Comparing policy options to address export-related carbon leakage

The role and potential of innovation support

Michael Jakob

Michael Mehling

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Contact

Michael Jakob
Senior Fellow

Ecologic Institute
Pfalzburger Straße 43/44
10717 Berlin
E-Mail: michael.jakob@ecologic.eu

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Abstract

With the recent passage of the Carbon Border Adjustment Mechanism (CBAM), the free allocation of emission permits under the EU Emissions Trading System (EU ETS) that currently acts as a safeguard against emissions leakage and industrial relocation will progressively be phased out. Because the CBAM only covers imports, however, European goods exported into global markets stand to become more vulnerable to emissions leakage. Different policy options have been discussed to counter such export-related leakage, but they variously face concerns regarding their environmental, political and legal implications. We describe and evaluate the three most important policy options based on their potential to reduce export-related leakage, support the net-zero transformation in Europe as well as globally, ensure conformity with international trade law, secure administrative feasibility, and foster political acceptance by affected trade partners. While no single option outperforms its alternatives on all criteria, our analysis identifies targeted innovation support as a promising option because it minimizes legal and political risks while also offering climate benefits beyond leakage protection for European industry. We then discuss the sectors that are most likely to require innovation support, the policy instruments that could serve to operationalize such support, and potential funding sources. We conclude with guiding principles for technology support measures, reflecting on the implications of the current surge in industrial policy within Europe and beyond.

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1 Background and Context of the Study

Climate policies for industrial decarbonization often face opposition because of their potential **impact on competitiveness** and the risk of **carbon leakage**, that is, the relocation of industrial production and investment to jurisdictions with less stringent climate policies (IPCC 2022). Carbon leakage is a concern for environmental, economic, and political reasons: when domestic emission reductions are (wholly or partly) offset by increased emissions abroad, leakage reduces the overall effectiveness of climate action. The accompanying loss of revenue, investment, and employment opportunities poses an economic challenge, and threatens to undermine political support for decarbonization policies. Currently there is only very limited evidence of carbon leakage taking place. As mitigation costs have been relatively low, incentives for firms to move to locations with laxer climate targets have likewise been limited (Jakob 2021b). Nevertheless, in the future more stringent climate policies in some regions that is not matched by comparable efforts in other regions could turn carbon leakage into a serious concern (Caron 2022).

For the EU, carbon leakage has likely been also limited by dedicated anti-leakage measures. The central policy to reduce emissions – the European Union Emissions Trading System (EU ETS) – has traditionally relied on **free allocation of emission allowances** to prevent carbon leakage (Antoci et al. 2022). Although it has proven effective at limiting leakage induced by carbon pricing (Joltreau and Sommerfeld 2019; Verde 2020), free allocation has also muted mitigation incentives under the EU ETS. It also is unlikely to be compatible with accelerated decarbonization as envisioned under the European Green Deal due to the very limited amount of emission permits that will be available in a net-zero economy (Jakob 2021b).[1]

Going forward, the EU will therefore deploy an **alternative policy instrument** to avert emissions leakage: the **Carbon Border Adjustment Mechanism** (CBAM). As a complement to the EU ETS, this instrument will apply the carbon price faced by domestic producers to the emissions embedded in imports of six categories of products: cement, iron and steel, aluminum, fertilizer, hydrogen, and electricity. As obligations under the CBAM are phased in, free allocation of allowances will gradually decline and reach zero by 2034. Unlike free allocation, however, which has benefitted European products regardless of the market in which they are sold, the CBAM will only apply to goods sold in the domestic market.

Despite calls from stakeholders to include a rebate or some other form of relief for EU-manufactured products sold in foreign markets, the CBAM currently contains **no mechanism** to address **carbon leakage risks for exported products**. Once free allocation declines, the absence of a leakage protection for exported products may result in a situation where European goods lose market share abroad and are substituted by more emissions-intensive goods from third countries, leading to an overall increase in emissions. In its impact assessment of the legislative proposal for the CBAM, the European Commission acknowledged that applying the CBAM only to imports would lead to a loss of market share for European exports, projecting a 6.8% decline in exports of covered goods for the policy option most closely resembling the final CBAM design (European Commission 2021a). Earlier academic literature on design options for a European border carbon adjustment had already suggested that “the inclusion of imports and exports would reduce world emissions more than the inclusion of imports alone“ (Monjon and

[1] Even with net-zero emissions, some emission permits can be awarded to firms corresponding to residual emissions that are set off with negative emissions from carbon dioxide removal from the atmosphere, e.g. through reforestation (Minx et al. 2018).

