RIEEM
Research Institute for Environmental Economics and Management

The Impact of Emissions Trading Systems on Manufacturing Installation Productivity: Evidence from Japan

Guanyu Lu, Kenta Tanaka & Toshi H. Arimura

WASEDA University

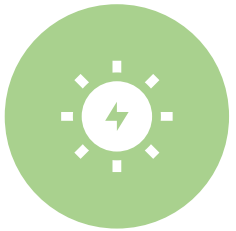
32nd NBER-TCER-CEPR (TRIO) Conference on 26-27
University of Tokyo, 26th April

CONTENTS

Background

Objective

Methodology



Results and Conclusion

Background

Emissions trading systems (ETSs) have become important instruments in global efforts for promoting carbon mitigation.

Installations are required to adopt various compliance measures, such as investing in green technologies, replacing equipment, and adjusting operational processes.

- Do ETSs affect their economic performance, particularly total factor productivity (TFP)?

Background

ETSs, which aim the emission reduction in cost efficient way, may also induce financial and operational burdens to regulated firms (Baier et al., 2006) , potentially affecting TFP (Mo et al., 2023).

Given the potential adverse effects in the initial stage, policymakers may announce the regulation in advance to provide installations with a transitional period to prepare for compliance to the reduction targets.

Importance of Announcement period

- Allowing installations to adjust operations, invest in cleaner technologies, and upgrade equipment to meet forthcoming targets, which may potentially affect TFP before the implementation of regulations.
- Installations may face financial pressures to increased compliance costs with new technologies (Xu et al., 2022), changes in operational processes, and training personnel.
- ETS may have a negative impact on short term performance, reducing profits and limit investment in research and development activities (Esso & Keho, 2016; Dechezleprêtre & Sato, 2017).

Compliance period

- During the **middle and later compliance stages**, ETSs can turn environmental costs into economic incentives for productivity improvements (Pan et al., 2019; Benatti et al., 2024).

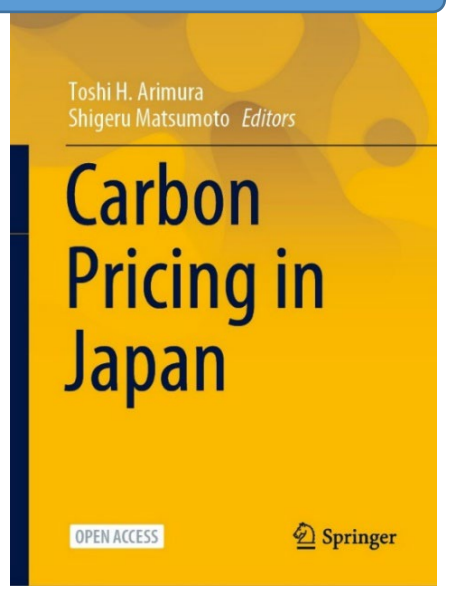
- Existing literature has not thoroughly examined how ETSs affect TFP across **different compliance stages**, particularly during the **announcement period** within Japanese manufacturing industry.

