis in Japan. Resour Conserv Recycl 154:104588

Washizu A, Nakano S (2019) Creation and application of the 2011 input-output table for the next-generation energy system. Waseda University, IASS WP 2019-E001,1-18

Yabe K, Hayashi Y (2020) Environmental and economic evaluation of the introduction of CO_2 reduction surcharge and storage battery considering the energy chain. J Jpn Soc Energy Resour 40(3):69–77

Yuyama Y, Ikumura R, Ohara A, Kobayashi H, Nakamura M (2006) Evaluation of performance and costs of various biomass conversion technologies. Tech Rep Natl Res Inst Agric Eng 204:61–103

Dr. Ayu Washizu is a Professor of School of Social Sciences, Director of the Institute for Economic Analysis of Next-generation Science and Technology, and Vice Director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Her research interests include input-output analysis, renewable energy, smart society utilizing information communication technology. She has published her research in academic journals such as *Renewable and Sustainable Energy Reviews, Journal of Environmental Management, Telecommunications Policy, Environmental Economics and Policy Studies, Journal of Japan Institute of Energy, or Economic System Research.* She holds a Ph.D. in commerce and an M.Sc. in economics and a B.A. in economics from Keio University. She has served on a number of Japanese local government committees on social works including the committees on public works evaluation committee of the City of Yokohama and the port council emission of City of Kawasaki. She has also been on editorial boards of academic journals such as *Energy and Resources.* She is awarded Best Presentation Paper Award from 4th International Symposium on Environmentally Conscious Design and Inverse Manufacturing EcoDesign (2005), and Paper Award from Japan Society of Material Cycles and Waste Management (2010).

Dr. Satoshi Nakano is a Professor of Faculty of Economics at Nihon Fukushi University in Aichi. Prior to joining Nihon Fukushi University, he was a researcher at the Japan Institute for Labour Policy and Training in Tokyo. His research interests include technological change, innovation, energy policies and environmentally friendly consumer behavior.

Chapter 10
The Competitiveness Issue of the Japanese Economy Under Carbon Pricing: A Computable General Equilibrium Analysis of 2050

Shiro Takeda

Abstract Using a computable general equilibrium (CGE) model, this paper investigates the impact of carbon regulations on the Japanese economy. We use an 11-sector, 15-region global dynamic CGE model with a time span from 2011 to 2050. We assume that Japan (along with other developed regions) reduces CO_2 emissions by 80% by 2050 and analyze the impact on the Japanese economy. In particular, we consider multiple scenarios of CO_2 reduction rates in less developed regions and analyze how changes in CO_2 reduction in these regions affect Japan. In addition, we also consider multiple scenarios of the use of a border adjustment policy and analyze its impact. Our simulation results are summarized as follows. First, an 80% CO_2 reduction in Japan generates large negative impacts on the Japanese economy in terms of both the macroeconomy and individual sectors. Second, changes in the reduction rates in less developed regions have only a small impact on Japan. Third, the use of border adjustment in Japan has a small impact on the GDP and welfare of Japan overall but a large impact on output in the energy intensive sectors. When future climate change policies in Japan are discussed, much attention is usually paid to climate policy in less developed regions. However, the second result of our analysis suggests that climate change policy in less developed regions has only a small impact on Japan. In addition, the third result indicates that the effectiveness of border adjustment is limited.

Keywords Climate change policy in Japan · Computable general equilibrium analysis · Emissions permit trading · Border adjustment · International competitiveness

S. Takeda (✉)
Faculty of Economics, Kyoto Sangyo University, Kyoto, Japan
e-mail: shiro.takeda@cc.kyoto-su.ac.jp

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_10

1 Introduction

The Paris Agreement aims to keep the global temperature increase below 2 °C (and 1.5 °C if possible) above the pre-industrial level. However, it has gradually been proven that the level of "Nationally Determined Contributions (NDCs)" provided by countries around the world is not sufficient to meet the Paris Agreement's temperature target. To achieve the Paris Agreement temperature goal, the world needs to aim for more ambitious reduction targets. However, in reality, many countries, including Japan, seem to be reluctant to actively address climate change problems.

The government of Japan aims to reduce CO_2 emissions by 80% by 2050. However, the government has not yet determined which policy measures to use to achieve the target and does not appear to be actively working on climate change problems. The reason for such an equivocal or passive attitude is the government's concern about negative economic impacts generated by climate mitigation policies. Since Japan has actively promoted energy saving activities, the marginal cost for CO_2 reduction is thought to be relatively high. The high marginal abatement cost means that if Japan tries to reduce a large amount of CO_2, the country will end up with a heavy economic burden.

In the environmental economics of climate change, computable general equilibrium (CGE) analysis has been widely used to evaluate the economic impacts of climate change policy. For example, the MIT EPPA model (Chen et al. 2015) and OECD ENV-linkages model (Château et al. 2014) are representative examples of CGE models for climate change policy analysis and have been used to analyze various climate change policies around the world. With respect to Japan, there are studies, for example, by Takeda et al. (2012, 2014). These studies have investigated how climate change policy in Japan will affect the macroeconomy and individual economic agents in Japan. In addition, the studies analyzed how policies aiming to lessen the burden on energy-intensive industries will affect the international competitiveness of Japanese industries.

These studies have provided useful insights into Japan's climate change policies. However, there are some shortcomings in the approaches. First, their CGE model was based on a static model, which makes it impossible to depict the dynamic path of the economy with carbon regulations. In reality, many less developed countries are rapidly growing, but at the same time, they are required to reduce their CO_2 emissions. A static model is difficult to depict this kind of economic situation.

Second, only a modest CO_2 reduction policy was analyzed. Recently, many developed countries have set long-term targets to significantly reduce their CO_2 emissions by 2050 (many developed countries have goals of at least 80% reduction by 2050). However, previous studies assumed reduction rates of less than 30% for developed countries, which is far lower than the long-term future reduction rates, with no CO_2 regulations for less developed countries.

Using a global multiregion dynamic CGE model, this research aims to evaluate the economic impact of the CO_2 reduction policy in Japan. To overcome the shortcomings in previous studies, our study has the following features. First, we reflect the

Table 1 List of sectors

Symbol	Sectors	Symbol	Sectors
COL*	Coal	ELE	Electricity
CRU*	Crude oil	EIS	Energy-intensive industries
GAS*	Gas	OTH	Other industries
AFF	Agriculture	SER	Services
FOO	Food products	TRS	Transport
OIL	Refined oil		

Asterisks indicate fossil fuel sectors (primary energy sectors)

actual long-term reduction target in Japan; in other words, we assume that Japan will reduce CO_2 emissions by 80% by 2050. We investigate how this reduction policy will affect the Japanese economy in terms of both the macroeconomy (GDP and national income) and individual industries (e.g., outputs of industries).

Second, we analyze how the change in climate policy in other regions, in particular, less developed regions such as China and India, will affect Japan. When climate change policy in Japan is discussed, we often have a strong interest in the climate policy of less developed countries because many people, in particular, business communities, have serious concern that if less developed countries do not take aggressive countermeasures against climate change, CO_2 reduction in Japan will damage the competitiveness of Japanese industries and impose a heavy burden on the Japanese economy. To determine whether this argument is indeed the case, this study considers multiple reduction scenarios of less developed countries and then analyzes how changes in reduction rates in less developed countries will affect the Japanese economy. Finally, this study investigates whether border adjustment policies will affect the impacts of CO_2 reduction. Although the use of border adjustment can alleviate the burden of CO_2 reduction, we analyze how the adoption of border adjustment actually changes Japan's burden.

The rest of the paper is organized as follows. Section 2 describes the CGE model and data used in our analysis, while Sect. 3 defines simulation scenarios. In Sect. 4, we discuss the results of the analysis, and finally, we present our conclusions in Sect. 5.

2 Model and Data

We use a simulation approach based on a CGE model. Our model is an extension of the model used in Takeda et al. (2012, 2014, 2019). It is a multiregion model based on the GTAP9 dataset (Aguiar et al. 2016), and we aggregate original regions and sectors in GTAP data into 15 regions and 11 sectors in Tables 1 and 2.[1] The classification of regions is selected to be consistent with the classification of regions

[1]For the aggregation of GTAP data, we used GTAPinGAMS by Lanz and Rutherford (2016).

Table 2 List of regions

Symbol	Region	List of countries included
JPN*	Japan	Japan
USA*	United States	United States of America
EUR*	European Union	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Bulgaria, Croatia, Romania
NAM*	North America excl. US	Canada, Mexico, Rest of North America
RUS*	Russia	Russian Federation
BRA	Brazil	Brazil
CSA	Other Central and South American regions	Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Rest of the Caribbean
OEU	Other European regions	Switzerland, Norway, Rest of EFTA, Albania, Belarus, Ukraine, Rest of Eastern Europe, Rest of Europe, Israel, Turkey
AFR	Africa	Egypt, Morocco, Tunisia, Rest of North Africa, Benin, Burkina Faso, Cameroon, Cote d Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Rest of Western Africa, Central Africa, South Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, Namibia, South Africa, Rest of SACU, Rest of the World
MDE	Middle East	Bahrain, Iran, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Rest of Western Asia
ERS	Eurasia	Kazakhstan, Kyrgyzstan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia

(continued)

Table 2 (continued)

Symbol	Region	List of countries included
CHN	China	China, Hong Kong
IND	India	India
SEA	South East Asia	Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of Southeast Asia
ASP	Asia Pacific	Australia, New Zealand, Rest of Oceania, South Korea, Mongolia, Taiwan, Rest of East Asia, Bangladesh, Nepal, Pakistan, Sri Lanka, Rest of South Asia

Asterisks indicate "developed regions", and other regions are "less developed regions"

in the World Energy Outlook (WEO) 2018 (IEA 2018). In the following, we label five regions, JPN, USA, EUR, NAM and RUS, as "developed regions" and other regions as "less developed regions".[2] The main difference between our model and the model in Takeda et al. (2012, 2014) is that (1) the model here is a dynamic one and (2) it considers both electricity generation by renewable energy and carbon capture and storage (CCS) activity. The basic structure of the model is similar to that used in Takeda et al. (2012, 2014). For details, see these papers.

In each region, there are three types of agents: a representative household, government, and firms. We assume perfect competition in all markets, and production is subject to constant-returns-to-scale technology. Since the different sectors have different production structures, we assume different production functions for the sectors. Following the approach in Takeda et al. (2012, 2014), we divide production sectors into two types (fossil fuel and nonfossil fuel sectors) and assume that they have different production functions.

The production of fossil fuel depends heavily on the endowment of natural resources, and fossil fuel plays important roles in our analysis. Thus, we treat fossil fuel sectors differently from other sectors.[3] Fossil fuel production activities include the extraction of the following three goods: coal (COL), crude oil (CRU), and gas (GAS). Figure 1 depicts the structure of the nested constant elasticity of substitution (CES) production function for fossil fuel sectors. This shows that the production function of fossil fuel sectors is a two-stage CES function. Fossil fuel output is produced as a CES composite of natural resources and nonnatural resource inputs. In turn, the nonnatural resource input is a Leontief composite of capital, labor and other intermediate inputs. E_ES(j) indicates the elasticity of substitution (EOS) between natural resource and nonnatural resource inputs for sector j. This specification of

[2]Note that some developed regions are included in "less developed regions". For example, Australia is included in "less developed regions" because it belongs to ASP in this classification.

[3]We consider only two types of production functions. However, some studies consider many types of production structures for different sectors. For example, the MIT EPPA model uses several types of production functions (Chen et al. 2015).

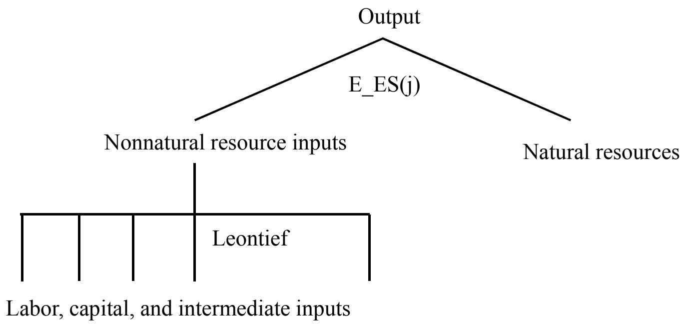


Fig. 1 Production function of fossil fuel sectors

the production function indicates that natural resources play an important role in the production of fossil fuel. In particular, the values of E_ES(j) greatly affect the change in the output of fossil fuel. The values of E_ES(j) are determined so that the supply elasticity of fossil fuel is equal to the target value.

Nonfossil fuel production (including electricity) has the structure shown in Fig. 2, where numerical values indicate values of the EOS between intermediate inputs and VA(j) indicates the EOS between primary factors in sector j. The production of output is from the Leontief aggregation of nonenergy goods and an energy-primary

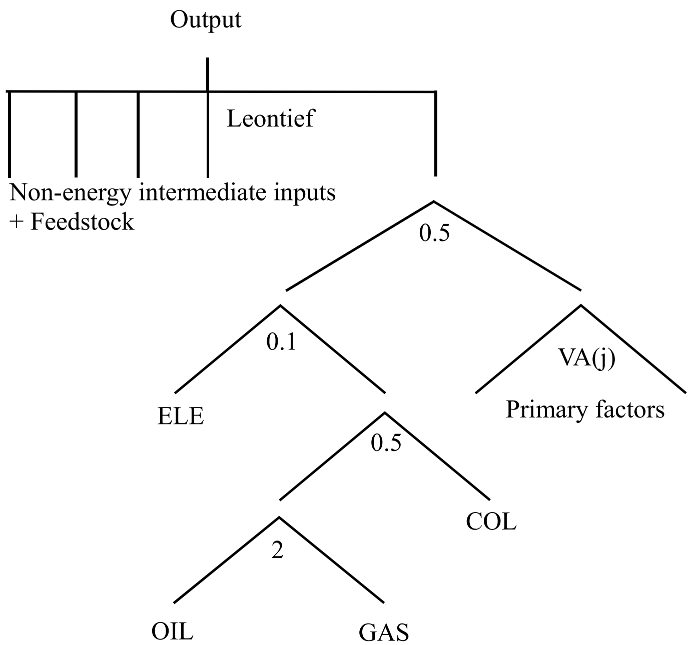


Fig. 2 Production function of nonfuel sectors

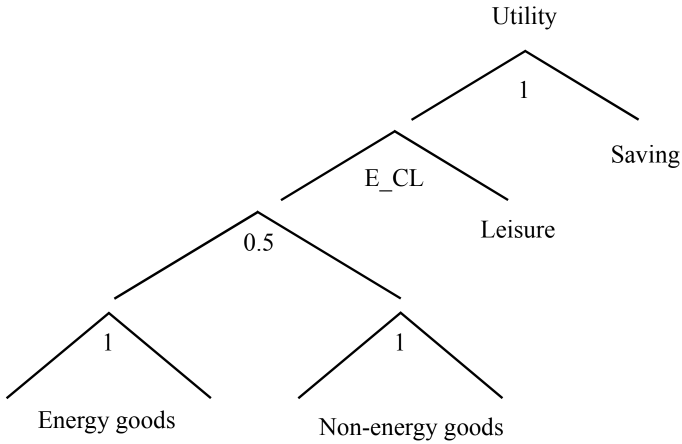


Fig. 3 Utility function

factor composite. The energy-primary factor composite is a nested CES function of energy goods and primary factors. We use this type of nested production structure because we would like to consider the differences in values of the EOS between various inputs.

In addition, with respect to the refined oil sector (OIL), we assume that crude oil enters the production function at the top-level Leontief nest because most crude oil serves as feedstock, which means that it is used as a material. The production functions above include many EOS parameters, and their values are basically taken from Takeda et al. (2012, 2014).[4]

The CES production function means that sector j's technology in region r is represented by a unit cost function c_{jr}. Let p_{jr} denote the price of goods j in region r. Then, the zero profit condition (the first-order condition for profit maximization) is given by $c_{jr} - p_{jr} = 0$, and it determines the output of sector j in region r.

To depict the demand side of the economy, we assume a representative household in each region. The representative household is endowed with primary factors such as capital, labor, land, and natural resources and supplies them to industries. Then, the household allocates its factor income to the purchase of goods and savings (investment). The household's utility has the structure depicted in Fig. 3. We assume that the representative household derives utility from saving, leisure and aggregate consumption. Aggregate consumption is a CES aggregation of a nonenergy composite and an energy composite. The nonenergy composite is a Cobb–Douglas aggregate of nonenergy goods, and the energy composite is a Cobb–Douglas aggregate of energy goods. E_CL indicates the EOS between aggregate consumption and leisure and is determined as follows. First, for the Japan parameter, we use a value of 0.73, which is estimated by Hatano and Yamada (2007) from leisure and labor data in Japan. To

[4]The different CGE studies use different production functions and EOS parameters. Note that these specifications are not necessarily based on empirical evidence.

derive the leisure-consumption elasticity and the leisure time for other regions, we use the same approach as Fischer and Fox (2007).

The household chooses consumption, saving and leisure (labor supply) to maximize its utility subject to the budget constraint. Since we assume a Cobb-Douglas function for the top nest of the utility function, the share of saving in total expenditure (i.e., saving rate) is held constant. The household's income consists of factor income minus tax payments.

Our model is a recursive dynamic model from 2011 to 2050 in which each period includes five years except for the first period (2011–2014), which includes only four years. Investment in each region is financed by saving, and the capital stock owned by the household accumulates over time according to the following formula:

$$K_{t+\phi} = (1-\delta)^{\phi} K_t + \phi I_t$$

where K_s is the capital stock in year s, I_s is investment in year s, δ is the annual depreciation rate of capital and ϕ is the number of years included in a period (four or five). We assume that the annual depreciation rate is 7%. In addition, we adjust the volume of endowment of primary factors over time. First, the total time used for leisure and labor in each region is adjusted proportionally with the change in its population. Second, the endowment of natural resources used for the production of fossil fuel is adjusted so that the supply of fossil fuel is close to the target value.

Our model is a multiregion global model that depicts international trade in goods and services across regions. To model international trade, we use the Armington assumption (Armington 1969), as many multiregion CGE models do; that is, we assume that goods produced in different regions are imperfect substitutes. Goods from different regions are aggregated through a two-stage CES function: First, imports from different regions are aggregated into composite imports, and then composite imports and domestic goods are aggregated.

Our model covers a long time span (from 2011 to 2050). In the model that aims to analyze climate change policy in the long run, technology improvement and new technology can play an important role. To capture these factors, we consider the following technology improvement and new technology. First, we assume total factor productivity (TFP) growth for every production sector. In addition, we assume autonomous energy efficiency improvement (AEEI) for energy inputs. These technology improvements are assumed to be exogenous. The rate of technology improvement is determined by the method described in Sect. 3.

Second, we assume that electricity is generated not only by conventional energy but also by renewable energy, which does not generate CO_2 emissions. Electricity from renewable energy is generated through a production function similar to that of fossil fuel sectors.[5] We assume that the cost of generating electricity from renewable energy is higher than electricity from conventional energy, and thus, the supply of

[5]Electricity generation from renewable energy uses specific resource factors instead of natural resources.

electricity from renewable energy is small in the early period. However, this supply gradually increases as the rise in carbon price increases the price of electricity.

Third, we consider CCS activity. In reality, CCS activity is usually connected with coal-fired electricity generation. However, as with other production sectors, we model CCS activity as an independent activity that provides capture and storage of CO_2 by using production factors and intermediate inputs. Since we assume that the cost of providing CCS activity is relatively high, CCS is not supplied at first because it is not profitable. However, the rise in carbon prices from more stringent carbon regulation makes CCS activity profitable, and the amount of CCS increases. We assume that the amount of CCS activity in each region is limited to half of the CO_2 emissions in the benchmark year 2011. For example, if CO_2 emissions in the benchmark year are 100 $MtCO_2$, the upper limit of CCS is given by 50 $MtCO_2$. The existence of CCS activity means that net CO_2 emissions are equal to gross CO_2 emissions minus CCS.

Later, in the simulation, we analyze carbon regulations. We assume that CO_2 emissions are regulated by cap-and-trade emissions permit trading. The government in each region imposes a cap on emissions, and emissions permits are traded in each region (no international trade in emissions permits). The market for emissions permits is perfectly competitive, and the permit price is determined so that the permit market is cleared. We assume that permits are initially allocated to industries and the household by auction and that permit auction revenue is rebated to the household in a lump-sum way.

3 Simulation Scenarios

In this section, we explain the scenarios for simulation. Table 3 shows the list of scenarios. The BAU scenario is a reference scenario where no (explicit) carbon regulation is executed. To depict the BAU equilibrium, we use the “current policies scenario” in the WEO 2018; that is, we adjust the model so that the BAU equilibrium replicates the situation of “current policies scenarios” in the WEO 2018. To do so,

Table 3 Scenarios

Scenarios		Explanation
BAU		Reference scenarios with no CO_2 regulation
Reduction rate in LDRs	MRR	Middle reduction rate (40%) in LDRs
	HRR	High reduction rate (60%) in LDRs
	LRR	Low reduction rate (20%) in LDRs
Border adjustment	NBA	No border adjustment
	BAA	Border adjustment in all DRs
	BAJ	Border adjustment in Japan

we adjust the TFP growth rate and the AEEI rate in individual regions so that the paths of GDP and CO_2 derived from the model replicate those in the WEO 2018. Although there is no carbon regulation in the BAU equilibrium, improvements in TFP and AEEI restrict increases in CO_2 emissions (or reduce CO_2 emissions in some developed regions).

In other scenarios, we introduce carbon regulation (cap-and-trade emissions permit trading). In particular, we assume that developed regions (DRs), including Japan, reduce their CO_2 emissions by 80% by 2050 from the 2020 level.[6] In addition, we consider multiple scenarios in the following aspects: (1) reduction rates in less developed regions (LDRs) and (2) the use of border adjustment policies.

Since we want to analyze how changes in climate change policies in LDRs affect Japan, we consider three different scenarios of reduction rates in LDRs. Scenario MRR is the scenario with a middle reduction rate, where LDRs reduce their CO_2 emissions by 40% (which is half of the reduction rate in DRs). HRR is the scenario with a high reduction rate, where LDRs reduce emissions by 60%. Finally, LRR is the low reduction rate scenario, where LDRs decrease CO_2 emissions by 20%.

With respect to border adjustment, we consider the following three scenarios. First, NBA is the scenario with no border adjustment in any region. In this scenario, we analyze the pure effects of carbon regulations. Next, we consider scenario BAA, where border adjustment policies are adopted for EIS sectors in all DRs. Border adjustment in this analysis is a combination of tariffs on the imports of EIS goods and refunds for the exports of EIS goods.[7] The details of border adjustment are explained in Takeda et al. (2012). Scenario BAJ assumes that only Japan introduces border adjustment. In addition to the BAU scenario, we consider nine scenarios that combine the three reduction rate scenarios with the three BA scenarios.

