

Economic Impacts of CBAM for Sweden and Beyond

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Knut Einar Rosendahl

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Knut Einar Rosendahl

SNS

Box 5629, SE-114 86 Stockholm

Phone: +46 8 507 025 00

info@sns.se www.sns.se

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Preface

Climate policy is becoming increasingly intertwined with questions of industrial competitiveness and international trade. As the EU tightens its climate policy, European industries face carbon costs that many of their competitors outside the EU do not face to the same extent, raising concerns about competitiveness and carbon leakage. At the same time, the EU is changing how it addresses these concerns, gradually replacing free allocation of emissions allowances to emissions-intensive and trade-exposed industries with the Carbon Border Adjustment Mechanism (CBAM), which puts a carbon price on certain imports into the EU.

Against this changing policy landscape, Christoph Böhringer, Professor of Economics at the University of Oldenburg, and Knut Einar Rosendahl, Professor of Economics at the Norwegian University of Life Sciences, seek to provide a better understanding of the trade-offs between different approaches to addressing carbon leakage and competitiveness concerns arising from carbon pricing. Using data on global production, emissions and trade together with a multi-sector, multi-region model of the world economy, they compare free allocation with CBAM-style carbon tariffs and analyse the effects on Swedish emissions-intensive and trade-exposed industries, the Swedish economy as a whole and global carbon leakage. The report also examines how the results change when carbon tariffs cover a broader range of emissions than under current CBAM rules and when they are combined with rebates for exports.

The report is part of SNS Climate, a three-year research project that examines the conditions for effective climate policy in a changing

economic and geopolitical environment. The project explores the conditions for the climate transition and how Sweden and the EU can contribute to reducing global emissions, with the interplay between emissions reductions, economic competitiveness and security of supply as a central theme. It brings together researchers, companies, public authorities and other organisations to contribute research-based knowledge and promote dialogue on climate policy.

The research project is made possible through contributions from the reference group that follows the project. The group consists of Atlas Copco Group, Ellevio, the Swedish Energy Agency, Ministry of Finance, Flower, the Swedish Research Council for Sustainable Development (Formas), IKEM – Innovation and Chemical Industries in Sweden, the Knowledge Foundation, Ministry of Climate and Enterprise, LKAB, the Federation of Swedish Farmers (LRF), Nordea, SCA, Skandia, Skanska, Skellefteå Municipality, Svenska kraftnät, the Swedish Association of Graduate Engineers, SYSAV, Södra, Technology Industries of Sweden (Teknikföretagen), the Swedish Confederation of Professional Employees (TCO), Uniper, Vattenfall, and WWF Sweden.

Maria Pettersson, Professor of Law at Luleå University of Technology, has represented the SNS Scientific Council in the reference group for this report.

Patrik Söderholm, Professor of Economics at Luleå University of Technology, reviewed an earlier draft of the report at an academic seminar and provided valuable and constructive comments.

SNS would like to thank all those mentioned above for their valuable comments and contributions. The authors are solely responsible for the analysis and conclusions presented in the report. SNS as an organisation does not take a position on these. SNS initiates and presents research-based and policy-relevant analyses of key societal issues.

It is our hope that the report will provide a useful basis for discussions about the implications of different approaches to addressing carbon leakage and industrial competitiveness in European climate policy.

Stockholm, October 2026

Charlotte Paulie

Research Director, SNS

Summary

The EU is in the midst of a major redesign of how it protects its emissions-intensive and trade-exposed industries as part of an increasingly stringent climate policy to meet its greenhouse gas emissions reductions commitments under the Paris Agreement. This shift aims to create a level playing field with competing industries abroad that are not subject to similar emissions restrictions. Until now, emissions-intensive and trade-exposed companies covered by the EU Emissions Trading System (EU ETS) have received most of their emissions allowances “free of charge”, by reimbursing the costs of these allowances indirectly as production subsidies. Between 2026 and 2034¹, this protection will be gradually phased out and replaced by the so-called Carbon Border Adjustment Mechanism (CBAM). Under CBAM, importers of emissions-intensive goods such as steel, cement, aluminium or fertilizers produced outside the EU pay a charge based on their embedded emissions and the difference between the EU carbon price and any carbon price already paid in the country of origin.

Both the current system of free allowances and the new CBAM regulations seek to address the same concerns: an excessive loss of competitiveness among European emissions-intensive and trade-exposed industries and counterproductive carbon leakage – that is, emissions reductions in Europe being partly offset by higher emissions in

1. In July 2026, the European Commission proposed slowing the phase-out of free allocation for sectors covered by CBAM, with some free allocation remaining until 2037 and full phase-out from 2038. At the time of writing, the proposal has not yet been adopted.

countries with less stringent climate policies. However, they protect industry in different ways: free allocation supports European production regardless of whether the goods are sold domestically or abroad, while CBAM primarily protects producers against competition from imports on the domestic European market. The effects of this shift will differ across Europe, depending on countries' industrial structure, the emissions intensity of their production and their exposure to international trade.

The shift from free allocation to CBAM raises several questions. What does it mean for the industries directly affected? What does it mean for Sweden and other European economies overall? And which policy is most effective in reducing carbon leakage from a global perspective? This report examines these questions based on simulations with a multi-sector, multi-region model of the world economy. The ex-ante analysis provides a consistent framework for assessing how proposed regulations may affect the economy relative to the status quo, but should not be read as a forecast of future outcomes.

Key findings

Carbon tariffs protect Swedish emissions-intensive and trade-exposed industry less than free allocation. Swedish emissions-intensive and trade-exposed production is 1.3% lower under carbon tariffs, compared with 0.6% under free allocation, relative to a hypothetical situation without climate policy. The main reason is Sweden's export orientation: free allocation supports production sold both within and outside Europe, whereas carbon tariffs protect producers mainly on the European market.

What is better for protected industries is not necessarily better for Sweden as a whole. For Sweden as a whole, free allocation comes with an estimated cost equivalent to around 0.05% of real income relative to a hypothetical situation without climate policy. In the model, that cost falls to approximately zero under carbon tariffs. Free allocation provides stronger protection for emissions-intensive and trade-exposed production, but it also effectively subsidizes that production, which can distort the allocation of resources and impose costs on the wider economy.

Carbon tariffs reduce carbon leakage only slightly more effectively than free allocation of emissions allowances. With carbon pricing alone, 28.5% of the emissions reductions achieved in Europe are offset by higher emissions elsewhere in the model. Free allocation reduces this leakage rate to 16.9%, while carbon tariffs reduce it slightly further, to 16.0%. The analysis also shows that addressing exports could make a substantial difference: adding rebates for the carbon costs faced by European exporters reduces the leakage rate further, to 10.6%.

No single policy dominates across multiple dimensions. Free allocation provides stronger protection for emissions-intensive and trade-exposed industry, while carbon tariffs perform better for the Swedish and European economies as a whole. From a global perspective, however, carbon tariffs achieve the same emissions reduction at a slightly higher global cost than free allocation. Combining carbon tariffs with export rebates performs best globally in the simulations, although the differences in global costs are small.

What this means for policy

The results highlight two design questions that are particularly important for Sweden.

What emissions should CBAM cover? Sweden's emissions-intensive and trade-exposed production has lower emissions intensity than that of most trading partners, particularly because Swedish electricity generates very low carbon emissions. In the analysis, when carbon tariffs cover not only direct emissions from production (scope 1), but also indirect emissions from the electricity used in production (scope 2), the decline in EITE production under carbon tariffs falls from 1.3% to 1.0%. A more inclusive emissions coverage therefore improves Sweden's relative position, although free allocation still provides stronger production protection.

What about exports? CBAM addresses competitive disadvantages on the European market but does not protect European producers competing in markets outside Europe. Adding export rebates largely closes this gap in the simulations: Swedish emissions-intensive and trade-exposed production falls by 0.7%, compared with 0.6% under free allocation. It also reduces carbon leakage further and marginally

improves global cost-effectiveness. Export rebates could, however, be expected to raise legal and political questions.

The central policy trade-off is therefore not simply between more or less protection. Different instruments protect different markets and produce different effects on industry, the wider economy and global emissions. What provides the strongest protection for Swedish emissions-intensive and trade-exposed industry is not necessarily what produces the best outcome for Sweden as a whole.

Glossary

Term	What it means
EU ETS	The EU's Emissions Trading System: a cap on total CO ₂ emissions from industry and power, with tradable emissions allowances. The allowance price is often referred to as the EU's carbon price (e.g. about \$75/ton in 2023).
EITE industries	Emissions-intensive and trade-exposed industries — steel, chemicals, paper, minerals and similar. They often emit a lot per unit of output and compete internationally, so a unilateral carbon price can have larger adverse impacts.
Carbon leakage	When emissions reduced in one region due to emissions regulations partly reappear abroad — because production moves to unregulated countries, or because lower fuel demand by the regulated region makes fossil energy cheaper elsewhere.
Leakage rate	Emissions increase abroad as a percentage of the emissions cut at home. For example, a rate of 30% means that for every 100 tons cut in Europe, 30 tons appear elsewhere.
Free allocation	Emissions allowances allocated to industry free of charge. In the model, the EU system of free allocation is represented as an output-based rebate, which effectively acts as a production subsidy and helps protect competitiveness.
CBAM / carbon tariff	Carbon Border Adjustment Mechanism – the border carbon adjustment legislated by the EU: importers pay for the CO ₂ embedded in goods entering the EU, at the EU carbon price. Phased in 2026–2034, as free allocation is phased out.
Border carbon adjustment	CBAM plus rebates of carbon costs for exports. Industry is thus protected not only via carbon tariffs in the domestic market but also via carbon rebates in export markets.
Scope 1 / 2 / 3	Three layers of a product's emissions: from the factory itself (1), from purchased electricity (2), and from all other inputs along the supply chain (3). Today's CBAM mainly covers scope 1.
MRIO	Multi-region input-output: a global accounting measure of who buys what from whom, by industry and country. Used here to calculate the emissions intensities and trade exposure of industries.
CGE model	Computable general equilibrium model: a simulation model of the economy computing the responses by firms and households to prices. Often used in ex-ante analysis to assess the economy-wide impact of changes in policy regulations.
Armington trade elasticity	A standard metric to measure how easily buyers can switch between domestic and foreign versions of the same good. High elasticity implies stiff international competition as consumers can more easily switch away from higher priced varieties of the same good.

I. Introduction

Since CO₂ emissions are a global externality, reducing emissions at lowest possible cost would require carbon prices to be aligned across countries. This has been the most important and unequivocal recommendation that climate economists have made in recent decades, following the logic of the so-called first welfare theorem: that competitive markets with a uniform price achieve a cost-effective allocation. In practice, however, climate policies differ widely in both ambition and design, reflecting incentives for free-riding, differences in national circumstances and views on how the costs of climate action should be shared.

In principle, questions about how the costs of climate action should be shared could be separated from the question of where emissions should be reduced. Burden sharing could be addressed by deciding how emission rights – which allow countries to emit a certain amount of CO₂ – are distributed initially across countries. If these rights can then be traded internationally, emissions can be reduced wherever it is cheapest to do so. In economic theory, this separation of equity from efficiency is captured by the so-called second welfare theorem.

The Paris Agreement, which constitutes the current international framework for limiting climate change, does not make this separation. Instead, each country sets its own Nationally Determined Contribution (NDC) as a politically negotiated compromise between what is cost-effective and what is seen as fair domestically and internationally. Cost-effectiveness (“abate where it is cheapest”) and burden sharing (“who should bear how much of the abatement cost”) are therefore addressed together rather than separately.

Current international climate policy is characterized by fragmented emissions pricing: only a few countries have implemented strict CO₂ pricing, while most have no or only very lenient pricing in place. Figure 1 provides an overview of CO₂ prices in a selection of regional emissions trading systems (ETS) and CO₂ taxes across countries in 2026.²

Differences in carbon prices across countries have two important consequences. First, they increase the global cost of reducing emissions, because emissions may be reduced in high-price countries even when cheaper abatement opportunities exist elsewhere. Second, they can cause carbon leakage: emissions reductions in countries with stringent climate policies may be partly offset by higher emissions elsewhere, undermining the global effectiveness of unilateral climate policy measures. Carbon leakage occurs mainly through two channels, both driven by changes in international prices. First, the so-called energy/fossil fuel market channel: reduced demand for fossil fuels in regulated regions can lower global energy prices. This makes carbon-intensive fossil energy cheaper elsewhere, encouraging higher fossil fuel consumption and increasing emissions in unregulated regions. Second, there is the so-called competitiveness channel: emissions-intensive and trade-exposed industries in countries with strict carbon policies face a cost increase which reduces their competitiveness in domestic and export markets leading to more production and emissions by less strictly regulated competitors abroad. Figure 2 illustrates the two major channels for carbon leakage for the case of unilateral carbon pricing in Europe.

The bulk of (ex-ante) model-based simulation studies on carbon leakage estimates a range for the leakage rate of 5–30% depending on the climate policy design such as the stringency and regional coverage of unilateral emissions pricing as well as the assumptions e.g. on market structure or time horizon implemented in the model (see e.g. Böhringer et al. 2012, 2022, Branger and Quirion 2014, Teusch et al. 2024). A leakage rate of 30% implies that for each 100 tons of CO₂ emissions reduction in the regulated jurisdiction, 30 tons of reduced emissions would be nullified by emissions increases outside that jurisdiction.