Background on Japan's ETSs

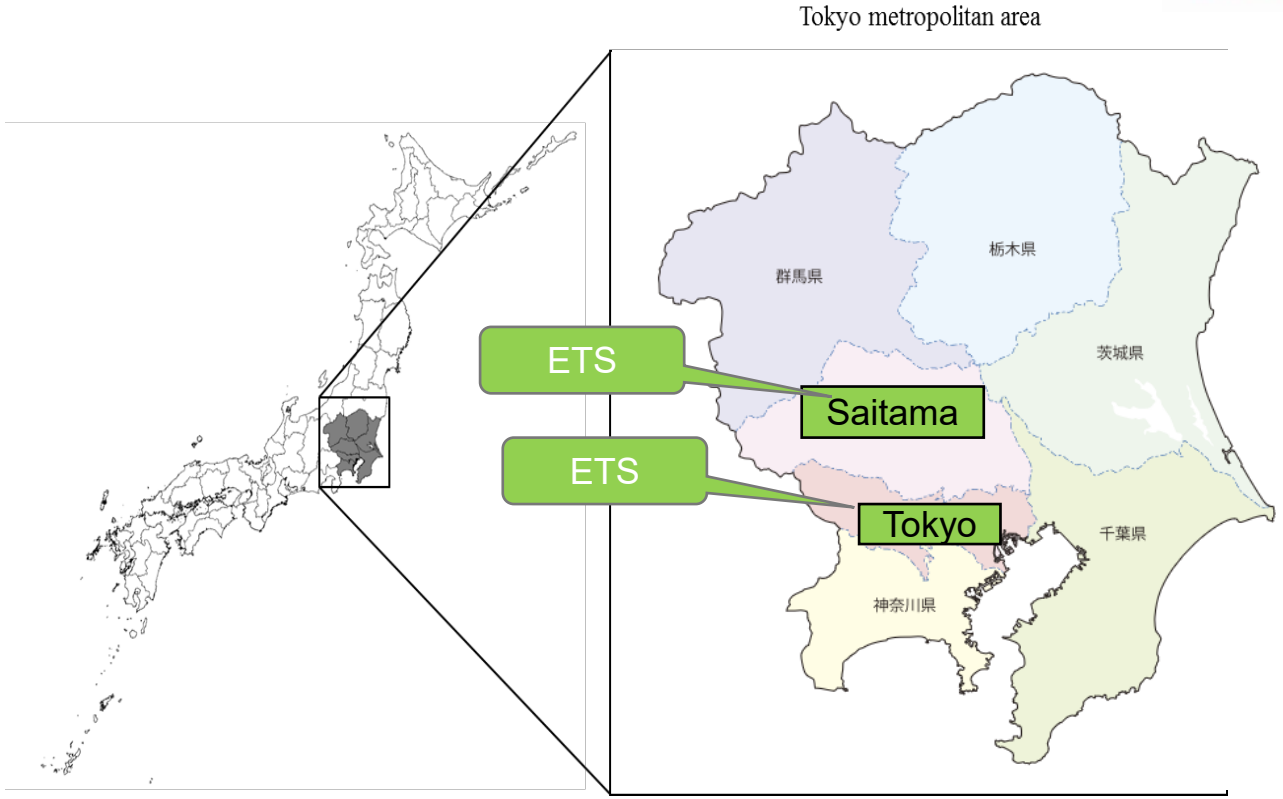
Feature	Tokyo ETS		Saitama ETS	
Year of announcement	**2007**		**2008**	
Year of implementation	**2010**		**2011**	
Sectors	**Service sector**, industrial sector, and public sector		Primarily **manufacturing**	
Inclusion threshold	Installations with annual energy consumption exceeding 1,500 kiloliters of crude oil equivalent (approximately 2,800 tons of CO2)			
Base-year emissions	Bassline emissions derived from the CO2 emissions of any consecutive three-year period from 2002 to 2006			
Reduction targets	**Factories**	**Commercial buildings**	**Factories**	**Commercial buildings**
Phase 1 (~2014)	6%	8%	6%	8%
Phase 2 (2015~2019)	15%	17%	13%	15%
Phase 3 (2020~2024)	25%	27%	20%	22%
(Financial) Penalty for non-compliance	Non-compliant installations must reduce emissions by the shortfall multiplied by 1.3, or else face public disclosure and fines.		**None,** but non-compliant installations are **publicly disclosed**.	
Number of total installations	**1300**		**600**	

RIEEM
Research Institute for Environmental Economics and Management

Arimura & Matsumoto Ed.



