Proceedings of ICFTBA 2025 Symposium: Data-Driven Decision Making in Business and Economics
DOI: 10.54254/2754-1169/2025.BL30829

The Impact Mechanism of Sweden's Carbon Tax on Manufacturing Carbon Emissions and Policy Implications

Rongbin Dong

New Huadu Business School, Minjiang University, Fuzhou, China
2429942490@qq.com

Abstract. The governance of global climate change has grown progressively imperative. As a core economic instrument for mitigating carbon emissions, the efficacy of carbon pricing mechanisms has emerged as a critical research focus. Sweden, as a pioneer in carbon tax policy practice, offers a paradigmatic case for assessing the environmental and economic impacts of carbon taxes via its institutional design and implementation outcomes. This study endeavors to systematically dissect the action pathways, influence mechanism, and ultimate emission reduction effect of Sweden's carbon tax on the carbon emissions of the manufacturing industry. Employing a mixed-methods research approach integrating a systematic literature review and in-depth case analysis, this paper systematically reconstructs the evolutionary trajectory of Sweden's carbon tax, elaborates on its unique tax rate design and compensation mechanism, and centers on the response behavior of the manufacturing sector. The findings reveal that under the drive of policies such as carbon taxes, the emissions of Sweden's industrial sector have declined by 25% from 1990 to 2023. This validates that carbon taxes, via explicit price signals, effectively incentivize energy conservation, emission reduction, and technological innovation. The conclusion of this study is that a well-designed carbon tax system, which is both strict and flexible, can effectively facilitate the green transition of the industrial sector.

Keywords: Carbon tax, manufacturing carbon emissions, Sweden, manufacturing

1. Introduction

Tackling climate change has evolved into a global consensus. Against this backdrop, carbon pricing mechanisms are widely recognized as the core policy instrument for attaining the temperature control targets stipulated in the Paris Agreement. Among diverse carbon pricing schemes, carbon taxes have garnered favor among numerous governments owing to their relatively low administrative costs and explicit, stable price signals. Sweden, a Nordic nation, pioneered the global implementation of a carbon tax in 1991. Following over three decades of development and refinement, it has established one of the world's highest tax rate levels and broadest coverage carbon tax systems, while achieving the decoupling of sustained GDP growth and a substantial reduction in total carbon emissions [1].

Existing research, particularly empirical analyses based on macro data, generally affirms the positive effects of Sweden's carbon tax on overall emissions reduction, especially in sectors such as

DOI: 10.54254/2754-1169/2025.BL30829

transportation. For instance, Andersson (2019)'s quasi-experimental study demonstrates that the carbon tax, in conjunction with value-added tax, drove an average annual reduction of 10.9% in carbon emissions within Sweden's transportation sector between 1990 to 2005, with the carbon tax alone accounting for approximately 6.3% (an average of 1.5 million tons of CO_2) of the reduction [1]. However, when the research focus shifts to the industrial sector, particularly the manufacturing industry, extant literature exhibits notable research gaps regarding the underlying mechanisms of action and differentiated impacts. Firstly, macro-level statistics obscure the heterogeneous responses across sub-sectors within the industrial sector. Although data shows that Sweden's industrial sector emissions have decreased by 25% from 1990 to 2023, this macro-level trend obscures the divergent technological paths and abatement costs of various sub-sectors. Existing research has not fully elucidated why the pulp and paper industry can achieve a low-carbon cycle by utilizing biomass residues, whereas the steel industry must depend on disruptive technologies such as hydrogen-based direct reduction under the same carbon price signal.

Secondly, there is a paucity of micro-level evidence to support the "induction" mechanism of carbon taxes on industrial innovation. However, existing research largely remains confined to the level of case descriptions and lacks systematic empirical tests based on micro-level data from enterprises regarding specific pathways such as how carbon taxes shape investment decision-making processes, risk assessment practices, and long-term R&D strategies of enterprises.

Furthermore, the competitiveness and carbon leakage effects arising from differentiated tax policies require rigorous quantification and assessment. Sweden has adopted highly differentiated carbon tax policies to protect the competitiveness of energy-intensive and trade-exposed industries, such as exempting facilities already covered by the EU ETS and imposing significantly reduced tax rates (about 20%-30% of the benchmark rate) to manufacturing sectors exposed to international competition. Extant literature has neither accurately quantified the emission-related costs of such "protection" nor fully clarified the optimal policy design threshold for balancing competitiveness safeguards and emission reduction incentives.