The public debate on the appropriate design of unilateral climate

2. <https://carbonpricingdashboard.worldbank.org/compliance/price>

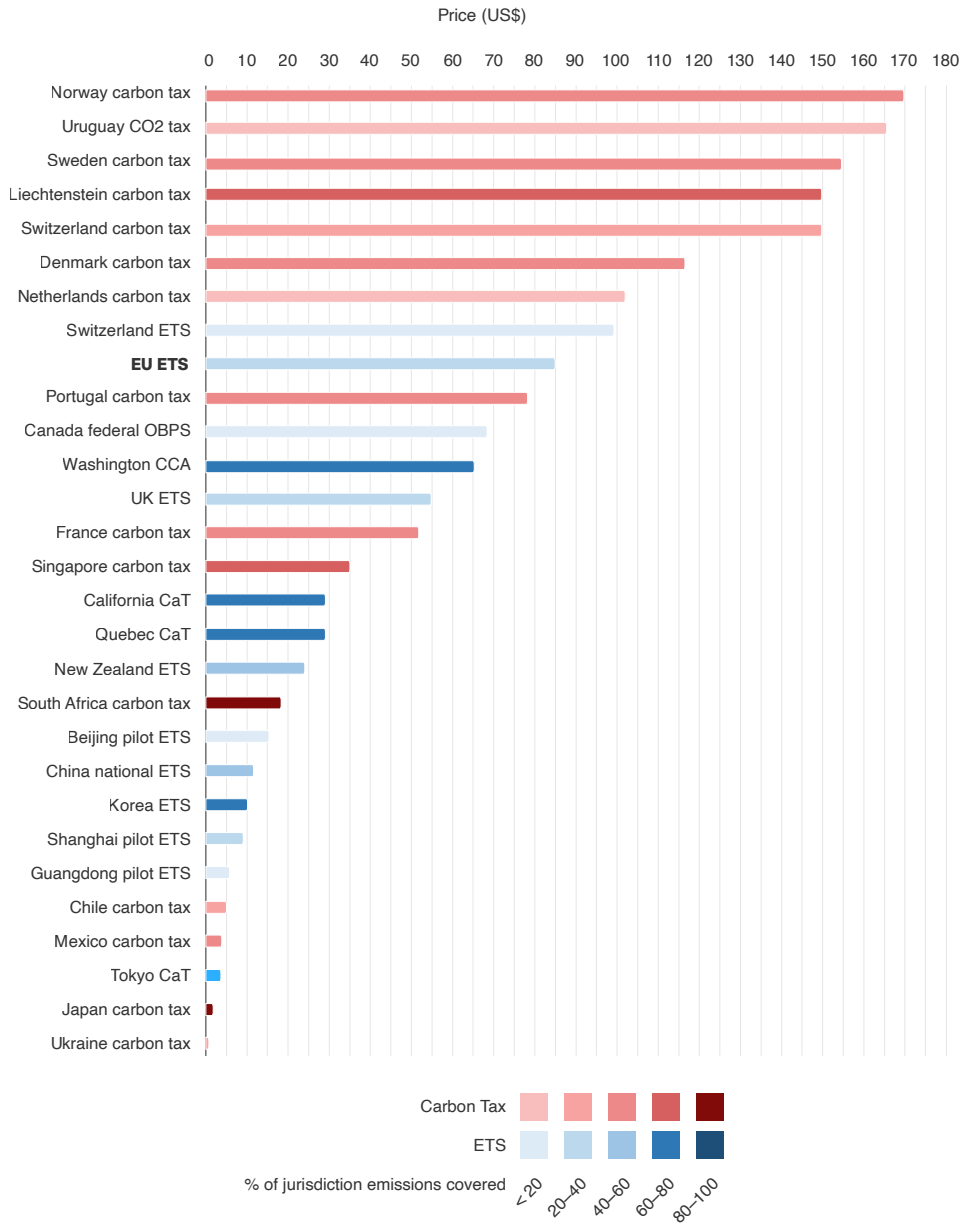
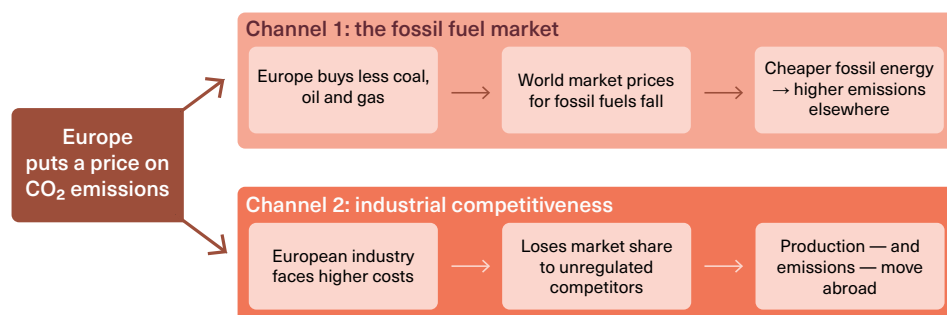
Figure 1. CO₂ prices in different jurisdictions (ETS and carbon taxes) in 2026 (USD/tCO₂e).

Figure 2. Important channels for carbon leakage.

policy is dominated by concerns on competitiveness losses for domestically regulated industries with its implications for carbon leakage through the competitiveness channel. This is especially the case in high-ambition regions, such as the EU, which have committed to decarbonizing their economies by mid-century, in line with the Paris Agreement’s goal of limiting global warming to well below 2°C above pre-industrial levels.

A central concern for policymakers is that emissions-intensive and trade-exposed (EITE) industries such as steel, cement and chemicals face higher costs than competitors in countries with lower carbon pricing. This can lead to excessive competitiveness losses and carbon leakage, as production and emissions shift towards countries with less stringent climate policies, reducing the global emissions reductions achieved by unilateral climate policy.

High-ambition jurisdictions – especially the European Union – have long sought to protect EITE industries from excessive competitiveness losses and counterproductive carbon leakage using free allocation of emissions allowances based on production volumes. In economic terms, this can be characterized as an output-based rebate. This is indeed the case in the EU Emissions Trading System (EU ETS), where free allocation is proportional to recent production levels. While keeping incentives for reducing emissions on the input side, free allocation effectively acts as a production subsidy. Because the number of

allowances increases with a firm's output, it lowers the marginal cost of production, thereby reducing competitiveness losses of unilateral carbon pricing and thus carbon leakage. One drawback of granting free allowances to EITE goods is that it tends to lead to excessive domestic consumption of these goods, which in turn restrains (desirable as cost-effective) substitution for less emissions-intensive goods. Free allocation thus blends efficiency on the input side with protection on the output side, rather than applying the full carbon price uniformly across the economy. If allocations are too generous, the instrument also carries the risk of generating windfall profits.

For this reason, the EU has more recently been exploring alternative approaches. Specifically, the EU plans to gradually replace free allocation with a Carbon Border Adjustment Mechanism (CBAM), under which importers of carbon-intensive goods – initially from sectors such as steel, cement, aluminium, or fertilizers – must purchase certificates reflecting the embedded emissions, at the prevailing CO₂ price of the EU ETS. This shifts the focus of protection from subsidizing overall domestic production (through free allowances) to aligning carbon costs at the border, so that EU producers and foreign competitors face comparable carbon pricing. The regulatory transition will take place over the next decade: free allocation will be phased out gradually from 2026 to 2034³, while CBAM levies will be increased. Both free allocation and CBAM are complementary measures aimed at correcting excessive competitiveness losses of domestic EITE industries and counteracting carbon leakage. Yet it is not clear a priori whether individual EITE industries will actually be better off under CBAM, how the regulatory change will affect the macroeconomic performance of EU Member States, and whether the EU CBAM will strengthen or weaken the global cost-effectiveness of ambitious unilateral EU emissions pricing compared to the previous regulatory practice of free allocation for EITE industries.

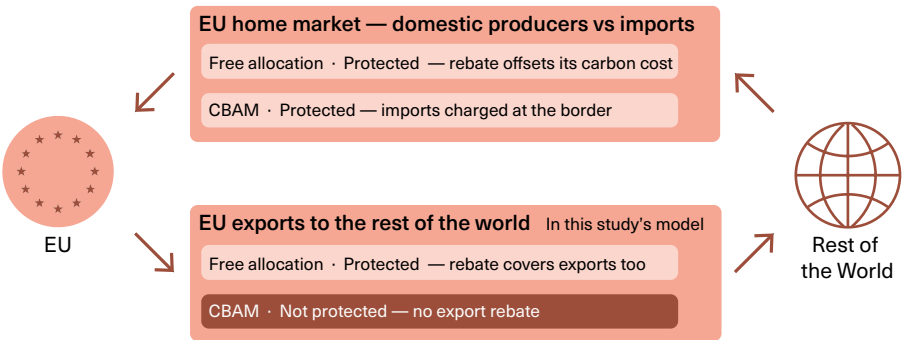
These issues are particularly relevant for EU Member States such as Sweden, the economy of which is characterized by a relatively large

3. In July 2026, the European Commission proposed slowing down the phase-out of free allocation for sectors covered by CBAM, with some free allocation remaining until 2037 and full phase-out to be concluded by 2038. At the time of writing, the proposal has not yet been adopted.

share of EITE industries (such as steel, pulp and paper, and chemicals) with a relatively strong export orientation (including exports to outside the EU). CBAM levels the playing field inside the EU market by charging importers for embedded carbon, but it does not protect exports to third countries, since it does not provide a rebate on carbon costs on EITE exports. Because CBAM also removes the free allocation subsidy, emissions-intensive industries in Europe that are export-oriented towards non-European countries are particularly affected by this policy shift. Under CBAM, Swedish firms could face higher effective carbon costs in global markets, where competitors are not subject to EU carbon pricing.

Figure 3 illustrates how free allocation and CBAM operate in both domestic and export markets: while free allocation, as an implicit output subsidy, cushions cost increases in both markets, CBAM, without export rebates, ensures a level playing field only in the domestic market.

Figure 3. The protective mechanisms of free allocation and CBAM.



Against this background, we examine the potential impacts of the shift from free allocation to CBAM in EU climate policy on the Swedish economy compared to the rest of Europe. We start with a multi-region input-output (MRIO) analysis to identify differences in

emissions intensities and trade exposure for EITE commodities as key determinants for the competitiveness effects and leakage potential caused by asymmetric climate policies. We then apply a multi-sector multi-region computable general equilibrium (CGE) model of the global economy to simulate the effects of the shift in EU climate policy from free allocation to CBAM with regard to EITE industries, macroeconomic performance, and global cost-effectiveness of unilateral emissions pricing. Specifically, we draw on the CGE analysis to gain insights into three policy-relevant questions:

- › How will CBAM affect the performance of EU EITE industries compared with the current free allocation of emissions allowances?
- › Does the shift to CBAM strengthen or weaken global cost-effectiveness of unilateral EU emissions pricing?
- › What are the welfare implications, measured as a change in real disposable income?

Due to the limited sectoral granularity of the MRIO data that provide the empirical basis for our analysis, we refer to EITE sectors and products that are covered by the EU ETS and CBAM in a more aggregate manner. While the MRIO structure of our analytical framework captures indirect effects across industries and regions, our level of disaggregation does not accommodate a more detailed assessment of downstream industries further along industrial value chains. This issue may become increasingly important in future discussions regarding a possible expansion of CBAM towards processed and downstream products, where competitiveness effects may propagate through industrial supply chains in more complex ways.

Our quantitative analysis of the effects of CBAM on the Swedish economy takes into account international spillover and feedback effects via bilateral trade links to other countries which are central to the discussion on industrial competitiveness. So far, there are only a few recent studies on the potential effects of CBAM for Sweden that, however, have a narrower focus. Konjunkturinstitutet has applied the CGE model EMEC to analyse the effects of transitioning from free allocation to CBAM (Konjunkturinstitutet 2022) and an extension of CBAM to include a wider range of products (Konjunkturinstitutet 2025). EMEC is a single-country model of the Swedish economy,

which neither features bilateral trade links with other EU countries nor the rest of the world. Fischer-Bogason et al. (2026) analyse some impacts of implementing CBAM on the three Nordic EU countries without simulating impact for Sweden in an economy-wide framework.

The remainder of this report is organized as follows. Section 2 presents the MRIO calculation of base-year emissions intensities and trade patterns for EITE industries. Section 3 discusses the economic impact of the forthcoming regulatory shift in EU climate policy from free allocation to CBAM. Section 4 presents concluding remarks.

2. What is at stake: insights from multi-region input-output analysis

For understanding how CBAM may affect the Swedish economy, two characteristics are particularly important: how emissions-intensive Swedish industry is relative to its competitors, and how exposed it is to international trade. A stock-taking of initial economic flows based on empirical data is an essential prerequisite for assessing the effects of policies such as free allocation and CBAM. It provides a quantitative characterization of existing production, consumption and trade structures with associated emissions, thereby identifying which EU industries are most exposed to carbon pricing and international competition. This empirical benchmark anchors subsequent simulation analysis of observed economic relationships and makes it possible to identify changes in production, consumption, trade, and associated emissions induced by policy interventions. In this way, the stock taking of initial data provides both the economic rationale for targeting protective measures and the benchmark against which their effectiveness and broader economic and environmental consequences can be measured and evaluated.

Multi-region input-output analysis (MRIO) is the standard economic method for tracing how production, consumption, and trade are interconnected across industries and countries, and for attributing associated environmental impacts—such as CO₂ emissions—to their ultimate sources and users along global supply chains. The data input to MRIO analysis is provided by MRIO tables recording economic patterns of production, consumption, investment, and trade, with detailed information on inter-industry transactions between sectors and countries (i.e., who buys inputs from whom in each sector and region).

The vulnerability of EITE industries to carbon pricing – and thus the risk of carbon leakage – is determined by two key factors: emissions intensity and trade exposure. The emissions intensity captures how much emissions are generated per unit (value) of output – the higher the emissions intensity, the larger the cost increase when a carbon price is applied. Trade exposure is an indicator of the competitive pressure that an industry faces. Export exposure is typically measured by export intensity, i.e., the ratio of exports to domestic production. The higher this ratio, the more an industry depends on supplying international markets. Similarly, domestic exposure, which captures competition in domestic markets, is typically measured as the share of imports over domestic demand. The higher this import penetration is, the more domestic firms compete with imports.⁴ In both markets, the ability to pass on additional costs, such as carbon prices, depends on the extent to which the domestically produced variant can be substituted by competing foreign goods (measured typically by trade elasticities).

As previously mentioned, the distortions of competitiveness resulting from unilateral emissions pricing lead to an excessive loss of competitiveness for EITE industries in regulated countries, since competing industries in other countries do not face a similar cost premium. Hence, domestic regulated industries will lose market shares on both the domestic and export markets as their products become relatively more expensive compared to those of their competitors.

