

Evaluating the Effectiveness of Japan's 2012 Carbon Tax: Evidence from the Synthetic Control Method

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ABSTRACT: What is the effect of Japan's 2012 carbon tax on CO₂ emissions? This paper analyzes Japan's 2012 carbon tax's efficiency in reducing carbon emissions by using the synthetic control method with data from 1990 to 2023. The synthetic control is made using the weighted average of countries without carbon taxation to replicate Japan's emission patterns in the absence of the policy. Japan's emissions track the synthetic closely before treatment, but diverged upwards largely in 2011–2012 due to the Fukushima nuclear disaster and the resulting surge in fossil fuel use. Even after the Fukushima accident, this paper's results suggest that the carbon emissions were not substantially affected by the carbon tax imposed in 2012. This finding suggests that Japan's low tax rate and its industrial exemptions have been insufficient in altering emission trajectories, emphasizing the need for stronger and complementary climate policies and higher carbon tax rates.

KEYWORDS: Carbon Tax, Synthetic Control Method, Japan, CO₂ Emissions, Climate Policy, Fukushima Nuclear Disaster, Pigouvian Tax, Placebo Tests.

■ Introduction

Carbon taxation was created based on the Pigouvian theory, where taxing carbon emissions internalizes its negative externalities.¹ Research indicates that well-crafted carbon taxes can reduce emissions, improving general welfare—consistent with the double dividend hypothesis and the Porter hypothesis of innovation.^{2,3}

Statistically, European cases provide convincing evidence of carbon tax effectiveness. Finland's carbon tax, for example, significantly reduced its CO₂ emissions per capita, as shown through the synthetic control method.⁴ Sweden's carbon tax has led to great declines in emissions from transportation without hindering GDP growth.⁵ In British Columbia, a fiscally neutral tax decreased fuel use without having to decrease competitiveness.⁶

The synthetic control method has surfaced as an effective tool for policy evaluation, especially for the effects of domestic interventions.^{7,8} Placebo tests within the synthetic control framework strengthen the validity of the analysis by showing whether the estimated treatment effects are statistically significant relative to the control groups. While there have been many applied studies in Europe regarding carbon taxes, there have not been any studies in Asia using the same method. This paper will contribute to the literature by filling this gap.

Japan's 2012 carbon tax (Named the Tax for Climate Change Mitigation) was implemented as a levy under Japan's already existing Oil and Coal Tax system.⁹ The tax is targeted upstream, meaning it is charged to fossil fuel importers and distributors, and not directly to consumers or emitting companies. So petroleum, natural gas, and coal importers are taxed on the carbon content of their fuels. Due to this tax structure, the burden is partially passed downstream via increased fuel prices, however it does not directly charge emitters.

Japan, one of the first Asian countries to implement a carbon tax in 2012, offers an important case. The tax rate was set at around ¥289 per ton of CO₂ (about USD \$2.60) and was intended to gradually increase, but it has stayed constant and remained modest compared to its European counterparts. Studies emphasize that Japan's carbon tax is one of the lowest in developed economies, which limits its ability to substantially change carbon emissions.^{10,11} Japan's heavy dependence on fossil fuels during the period after the Fukushima nuclear incident, along with widespread exemptions for energy-intensive industries, increasingly constrains the policy's effectiveness. Current assessments for the tax remain mostly descriptive or based on computable general equilibrium (CGE) models, leaving space for empirical evaluations such as the synthetic control method to determine whether the tax has had a measurable impact on emissions.

Modeling studies confirm that Japan's carbon tax has only a limited impact at its current level. Takeda estimate that the tax alone would achieve only small reductions unless combined with other complementary energy and emission policies.¹² Similarly, Inoue stated that the carbon tax's effect is diluted by exemptions and its low price compared to international standards.¹¹ These studies suggest that Japan's carbon tax effectiveness depends heavily on raising its rate and integrating it with broader energy transition measures.