Building on this, the core research questions of this study is: Through what specific mechanisms does the Swedish carbon tax system shape the carbon emission behavior of manufacturing enterprises (especially energy-intensive industries)? What are the environmental and competitiveness effects? The significance of this study resides in providing empirical evidence from a global leading case for the theory of the interaction between environmental regulations and firm behavior by deconstructing the micro-level practices of the Swedish carbon tax in the manufacturing sector.

2. Theoretical foundations and global practices of carbon tax systems

2.1. Economic principles of carbon tax

The theoretical underpinning of carbon taxes originates from the "Pigouvian tax" theory in neoclassical economics, which seeks to rectify market failures by internalizing the negative externalities of carbon emissions - the harm to social welfare and the environment that is not reflected in market transaction prices. According to this theory, the optimal carbon tax rate should be equivalent to the marginal social cost of carbon emissions, thereby forcing private decision-makers to confront the true social costs and realizing Pareto improvement in resource allocation [2].

Sweden's carbon tax practice represents a sophisticated application and necessary adaptation of this classic theory in the context of an open economy. Its institutional design does not mechanically apply a uniform Pigouvian tax rate on all emission sources; instead, it adopts highly differentiated

DOI: 10.54254/2754-1169/2025.BL30829

tax policies based on the emission characteristics, abatement costs, and exposure to international competition of various sectors. Rate adjustments for competition-exposed industrial sectors: To avoid carbon leakage and impose an unbearable burden on energy-intensive industries, the Swedish government has implemented significant tax rate reductions for the industrial sector, especially manufacturing sectors confronting intense international competition. For instance, industrial facilities included in the EU Emissions Trading System (EU ETS) are fully exempted from national carbon taxes to avoid double regulation; for manufacturing sectors not included in the ETS but under international competitive pressure, a substantially reduced tax rate (approximately 20%-30% of the benchmark rate) is levied [1].

Strict application in sectors with clear price signals: In contrast, in consumer terminal sectors such as household heating and transportation, where international competitive pressures are relatively small and price signals are more direct, Sweden's carbon tax strictly adheres to the Pigouvian principle and adopts one of the world's highest tax rates (having gradually increased from about 250 Swedish kronor/ton CO_2 equivalent in 1991 to 1,450 Swedish kronor/ton in 2024, equivalent to more than 120 euros per ton) [3]. This delivers sustained and robust incentives for households and motorists to curtail carbon emissions, thereby effectively guiding their energy consumption patterns and technological choices.

2.2. Overview of global carbon tax implementation and Sweden's benchmark status

As of 2024, dozens of national and sub-national jurisdictions across the globe have introduced carbon taxes or emissions trading systems. The design frameworks of these carbon pricing instruments differ substantially in aspects such as tax rate magnitude, coverage, revenue use, and measures to protect international competitiveness, and these details directly determine the environmental effectiveness, economic efficiency, and social acceptance of the policies.

In terms of revenue use, different countries' practices reflect different policy priorities. For example, Canada's federal carbon pricing regime employs a "carbon fee and rebate" mechanism, which channels the majority of carbon tax revenues directly to households in the form of "climate action incentives" payments. This approach seeks to enhance social equity and political acceptability by alleviating the tax burden on low- and middle-income households. In contrast, Sweden integrates carbon tax revenues into the national general budget, primarily utilizing them to lower personal income taxes and labor taxes. This "tax-neutral" revenue recycling framework has successfully realized a "double dividend" of environmental and economic benefits: improving environmental quality while mitigating tax system distortions in the labor market, thereby boosting employment levels and economic growth potential and fostering a broader public support base [4].

In terms of coverage, different systems also have their own focuses. The "cap and trade" model represented by the EU Emissions Trading System (EU ETS) mainly covers power generation, energy-intensive industries, and aviation sectors. Carbon prices under this system are determined by market supply and demand, exhibiting relatively high volatility. The Swedish carbon tax, as a complement to the ETS, mainly targets transportation, residential heating, and certain industrial processes not covered by the ETS, thereby establishing a comprehensive hybrid carbon pricing system [5]. This design not only transmits clear price signals to ETS-uncovered sectors but also, more critically, furnishes enterprises and investors with long-term stable policy expectations through a government-mandated, predictable, and gradually escalating tax rate (from approximately 250 Swedish kronor per ton of CO_2 equivalent in 1991 to over 1,200 Swedish kronor per ton in 2024). This substantially mitigates the policy uncertainty risks associated with low-carbon investments [1,6].