4 Simulation Results[8]

In this section, we explain the results of the simulation. Before examining the impact of carbon regulations, let us investigate the BAU equilibrium. Table 4 reports the level of GDP and CO_2 emissions in 2050 in the BAU scenario. Many regions in the world, in particular LDRs in Asia and Africa, continue to grow toward 2050. Although DRs reduce CO_2 emissions gradually, CO_2 emissions from LDRs increase with their economic growth, and as a result, the world's total CO_2 emissions in 2050 reach 45,928 $MtCO_2$ in the BAU scenario.

Table 5 reports GDP and CO_2 emissions in Japan in the BAU scenario. In the BAU scenario, while GDP increases, CO_2 emissions decrease in Japan. The increase in GDP is mainly due to capital accumulation and improvement in productivity and

[6]Note that what is regulated is net CO_2 emissions (=gross CO_2 minus CCS).

[7]The border adjustment in our simulation is the BIEDR type in Takeda et al. (2012).

[8]The simulation is conducted with GAMS. The simulation program and all simulation results are available from the author upon request.

Table 4 GDP and CO_2 in 2050

	Level		Share (%)	
	GDP	CO_2	GDP	CO_2
JPN	8115	778	3.8	1.7
USA	32,991	4,536	15.6	9.9
EUR	35,378	2,632	16.7	5.7
NAM	7437	1,352	3.5	2.9
RUS	4038	2,006	1.9	4.4
BRA	7139	654	3.4	1.4
CSA	6938	1,653	3.3	3.6
OEU	5706	1,265	2.7	2.8
AFR	12,294	3,048	5.8	6.6
MDE	13,053	5,032	6.2	11.0
ERS	987	875	0.5	1.9
CHN	34,505	10,297	16.3	22.4
IND	14,496	5,097	6.9	11.1
SEA	12,261	3,964	5.8	8.6
ASP	15,985	2,739	7.6	6.0
World	211,324	45,928	100.0	100.0

GDP is in billion US$, and CO_2 is in $MtCO_2$

Table 5 GDP and CO_2 emissions in Japan in the BAU scenario

	Level		Annual growth rate (%)	
	GDP	CO_2	GDP	CO_2
2020	6,368	1,031		
2025	6,593	975	0.7	−1.1
2030	6,827	941	0.7	−0.7
2035	7,117	920	0.8	−0.5
2040	7,426	903	0.9	−0.4
2045	7,736	810	0.8	−2.2
2050	8,115	778	1.0	−0.8

GDP is in billion US$, and CO_2 is in $MtCO_2$

efficiency (TFP growth and AEEI). On the other hand, the decrease in CO_2 is due to AEEI and the increase in renewable energy supply. As explained in the previous section, the paths of GDP and CO_2 emissions in BAU are adjusted according to the WEO 2018 scenario.

Figure 4 shows the path of global CO_2 emissions in the BAU and CO_2 reduction scenarios. The blue line indicates the path of global CO_2 emissions in BAU. Global

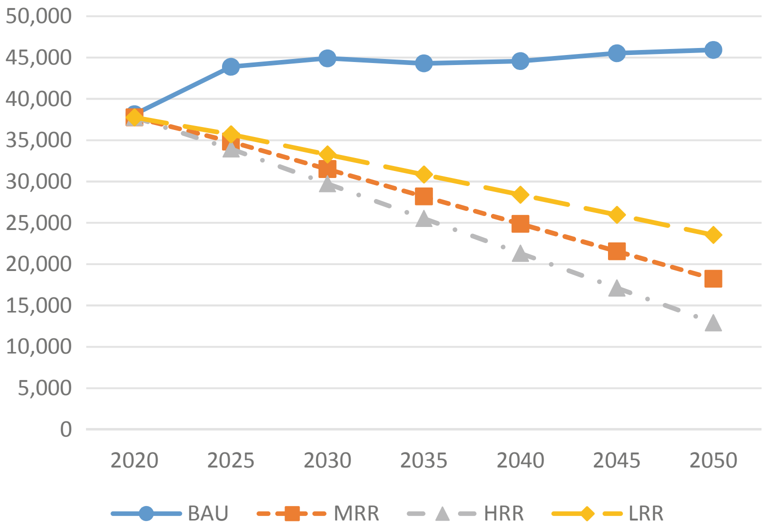


Fig. 4 Global CO_2 emissions path ($MtCO_2$)

CO_2 emissions in the BAU scenario will increase in the early 2020s but will then remain almost unchanged, i.e., at approximately 45,000 $MtCO_2$. The other three lines indicate the paths of global CO_2 in scenarios with CO_2 regulations.

Next, let us examine the impact of CO_2 regulation on Japan. Table 6 reports the simulation results for 2050. Numerical values in the table represent the percentage change from the BAU equilibrium values in 2050 unless otherwise indicated. First, let us examine the scenarios without border adjustment (the three NBA scenarios). In the simulation with CO_2 regulations, Japan reduces CO_2 emissions by 80% by 2050 from the 2020 level, which means that (net) CO_2 emissions are reduced to 206.1 $MtCO_2$ by 2050. In scenario NBA-MRR, the level of CCS activity reaches approximately 160 $MtCO_{2,}$ and the emissions permit price is approximately US$850 in 2050. We obtain almost the same values in other NBA scenarios. Because the permit price indicates the marginal abatement cost (MAC) of CO_2, this result means that the MAC in Japan is hardly affected by the change in the reduction rates in LDRs.

Next, let us examine macroeconomic variables. In Table 6, we can see the percentage change in consumption, investment, exports, imports, GDP and welfare.[9] Because of the large reduction in CO_2, consumption, exports and imports decrease by approximately 6% in scenario MRR. As a result, GDP and welfare decrease by approximately 3–4%. The rates of decrease in GDP and welfare are only slightly changed in scenarios HRR and LRR. This means that the impact on GDP and welfare in Japan are not dependent on the rates of decrease in CO_2 of LDRs.

Table 6 also reports the impact on output in four sectors: EIS, AFF, OTH and SER. The results show that the output of the EIS sector, which uses energy inputs

[9]Welfare here indicates the level of utility of the representative household in each region.

Table 6 Impact on Japan in 2050

	w/o BA			BA in all developed regions			BA only in Japan		
	NBA-MRR	NBA-HRR	NBA-LRR	BAA-MRR	BAA-HRR	BAA-LRR	BAJ-MRR	BAJ-HRR	BAJ-LRR
CO_2 (gross, $MtCO_2$)	365.7	367.3	364.6	369.9	371.6	368.8	369.3	371.0	368.2
CO_2 (net, $MtCO_2$)	206.1	206.1	206.1	206.1	206.1	206.1	206.1	206.1	206.1
CCS ($MtCO_2$)	159.5	161.2	158.5	163.8	165.5	162.7	163.2	164.9	162.1
Permit price ($/t$CO_2$)	853.1	854.1	852.8	858.1	859.2	857.7	858.8	859.9	858.4
Consumption	−6.0	−6.0	−6.0	−6.0	−6.0	−6.0	−6.1	−6.0	−6.1
Investment	−2.8	−2.9	−2.8	−2.8	−2.8	−2.8	−2.8	−2.9	−2.8
Export	−6.6	−6.6	−6.7	−7.6	−7.5	−7.7	−7.5	−7.5	−7.6
Import	−7.3	−7.5	−7.0	−8.4	−8.6	−8.2	−8.5	−8.7	−8.3
GDP	−4.1	−4.0	−4.1	−3.9	−3.9	−4.0	−3.9	−3.9	−4.0
Welfare	−3.0	−3.0	−3.0	−2.9	−2.9	−2.9	−3.0	−3.0	−3.0
Output of individual sectors									
EIS	−12.1	−11.6	−12.7	−6.7	−6.1	−7.3	−6.4	−5.9	−7.0
AFF	−0.9	−1.0	−0.8	−1.0	−1.1	−0.9	−1.0	−1.1	−0.9
OTH	−2.1	−2.3	−2.0	−5.6	−5.7	−5.4	−5.5	−5.7	−5.4
SER	−2.7	−2.7	−2.7	−2.8	−2.8	−2.8	−2.8	−2.8	−2.8

All figures indicate percentage change from the BAU values intensively, decreases significantly (by more than 11%). This means that energy-intensive sectors in Japan are likely to experience a large negative impact from an 80% CO_2 reduction. On the other hand, the output of other sectors decreases only slightly. Like the impact on macroeconomic variables, the impact on individual sectors is hardly affected by the change in the reduction rates in LDRs.

We have thus far examined scenarios without border adjustment. Next, let us examine scenarios with border adjustment. BAA is the scenario in which all DRs adopt border adjustment for the EIS sector. Compared to the scenario without border adjustment, the amount of CCS and the permit price increase. However, the changes in CCS and the permit price are not that large, and there is only a small difference with and without border adjustment. With respect to macroeconomic variables, the rates of decrease in GDP and welfare shrink with border adjustment, which means that border adjustment improves the macroeconomic impact. However, the difference with and without border adjustment is also small in terms of macroeconomic variables. As observed above, the impact on CCS, permit price and macroeconomic variables changes only slightly with border adjustment. In contrast, the impact on the outputs of EIS sectors changes to a large extent with border adjustment. To be more precise, the decrease in EIS output is almost halved when border adjustment policies are used.

Finally, let us examine scenario BAJ, where only Japan uses border adjustment. The numerical results for this scenario are almost the same as those in scenario BAA. This means that irrespective of whether other developed regions use border adjustment, Japan is not affected.

Our simulation results show that the Japanese economy is hardly affected by the change in reduction rates in LDRs. In particular, the macroeconomic impact in Japan is almost the same whether the reduction rates in LDRs are high or low. There are two possible reasons for this result. The first reason lies in the industrial structure of Japan. In Japan, more than 70% of value added is generated in services sectors, and the value added share of energy-intensive sectors is very low. Thus, the change in foreign policies related to carbon restriction and thus energy-intensive sectors has a small impact on Japan. Second, the share of trade (net exports) in GDP is relatively low in Japan (less than 10%), which also makes it difficult for the change in foreign policies to affect the Japanese economy.

5 Concluding Remarks

Using a CGE model, this paper investigates the impact of carbon regulations on Japan. We use an 11-sector, 15-region global CGE model with a time span from 2011 to 2050. We assume that Japan reduces CO_2 emissions by 80% by 2050 and analyze the impact on the Japanese economy. In particular, we consider multiple scenarios of CO_2 reduction rates in less developed regions and analyze how changes in CO_2 reduction in these regions affect Japan. In addition, we also analyze the impact of border adjustment policies.

Our simulation results are summarized as follows. First, an 80% CO_2 reduction in Japan generates a large negative impact on the Japanese economy in terms of both the macroeconomy and individual sectors. Second, the change in the reduction rates in less developed regions only has a small impact on Japan. Third, the use of border adjustment in Japan has a small impact on GDP and the welfare of Japan but a large impact on output in the EIS sector.

Finally, let us mention the policy implications of our research. When future climate change policies in Japan are discussed, much attention is usually paid to climate policy in less developed regions such as China and India. This is because climate change policies in less developed regions are thought to have a large impact on Japan. However, the second result of our analysis indicates that climate change policy in less developed regions has only a small impact on Japan. In addition, in the context of climate change policy in Japan, the need for border adjustment is often discussed. The third result of our analysis suggests that border adjustment has a small effect on mitigating negative macroeconomic impacts but a large effect on mitigating the large negative impact on the EIS industry.

References

Aguiar A, Narayanan B, McDougall R (2016) An overview of the GTAP 9 data base. J Glob Econ Anal 1(1):181–208. https://doi.org/10.21642/jgea.010103af

Armington PS (1969) A theory of demand for products distinguished by place of production. IMF Staff Papers 16

Château J, Dellink R, Lanzi E (2014) An overview of the OECD ENV-linkages model: version 3. OECD environment working papers, No. 65, OECD Publishing, Paris. https://doi.org/10.1787/5jz2qck2b2vd-en

Chen Y-HH, Paltsev S, Reilly JM, Morris JF, Babiker MH (2015) The MIT EPPA6 model: economic growth, energy use, and food consumption. Joint program report series report 278, 43. http://globalchange.mit.edu/publication/16262

Fischer C, Fox AK (2007) Output-based allocation of emission permits for mitigating tax and trade interactions. Land Econ 83(4):575–599

Hatano T, Yamada M (2007) The household behavior and the effects of public policy: investigation and estimation of structural parameters. In: Tachibanaki T (ed) The size of government and social security system. Tokyo University Press, Tokyo, pp 203–222 (in Japanese)

IEA (2018) World energy outlook 2018, OECD. International Energy Agency, https://www.oecd-ilibrary.org/energy/world-energy-outlook-2018_weo-2018-en

Lanz B, Rutherford T (2016) GTAPinGAMS: multiregional and small open economy models. J Glob Econ Anal 1(2):1–77. https://doi.org/10.21642/jgea.010201af

Takeda S, Tetsuya H, Arimura TH (2012) A computable general equilibrium analysis of border adjustments under the cap-and-trade system: a case study of the Japanese economy. Clim Change Econ 03(01). https://doi.org/10.1142/s2010007812500030

Takeda S, Arimura TH, Tamechika H, Fischer C, Fox Alan K (2014) Output-based allocation of emissions permits for mitigating the leakage and competitiveness issues for the Japanese economy. Environ Econ Policy Stud 16(1):89–110. https://doi.org/10.1007/s10018-013-0072-8

Takeda S, Arimura TH, Sugino M (2019) Labor market distortions and welfare-decreasing international emissions trading. Environ Resource Econ 74(1):271–293. https://doi.org/10.1007/s10640-018-00317-4

Shiro Takeda is a professor of Faculty of Economics at Kyoto Sangyo University and a member of the Research Institute for Environment Economics and Management at Waseda University. His research focuses on climate change policies in Japan and computable general equilibrium analysis. He holds his Ph.D. in Economics from Hitotsubashi University. In 2010, he is awarded Young Achievement Award from Society for Environmental Economics and Policy Studies in Japan.

Chapter 11
The Economic Effects of Equalizing the Effective Carbon Rate of Sectors: An Input-Output Analysis

Makoto Sugino

Abstract The 2 °C target of the Paris Agreement has stimulated the implementation of carbon reducing policies such as carbon taxes and emission trading schemes, which explicitly applies a price on carbon emitting fuels. However, OECD (2016) reports that the effective carbon rate must be at least 30 Euros per ton of CO_2. The effective carbon rate includes the implicit carbon price, e.g. energy taxes, along with the explicit carbon price. Previous studies have focused on the effects of explicit carbon prices. In this chapter, we will focus on the effective carbon rate and estimate the effects of carbon policies that increase the effective carbon rate to the 30 Euro threshold. We find that the short-term effect of a carbon tax that raises the effective carbon rate for all industries above 30 Euros will not only effect energy intensive industries, but also downstream industries that already have high effective carbon rates. Furthermore, we find that the carbon tax implemented in 2012 increase the average effective carbon rate, but increases the difference between taxed emitters and non-taxed emitters. Thus, tax exemption for energy intensive industries sacrifices economic efficiency.

Keywords Effective carbon rate · Input output analysis · Carbon tax · Cost containment measures · Energy tax · Tax exemption

1 Introduction

The emission of greenhouse gases (GHG) continued to increase even though the Kyoto protocol came into effect. The increase in emissions was due to global economic growth, which depends on fossil fuel usage, and voluntary emission reductions for developing countries. The -2 °C target, however, requires global reductions of more than 50% compared to 1990 emission levels. The Paris agreement aims to

M. Sugino (✉)
Faculty of Humanities and Social Sciences, Yamagata University, Kojirakawa-machi 1-4-12, Yamagata City, Yamagata 990-8560, Japan
e-mail: makoto.sug@gmail.com

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_11

reduce GHG emissions globally, by stimulating emission reduction for all countries that have ratified the UNFCCC.

The countries that have signed the Paris agreement have been designing policies that would fadeout carbon usage. The main policy instrument discussed has been carbon pricing. A narrow definition of carbon pricing or explicit carbon pricing, refers to carbon taxes and emission trading schemes (ETS), which sets a price on carbon emissions. A broader definition of carbon pricing or implicit carbon pricing, includes energy taxes, feed-in tariffs and other indirect policies or instruments that effectively places a price on carbon.

Which definition of carbon pricing is important in reducing carbon emissions? To answer this question, the concept of effective carbon rate has recently been used. The effective carbon rate is the sum of taxes and tradable permits levied on carbon usage (OECD 2016). Taxes refers to energy taxes along with carbon taxes. Energy taxes are levied on energy based on volume, whereas carbon taxes are levied on energy based on their carbon content. Thus, feed-in tariffs are included in the calculation of the effective carbon rate.

Going back to the question above, the implicit carbon price is important in reducing emissions, because they give direct and indirect signals to consumers about the environmental damage caused by the use of carbon containing energy. On the other hand, the explicit carbon price is useful in comparing countries/regions having similar energy tax institutions.

Carbon Pricing Leadership Coalition (2017) suggests that the price on carbon needs to be at least \$50 to \$100/t-CO_2 by 2030 to achieve the Paris climate goals. Similarly, OECD (2016) estimates that the minimum effective carbon rate of 30 Euros per ton of carbon dioxide emissions is needed to cover the damage caused by the emissions. However, OECD (2016) shows that the average effective carbon rate for 90% of emissions in 41 OECD and G20 countries is less than the minimum requirement.

OECD (2016) also shows that the effective carbon rate differs greatly within a country. The transport sector, in general, faces an extremely high effective carbon rate with 46% of emissions priced higher than 30 Euros per ton. On the other hand, other sectors face a low or no carbon price. For example, the manufacturing sector, which includes energy intensive trade exposed (EITE) industries, are often given special treatment because of the competitiveness and carbon leakage issues.

The carbon pricing gap, which is the percentage of emission without the 30 Euro carbon price, for Japan was 75% in 2012. In 2015, the percentage has gradually decreased to 69%. Compared to EU counterparts, such as France, Germany and the United Kingdom, this percentage is 15–25% higher (OECD 2018). This means that the Japanese economy does not pay enough for their carbon emissions, even though an economy-wide carbon tax was introduced in October 2012.

Why kind of economy-wide carbon tax was introduced in Japan starting from October 2012? The Japanese government introduced a carbon tax covering all carbon emitting energy usages at the rate of ¥96/t-CO_2. The tax rate was scheduled to be raised to ¥192/t-CO_2 in April 2014 and reach ¥289/t-CO_2 in April 2016. The Japanese carbon tax can be consider to be an explicit carbon price because it is added on to the price of energy.

In March 2018, the Japanese Ministry of the Environment (MOEJ) published a report on the possibility of future carbon pricing policies in Japan. In this report, three options were presented to reduce CO_2 emissions. The first option makes use of the economy-wide carbon tax introduced in 2012, by increasing the per ton carbon price. The second option is a mixture of emission trading scheme (ETS) and carbon tax. Under this option, large emitters will be regulated under the ETS while medium and small-sized emitters will be regulated by increasing the per ton carbon tax. The third option directly regulates each sector differently by setting individual targets. In other words, the first two options aim at increasing the effective carbon rate and reduce the carbon pricing gap.

The manufacturing industries, especially the EITE industries, have shown apprehension towards high carbon prices. The main discussion of high carbon prices is that the production costs will increase drastically, resulting in the loss of competitiveness in the global market (Arimura et al. 2019). As a consequence, domestic jobs related to manufacturing could be lost.

What will the short-term economic impact be if the effective carbon rate is raised to 30 Euros per ton CO_2? To answer this question, we will test two hypothetical scenarios. The first scenario will assume that an economy-wide carbon tax of ¥289/t-CO_2 is implemented. This scenario will also assume that EITE industries are given special treatment to reduce the burden of the carbon tax. The second scenario will assume that an industry specific carbon tax is implemented to increase the effective carbon rate to the minimum of ¥4000/t-CO_2.[1]

2 Existing Literature

The short-run effect of carbon pricing (CP) has been analyzed in depth using input-output (I-O) models. In I-O models the effect of CP is analyzed by changing the value-added coefficients, because CP can be considered as indirect taxes, which is part of value added. The direct and indirect effect of CP are then calculated as increases in prices or costs.

Early research such as Sugimoto (1995) and Shimoda and Watanabe (2006) analyzed the impact of an upstream carbon tax using highly aggregated data. An upstream carbon tax is relatively easy to implement in Japan because more than 95% of primary fuel are imported from abroad. They find that CP will increase prices of energy intensive industries more than their non-energy intensive industries counterparts.

Recent research focuses on downstream carbon taxes using detailed industrial classification data because they are consistent with the polluter pays principle (Morgenstern et al. 2004; Sugino et al. 2012; Sugino et al. 2013). In addition, the

[1]This price is equivalent to a 30 Euro/t-CO_2 effective carbon price.

downstream carbon taxes are more practical because the indirect emissions from electricity usage can be taxed properly to users of electricity, when the carbon taxes are implemented downstream. These studies have found that energy intensive industries have higher price or cost increases.

To understand the source of the price or cost increase, Morgenstern et al. (2004) and Sugino et al. (2013) decomposes the price increase into three components; direct emission, indirect emission and intermediate goods. The decomposition provides vital information on the source of the price increase. By determining the source of the cost increase, policy makers can introduce cost containment measures that effectively reduces the burden of carbon pricing policies. Their studies find that even though direct and indirect emissions are initially taxed, industries that use large quantities of intermediate goods also pays the burden of the tax. For example, the pig iron experiences high price increases because this industry uses coal and pays for the direct emissions. However, the crude steel (converters) industry uses large amounts of pig iron produced by the pig iron industry. Thus, the major source of the increase in price arises from intermediate goods.

Other research questions explored using I-O models concerning CP includes the burden on households in different regions and income classes (Shimoda and Watanabe 2006; Sugino et al. 2012), effect on GDP and employment (Nakamura and Kondo 2004; Sugino et al. 2013) and the effectiveness of cost containment measures (Chuo Kankyo Shingikai 2005; Sugino et al. 2013; Sato 2016).

These studies discussed above are similar in that they calculate the effect of a newly employed uniformed explicit CP. Energy related taxes, however, exists which differs among fuel types. Thus, the existing energy related taxes can be considered as a carbon tax with different per ton price. In this chapter, we will examine the effect of an explicit CP that differs between industries, which raises the effective carbon rate above 30 Euros. We will also estimate the effect of the carbon tax implemented in 2012 and compare the results using the I-O model.