2.1 MRIO data

For our analysis, we use MRIO data provided by the Global Trade Analysis Project (GTAP). GTAP is a research consortium founded in 1992 that provides the economic community with a global economic dataset for quantitative analyses of economic issues. The GTAP data provide input-output and final demand transactions within a globally consistent set of national accounts. The latest GTAP release (GTAP12) from February 2026 contains detailed accounts of production, con-

4. The EU combines both dimensions into a single indicator for trade exposure (the ratio of (Imports + Exports) over (Domestic production + Imports)) to identify EITE sectors at risk of carbon leakage that are eligible for protective measures such as free allocation or CBAM.

sumption, and bilateral trade flows for the base year 2023 for 145 individual countries and 18 aggregate regions (Aguiar et al. 2025). The database features detailed breakdowns of CO₂ emissions from the combustion of fossil fuels as well as process CO₂ emissions by sector and region. GTAP also includes estimates for elasticities, i.e., parameters that capture how strongly producers and consumers respond to changes in prices and income. These include trade elasticities, which capture how readily buyers switch between similar goods from different regions when relative prices change, substitution elasticities, which capture to what degree inputs and goods are swapped for one another in production and consumption, and income elasticities, which capture how demand for different goods changes as incomes rise. Together, these parameters are key drivers of supply and demand responses in the CGE analysis.

We aggregate the GTAP database to focus on the sectors and regions that are central to our quantitative impact assessment. All original primary and secondary energy carriers (coal, gas, crude oil, refined oil products, and electricity) in GTAP are retained in the aggregated dataset to account for inter-fuel substitution possibilities. Since we are interested in the impact of EU climate policy changes on EITE industries, we keep all individual sectors of the GTAP dataset that are covered by the EU ETS and are expected to be more significantly affected by the switch in protective measures from free allocation to CBAM: chemical products; iron and steel; non-ferrous metals; non-metallic minerals; paper, pulp and printing; rubber and plastic products; metal products; other mining extraction; air transport.⁵ The remaining sectors except for water transport and other (mainly road) transport are attributed to three larger categories, namely agriculture, manufacturing, and services. At the regional level, we focus on Sweden as the EU country of our primary interest while – for the sake of compactness – we group the remaining EU Member States into a “Rest of Europe”. Note that this composite also includes Norway, Switzerland, the rest of EFTA (Iceland and Liechtenstein), and the United Kingdom –

5. Several specific industries such as cement or fertilizers which are targeted by the EU CBAM are not explicitly represented in the GTAP12 dataset but subsumed in composite sectors such as non-metallic minerals (includes cement) or chemical products (includes fertilizer).

countries that are closely linked to the EU through a single market (EEA – European Economic Area) or bilateral trade agreements, have very similar stringencies in emissions pricing, and are likely to adapt to changes in EU climate policy regulations, such as the replacement of output-based rebates with CBAM. We furthermore consider the USA, China and the “Rest of OECD” as key trading partners while all other countries and regions in the GTAP12 dataset are aggregated into the “Rest of the World”. Table I summarizes the aggregation of sectors and regions underlying our quantitative impact assessment.

The GTAP data can be used to calculate emissions intensities and trade intensities across sectors and regions. These serve as the starting point for assessing the potential impacts of carbon pricing, as well as the potential effects of protective measures such as free allocation or CBAM.

Table 1. Sectors and regions in the composite dataset.

Primary and secondary energy carriers	Other composite macroeconomic sectors
Coal (mining)	Water transport
Gas (extraction and distribution)	Other transport
Crude oil	Agriculture
Oil (refined oil products)*	Manufacturing
Electricity (incl. heat)	Services
Emissions-intensive and trade-exposed goods (EITE)	Countries with emissions pricing
Chemicals	Sweden
Iron and steel	Rest of Europe**
Non-ferrous metals	
Non-metallic minerals	Countries without emissions pricing
Paper, pulp and printing	USA
Rubber and plastic	Rest of OECD
Metal products	China
Other mining (extraction)	Rest of the World
Air transport	

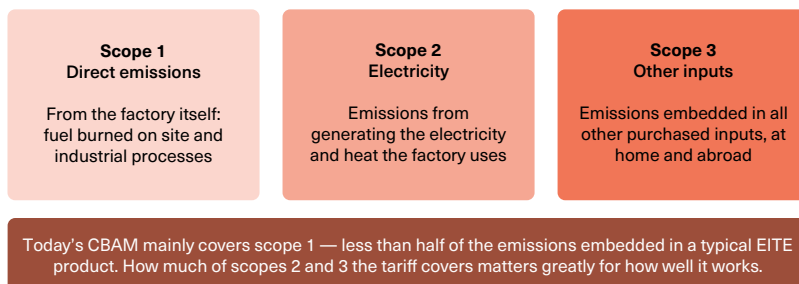
* Refined oil products are also classified as EITE goods

** Remaining 26 EU countries, Norway, Switzerland, United Kingdom, Rest of EFTA

2.2 Emissions intensities across industries and regions

Carbon border adjustment proposals differ in which emissions they include when calculating the carbon content of traded goods.⁶ Using the terminology applied in the EU CBAM, emissions can be divided into three categories: scope 1 covers emissions released directly during production, for example from burning fossil fuels or from industrial processes; scope 2 covers emissions associated with the electricity and heat used in production; and scope 3 covers emissions associated with other inputs used along the supply chain. Under the current EU CBAM regulation, the charge is based mainly on emissions released directly during the production of imported goods (scope 1). For a few sectors and products such as cement and fertilizers, indirect emissions from electricity (scope 2) are included as well, while the scope could be further expanded in the future to include imported indirect emissions from other intermediate inputs (scope 3). The three categories (scopes) of emissions are shown in Figure 4.

Figure 4. Categorization of CO₂ emissions.



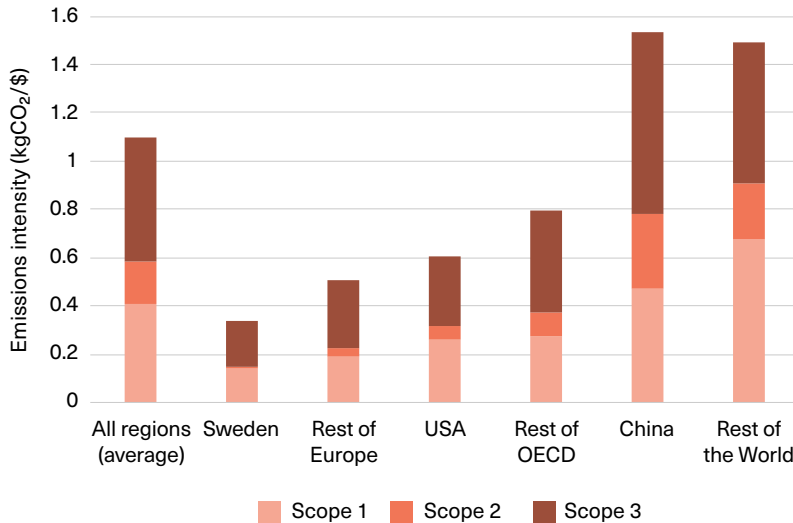
6. Note that we use the more informal and intuitive term “carbon tariffs” instead of border carbon taxes or border carbon adjustments on imports, which are preferred by economists or lawyers since (i) a tariff is traditionally a customs duty primarily aimed at trade protection or revenue raising and (ii) border carbon adjustment is designed (at least officially) to mirror domestic carbon pricing and prevent carbon leakage.

Figure 5 shows the region-specific CO₂ emissions intensities together with the global mean for the average of EITE production (measured in kilograms of CO₂ emitted per dollar of production value). The total emissions intensity is parsed into direct emissions from fuel combustion and/or industrial processes (scope 1), indirect (average) emissions from electricity inputs (scope 2), and indirect emissions embedded in all other intermediates used in production (scope 3).

The average carbon intensity in EITE production is by far the lowest for Sweden, followed by the Rest of Europe, the United States and the regional composite of the Rest of OECD countries – all of which are below the global mean – while China and the Rest of the World are above. This ranking holds true both in total and for each of the three scopes.

The decomposition of total emissions intensities into scope 1, scope 2, and scope 3 shows that direct emissions from combustion and industrial processes (i.e., scope 1) account for less than half of total emissions. Indirect emissions from electricity play virtually no role in

Figure 5. Average carbon intensities of EITE products by region (kg CO₂/\$).



Sweden as electricity there is largely CO₂-free due to the predominant generation from hydro and nuclear, whereas these scope 2 emissions are particularly high in China due to the widespread use of coal-fired power plants.⁷ Scope 3 emissions, i.e. indirect emissions from intermediate inputs other than electricity – both from domestic and imported sources – are substantial and make it clear that the impact of unilateral carbon pricing on competitiveness as well as the impact of complementary second-best measures such as CBAM can depend crucially on whether the total carbon footprint is taken into account, i.e., including scope 3 emissions in addition to scope 1 and scope 2 emissions.

Figure 6 provides a more detailed overview of the differences in carbon intensity across the ten individual EITE sectors identified in the GTAP database (all scaled on the y-axis to a maximum of 3.5 kg CO₂/\$ for better comparability). The average EITE intensities shown in Figure 5 mask considerable heterogeneity in the level and composition of carbon intensities across individual EITE goods – differences in the average carbon intensities by region can be attributed to both differences in the product-specific carbon intensity and differences in the production mix across regions.

The regional ranking of emissions intensities for individual goods remains largely stable and corresponds to the ranking of the average EITE product, with Sweden (in particular) and the Rest of Europe having the lowest emissions intensities, while the United States and the Rest of OECD countries are in the middle of the pack, and China together with the Rest of the World are at the top.

Among EITE products, iron and steel and non-metallic minerals are by far the most carbon-intensive, followed by air transport, non-ferrous metals, chemicals, oil, and then at the lower end, extraction, paper, pulp and printing, as well as rubber and plastics. Scope 1 emissions dominate for air transport and non-metallic minerals, while scope 3 emissions account for the larger share in chemicals, oil, non-ferrous metals, paper, pulp and printing, as well as rubber and plastics. The relative importance of scope 2 emissions clearly depends on the electricity-intensity of production and the carbon-intensity of power gen-

7. Electricity is only traded to a limited extent across borders such that intermediate electricity use predominantly stems from domestic power generation. This is especially the case for larger countries or regions.

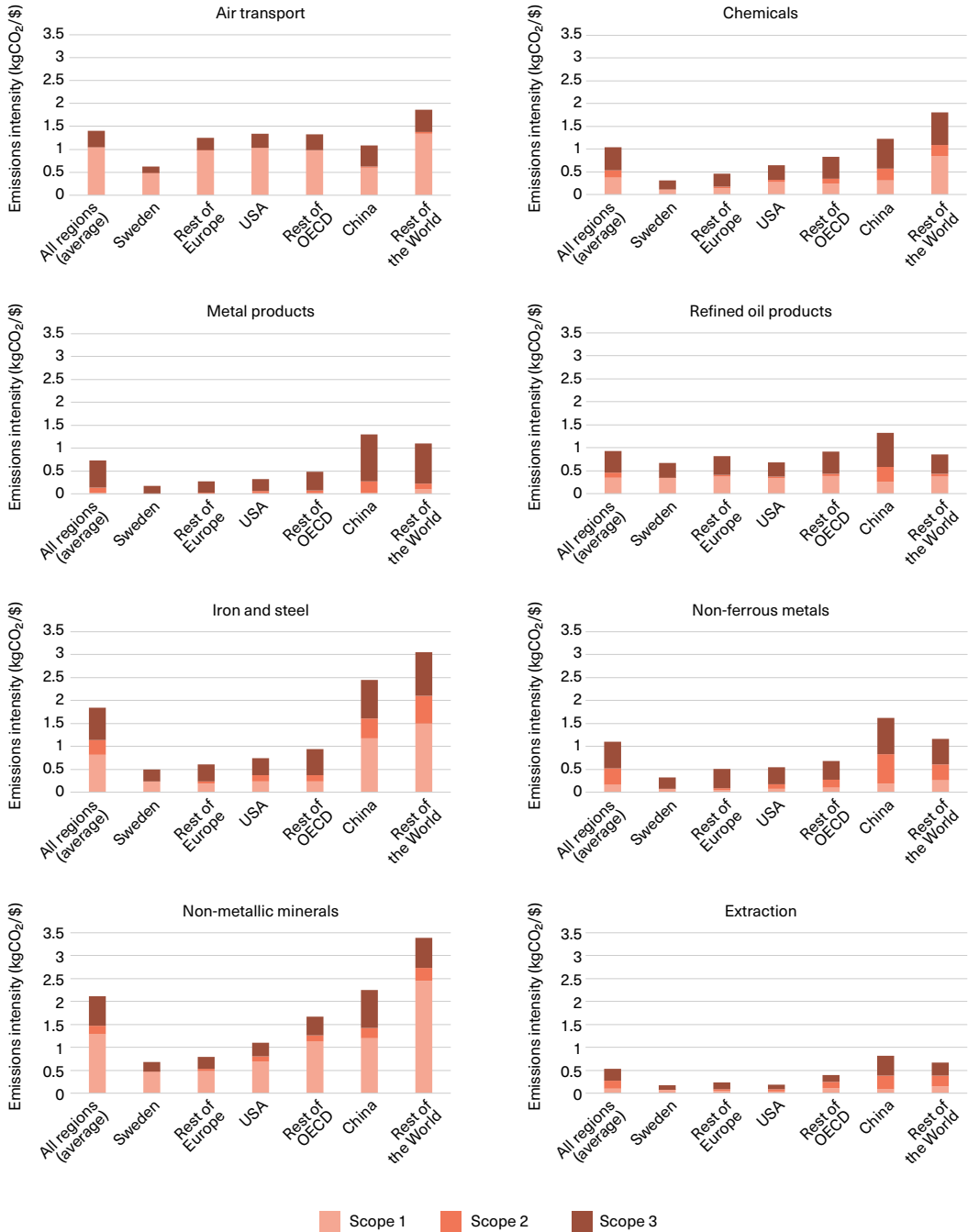
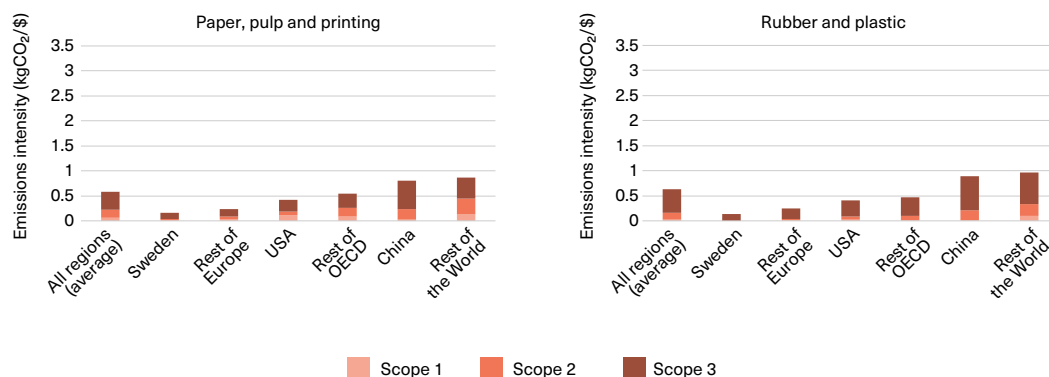
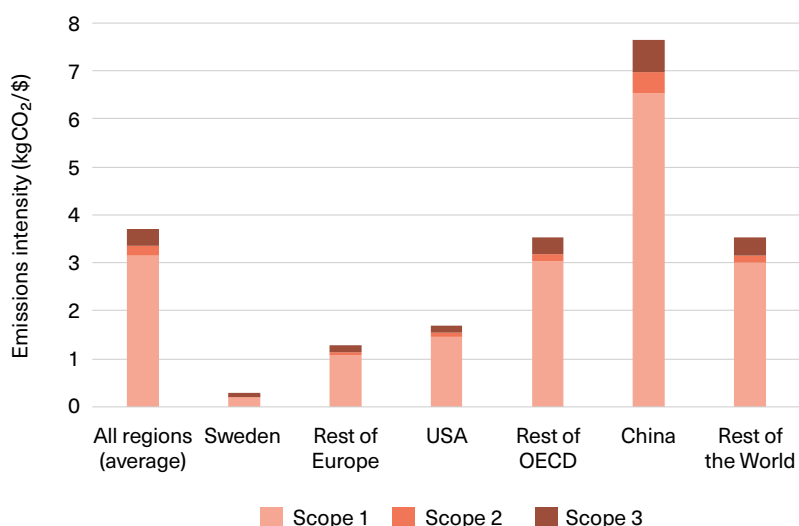
Figure 6. Carbon intensities of individual EITE products by region (kg CO₂/\\$).