Evidence from the United States suggests that fuel and energy taxes often shift consumer and firm behaviors more effectively when combined with revenue recycling systems (transfers to households that are more affected by these policies).¹³ Likewise, studies from the OECD also highlight how carbon tax outcomes are variable depending on sectoral exemptions.¹⁴ Poorly designed frameworks risk efficiency loss when their coverage is narrow or the policy's enforcement is weak.¹⁵

In a theoretical sense, models of optimal tax illustrate that carbon taxation can be welfare-improving even under uncertainty.¹⁶ Further extensions later underline the political economy trade-offs in actual carbon tax adoptions.¹⁷

France's fuel tax protests provide evidence suggesting that equity and distributional considerations affect a policy's durability greatly.¹⁸ Relatedly, climate damage disproportionately affects lower-income regions, further enforcing the need for redistributive policy design in carbon taxation.¹⁹

Empirical macroeconomic evaluations propose that carbon taxation does not always need to reduce economic growth. Using panel data, researchers found that there was no systematic negative impact of carbon taxation on GDP across the OECD countries.²⁰

Micro-level evidence also shows behavioral adjustments. Vehicle fuel taxation leads to significant decreases in gasoline demand, showing the responsiveness of consumption to carbon-pricing signals.²¹ Meanwhile, policy review experiences conclude that the political feasibility and institutional stability determine effectiveness more than the theoretical efficiency proposed by pure economics by itself.²²

In environmental economics, reductions in emission intensity are consistently linked to the effects of innovation. Higher carbon prices incentivize clean innovation, particularly in automotive and transport technologies.²³ Likewise directed technical change models argue that carbon taxation can accelerate the transition to green economic growth if applied consistently over time.²⁴

Regional studies highlight policy effect variation. For example, Japan's carbon tax had a limited impact due to its low rate and overlapping regulations, while Ireland's showed substantial emission reductions despite its political turnover.^{12,24} Together, these studies show that carbon tax effectiveness depends not only on tax level, but also on the supporting or overlapping policies, as well as enforcement quality—how effectively the government can actually tax subjects. This study provides new insight by utilizing the synthetic control method and placebo tests to assess whether Japan's carbon tax has measurably reduced Carbon dioxide emissions, and how its structure compares to successful carbon taxation examples such as Sweden's.

The rest of the paper will proceed as follows: Section 2 will contain the methodology of the research and the data used, Section 3 will present the results of the study and analyze the implications behind it, and Section 4 will have a conclusion.

■ Empirical Method and Data

Within this section, the synthetic control method is briefly presented, followed by a description of the data utilized in the analysis. A more formal description of the model can be found in previous studies.

2.1. Empirical method:

The synthetic control method (SCM) is made to evaluate the effect of a policy intervention at the comprehensive level when the number of units is limited.⁸ In this paper, the units are countries, observed during T periods indexed by t . Let T_0

represent the number of pre-treatment years and T_1 represent the amount of post-treatment years, with $T = T_0 + T_1$.

Among $J+1$ countries, only one (Japan) is exposed to the policy intervention (the 2012 carbon tax). The remaining J countries create the donor pool. It is assumed that Japan is only affected by the policy from T_0+1, \dots, T , and that no spillovers occur across units.

Let $Y_{[jt]}$ represent the result (CO₂ emissions per capita) of the country j in period t . The treatment effect for Japan in period t , a_{1t} , is defined as:

$$a_{1t} = Y^1_{1t} - Y^N_{1t},$$

where Y^1_{1t} is the observed outcome under treatment and Y^N_{1t} is the (unobserved) counterfactual outcome in the absence of treatment. Due to the unobserved untreated outcome for Japan after 2012, a counterfactual must be constructed.

The synthetic control is the weighted average of the untreated countries that best reproduces the pre-treatment characteristics of Japan. Specifically, let $W = (W_2, W_{J+1})'$ represent a vector of weights, where $W_j \geq 0$ and $\sum W_j = 1$. For a set of predictors X , SCM chooses W^* to minimize the distance between Japan's predictors (X_1) and those of the donor pool (X_0W):

$$\min_W (X_1 - X_0W)' V (X_1 - X_0W),$$

where V is a diagonal matrix that assigns importance to each predictor. Effectively, V and W are chosen to minimize the mean squared prediction error (MSPE) of the outcome variable during the pre-treatment period.⁵

The treatment effect in period t is then obtained through the equation:

The treatment effect in period t is then obtained through the equation:

$$a_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w^*_j Y_{jt}.$$

2.2. Data:

All the data was originally compiled from *Our World in Data*, which is a compilation of data sets. Data like CO₂ emissions originate from the *Global Carbon Project* and the *Carbon Dioxide Information Analysis Center*. Data on GDP per capita and merchandise trade come from the *World Bank's World Development Indicators*, and employment shares are taken from the International Labor Organization. Urbanization data is taken from the *United Nations World Urbanization*.