Open Access



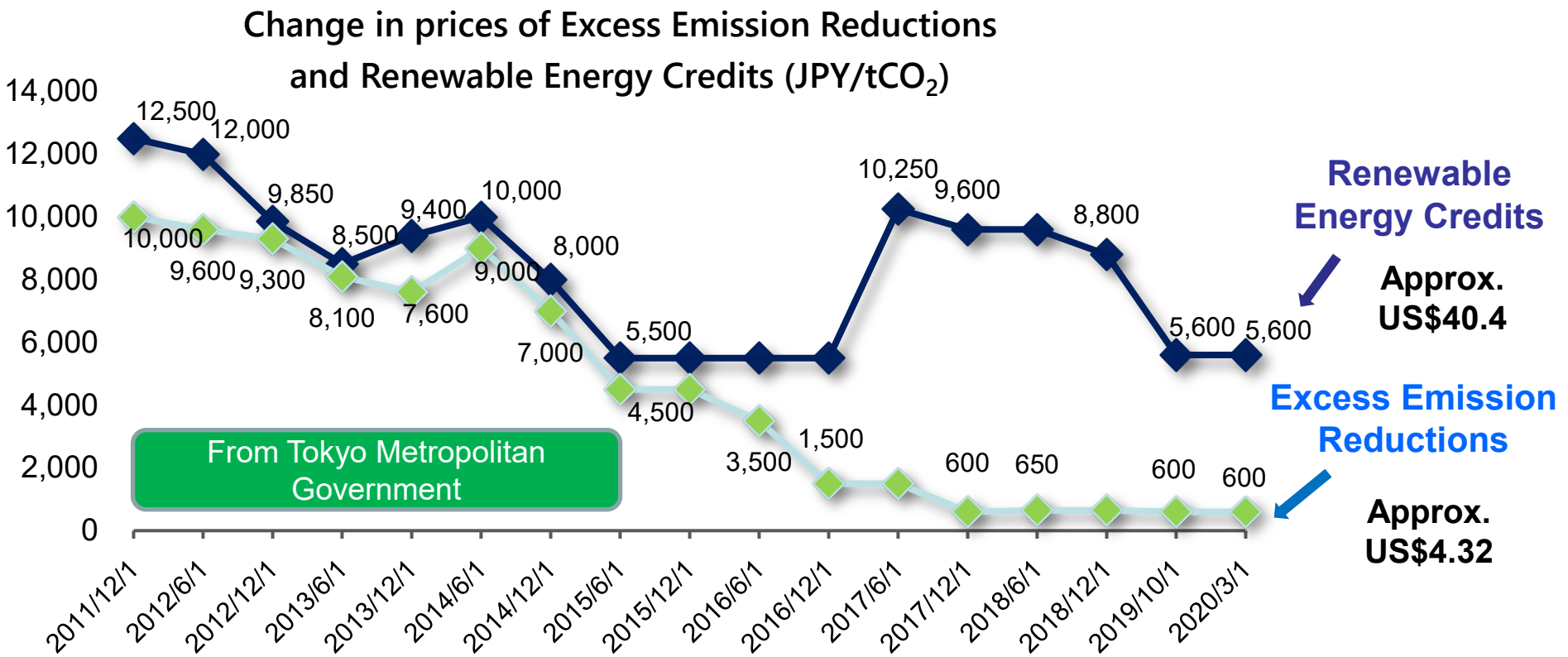
Regional Carbon Pricing

Tokyo/Saitama Emissions Trading Schemes

WASEDA University

Transition of Permit Prices in Tokyo ETS

Bilateral Trading Only due to "Money Game" Criticism



No Price Signaling due to the lack of the financial sector

Weak Price Signaling

Literature on ETSs

EU ETS:

- It initially reduced productivity growth in high-emission firms due to adjustment costs but **lead to productivity gains in the long run** through technological adaptation (Benatti et al., 2024; Colmer et al., 2024).
- It significantly **increased economic performance** despite short-term productivity impacts (Dechezleprêtre et al., 2023).

Literature on ETS

Chinese ETSs:

- Firms in high-carbon industries show improved productivity under the pilot carbon markets
  - ➢ suggesting that stringent environmental regulations can incentivize productivity improvements (Bai et al., 2023).
- SO_2 emissions trading in China aids firms in improving productivity (Feng et al., 2020).

Korean ETS:

- The impacts differ by industry sector:
  - ➢ manufacturing firms focus on energy efficiency improvements, while firms in the power sector shift towards clean energy sources (Kim & Bae, 2022).

