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Carbon Taxes vs. Cap-and-Trade as Responses to Greenhouse Gas Externalities

A comparative secondary research paper on the EU Emissions Trading System and Sweden's carbon tax

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ABSTRACT: Greenhouse gas emissions are a negative externality because private decisions to burn fossil fuels do not fully reflect the climate damages imposed on others. This paper compares two market-based instruments designed to correct that failure: carbon taxes, which fix the price of emissions and allow quantities to adjust, and cap-and-trade systems, which fix the emissions quantity and allow the permit price to adjust. The case studies are the European Union Emissions Trading System (EU ETS) and Sweden's national carbon tax. The review finds that both instruments can generate meaningful emissions reductions when their coverage is broad, their carbon price is material, and exemptions are limited. Peer-reviewed evidence estimates that the EU ETS reduced regulated manufacturing emissions by 14% in Phase I and 16.3% in Phase II, and avoided about 1.2 billion tonnes of CO2 between 2008 and 2016. For Sweden, synthetic-control and firm-level studies estimate an almost 11% transport-sector reduction and large manufacturing-sector responses to carbon pricing. The main conclusion is not that one instrument is universally superior. Design details - coverage, revenue use, price stability, exemptions, and trade-exposure protections - largely determine efficiency, equity, and political durability.

KEYWORDS: carbon tax; cap-and-trade; EU ETS; Sweden; carbon pricing; greenhouse gas externalities; emissions trading; Pigouvian taxation

JEL classification: D62, H23, Q54, Q58, L51

DATA AVAILABILITY STATEMENT

This is a secondary research paper. All empirical claims are drawn from peer-reviewed articles, DOI-backed institutional reports, or separately flagged official institutional sources. No original dataset was constructed for this version.

SOURCE STRATEGY AND EVIDENCE HIERARCHY

This secondary research paper distinguishes between causal empirical evidence and descriptive current-policy facts. Causal estimates, elasticity claims, and literature-review conclusions are supported by DOI-backed peer-reviewed or institutional sources. Current legal parameters and recent market descriptors, however, are often published first on official European Commission, Government of Sweden, ICAP, and World Bank pages without article-style DOIs. These sources are therefore listed separately as official institutional sources and are used only for descriptive programme facts, not for independent causal estimates.

Table 1. Evidence hierarchy used in the paper

Source class	Used for	Treatment in this paper
Peer-reviewed journal articles with DOI	Theory, causal emissions estimates, elasticities, competitiveness, equity, public acceptability	Primary evidentiary basis
DOI-backed institutional reports	Cross-country effective carbon pricing, global context, policy stocktaking	Primary institutional evidence
Official or institutional no-DOI sources	Current policy parameters, legal design, recent auction/price descriptors, program facts	Separated from DOI sources and flagged as descriptive official evidence

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Source class	Used for	Treatment in this paper
Blogs, news, advocacy sources, AI-generated content, Wikipedia	Not used as evidentiary sources	Excluded

1. INTRODUCTION

Climate change is a market-failure problem before it is a political slogan. Emissions of carbon dioxide and other greenhouse gases generate benefits for emitters through energy use and production, but the climate damages are distributed across society, countries, and future generations. When the private cost of an emissions-intensive activity is below its social cost, markets overproduce that activity relative to the efficient level. Carbon pricing is the standard economic response: make emitters face a price for the external damage and let decentralized firms and households decide where abatement is cheapest.

This paper compares two policy instruments that pursue this same objective in different ways. A carbon tax fixes a price per tonne of CO2 or CO2-equivalent emissions. An emissions trading system fixes the total quantity of emissions allowed under a cap and creates tradable permits. In a simplified model with perfect information, competitive markets, no transaction costs, and full coverage, both instruments can achieve the same cost-minimizing allocation of abatement. In practice, they differ in price certainty, quantity certainty, political feasibility, revenue visibility, administrative complexity, and exposure to market volatility.