DOI: 10.54254/2754-1169/2025.BL30829

Among them, Sweden's carbon tax system regime distinguishes itself through its forward-looking orientation, high policy intensity, and sophisticated design, emerging as a benchmark for global carbon pricing policies. The high-intensity price signal serves as the core driver for deep decarbonization reduction, while the "revenue-neutral" income recycling model and the complementary coverage with the EU ETS collectively form the key institutional guarantees for attaining substantial emission reduction outcomes while preserving economic competitiveness and social equity, providing a valuable reference model for other nations in designing carbon pricing systems that are both environmentally effective and economically efficient.

3. In-depth analysis of the Swedish carbon tax system

3.1. System design: tax rates, coverage, and compensation mechanisms

The Swedish carbon tax primarily targets fossil fuels utilized for household heating, transportation, and specific industrial processes. The ingenuity of its system design resides in reconciling environmental objectives with economic competitiveness. To preclude carbon leakage and excessive burdens on energy-intensive industries, the Swedish government has adopted differentiated taxation policies: Complete exemption for facilities covered by the EU ETS: Industrial facilities already incorporated into the EU Emissions Trading System (EU ETS) are fully exempted from the national carbon tax. This design is intended to avert double regulation and ensure that these sectors—subject to stringent carbon constraints—do not forfeit international competitiveness due to additional carbon costs. At the EU level, this functional division between the ETS and carbon taxes is also reflected in the emerging Carbon Border Adjustment Mechanism (CBAM), which explicitly covers high-carbon leakage risk industries such as steel, aluminum, and cement. Reduced tax rates are applied to non-ETS-covered sectors confronting intense competitive pressure: For manufacturing sectors not covered by the EU ETS but facing severe international competition (such as some non-ETS-covered energy-intensive industries), significantly reduced tax rates are applied, roughly 20%-30% of the standard carbon tax rate. The core rationale of this compensation mechanism is to provide a necessary transition period for low-carbon technology adoption and upgrading, trajectory while safeguarding their market viability and international competitiveness [1]. It is worth noting that Sweden's carbon tax exemption mechanism is not static. As the EU's climate governance policies evolve, particularly with the phased phase-out of free allowances in the EU ETS and the full-scale implementation of the CBAM, Sweden's domestic carbon taxation regime may also undergo commensurate adjustments.

3.2. Induced effects on manufacturing competitiveness and innovation

This is primarily accomplished through the dual channels of "cost compensation" and "signal guidance". On the one hand, the continuously escalating carbon tax rate (such as 1.45 SEK/kg CO_2 in Sweden in 2024) directly elevates the cost of using fossil fuels, driving enterprises to pursue "innovation compensation" through energy efficiency improvements and low-carbon technology research and development. On the other hand, the long-term stability of policy framework provides enterprises with clear policy expectations, guiding them to integrate low-carbon transition into their core strategic planning. Under this mechanism, Sweden's manufacturing sector has attained deep decarbonization and technological upgrading: industrial emissions have decreased by 25% from 1990 to 2023, and the proportion of biomass and electricity in the energy structure has reached 74%, with disruptive innovations such as the HYBRIT hydrogen steelmaking project emerging, validating the carbon tax's effectiveness as an "innovation-inducing" policy instrument. For example, in the paper industry, which is the largest energy consumer in Sweden but has relatively low carbon intensity, this is mainly due to the extensive use of biomass energy (such as bark and black liquor residues produced during the production process) as the main energy source. Currently, biomass energy and electricity together constitute the main energy sources for the Swedish paper industry, reducing its dependence on fossil fuels to an extremely low level. This transformation in the energy structure not only significantly reduces carbon emissions but also enables enterprises to achieve energy self-sufficiency and operational cost savings by using low-cost or even negative-cost internal biomass residues. Similarly, in the steel sector, carbon taxation and other policy measures have spurred fundamental process innovations. The globally acclaimed HYBRIT demonstration project seeks to substitute fossil-free hydrogen to replace coking coal, and its pilot facility has successfully produced sponge iron [7].

3.3. Case study: response strategies of typical manufacturing enterprises take SSAB, a Swedish steel company, as an example

To address carbon taxes and broader climate policies, the company has developed a "fossil-free steel" strategy. The core pillar of this strategy is the HYBRIT project, which seeks to fully substitute coke in the traditional blast furnace ironmaking process with fossil-free hydrogen. This technological transition is projected to reduce carbon dioxide emissions in the production process by roughly 95%. The HYBRIT demonstration plant successfully produced its first batch of sponge iron in 2021 and intends to attain commercial-scale production by 2026. Estimates indicate that the full-scale implementation of the HYBRIT project alone could reduce Sweden's national carbon dioxide emissions by 7%, underscoring the substantial contribution of a leading enterprise's deep decarbonization efforts to the attainment of national climate goals. Meanwhile, SSAB is accelerating the electrification transformation of its production assets. The company has decided to invest 4.5 billion euros in building mini steel mills based on electric arc furnaces in its factories in Sweden and Finland. This transition will substantially increase the share of scrap steel utilized and directly harness the abundant fossil-free electricity in the Nordic region, thereby fully phasing out traditional blast furnace production lines. This case vividly demonstrates the profound impact of carbon taxes in guiding enterprises to pursue long-term and fundamental technological transformations [8].