Figure 6. Continued.

eration, which is highest for China and lowest for Sweden. Figure 7 provides quantitative evidence on the differences in the carbon intensity of electricity production across regions, which is the main driver for scope 2 emissions.

The differences in carbon intensities between Europe (Sweden and the Rest of Europe) as compared to their trading partners clearly confirm policy concerns about counterproductive carbon leakage resulting from unilateral European emissions pricing. They also highlight that there is some scope for competitiveness gains for EITE industries in Europe should other countries follow suit with strict emissions pricing. In this case, while EITE industries worldwide would suffer from the socially desirable structural change toward decarbonization, European industries could not only (re)gain market shares but possibly even increase their total production due to relatively cleaner production patterns.

Emissions intensities are crucial to the sector-specific impact of free allocation and CBAM measures. Free allocation protects domestic producers by reducing the CO₂ costs they incur as long as they continue production. Its benefit for the domestic producer therefore depends mainly on the domestic industry's own emissions and on how generous the free allocation is, rather than on the emissions of foreign competitors. A carbon border adjustment such as CBAM,

Figure 7. Carbon intensities of electricity generation by region (kg CO₂/\$US).

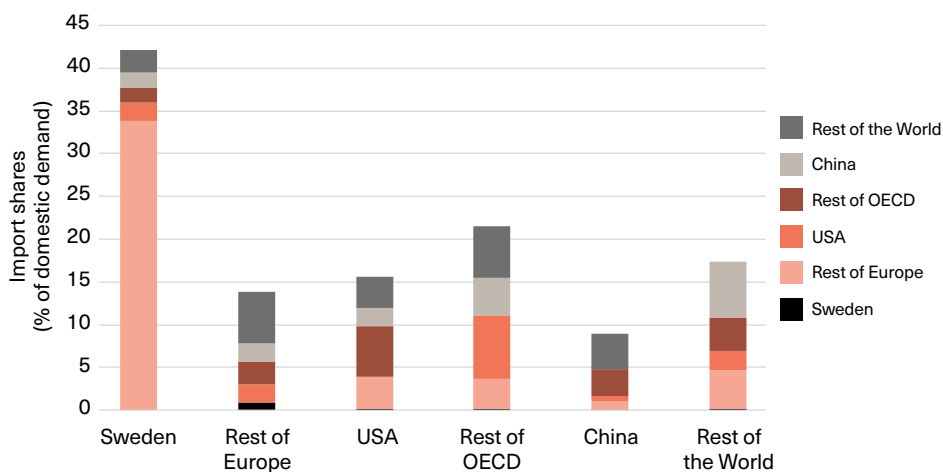
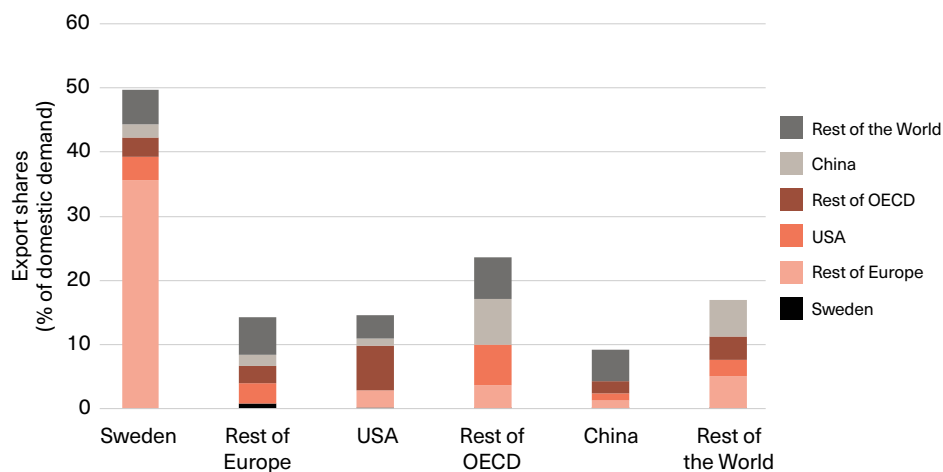
on the other hand, protects domestic producers by imposing a carbon cost on imports. Its benefit for the domestic producer therefore depends strongly on how carbon-intensive foreign competitors are: the dirtier the imported product relative to domestic production, the greater the competitive advantage for the domestic producer. A near-zero-emissions domestic industry would generally prefer CBAM, particularly if its foreign competitors remain carbon intensive. Since the domestic producer has already reduced its emissions or operates on clean energy from the very beginning, it has little carbon cost left that needs to be rebated. It benefits more when emissions-intensive foreign competitors are faced with comparable CO₂ costs. This also suggests that industry preferences may shift in the course of decarbonization: CO₂-intensive domestic manufacturers may initially prefer free allocation that lowers their own costs, while more environmentally friendly manufacturers increasingly prefer border adjustment payments that reward their emissions advantage.

2.3 Trade exposure across industries and regions

Unilateral emissions pricing imposes costs on domestic EITE industries and reduces their competitiveness in both the domestic and export markets. In the domestic market, the higher the share of (untaxed) competing imports, the greater the negative impact on domestic EITE supply; similarly, in export markets the higher the share of competing goods (whether from untaxed domestic supply of the export-destination region or untaxed competing exports from other regions), the greater the negative impact on export supply from unilaterally taxed EITE production. Border carbon adjustments are intended to create a level playing field between domestically regulated industries and their competitors abroad, where there is no (or much more lenient) emissions pricing. Border carbon tariffs aim to restore competitiveness in the domestic market; export rebates serve the same purpose in export markets.

Figures 8 and 9 show the initial bilateral trade patterns between regions in 2023. Figure 8 reports the import share of EITE products as a percentage of domestic demand, while Figure 9 reports the export share as a percentage of domestic production. In each case, the balance to 100% represents the domestic component: demand met by domestic production in Figure 8 and output sold on the domestic market in Figure 9. One striking finding is Sweden's heavy reliance on trade with the Rest of Europe, with import and export shares of around 33% and 35% respectively, while other regions account for only additional shares of 8% of imports and 15% of exports. The remaining shares show that 59% of Swedish domestic demand is supplied by domestic production, while 50% of Swedish domestic production is sold on the domestic market. In terms of climate policy, this means that Sweden's competitiveness on EITE markets depends to a large extent on regulatory differences compared to the Rest of Europe. Since EITE emissions are identically priced under the EU ETS, there are no competitive distortions between the two European regions.⁸ As with emissions

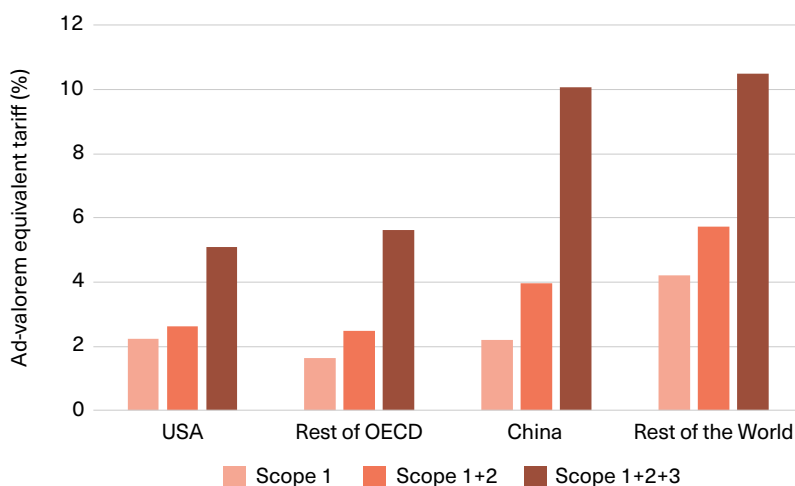
8. Clearly, our exposition of trade patterns hinges on the regional aggregations which may mask similar trade dependencies of individual countries such as other EU Member States with respect to the rest of the EU, or Canada (as part of the OECD) with respect to the United States.

Figure 8. Import shares of composite EITE products by region (in % of domestic demand).**Figure 9.** Export shares of composite EITE products by region (in % of domestic production).

intensities, there is considerable heterogeneity in trade exposure across individual EITE sectors.

The level of the carbon tariff will be determined by the emission intensities of the EITE products in exporting countries without emissions pricing and the carbon price of the importing countries. Figure 10 translates the carbon tariff into the ad-valorem equivalent of an ordinary import tariff on EITE imports to Sweden and the Rest of Europe, assuming a base-year emissions price in the EU ETS of \$75/tCO₂.⁹ The ad-valorem equivalent rates are shown for different carbon metrics that are considered for import adjustments: scope 1, scope 1+2, and finally the full embedded carbon content as indicated by scope 1+2+3. The cost premium on the average EITE import good from countries outside the EU is relatively moderate, with maximum tax rates close to 10% for EITE products from China or the Rest of the World even when border adjustments cover the full embedded carbon content. As shown in Figure 10, the carbon tariffs drop by half or even more if carbon prices are applied only to scope 1+2 or even just to scope 1 emissions (as is

Figure 10. Ad-valorem equivalent border carbon taxes.

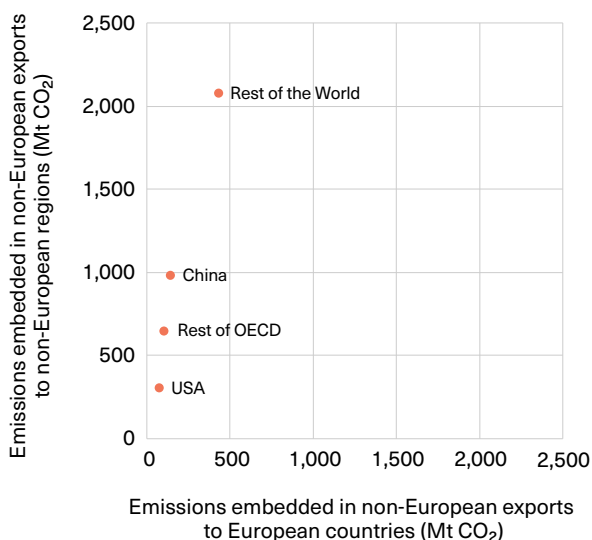


9. The ad-valorem equivalent is equal to the carbon tariff payments (i.e., the prevailing CO₂ price times the covered carbon content) over the value of imports.

largely the case with CBAM). Tariffs on EITE imports from the USA and other OECD countries are substantially lower, reflecting the less emissions-intensive production there. Note that these tariff rates are calculated as averages of base-year trade flows across all EITE products, thereby masking larger differences across individual EITE products of the regions (as shown in Figure 6).

Carbon tariffs will reduce the competitiveness of products from countries outside Europe in their European export markets compared to EITE products from Sweden or the Rest of Europe. However, with the phase-in of carbon tariffs under CBAM, the existing protective free allocation will be phased out. And since CBAM does not, at least for the time being, provide export rebates, European EITE products will no longer be protected in export markets, as is at least partially the case with free allocation. The overall impact of the transition from free allocation to CBAM is therefore ambiguous and requires a quantitative analysis.