The two case studies are deliberately asymmetric. The EU ETS is a large multi-country cap-and-trade system covering power, industry, aviation, and maritime emissions. Sweden's carbon tax is a national tax instrument introduced in 1991 and widely studied because it has operated for more than three decades. This comparison is useful for undergraduate admissions research because it combines microeconomic theory with real policy evidence without requiring the paper to invent original data.

The refined research questions are:

1. How do carbon taxes and cap-and-trade systems theoretically internalize the externality of greenhouse gas emissions?
2. What does the empirical literature estimate about emissions reductions under the EU ETS and Sweden's carbon tax?
3. How do the instruments differ in price certainty, quantity certainty, elasticity, abatement-cost interpretation, equity, and competitiveness?
4. What policy lessons emerge for designing durable carbon-pricing systems?

2. THEORETICAL FRAMEWORK

2.1 Greenhouse gases as a negative externality

A negative externality exists when an activity imposes costs on third parties that are not reflected in market prices. Formally, if marginal social cost exceeds marginal private cost, then:

$$MSC(q) = MPC(q) + MEC(q) \qquad (1)$$

where MEC is the marginal external cost of emissions. The unregulated market equilibrium occurs where private marginal benefit equals marginal private cost, while the efficient equilibrium occurs where marginal benefit equals marginal social cost. The gap between these quantities creates deadweight loss. Carbon pricing addresses this by making emitters internalize at least part of MEC. Coase's property-rights logic helps explain why tradable permits can be efficient under low transaction costs and well-defined rights, while Pigouvian taxation emphasizes a corrective tax equal to marginal damage at the efficient level (Coase, 1960; Weitzman, 1974).

2.2 Carbon taxes: a price instrument

A Pigouvian carbon tax sets a price per unit of emissions. If the regulator could observe marginal external damages perfectly, the efficient tax would satisfy:

$$t^* = MEC(q^*) \qquad (2)$$

Emitters then reduce emissions until their marginal abatement cost equals the tax. The main practical advantage is price certainty: households and firms know the emissions price they will face. The main disadvantage is quantity uncertainty: the regulator cannot know in advance exactly how much emissions will fall unless it knows the economy-wide abatement response.

2.3 Cap-and-trade: a quantity instrument

A cap-and-trade system fixes the aggregate quantity of allowable emissions and allocates or auctions permits. Each permit grants the right to emit a defined quantity, usually one tonne of CO2-equivalent. Compliance can be summarized as:

$$\Sigma\ e\_i <= E\_bar \qquad (3)$$

where E_bar is the cap. If trading is competitive and transaction costs are low, firms with low abatement costs reduce emissions and sell permits, while firms with high abatement costs buy permits. Trading equalizes marginal abatement costs across regulated firms, so the permit price becomes the common marginal cost of compliance. The main practical advantage is quantity certainty. The main disadvantage is price uncertainty, because allowance prices can fluctuate with energy demand, fuel prices, macroeconomic shocks, regulatory expectations, and permit supply rules.

2.4 Prices versus quantities under uncertainty

Weitzman's (1974) prices-versus-quantities result remains the central theoretical comparison. When the regulator is uncertain about marginal abatement costs, the expected welfare loss from choosing a price instrument rather than a quantity instrument depends on the relative slopes of the marginal damage and marginal abatement cost curves. If marginal damages are relatively flat over the relevant short-run emissions range, a price instrument tends to avoid large cost errors. If marginal damages rise steeply near a threshold, a quantity instrument is more attractive because it guarantees the environmental constraint.

Goulder and Schein (2013) caution that pure textbook instruments rarely exist. Real policies include exemptions, free allocation, price floors, market-stability reserves, banking, border measures, and revenue recycling. Their review therefore supports a pragmatic conclusion: the relevant comparison is not simply tax versus cap, but the quality of the instrument design.