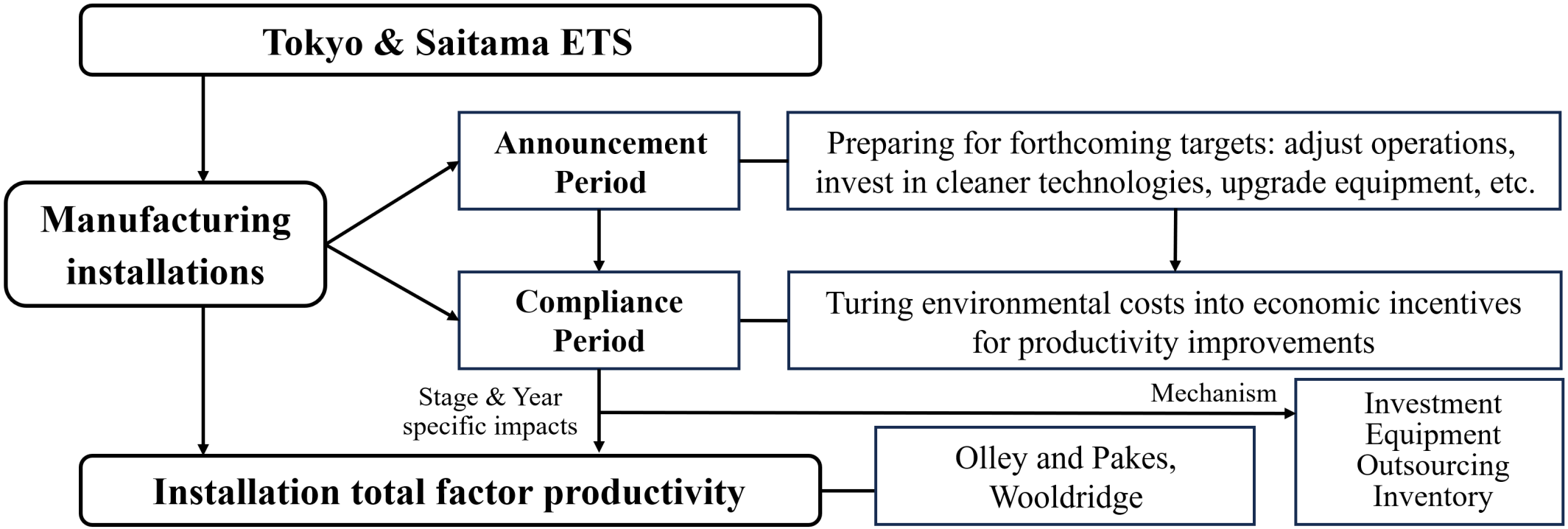
Literature on ETS (Japan)

- **Innovation and emissions reduction:**
- **Saitama ETS**
  - Significantly reduced emissions, especially during initial compliance (Hamamoto, 2021a).
  - Initial compliance relied on cost-effective emission reduction strategies;
    - stricter targets in Phase II required greater resource investment and productivity improvements (Hamamoto, 2021b).
- **Energy consumption and ETS effectiveness:**
- Clear reductions observed under Tokyo ETS, but inconclusive results for Saitama ETS, highlighting gaps in understanding ETS mechanisms (Yajima et al., 2021).

Objective

- This study examines how Japan's regional ETSs affect TFP considering both announcement and compliance periods.
- This study considers the staggered announcement years of the Tokyo and Saitama ETSs as policy shocks, employing a difference-in-differences (DiD) methodology based on the Callaway and Sant'Anna (2021) estimator to estimate their impacts on TFP

Outline


Tokyo & Saitama ETS
Manufacturing installations
Announcement Period
Preparing for forthcoming targets: adjust operations, invest in cleaner technologies, upgrade equipment, etc.
Compliance Period
Turing environmental costs into economic incentives for productivity improvements
Stage & Year specific impacts
Mechanism
Investment
Equipment
Outsourcing
Inventory
Installation total factor productivity
Olley and Pakes, Wooldridge

Data

- *Economic Census for Business Activity* and the *Ministry of Internal Affairs and Communications* from 2002 to 2016.
- We focus on **manufacturing installations** with more than 30 employees.
- Installations with fewer than 30 employees are not required to report fixed asset amounts, which are essential for our analysis.
- The total sample covers approximately *45,000 facilities* annually for four-digit manufacturing sectors
  - Variables: production value, the number of employees, *the expenditure of electricity and fuel*, fixed assets, intermediate material costs, payment, shipment value of products, usage of freshwater, and export ratio.

