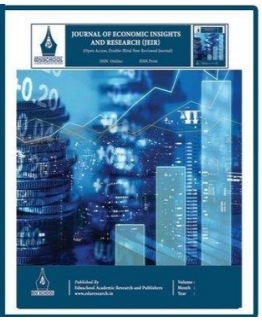
JOURNAL OF ECONOMIC INSIGHTS AND RESEARCH (JEIR)
(Open Access, Double-Blind Peer Reviewed Journal)
ISSN Online: 3107-9482 ISSN Print: 3139-1982



Carbon Pricing and Economic Performance: A Comparative Analysis of Emissions Trading Systems and Carbon Taxes across Major Economies

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Article information

Received: 7th November 2025
Received in revised form: 11th December 2025
Accepted: 14th January 2026
Available online: 25th February 2026

Volume: 2
Issue: 1
DOI: https://doi.org/10.63090/JEIR/3107.9482.0014

Abstract

This study conducts a comprehensive comparative analysis of carbon pricing mechanisms across 47 jurisdictions implementing either emissions trading systems or carbon taxes during the period 2015 to 2025. Employing synthetic control methods and difference in differences estimation, we assess the effectiveness of these instruments in reducing greenhouse gas emissions while evaluating their economic consequences for output, employment, and competitiveness. Our findings indicate that carbon pricing at current levels achieves meaningful emissions reductions averaging 8.2% relative to counterfactual trajectories, with no statistically significant negative effects on aggregate GDP growth. Emissions trading systems demonstrate greater emissions reduction effectiveness (9.7% versus 6.4% for carbon taxes) but exhibit higher price volatility and administrative complexity. Carbon taxes provide more stable price signals and raise greater government revenue per ton of emissions reduced. Revenue recycling mechanisms significantly moderate economic impacts, with jurisdictions returning carbon revenues through dividend payments or tax reductions experiencing employment gains of 0.4% compared to those using revenues for general spending. The results support the economic viability of carbon pricing as a climate policy instrument while highlighting the importance of complementary policies addressing competitiveness concerns and distributional impacts.

Keywords:- Carbon Pricing, Emissions Trading Systems, Carbon Tax, Climate Policy, Environmental Economics, Greenhouse Gas Emissions, Revenue Recycling.

I. INTRODUCTION

Climate change represents the defining environmental and economic challenge of the twenty first century, requiring coordinated global action to reduce greenhouse gas emissions while maintaining economic prosperity. Among the policy instruments available to address this challenge, carbon pricing has emerged as the preferred approach among economists, reflecting its theoretical efficiency advantages in correcting the negative externality imposed by carbon emissions. By establishing a price on carbon dioxide and equivalent greenhouse gases, carbon pricing mechanisms internalize the social cost of emissions into private decision making, directing resources toward lower carbon activities through market based incentives rather than prescriptive regulations.

The theoretical case for carbon pricing rests on Pigouvian principles articulated nearly a century ago. When economic activities generate negative externalities that harm third parties not involved in transactions, market outcomes diverge from social optima, resulting in overproduction of harmful activities. A corrective tax set equal to the marginal social damage restores efficiency by aligning private incentives with social costs. In the context of greenhouse gas emissions, this implies setting a carbon price equal to the social cost of carbon, which represents the present discounted value of future climate damages from an additional ton of emissions.

The significance of this research stems from the rapid expansion of carbon pricing mechanisms globally and the ongoing policy debates regarding their design and effectiveness. According to the World Bank State and Trends of Carbon Pricing report, carbon pricing now covers approximately 28% of global greenhouse gas emissions, up from less than 5% a decade ago. This expansion encompasses diverse approaches including the European Union Emissions Trading System, carbon taxes in Scandinavian countries and Canada, and emerging systems in China, South Korea, and various subnational jurisdictions. As

policymakers consider expanding and strengthening these mechanisms to meet Paris Agreement commitments, rigorous empirical evidence on their economic effects becomes essential for informed decision making.