3 Energy Related Taxes

Energy related taxes in Japan are imposed at the national and local level. At the national level there are six indirect taxes; gasoline tax, local gasoline tax, liquefied petroleum gas tax, aviation fuel tax, petroleum and coal tax and promotion of power-resources development tax. In addition, there is the light-oil delivery tax imposed as a local tax. Thus, there are 7 energy related taxes imposed in Japan along with the carbon tax as of January 2020.

The gasoline tax and local gasoline tax is imposed on gasoline at the rate of ¥48,600/kL and ¥5,200/kL, respectively. Thus, gasoline is taxed a total of ¥53,800/kL, which is equivalent to a ¥23,000/t-CO_2 carbon tax. The Liquefied petroleum gas tax is imposed on LPG at the rate of ¥17,500/t, whereas the aviation fuel tax is implemented on aviation fuel at the rate of ¥26,000/kL. These four taxes are imposed on the transportation sector.

Other than the taxes on transportation, the petroleum and coal tax is imposed upstream on crude oil, petroleum products, coal and LNG/LPG, when these fossil fuels are imported to Japan or extracted within Japan. The tax rates for crude oil, LNG/LPG and coal are ¥2,040/kL (¥780/t-CO_2), ¥1,080/t (¥400/t-CO_2) and ¥700/t (¥290/t-CO_2), respectively.

The final indirect tax on energy is the promotion of power-resources development tax which is imposed on the usage of electricity at the rate of ¥0.375/kWh. This tax covers all economic agents that purchase electricity from the 10 major power companies in Japan, including self-consumption of power companies.

The light-oil delivery tax is imposed on light-oil (diesel fuel) because fuel taxes differs greatly between gasoline and diesel fuel. The tax rate is ¥32,100/kL, which is equivalent to a ¥12,000/t-CO_2 carbon tax, that is less than the tax imposed on gasoline.

The energy related taxes in Japan puts a high carbon price on transportation fuels and a low carbon price for fuels used for electricity and the manufacturing industry. Thus, it can be anticipated that the effective carbon rate for the industrial sector is lower than the effective carbon rate, as reported in OECD (2016).

Other than the taxes discussed above the Japanese government implemented a carbon tax at the rate of ¥289/t-CO_2, which is added to the existing energy tax. The tax rate seems to be small compared to carbon taxes imposed in Europe. However, the coverage of the Japanese carbon tax is greater than 66% of total CO_2 emissions. Thus, the carbon tax should increase the effective carbon rate of the entire Japanese economy.

The taxes discussed above are considered to raise costs for energy intensive industries. For example, the agriculture and fisheries sector use large amounts of light-oil, heavy oil and kerosene. Thus, production costs increase due to the taxes, in turn raising the prices of these products. As a countermeasure, tax exemptions and tax rebates are applied for those industries facing competitiveness issues and those who will suffer greatly due to the energy related taxes.

The petroleum and coal tax provide tax rebates for specific industries to ease the burden of the tax. For example, the coal for producing iron and steel, coal used to produce corks, coal used to produce cement and coal used to produce electricity in Okinawa prefecture are subject for tax rebates.

Similarly, the carbon tax implemented in 2012 also provides exemption and refund measures for the rates added by the carbon tax along with the petroleum and coal tax exemption for the following 5 cases.

1. Imported and domestic volatile oil for petrochemical products production
2. Imported specific coal
3. Specific coal for electric generation in Okinawa
4. Imported and domestic bunker A heavy oil for agriculture, forestry and fishery
5. Domestic oil asphalt.

In addition, the exemption and refund measures are provided only for the tax rates added by the carbon tax for the following 6 cases.

1. Imported coal used for home generation of electricity for caustic soda production in caustic soda manufacturing industry
2. Heavy oil and light oil used for domestic cargo ships and passenger ships
3. Light oil used for railway
4. Aviation fuel for domestic flight
5. Imported coal used for home generation of electricity for salt production in salt manufacturing industry by the ion exchange membrane method
6. Light oil used for agriculture, forestry and fishery.

These countermeasures will lower the effective carbon rate. From the economic efficiency point of view, all economic agents should face the same effective carbon rate. Thus, the countermeasures provided by the government lowers economic efficiency of the energy related tax.

4 Model and Data

4.1 Model

The model used to estimate the increase in total cost due to CP applies the concept of embodied environmental burden emissions intensity discussed in Nansai and Moriguchi (2012). The embodied environmental burden emissions intensity uses the data provided by the input-output table and the emission intensity of each industry.

The embodied environmental burden emissions intensity is calculated by using the quantity determination model, which depicts the relationship between final demand and domestic production as,

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F} \tag{1}$$

where $\mathbf{X}$ is the vector of total production, $\mathbf{I}$ is the identity matrix, $\mathbf{A}$ is the input coefficient matrix and $\mathbf{F}$ is the vector of final demand. The inverse matrix, $(\mathbf{I} - \mathbf{A})^{-1}$, is known as the Leontief inverse, which represents the amount of additional input that is required to produce an additional unit of output for each industry. The Leontief inverse is calibrated by using the figures in the input-output table. This model does not distinguish between domestic and imported goods. Thus, the additional domestic final demand will be satisfied by increases in domestic production, rather than importing goods from abroad to meet the additional domestic final demand.

Next, the Leontief inverse is used to estimate embodied environmental burden emissions intensity for each industry, $\mathbf{B}_i$ as,

$$\mathbf{B}_i = \mathbf{E}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{i}_i \tag{2}$$

where $\mathbf{E}$ is the emission intensity vector and $\mathbf{i}_i$ is a unit vector where the component equals one for industry i and zero otherwise.

Using Eq. 2 and a carbon price t, the total cost due to the carbon price can be calculated as,

$$\mathbf{C}_i = t\mathbf{E}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{i}_i \tag{3}$$

where, $\mathbf{C}_i$ is the total cost increase of industry i. Total cost increase calculated by using Eq. 3, includes direct and indirect effects of the implemented CP. Indirect effect refers to the indirect cost increase caused by the price increase in intermediate goods. The direct effect is the cost increase caused by the implementation of CP.

By changing the carbon price t, we can estimate the effect of a newly implemented tax on each industry by using Eq. 3. In the simulation, we will use a uniformed tax increase to depict the carbon tax implemented in 2012, while we use an industry specific carbon tax to raise the effective carbon rate above the ¥4000/t-CO_2 threshold. The details of the simulation scenario will be discussed in the next subsection.

4.2 Simulation Scenario

We will conduct two simulation scenarios; implementation of the carbon tax of ¥289/t-CO_2 and carbon pricing that increases the effective carbon rate over ¥4000/t-CO_2.

The first scenario examines the effect of the carbon tax implemented in 2012, which covers the entire Japanese economy. The cost containment measure will also be included in this scenario. Thus, the cost increase calculated will depict the cost increase associated with the implementation of the carbon tax of 2012.

The second simulation scenario is the case where all emitters are confronted by a new carbon tax with an ununiformed tax rate. In this scenario, emitters that presently face a high effective carbon rate will face a low newly implemented carbon tax. On the other hand, industries that have low effective carbon rates will be taxed heavily by the new carbon tax.

4.3 Data

The newest input-output table available is the 2015 Japanese national input-output table. However, we will make use of the 2011 Japanese national input-output table due to the following reason. The economy-wide carbon tax was introduced in 2012. If we use the 2015 data, we will need to accurately determine the payment of the carbon tax for each industry. If we use the 2011 data, then we do not need to calculate the additional carbon tax payment for each industry. In other words, the 2011 data does not include the effect of the carbon tax whereas the 2015 data will include the effect of the carbon tax.

The Japanese national I-O table list more than 400 industries that produce over 500 products. When calculating the direct and indirect effects of the CP, we need to aggregate the industries/products so that 1 industry produces 1 product, in other words we aggregate the data so that the matrix is a square matrix. The dimension of the square matrix for the 2011 data is 393 by 393. Of the 393 industries, 237 industries belong to the manufacturing industry.

Tax revenues are reported annually by the National Tax Agency in the "National Tax Agency Annual Statistics Report." In this report, energy related tax reported are (1) gasoline tax and local gasoline tax, (2) aviation fuel tax, (3) liquefied petroleum gas tax, (4) petroleum and coal tax and (5) promotion of power-resources development tax.[2]

One shortcoming of this data set is that the tax payments are not aggregated at the sector level. Thus, the tax payments of the entire economy can be observed, but not in detail. To overcome this shortcoming, we need to estimate the amount of energy related tax payments for the year 2011.

The Japanese national I-O table provides the quantities of fossil fuels, electricity and other products purchased by each industry in the "Value and Quantity table." Using these values, we could estimate the CO_2 emissions for each industry along with the energy related tax payment. However, it is known among researchers that the values for coal is inaccurate. To over come this problem, we make use of Nansai (2019).[3]

3EID estimates the amount of energy used along with the CO_2 emitted by fuel type for industries listed in the 2011 Japanese national I-O table. Since the industrial classification is identical, we can estimate the amount of energy related tax payment for each industry with high accuracy. In addition, the tax system is very complex, as discussed in the previous section, to model precisely. We estimate the tax payment for each industry by using the emission data and fuel usage provided by 3EID because we can determine whether the emissions are taxed.

Direct emissions are calculated by using the information provided by 3EID, but we use the "Value and Quantity table" provided as supplementary data in the Japanese input-output table. We allocate the direct emissions from the electricity and private power generation to the industries that uses electricity produced by these two industries. Thus, we treat total emissions by each industry as the sum of direct and indirect emissions.

We will focus on the six indirect taxes (gasoline tax, local gasoline tax, liquefied petroleum gas tax, aviation fuel tax, petroleum and coal tax and promotion of power-resources development tax) and the carbon tax in our analysis.

---

[2]There are other energy related taxes imposed by the local authority. However, we will omit these local taxes in the simulation due to data restriction.

[3]Nansai (2019) is also refer to as 3EID which is the abbreviation of "Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables".

Table 1 Effective carbon rate w/and w/o carbon tax(¥/t-CO_2)

Sector	Effective carbon rate	
	w/o carbon tax	w/carbon tax
Agriculture, forestry and fishery	1,397	1,586
Mining	867	1,152
Manufacturing	411	594
Transportation	6,798	6,985
Other sectors	2,030	2,315
Households	7,549	7,715
Total	3,236	3,463

5 Results

5.1 Effective Carbon Rate

The 3EID data reports that the total CO_2 emission from combustion of fossil fuels was 1.235 Gt-CO_2 for 2011. Thus, if the minimum carbon price of ¥4,000/t-CO_2 is applied to all of Japan's CO_2 emission, then the total tax revenue will be 4.942 trillion yen. The tax revenue in our model for 2011 is 3.996 trillion yen.[4] This means that the present energy related tax falls short by 22% to reach the minimum threshold. The carbon tax implemented in October 2012 increases the total tax revenue to ¥4.269 trillion, which is still 15% short of the minimum requirement.

The effective carbon rate for the entire Japanese economy is calculated to be ¥3,236/t-CO_2, before the implementation of the carbon tax. The carbon tax raises the effective carbon rate to ¥3,457/t-CO_2 (Table 1). Thus, an additional tax of ¥543/t-CO_2 is need to reach ¥4000/t-CO_2. Therefore, this implies that the present energy related tax seems to be quite high.

The effective carbon rate for each sector, however, tells a different story. The effective carbon rate is ¥2,045/t-CO_2, if we exclude the energy related tax paid by households which is ¥7,549/t-CO_2 (Fig. 1). The household effective carbon rate raises to ¥7,715/t-CO_2 with the carbon tax. Thus, the household faces a higher effective carbon rate compared to other parts of the economy.

Looking at each individual sector we can observe that the effective carbon rate differs greatly. For example, the transportation sector faces an effective carbon rate of ¥6,798/t-CO_2 as of 2011, which is higher than the minimum effective carbon rate. On the other hand, the manufacturing sector faces an effective carbon rate of only ¥411/t-CO_2. Thus, the difference in the effective carbon rate is more than 16 times. Furthermore, only the transportation sector and the households face more than the minimum effective carbon rate of ¥4,000/t-CO_2. This means that the prior

[4]The total tax revenue reported was 3.855 trillion yen, which is approximately 3.65% less than our model.

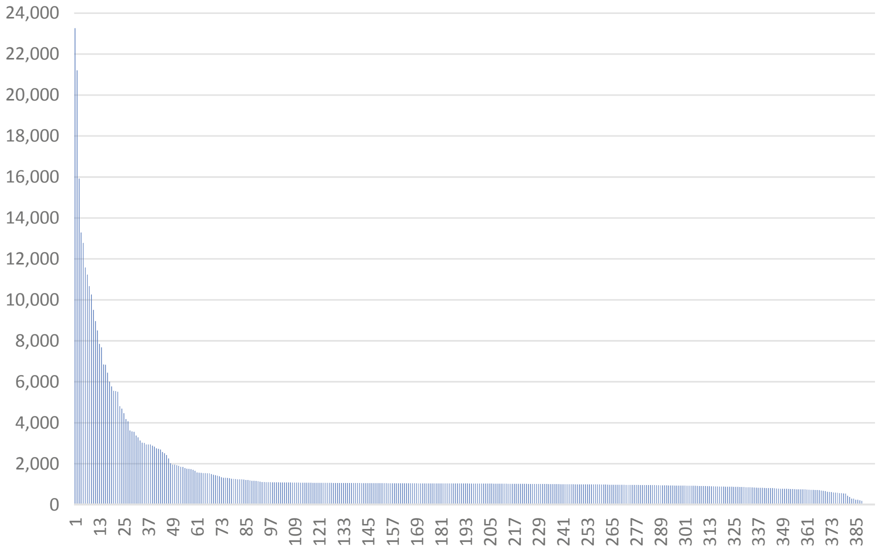


Fig. 1 Effective carbon rate by sector

to 2012, energy related taxes focuses on taxing transportation and heating rather than production activities.

The carbon tax implemented in 2012 increases the effective carbon rate for all sectors because the tax is imposed on 66% of Japan's emissions at the rate of ¥289/t-CO_2. However, the difference between the top and bottom industry becomes ¥6,391/t-CO_2 from ¥6,387/t-CO_2. From the equity point of view, the carbon tax increases the inequality of the energy related tax burden. This is the result of the special treatment given to certain industries that faces the competitiveness issue.

What does the distribution of the effective carbon rate look like? Figure 1 shows the distribution of the effective carbon rate, including the carbon tax, for the entire Japanese economy. The vertical axis shows the effective carbon rate (yen per ton CO_2) and the horizontal axis shows the number of industries. From the figure, only 27 sectors face an effective carbon rate over ¥4,000/t-CO_2 and 21 sectors with effective carbon rate between ¥3,000 and ¥4,000/t-CO_2. On the other hand, 346 sectors out of 393 sectors (88% of the industries) face an effective carbon rate less than ¥2,000/t-CO_2, of which 154 sectors face effective carbon rates below ¥1,000/t-CO_2. This result confirms the findings reported in OECD (2016), which reported that only a fraction of sectors faces more than the minimum requirement, whereas most of the sectors face a low or no effective carbon rate.

5.2 Cost Increase Due to Carbon Tax (¥289/t-CO_2)

In the previous subsection, it was shown that the effective carbon rate differs greatly among industries. In this subsection, the effects of the carbon tax implemented in 2012 are presented.

The cost increases due to the implementation of the carbon tax of ¥289/t-CO_2 is shown in Table 2. The highest cost increase is estimated as 3.951% for electricity. Electricity is followed by compressed and liquified gas, self-transport (freight), self-transport (passengers) and road freight transport. The top 20 sectors include energy intensive industries that are not given special treatment towards competitiveness and leakage issues within the carbon tax.

The average cost increase, due to the ¥289/t-CO_2 carbon tax is 0.385%. Thus, the cost increase for the top 20 industries ranges from 2 to 10 times the average cost increase. As for the energy intensive industries, such as pig iron and cement, the cost increase was estimated at 0.553% and 0.643%, respectively. These two industries have cost increases above the average, implying that the special treatment

Table 2 Cost increase due to carbon tax (Top 20 sectors)

Sector	Carbon tax (%)
Electricity	3.951
Compressed gas and liquefied gas	1.604
Self-transport (freight)	1.471
Self-transport (passengers)	1.427
Road freight transport (except self-transport)	1.313
Petrochemical basic products	1.271
Retail trade	1.103
Aliphatic intermediates	1.076
Petroleum refinery products (including greases)	1.046
Petrochemical aromatic products (except synthetic resin)	1.007
Cyclic intermediates	0.994
Wheat, barley and the like	0.952
Crude steel (electric furnaces)	0.926
Thermoplastics resins	0.924
Industrial soda chemicals	0.881
Lead and zinc (including regenerated lead)	0.829
Synthetic fibers	0.775
Plastic products	0.755
Synthetic rubber	0.747
Cold-finished steel	0.742

for these industries does not completely exempt them from production cost increase. However, the cost increase calculated in Sugino et al. (2013) for pig iron showed that the expected cost increase was more than 30% when a ¥4,000/t-CO_2 carbon tax is implemented. Thus, the estimated cost increase without the special treatment will be approximately 2% using the results from Sugino et al. (2013).[5] Therefore, a 0.553% increase is much lower than the 2% if there were no exemption program in the carbon tax.

The carbon tax scenario is not fictitious, because the Japanese government implemented the ¥289/t-CO_2 tax in 2012. Thus, we can check if the cost increase calculated above was actually experienced.

The Agency for Natural Resources and Energy reports the average electricity price for household usage and industrial usage. The figures for the year 2011 were ¥21.3/kWh and ¥14.6/kWh for households and industry, respectively. These figures changed to ¥22.3/kWh and ¥15.7/kWh in 2012, which is an increase of 4.7% and 7.5%. These figures seem to indicate an increase higher than the estimated cost increase, but caution is needed in interpreting the figures. In other words, these figures, i.e., real electricity prices, includes the cost increase in inputs such as oil prices. In addition, eastern Japan experienced an earthquake of M9 on the Richter Scale in 2011, which lead to the meltdown of the nuclear power plant in Fukushima. After the earthquake, nuclear power plants were shut down and were substituted by carbon emitting power plants. Thus, the price increase between 2011 and 2012 may reflect these incidents. The carbon tax rate was raised twice between 2012 and 2016 from approximately ¥96/t-CO_2 to ¥289/t-CO_2, However, the electricity prices were ¥22.4/kWh and ¥15.6/kWh in 2016. Thus, the change between 2012 and 2016 was -¥0.1/kWh for both household and industrial usage. Fossil fuel prices during this period fell, which contributed in the fall in electricity prices.

The Bank of Japan database reports the prices of domestically traded products. The price increase for compressed gas and liquified gas between 2011 and 2016 was 3.5%, whereas the price decreased for petrochemical basic products by 28% during the same time span. Thus, the cost increase calculated using the input output model is only a small aspect of the “real” price. The cost increase calculated here are not realized in the real world, because firms do not always pass through the carbon cost to consumers, because of the risk of losing the market share. Another reason why the estimated figures are not realized is because the model assumes that the technology is fixed. In reality, firms may invest in newer technology that are energy efficient, which may lower production costs even though the carbon tax is levied on fossil fuels.

[5]The cost increase calculated using the I-O model increases linearly with the carbon tax rate. Therefore, the results can be compared by adjusting the tax rate. In Sugino et al. (2013), the tax rate used was ¥4,000/t-CO_2. The estimated cost increase is calculated by multiplying 30% with ¥289/t-CO_2 and dividing by ¥4,000/t-CO_2, which is approximately 2%.

5.3 Cost Increase Due to Increasing the Effective Carbon Rate

What will the cost increase be if an industry specific carbon tax is implemented to raise the effective carbon rate to ¥4,000/t-CO_2? The cost increase for the top 20 industries, due to a tax that raises the effective carbon rate over ¥4,000/t-CO_2 is shown in Table 3. Pig iron is estimated to experience the highest cost increase of 40.383% when the effective carbon rate is raised to the minimum price. Other industries that are estimated to experience high cost increases is international shipping, crude steel (converters), hot rolled steel and cold-finished steel at 35.545%, 29.996%, 24.730% and 18.891%, respectively.

Ten out of the twenty industries listed in Table 3 belong to the iron and steel industry. The high cost increase of the iron and steel reflects the indirect cost increase associated with the minimum effective carbon rate also shown in Sugino et al. (2013). These industries have high cost increases because their intermediate products are mainly from the pig iron industry, which will face a high carbon tax to meet the

Table 3 Cost increase due to effective CR (Top 20 sectors)

Sector	Effective CR (%)
Pig iron	40.383
International shipping	35.545
Crude steel (converters)	29.996
Hot rolled steel	24.730
Cold-finished steel	18.891
Petrochemical basic products	17.370
Steel pipes and tubes	16.019
Petroleum refinery products (including greases)	15.891
Iron and steel shearing and slitting	15.351
Petrochemical aromatic products (except synthetic resin)	14.143
Coated steel	13.836
Aliphatic intermediates	12.763
Cast and forged materials (iron)	12.703
Miscellaneous iron or steel products	12.009
Cyclic intermediates	11.940
Road freight transport (except self-transport)	11.783
Thermoplastics resins	11.142
Retail trade	10.742
Coal products	10.742
Metal products for construction	10.193

minimum effective carbon rate, because they have been granted special treatment in existing energy related taxes.

The average cost increase in the minimum effective carbon rate scenario was 3.789%. The pig iron and international shipping industry is more than ten times the average, meaning that these industries will suffer the most from the minimum effective carbon rate policy. Other industries listed in Table 3 have cost increases higher than two times the average.

The results above show that if the Japanese government chooses to implement a new tax or raises taxes to close the carbon pricing gap to zero, then EITE industries such as the iron and steel sector will experience a price increase ranging from 10% to 40%. The cost increase has a possibility of deteriorating the competitiveness of EITE industries in the domestic and international market, if the cost increase due to the carbon price is increased to cover the minimum damage of CO_2 emissions. Thus, the cost increase will not be acceptable or actions against the implementation of carbon prices may arise, at least in the short-run, where production processes are not adjustable.

What kind of options are available to lower the burden of carbon pricing for EITE industries to accept new carbon pricing schemes? One obvious option is the exclusion of EITE industries altogether from carbon pricing. This option, however, will reduce the economic efficiency of the carbon pricing scheme and shift the burden to other parts of the economy. The second option is the use of cost containment measures such as free allocation or output-based allocation discussed in Fischer and Fox (2007) and Takeda et al. (2014).

In the third phase of the EU-ETS, industries defined as EITE, can receive free allocation of emission permits. The free allocation of permits will lower compliance costs for EITE industries, resulting in lower product prices. Firms that receive free permits are not required to produce the same amount after implementation of the carbon price. Thus, firms may reduce the amount of production and sell the over allocated permits, which increases net profits of the firm.