Data

	Obs	Mean	S.D	Min	Max
Inputs and output of TFP					
Employment	202019	145.96	206.352	1	5385
expenditure of electricity and fuel	202019	13026.06	45904.04	2	1799776
Fixed assets	202019	118618.0	348283.7	1	15851265
Intermediate material costs	202019	239973	576360	0	13914263
Production value	202019	518702	1037679	17478	10142741
Outcome and estimates					
TFP	202016	4.058	0.405	0.304	8.153
Payment	202019	71207.14	130737.9	25	4003395
Shipment value of products	202019	504304.1	1041084.	0	41075600
Usage of freshwater	202019	1981.78	22937.36	1	1736666
Export ratio	202019	3.085	11.265	0	100

Data Source: Economic Census for Business Activity and the Ministry of Internal Affairs and Communications

➢ **Notes:**

- Output: production value; Input (intermediate): employment, fixed assets, intermediate material costs, expenditure of electricity and fuel

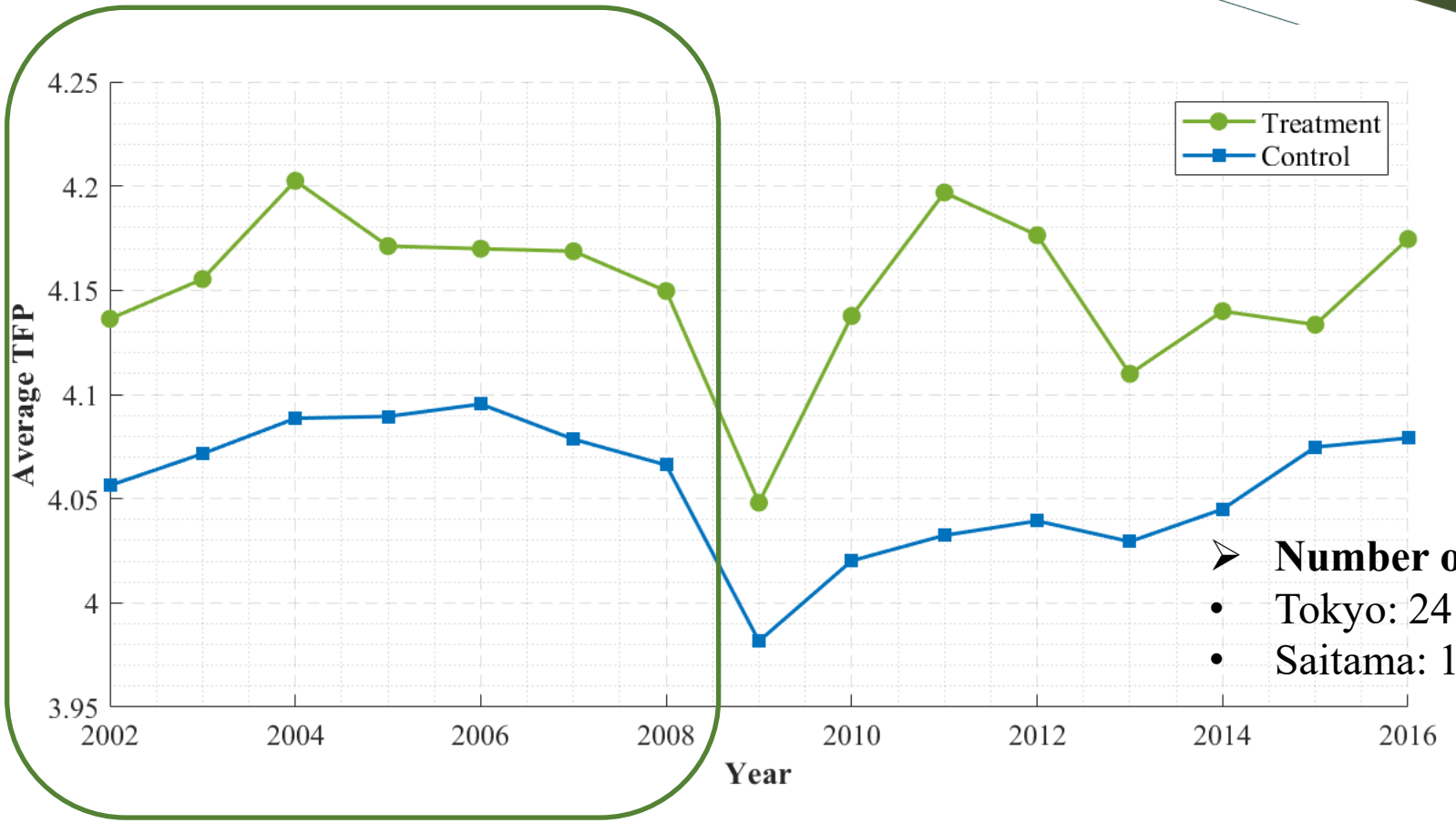
TFP

We adopt Wooldridge (2009) methodology to estimate production functions for installation TFP within a generalized method of moments (GMM) framework.