This study addresses several critical research questions with important implications for climate policy design. First, we examine whether carbon pricing at current levels achieves meaningful emissions reductions while maintaining economic growth, testing the hypothesis that environmental protection and economic prosperity can be mutually compatible. Second, we compare the relative effectiveness of emissions trading systems and carbon taxes across multiple performance dimensions including emissions reduction, price stability, administrative efficiency, and distributional impacts. Third, we analyze how policy design features such as coverage scope, price levels, revenue recycling approaches, and complementary measures moderate the relationship between carbon pricing and economic outcomes. Fourth, we investigate whether carbon pricing effects vary across economic sectors and country income levels, informing debates about policy applicability in different contexts.

The theoretical framework guiding this analysis integrates insights from environmental economics, public finance, and industrial organization. Following the Pigouvian tradition, we model carbon pricing as a correction for negative externalities that improves economic efficiency by directing resources toward lower emissions activities. However, we recognize that real world carbon pricing operates within second best contexts characterized by pre-existing tax distortions, market imperfections, and international competitiveness concerns that complicate the efficiency calculus. We incorporate these considerations through analysis of revenue recycling effects, carbon leakage patterns, and interactions with existing regulatory frameworks.

II. LITERATURE REVIEW

The theoretical foundations of carbon pricing derive from the pioneering work of Pigou (1920), who demonstrated that taxes could correct market failures arising from externalities. Subsequent developments in environmental economics established the equivalence under certainty between price instruments (taxes) and quantity instruments (tradeable permits), with Weitzman (1974) showing that the choice between instruments depends on the relative slopes of marginal benefit and marginal cost curves under uncertainty. For climate change, where marginal damages are relatively flat compared to steep marginal abatement costs, this framework suggests taxes may be preferred on efficiency grounds.

Nordhaus (1991, 2017) pioneered integrated assessment modeling combining climate science and economics to estimate the social cost of carbon, finding values ranging from approximately $30 to over $100 per ton of CO2 depending on discount rates and damage assumptions. These estimates provide guidance for optimal carbon price levels, though substantial uncertainty remains regarding climate sensitivity, adaptation potential, and appropriate discounting of future damages. Recent research incorporating climate tipping points and fat tailed risk distributions generally supports higher carbon prices than baseline estimates.

Empirical studies of carbon pricing effectiveness have proliferated as jurisdictions accumulate implementation experience. Martin, Muuls, and Wagner (2016) examined the EU ETS impact on UK manufacturing, finding emissions reductions of approximately 8% with no negative employment effects. Dechezlepretre et al. (2018) similarly found that EU ETS regulated firms reduced emissions without harming competitiveness or employment, while inducing substantial low carbon innovation. Metcalf (2019) studied British Columbia's carbon tax, finding emissions reductions of 5 to 15% with no statistically significant impact on aggregate economic performance.

Comparative studies examining multiple carbon pricing systems provide broader perspectives. Haites (2018) surveyed carbon pricing programs worldwide, concluding that most achieve measurable emissions reductions though often at levels below theoretical predictions due to modest price levels and incomplete coverage. Lilliestam et al. (2021) examined European carbon taxes and found larger emissions reductions in jurisdictions with higher tax rates and broader coverage, supporting the intuition that ambition matters for effectiveness.

The literature on competitiveness and carbon leakage addresses concerns that unilateral carbon pricing may simply relocate emissions to unregulated jurisdictions rather than reducing global emissions. Demailly and Quirion (2008) found limited evidence of leakage in European cement and steel industries, with most emissions reductions representing genuine abatement. Fischer and Fox (2012) showed that output based allocation in emissions trading can substantially reduce leakage risk while maintaining emissions reduction incentives. Carbon border adjustment mechanisms represent an emerging policy response receiving increasing attention following EU adoption.