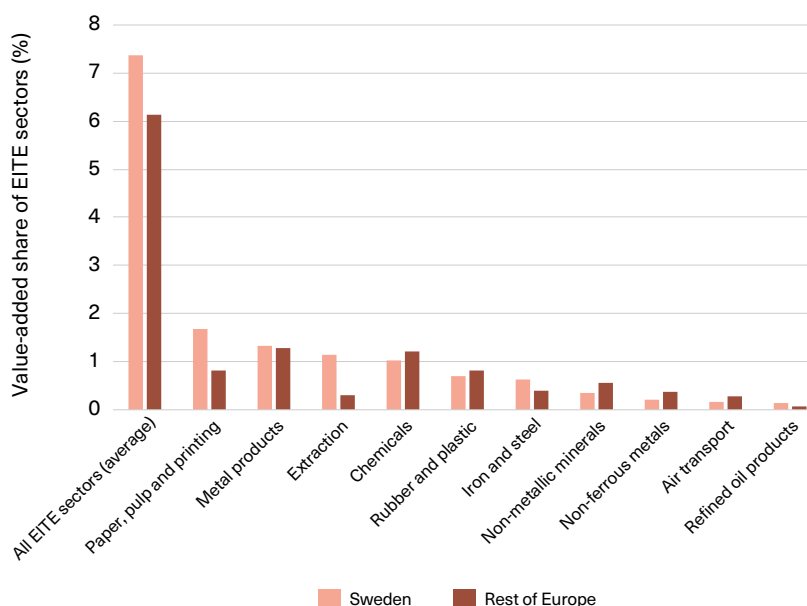
From a global cost-effectiveness perspective, the potency of border carbon taxes depends on the emissions embedded in trade that can be targeted by this instrument. Figure 11 shows a scatter plot of the full emissions (i.e., scope 1+2+3) embedded in EITE exports from countries outside Europe to European trading partners (Sweden and the Rest of Europe) as well as to the non-European trading partners (without emissions pricing). In total, emissions embedded in EITE exports from countries outside Europe to European countries amount to 750 million tons of CO₂, compared to 4,029 million tons of CO₂ in gross EITE trade between non-European countries. To put these numbers in a global context: the emissions embedded in EITE exports from non-European regions to Europe account for only 2.1% of total economy-wide production-based emissions in non-European countries, and 1.9% of global CO₂ emissions. CBAM thus only targets a relatively small share of unpriced emissions outside Europe, and re-routing of exports that had been initially shipped to the EU to other non-EU countries may further erode the targeted trade flows and emissions. When border carbon taxes are applied at the industry level, they act like ad-valorem taxes on EITE imports from non-European countries and offer no direct incentive for emissions reduction measures in those countries. While CBAM applies legally at the installation level, it can be difficult for an importer to secure installation-level monitoring and

Figure 11. CO₂ emissions embedded in EITE trade of non-European countries.

obtain verified emissions data – in this case, industry averages serve as fallback (default) values and an individual exporting firm will have no incentive for direct emissions abatement as the latter will not be credited under CBAM.

Concerns regarding loss of competitiveness in domestic EITE industries must also be viewed from an economy-wide perspective. As Figure 12 shows, the ten EITE industries classified in our analysis as emissions-intensive and trade-exposed together account for only about 7% of total value added in Sweden and 6% in the Rest of Europe. While a marked decline in EITE production would be a cause for concern for these industries, it would not necessarily pose a problem for the economy as a whole, unless there were economy-wide repercussions due to strong interdependencies in supply chains.

In sum, the MRIO analysis highlights four main points. First, Sweden's EITE industries on average are the cleanest among the regions in the dataset, meaning that a uniform carbon price would strengthen the relative competitiveness of Swedish producers within the EU. Sec-

Figure 12. Value-added share of EITE industries in Sweden and the Rest of Europe.

ond, more than two-thirds of Sweden's EITE trade takes place with the Rest of Europe, where the EU ETS already provides broadly comparable carbon-pricing conditions. The leakage concern is therefore concentrated mainly in the less than one-third of trade undertaken with countries outside this framework. Third, the current CBAM covers less than half of the carbon embedded in a typical product and less than 2% of global emissions, making the scope of the mechanism an important determinant of its overall effectiveness. Finally, EITE industries account for only around 7% of value added in Sweden and 6% in the Rest of Europe. Measures that have substantial consequences for these industries may therefore still have relatively modest effects on the economy as a whole.

The MRIO analysis further shows that the competitiveness and leakage implications of unilateral carbon pricing — and hence the relative merits of CBAM and free allocation — depend critically on both

emissions intensity and trade exposure. Sweden stands out for having the least carbon-intensive EITE production among the regions considered, with especially low indirect emissions from electricity; more generally, European EITE production is substantially cleaner than production in China and the Rest of the World. The differences in carbon intensities – together with trade exposure – matter for the preference of a specific EITE industry in a specific country between free allocation and CBAM as protective measure: free allocation primarily benefits carbon-intensive domestic producers by rebating part of their own carbon costs, whereas CBAM benefits relatively clean domestic producers by imposing carbon costs on more emissions-intensive foreign competitors. Consequently, very clean or near-zero-emission domestic industries would tend to prefer CBAM over free allocation, particularly when competing imports are substantially more carbon intensive, while relatively emissions-intensive domestic industries are more likely to prefer free allocation (as domestic industries decarbonize, their preference may therefore shift toward CBAM).

As to environmental concerns, current trade patterns limit the relevance of leakage protection for Sweden: roughly one-third of Swedish EITE domestic demand comes from the Rest of Europe and about 35% of Swedish EITE production is exported there, whereas trade exposure to trading partners outside the EU without comparable carbon pricing is much smaller. Since European producers already face broadly similar carbon prices under the EU ETS, the main competitiveness problem concerns trade with non-European regions. CBAM addresses this problem on the import side, but unlike free allocation it currently provides no protection for European exports, creating an important trade-off in moving from free allocation to CBAM, in particular for domestic industries that are export-oriented and rely heavily on carbon-intensive intermediate inputs from abroad. For these industries, CBAM may even put them at a disadvantage, as they face additional costs on imported inputs while receiving no corresponding protection for their exports to non-European markets. The effectiveness of CBAM thereby depends strongly on emissions coverage: scope 1 represents less than half of the carbon embedded in an average EITE product, so extending CBAM toward scope 2 and (if feasible) scope 3 would substantially increase the effective border adjustment; even with broader coverage, however, CBAM targets only a relatively small

fraction of global emissions. Finally, although these policy choices can be highly consequential for individual EITE industries, those industries represent only a limited share of value added, suggesting that even stronger repercussions for individual EITE industries need not translate into similarly large aggregate economic losses.

3. Shifting from free allocation to CBAM: an economy-wide simulation analysis

The MRIO calculations above provide information on differences in emissions intensities and market shares of EITE industries across regions for the base year. This information is important for understanding the potential impacts of unilateral emissions pricing and complementary second-best measures aimed at restoring competitiveness and reducing carbon leakage. However, the MRIO analysis is not suitable for mid- or long-term impact assessment, as the standard input-output approach with fixed coefficients abstracts away from any price response by economic agents on the supply and demand sides. To quantify the sector-specific and economy-wide effects of a transition in European carbon regulation from free allocation to carbon tariffs à la CBAM, we conduct simulation analysis using a computable general equilibrium (CGE) model of the global economy with economic agents – firms and households – that adjust their behaviour as policy measures trigger changes in commodity and factor prices. Below, we first provide a brief, non-technical summary of the modeling framework, followed by a description of the climate policy scenarios to be simulated. We then discuss and interpret the simulation results.

3.1 The model in brief

Computable general equilibrium (CGE) models retain the inter-industry structure that is central to the MRIO analysis while adding explicit mechanisms for price-responsive economic behaviour on both the supply and demand sides, combined with market clearing as established in microeconomic general equilibrium theory: producers

employ primary factors and intermediate inputs at least cost, subject to technological constraints; consumers with given preferences maximize their well-being, subject to budget constraints. CGE analysis provides counterfactual *ex-ante* comparisons, assessing the outcomes with a policy reform in place as well as the outcomes if a policy reform had not been undertaken.

For our analysis, we draw on a generic static multi-sector multi-region model of global trade and energy use (see e.g. Böhringer et al. 2018, 2021, and 2025 for a detailed algebraic summary). The choice of a static time treatment is justified by our primary interest in lasting impacts of regulatory interventions rather than their transitional effects. The multi-sector input-output framework is essential for capturing policy-induced economy-wide structural change including indirect effects on downstream industries that use EITE products as intermediate inputs. The multi-region setting with bilateral trade flows is necessary to capture international spillover and feedback effects of emissions reduction strategies through endogenous changes in international prices, i.e., the terms of trade.

CO₂ emissions are linked to fuel use (combustion) in fixed proportions, with CO₂ coefficients differentiated according to the specific carbon content of the fuel (coal, gas, and refined oil). Economy-wide restrictions on the use of CO₂ emissions in production and consumption are implemented through emissions pricing. CO₂ emissions can be reduced by fuel switching (inter-fuel substitution) or energy savings (either by substituting fuels with non-fuel inputs such as capital or by reducing the scale of production and final consumption).¹⁰

The basic mechanisms of CO₂ pricing captured by the CGE model are as follows: CO₂ pricing raises the effective cost of carbon-intensive fossil-fuel use, triggering adjustments throughout the economy. Producers respond by substituting away from carbon-intensive energy toward cleaner energy sources and other factors of production, while higher production costs are transmitted through intermediate input and consumer prices. The price changes reallocate production and

10. A reduction in process-related CO₂ emissions can only be achieved through a proportional reduction in output, which leads to an overestimation of the economic adjustment costs to the extent that there are more cost-effective technological options for reducing the intensity of process-related CO₂ emissions (such modeling would call for detailed bottom-up information on process-based abatement options across industries).

factor inputs across sectors, causing structural change which typically shows contraction of energy- and emissions-intensive industries while relatively low-carbon sectors might expand. Households adjust consumption in response to changes in commodity prices and factor incomes, generating changes in real income. Real income typically declines relative to the no-policy benchmark because carbon pricing introduces additional costs. The magnitude and possibly also the sign of the adjustment cost depend on a number of factors: how easily households and firms can substitute away from carbon-intensive goods and activities (the more easily they can, the smaller the cost); whether other market distortions such as initial taxes (subsidies) or market power exist alongside the carbon price; and how any revenue raised by carbon pricing is used elsewhere in the economy (for example, to reduce other distortionary taxes).

The CGE model is calibrated (parameterized) to the multi-sector multi-region input-output tables for 2023 provided by the GTAP database with the aggregation of sectors and regions being identical to that used for the MRIO analysis (see Table 1). The GTAP data do not contain explicit information on CO₂ emissions pricing. The cost of using fossil fuels in sectors and regions includes intermediate input taxes, but these taxes are not broken down into different components. To account for initial emissions pricing, we complement the GTAP data with regional emissions-pricing data published by the World Bank.¹¹ World Bank data for 2023 show that most countries outside Europe had little or no CO₂ pricing, while in Europe, sectors covered by the EU ETS were subject to a substantial CO₂ price of approximately \$75/tCO₂ on an annual average, whereas sectors outside the EU ETS faced an average CO₂ price of approximately \$25/tCO₂ (see also Figure 1 above). In the model calibration, we assume zero emissions pricing for countries and regions outside Europe (USA, China, Rest of OECD, and the Rest of the World) and the aforementioned CO₂ prices for ETS and non-ETS sectors within Europe (i.e., Sweden and the Rest of Europe). At the same time, EITE industries in Sweden and the Rest of Europe have received substantial free allocation, which mitigates the increase in their input costs by effectively subsidizing production.¹²

11. <https://carbonpricingdashboard.worldbank.org/compliance/price>

12. By default, we assume 100% free allocation. Note that 100% free allocation does not

3.2 Scenarios

The base-year dataset with its climate policy regulations constitutes the *free allocation scenario*, against which we measure the impacts of a shift to EU CBAM, represented by the *carbon tariffs scenario*. Free allocation for EITE sectors is here replaced with a carbon tariff on scope 1 emissions embedded in EITE imports from trading partners.¹³ The CO₂ price of the tariff is set equal to the EU ETS price for CO₂ emissions allowances. The main objective of both complementary policy measures – *free allocation and carbon tariffs* – is to reduce leakage and restore competitiveness of EITE sectors compared to a situation with unilateral emissions pricing only. We include this latter situation as the *carbon pricing only* scenario in our set of policy counterfactuals. Furthermore, we provide an extension of the border carbon adjustments towards more comprehensive protection where EITE sectors are not only protected in domestic markets through a carbon tariff but also receive an export rebate to restore their competitiveness in export markets (this scenario is labeled *carbon tariffs and export rebates*). The rebate is set in the same way as the free allocation. This represents our scenario of a full border carbon adjustment although it still only covers scope 1 and parts of scope 2 emissions. In all these four scenarios, EITE industries and the electricity sector are covered by a single European-wide EU Emissions Trading System (EU ETS) with one common CO₂ price, whereas emissions outside the ETS in each European region are priced at region-specific levels. All scenarios assume there is no emissions pricing in other regions. Table 2 provides an overview of the key characteristics of the scenarios simulated and investigated in the CGE analysis.

All four of these scenarios, which represent different variants of unilateral climate policy design in Europe, are compared to a hypothetical no-policy scenario that does not include any emissions regulation. The

mean that firms receive free allowances corresponding to 100% of their business-as-usual emissions. Rather, in our model, free allocation is represented as an output-based rebate, with the total rebate payment equal to the sector's total (endogenous) emissions payment.

13. As mentioned above, the EU's CBAM currently only includes scope 2 emissions for a few sectors and products (cement and fertilizers). In the sensitivity analysis, we consider the effects of accounting for scope 1+2 emissions in scenarios with carbon tariffs.

Table 2. Key features of climate policy scenarios.