4. Comprehensive discussion and lessons learned from international experience

4.1. The Swedish model in an international comparative perspective

In comparison with the EU ETS—centered on "cap-and-trade"—Sweden's carbon tax delivers more stable long-term price expectations and mitigates the policy uncertainty risks enterprises confront when investing in low-carbon technologies. Compared with the carbon taxes implemented in countries like Canada, which have relatively low initial rates and limited coverage, the success of the Swedish model underscores the paramount importance of policy stringency (i.e., a sufficiently high tax rate) in achieving significant emission reduction effects [2]. Furthermore, the revenue utilization mechanism of Sweden's carbon tax is particularly noteworthy. According to data from the Swedish Ministry of Finance, the use of carbon tax revenue strictly adheres to the principle of "tax neutrality", with all proceeds incorporated into the national general budget and no special environmental protection fund established. Specifically: about 60-70% of the carbon tax revenue is used to reduce personal income tax, especially for the middle and low-income groups; about 20-30%

is dedicated to reducing employers' social security contributions, thereby directly lowering labor costs; the remaining part is allocated to balancing the budget or fund general government expenditures. This meticulously designed revenue recycling model has yielded a substantial "double dividend" effect: while improving environmental quality, it stimulates employment growth by reducing labor tax burdens. Empirical research demonstrates that this mechanism has allowed Sweden's carbon tax to sustain a high public acceptance rate of over 65% while retaining the highest tax rate in the world (1.45 SEK/kg CO_2 in 2024). In contrast, other countries implementing carbon taxes adopt distinct revenue distribution approaches: Canada returns over 90% of carbon tax revenue directly to households via "climate action incentive payments"; Switzerland uses two-thirds of its carbon tax revenue to subsidize the medical insurance costs of enterprises and residents. Sweden's unique "tax reduction over subsidy" model exhibits distinct advantages in fostering synergy between economic growth and emission reduction objectives.

Overall, the success of the Swedish model stems not only from its high tax rate but also from its sophisticated institutional configuration: the coordinated coverage of different sectors by carbon taxes and the EU ETS, the safeguarding of competitiveness via differentiated tax rates, and the cultivation of broad social support through a "tax-neutral" revenue circulation mechanism, collectively forming an incentive-compatible and cost-effective comprehensive climate governance regime [9].

4.2. Policy experiences worth learning from

Drawing on the practice of the Swedish carbon tax over the past three decades, its successful experience offer a highly valuable policy framework for other countries and regions, especially those in the early stages of building a carbon pricing system. A carbon tax system framework with portability and adaptability should be meticulously designed around the following aspects:

First, formulate a credible and progressively increasing tax rate trajectory. One of the core features of Sweden's carbon tax is its high tax rate level and clear long-term growth trajectory. Policy makers should publish a phased and transparent tax rate increase schedule at the beginning of the system's establishment. For example, a fixed nominal or proportional increase in the carbon tax rate can be stipulated for every year or every two years within the next 10 to 15 years. This design not only delivers stable policy expectations for enterprises and investors, reducing the uncertainty risks they encounter when investing in low-carbon technologies and equipment, but more importantly, it guides market participants to make intertemporal decisions through increasingly strengthened price signals, gradually phasing out high-carbon assets, and systematically transitioning toward a low-carbon development pathway.

Second, develop a well-designed compensation and exemption mechanism to balance environmental effectiveness and economic competitiveness. To prevent intolerable competitiveness losses to energy-intensive and trade-exposed industries and even triggering carbon leakage, Sweden has implemented highly differentiated tax policies. The core logic is: facilities included in the EU Emissions Trading System (EU ETS) are exempted from carbon taxes to avoid double regulation; for manufacturing sectors that are not included in the ETS but confronting intense international competition pressure, significantly reduced tax rates (such as about 20%-30% of the benchmark rate) are applied. This compensation mechanism, while sustaining overall emission reduction momentum, affords necessary buffer periods and political support for the green transformation of key industries. When other countries design similar mechanisms, they should scientifically delineate the scope of sectors eligible for preferential policies based on indicators such as the energy intensity

DOI: 10.54254/2754-1169/2025.BL30829

and trade exposure of their domestic industries, and establish clear exit mechanisms to ensure that compensation measures are transitional rather than permanent [1].