To tackle this problem, in an output-based allocation (OBA) program, firms receive emission permits for free based on the amount of products produced. Thus, OBA will not lower the supply of goods produced as in the EU-ETS allocation regime.

In any case, cost containment measures may be needed in the short-run for firms to adjust to the expected cost increase brought by the carbon price. The cost containment measure will lower the effective carbon rate and increase the carbon pricing gap for the EITE industries. Policy makers will need to understand the tradeoffs associated with the cost containment measure and carefully plan the fading out of such measure to increase the effective carbon rate in the future.

Table 4 Descriptive statistics of cost increase due to carbon tax and effective CR

	Carbon tax	Effective CR
Mean	0.385%	3.789%
Median	0.332%	2.953%
St. Dev	0.279%	4.007%
Kurtosis	70.022	34.052
Skewness	6.291	4.999
Minimum	0.027%	0.206%
Maximum	3.951%	40.383%

5.4 Comparison of the Two Simulations

The previous two sub-sections presented the results of the two simulation scenarios. In this sub-section we will compare the two simulation results.

Table 4 summarizes the descriptive statistics of the two simulation results. The average cost increase differs greatly for the two scenarios. The carbon tax scenario and effective carbon rate scenario differs by the order of magnitude. This is because the additional tax needs to raise the effective carbon rate is 10 times greater than the carbon tax implemented in 2012. Thus, the average cost increase is approximately 10 times greater for the effective carbon rate scenario.

Likewise, the minimum and maximum cost increase differs by the order of 10. Thus, the effective carbon rate aims at increasing the burden equally by 10 times of the carbon tax.

The figures for kurtosis and skewness, shows that the distribution of the cost increase for both carbon tax and effective carbon rate will not be symmetric around the mean with fat tails. In other words, the distribution will be positively skewed and have a long tail to the right. The effective carbon rate, however, has a smaller value for skewness, meaning that the cost increases are more symmetric than the carbon tax. This result arises from the fact that the carbon tax gives special treatment to energy intensive industries, while the effective carbon rate taxes the energy intensive industries heavily because the present energy related tax lowers the effective carbon rate well below ¥4,000/t-CO_2.

What kind of energy tax reforms are need to meet the minimum effective carbon rate requirement? The present energy tax implemented in Japan, provides tax cuts and tax exemptions for industries that are highly affected by the energy tax, i.e., mainly EITE industries. If these measures are abolished, then the effective carbon rates are expected to rise. The minimum will not be met by taking away the tax cut/exemption. Therefore, further measures will be need to raise the effective carbon rate. One option will be the raise in tax rates for coal, because coal has the highest carbon content with the lowest tax rate in Japan. By raising the tax rate for coal, electricity and iron and steel prices are expected to raise because of their heavy use of coal.

As Table 1 shows, the effective carbon rate for the manufacturing sector is approximately ¥600/t-CO_2 which falls short of the ¥4,000/t-CO_2 minimum. Another option is to raise the carbon tax rate or implement a cap-and-trade type emission trading scheme for the manufacturing sector. The former will raise the effective carbon rate of the transportation and household sector, which is already higher than the minimum. The latter, will raise the effective carbon rate for those that are subject to the emission trading scheme. Thus, only the effective carbon rate of the manufacturing sector is affected. The latter seems to be a better choice from the perspective of equality, but from a political perspective the former seems to be the better choice.

6 Conclusion

The results of the two simulation scenarios show that the cost increase of industries will differ greatly. The carbon tax will increase the cost for the non-energy intensive industries more that their energy intensive counterparts. On the other hand, the effective carbon rate scenario will increase the cost of energy intensive industries, because these industries are excluded from the energy related taxes including the carbon tax.

If a new tax which raises the effective carbon rate above the ¥4,000t/CO_2 threshold is implemented, then the energy related industries will experience high production costs. Thus, these industries may resist or lobby against the implementation of an industry specific carbon tax. For example, the iron and steel industry will suffer the most if the effective carbon rate gap is filled by the new carbon tax, because the iron and steel sector is responsible for approximately a quarter of direct emissions in Japan.

Caution is needed in interpreting the results for the cost increase. First, the cost increase estimated can be consider as the upper estimate of the carbon tax. The I-O model assumes a Leontief production function where the input requirements cannot be adjusted, at least in the short-run. This assumption will increase the cost of production because firms are unable to adjust their inputs to cheaper substitutes or install new and efficient technology. Furthermore, the I-O model assumes that the increase in costs are 100% passed through to the products. Some industries, however, may not be able to pass the increased cost through because the demand for their products could be elastic. Thus, if they passed the increased cost through to their products, the demand will drop significantly, leading to drops in market shares home and abroad. These industries may not increase the price even though the production cost is levied, by reducing profits or jobs. In addition, as discussed in Sect. 4.2, the actual cost increase in production is affected by other aspects other than carbon pricing, such as fuel prices and mineral prices.

Secondly, the cost increase calculated using the I-O model assumes that the tax revenues are not redistributed or used to increase government expenditure. If the tax revenue from CO_2 emission is used to reduce corporate taxes, social security payments or other taxes imposed on firms, then the cost of production will not increase as estimated by the model because subsidies and the like will lower the value-added vector. In addition, these tax reductions can also increase economic efficiency (double dividend) as discussed in Chap. 13.

Thirdly, the effective carbon rate calculated in this chapter omits the feed-in tariff (FIT), which was implemented in 2009. The data used to calculate the cost increase was 2011. Thus, the burden of FIT is included in the original data. However, the volume of renewable energy has increased, leading to a higher kW/h price increase for electricity users. The inclusion of FIT may lower the additional industry specific carbon tax needed to fill in the gap between the current effective carbon rate and the minimum effective carbon rate. This will in turn, lower the cost increase calculated in this chapter.

Finally, the effective carbon rate calculated in this chapter may be lower than predicted due to hidden and/or indirect subsidies. Subsidies can be considered as a negative carbon tax rate, which will lower the actual effective carbon rate, If this is the case, raising the effective carbon rate will increase the cost even more than shown in this chapter.

In any case, the effective carbon rate of ¥4,000/t-CO_2 is a minimum requirement to internalize the damages caused by CO_2 emissions. The cost increase caused by the internalization of the externality will properly signalize the environmental impacts of the goods produced by the industries. The final demand, mainly the households, could change the consumption bundle from energy intensive goods to less energy intensive goods if the prices of goods properly presents the environmental impacts. However, the present energy related taxes have not priced carbon equally, leading to inefficient carbon reductions.

The unequal effective carbon price arises from the fear of the loss of international competitiveness. Thus, one solution is to implement an international carbon tax that assures that all internationally traded goods faces the minimum effective carbon rate of ¥4,000. Then, EITE industries will at least pay the minimum carbon price even though they a given special treatment within their own country, while non-traded goods and services will face the effective carbon rate by domestic energy related taxes and the carbon tax.

Recently, the EU has restarted the discussion of implementing border tax adjustment measures for countries that do not have compatible carbon prices with the EU. The compatibility can be based on the effective carbon price or the carbon pricing gap. If the effective carbon price is used as a measure of compatibility, Japan may be penalized for not taxing EITE industries the minimum carbon price. If so, further carbon pricing within Japan may be stimulated from the threat of border adjustment measures. The border adjustment measure has not materialized, but may stimulate implementation of carbon pricing schemes in the near future.

References

Arimura TH, Kaneko S, Managi S, Shinkuma T, Yamamoto M, Yoshida Y (2019) Political economy of voluntary approaches: a lesson from environmental policies in Japan. Econ Anal Policy 64:41–53

Carbon Pricing Leadership Coalition (2017) Report of the high-level commission on carbon prices. The World Bank, Washington, D.C., May 29, 2017. Accessed 25 Dec 2019. https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices/

Chuo Kankyo Shingikai (2005) Sangyo renkanhyo wo mochiita kankyozei dounyu ni yoru bukka jyosyo ni kansuru bunseki. Analysis of the Impacts of Environmental Tax Implementation on Price Increases Using the I–O Table Ministry of the Environment. Government of Japan, Tokyo, Japan

Fischer C, Fox AK (2007) Output-based allocation of emissions permits for mitigating tax and trade interactions. Land Econ 83(4):575–599

Morgenstern R, Ho M, Shih JS, Zhang X (2004) The near term impacts of carbon mitigation policies on manufacturing industries. Energy Policy 32:1825–1841

Nakamura S, Kondo Y (2004) Tansozei Donyuga Motarasu Tanki Keizaikouka no Sangyo Renkan Bunseki. Short-term economic impacts of carbon taxation using input–output analysis. Working Paper Series no. 0403. Waseda University. Tokyo, Japan, 1–21 (in Japanese)

Nansai K (2019) Embodied energy and emission intensity data for Japan using input–output tables (3EID), National Institute for Environmental Studies, Japan. http://www.cger.nies.go.jp/publications/report/d031/index.html

Nansai K, Moriguchi Y (2012) Embodied energy and emission intensity data for Japan using input–output tables (3EID): For 2005 IO table, CGER, National Institute for Environmental Studies, Japan. (http://www.cger.nies.go.jp/publications/report/d031/index.html)

OECD (2016). Effective carbon rates: pricing CO_2 through taxes and emissions trading systems. OECD Publishing, Paris. https://doi.org/10.1787/9789264260115-en

OECD (2018) Effective carbon rates 2018: OECD Publishing, Paris

Sato K (2016) Tanso eneruri zei no nichi doku hikaku. Comparing Japanese and German carbon and energy taxes. Chapter 2 in *Kankyo zei no nichi doku hikaku. Comparing Japanese and German Environmental Taxes*. Keio Gijyuku Daigaku Syuppankai (in Japanese)

Shimoda M, Watanabe T (2006) Re-examination of the scheduled carbon tax on the basis of IO analysis: a quantitative analysis on household burden by income class and by region. Shogaku Kenkyu (Aichi Gakuin University) 46(3):151–166 (in Japanese)

Sugimoto Y (1995) “An input—output analysis of carbon emission: on the effect of carbon tax and the amount of carbon embodied in tradable goods”. the technical bulletin of faculty of horticulture. Chiba Univ 49:213–221 (in Japanese)

Sugino M, Arimura TH, Morita M (2012) The impact of a carbon tax on the industry and household: an input-output analysis. Environ Sci 25(2):126–133 (in Japanese)

Sugino M, Arimura TH, Morgenstern R (2013) The effects of alternative carbon mitigation policies on Japanese industries. Energy Policy 62:1254–1267

Takeda S, Arimura TH, Tamechika H, Fischer C, Fox AK (2014) Output-based allocation of emissions permits for mitigating the leakage and competitiveness issues for the Japanese economy. Environ Econ Policy Stud 16(1):89–110

Makoto Sugino is an Associate Professor of Faculty of Humanities and Social Sciences at Yamagata University in Yamagata prefecture. His research interests include climate change, energy and waste policies. He has published his research in academic journals such as*, Environmental and Resource Economics, Energy Policy, and Environmental Economics and Policy Studies.* Dr. Sugino holds a Ph.D. in economics from Sophia University in Tokyo, an M.Sc in economics from the Okayama University and a B.A. in Liberal Arts from International Christian University in Tokyo. He has served on an advisory committee of the local government of Yamagata.

Chapter 12
Inequalities in the Impact of the Carbon Tax in Japan

Nozomu Inoue, Shigeru Matsumoto, and Minoru Morita

Abstract Although Japan's current carbon tax rate is much lower than the rates applied in European countries, the Japanese government may increase the tax rate in the near future, in order to strengthen measures to combat global warming. Since a country's carbon-pricing policy does not distort its economy, it is considered to be an efficient policy measure. However, the burden of carbon pricing varies across regions and across households. Since low-income households generally allocate a larger proportion of their disposable income to energy costs than high-income households, the burden of carbon taxes on low-income households tends to be higher than for high-income households. In addition, households in cold regions spend more money for space heating, and those in rural areas spend more money for gasoline. Unless the government objectively analyzes the impact of carbon pricing and proposes convincing countermeasures to deal with these unequal impacts, the government is unlikely to obtain public support for a carbon tax increase. In this study, we analyze microlevel data from the Japanese National Survey of Family Income and Expenditure (NSFE) collected from 1989 to 2014, and examine how past energy price changes affected the welfare of different types of households. We then propose countermeasures to address the problems arising from the regressive nature of taxing energy use.

Keywords Distributional impacts · Japanese national survey of family and expenditure · Welfare

This work was supported by JSPS KAKENHI Grant Numbers 18K01578.

N. Inoue
National Institute of Population and Social Security Research, Tokyo, Japan

S. Matsumoto (✉)
Faculty of Economics, Aoyama Gakuin University, Room 828, Building 8, 4-4-25 Shibuya, Shibuya, Tokyo 150-8366, Japan
e-mail: shmatsumoto@aoyamagakuin.jp

M. Morita
Faculty of Regional Policy, Takasaki City University of Economics, Takasaki City, Gunma, Japan

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_12

1 Introduction

Although carbon taxes were introduced in European countries in the early 1990s, the Japanese government spent a quarter century debating the issue until finally introducing a carbon tax, refered as “global warming countermeasure tax (Chap. 1)”, in 2012. The present carbon tax rate in Japan is very low, equal to USD 2.63 per CO_2 ton, which correspond to USD 0.007 per kilo liter of gasoline, USD 0.007 per liter of kerosene, and USD 0.001 per kWh of electricity, which is much lower rates observed in European countries (Cabinet Office of Japan 2009). According to estimates by the Ministry of the Environment (2012), the burden of the new carbon tax remains at USD 11.2 per year on the average household in Japan.

Prior to introducing the new carbon tax, various energy taxes had been imposed in Japan. Both a crude oil tariff (USD 0.0015 per liter) and a petroleum coal tax (USD 0.019 per liter) are levied on energy imports. At the sales stage, energy taxes are imposed on gasoline (USD 0.49 per liter), diesel oil (USD 0.29 per liter), jet fuel (USD 0.24 per liter), and LP gas (USD 0.09 per liter), in addition to a consumption tax (5%).[1] Even if the “effective carbon rate” that includes the above-mentioned energy-related taxes is used, the tax rate in Japan is still lower than the rates in many European countries. For instance, gasoline and diesel fuel taxes in Germany are USD 0.83 and USD 0.60 per liter, respectively (Cabinet Office of Japan 2009). Despite the large differences in tax rates between Japan and European countries, there is no significant difference in the retail energy prices that households actually pay. This is due to the large difference in energy prices before taxation (see Sect. 3 for more detail).

One of the major differences between the new carbon tax introduce in 2012 and the energy taxes which existed before its introduction would be the consideration of the energy use purpose. Energy use purposes are considered in Japan’s existing energy taxes, as the rates are differentiated according to energy use purposes. In contrast, energy use purposes are not a factor in the carbon tax; the tax rates are simply based on a CO_2 basis. Therefore, the new carbon tax is economically more efficient than the existing approach. On the other hand, the new carbon tax would impose different burdens across regions and households. Households living in cold regions spend substantially more money for heating than households in warmer areas, as the energy bill must be paid even if prices increase since heating is an essential service in winter time. Private motor vehicles are used intensively in rural areas where public transportation networks are inadequate. Consequently, households in rural areas consume more gasoline than those in urban and suburban areas. However, if gasoline prices were to increase due to a carbon tax without an increase in alternative transportation services, the mobility of rural households will be restricted. Low-income households generally allocate a larger proportion of their disposable income to energy services than high-income households. Thus, if the carbon tax is increased, the tax burden will tend to fall disproportionately on low-income households compared to high-income households. In addition, even though certain energy

[1] The consumption tax rate is 10% in 2020.

services are required to live a normal life, a carbon tax increase could make such energy services unaffordable for low-income households.

In order to gain public support for a higher carbon tax, the government would have to propose convincing countermeasures to mitigate the regressive nature of a carbon tax. To propose feasible and convincing countermeasures, we need to understand how much energy different types of households use as well as for what purposes they use energy. The purpose of this study is to analyze household energy consumption data over the last 25 years and to propose countermeasures to mitigate the regressive nature of a carbon tax.

For this analysis, we use micro-level data from Japan's National Survey of Family Income and Expenditure (NSFIE). In Sect. 2, we explain our data construction. Households use various types of energy and their usage patterns have changed over time. In Sect. 3, we report historical changes in household energy consumption. We also examine how the pattern of energy consumption also varies across regions. For example, households in colder regions use energy differently than households in warmer regions. Finally, previous studies reveal that household characteristics affect energy usage patterns, so Sect. 3 also examines family composition, age of the head of household, and household income. We also examine how these household characteristics are related to household energy consumption. Our data analyses reveal a considerable variation in the pattern of energy consumption across regions as well as across households, and how large the difference in the tax burden can be across households. In Sect. 4, we make policy proposals to mitigate the regressive nature of the carbon taxation.

2 Data

Our primary data source is Japan's National Survey of Family Income and Expenditure (NSFIE) for 1989, 1994, 1999, 2004, 2009, and 2014 (Statistics Bureau of Japan Statistical Bureau of Japan 1989a–2018a). The NSFIE is a nationwide cross-sectional survey that was initiated in 1959 is conducted every five years. Each survey covers more than 55,000 households that are asked about their expenditures for electricity, city gas, gasoline, kerosene, and propane gas use from September to November.

Energy prices vary between regions and over time. We identify the location of each household surveyed in the NSFIE and obtain the energy prices that household faced from the Retail Price Survey provided by Statistics Bureau of Japan (1989–2014b). By dividing the expenditure by these energy prices, we calculate the energy consumption for each household in the appropriate unit of measure, such as kWh, liter, and m^3.

Although gasoline, kerosene, and propane gas are sold by volume, electricity and city gas have a "base charge" that does not depend on usage and a "meter charge" that increases with usage. Moreover, block pricing is applied for the meter charge.

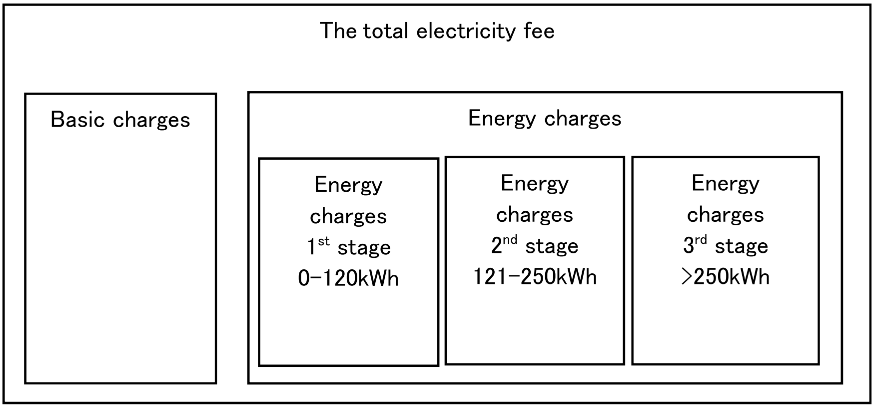


Fig. 1 An example of electric pricing scheme

Figure 1 is an example of the block pricing from the Retail Price Survey in 1989 and 1994.[2]

In the first block, from 1 to 120 kWh, the lowest unit price was charged. In the second block, from 121 to 250 kWh, the unit price is higher than in the first block. The maximum unit price is charged if monthly electricity consumption is greater than 250 kWh. We account for the price variation in the block pricing scheme in estimating electricity consumption for each household.[3]

Next, we converted the energy consumption based on physical units to energy units (mega joules (MJ)), using the Fact-finding Survey on Estimation of Carbon Dioxide Emissions from Homes by the Ministry of the Environment Japan (see appendix for details).

Figure 2 shows the change in total energy consumption for the average household

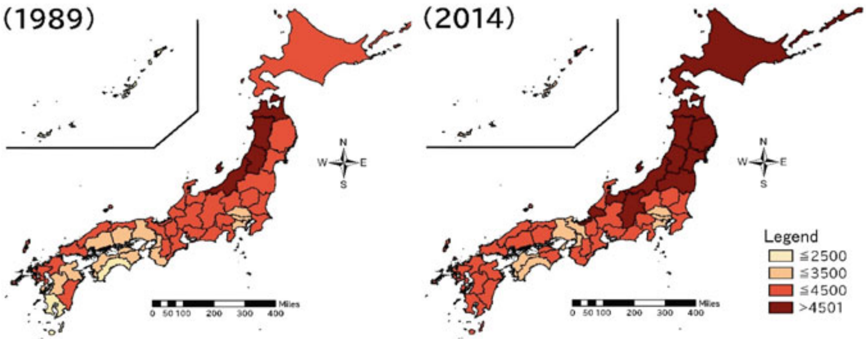


Fig. 2 The change in the total energy consumption

[2]The threshold value in block pricing has been changed since 1999.

[3]We made seasonal adjustments for the CPI time series data.

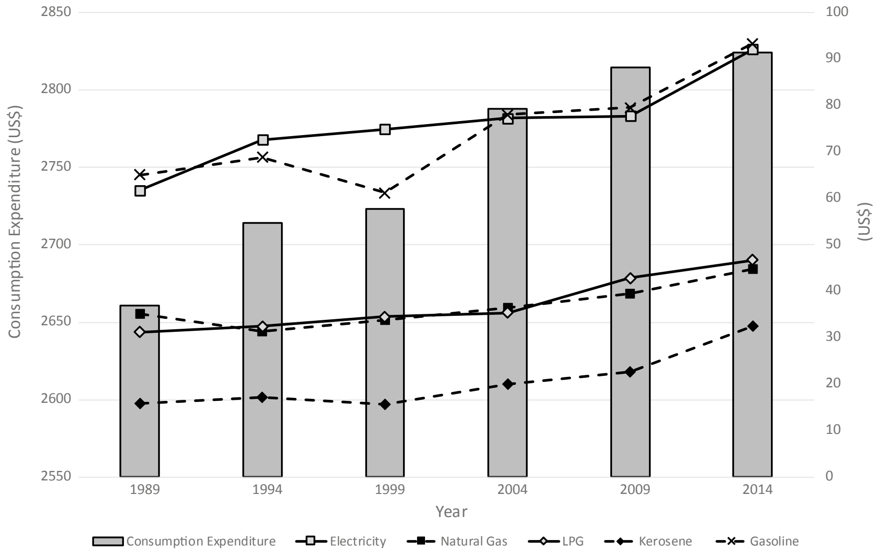


Fig. 3 Historical change in household energy expenditures *Source* "Consumption Expenditure" from Family Income and Expenditure Survey (Ministry of Internal Affairs and Communications), "Electricity", "Natural Gas", "LPG", "Kerosene" and "Gasoline" from NSFIE. *Note 1*. "Consumption Expenditure" is the average per month for all worker-households. *Note 2*. Using the 2011 GDP deflator, we initially convert all nominal values into real values. We then convert Japanese yen into US dollars, assuming that one USD is equivalent to 110 yen

in each prefecture in Japan from 1989 to 2014. The figure clearly shows that overall energy consumption increased from 1989 to 2014.