	Carbon pricing in the EU	Free allocation of emissions allowances to EU EITE industries	Carbon tariff on imports	Export rebates
No climate policy (NOP) Baseline for comparison	✗	✗	✗	✗
Carbon pricing only EU carbon price without additional measures	✓	✗	✗	✗
Free allocation Free allowances linked to production	✓	✓	✗	✗
Carbon tariffs Carbon tariff on imports	✓	✗	✓	✗
Carbon tariffs + export rebates Carbon tariff on imports and export rebates	✓	✗	✓	✓

Note: EITE = emissions-intensive and trade-exposed industries. Free allocation is modelled as output-based rebates, where free emissions allowances are allocated in proportion to production. Carbon tariff + export rebates corresponds to a full border carbon adjustment that applies the carbon price to both imports and exports.

choice of hypothetical *no-climate-policy* scenario as our benchmark makes it possible to fully quantify the impacts of different designs of unilateral European climate policy on industrial competitiveness and global CO₂ emissions reduction. Note that we keep global emissions reduction at the level of the *free allocation* scenario (i.e., the base-year situation specified in the GTAP data) for all climate policy variants – this allows us to compare the global cost-effectiveness of unilateral climate policy variants without having to evaluate the environmental benefits from emissions reduction. To keep global emissions

unchanged at the free allocation level, the emissions prices in the EU (Sweden and the Rest of Europe) are endogenously and proportionally scaled. Effectively this means that the EU adjusts its original emissions cap for ETS and non-ETS sectors (i.e., those prevailing in the base year) to adjust for carbon leakage such that global emissions remain at the initial base-year level. This implies that the scenarios can be interpreted as alternative policy designs for achieving the same global emissions level — differing not in their aggregate environmental outcome, but in how that outcome is distributed between regions, and at what cost it is achieved.

3.3 Results

Our primary focus is on quantifying the impact of the shift of EU climate policy from free allocation to carbon tariffs under EU CBAM. Both instruments aim to restore the level playing field for domestic EITE producers compared to foreign EITE producers, but there are important differences.

While free allocation provides protection for domestic EITE producers in both the domestic and export markets, carbon tariffs provide protection only in the domestic market. Therefore, it is to be expected that EITE producers with a strong export-orientation would fare better with free allocation than with carbon tariffs. Consequently, it would also be expected that export-oriented sectors (and countries) would prefer free allocation over carbon tariffs. If CBAM were expanded to a combination of carbon tariffs and export rebates, this would also restore the competitiveness of domestic EITE producers abroad; however, export rebates are far more politically controversial than carbon tariffs (as they may be viewed as illegal export subsidies) and have therefore (at least so far) not been included in EU's CBAM.

Another key difference is that free allocation acts as an implicit subsidy for domestic EITE producers thereby stimulating overall supply, whereas carbon tariffs act as a tax on foreign supply, thereby depressing overall supply. Therefore, it is to be expected that free allocation will lead to lower prices and higher overall consumption of EITE products in Europe than carbon tariffs (and carbon tariffs combined with export rebates). In an economy, a cost-effective abatement mix

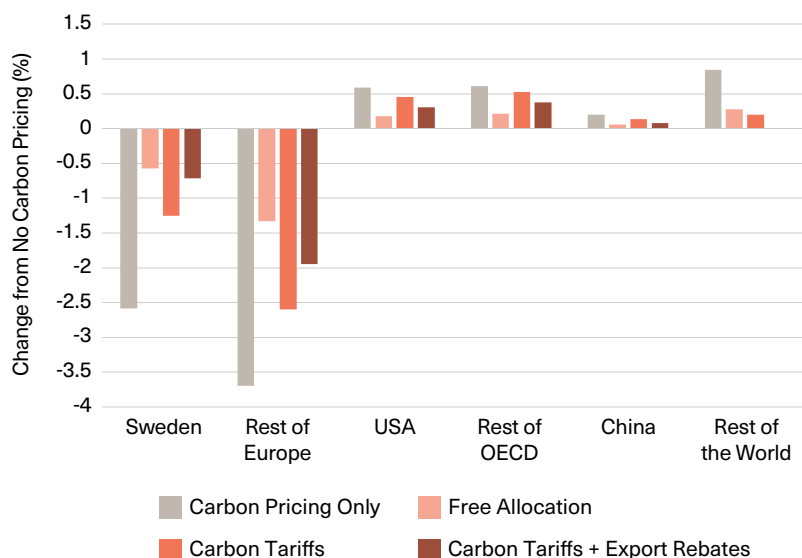
would normally imply reduced production and consumption of EITE products, reflecting the efficient reallocation of resources away from emissions-intensive activities. This is also the economic rationale behind proposals to supplement free allocation with a consumption tax (see e.g. Böhringer et al. 2017, 2025). Furthermore, it explains why carbon tariffs combined with export rebates typically outperform free allocation when it comes to global cost-effectiveness of unilateral climate policies. The combination of carbon tariffs and export rebates also has better global cost-effectiveness properties than free allocation, since it targets the carbon price gap between the EU and its trading partners rather than subsidizing domestic output as such. This means that the combination of carbon tariffs and export rebates scales down as more countries adopt carbon pricing and becomes redundant once the entire world does so — whereas free allocation would continue to distort production even in the absence of any remaining leakage risk (Böhringer et al. 2014).

The following presentation of simulation results responds to our initial research questions regarding the economic impacts of the EU's regulatory shift towards protecting its EITE industries through carbon tariffs rather than free allocation. Specifically, we draw on the quantitative general equilibrium analysis to gain insights into three policy-relevant questions. Firstly: How will the forthcoming EU CBAM affect the performance of the EU EITE industries compared with the current approach of free allocation of emissions allowances? Secondly: Does the shift to CBAM strengthen or weaken global cost-effectiveness of unilateral EU emissions pricing? And thirdly: What are the welfare implications, measured as a change in real disposable income? We compare the effects for Sweden with those for the rest of Europe. Unless otherwise stated, the simulation results are presented as percentage changes compared with the hypothetical no-climate-policy scenario.

3.3.1 EFFECTS ON INDUSTRY PRODUCTION

Figure 13 shows the impact of carbon pricing – with and without anti-leakage measures – on aggregate EITE production across regions. With carbon pricing only, total EITE production in Sweden falls by 2.6%, compared to 3.7% in the Rest of Europe. The smaller impact on Swedish producers compared to other EU producers can be attributed to the lower emissions intensities in Swedish production (as shown in

Figure 13. Aggregate EITE production in different regions (% change from the hypothetical no-climate-policy scenario).



Figures 5 and 6 of our MRIO analysis) – at a given carbon price, EITE producers in Sweden suffer a smaller competitiveness loss than EITE industries in the Rest of Europe. The decline in EITE production in Europe goes along with higher production in other regions, with the largest percentage increase being recorded in the Rest of the World composite region; in contrast, production in China is barely rising. The relocation of EITE production from Europe to abroad highlights the problems of an excessive competitiveness loss for European EITE industries and the risk of carbon leakage due to asymmetric emissions pricing.

In our base year 2023, EITE producers received large shares of free allowances in proportion to their (recent) output. As Figure 13 shows, these free allowances have to a large degree protected Swedish EITE producers. The combination of carbon pricing and free allocation leads to a decline in aggregate EITE production of just 0.6%. Free allocation

has also helped to protect EITE production in the Rest of Europe, where production losses are more than halved compared to carbon pricing only.

As the EU is now gradually transitioning from free allocation to a variant of carbon tariffs (CBAM), we are especially interested in comparing the *free allocation* and *carbon tariffs* scenarios. Figure 13 suggests that tariffs are less effective than rebates in protecting Swedish EITE producers, as the loss of production more than doubles from 0.6% under free allocation to 1.3% under carbon tariffs. Similarly, EITE producers in the Rest of Europe fare better under free allocation than under carbon tariffs. This finding can be explained by the fact that carbon tariffs merely restore competitiveness in the domestic market, whereas free allocation offers protection in both the domestic and export markets. Furthermore, carbon tariffs are only levied on scope 1 emissions, meaning that the carbon tariff falls far short of covering the full embedded carbon content. We will return to these points in the sensitivity analysis below.

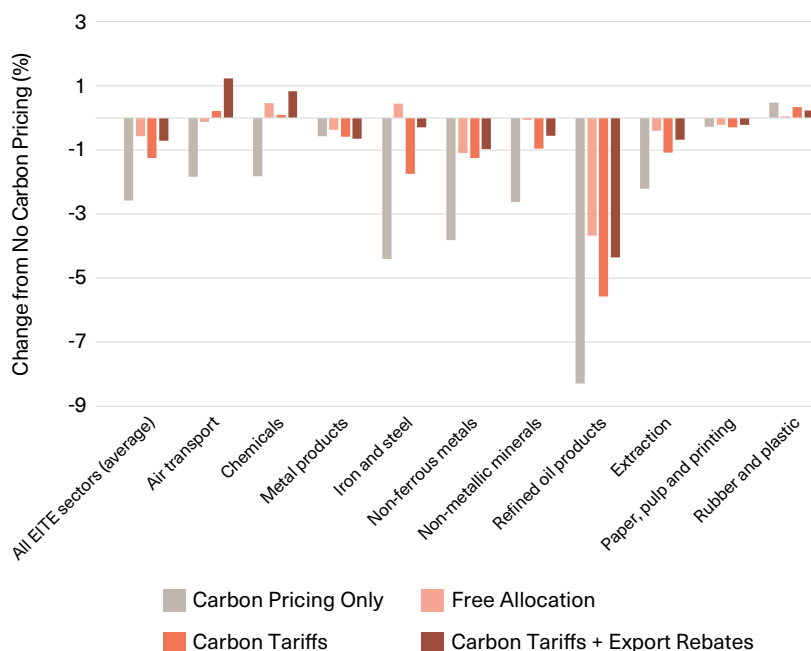
Adding export rebates on top of carbon tariffs provides additional protection on the export markets. As shown in Figure 13, this limits the decline in Swedish EITE production to 0.7%, i.e., almost the same as under free allocation (0.6%). EITE production in the Rest of Europe also gains from this full border carbon adjustment including both tariffs and export rebates, but less than under free allocation.

3.3.2 SECTOR BY SECTOR: THE AGGREGATE RESULTS HIDE LARGE DIFFERENCES

Behind this impact on aggregate EITE production lie quite heterogeneous effects across individual EITE sectors. Figure 14 shows how the aggregate EITE production impact is distributed across the individual EITE sectors in Sweden.

We can see that the impact varies considerably from sector to sector, both when it comes to the effects of carbon pricing in general, but also the effects of anti-leakage policies. Carbon pricing only has the biggest negative impacts on the refined oil products sector (oil), with an 8.3% output reduction, followed by iron and steel (-4.4%) and non-ferrous metals (-3.8%). Refineries and iron and steel have relatively high emissions intensities (scope 1 and 2, see Figure 6). Furthermore, unlike in some other sectors, the Swedish emissions intensities in these two

Figure 14. EITE production for different sectors in Sweden (% change from the hypothetical no-climate-policy scenario).



sectors are *not* notably lower than in the Rest of Europe (for iron and steel, it is even slightly higher). Hence, they lose out in competition with the Rest of the World, while not gaining vis-à-vis other European countries. Non-ferrous metal production is particularly trade-intensive, which explains why this sector is hit more than most others. Rubber and plastic, on the other hand, see a slight increase in production when carbon pricing is implemented, as this sector has a negligible emissions intensity.

Regarding the effects of anti-leakage policies, free allocation outperforms carbon tariffs in terms of production for all sectors except air transport. The difference is particularly pronounced for iron and steel, where free allocation leads to a slight production increase (compared with the hypothetical no-climate-policy scenario), whereas tariffs

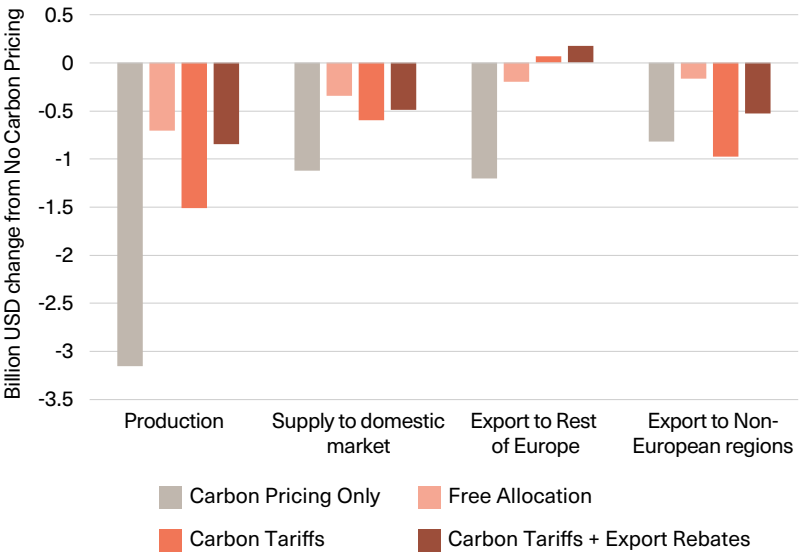
reduce output by 1.7%. One reason is that Sweden exports a relatively high share of its iron and steel production (while the import share is lower). While free allocation and carbon tariffs combined with export rebates dominate carbon tariffs alone in their protective effects, there is no clear ranking between free allocation and carbon tariffs combined with export rebates: full border carbon adjustment is the most effective policy for some sectors, while free allocation is most effective for others.

3.3.3 WHERE THE CHANGES HAPPEN: HOME MARKET VERSUS EXPORTS

To provide a clearer picture of the impact of changes in EITE production for Sweden, Figures 15–16 break these down into supply to the domestic market, exports to European partners, and exports to non-European markets, where no climate regulations are in place.