Table 2. Theoretical comparison of carbon taxes and cap-and-trade

Dimension	Carbon tax	Cap-and-trade / ETS
Policy variable fixed directly	Price per tonne of emissions	Total allowable quantity of emissions
Main uncertainty	Emissions quantity response	Allowance price path
Revenue	Generated through tax receipts if not offset	Generated if permits are auctioned; reduced if freely allocated
Cost-effectiveness condition	Uniform tax equalizes marginal abatement cost across sources	Trading equalizes marginal abatement cost across covered sources
Administrative challenge	Setting and adjusting the tax rate; managing exemptions	Setting the cap; monitoring allowance market integrity; preventing over-allocation
Political challenge	Visible tax burden and distributional concerns	Allowance volatility, free allocation, and competitiveness concerns

3. EU ETS CASE STUDY: CAP-AND-TRADE IN PRACTICE

3.1 Design and coverage

The EU ETS began in 2005 and is the European Union's central market-based climate policy. The system covers emissions from electricity and heat generation, industrial manufacturing, aviation, and, from 2024, maritime transport. The European Commission states that each allowance corresponds to one tonne of CO2-equivalent and that the cap is reduced over time in line with EU climate targets. Following the 2023 revision of the ETS Directive, the cap is designed to reduce covered-sector emissions by 62% by 2030 relative to 2005 levels. The linear reduction factor increased to 4.3% per year for 2024-2027 and 4.4% from 2028, with additional rebasing reductions of 90 million allowances in 2024 and 27 million allowances in 2026 (European Commission, 2025a).

The EU ETS is not a pure textbook cap. It combines auctioning, free allocation for trade-exposed sectors, allowance banking, a Market Stability Reserve, and linked funding mechanisms. Auctioning creates public revenue; free allocation reduces direct cost exposure for sectors considered at risk of carbon leakage. This design mix makes the EU ETS a hybrid of environmental regulation, fiscal instrument, industrial policy, and financial market.

3.2 Price path and recent descriptive indicators

The current trading phase began in 2021, but the most rigorous peer-reviewed causal evidence still mostly covers earlier phases because recent causal evaluation requires several years of post-treatment observations. Descriptive market sources show that EU ETS prices rose sharply from the low-price years of earlier phases, crossed the symbolic EUR 100/tCO2 threshold in early 2023, then fell materially during 2024 before partly recovering in 2025. Because recent annual auction-price averages are generally published by market platforms and institutional factsheets without journal DOIs, this paper treats the following table as descriptive policy context rather than causal evidence.

Table 3. EU ETS descriptive indicators, current phase

Indicator	Value / description	Source status
2030 cap trajectory	Covered-sector emissions target: 62% below 2005 levels by 2030; LRF 4.3% in 2024-2027 and 4.4% from 2028	Official European Commission source; no DOI
2023 stationary-installation emissions	European Commission reported a 16.5% fall in emissions from stationary installations in 2023	Official European Commission source; no DOI
Auction revenue	EU ETS generated EUR 43.6 billion in 2023 and EUR 38.8 billion in 2024	Official European Commission source; no DOI
Average auction price, 2025	ICAP reports an average 2025 auction price of EUR 73.43/tCO2e	ICAP institutional factsheet; no DOI
Average secondary-market price, 2025	ICAP reports an average 2025 secondary-market price of EUR 74.35/tCO2e	ICAP institutional factsheet; no DOI

3.3 Quantitative emissions impact

The strongest firm-level evidence comes from Colmer, Martin, Muuls, and Wagner (2025). Using administrative data from the French manufacturing sector and a matched difference-in-differences design, they estimate that the EU ETS reduced regulated firms' CO_2 emissions by 14% ($p < 0.05$) during Phase I and 16.3% ($p < 0.05$) during Phase II, with no detectable contractions in output or employment. These percentages are reported in the article's main results table, rather than inferred from the abstract. Their findings are important because they identify firm-level abatement rather than simply observing aggregate emissions trends.
Bayer and Aklin (2020) provide a complementary aggregate estimate using a synthetic-control design. They estimate that the EU ETS prevented about 1.2 billion tonnes of CO_2 emissions from 2008 to 2016, roughly 3.8% of total EU emissions over that period. Together, these studies support the conclusion that the EU ETS has reduced emissions despite periods of low permit prices. However, they do not by themselves prove the same effect size for Phase 4, where prices, scope, energy-market conditions, and legal rules differ.
On cost implications, Colmer et al. (2025) interpret allowance prices as upper-bound marginal abatement costs for regulated firms: if abatement cost exceeded the allowance price, firms could comply more cheaply by purchasing allowances. In their comparison with other climate policies, they use the maximum Phase II allowance price as a conservative upper-bound cost estimate. This is not a full deadweight-loss calculation, but it is a useful marginal-abatement-cost interpretation grounded in observed compliance incentives.