Data:	Description:
GDP Per Capita	GDP per capita is calculated as the value of all final goods and services produced each year in a country (the gross domestic product), divided by the population. It represents the average economic output per person. Represented in PPP—purchasing power parity—at constant 2021 international dollars. GDP per capita generally increases as economies transition from agriculture towards industry and services.
Emissions per capita	Carbon dioxide (CO ₂) emissions from burning fossil fuels and industrial processes. This includes emissions from transport, electricity generation, and heating, but not land-use change. Measured in metric tons. Land-use change, like deforestation and urban expansion, releases stored carbon and contributes to about 10–15% of global CO ₂ emissions. It is omitted due to data uncertainty and differing estimation methods from other energy related emissions. Emissions per capita increase with industrialization and income, then stabilize or decline at higher GDP per capita.

Share of the population living in urban areas	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by the United Nations Population Division. Urbanization increases with economic development and generally demands higher energy usage and emissions.
Employment in services as a percent of population	Distribution of total employment between the services sector. This includes employment in the informal economy. The share of employment services generally increases as GDP per capita rises.
Employment in industry as a percent of population	Distribution of total employment between the industry sectors. This includes employment in the informal economy. Industrial employment generally rises in early stages of development, declining as economies become service-dominated.
Employment in agriculture as a percent of population	Distribution of total employment in the agriculture sector. This includes employment in the informal economy. Agricultural employment generally declines with a country's urbanization and increasing income.
Merchandise trade as a share of GDP	the proportion of a country's economic output (Gross Domestic Product) that is accounted for by the international trade of physical goods (exports and imports). Merchandise trade generally accounts for a larger share of GDP as countries industrialize.

Model Application:

The outcome variable is total CO₂ emissions per capita—measured in metric tons. The predictors include a series of lagged values of CO₂ emissions per capita (1991–2010), GDP per capita (PPP, constant 2021 international dollars), the percentage of the urban population, the employment shares in services, industry, and agriculture, as well as all merchandise trade as a share of GDP. These predictors were selected to capture both the emissions trajectory and the economic-demographic structure of Japan relative to the donor pool.

The panel covers 1991 to 2023, with 22 pre-treatment years (1991–2011) and 12 post-treatment years (2012–2023). All countries with carbon taxes were removed from the list of potential donor countries to avoid spillover effects. The most important contributors to synthetic control based on their unit weights are: the United States (0.272), Zimbabwe (0.244), South Korea (0.177), and Romania (0.097). Additional contributors include Hong Kong (0.060), Libya (0.049), Russia (0.043), Bulgaria (0.027), Oman (0.015), Singapore (0.008), and Saudi Arabia (0.007).

To strengthen the credibility of the analysis, placebo tests are also implemented. These include reassigning the treatment to donor pool countries that did not introduce carbon taxes in 2012. If the placebo countries show no large post-treatment gaps compared to Japan, it supports the interpretation that any divergence observed for Japan is due to its carbon tax rather than random variation

Results

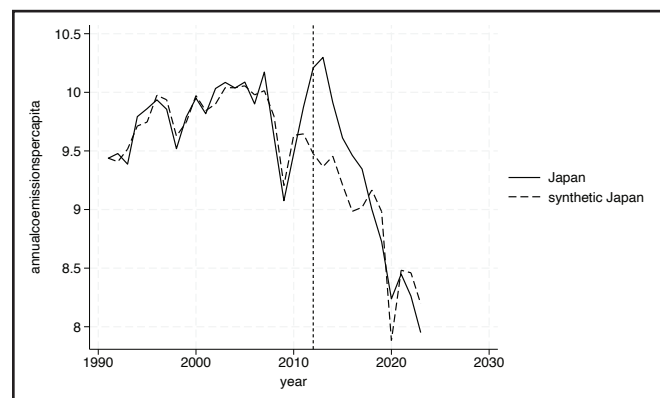


Figure 1: Figure 1 shows the trajectory of Japan's per capita CO₂ emissions compared to its synthetic control between the years 1990 and 2023. The pre-treatment period (1990–2011) shows a tight fit, suggesting that the synthetic control offers a credible counterfactual. From 2011 onward however, Japan's emissions diverge upward greatly from the synthetic. This spike corresponds to the Fukushima nuclear disaster, which forced the closing of nuclear power plants driving a large increase in fossil fuel demand and use. The divergence closes in through the post-treatment period, but never reaches a significant negative value, suggesting that the 2012 carbon tax has had limited impact in reducing emissions.