Figure 15 shows that with only carbon pricing, the Swedish decline

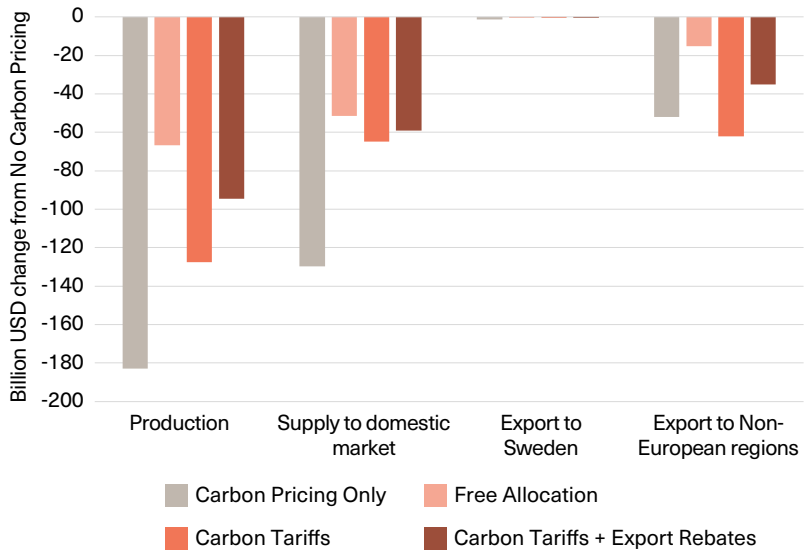
Figure 15. Decomposition of changes in EITE production for Sweden by supply to the domestic market, export to the Rest of Europe and export to other markets (billion USD change from the hypothetical no-climate-policy scenario).



in EITE production is divided fairly evenly across the three markets. For the Rest of Europe (Figure 16), however, more than two-thirds of the EITE supply contraction falls on the domestic market, with only negligible reduction in supply to Sweden. These differences simply reflect the huge differences in size between the two European markets. With free allocation, the supply contraction in Sweden is less pronounced, and as the figure shows especially export reductions are lower. Half of the decline in Swedish supply is absorbed in the home market (compared with almost 80% for the Rest of Europe).

Carbon tariffs lead to a substantial decline in Swedish exports to non-European countries (in fact, slightly more than in the scenario with carbon pricing only), while exports to the Rest of Europe increase slightly compared with free allocation. This can be explained by the fact that exports from Europe are no longer protected, while there is less competition from non-European producers on the European market.

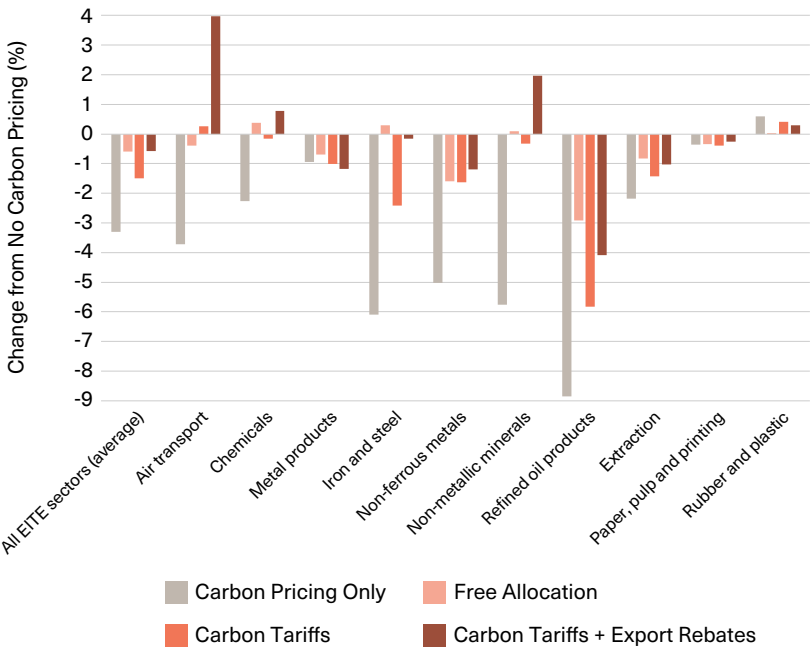
Figure 16. Decomposition of changes in EITE production for the Rest of Europe by supply to the domestic market, export to Sweden and export to other markets (billion USD change from the hypothetical no-climate-policy scenario).



With additional export rebates on top of carbon tariffs, exports from Europe are less adversely affected, which explains most of the increase in EITE production compared with the carbon tariffs scenario.

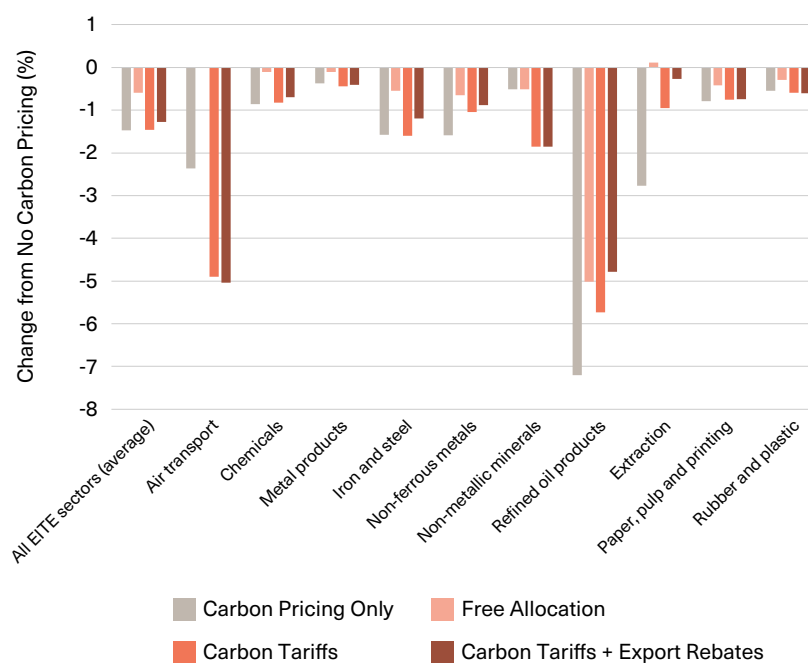
Figure 17 shows the corresponding effects on EITE exports by sector. The results are largely consistent with the production effects discussed above in Figure 14, yet the effects are generally more pronounced in relative terms. Exports of refined oil products, iron and steel, non-metallic minerals and non-ferrous metals are affected most, while exports of rubber and plastics increase slightly. The effects of anti-leakage policies are similar to those discussed above for production.

Figure 17. EITE exports for different sectors in Sweden (% change from the hypothetical no-climate-policy scenario).



Similarly, Figure 18 shows the effects on EITE imports by sector. Somewhat surprisingly, imports of EITE products to Sweden decline when carbon pricing is implemented in Europe. The main reason for this is that imports from the Rest of Europe fall (by 3%), which outweighs the 4.6% increase in imports from non-European regions (which account for a smaller share of total Swedish EITE imports). As can be seen in Figure 13 above, Swedish EITE production is affected less severely than production in the Rest of Europe, which affects intra-European trade. Another explanation is that EITE products are (also) used as own consumption in EITE production. Thus, when Swedish EITE production declines, demand for EITE intermediate inputs (also imported) declines as well.

Figure 18. EITE imports for different sectors in Sweden (% change from the hypothetical no-climate-policy scenario).



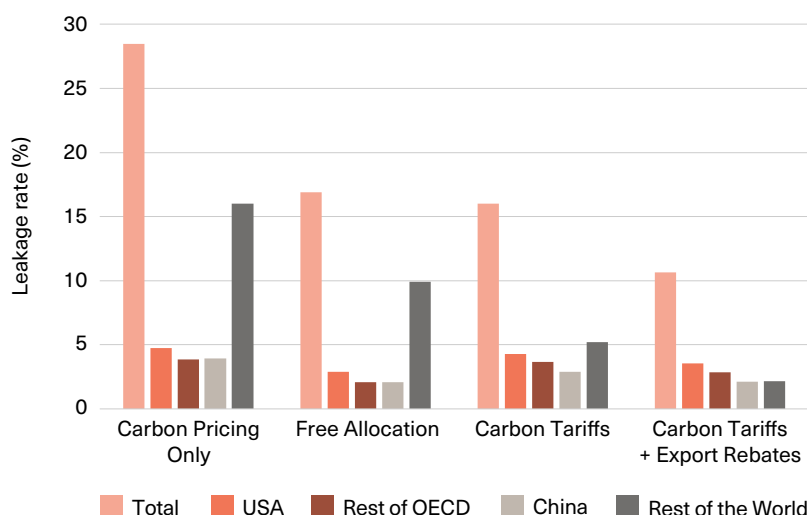
3.3.4 CARBON LEAKAGE

The purpose of anti-leakage policies is, in addition to protecting domestic industries, to reduce carbon leakage. Leakage is usually measured as the ratio between the increase in emissions in the non-regulated regions (here: non-European regions) over the decrease in emissions in the regulated regions (here: Sweden and the Rest of Europe), and is referred to as the leakage rate. Leakage rates for the different climate policy variants are shown in Figure 19 broken down by regions to which leakage occurs, as no emissions pricing applies in those regions. With carbon pricing only, the leakage rate is 28.5%. This means that for every 100 Mt of emissions reduced in Sweden and the Rest of Europe, emissions in other parts of the world increase by 28.5 Mt. These 28.5 Mt (or percent) are divided into 4.7 Mt increase in the US, 3.8 Mt in other OECD countries, 3.9 Mt in China, and 16.0 Mt in Rest of the World.

Anti-leakage policies can indeed reduce leakage rates, to 16.9% for free allocation, 16.0% for carbon tariffs, and 10.6% for carbon tariffs and export rebates combined. This ranking is consistent with earlier simulation studies of policy measures intended to reduce carbon leakage. The combination of carbon tariffs and export rebates is most effective, but still more than one third of initial leakage persists. The main reason for this is that none of the three anti-leakage policies considered here – free allocation, carbon tariffs, and carbon tariffs with export rebates – targets leakage via the international energy markets, i.e., the stimulus of fossil fuel use elsewhere from lower global fossil fuel prices caused by reduced European demand.¹⁴

Figure 19 provides interesting insights into how the different policies affect leakage to the four regions. Leakage rates to the USA, other OECD countries, and China decline from 12.5% with carbon pricing only to 8.5% with carbon tariffs combined with export rebates. This is very different from the induced changes in leakage to the Rest of the World, where the leakage rate drops from 16.0% with carbon pricing only to just 2.2% with carbon tariffs combined with export rebates. This suggests that a large share of leakage to the USA, other OECD countries and China occurs via the fossil fuel market channel, whereas most of the leakage to the Rest of the World is attributable to competitiveness losses for the EITE sectors.

14. The fossil fuel channel is often found to be at least as important as the competitiveness channel when it comes to the extent of leakage (see e.g. Böhringer et al., 2022).

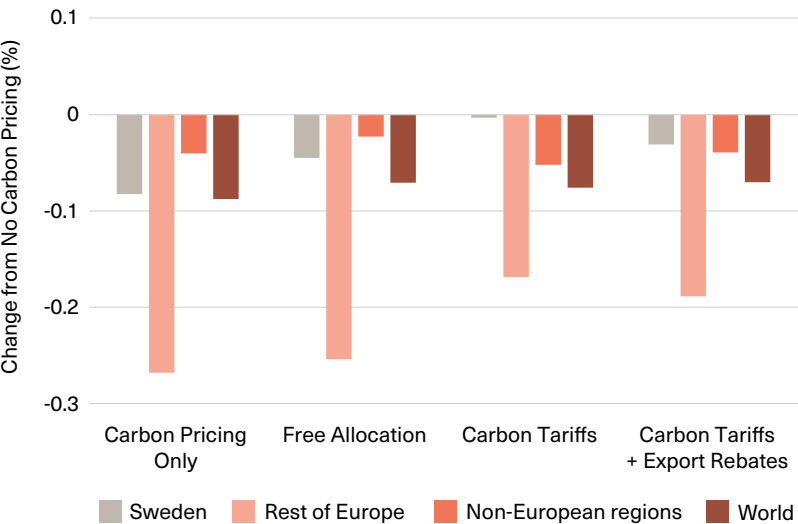
Figure 19. Leakage rates from climate policies in Sweden and the Rest of Europe (%).

3.3.5 EFFECTS ON WELFARE – WHO IS BETTER OFF?

Finally, we assess the welfare effects of the four climate policy scenarios. Welfare is measured using the standard microeconomic metric of Hicksian equivalent variation, which quantifies how much household income would need to increase or decrease at benchmark prices to achieve the same level of welfare as under the policy scenario. In our model setting, the Hicksian equivalent variation can be readily understood as a monetary measure of changes in households' real consumption. We focus on the welfare effects for Sweden and the Rest of Europe, as well as the aggregate effects for the other regions outside the abatement coalition and for the world as a whole. Recall that we keep global emissions constant across scenarios, so that welfare effects for the world allow for a global cost-effectiveness ranking of our unilateral climate policy scenarios.

With carbon pricing only, the Rest of Europe is much more adversely affected than Sweden, see Figure 20. Carbon pricing only reduces Swedish welfare by 0.08% (compared to the no-climate-policy sce-

Figure 20. Welfare effects of climate policies in different regions (% change from the hypothetical no-climate-policy scenario).



nario), compared to 0.27% for the Rest of Europe. As noted earlier, this small effect for Sweden is likely due to the lower emissions intensities in Sweden compared to the Rest of Europe. Carbon pricing has less negative effects on Swedish EITE producers, and some EITE sectors in Sweden may even gain from such a policy. The fact that EITE sectors account for a relatively small share of total value added in both Sweden and the Rest of Europe (as shown in Figure 12) also limits the effects on overall welfare. Non-European regions also see a slight welfare loss despite somewhat improved competitiveness in EITE sectors. The reason lies in world prices: by pricing carbon, Europe shifts the balance between what regions earn for their exports and what they pay for their imports. In other words, this change in terms of trade means that non-European regions on average receive less for what they sell abroad relative to what they pay for what they buy, which leaves them marginally worse off on aggregate. The global welfare effects shown in the figure are a weighted sum of the welfare effects in the different regions.

Free allocation is better than carbon pricing only for Sweden. Compared to no climate policy, Swedish welfare is reduced by only 0.05%. Free allocation hardly reduces the welfare costs in the Rest of Europe, whereas the non-European regions (on aggregate) are in fact slightly better off (due to terms-of-trade effects).