$$\log(TFP_{it}) = \log(Y_{it}) - \hat{\alpha}_L \log(L_{it}) - \hat{\alpha}_K \log(K_{it}) - \hat{\alpha}_m \log(M_{it})$$

TFP_{it} is the total factor productivity, Y_{it} is installation output, L_{it} and K_{it} are employment and fixed assets. M_{it} is the intermediate input including the expenditure of electricity and fuel (ten thousand yen) and intermediate material costs (ten thousand yen). $\hat{\alpha}_L$, $\hat{\alpha}_K$, and $\hat{\alpha}_m$ are elasticities that are estimated based on one-step GMM estimator suggested by Wooldridge (2009).

Data (TFP)



- **Number of regulated installations**:
  - Tokyo: 24
  - Saitama: 138

2002~2006 (2007)	2007 (2008) ~2009 (2010)	2010 (2011)~2014	2015~
Pre-announcement	Announcement	First compliance	Early second

Model

$$TFP_{it} = \alpha + \beta ETS_{it} + \boldsymbol{X}_{it}\delta + \mu_t + \gamma_i + \varepsilon_{it}.$$

TFP_{it} : outcomes, including the energy inefficiency.
ETS_{it} : a dummy variable with a value of one for installations complying with Tokyo or Saitama ETS.
$\boldsymbol{X}_{it}$: a vector of control variables including employee pay (ten thousand yen), the shipment value of products (ten thousand yen), the export ratio, the usage of freshwater (m^3), and area (m^2).
All continuous variables are logarithmically transformed.
The subscript i is the installation, and t is the year. μ_t and γ_i are the annual fixed effect and installation fixed effect, respectively. ε_{it} is an error term.

Baseline result

TFP	(1)
ATT	0.014*
	(0.008)
Controls	Yes
Fixed effects	Yes
Observation	202016
Methods	Wooldridge

Notes: The aggregation of overall coefficient of *ATT* based on Callaway and Sant'Anna (2021) estimator are reported in this table. Column (1) and Column (2) report coefficients of *ATT* by using Wooldridge methodology and Olley-Pakes methodology separately. Observations not yet regulated are used as control group. Standard error is estimated by Wild Bootstrap procedure with 1000 repetitions. *p < 0.1; **p < 0.05; ***p < 0.01.

- **1.4% TFP improvement**
- →Announcement and subsequent implementation of the ETSs induce regulated manufacturing installations to improve their productivity.
- The increase in TFP might result from installations adopting more efficient production processes, investing in technology or better utilizing the resources in response to future emissions reduction targets.
- **The statistical significance of the overall ATT at the 10% level may be susceptible to sampling variability.**

Stage-dynamic results

TFP	(1)	(2)
$ATT_{announce}$	0.011	
	(0.007)	
$ATT_{annfirst}$		0.014**
		(0.007)
ATT		
Controls	Yes	Yes
Fixed effects	Yes	Yes
Observations	136406	176289
Covering stages	Announcement	Announcement to first

- **Installations do not immediately enhance their TFP**
- →Although installations **may** start to conduct activities to comply with upcoming regulation or conduct early investments, such efforts do not translate to gains in productive efficiency at this early stage.
- **Significant positive impact at the 5% level in first stage.**
- →While installations do not show immediate TFP improvements, they are able to implement effective operational adjustments during the first compliance period, resulting in measurable productivity gains.