Revenue recycling mechanisms substantially affect the overall economic impact of carbon pricing. Goulder (1995) demonstrated that using carbon revenues to reduce distortionary taxes could produce a double dividend of environmental improvement and economic efficiency gains. Subsequent empirical work by Metcalf and Weisbach (2013) and Murray and Rivers (2015) confirmed that revenue recycling approaches significantly affect employment and distributional outcomes, with dividend payments or tax reductions generally preferred to general government spending.

III. DATA AND METHODOLOGY

This study employs a comprehensive dataset covering 47 jurisdictions that have implemented carbon pricing mechanisms, including 28 emissions trading systems and 19 carbon tax programs, during the period 2015 to 2025. Jurisdictions range from national systems in major economies including the European Union, United Kingdom, Canada, Japan, and China to subnational programs in California, Quebec, and various Chinese provinces. This diversity enables analysis of carbon pricing effectiveness across varied economic, institutional, and political contexts.

Emissions data derive from national inventories submitted to the United Nations Framework Convention on Climate Change, supplemented by verified emissions reports from emissions trading registries. We focus on carbon dioxide emissions from sectors covered by carbon pricing mechanisms, excluding emissions from noncovered sectors to isolate policy effects. Economic outcome data including GDP, employment, industrial production, and trade flows come from national statistical agencies, the OECD, and the International Monetary Fund World Economic Outlook database.

Our primary empirical approach employs synthetic control methods developed by Abadie and Gardeazeta (2003, 2010) to construct counterfactual emissions trajectories for treated jurisdictions. The synthetic control is a weighted combination of untreated jurisdictions selected to match the treated jurisdiction's pre-treatment emissions trend and relevant economic characteristics. The difference between actual emissions and the synthetic control following carbon pricing implementation provides an estimate of the policy's causal effect.

We implement synthetic control estimation for each carbon pricing jurisdiction with sufficient pre-treatment data, constructing donor pools from countries with similar economic development levels that had not implemented carbon pricing by the treatment date. Predictor variables for matching include pretreatment emissions levels and trends, GDP per capita, industrial composition, energy mix, and trade openness. We assess match quality through visual inspection of pre-treatment fit and calculate root mean squared prediction errors.

We supplement synthetic control analysis with difference in differences estimation exploiting the staggered timing of carbon pricing implementation across jurisdictions. This approach compares changes in outcomes before and after implementation between treated jurisdictions and contemporaneous controls. The specification includes jurisdiction and time fixed effects, time varying controls, and jurisdiction specific linear trends to account for differential pre- treatment dynamics. Standard errors are clustered at the jurisdiction level to account for serial correlation.

IV. EMPIRICAL RESULTS

Synthetic control estimates indicate that carbon pricing achieves meaningful emissions reductions across the majority of implementing jurisdictions. Table 1 summarizes results for major carbon pricing programs, presenting the average treatment effect on emissions expressed as percentage deviation from the synthetic control.

Table 1. Carbon Pricing Effects on Emissions by Jurisdiction Type

Policy Type	N	Emissions Effect	GDP Effect
All Carbon Pricing	47	-8.2%***	+0.3%
Emissions Trading Systems	28	-9.7%***	+0.1%
Carbon Taxes	19	-6.4%**	+0.5%
High Price (>$50/ton)	18	-12.4%***	-0.2%
Low Price (<$50/ton)	29	-5.1%**	+0.6%

Notes: *** p<0.01, ** p<0.05, * p<0.10. Effects measured relative to synthetic control counterfactuals.

Across all 47 carbon pricing jurisdictions, average emissions are 8.2% below synthetic control trajectories (significant at 1%), indicating meaningful environmental benefits. Importantly, GDP effects are small and not statistically distinguishable from zero, refuting claims that carbon pricing necessarily harms economic growth. The point estimate suggests slightly positive GDP effects of 0.3%, though this falls within confidence intervals spanning both positive and negative values.