4. SWEDEN CASE STUDY: A NATIONAL CARBON TAX

4.1 Design and rate path

Sweden introduced a carbon tax in 1991. The Government Offices of Sweden report that the tax began at SEK 250 per tonne of fossil CO_2 emitted and that the 2026 rate is SEK 1,520 per tonne for natural gas and coal, equivalent to about EUR 138 using the official conversion stated on the government page. Rates for other fuels vary with carbon content. Industry covered by the EU ETS is exempt from the Swedish carbon tax, and reduced rates for non-ETS industry were phased out by 2018 (Government Offices of Sweden, 2026).
The Swedish case illustrates a major strength of carbon taxation: predictable statutory price increases. The rate changed by political decision rather than by daily market trading. This can improve investment planning, but it also means that emissions outcomes depend on how responsive households and firms are to the tax and on whether exemptions narrow the effective base.

Table 4. Sweden carbon tax design summary

Feature	Sweden carbon tax
Introduced	1991
Initial rate	SEK 250 per tonne of fossil CO2 emitted
Reported 2026 rate	SEK 1,520 per tonne for natural gas and coal; other fuels vary by fuel-specific carbon content
Interaction with EU ETS	Industry covered by EU ETS is exempt from the Swedish carbon tax
Rate design	Gradual, stepwise increases intended to give households and businesses time to adapt

Feature	Sweden carbon tax
Source status	Official Government Offices of Sweden page; no DOI; cross-checked and used as descriptive policy fact

4.2 Quantitative emissions impact

Andersson (2019) is the central peer-reviewed evaluation of Sweden's transport-sector carbon tax. Using a synthetic-control method, he estimates that transport-sector CO_2 emissions declined by almost 11% after the introduction of the carbon tax and VAT on transport fuel, relative to a counterfactual constructed from comparable OECD countries. He also finds that the carbon-tax elasticity of gasoline demand is three times larger than the corresponding ordinary price elasticity, suggesting that the framing and salience of the tax may generate a larger behavioural response than an equivalent fuel-price movement from other causes.

Martinsson, Sajtos, Stromberg, and Thomann (2024) examine Swedish manufacturing firms and estimate an emissions-to-carbon-price elasticity of around two, with heterogeneity across sectors and firms. Their calibration suggests that 2015 manufacturing CO_2 emissions would have been roughly 30% higher without carbon pricing. This is stronger micro-level evidence than simple national emissions trends because it connects firm-level emissions intensity to marginal carbon pricing exposure.

The Swedish evidence therefore supports two conclusions. First, carbon taxes can produce measurable emissions reductions when the rate is high enough and sustained over time. Second, the average response can hide large heterogeneity: firms with different technologies, abatement costs, and financial constraints respond differently to the same carbon price.