The placebo tests reinforce this interpretation. Table 1 reports p-values for each year after the carbon tax was introduced. If the p-values are low, the divergence between Japan and its synthetic control is unlikely to be due to random chance; higher values imply that the divergence could have occurred by coincidence.

Year	P-Value
2012	0.083
2013	0.066
2014	0.23
2015	0.28
2016	0.25
2017	0.39
2018	0.61
2019	0.5
2020	0.45
2021	0.91
2022	0.6
2023	0.54

Placebo test results show that only the first two post-treatment years (2012–2013) show relatively low p-values (~0.08 & ~0.07), indicating that Japan's divergence from its synthetic control was somewhat unusual immediately after the tax introduction—most likely due to the Fukushima incident abruptly increasing demand for fossil fuels for the next two years after 2011. However, from 2014 onward, the p-values rise, staying above 0.20 every year, even surpassing 0.90 by 2023. This suggests that most of the observed differences are statistically indiscernible from the placebo.

The findings indicate that Japan's carbon tax has not generated a strong or consistent reduction in CO₂ emissions per capita. The persistent reliance on fossil fuels after Fukushima, along with the tax's low rate and broad exemptions, appears to be the reason for its ineffectiveness, which is consistent with

current research on Japan's carbon tax (Even though different methods were used by them).

■ Discussion

This study utilized the synthetic control method to evaluate the effectiveness of Japan's 2012 carbon tax in reducing CO₂ emissions per capita. The results show that Japan's emissions diverged upward from its synthetic control immediately after the tax's introduction, but mainly due to the 2011 Fukushima nuclear disaster and the resulting increase in fossil fuel use. After 2013, however, the difference between Japan and its synthetic counterpart became statistically insignificant.

The synthetic control was built by combining data from countries without carbon taxation to replicate Japan's pre-treatment emissions trend. Control variables included GDP per capita, employment shares by sector, trade share of GDP, and urban population percentage. This model created a "synthetic Japan" that closely mirrored Japan's economic and demographic structure before 2012, isolating the policy's post-treatment effects. In accordance with existing research on carbon taxation these controls effectively represent the economic and structural factors that are highly linked to national emission levels.^{4,5} This study improves upon several of the previous papers by adding a larger set of socio-economic indicators and broadening the donor pool.

The findings indicate that Japan's carbon tax has not achieved a measurable reduction in emissions. The main reasons are its low rate, broad industrial exemptions, and introduction during an energy crisis. Large industries—such as manufacturing steel, cement, and energy production—face partial or complete exemptions, undermining the price signal. At ¥289 per ton (USD \$2.60), Japan's carbon tax is much lower than that of other countries. For example, Finland and Canada charge USD \$70–90 per ton, and Sweden's rate is above USD \$130 per ton—making its price signal too weak to significantly alter behavior. Japan's reliance on imported fuels as it turned to fossil fuels, natural gases, and coal, after the Fukushima incident, offset its potential emission gains.

Ultimately, this analysis suggests that Japan's carbon tax serves more as a symbolic measure than a significant emission control tool.

■ Conclusion

The results emphasize that carbon tax effectiveness requires proper rates, coverage, and integration with other policies. Japan's low rate and small scope provide little incentive for decarbonization. To improve effectiveness, Japan should gradually increase the tax and narrow industrial exemptions.

The Fukushima disaster continues to confound the policy evaluation, making it difficult to purely isolate the tax's impact. As new data becomes available, replicating this analysis will reveal whether Japan's emissions eventually diverge from its synthetic control or continue to follow the same path. Future research could refine this model by including energy mix (e.g. ... share of coal, LNG, oil, renewable energy) and sector-specific emissions (power generation, transportation, manufacturing), to better capture these effects.

Japan's case shows carbon tax adoption is only the starting point. Without strong price signals, enforcement, and compatible policies, carbon taxation can become purely symbolic rather than effective.

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