Turning to border carbon adjustment policies, carbon tariffs reduce the Swedish welfare cost to nearly zero. In other words, according to our central case simulations, the switch from free allocation to carbon tariffs would be beneficial for Sweden. This highlights an important distinction between industry-level and economy-wide effects. Free allocation protects EITE production, but because it effectively subsidizes that production, stronger protection of EITE industries does not necessarily translate into a better outcome for the Swedish economy as a whole.

A switch from free allocation to carbon tariffs is also beneficial for the Rest of Europe, whereas regions outside Europe are worse off (both compared to free allocation and carbon pricing only). From a global cost-effectiveness perspective, carbon tariffs are slightly worse than free allocation (but better than carbon pricing only). Finally, full border carbon adjustment with both tariffs and export rebates is the best policy from a global cost-effectiveness perspective (although only marginally better than free allocation), yet not from a European perspective. Both Sweden and the Rest of Europe are slightly better off with tariffs only than with a combination of tariffs and export rebates. Whereas export rebates protect European EITE exporters, the implicit subsidization of EITE exports likely has negative terms-of-trade effects for Europe (similar to what we observed above for free allocation).

3.3.6 OVERVIEW OF RESULTS

The preceding analysis covers a range of outcomes — EITE production, carbon leakage, and welfare — for four policy scenarios and across multiple regions. Before turning to the sensitivity analysis, we briefly summarize the main findings and highlight the key trade-offs between policy instruments. Table 3 summarizes the main results across the four climate policy scenarios for EITE production, carbon leakage, and welfare.

The results reveal clear trade-offs between policy instruments, with no single instrument standing out as superior across all dimensions.

Table 3. Summary of CGE model results.

Scenario	EITE output (% change from NOP)			Welfare, HEV (% change from NOP)		
	Sweden	Rest of Europe	Leakage rate (%)	Sweden	Rest of Europe	Global
Carbon pricing only	-2.6	-3.7	28.5	-0.08	-0.27	-0.088
Free allocation	-0.6	-1.3	16.9	-0.05	-0.25	-0.071
Carbon tariffs	-1.3	-2.6	16.0	~0.00	-0.17	-0.076
Carbon tariffs + export rebates	-0.7	-1.9	10.6	-0.03	-0.19	-0.070

From a Swedish perspective, the transition from free allocation to carbon tariffs is welfare-improving, reducing the welfare cost from 0.05% to practically zero. However, this comes at the cost of weaker protection for Swedish EITE industries, where production losses more than double from 0.6% to 1.3%. Full border carbon adjustment (combination of carbon tariffs and export rebates) largely restores production protection to free allocation levels, but at a slight welfare cost relative to carbon tariffs.

From a European perspective, the pattern is similar. EITE production in the Rest of Europe is more adversely affected by carbon pricing than in Sweden, reflecting higher emissions intensities. The Rest of Europe also benefits in welfare terms from the shift from free allocation to carbon tariffs, but this too comes at the expense of EITE production. A combination of carbon tariffs and export rebates restores some production protection relative to tariffs alone, but to a lesser extent than in Sweden.

From a global perspective, free allocation outperforms carbon tariffs in terms of cost-effectiveness, while the combination of carbon tariffs and export rebates performs best overall — both in reducing carbon leakage (10.6% compared to 16.9% under free allocation) and in minimizing global welfare costs. However, the differences are modest, and

the advantage of combining carbon tariffs with export rebates depends on the inclusion of the latter, which remain politically contentious.

In sum, the transition from free allocation to carbon tariffs involves a trade-off: weaker protection for EITE industries — particularly in export markets — in exchange for welfare gains and lower carbon leakage. Extending to full border carbon adjustment with both tariffs and export rebates restores export market protection, but brings some terms of trade losses that reduce European welfare relative to tariffs alone.

3.4 Sensitivity analysis

To check the robustness of the simulation results above, we conduct several sensitivity analyses. Here, we focus on two particularly important sets of parameters and one important policy assumption:

- i. EITE trade (Armington) elasticities: Imported and domestically produced goods of the same variety are treated as imperfect substitutes, reflecting differences in, for example, product characteristics and quality. How easily goods produced in different regions can substitute for each other, and hence how strongly domestic producers are exposed to foreign competition and carbon leakage, is determined by Armington elasticities. In our simulations, we use the Armington elasticities specified in the GTAP database. Here, we consider the effects of halving or doubling these elasticities.
- ii. Energy substitution elasticity: Energy can be substituted for the value-added composite in the production of goods and services. The values of the substitution elasticities determine how expensive it is to reduce emissions via reducing the use of (fossil) energy. In our central case simulations, we have adopted a default value of 0.5, and here we consider the effects of halving or doubling these elasticities.
- iii. Design of CBAM: In our simulations, we have only accounted for scope 1 emissions (like in CBAM) in the scenarios of carbon tariffs and carbon tariffs combined with export rebates. Here, we consider the effects of accounting for both scope 1 and scope 2 emissions in these two trade scenarios.

We limit the discussion of results to the impacts on aggregate Swedish EITE production and trade, as well as on overall leakage and economy-wide welfare.

Lower exposure to international competition. Starting with the Armington elasticities, halving these elasticities hardly changes the effects of free allocation or carbon tariffs on Swedish EITE production and exports – free allocation still outperforms tariffs. The combination of carbon tariffs and export rebates, however, is now less effective at mitigating the decline in production. The effects of anti-leakage policies on leakage rates also do not change much compared to the central case simulations, except that the combination of carbon tariffs and export rebates is now slightly less effective (but still represents the policy with the lowest leakage rate). When it comes to welfare costs for Sweden, both free allocation and the combination of carbon tariffs and export rebates lead to slightly bigger welfare losses than carbon pricing only, while carbon tariffs are now the best policy from a Swedish welfare perspective. This ranking is due to terms-of-trade effects, which become more pronounced when goods from different countries are poorer substitutes.

Higher exposure to international competition. When Armington elasticities are doubled — i.e. goods from different countries compete more closely with one another — the results are pretty much symmetric to what we observed when these elasticities were halved. The ranking between free allocation and carbon tariffs in terms of EITE output and exports is the same as above, while the combination of carbon tariffs and export rebates is now the preferred policy in this regard. The effects on leakage are also symmetric (doubling vs. halving the Armington elasticities), and the same holds for welfare costs. Anti-leakage policies are now much more effective in reducing welfare costs, with carbon tariffs and carbon tariffs combined with export rebates performing slightly better than free allocation.

Harder or easier abatement. With regard to the energy substitution elasticity, making substitution more difficult by halving this elasticity (for all sectors and regions) results in the same ranking of anti-leakage policies as before, in terms of their effects on EITE production and exports. The same holds true if the elasticity is doubled. With lower

elasticities, the policies are much more effective in reducing leakage. This reflects the fact that it is more costly to reduce emissions and hence protective measures are more useful. The ranking of instruments does not change though. When it comes to Swedish or global welfare costs, the ranking is the same as before whether the elasticity is increased or decreased.

Broader CBAM coverage. Finally, we examine the implications of accounting for both scope 1 and 2 emissions in the calculations of the two scenarios with carbon tariffs. Not surprisingly, Swedish EITE production becomes more competitive in these two scenarios than in the central case simulations. EITE output is reduced by 1.0% instead of 1.3% in the carbon tariff scenario. This is still a slightly bigger production loss than with free allocation though (0.6%). The combination of carbon tariffs and export rebates now leads to the smallest EITE output loss (0.4%). The same ranking holds for EITE exports.

With regard to leakage, carbon tariffs lead to slightly smaller leakage rates than before, though the difference is rather small (14.8% vs. 16.0%). The same holds for the combination of carbon tariffs and export rebates scenario. The expansion from scope 1 to scope 1+2 improves Swedish welfare slightly, above all in the tariff and export rebate combination scenario which now corresponds practically to carbon tariffs alone in terms of Swedish welfare. From a global welfare perspective, free allocation is still better than carbon tariffs.

4. Concluding remarks

The results in this study point to a clear conclusion: the EU's shift from free allocation to carbon tariffs through CBAM is a genuine trade-off. The numerical analysis, based on the multi-sector multi-region computable general equilibrium (CGE) model of the global economy, suggests that the transition in the EU from free allocation to carbon tariffs has a mixed impact on Sweden.

On the one hand, emissions-intensive and trade-exposed (EITE) production is on average slightly lower with carbon tariffs than with free allocation. According to our simulations, carbon pricing at current levels in Europe combined with carbon tariffs leads to an EITE production loss of 1.3% in Sweden (*vis-à-vis* no climate policies), compared to 0.6% with free allocation. For individual EITE sectors, however, there is more variation, with a couple of sectors benefiting from the transition to carbon tariffs, while most sectors are worse off.

On the other hand, from a Swedish economy-wide perspective, the transition from free allocation to carbon tariffs reduces the loss in real income (*vis-à-vis* no climate policies) from 0.05% to practically zero. The small numbers partly reflect the limited share of the EITE sectors in the Swedish (and European) economy. The transition from free allocation to carbon tariffs in the EU leads to a slight reduction in carbon leakage from Europe to other parts of the world. From a global cost-effectiveness perspective, free allocation performs slightly better than carbon tariffs, but full border carbon adjustment, which includes export rebates on top of carbon tariffs, has the lowest global welfare cost in our simulations.

A second finding is that Swedish EITE producers are hurt less by

carbon pricing than their European peers. A key reason for this is that Swedish EITE producers generally have lower emissions intensities than their European competitors. Thus, if the same carbon price is applied to EITE industries throughout Europe (which is the case under the EU ETS), Swedish producers gain competitiveness relative to other European producers (while losing vis-à-vis competitors abroad). When carbon pricing is introduced, EITE output falls by nearly 50% more in the Rest of Europe than in Sweden. Swedish EITE production also tends to be better protected by anti-leakage measures such as carbon tariffs, reflecting its lower emissions intensity.

The sensitivity analysis confirms that the qualitative results are quite robust to changes in key model parameters such as the substitution elasticities between domestic production and imports, and between energy and value-added in production of goods and services. Extending the scope of the carbon tariff from scope 1 to scope 1 and 2 improves CBAM's ability to protect Swedish EITE production, but it still protects Swedish EITE production less effectively than free allocation. If this extended CBAM were also combined with export rebates, Swedish EITE production would increase slightly compared to free allocation.

Finally, which instrument looks best depends on the wider policy environment. A limitation of the analysis is that the simulations assume no carbon pricing outside Europe. This reflects the situation in the base year 2023 quite accurately but could change in the future. If major trading partners — such as the United States or China — were to implement carbon pricing to a larger extent, the price differential that motivates both free allocation and tariffs would narrow, reducing leakage and the need for protective measures. However, the effect would depend critically on which countries act: our results suggest that leakage to China is relatively modest compared to the Rest of the World, implying that high carbon prices in China alone would have a limited impact on overall leakage. In the extreme case, if all countries adopted equivalent carbon pricing, tariffs would become redundant while free allocation would continue to distort production unnecessarily — strengthening the case for tariffs over free allocation from a long-run perspective. The analysis does not simulate such scenarios explicitly, and results should therefore be interpreted as reflecting the current asymmetric policy environment rather than a future in which climate policy coordination has advanced.

For Swedish and European policymakers, the results help frame a few of the decisions ahead. In the simulations, replacing free allocation with carbon tariffs slightly improves Sweden's aggregate welfare but implies costs for its emissions-intensive export industry — and this trade-off is, if anything, more pronounced at the EU level. Although Swedish industry is cleaner and therefore withstands carbon pricing better than the European average, the switch to tariffs makes the Swedish industry slightly worse off because tariffs — unlike the free allocation they replace — do not protect exports. Because the effects are concentrated in the exposed sectors rather than spread across the economy, a central question is whether the issue is approached as one of sector interest or of national interest.

Two choices follow. The first is coverage: because Swedish electricity is almost carbon-free, extending CBAM from scope I to scope I+2 improves the relative position of Swedish producers compared with more carbon-intensive competitors — an area where Sweden stands to gain most. The second is whether to add export rebates, which would restore protection for Sweden's exporters almost to today's level. It is also the most cost-effective option globally, but at a small welfare cost relative to tariffs alone and with real legal risk as a potential export subsidy. However, neither of these choices is up to Sweden alone to decide, as they are determined at the EU level.

Two questions that are important for policy remain beyond the scope of this analysis. First, the economy-wide effects reported here show net winners and losers together, so they reveal little about how those effects are distributed within the economy. In particular, how the industries downstream of EITE producers fare when carbon pricing raises the cost of the materials they buy — both domestic and imported — would provide a fuller picture of the competitiveness effects. This question bears directly on ongoing discussions about extending CBAM beyond imported materials to the carbon embedded in imported finished goods that contain them. Second, the analysis treats climate policy abroad as fixed; how the different instruments might influence other countries' own climate policies — for instance by encouraging them to price carbon (see e.g. Beaufils et al., 2026) — could have important implications for competitiveness and carbon leakage, and would be valuable to examine.

Within these limitations, the results show that the transition from free allocation to CBAM changes not only the level but also the nature of the protection provided to European industry. The choice between the instruments therefore has different implications for export-oriented industries, economy-wide welfare and global carbon leakage.

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Carbon pricing can reduce emissions but may also affect the competitiveness of emissions-intensive industries and lead to carbon leakage. The EU has long sought to limit these effects through free allocation of emissions allowances, a system that is now being gradually replaced by the Carbon Border Adjustment Mechanism (CBAM), which puts a carbon price on certain imports into the EU. The two approaches provide different forms of protection for European industry, with different implications for production, trade and emissions.

In this report, economists Christoph Böhringer and Knut Einar Rosendahl compare the economic effects of free allocation and carbon tariffs, with a particular focus on Sweden. They analyse the effects on Swedish emissions-intensive and trade-exposed industries, the Swedish economy as a whole and global carbon leakage. The report also examines how the results change with broader emissions coverage and when carbon tariffs are combined with rebates for exports.

The analysis is based on data on global production, emissions and trade together with a multi-sector, multi-region model of the world economy.

Christoph Böhringer is Professor of Economics at the University of Oldenburg. *Knut Einar Rosendahl* is Professor of Economics at the Norwegian University of Life Sciences.

The report is part of the research project “SNS Climate”.