3 Analysis

3.1 Historical Changes in Household Energy Expenditure

Figure 3 shows the historical changes in monthly consumption expenditures of all worker-households and the expenditures for each type of energy (electricity, city gas, LP gas, kerosene, and gasoline). Total monthly expenditures are shown by the bars in the graph and are measured on the left vertical axis. The expenditures for each type of energy are shown by the lines and are measured on the right vertical axis.

The line graphs show that all energy expenditures increased over the sampling period.[4] The figure further shows that expenditures for electricity and gasoline were two to three times greater than for other types of energy throughout the sampling

[4]Even when the data are broken down by region, we confirm that monthly energy expenditures increased in all regions.

period.[5] This reflects the fact that as the Japanese economy has matured, many households own and use a greater variety of electric appliances (e.g. air conditioners, refrigerators, and TVs, etc.) and own private automobiles. Taking a closer look at the changes in the expenditure for each type of energy, we find that expenditures for kerosene increased by 2.1 times from 1989 to 2014, while expenditures for electricity, city gas, and gasoline increased about 1.5 times and expenditures for LP gas increased about 1.3 times.

As shown by the bar graph, monthly total expenditures for the average Japanese household increased only 1.1 times from 1989 to 2014, due to sluggish growth after the end of the bubble economy. However, despite slowing growth in overall spending, Japanese households did not reduce energy expenditures and still spend a substantial amount of money on electricity and gasoline; the average household spends about USD 60–90 per month. This amount is much larger than the amount spent for city gas, LP gas, and kerosene; the expenditures for those energies are about USD 15–45 per month. These facts suggest that the expenditures for electricity have been becoming relatively more important for Japanese households in recent years.

3.2 *Historical Change in Household Energy Consumption*

Figure 4 presents the historical changes in average monthly energy consumption for the average Japanese household, in terms of mega joules (MJ). Total energy consumption per month is represented by the bars in the graph and is measured on the right axis. Consumption for each type of energy is shown by the lines in the graph and is measured on the left axis.

The figure shows that total energy consumption increased from 1989 to 1999, then started to decline. Specifically, total energy consumption increased by about 6% from 1989 (7045 MJ) to 1999 (7453 MJ), then decreased to 5874 MJ in 2014. The decrease from peak consumption in 1999 to 2014 is about a 21%.

Next, we look at the line graphs to examine the consumption change by energy type. Electricity consumption has been increasing steadily since 1989; average monthly consumption was 1.086 MJ in 1989 and rose to 1.467 MJ in 2014, an increase of roughly 35%. In contrast, the consumption of city gas, LP gas and kerosene decreased over the period. In particular, the decline in city gas consumption is remarkable, decreasing from 1910 MJ in 1989 to 837 MJ in 2014, a 56% reduction. As for LP gas and kerosene, LP gas decreased by 28% (from 194 MJ to 139 MJ), and kerosene decreased by 25% (from 1669 MJ to 1256 MJ). Although gasoline consumption increased from 1989 (2187 MJ) to 2004 (2690 MJ), it then started to decline. Average monthly consumption in 2014 was 2175 MJ, a 19% reduction from 2004. These results suggest energy consumption in the household sector has been declining since the 2000s.

[5]In all regions, expenditures for electricity and gasoline are higher than for other types of energy. However, kerosene expenditures tend to be larger in cold regions.

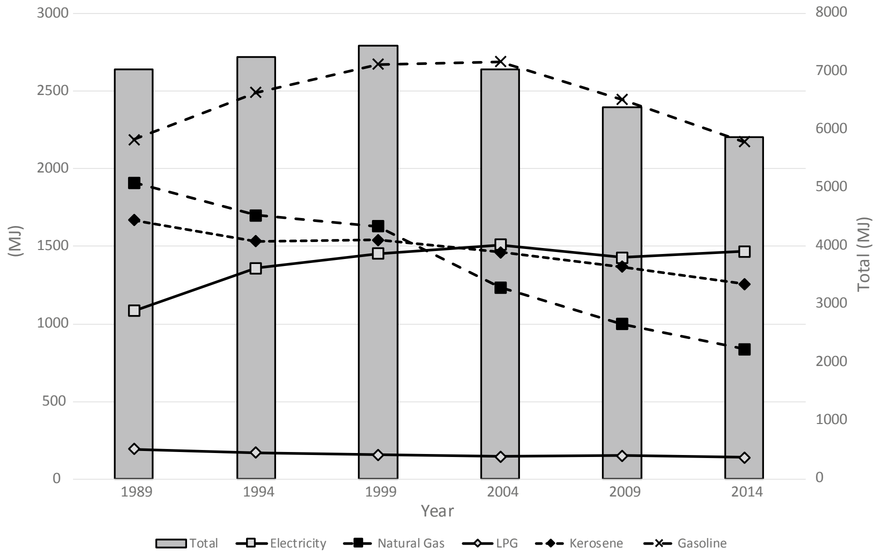


Fig. 4 Historical change in household energy consumption. *Note 1* The total is the sum of consumption for all types of energy

Energy consumption is primarily affected by energy prices[6] and thus it is important to know how energy prices have changed during the sample period. Below we report the historic change in energy prices in Japan.

As mentioned in Sect. 2, electricity costs for Japanese households consist of a "basic charge" and a "meter charge." To determine the basic charge, Japanese power companies use two types of systems: an ampere rating system and a basic charge system.[7] In the ampere rating system, households pay a base fee according to the number of amperes contracted for with the power company. Households that want to use many appliances at once are required to contract for a higher number of amperes. In the basic charge system, households pay a minimum fixed fee regardless of their electricity consumption level. Although the lowest base fee in the ampere system and the minimum fixed fee in the basic charge system both remained between USD 2.4 and USD 3.0 during the sampling periods, since 2009 power companies have rapidly increased the unit price for electricity applied in the meter charge.[8] These price increases are largely due to the rise in crude oil prices, the expansion of thermal

[6] All prices below, including electricity prices, have been converted to real values using a 2011-based GDP deflator. USD 1 is assumed to JPN 110.

[7] Hokkaido Electric Power Company, Tohoku Electric Power Company, Tokyo Electric Power Company, Hokuriku Electric Power Company, Chubu Electric Power Company, and Kyushu Electric Power Company use the ampere rating system. Kansai Electric Power Company, Chugoku Electric Power Company, Shikoku Electric Power Company, and Okinawa Electric Power Company use the basic rate system.

[8] Japanese electric companies are increasingly using a block pricing system, in which the unit price increases as consumption increases. For example, since 2009 Tokyo Electric Company has increased

power generation caused by the shutdown of nuclear power plants after the Great East Japan (Fukishima) Earthquake in 2011, and the promotion of renewable energy sources.

Next, we summarize the changes in kerosene and gasoline prices. The price of kerosene had remained around USD 0.35 per liter from 1989 to 2004, but increased to USD 0.96 per liter between 2004 and 2014. A similar price increase was observed for gasoline prices; the gasoline price had been around USD 1.03 per liter from 1989 to 2004, but had increased to USD 1.50 per liter by 2014. These price increases are mainly caused by increases in crude oil prices.

Finally, we look at the price changes of city gas and LP gas. The minimum or basic monthly charge for city gas had been set at less than USD 10 from 1989 to 1999, but exceeded USD 10 in the 2000s, and in 2014, the price reached to about USD 13. Although the unit price of city gas was less than USD 1 per m^3 in 1999, it was approaching USD 2 per m^3 in 2014. In contrast, the price of LP gas has not changed much over the period we analyzed, remaining between USD 4.0–6.0 per m^3 from 1989 to 2014.

From the analyses above, we can draw the following two important inferences. First, prices for all types of energy have been rising in recent years. Second, Japan's household sector has become increasingly dependent on electricity over the years. In 1989, the shares of electricity, city gas, kerosene, LP gas, and gasoline as a percentage of total energy consumption were 15.7%, 27.1%, 23.7%, 2.8%, and 31.0%, respectively. However, the share of electricity rose sharply to 25.0% in 2014 while the share of city gas dropped to 14.2% over that period. Clearly, Japan has already experienced a rapid household electrification but this shift is expected to further advance in the future.

3.3 Comparison of Energy Consumption Across Regions

We divide the country into 10 regions presented in Fig. 5 and compare monthly energy consumption for the average household across these regions in Fig. 6.[9,10] Total energy consumption is shown by the bars as measured on the right vertical axis, while consumption by type of energy is shown by the line graphs, measured on the left axis.

The bars show that the region with the highest overall energy consumption was the Tohoku region, and that the average Tohoku household consumed 8452 MJ of energy per month. Households in Hokuriku and Hokkaido regions were also high

its unit price by USD 0.02 per kWh in the initial block of 1–120 kWh and by USD 0.03 per kWh in the block beyond 120 kWh.

[9]Prior to liberalization in 2016, the Japanese electricity market was a regional monopoly system. We divided the country into 10 regions on the basis of the previous monopoly system.

[10]The value of each type of energy consumption presented in Fig. 11.5 is the average of the monthly consumption from 1989 to 2014 for each region.

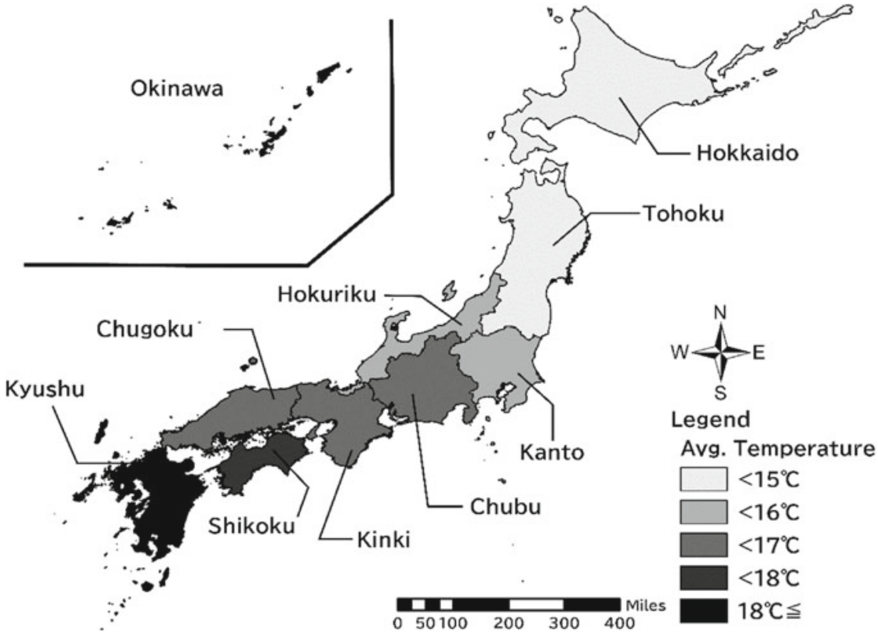


Fig. 5 Weather conditions in Japan

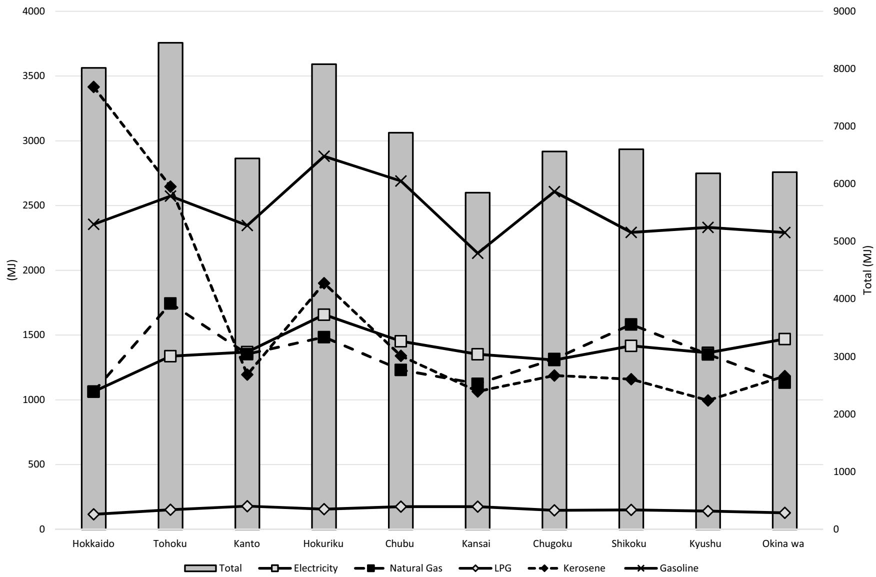


Fig. 6 Comparison of energy consumption across regions

energy consumers; Hokuriku households consumed an average of 8081 MJ while the Hokkaido households consumed 8016 MJ of energy per month, on average. In contrast, the lowest energy consumption was observed in the Kansai region, where the average household consumed only 5849 MJ.[11] We can see that, energy consumption is higher in northern regions than in southern regions, and that the difference between the two is large.

Next, we compare energy consumption across regions by type. Figure 6 shows there are large differences in kerosene consumption across regions. The Hokkaido region had the highest kerosene usage (3416 MJ), the Tohoku region consumed 2646 MJ while the Hokuriku region consumed 1901 MJ. These three regions used much larger amounts of kerosene than the other regions, most likely because these three regions are located in the northern part of Japan where temperatures throughout the year are lower than in other regions and kerosene-fueled oil stoves tend to be used more frequently for space heating. As a result, kerosene consumption accounts for 42.6% of total energy consumption in the Hokkaido region and 31.3% in the Tohoku region. These percentages are far greater than in other regions. This suggests that carbon pricing would be a significant burden to households in the northern regions since they use a large amount of kerosene for heating purposes. It is worth noting that kerosene consumption has decreased in the southern part of Japan over the last two decades and now accounts for only about 20% of total energy use.

There was no significant difference in the amount used for the remaining types of energy across regions. The highest consumption of electricity, 1658 MJ per month, was observed in Hokuriku region, while the lowest consumption of 1064 MJ was observed in the Hokkaido region. The relatively large electricity consumption in the Hokuriku region may be due to the relatively low cost of electricity provided by Hokuriku Power Companies, which generates much of its electricity through hydro power. The dependence on electricity as a percent of all energy sources was roughly 20% in all regions, except for Hokkaido (13.3%) and Tohoku (15.8%), where the large usage of kerosene makes energy consumption patterns different than the other regions.

Given the fact that many Japanese households rely heavily on electricity, it is important to know how household electricity consumption responds to changes in electricity prices. There are several studies that compare the price elasticity of household electricity demand across regions in Japan. Tanishita (2009) used electricity consumption data at the prefectural capital level from 1986 to 2006 and conducted a panel data analysis. They calculated electricity consumption by dividing the electricity bill by the unit electricity price and estimated short-run price elasticity at approximately -0.9 to -0.5, and long-run price elasticity at about -2.7 to -1.0. They also estimated price elasticities for each region and confirmed that Hokkaido, Tohoku, Hokuriku, Chugoku, Shikoku, and Kyushu have relatively low price elasticities, while Kanto, Kansai, and Chubu have relatively high price elasticities. Mizobata et al. (2011) used electricity consumption data for multi-person

[11] Households in the Kanto region, including Tokyo, used 6444 MJ, one of the lowest consumption levels.

households from 1986 to 2010 and conducted a panel data analysis. They estimated the price elasticity of electricity for each power company region and reported a large variation in the price elasticity of demand for electricity across regions. They reported that short-run price elasticity ranged from −0.96 in the Hokuriku region to −0.28 in the Chubu region, while the long-run price elasticity ranged from −2.30 in the Hokuriku region to −0.95 in the Chubu region.[12]

Although the average price elasticity of demand for electricity in Japan as indicated in the above mentioned studies is similar to the averages found in previous studies conducted outside Japan (Espey and Espey 2004), there is a huge variation across regions within the country.

As for city gas, households in the Tohoku region consumed the greatest amount, 1744 MJ per month, while those in the Hokkaido region consumed the lowest amount, 1064 MJ. The dependence on city gas was about 20% in all regions except in the Hokkaido region. As for LP gas, households in the Kanto region consumed the greatest amount, 180 MJ while those in the Hokkaido region consumed the lowest amount, 116 MJ. With respect to gasoline, households in the Hokuriku region consumed the greatest amount, 2881 MJ per month, while those in the Kansai region consumed the lowest amount of gasoline, 2132 MJ per month. There is no significant difference in LP gas or gasoline consumption between the regions; the percentage of energy consumption using LP gas is about 2–3% while that of gasoline is about 30–40%.

3.4 Household Income and Energy Consumption

Since household energy consumption depends not only on price but also on household income, in this sub-section we examine the relationship between household income and energy consumption. For this purpose, we classified households into seven income classes: (1) less than 2.0 million yen per year, (2) 2.0 million yen to less than 3.5 million yen, (3) 3.5 million yen to less than 5.0 million yen, (4) 5.0 million yen to less than 7.0 million yen, (5) 7.0 million yen to less than 10.0 million yen, (6) 10.0 million to less than 15 million yen, and (7) 15 million yen or more. We then calculated the monthly energy consumption of the average household in each income category. Income distribution among Japanese households is presented in Fig. 7.

Figure 8 shows the monthly energy consumption in each income category.[13] Total energy consumption is presented by the bars and is measure on the right axis, and energy consumption per type of energy is presented by the lines, measured on the left axis.

[12]The estimated price elasticity is similar to findings in studies conducted in other countries (Espey and Espey 2004; Narayana et al. 2007; Krishnamurthy and Kriström 2015).

[13]The energy consumption presented in Fig. 11.6 is the monthly energy consumption averaged over between 1989 and 2014.

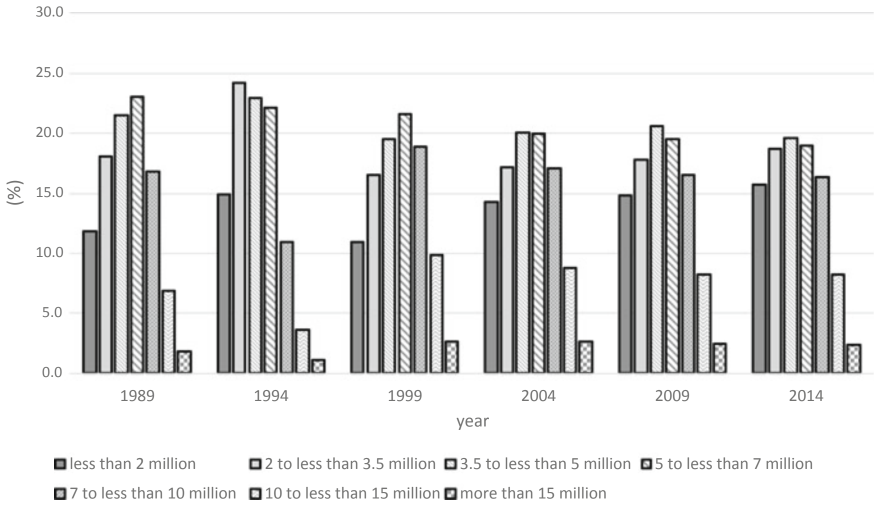


Fig. 7 Income distribution among Japanese households

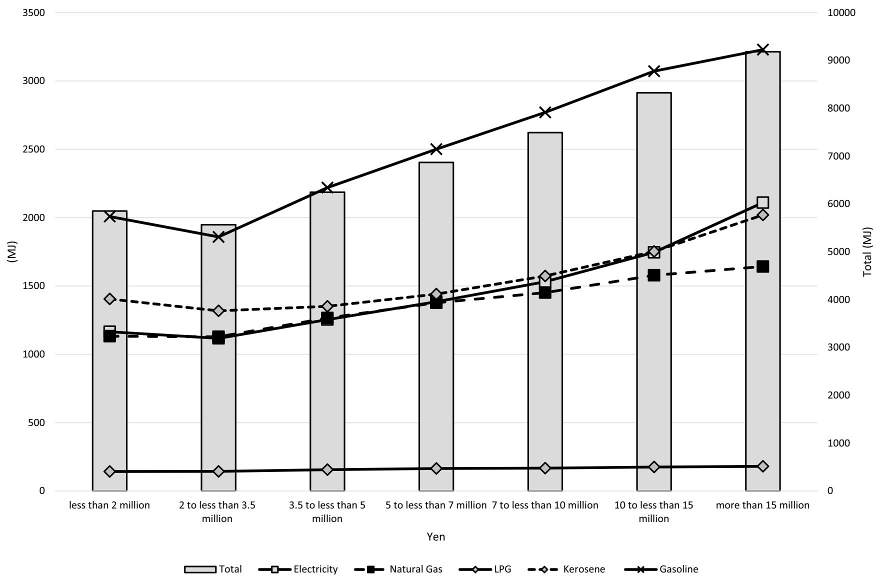


Fig. 8 Household income and energy consumption

Figure 8 shows that total energy consumption generally increases as income rises. Average energy consumption was 5853 MJ in the lowest income group and slightly less, at 5565 MJ, in the second lowest category. Thereafter, energy use increased with income; the average monthly energy consumption of the highest income group was 9181 MJ.

We can see that monthly consumption of each type of energy follows the same pattern as total energy consumption. This suggests that there is an overall positive relationship between household income and energy consumption for each type of energy.

Next, we discuss the relationship between household income and relative consumption of each type of energy. The data clearly show that the ratio of electricity to total energy consumption increases as income increases. In contrast, we observe an inverted U-shaped relationship between household income and the ratios of the remaining types of energy to total energy consumption. For example, the ratio of gasoline consumption to total energy consumption initially increases as household income increases, then reaches a peak when annual household income is between JPY 7-10 million. After that, the ratio starts to decline. In the case of city gas, the ratio rises initially, then starts to decrease after annual household income reaches JPY 3.5–5 million. The ratio of LP gas to total energy consumption, and also kerosene, start declining once household income reaches JPY 2.0–3.5 million. These results show that electricity dependence increases consistently as income increases, but dependence on the remaining types of energy peak, and then decline after household income reaches a certain threshold. This suggests that as their income levels rise, households allocate additional more of that income to purchase of appliances, computers and other devices that require electricity to power them. This phenomenon is not observed for LP gas, kerosene, or city gas. Indeed, high-income households consume relatively less of those types of energy compared to middle-income households. Households use these energies primarily for heating and cooking, but energy consumption for such purposes does not increase significantly with income rise.