2003~2006 (2007)	2007 (2008) ~2009 (2010)	2010 (2011)~2014	2015~
Pre-announcement	Announcement	First compliance	Early second

Further analysis

- Col. (1): New equipment purchases
- Col. (2): New building acquisitions
- Col. (3): Outsourcing expenditures;
- Col. (4): Changes in inventory levels (measured as the difference between year-start and year-end inventory)

	(1) Equipment	(2) Building
ATT	-0.646***	-0.226
	(0.145)	(0.181)
Other ATTs	Yes	Yes
Controls	Yes	Yes
Fixed effects	Yes	Yes
Observation	161289	128673

- **Similar pattern with the baseline result while has consistent positive effects during the compliance period.**
- **Tokyo ETS in Column (2) show an insignificant impact of ETSs.**
- → It may relate to the industrial structure of Tokyo, which is more service-oriented with a smaller proportion of manufacturing installations compared to Saitama, may affect the overall impact of the ETS on productivity.

- **No investment in promoting efficiency: *Operational changes in improving efficiency?***

Conclusion

- The results show a positive impact of Japan's regional ETSs on TFP, suggesting that the ETSs improve TFP in the context of Japan.
- The stage specific results show that the improvement on TFP occurred at the beginning of initial compliance stage.
- The analysis of the mechanism hints that the TFP growth may be attributable to the operational or managemental changes rather than higher levels of capital investment.

Literature

- Baier, S. L., Dwyer Jr, G. P., & Tamura, R. (2006). How important are capital and total factor productivity for economic growth? Economic Inquiry, 44(1), 23-49.
- Mo, J., Tu, Q., & Wang, J. (2023). Carbon pricing and enterprise productivity-The role of price stabilization mechanism. Energy Economics, 120, 106631.
- Xu, Y., Li, S., Zhou, X., Shahzad, U., & Zhao, X. (2022). How environmental regulations affect the development of green finance: Recent evidence from polluting firms in China. Renewable Energy, 189, 917-926.
- Esso, L. J., & Keho, Y. (2016). Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries. Energy, 114, 492-497.
- Dechezleprêtre, A., & Sato, M. (2017). The impacts of environmental regulations on competitiveness. Review of environmental economics and policy.
- Pan, X., Ai, B., Li, C., Pan, X., & Yan, Y. (2019). Dynamic relationship among environmental regulation, technological innovation and energy efficiency based on large scale provincial panel data in China. Technological Forecasting and Social Change, 144, 428-435.
- Benatti, N., Groiss, M., Kelly, P., & Lopez-Garcia, P. (2024). Environmental regulation and productivity growth in the euro area: Testing the porter hypothesis. Journal of Environmental Economics and Management, 126, 102995.
- Colmer, J., Martin, R., Muûls, M., & Wagner, U. J. (2024). Does Pricing Carbon Mitigate Climate Change? Firm-Level Evidence from the European Union Emissions Trading System. Review of Economic Studies, rdae055.
- Dechezleprêtre, A., Nachtigall, D., & Venmans, F. (2023). The joint impact of the European Union emissions trading system on carbon emissions and economic performance. Journal of Environmental Economics and Management, 118, 102758.
- Bai, C., Liu, H., Zhang, R., & Feng, C. (2023). Blessing or curse? Market-driven environmental regulation and enterprises' total factor productivity: Evidence from China's carbon market pilots. Energy Economics, 117, 106432.
- Feng, Y., Chen, S., & Failler, P. (2020). Productivity effect evaluation on market-type environmental regulation: A case study of SO2 emission trading pilot in China. International journal of environmental research and public health, 17(21), 8027.
- Kim, P., & Bae, H. (2022). Do firms respond differently to the carbon pricing by industrial sector? How and why? A comparison between manufacturing and electricity generation sectors using firm-level panel data in Korea. Energy Policy, 162, 112773.
- Hamamoto, M. (2021a). Target-Setting Emissions Trading Program in Saitama Prefecture: Impact on CO 2 Emissions in the First Compliance Period. Carbon Pricing in Japan, 117-127.
- Hamamoto, M. (2021b). Impact of the Saitama Prefecture target-setting emissions trading program on the adoption of low-carbon technology. Environmental Economics and Policy Studies, 23(3), 501-515.
- Yajima, N., Arimura, T. H., & Sadayuki, T. (2021). Energy consumption in transition: Evidence from facility-level data. Carbon Pricing in Japan, 129-150.

WASEDA University

Thanks!

RIEEM
Research Institute for Environmental Economics and Management