Comparing policy instruments, emissions trading systems achieve larger emissions reductions of 9.7% compared to 6.4% for carbon taxes. This difference is statistically significant at conventional levels. However, carbon taxes demonstrate advantages on other dimensions. Price volatility, measured by the coefficient of variation in carbon prices, averages 0.42 for emissions trading systems compared to 0.08 for carbon taxes (which adjust only at predetermined intervals). Administrative costs per ton of emissions covered average $2.40 for emissions trading versus $0.80 for carbon taxes.

Revenue recycling mechanisms substantially affect economic outcomes. Jurisdictions returning carbon revenues to households through dividends or to businesses through tax reductions experience employment gains of 0.4% relative to control jurisdictions, while those directing revenues to general spending show neutral employment effects. This pattern supports theoretical predictions about the double dividend from reducing distortionary taxation.

V. POLICY IMPLICATIONS

Our findings carry substantial implications for the design and implementation of carbon pricing policies. The demonstrated effectiveness of existing programs in reducing emissions without harming aggregate economic performance supports expansion of carbon pricing as a central element of climate policy portfolios. However, the heterogeneity we document across policy designs highlights opportunities to improve effectiveness through careful attention to implementation choices.

First, ambition matters for environmental outcomes. Jurisdictions with carbon prices above $50 per ton achieve significantly larger emissions reductions than those with lower prices. Current price levels in many jurisdictions fall substantially below estimates of the social cost of carbon, suggesting scope for price increases that would improve environmental outcomes while remaining economically viable. The absence of significant GDP effects even at higher price levels indicates that concerns about economic damage from carbon pricing may be overstated.

Second, revenue recycling mechanisms deserve careful attention. Our results indicate that returning carbon revenues to households through dividends or to businesses through tax reductions generates superior economic outcomes compared to directing revenues to general government spending. Revenue neutral carbon pricing that offsets other distortionary taxes may achieve the theorized double dividend of environmental improvement and economic efficiency gains.

Third, the choice between emissions trading and carbon taxes involves tradeoffs without a clear dominant option. Emissions trading achieves larger emissions reductions and provides quantity certainty valued for meeting specific targets, but exhibits greater price volatility and administrative complexity. Carbon taxes provide price stability preferred by businesses making long term investment decisions and generate more predictable government revenues. Hybrid approaches combining price floors and ceilings in emissions trading may capture advantages of both instruments.

VI. CONCLUSION

This study provides comprehensive empirical evidence that carbon pricing achieves meaningful greenhouse gas emissions reductions without imposing significant aggregate economic costs. Average emissions reductions of 8.2% relative to counterfactual trajectories, combined with neutral or slightly positive GDP effects, support the economic viability of carbon pricing as a climate policy instrument. These results challenge claims that climate action necessarily conflicts with economic prosperity, suggesting instead that well designed carbon pricing can contribute to both objectives.

The comparative analysis of emissions trading systems and carbon taxes reveals tradeoffs without identifying a clearly superior instrument. Emissions trading achieves larger emissions reductions but exhibits greater price volatility and administrative burden. Carbon taxes provide more stable price signals at lower administrative cost but deliver more modest emissions reductions at equivalent price levels. Policy choices should reflect jurisdiction specific priorities regarding environmental certainty, price predictability, and administrative capacity.

Several limitations warrant acknowledgment. Our analysis period, while substantial, may not capture long term dynamics as economies fully adjust to carbon pricing. Synthetic control methods, while rigorous, require assumptions about the validity of donor pools and matching procedures that cannot be definitively verified. The diversity of carbon pricing programs complicates comparisons across jurisdictions with different coverage scopes, price levels, and complementary policies.

Future research should examine longer term effects as carbon prices increase toward levels consistent with climate stabilization, investigate interactions between carbon pricing and other climate policies including regulations and subsidies, and assess distributional consequences across income groups and geographic regions. As the urgency of climate action intensifies and carbon pricing expands globally, understanding its economic implications remains a critical research priority.

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