Otsuka et al. (2013) estimated price and income elasticity of demand for electricity. When a model that includes a lag term is used, they found that short-run price elasticity was -0.483 while long-run price elasticity was -1.541, while short-run income elasticity was estimated to be 0.086 while long-run income elasticity was 0.273. They found that the Hokkaido region had the lowest response to price change while the Hokuriku region had the highest response. In addition, they reported that income elasticity was highest in the Kyushu region and lowest in the Kanto region. Using micro-level data from the Survey on Carbon Dioxide Emission from Households (SCDEH), Onuma et al. (2019) estimated the income elasticity of demand for electricity after controlling for appliance ownership. According to their estimates, the income elasticity of demand for electricity among Japanese households is approximately 0.07. Espey and Espey (2004) conducted a meta-analysis of 36 studies published between 1971 and 2000 and reported that short-run income elasticities ranged between 0.04 and 3.48 in previous studies. They further found that the short-run elasticity tends to be lower when controlling for appliance ownership. Their results suggest the income elasticity of Japanese households similar to that of other countries. In addition, Onuma et al. (2019) compared the price elasticity of electricity demand across different income categories and found that it has an inverted U-shaped. In other words, price elasticity increases until income rises to a certain level and then decreases.

3.5 Household Characteristics and Energy Consumption

Here we examine the relationship between household characteristics and energy consumption. We focus specifically on two types of household characteristics: family composition and age of the head of household. Japan is facing a declining birth rate and aging population; in 2019 the percentage of the country's population aged 65 and older was over 28% (Cabinet Office Japan 2019). The declining birth rate and aging population are affecting the family structure, and the proportion of married couples without children and elderly single-person households relative to all households has been increasing in recent years. Although the Japanese government has introduced various policy measures to address the problems of the declining birthrate and aging population, those policies have not yet been successful. Thus, it is important to know how household energy consumption relates to family composition and the age of the head of household.

We classify households into nine types and calculate monthly energy consumption of each type. The average energy consumption across all households was 6843 MJ in 2014. Households composed of a couple with one child consumed an average of 6800 MJ of energy per month, which is very close to the overall average amount. Larger households consumed much more energy. Three-generation households composed of a couple with their children and their parents consumed 9028 MJ per month, while households composed of a couple with three or more children consumed 7544 MJ per month. Households composed of a couple with two children, or a couple with their parents consumed slightly more energy than average; the former consumed 7097 MJ and the latter consumed 7459 MJ per month. In contrast, consumption by single-person, single-parent, and couple-only households consumed much less energy, using 4563 MJ, 5584 MJ, and 5822 MJ per month, respectively.

It is natural to expect energy consumption to increase as household size increases. However, it is worth noting that there is an economy of scale in household energy consumption. Household members share some energy services and therefore energy consumption per capita decreases as family size increases.

The same trend was observed for energy consumption by type of energy as for total energy consumption. Single-person, couple-only, and single-parent households all consume less energy than average across all types. However, we find that households composed of a couple with children or parents consumed more kerosene than other types of households.[14]

The usage of each type of energy as a percent of the total energy consumption was 35–40% for gasoline and 15–25% for electricity, kerosene and city gas. However, single households tended to consume relatively more gasoline and kerosene than

[14]Energy consumptions of single-person household were 721 MJ for electricity, 693 MJ for city gas, 102 MJ for LP gas, 1273 MJ for kerosene, and 1775 MJ for gasoline. Consumption for couple-only household were 1223 MJ for electricity, 1111 MJ for city gas, 137 MJ for LP gas, 1332 MJ for kerosene, and 2019 MJ for gasoline. Those of single-parent household were 1169 MJ for electricity, 1235 MJ for city gas, 147 MJ for LP gas, 1188 MJ for kerosene, and 1845 MJ for gasoline.

other households. In contrast, their electricity consumption is relatively lower than in other types of households.

Next, we examine the relationship between energy consumption and the age of the head of household. We categorize households into six age groups: (1) up to 29 years old, (2) 30–39 years old, (3) 40–49 years old, (4) 50–59 years old, (5) 60–69 years old, and (6) 70 years old and older. We then calculate average monthly energy consumption for each age group.

We find that energy consumption increases from households headed by those in the youngest age groups to those in the middle age groups, then decreases from the middle to the oldest age groups. Specifically, energy consumption increases from 5245 MJ for households where the head of household is age 29 or younger to 7437 MJ where the head of household is age 50–59. This pattern can be explained by an individual's life cycle. Households headed by younger adults typically live in small houses and do not own many energy-consuming appliances. However, as family size increases for adults in their 30s and 40s, the number of energy-consuming appliances and the frequency of use increases. When adults are in their 50s and children typically leave the household, the family size decreases and the use of energy-consuming appliances begin to decrease.

Finally, we compare consumption of each type of energy across different head of household age groups. The result reveals that households rely on electricity and kerosene more as the age of the head of household increase. Previous studies have shown that seniors prefer warmer room temperature and use more energy for space heating, and the higher electricity and kerosene consumption by households headed by older adults reflect this. In contrast, we find that households headed by seniors consume proportionately less gasoline, city gas and LP gas than households headed by younger adults. This makes sense, as seniors tend to drive less and thus consume less gasoline. Although both city and LP gases are used for cooking, seniors cook less often than young or middle-age heads of households, explaining why gas consumption declines in households headed by seniors.

4 Conclusion

Although the carbon tax rate is currently low in Japan, it could be increased in the near future. A carbon tax solely based on carbon content is an economically efficient that would provide an incentive to reduce energy use, but it may impose very different burdens across regions and types of households. In this study, we used household energy consumption data from NSFE to examine (1) how household energy consumption has changed over time, (2) how energy dependence differs across regions, and (3) how energy consumption patterns vary across households. The results of our analyses reveal that the burden of a higher carbon tax based on carbon content would vary widely between regions and households.

Although households living in cold regions use more kerosene for space heating in winter time than households in warmer regions, the tax rate for kerosene had been set at much lower rate than for other forms of energy. If the energy tax is increased simply based on carbon content, the burden among rural households in cold regions could become much larger. Given that kerosene is indispensable for these households, countermeasures to reduce the burden would be necessary. One potential approach would be to differentiate a basic deduction based on weather conditions; the government increases the base deduction in cold regions for space heating in wintertime while it decreases it in warm regions. If such a countermeasure was applied, regional equity could be insured without increasing the pre-existing distortion of the energy tax.

We also show that although electrification has progressed among Japanese households over the past 25 years, the level of electrification differs according to household income levels. Low-income households still depend primarily on kerosene and gas and we need to carefully examine the effect of a carbon tax on the prices of these forms of energy. Previous studies in Japan have focused on electricity demand and studies that include demand for kerosene and gas are lacking. Obviously, such studies are needed.

It is expected that the average age of Japanese households will continue to increase and the size of households will shrink. Elderly people drive less and thus consume less gasoline. Therefore, an aging population will result in lower gasoline consumption. However, an aging population may increase energy consumption inside the home since elderly people spend more time at home and use more energy for space heating. Given the fact that higher income, healthy seniors are able to go out but poor and unhealthy older people are likely to stay at home, it may be necessary to reconsider the taxation of energy use at home versus energy use outside home. Finally, we confirmed that household size significantly affects energy efficiency, with smaller households exhibiting less energy efficiency. Although aging is expected to increase the number of single-person households, it may be worth considering a preferential tax treatment to encourage seniors to live with their adult children or with other seniors.

Appendix

Conversion from Physical Units to Energy Units

We converted energy consumption given in physical units to energy units (mega joules (MJ)), using the following table (Table 1).

Table 1 Conversion from physical unit to energy unit

Type of energy	Conversion rate
Electricity	3.6 MJ/kWh
City gas	44.8 MJ/m^3
LP gas	50.8 MJ/kg
Kerosene	36.7 MJ/L
Gasoline	34.6 MJ/L
Light oil	37.7 MJ/L

References

Cabinet Office of Japan (2009) Energy taxation etc. https://www.cao.go.jp/zei-cho/history/2009-2012/gijiroku/zeicho/2009/__icsFiles/afieldfile/2010/11/22/21zen9kai5.pdf. Accessed 20 Feb 2020

Cabinet Office of Japan (2019) Annual report on the ageing society. https://www8.cao.go.jp/kourei/english/annualreport/2019/pdf/2019.pdf. Accessed 20 Feb 2020

Espey JA, Espey M (2004) Turning on the lights: A meta-analysis of residential electricity demand elasticities. J Agric Appl Econ 36(1):65–81

Krishnamurthy CKB, Kriström B (2015) A cross-country analysis of residential electricity demand in 11 OECD-countries. Resour Energy Econ 39:68–88

Ministry of the Environment (2012) Introducing taxes for global warming countermeasures. http://www.env.go.jp/policy/tax/about.html. Accessed 20 Feb 2020.

Mizobata M, Kanda K., Manabe Y, Oguro, Y, Suzuki J (2011) The key to addressing power shortages lies in the household sector. Daiwa Institute of Research Holdings Ltd. Economic Report

Narayana PK, Smyth R, Prasad A (2007) Electricity consumption in G7 countries: A panel cointegration analysis of residential demand elasticities. Energy Policy 35:4485–4494

Onuma H, Arimura TH, Matsumoto S (2019) How much household electricity consumption is actually saved by replacement with Light-Emitting Diodes (LEDs)? Research Institute for Environmental Economics and Management. Discussion Paper Series No.1803

Otsuka A, Taguchi YHM, Mase T (2013) An analysis of price elasticity of electric power demand in Japanese regions. Cent Res Inst Electr Power Ind. Research Paper: Y12015

Statistical Bureau of Japan. (1989-2014a). National survey of family and expenditure. http://www.stat.go.jp/english/data/zensho/index.htm. Accessed on 29 July 2017

Statistical Bureau of Japan (1989–2014b) Retail price survey. http://www.stat.go.jp/english/data/kouri/index.htm. Accessed on 20 Oct 2018

Tanishita M (2009) Estimation of regional price elasticity of household elecricity's demand. J Jpn Soc Energy Resour 30(5):1–7

Nozomu Inoue is a demographer at National Institute of Population and Social Security since 2018. He was received the M.A. in Economics from Aoyama Gakuin University, Tokyo Japan, in 2012. He also received the B.A. in Economics from Aoyama Gakuin University. Before coming to National Institute of Population and Social Security, he was a member of the faculty of Aoyama Gakuin University.

His research interests lie in the area of regional demography and geographical information system. In his recent research, he has collaborated with Shigeru MATSUMOTO in the research on the household electricity consumption. He has contributed to the research by issuing an opinion on the time-series changes in household structure.

Shigeru Matsumoto joined the Aoyama Gakuin University faculty in 2008. He studied on Heiwa Nakajima Foundation Scholarship at North Carolina State University, where he earned his Ph.D. in economics. He also holds his Masters of Environmental Science from Tsukuba University. Before coming to Aoyama Gakuin University, he spent seven years on the faculty of Kansai University.

His research interest lies in the applied welfare economics, with particular focus on consumer behavior analysis. In recent years, he studies households' pro-environmental behaviors such as recycling and energy-saving practices as well as consumers' valuation on food attributes such as organic farming.

http://shigeruykr.wixsite.com/happy-environment.

Minoru Morita joined the Takasaki City University of Economics faculty in 2018. He received a Ph.D. in economics from Sophia University in 2014. He also holds his Masters of Economics from Nihon University.

His research interest lies in the environmental and energy economics, with particular focus on consumer behavior analysis. Recently, he studies elderly households' energy use and behavior such as energy-saving practices in Japan.

Chapter 13
Double Dividend of the Carbon Tax in Japan: Can We Increase Public Support for Carbon Pricing?

Kenji Asakawa, Kouichi Kimoto, Shiro Takeda, and Toshi H. Arimura

Abstract Carbon pricing is difficult to introduce in many countries because it is not easy to obtain public support for carbon pricing due to the burden associated with it. One way to overcome this difficulty is to rely on the double dividend of a carbon tax. If a government uses revenue from a carbon tax to reduce existing distorting taxes, such as corporate taxes or labor taxes, a carbon tax can improve economic efficiency while reducing greenhouse gas (GHG) emissions. This chapter examines the net burden of a carbon tax with revenue recycling (RR) for two types of stakeholders: firms and households. Using dynamic computable general equilibrium (CGE) modeling, we examine the carbon prices needed to achieve the emission targets set for 2030 and 2050. Then, we simulate two types of RR: corporate tax reduction and a reduction in social security payments. We compare the benefit of the tax reduction to the increase in the burden from the carbon tax in scenarios for 2030/2050. In the scenario of corporate tax reduction, by selecting firms from the land transportation sector and power sector, we examine how profit changes due to the carbon tax. We find that the tax burden for a firm in the land transportation sector can be eased greatly with the corporate tax reduction. In the scenario of the social security payment reduction, we find that some households are better off under carbon pricing despite expenditure

Toshi Arimura and Shiro Takeda appreciate financial support from the Foundation of Japanese Bankers' Association.

K. Asakawa
Institute for Global Environmental Strategies (IGES), Hayama, Japan

K. Kimoto · T. H. Arimura (✉)
Faculty of Political Science and Economics, Waseda University, 1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo 169-8050, Japan
e-mail: toshi.arimura@gmail.com

S. Takeda
Kyoto Sangyo University, Kyoto, Japan

K. Kimoto
Research Institute for Environmental Economics and Management, Waseda University, Tokyo, Japan

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*, Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7_13

increases due to the carbon tax. Thus, we show that RR can increase support for the carbon tax.

1 Introduction

Carbon pricing is known as the most efficient way to reduce greenhouse gas (GHG) emissions in an economy. As shown in the previous chapters, carbon pricing at the regional level in Japan, namely, the Tokyo emissions trading system (ETS) (Chap. 6) and Saitama ETS (Chap. 7), has been successfully reducing GHG emissions. The national government, however, has not introduced an ETS. Moreover, the carbon tax introduced at the national level in 2012 was only 289 yen per ton of CO2 (Chap. 1), which is equivalent to 0.78 yen per liter of gasoline.

In Japan, the current level of the carbon tax is still not enough to achieve the long-term emission reduction goal set for 2050 (Chap. 1); thus, it is expected that the government will increase the tax rate (or introduce a nationwide emissions trading scheme) in the near future. However, when increasing the carbon tax, policymakers often face strong opposition from various stakeholders, who bear the burden of the direct price increase due to carbon pricing (Carattini et al. 2017). Overall, the opposition from the economic sector is most prominent. The economic cost, however, can be eased if the revenue from carbon pricing is used wisely. For example, if the revenue of the carbon tax is used to reduce the corporate tax, we can expect an expansion in investment because the net return of the investment increases as the corporate tax rate is reduced. This increase in investment will lead to an increase in production and hence an increase in the GDP. Alternatively, governments can use the revenue of the carbon tax to reduce the social security burden of employers. In this case, we can expect an increase in employment, which also leads to an increase in the GDP through an expansion in production activities. In this way, the revenue recycling (RR) of the carbon tax can lead to economic growth.

This revenue recycling process is known as the "double dividend" of carbon pricing[1]. When the gains from RR offset the cost of the price increase due to carbon pricing, GDP or welfare can improve to a level better than that without carbon pricing. The introduction of carbon pricing with RR is also known as "environmental tax reform" because environmental tax (carbon tax) revenue is used to reduce the existing distorting tax. A carbon tax with RR can even increase the GDP or welfare if the strong double dividend holds.

Various studies have investigated the possibility of the double dividend. Saveyn et al. (2011) used a computable general equilibrium (CGE) model for the EU and investigated the impacts of carbon regulations on economies. They found a double dividend when permit revenues are used to reduce the social security contribution

[1]There are two types of double dividends. When the net gain is positive, it is referred to as the "strong double dividend". Otherwise, it is known as the "weak double-dividend". See Goulder (1995) for the details.

of employees. Carbone et al. (2013) developed a dynamic CGE model for the US economy and found a double dividend when recycling revenues are used to reduce capital taxes (i.e., corporate taxes or personal income taxes on interest, dividends, or capital gains). Jorgenson et al. (2013) also examined the possibility of a double dividend by developing a CGE model for the US economy and found a double dividend when carbon tax revenues are used to reduce capital tax. Furthermore, Pereira et al. (2016) constructed a dynamic CGE model for Portugal and examined the carbon tax policy. They found a double dividend when carbon tax revenues are used for the policy, including the cut in social security contribution and personal income taxes. Thus, researchers validated the idea of the double dividend for several countries with economic models. One can refer to Freire-González (2017) for the literature of the double dividend

The idea of the double dividend has been adopted in the reforms of other countries. When Germany adopted energy tax reform in 1999, tax revenue was used to reduce statutory pension contributions (Beuermann and Santarius 2006). The United Kingdom adopted this idea as well (Agnolucci 2009). Recently, the province of British Columbia in Canada has adopted this idea. They used carbon tax revenue to reduce corporate taxes and successfully achieve economic growth and GHG emission reduction (Yamazaki 2017).

In the case of Japan, using a CGE model, Takeda (2007) shows the possibility of double dividends using RR for corporate taxes. Lee et al. (2015) also assesses the double dividend for the Japanese economy using a macroeconometric model. More recently, to achieve the long-term goal of emission reduction, Takeda and Arimura (2020) characterize the nature of the double dividend for the Japanese economy and confirm that corporate tax reduction using carbon tax revenue can lead to economic growth by 2030. However, even if economic growth is achieved at the macro level, the tax burden varies among strong stakeholders. Some may win or some may lose.

To increase public support for the carbon tax with RR, it is useful to illustrate how the tax burden can be eased with RR. To address the concerns of industrial stakeholders, it is important for policy makers to show how much tax burden would be reduced for each sector. However, it is often the case that firms would not appreciate an analysis conducted at the sector level. Industrial stakeholders often want to see the results of an analysis at the firm level showing how their profit would be affected by the carbon tax with RR (IGES 2016). Thus, by selecting specific firms from two sectors, this chapter investigates how the profit would change under the carbon tax with RR in 2050.

Another important stakeholder that affects the public support of carbon pricing is households. The tax burden from carbon pricing can be eased with RR. There are several ways to improve the economic efficiency of household behavior through RR. One way to do so is to use carbon tax revenue to reduce social security payments. In this case, households have incentives to increase their labor supply. Moreover, under this scenario, households' payments to social security would decrease, and hence, households may be better off even with the increase in the carbon tax burden. We investigate whether this can be case for the Japanese economy while aiming for a long-term reduction in CO_2.

The analysis in this chapter is conducted in the following way. First, we conduct a CGE analysis of carbon pricing needed to reach the 2050 long-term reduction target. We calculate the carbon tax rate necessary to achieve the 2030 and 2050 targets. In this simulation, we make several assumptions. In the BAU scenario (where the carbon tax is not introduced), we adopted the *current policies scenario* in World Energy Outlook 2018 (IEA 2018), i.e., an average annual GDP growth rate of 0.7% and an average CO_2 emission reduction rate of 0.6%. By employing the CGE model, we can identify the output for each sector in 2050 and use the results for the simulation for corporate tax reduction. We also use the tax revenue obtained from CGE modeling to determine the size of a feasible corporate tax reduction. Regarding the social security payment reduction scenario, we use carbon pricing needed to achieve the 2030 target. Again, we use the CGE simulation results to calculate a social security payment reduction that is feasible with the carbon tax revenue. Furthermore, we use the results from the input-output analysis conducted by Kameoka & Arimura (2019) to identify the increase in household expenditures. This chapter is organized as follows. Section 2 describes the CGE model used to calculate the macro outcome of the carbon tax to achieve the 2050 long-term goal. In Sect. 3, we analyze the impacts of the corporate tax reduction under the carbon tax on firms in selected sectors. Section 4 examines the impacts of the social security tax reduction under carbon tax reform on households. The final section concludes the chapter by discussing public support for carbon pricing.

2 A Dynamic CGE Model for the 2050 Long-Term Target and the Results

2.1 A CGE Model

We use a dynamic CGE model for the Japanese economy, which is constructed in Takeda and Arimura (2020), and analyze the impacts of environmental tax reform under a scenario that includes the long-term emission reduction target for the year 2050. Using the CGE model, we derive the quantitative impacts of environmental tax reform on aspects of the macroeconomy, such as the GDP, national income and tax revenue, including carbon tax revenue. In addition, we calculate the sectoral impacts such as the output and price of individual sectors. These results are used in later sections. In this section, we explain the simulation based on the CGE model. Because of space limitations, we provide only a brief summary of the analysis. The complete description of the analysis is presented in Takeda and Arimura (2020). For details, see this article.

Our model is a forward-looking dynamic general equilibrium model for the Japanese economy. To perform a CGE analysis, we need to construct a benchmark dataset. For this, we use 2011 input-output data on Japan (MIC 2016). To analyze CO_2 regulations, we also need CO_2 emissions data associated with the energy use of production sectors and households. For CO_2 emissions data, we use the 3EID (Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables) dataset (Nansai et al. 2018). Our model is a general equilibrium model with 49 goods and 39 sectors including 14 energy goods and four electricity sectors. We aggregate the original input-output (IO) data for Japan and create the aggregated datasets. To analyze the role of energy goods in detail, we highly disaggregate the energy goods and sectors. Basically, one sector produces one good. However, some sectors, such as the petroleum goods sector and coal products sector, produce multiple energy goods. Moreover, some goods, such as electricity, are produced by multiple sectors. Thus, there is not always a one-to-one relation between goods and sectors.

All markets are perfectly competitive, and all agents behave as price takers. We assume that all producers have “constant returns to scale” technology, and producers maximize their profit by choosing the quantity of output and input (primary factors and intermediate inputs). We employ two types of production functions: the fossil fuel production function and the nonfossil fuel production function. Fossil fuel production activities include the extraction of coal, crude oil, and natural gas. However, nonfossil fuel production activities are used for all other sectors, including the electricity sector.

To represent the demand side of the economy, we use a representative household. The period utility (utility in a period) of the representative household depends on consumption and leisure. Because it is under a budget constraint, the household chooses values for consumption, leisure and saving (= investment) that will maximize lifetime utility, which is the sum of discounted period utility. Household income consists of primary factor income minus tax payments. In this model, the household labor supply is determined by the choice between leisure and labor supply. Thus, labor supply is an endogenous variable. The decreasing population of Japan is captured by the decreasing endowment of time that the representative household can use for leisure and work.

For CGE analyses on climate change policy, a recursive dynamic model is often used. In a recursive dynamic model, investment is determined by myopic agents and thus not affected by policy changes in the future (only affected by the past and current policy). In this analysis, we would like to analyze a scenario in which corporate tax is reduced. To capture the effects of a change in corporate tax, we use a forward-looking dynamic model used in the macroeconomic literature. In a forward-looking model, investment is determined by the dynamic optimization behavior of the household, and the capital stock owned by the household accumulates gradually through investment.