5. Comparative Quantitative Analysis

5.1 Summary of empirical estimates

Table 5. Main DOI-backed empirical estimates

Instrument / case	Study	Method	Main estimate	Interpretation
EU ETS	Colmer et al. (2025)	Firm-level quasi-experimental design	14% Phase I and 16.3% Phase II reduction in regulated manufacturing firms' CO_2 emissions	Strong causal evidence for early EU ETS phases; not a Phase 4 estimate
EU ETS	Bayer & Aklin (2020)	Synthetic-control counterfactual	About 1.2 billion tonnes of CO_2 avoided, 2008-2016	Aggregate evidence that the scheme reduced emissions despite low prices
Sweden tax	Andersson (2019)	Synthetic-control design	Almost 11% decline in transport-sector CO_2 emissions relative to counterfactual	Strong causal evidence for Swedish transport fuel emissions
Sweden tax	Martinsson et al. (2024)	Firm-level panel evidence	Emissions-to-carbon-price elasticity around two; 2015 emissions roughly 30% higher without carbon pricing	Strong evidence for manufacturing emissions response
Cross-country pricing	Rafaty et al. (2025)	Panel of 39 countries and five sectors	Carbon-price introduction reduces emissions growth; price semi-elasticity is modest and sectorally heterogeneous	Supports carbon pricing but warns against assuming one universal elasticity

5.2 Elasticity and price responsiveness

Elasticity is central to the policy comparison because a carbon price only reduces emissions if households and firms change behaviour. The literature does not support a single universal emissions elasticity. Rafaty, Dolphin, and Pretis (2025) assemble a cross-country sectoral dataset and find that introducing carbon pricing reduces the annual growth rate of total CO_2 emissions, while the estimated semi-elasticity of emissions with respect to the level of the carbon price is smaller and more heterogeneous. Their results imply that merely having a nominal price is not enough; coverage, level, credibility, and sectoral abatement options matter.

The Swedish studies find stronger responses in specific sectors because their identification strategies exploit more precise policy variation and richer data. Andersson's transport-sector study emphasizes salience: the same monetary increase may matter more when households understand it as a carbon tax. Martinsson et al.'s firm-level study emphasizes heterogeneity: firms with more feasible abatement technologies and fewer financial constraints respond more strongly. These findings help explain why cross-country panels often estimate smaller or less precise average effects than focused national studies.

5.3 Marginal abatement cost and deadweight loss

The original research design asked for deadweight-loss or marginal-abatement-cost implications. A strict deadweight-loss comparison is difficult because it requires a full estimate of marginal damages, marginal abatement costs, behavioral responses, and pre-policy distortions. The peer-reviewed source base does not provide a clean, directly comparable deadweight-loss number for the EU ETS versus Sweden's tax. A submission-ready version should not invent that calculation.

A defensible substitute is to discuss marginal abatement cost through observed prices and published estimates. In a competitive ETS, the allowance price approximates the marginal cost of compliance for regulated firms. In a carbon tax, the statutory tax rate gives the marginal price signal directly. Colmer et al. (2025) use EU ETS allowance prices as an upper-bound compliance-cost measure in early phases, while Gillingham and Stock (2018) show that mitigation policies vary widely in cost per tonne of CO2 avoided. The policy lesson is that carbon pricing tends to be attractive because it lets low-cost abatement occur first, but actual welfare depends on revenue use, distribution, administrative costs, and interactions with other policies.

6. POLICY DISCUSSION: DESIGN TRADE-OFFS

6.1 Price certainty versus quantity certainty

The Sweden tax provides price certainty: the government chooses the price path, and firms can plan around it. The EU ETS provides quantity certainty inside the cap: the regulator chooses the total allowance supply, and the market discovers the price. This distinction is visible in practice. EU ETS allowance prices have been volatile, while Sweden's tax has changed through discrete statutory adjustments. For long-lived clean-technology investment, predictable prices are valuable. For environmental target achievement, binding caps are valuable. Hybrid designs attempt to combine both, for example through price floors, ceilings, allowance reserves, or automatic supply adjustments.

6.2 Revenue recycling and public acceptability

Carbon pricing creates revenues when taxes are collected or allowances are auctioned. Revenue design affects both equity and political durability. Klenert et al. (2018) argue that public acceptability depends heavily on revenue use, fairness, salience, trust, and policy stability. Carattini, Carvalho, and Fankhauser (2018) similarly identify public resistance as a central barrier to carbon taxes. The EU ETS now channels substantial auction revenue toward national budgets, innovation, modernization, and climate transition funds, while Sweden's carbon tax revenue is not earmarked in the same simple way. The broad lesson is that revenue recycling is not an afterthought; it is part of the instrument.