Third, strengthen policy coordination and systematic integration. Sweden's successful practice illustrates the organic integration of carbon taxes with energy efficiency standards, renewable energy subsidies, and green research and development funding. For instance, a portion of carbon tax revenue can be specifically earmarked for establishing a "green transformation fund" to provide matching financing support for enterprises' energy efficiency improvement and low-carbon technology innovation projects. Simultaneously, policy formulation must ensure that the carbon tax regime is aligned with top-level design objectives such as nationally determined contributions and long-term low-carbon development strategies, forming a policy synergy and avoiding overlaps, conflicts, or regulatory gaps among different policy instruments, and collectively constructing an incentive-compatible and cost-effective comprehensive climate governance system [3,10].

Fourth, focus on social equity and the recycling of tax revenue to build a broad social support base. Sweden has successfully achieved a "double dividend" effect of both environmental and economic benefits by using the majority of carbon tax revenue to reduce personal income taxes (mainly at lower rates) and labor taxes. This revenue-neutral recycling model not only alleviates the adverse impacts of carbon taxes on residents' disposable income and enhances social equity but also stimulates employment and economic growth to a certain extent by reducing labor tax burdens, thereby winning broader public and industrial acceptance. Other countries can draw on this approach and explore utilizing carbon tax revenue for targeted subsidies to low-income groups, investments in inclusive green public services (such as public transportation), or reduction of other distortive taxes to enhance the political feasibility and social resilience of carbon tax policies [4,9].

5. Conclusion

This study demonstrates that the Swedish carbon tax system, through its high intensity, predictable price signals, and sophisticated compensation mechanism design, has successfully internalized environmental externalities, significantly reducing the carbon emission intensity of the manufacturing sector, especially energy-intensive industries, and effectively stimulating technological innovation activities aimed at improving energy efficiency and developing low-carbon processes. This research primarily draws on macro-statistical data and literature, and lacks empirical tests based on firm-level microeconometric analysis. Moreover, the research perspective is confined to the domestic context of Sweden, and the applicability and migration conditions of its policy effects in countries with different political economic structures and development stages need to be further explored. Future research can focus on constructing a econometric model with multi-country panel data to more accurately identify the utility of the carbon tax. Simultaneously, it is essential to conduct in-depth exploration of the impact mechanisms of the carbon tax on a broader range of economic performance indicators.

References

[1] Andersson, J. J. (2019). Carbon taxes and CO_2 emissions: Sweden as a case study. American Economic Journal: Economic Policy, 11(4), 1–30.
[2] Wang, Y., & Song, F. (2019). Carbon Tax versus Carbon Emission Trading: Theoretical Comparison and China's Choice. Management World, 35(4), 81-94.
[3] Criqui, P., Jaccard, M., & Sterner, T. (2019). Carbon Taxation: A Tale of Three Countries. Sustainability, 11(22), 6280.

DOI: 10.54254/2754-1169/2025.BL30829

[4] Jagers, S. C., Martinsson, J., & Matti, S. (2019). The impact of compensatory measures on public support for carbon taxation: An experimental study in Sweden. Climate Policy, 19(2), 147–160.
[5] Higa, C., Cunha, M., & Silveira, S. (2020). Coalitions towards the carbon tax in the Swedish heating sector. Sustainability, 12(20), 8530.
[6] European Commission. (2016). Regulation of the European Parliament and of the Council. European Commission: Brussels, Belgium.
[7] Huang, W. (2022). Demand for plant-based milk and effects of a carbon tax on fresh milk consumption in Sweden. Economic Analysis and Policy, 75, 518–529.
[8] Knaggård, Å., & Hildingsson, R. (2025). The adoption of the Swedish carbon tax: Influences and interactions across multiple political levels, jurisdictions, and policy areas. Policy Studies Journal, 53(2), 414–435.
[9] Linder, N., Sörqvist, P., Lindvall, D., Jagers, S., & Barthel, S. (2025). It would feel weird to not drive my car! Exploring the role of habits in public policy acceptance of carbon taxations. Ambio, 54, 670–679.
[10] Haites, E., Bertoldi, P., König, M., Bataille, C., Creutzig, F., Dasgupta, D., de la rue du Can, S., Khennas, S., Kim, Y.-G., Nilsson, L. J., Roy, J., & Sari, A. (2024). Contribution of carbon pricing to meeting a mid-century net zero target. Climate Policy, 24(1), 1–12.