Our model covers a long time span (from 2011 to 2050). In the model that aims to analyze climate change policy in the long run, technology improvement and new technology can play important roles. To capture these factors, we consider the following technology improvement and new technology. First, we assume total factor productivity (TFP) growth for every production sector. TFP here means the efficiency of the inputs of primary factors, and it is captured by a parameter in the production functions. In addition, we assume autonomous energy efficiency improvement (AEEI) for energy inputs in production and consumption. These technology improvements are assumed to be exogenous. Second, we assume that electricity is generated not only by conventional energy (fossil fuel, hydropower and nuclear energy) but also by renewable energy. Although the supply of electricity by renewable energy is limited at first due to its high cost, it increases gradually as the price of electricity rises.

Third, we consider carbon capture and storage (CCS) activity. CCS activity is modeled as an independent production activity that uses production factors and intermediate inputs. As electricity can be generated by the use of renewable energy, CCS activity is not supplied at first because it is not profitable. However, the increase in carbon prices caused by carbon regulation makes CCS activity profitable, and the amount of CCS will gradually increase. Due to the existence of CCS activity, we calculate net CO_2 emissions as gross CO_2 emissions minus CCS.

Although our model focuses on Japan, we need to consider international trade with other regions. To model international trade, we employ the small country assumption, where the terms of trade of Japan are kept constant. In addition, we use the so-called Armington assumption, which means that imported goods are imperfect substitutes of domestic goods. To incorporate the Armington assumption, we use the constant elasticity of substitution (CES) function to aggregate imported and domestic goods.

In the simulation, we analyze the regulation of CO_2 emissions. To regulate CO_2 emissions, we use a carbon tax. The carbon tax generates additional revenue for the government, and we consider the following two uses. First, we assume that carbon tax revenue is directly rebated to the representative household. Second, we assume that carbon tax revenue is used to reduce existing taxes such as the income tax, corporate tax and consumption tax. The latter case indicates environmental tax reform (the combination of a carbon tax and the reduction in existing taxes). We assume that the (net) CO_2 emissions in Japan are reduced by 80% by 2050, which is the actual reduction target of Japan. CO_2 emissions are gradually reduced to achieve the target level in 2050.

2.2 Scenarios

In this subsection, we explain the scenarios employed in the simulation. Table 1 lists the scenarios. The BAU scenario is a reference scenario where no (explicit) carbon regulation is executed. In the other three scenarios from LMP to COR, a carbon tax is adopted to regulate CO_2 emissions. In scenario LMP, we assume that carbon tax revenue is rebated to the household in a lump-sum way. In the other two scenarios, carbon tax revenue is used to reduce the existing taxes. In scenario SSC, we reduce the social security contribution of the employer. Strictly speaking, the social security

Table 1 Simulation scenarios

Scenario	Explanation
BAU	Reference scenario (without carbon tax)
LMP	Carbon tax + lump-sum rebate
SSC	Carbon tax + social security contribution cut
COR	Carbon tax + corporate tax cut

Table 2 Simulation results of a dynamic CGE

		LMP	SSC	COR
2030	GDP	−0.59	−0.10	0.38
	Income	−0.83	−0.34	0.44
	Carbon tax revenue	10,287	10,651	10,364
	Rebated revenue	0	7,634	6,707
2050	GDP	−2.06	−1.44	−0.95
	Income	−2.93	−2.25	−1.51
	Carbon tax revenue	14,055	14,403	14,499
	Rebated revenue	0	8,509	7,480

GDP, Income → %
Carbon tax revenue and rebated revenue → billion yen

contribution of the employer is not a tax. However, it is similar to a tax on labor because employers have to contribute to the social security of their employees. The reduction in the social security contribution will stimulate employment and the labor supply, thereby increasing production. The results of scenario SSC are presented in Sect. 4.

Scenario COR assumes that the carbon tax revenue is used to reduce the corporate tax. The corporate tax in this model is a tax on return on capital.[2] Therefore, the reduction in the corporate tax stimulates investment (accumulation of capital stock), thereby increasing production. The results from scenario COR are discussed in Sect. 3.

2.3 *Simulation Results*

Although our simulation derives various quantitative economic impacts, we present only the results relevant for the analyses in later sections. Table 2 reports the simulation results. “GDP” and “Income” indicate the percentage change in the GDP and national income caused by the values (%) used in scenario BAU in 2030 and 2050. “Carbon tax revenue” indicates carbon tax revenue (billion yen), and “Rebated revenue” (billion yen) indicates how much the existing taxes are reduced. In scenario LMP, carbon tax revenue is rebated directly to the household, and the value of the “rebated revenue” is zero. Carbon tax revenue is used to reduce the existing taxes in scenarios SSC and COR. The value of the “rebated revenue” is less than that of “carbon tax revenue” because carbon regulation decreases other tax revenue (revenue, for example, from the income tax, consumption tax and so on), and we cannot use all of the carbon tax for reducing the existing taxes.

[2]In the CGE analysis, “profit” is captured as payment toward capital. Thus, the corporate tax is understood as a tax on the return on capital.

Let us examine the results. In scenario LMP, the carbon tax decreases the GDP and income in 2050 by 2.06% and 2.93%, respectively. This is the pure impact of CO_2 regulation, and this result indicates that an 80% reduction in CO_2 has large negative macroeconomic impacts on the Japanese economy. The GDP and income also decrease in SSC. However, the size of the decrease is less than that in scenario LMP. This is because scenario SSC with the reduction in the social security contribution generates a RR effect that increases employment and the labor supply. This RR effect offsets some of the negative impacts of CO_2 regulations, thus reducing the decrease in GDP and income.

Similarly, in scenario COR, the GDP and income decrease in 2050, and as in scenario SSC, the size of the decrease in the GDP and income is less than that in the previous simulation. However, CO2 regulation in scenario COR has positive impacts on the GDP and income in 2030; in other words, we have the strong double dividend effect in scenario COR in 2030. This is because the RR effect in scenario COR significantly stimulates investment and thereby increases the GDP and income.

Finally, let us see the value of the carbon tax. Carbon regulations generate carbon tax revenue of approximately 10 trillion yen in 2030 and 14 trillion yen in 2050. In scenarios SSC and COR, a part of this carbon tax revenue is used to reduce social security contributions and corporate taxes. These values are used in a later section.

In Sect. 3, we evaluate the impacts of RR on individual sectors in detail. For that analysis, we use other simulation results not shown in this section, for example, impacts on sectoral outputs and prices. Due to space limitations, we omit these results.

3 Double Dividend Through Corporate Tax Reduction

This section discusses the impact of the corporate tax reduction under the carbon tax reform examined in the previous section. We focus on the financial impacts on selected industries. The most common method for assessing the impact of carbon pricing on industry is employing economic simulation models to quantify the impact on each industrial sector. The information regarding the overall impact on each sector obtained through this method can be useful for planning measures such as tax exemptions.

However, carbon pricing has often been understood only as a short-term increase in the cost of energy and raw materials for firms (IGES 2016). This is also true even if the economic simulation models predict the possibility of some sectors having increased profits or a very small negative impact on profits. Individual firms are rarely aware that profits can increase as a result of a positive economic effect and the tax RR effect. These firms can understand the benefit of RR only after they see the simulation for each individual firm.

We analyze the financial impact of carbon pricing on individual firms by reflecting the effects of the carbon tax predicted by the economic simulation model in Sect. 2. In the analysis, we build on the results provided in Sect. 2.

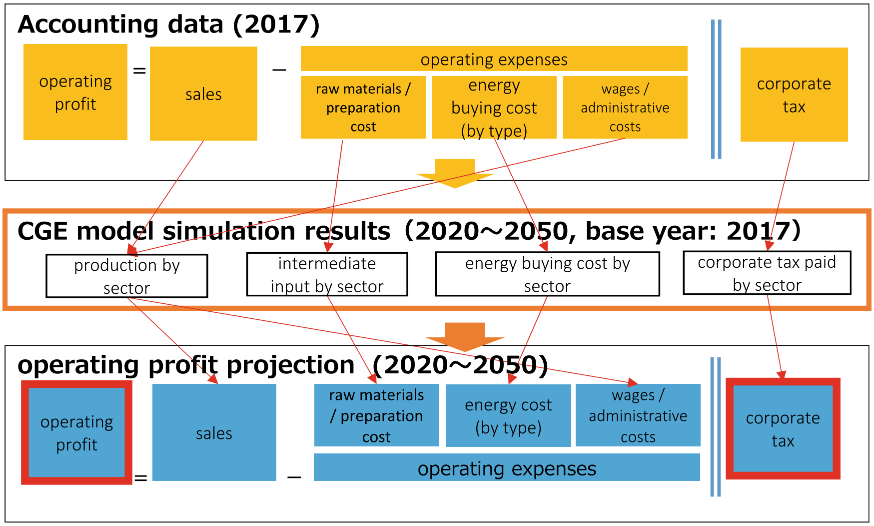


Fig. 1 Methodology used to assess the results of the economic simulation model on firm accounting

3.1 Analysis Method

1. **Analysis indicators and methodology**

This analysis assumes that the carbon tax proposed in Sect. 2 is employed and examines the financial impact on individual firms. To indicate financial performance, we employ operating profit (or operating loss) and the operating profit ratio.[3]

Figure 1 shows the methodology used to calculate the results of the economic simulation model (CGE model) that is described in Sect. 2 on firm accounting.

As shown in Fig. 1, first, data on the sales and operating expenses, which are the two factors to calculate the operating profit, were obtained from the financial disclosure reports of the firms targeted for the analysis. Data on the energy cost, which is a part of the operating expenses, and the consumption structure of each type of energy were obtained from the corporate social responsibility (CSR) reports of the targeted firms.

Next, for each sector, each component of the operating profit, i.e., the production amount, energy cost by energy type, and corporate tax cost, was calculated from 2020 to 2050 (in 10-year intervals) by applying the growth rate from 2017 calculated by

[3]Operating profit and the operating profit ratio are the financial indicators of the core business of the firm and affect its decision-making; they are not affected by financial factors unrelated to the core business, such as the corporate tax. Therefore, even if the collection of a carbon tax results in a reduction of the corporate tax, operating profit and the operating profit ratio would remain unchanged. To overcome this issue, this analysis includes in its calculations the corporate tax reduction in addition to the variation in operating profit. In this way, the analysis compares the impact of the corporate tax reduction when there is a decrease in operating profit.

Table 3 Financial data of the firms targeted for analysis (2017) (Unit: million JPY)

Sector	Operating profit ratio (%)	Operating profit	Sales	Energy cost	Other operational costs	Corporate tax
Land transport	2.30	40,000	1540,000	30,000	1470,000	10,000
Electric power	4.40	110,000	2,600,000	710,000	1,770,000	20,000

Note regarding land transportation, operating costs apart from "Energy purchasing costs", such as vehicle depreciation costs, leasing costs, etc. are included in "Other operational costs"

the CGE model simulation in Sect. 2. We use data from 2017 as the reference year. For instance, the growth rate of the production in each sector was used to calculate the sales and the wages/administrative cost. The growth rate of the intermediate inputs, energy costs and the coporate tax paid in each sector were used to calculate the raw material cost, energy cost and corporate tax, respectively.

2. **Scenarios and the target sectors**

To analyze the effects of the carbon tax as well as the tax RR effect, the following two scenarios were analyzed. One is a scenario where a carbon tax is not introduced (BAU). Another is a scenario where a carbon tax is introduced, and tax revenue is used to reduce the corporate tax (COR).

Out of the 17 sectors that are included in the economic simulation models (CGE models) in Sect. 2, we target the land transportation sector and the electric power sector. These two sectors were chosen for this analysis for two reasons. First, the firms in these sectors focus on the activities in that sector and do not conduct business activities in other sectors. In this sense, they are highly homogeneous. Second, these two sectors could be directly affected by the carbon tax because they use a large amount of fossil fuel.

3. **Firms targeted for analysis**

We target one firm from each sector chosen for the analysis, as shown in Table 3. We selected firms that mainly focused on their own main sector and conducted few activities in other sectors.[4]

[4]For example, firms in the paper and pulp industry often are involved in business activities outside the paper and pulp industry. In this case, the analysis of the carbon tax burden becomes complex. We avoid those sectors.

3.2 *Impacts of the Corporate Tax Reduction Under a Carbon Tax on the Selected Sectors*

To assess the effect of this corporate tax reduction on operating profit, a comparative analysis between the BAU and COR scenarios was carried out for the year 2050 focusing on the profits and losses resulting from the carbon tax (Figs. 2 and 3).

1. **Land transportation sector**

Figure 2 illustrates how profit changes due to the carbon tax and the corporate tax reduction for a firm in the land transportation sector. The increase in energy costs due to the carbon tax equals 38.6% of the operating profit in scenario BAU. However, the increase is neutralized by other profits, namely, increased profit from an increase in sales. Thus, the reduction in the operating cost is 29.4% before the corporate tax reduction.

In the COR scenario, however, the reduction in the corporate tax will financially help the firm financially by the amount of 10.9% of the profit. Consequently, the profit loss is reduced to 18.5%. The corporate tax reduction significantly eases the economic burden.

2. **Electric power**

Figure 3 illustrates how profit changes due to the carbon tax and the corporate tax reduction for a firm in the electric power sector. The increase in energy costs due to the carbon tax equals 52.2% of the operating profit in scenario BAU. However, the

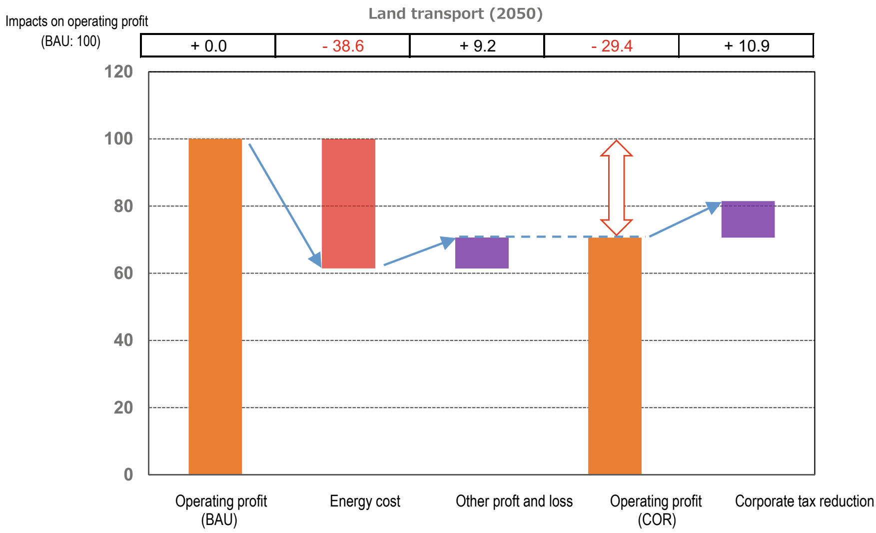


Fig. 2 Comparative analysis of operating profits in the BAU and COR scenarios (Land transport in 2050)

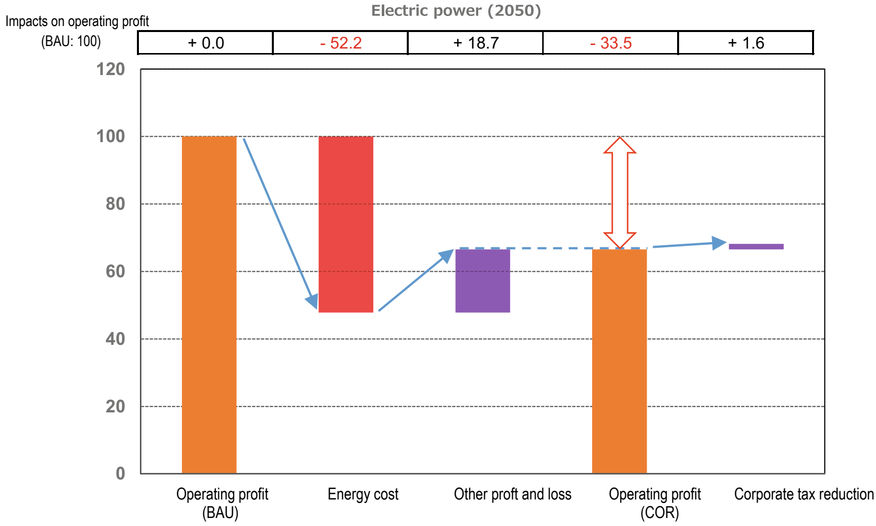


Fig. 3 Comparative analysis of the operating profits in the BAU and COR scenarios (electric power in 2050)

increase is neutralized by other profits, namely, increased profit from an increase in sales. Thus, the operating cost is reduced by 33.5% before the corporate tax reduction.

In the COR scenario, however, the reduction in the corporate tax will financially help the firm by the amount of 1.6% of the profit. Consequently, the profit loss is 31.9%. The corporate tax reduction eases the economic burden only slightly in this case compared to the case of land transport.

3.3 Discussion on the Corporate Tax Reduction

Our analysis shows that the increase in energy costs is neutralized by the corporate tax reduction in the COR scenario to a certain degree, although the operating profit decreases as a result of the carbon tax. Thus, we confirm the benefits of the double dividend policy for industry stakeholders. By showing these results, we may be able to obtain more public support for carbon pricing from industry stakeholders.

We would like to note that the benefit of the corporate tax reduction depends on the size of the corporate tax on the operating profit. It is expected that the effect of the corporate tax reduction on profit will increase as the ratio of the corporate tax to operating profit increases. Moreover, the costs resulting from the carbon tax increase as the level of carbon intensity increases. When we consider these two factors together in the COR scenario, the net cost of the carbon tax would follow the patterns shown in Table 3. In fact, firms in some sectors, such as the service sector, may earn more “profit” when the effect of the tax reduction is larger than the costs.

Table 4 Level of the net cost of carbon tax in the COR scenario

Net cost resulting from carbon tax		Carbon intensity		
		Low	Medium	High
The ratio of corporate tax per operating	High	(Minus)	Low	Medium
	Medium			
	Low (- zero)	Low	Medium	High

Land transport

Electric power

When we consider the carbon intensity and the ratio of corporate tax per operating profit of the targeted firms, the values in the land transport sector could be low and those in the electric power sector could be high in terms of the level of net cost of the carbon tax under the COR scenario (Table 4).

4 Revenue Recycling to Households Through the Social Insurance System

4.1 Significance of Revenue Recycling to Households: Viewpoint of Labor Market Efficiency

This section discusses the impacts of the RR of carbon tax through the social insurance system. There are two channels in which RR can stimulate economic activities by removing distortions in markets. First, RR can increase the labor demand of firms. RR through the social insurance system encourages firms by providing incentives to hire more employees. The financial resources of the social insurance system mainly consist of taxes and social insurance premiums. If the insured is an employee, there is an employer burden. In Japan, social insurance premiums are borne equally by workers and employers (50% each) basically. For firms, the employer burden is only reflected as labor costs. firms are less willing to hire employees if they face a greater insurance burden. The presence of social insurance premiums has created inefficiencies in the labor market. Therefore, if government revenue from carbon pricing is used to reduce social insurance premiums, labor costs will decrease, and firms will have more incentives to hire employees. In other words, RR through the social insurance system increases the efficiency of the labor market.

Second, RR through the social insurance system can encourage households to increase their labor supply. Households supply labor and earn wages in the labor market. However, wages are different from disposable income. Households obtain disposable income when the government deducts taxes and social insurance premiums from wages. The determination of the household labor supply depends on disposable income. The burden of taxes and social insurance premiums basically increases as income increases. Therefore, to avoid the burden of social insurance premiums, employees often suppress their labor supply. Social insurance premiums work as a disincentive for the labor supply of households, creating labor market inefficiencies. If government revenue from carbon pricing is used to reduce social insurance premiums, disposable income will increase, and household labor supply will increase. In other words, the recycling of government revenue through the social insurance system increases the efficiency of the labor market.

4.2 Revenue Recycling Through the National Pension System

1. **Structure of the public pension system in Japan**

There are three ways we can recycle carbon tax revenue through the social insurance system: (1) the public pension system, (2) the public health insurance system, and (3) the long-term care insurance system. In this study, the public pension system is considered.

Japan's public pension system is a universal pension system. Figure 4 illustrates the basic structure of the national pension system in Japan. An employee joins the employee's pension insurance system and simultaneously becomes an insured person of the national pension system. In the national pension system, the person insured through the employee's pension is called a Category II insured person. The dependent spouse of a Category II insured person is a Category III insured person. If s/he is not a Category II or the Category III insured person, s/he will be a Category I insured person, basically a self-employed person, unemployed person, student, part-time worker, etc.

A person insured by the employee's pension bears an insurance premium in proportion to his or her wages. This premium includes the national pension premium. Similarly, a person insured by the employee's pension receives pension benefits in proportion to his or her wages. This pension benefit includes the benefit of the national pension (basic pension). The employee's pension premium is equally borne by the workers and employers (50% each). However, Category I insured persons with only the national pension system basically bear a fixed premium (¥ 16,410 in FY2019).

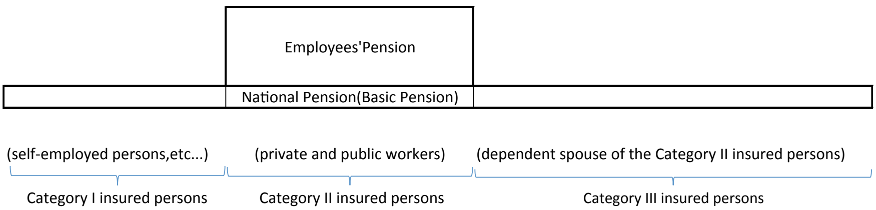


Fig. 4 Structure of the Public Pension System in Japan. *Source* Drawn by the Author

Category III insured persons can benefit from the national pension (basic pension) without paying premiums.[5]

2. **Revenue recycling method in the public pension system**

In the discussion of RR through the public pension system, it is assumed that the insurance premium burden for the national pension system will be reduced.[6] This is because the national pension system forms the basis of the universal pension system and can be widely recycled to the insurance of the public pension system. Based on the basic pension contribution structure, the government revenue from carbon pricing is recycled to the insured of the employee's pension system (for Category II insured persons) and Category I insured persons in the national pension system according to the number of insured persons. According to the basic pension contribution structure, the number of Category III insured persons is the number of insured persons under the employees' pension insurance system. For Category I insured persons, the insurance premium is reduced by dividing the government revenue by the number of insured persons covered by the national pension system. For Category II insured persons, the insurance premium will be reduced in consideration of the number of Category III insured persons. However, since the insurance premium burden is equally borne by workers and employers (50% each), the reduction in the insurance premium burden for Category II insured persons will be 50%. In this way, the government revenue from carbon pricing is recycled to households in the form of reducing the insurance premium burden for the national pension system. For firms, the burden of social insurance premiums is also reduced.