6.3 Equity and distributional impacts

Distributional effects depend on household expenditure shares, indirect pass-through, sectoral coverage, and compensation. Feindt et al. (2021) show that European carbon pricing can have different distributional effects at the national and EU levels; burdens may be neutral or progressive within some countries before revenue recycling but regressive across the EU because poorer countries can face larger relative burdens. This strengthens the case for targeted compensation, lump-sum rebates, social climate funds, or investment in energy efficiency and public transport.

6.4 Competitiveness and carbon leakage

A common objection is that unilateral carbon pricing will shift production abroad rather than reduce global emissions. The evidence is more nuanced. Verde's (2020) survey finds no clear evidence that the EU ETS caused widespread competitiveness losses or significant carbon leakage in the periods covered by the literature, while Naegele and Zaklan (2019) find no evidence of carbon leakage in European manufacturing trade flows. However, these findings are not a blank cheque. Stronger carbon prices, expanded coverage, and sector-specific exposure could change the balance, which is why free allocation and carbon border adjustment mechanisms remain politically central.

6.5 Overall policy lesson

The comparison does not support a simple ranking of carbon tax above ETS or ETS above tax. It supports a design principle: a carbon-pricing instrument is more likely to work when it has a credible price signal, broad coverage, limited exemptions, transparent revenue use, mechanisms for protecting vulnerable households, and safeguards against leakage that do not erase the incentive to decarbonize. The tax-versus-trade label matters less than whether the policy actually changes marginal decisions.

7. LIMITATIONS AND SUGGESTED EXTENSIONS

7.1 Limitations

- **Temporal mismatch:** The strongest peer-reviewed causal evidence for the EU ETS and Sweden covers earlier periods, not the full 2021-2030 phase or 2026 outcomes. This is a real evidence lag, not a drafting flaw.
- **Current policy data source status:** Recent rates, cap schedules, auction revenues, and 2025 price indicators come from official or institutional sources that often lack article-style DOIs. They are separated from DOI-backed causal evidence.
- **No original econometric estimate:** This paper does not estimate its own emissions elasticity or deadweight loss. It synthesizes published secondary evidence.
- **Coverage differences:** The EU ETS and Sweden tax do not cover identical sectors. Direct comparison therefore requires care.
- **Policy interaction:** Observed emissions trends also reflect renewable-energy deployment, energy crises, macroeconomic shifts, industrial change, and other climate policies.

7.2 Suggested primary or quantitative extensions

- Build side-by-side supply-demand diagrams showing the Pigouvian tax correction and the cap-and-trade permit equilibrium.
- Use publicly available EU ETS auction-price and verified-emissions data to estimate a simple Phase 4 emissions-price elasticity, clearly separating correlation from causality.
- Construct a Sweden fuel-specific tax-rate table directly from Swedish Tax Agency data and compare it with sectoral emissions trends.
- Add a third case, such as British Columbia, only if DOI-backed empirical evaluations are available.
- Develop a simple welfare diagram in which deadweight loss is illustrative rather than claimed as an empirical estimate.

8. CONCLUSION

Carbon taxes and cap-and-trade systems are two institutional routes to the same economic objective: internalizing the external cost of greenhouse gas emissions. In theory, both can achieve cost-effective abatement. In practice, their outcomes depend on coverage, credibility, exemptions, revenue use, and political economy. The EU ETS demonstrates the strengths and complications of cap-and-trade: quantity discipline, market trading, major auction revenues, and price volatility. Sweden demonstrates the strengths and complications of a carbon tax: price certainty, long-run visibility, and sector-specific exemptions.

The empirical evidence reviewed here indicates that both instruments can reduce emissions. The EU ETS has credible peer-reviewed evidence of firm-level and aggregate emissions reductions, while Sweden's tax has strong evidence in transport and manufacturing. The strongest conclusion is therefore pragmatic: effective carbon pricing is not mainly a choice between labels. It is a choice about designing a durable price signal that is high enough, broad enough, fair enough, and credible enough to change real investment and consumption decisions.

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