The Japanese economy is facing a decreasing and aging population. Therefore, it is important to clarify the assumption regarding the structure of the population. We adopt a scenario based on government planning for the pension system. Specifically, in this analysis, we use the median estimate of the number of insured persons as shown in the fiscal verification published in 2019 by the Ministry of Health, Labor and Welfare. Fiscal verification is employed to examine the sustainability of the public pension system in several cases with respect to economic assumptions regarding factors such as the population and labor participation. The case used in the analysis is a case where labor participation progresses. The population is based on the median estimates published by the National Institute of Population and Social Security Research, where the sustainability of the public pension system as indicated in the 2004 pension reform will be maintained. The government should employ this economic assumption. Therefore, this case is used as a premise of the analysis here. A detailed discussion of the 2004 pension reform is beyond the scope of this book. The total amount of RR is 8.5 trillion yen in 2030 and 7.6 trillion yen in 2050.

[5]This is called the problem of Category III insured persons. This problem can be divided into two parts. The first part concerns the fairness of the burden and benefits. The second part concerns a reduction in working hours to avoid the premium burden. Please see Kimoto (2016), which elaborates on this problem, for a detailed discussion.

[6]The benefit from revenue recycling is the reduction in the premium burden. However, if the premium is exempted, and the burden is less than the benefit from revenue recycling, the difference will be paid in cash.

Table 5 Decrease of the Burden under Revenue Recycling through the National Pension System (yen)

Year	RR to category I	RR to category II	The revenue to employers (Trillion)
	(1)	(2)	(3)
2030	137,346	78,710	3.4
2050	159,070	90,187	3.1

Source Authors' own calculation

3. **Simulation results**

The simulation results are shown in Table 5. Column (1) shows the decrease in the burden for a Category I insured person. Similarly, column (2) shows the decrease in the burden for a Category II insured person. Finally, column (3) exhibits the decrease of the payment for the employer sector. The employer sector refers to firms that employ Category II insured persons.[7] All figures are shown in nominal amounts.

According to the simulation results, the payment for the national pension for Category I insured persons would decrease by 137,346 (159,070) yen annually in 2030 (2050) if they are paying the premium fully without any exemptions. Similarly, column II shows that the payment of the premium for Category II insured persons would decrease by 78,710 (90,187) yen annually in 2030 (2050). Column (3) shows the decrease in the payment for the employers. The burden for the employer would decrease by 3.4 (3.1) trillion yen in 2030 (2050).

4. **Discussion**

First, Table 5 shows that the amount of RR to a Category I insured person is greater than that to a Category II insured person. Category I insured persons are better off than those in Category II. The reason for this difference is that, for a Category II insured person, the amount of the RR will be split with the employer. That is, some portion of the revenue is given to employers, while employees would receive only a part of the revenue.

The total amount of the recycled revenue will be lower in 2050 than in 2030. However, the amount of recycled revenue to the insured will be larger in 2050 than in 2030 for both (1) and (2). This is because the number of insured persons decreases simply due to the declining birthrate, and the amount per person increases. However, the amount of RR to the employer is not affected by the declining birthrate, so the amount of RR is higher in 2030 than in 2050.

Let us consider the following three types of households based on the simulation results for 2030: (1) self-employed married households (*family type I*), (2) married households of firm employees (*family type II*), and (3) married households of firm employees and full-time housewives (*family type III*). The self-employed married households (*family type I*) consist of two Category I insured persons, so the amount of RR is 274,692 yen, doubling the benefit of Category I insured persons. For the

[7]Therefore, this sector includes not only firms but also the government sector.

Table 6 Net Benefit of Revenue Recycling through the National Pension System (Yen)

	Self-employed married households	Married households of firm employees	Married households of firm employee and full-time housewife
	Family type I	Family type II	Family type III
Benefit	274,692	157,420	78,710
Net benefit	120,239	2967	−75,743

Source Authors' own calculation

married households of firm employees (*family type II*), the amount of RR is 157,420 yen. Here, we also assume that both the wife and husband work full-time. The married households of firm employees and full-time housewives (*family type III*) are composed of a Category II insured person and a Category III insured person, so the amount of RR is only 78,710 yen. As a result, households with a Category I insured person receive a generous benefit. The results of this simulation for all three types of households are illustrated in the first row of Table 6.

Meanwhile, households face an increase in expenditures if firms pass all the costs of the carbon tax to their customers. Using IO table analysis, Kameoka and Arimura (2019) examined the impacts of the cost increase from a carbon tax on the Japanese economy. They simulated a carbon tax of 2905 yen per ton of CO_2 and found that the expenditures of a typical household consisting of two family members or more is 28,968 yen annually. In the CGE analysis, the level of carbon tax in 2030 is 15,489 yen. Given the linear nature of the IO analysis, we can infer that the expenditures of a typical household increases by 154,453 yen. Using this estimate, we can compute the net benefit of RR under carbon pricing. The net benefit for each family type by subtracting this increase in expenditures from the benefit of RR is shown as the "net benefit" in the second row of Table 6.

What will be the outcome of RR be for each family type? Family type I is better off with a carbon tax if RR is adopted for the national pension system. Thus, family type II is not worse off even under carbon pricing. We expect that the government can gain public support for the carbon tax from these types of households if the revenue is recycled in this way. In contrast, the burden for family type III will increase by 75,473 yen annually.

RR can have an impact on the labor supply. The RR method described above provides incentives for the labor supply of Category III insured persons. Category III insured persons can receive benefits from the national pension (basic pension) without incurring premiums. Therefore, the labor supply is adjusted such that Category III insured persons will remain in their position to avoid the premium burden. In this situation, what will happen if RR through the national pension system is implemented? If Category III insured persons remain in their position, they will not benefit from RR. Therefore, there is a possibility to shift to Category II insured persons without adjusting the labor supply to benefit from RR. Of course, if Category III insured persons shift to Category II insured persons, insurance premiums will be incurred, so even if RR is considered, disposable income will not necessarily increase. However, if Category III insured persons become Category II insured persons, they will obtain pension benefits proportional to their wages. This pension benefit is greater than that of the basic pension. Considering this pension benefits when they become the elder, the workers determine the labor supply. If RR through the national pension system is implemented, the labor supply will be encouraged, and thus, they could receive this pension benefits and also benefit from RR. Thus, RR through the national pension system will promote the labor supply.

The RR in this section is consistent with the current government policy regarding social security reform. The setting of RR is intended for "insured persons" of the national pension. Pensioners (basically the elderly) are not eligible for this benefit. The RR considered in this study benefits the working generation. Until now, social security in Japan has been concentrated on the elderly, but in recent years, the government has started to pay attention to younger generations. Thus, social security for the working generation has been emphasized. The RR envisaged in this study is targeted at the working generation and is consistent with government policy regarding social security reform.

5 Conclusion

In this chapter, we examined the impacts of environmental tax reform on households and firms in selected sectors with the aim of reducing GHG emissions by 80% in 2050. Specifically, based on the simulation results of a dynamic CGE model, we investigated the impacts of two types of RR. One is corporate tax reduction for firms, and the other is a reduction in social security payments.

To assess the corporate tax reduction, we examined two sectors: the land transportation and the electric power sectors. We found that even when employing a high carbon price to achieve the national emission reduction target, the cost increase from the carbon tax can be offset to a certain degree with RR through a corporate tax reduction.

For the case of a reduction in social security payments, we found that some households are better off if the government uses the revenue from the carbon tax to reduce social security payments. Thus, RR from a carbon tax is an attractive option for some firms and households.

In many cases, the introduction of carbon pricing faces opposition from various stakeholders. However, the simulations conducted in this chapter illustrate that, at the individual firm level or at the household level, some stakeholders that are better off with RR. Therefore, providing information on these micro data analyses can increase support for carbon pricing.

We should mention some caution should be taken when interpreting these results. Regarding the corporate tax reduction, we should pay attention to the following. First, we should scrutinize the benefit for firms more carefully. That is, it is necessary to further divide the operating costs of the target firms to increase the accuracy of the future projection of operating costs. However, published data on the land transportation sector and electric power sector, which were targeted for this analysis, are limited at this time. As a result, almost all operating costs apart from energy costs had to be included in “other operating costs” and managed in the same way, and the accuracy of the projections may have decreased. In the future, it would be desirable to use detailed data on operating costs.

In addition, regarding the effect of the corporate tax reduction on profits, as noted in an article published in a Japanese newspaper (Shimbun NK 2019),[8] the tax burden rate (the ratio of taxes paid to profit) varies largely between firms due to an adjustment in the tax standards (from under 10% to approximately 40%), and this may also be true for the corporate tax. This variation can result in a large difference between the predicted and real effects of the corporate tax reduction. Therefore, when implementing corporate tax reduction measures, it will be necessary to be careful and use more detailed data.

Regarding the effect of the reduction in taxes on the labor supply, we should examine other channels of RR. Specifically, in addition to the national pension system, Japan has a public health insurance system and a long-term care insurance system. The government can recycle carbon tax revenue using these systems as well. This can be a topic for further study, as the discussion on RR through these systems will also be important.

References

Agnolucci P (2009) The effect of the German and British environmental taxation reforms: a simple assessment. Energy Policy 37(8):3043–3051

Beuermann C, Santarius T (2006) Ecological tax reform in Germany: handling two hot potatoes at the same time. Energy Policy 34(8):917–929

Carattini, S, Carvalho M, Fankhauser S (2017) How to make carbon taxes more acceptable. Grantham Research Institute on Climate Change and the Environment, and Centre for Climate Change Economics and Policy, London School of Economics and Political Science, London

Freire-González J (2017) Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review. J Policy Model 40(1):194–223. https://doi.org/10.1016/j.jpolmod.2017.11.002

Goulder LH (1995) Environmental taxation and the ‘double dividend’: a reader’s guide. Int Tax Publ Financ 2:157–183

IEA (2018) World energy outlook 2019, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2018

IGES (2016) Effectiveness and economic efficiency of carbon tax as an economic instrument to achieve substantial GHG emission reduction by 2050. Policy Stud Environ Econ, Ministry Environ (in Japanese)

Jorgenson DW, Goettle RJ, Ho MS, Wilcoxen PJ (2013) Double dividend: environmental taxes and fiscal reform in the United States. MIT Press, Cambridge, MA

Kameoka R, Arimura TH (2019) The impact of carbon tax & feed-in tariff on the industry & household expenditure-an input-output analysis-. Environ Sci 32(4):103–112 (in Japanese)

[8] *Kigyo, Baratsuku Zei Futan* (“Varying tax burdens for firms”, published on *Nhon Keizai Shinbun*, 24 August 2019, morning newspaper, page 2).

Kimoto K (2016) The problem of the Category-3 insured persons and policy-making for the expansion of the Employee's Pension Scheme. Nihon Univ Econ Rev 86(2/3):145–156 (*in Japanese*)

Lee S, Pollitt H, Park SJ (eds) (2015) Low-carbon, sustainable future in East Asia: Improving energy systems, taxation and policy cooperation. Routledge Studies in the Modern World Economy

MIC (2016) 2011 input-output tables for Japan. Ministry of Internal Affairs and Communications Japan

Nansai K, Kawasima K, Morimoto T (2018) The development of 3EID based on 2011 input-output table. In: The 13th Meeting of the Institute of Life Cycle Assessment, Japan

Pereira AM, Pereira RM, Rodrigues PG (2016) A new carbon tax in Portugal: a missed opportunity to achieve the triple dividend? Energy Policy 93:110–118. https://doi.org/10.1016/j.enpol.2016.03.002

Saveyn B, Van Regemorter D, Ciscar JC (2011) Economic analysis of the climate pledges of the Copenhagen accord for the EU and other major countries. Energy Econ 33:S34–S40. https://doi.org/10.1016/j.eneco.2011.07.024

Shimbun NK (2019) Varying tax burdens for firms. (in Japanese): 2. Print

Takeda S (2007) The double dividend from carbon regulations in Japan. J Jpn Int Econ 21:336–364. https://doi.org/10.1016/j.jjie.2006.01.002

Takeda S, Arimura TH (2020) A computable general equilibrium analysis of environmental tax reform in Japan. Waseda RIEEM Discussion Paper No. 2002

Carbone J, Morgenstern RD, Williams RC, III, Burtraw D (2013) Deficit reduction and carbon taxes: Budgetary, economic, and distributional impacts. Resour Future

Yamazaki A (2017) Jobs and climate policy: evidence from British Columbia's revenue-neutral carbon tax. J Environ Econ Manage 83:197–216

Kenji Asakawa is a policy researcher of the Institute for Global Environmental Strategies, a semigovernmental think-tank for national and local policy on global environemnt. His research focuses on policy design of carbon pricing, such as the mitigation measures of the pricing impacts on carbon intensive companies, through a level playing field by minimizing the potential legal risks due to reverse discrimination against the mitigation measures. He obtained his Juris Doctor from Omiya Law School and passed the National Bar Examination.

Kouichi Kimoto is a Junior Researcher (an assistant professor) at Research Institute for Environmental Economics and Management, Waseda University. He received a PhD in Economics from Waseda University in 2019.

Shiro Takeda is a professor of Faculty of Economics at Kyoto Sangyo University and a member of the Research Institute for Environment Economics and Management at Waseda University. His research focuses on climate change policies in Japan and computable general equilibrium analysis. He holds his Ph.D. in Economics from Hitotsubashi University. In 2010, he is awarded Young Achievement Award from Society for Environmental Economics and Policy Studies in Japan.

Toshi H. Arimura is a Professor of Political Science and Economics and Director of the Research Institute for Environment Economics and Management at Waseda University in Tokyo. Prior to joining Waseda, he was a Professor at Sophia University in Tokyo and was a visiting scholar with George Mason University and Resources for the Future as a recipient of the Abe Fellowship. His research interests include climate change, energy policies, air pollution regulations and voluntary environmental actions. He has published his research in academic journals such as *Journal Environmental Economics and Management, Journal of Association of Environmental and Resources Economics, Environmental and Resource Economics, Ecological Economics* or *Energy Policy*. He is a coauthor of *An Evaluation of Japanese Environmental Regulation: A Quantitative Approach*

from Environmental Economics (Springer 2015). Dr. Arimura holds a Ph.D. in economics from the University of Minnesota, an MSc in environmental sciences from the University of Tsukuba and a BA in history of science from the University of Tokyo. He has served on a number of Japanese government committees on environmental issues including the committees on carbon pricing (2018) and emission trading scheme (2010) of the environmental council under Ministry of the Environment. He is also a member of the Tokyo Metropolitan environmental council. He has served on advisory committees of local governments for emission trading schemes of Tokyo and Saitama. He has also been on editorial boards of academic journals such as *Review of Environmental Economics and Policy, Agricultural and Resource Economics Review, Economics of Energy and Environmental Policy* or *Environmental Economics and Policy Studies.* Since 2018, Waseda University has choses him as one of 10 next generation core researchers. He is a recipient of SEEPS Outstanding Publication Award from Society for Environmental Economics and Policy Studies (Japanese Association of Environmental Economics and Policy) and the academic award from Society of Environmental Science, Japan.

Concluding Remarks and Future Directions

Toshi H. Arimura & Shigeru Matsumoto

Summary and Findings

The objective of this book is to review Japanese CO_2 emission mitigation policies in various sectors and assess their effectiveness. The book also aims to offer future mitigation policy options to achieve the long-term 2050 emission goal, with a focus on the role of carbon pricing. To fulfill these objectives, the book first reviewed mitigation policies in selected sectors and discussed the pro and cons of those policies in each sector. Second, focusing on the carbon pricing already implemented in Japan, we examined the impacts of two local ETSs in Japan on CO_2 emissions using appropriate econometric techniques. Finally, the book assessed the policy options of carbon pricing using the economic model of input-output analysis or computable general equilibrium models. More precisely, the book consisted of the following three parts.

Part I reviewed the mitigation policies implemented across various sectors in Japan. Our review reveals that both national and local governments in Japan have already adopted various mitigation policies in the sectors of manufacturing, office buildings, households, transport and electric power. We found that these policies have increased implicit carbon pricing and have contributed to CO_2 mitigation in the corresponding sector. However, we also demonstrate that there is room for further reductions in each sector. Furthermore, energy efficiency can be improved from the perspective of the effective carbon rate. Contrary to conventional wisdom, we found that carbon pricing and feed-in tariffs can be complementary in the power sector characterized by an oligopolistic market structure. In sum, carbon pricing can play an important role in the further reduction of CO_2 emissions in a more efficient way.

Part II empirically reviewed the carbon pricing instruments implemented in Japan. The examination of the effectiveness of ETS is a critical issue in climate policy

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7

politics because some stakeholders are skeptical of its effectiveness and often opposed to its introduction. Our analyses provided solid empirical evidence that the two local ETSs in Tokyo and Saitama have effectively reduced CO_2 emissions through the promotion of energy efficiency. Although the ETS studies conducted outside of Japan have focused primarily on the manufacturing sector, the analysis of this book revealed that ETS can be an effective policy not only for the reduction of electric power consumption from the manufacturing sector but also for the reduction of such consumption from the service sector. It is also worth reporting that the Saitama ETS was successful in reducing carbon emissions in the manufacturing sectors, despite its voluntary nature. It was also shown that ETS can reduce emissions from facilities that it does not cover through spillover effects. All these results suggest that ETSs can be effective policy instruments if they are properly operated.

Part III proposed several policy options and assessed the potential impacts of carbon pricing for further emission reduction. We offer a policy option of a carbon tax with revenue recycling, aimed at the long-term emission reduction of 80% by 2050. We examined the impacts of the revenue recycling on the household expenditures and profits of firms in the selected sector. It was shown that the economic burden can be eased with revenue recycling both for households and for the selected industries.

Regarding the household sector, we found that carbon prices generate significant heterogeneity in the tax burden across geographical regions and income classes. Our analyses show that low-income households living in cold regions will be affected very severely. If the redistribution policies proposed in the book are successfully implemented, then the regressiveness problem of carbon taxes can be resolved to a great degree.

Policy Implications and Messages for the Government

Several policy implications can be drawn from the findings in the book. First, the assessment of the Tokyo ETS demonstrates that the ETS works for service sectors. As in the case of EUETS, many emission trading schemes cover the manufacturing sector and the power sector. Thus, countries or regions without regulation of the service sector can consider ETS as a candidate for the major policy instruments.

Second, the Saitama ETS is a Target-Setting Emissions Trading (TSET) program, a unique ETS that imposes no financial penalty on facilities that fail to achieve the emission target. Despite the voluntary nature of the scheme, it was effective in reducing CO_2 emissions in the manufacturing sector. Therefore, for those countries or regions that consider a mitigation policy but cannot adopt a stringent ETS, the TSET program implemented in Saitama is a useful policy measure that can be adopted as a first step.

For the national and local governments in Japan, the findings for the two ETSs in this book have an important and direct implication. Because these two schemes worked well at the local level, it is natural to extend these schemes to the remaining 45 prefectures. If ETSs are introduced into other prefectures, then facilities in the energy-intensive and trade-exposed (EITE) sector may face the risk of carbon leakage and competitiveness issues. However, the findings in Chaps 10 and 11 will be useful and effective in dealing with the competitiveness issue that the EITE may face in regard to carbon pricing. Moreover, there is plenty of literature, including that of the authors of these chapters, showing ways to deal with this competitiveness issue (Takeda et al. 2012, 2014; Sugino et al. 2013).

The reduction and fairness of the burden become a point of issue in regard to the carbon tax. Another important policy implication obtained from this book is that the carbon tax with revenue recycling is an attractive policy option for long-term emission reduction goals. This is an important message for the Japanese government. The negative impact on the Japanese economy can be significantly offset by including revenue recycling schemes. Moreover, for countries/regions aiming for deeper GHG emission reduction, the carbon tax with revenue recycling is a useful option to consider.

Future Directions

There are several directions we can consider in our future work. First, designing carbon pricing instruments with the consideration of effective carbon rates is another important direction. Japan has already imposed an energy tax on various fossil fuels at different levels. We know that the tax rate per ton of CO_2 emissions varies widely across fuel types. Thus, the future carbon tax for the long-term emission reduction goal should take a form in which the effective carbon rate is equalized across fuel types to pursue efficiency.

Second, this book focuses on efficiency rather than equity. Carbon pricing can incur the burden disproportionally for some stakeholders. Given that energy is essential to modern life, it is worth investigating how to reconcile efficiency and equity under carbon pricing.

Although our empirical studies identify the effectiveness of ETSs, the amount of the emission reduction is far below the level of the reduction required to achieve the long-term emission goal. Although this book finds that ETSs in Japan promoted energy efficiency, they did not promote the renewable energy that is necessary to meet the Japanese long-term emission reduction target. Thus, there is still a gap between what the Japanese economy has to reduce in the long run and what the ETSs have achieved so far. Research to fill this gap can be the third direction.

Fourth, for the analysis of the long-term goal, we must model new and future technologies in more detail. The model in this book does not incorporate certain new technologies. For example, the model in this book does not capture hydrogen fuel, which is an important energy source to realize decarbonization. However, the diffusion of hydrogen fuel is expected to be important in 2050. This is particularly true for transportation. Electric vehicles or fuel cell vehicles that make use of hydrogen fuel need to be incorporated in detail. The modeling of new and future technologies would be another direction for future research.

Feed-in tariffs have increased the effective carbon rate and have contributed to the diffusion of renewable energy in the Japanese electric power sector. We have not examined the impact of FIT quantitatively. It is worth assessing the impact of FIT on CO_2 emission reduction. Moreover, we should investigate the interaction of explicit carbon pricing and FIT/feed-in premiums in promoting renewability in the long-term model.

Japan has implemented various carbon pricing programs since the Rio de Janeiro Earth Summit and has introduced new programs since the Paris Agreement. However, it seems that these programs have not been fully reported to overseas researchers, and the effectiveness of these programs has not been adequately assessed. We hope that this book will contribute to the understanding of carbon pricing programs in Japan.

References

Sugino M, Arimura TH, Morgenstern R (2013) The effects of alternative carbon mitigation policies on Japanese industries. Energy Policy 62:1254–1267

Takeda S, Tetsuya H, Arimura TH (2012) A computable general equilibrium analysis of border adjustments under the cap-and-trade system: A case study of the Japanese economy. Clim Change Econ 03(01). 10.1142/S2010007812500030

Takeda S, Arimura TH, Tamechika H, Fischer C, Fox AK (2014) Output-based allocation of emissions permits for mitigating the leakage and competitiveness issues for the Japanese economy. Environ Econ Policy Stud 16(1):89–110. https://doi.org/10.1007/s10018-013-0072-8

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7

Index

T. H. Arimura and S. Matsumoto (eds.), *Carbon Pricing in Japan*,
Economics, Law, and Institutions in Asia Pacific,
https://doi.org/10.1007/978-981-15-6964-7