Quirion 2011). A meta-analysis of model studies on border carbon adjustment identified export rebates as one of the most effective design features, reducing leakage rates by on average four percentage points (Branger and Quirion 2014). Moreover, ensuring that EU firms can compete on the global market might increase political support for (and ease political resistance against) ambitious climate policies (Jakob et al. 2022).

Concern about the implications of the CBAM for exports has prompted the inclusion of a mandate in the legislative text instructing the European Commission to "assess the effectiveness of the CBAM in addressing the carbon leakage risk for goods produced in the Union for export to third countries" and to report its findings, along with any appropriate legislative proposals, to the European Parliament and to the Council every two years (European Parliament and Council of the European Union 2023). Going forward, therefore, the issue of leakage in relation to exports will **remain high on the agenda** of European policy makers and stakeholders, and prompt continued discussion about possible policy responses, including different forms of **export rebates** for goods sold in international markets.

Adequate solutions to the challenge of export leakage will not necessarily be limited to changes in the design of the CBAM. Ever since the United States adopted legislation setting out generous tax credits, loans, and grants for climate change mitigation activities under its Inflation Reduction Act of 2022 (IRA) and Infrastructure Investment and Jobs Act (IIJA), a discussion about the role and importance of **subsidies for industrial decarbonization** has also gained significant momentum in Europe. As part of the Green Deal Industrial Plan (GDIP), the European Commission has temporarily relaxed state aid rules and issued a legislative proposal for a Net Zero Industry Act, which identifies an aspirational target for domestic manufacturing capacities of eight strategic technologies and aims to streamline the relevant regulatory environment (European Commission 2023).

In its summary report of the public consultation on the CBAM, the European Commission recognized that "most participants argued that the possibility to grant a rebate to EU exporters should be explored under the CBAM" (European Commission 2020). The subsequent political debate revealed the issue of exports to be one of the most divisive elements of the proposed CBAM, meaning that the treatment of exports could prove critical to sustain stakeholder acceptance and support for industrial decarbonization in line with the accelerated timeline set out by the European Green Deal and the European Climate Law, including the **agreed withdrawal of free allocation** of allowances. To inform the political and legislative debate about potential solutions, Section 2 of this study identifies several options to prevent emissions leakage in relation to exports and proceeds to evaluate these options on the basis of five relevant dimensions. The most promising option emerging from this assessment, support for innovation in low-carbon technologies, is discussed in greater detail in Section 3. Section 4 concludes with concrete policy recommendations.

2 Assessing Policy Options to Address Export Leakage

This section first presents a list of desirable characteristics for policies designed to address export-related leakage. We then use these characteristics to discuss the respective advantages and disadvantages of different approaches. Finally, we compare the performance of these approaches along the relevant characteristics and select one of the options considered for further analysis.

2.1 Relevant Dimensions of Analysis

In Section 2.2, we analyze policies that could complement the CBAM to reduce export-related carbon leakage along five desirable characteristics. These are: (i) leakage protection and maintaining the competitiveness of energy-intensive EU industries, (ii) support for the net-zero transformation in the EU as well as globally, (iii) administrative feasibility, (iv) conformity with international trade agreements, and (v) international acceptance. These five dimensions are not independent. For instance, a policy will be less likely to spark international resistance the less stringent it is in reducing export-related leakage. Likewise, WTO conformity is less crucial for policies that are designed in ways that achieve political buy-in by the EU's trade partners, so that they would be unlikely to challenge this measure under the WTO dispute settlement mechanism, even if they might stand a high chance of success.

First, the most straightforward desirable result of the measures is **leakage protection and maintaining the competitiveness of energy-intensive EU industries** on the world market. This criterion is central, as policies that do not reduce export leakage are not relevant for our analysis. Yet, a policy that is less effective in reducing leakage might nevertheless be preferable because of synergies with other policy objectives or higher administrative, legal and political feasibility. For this reason, policy makers may decide for a measure that does not display the most favorable characteristics in terms of reducing export-related leakage, but which performs better on the latter aspects.

Second, measures should be designed so that they **support the net-zero transformation in the EU as well as globally**. Leakage protection is by itself an enabling factor, as it allows to implement more stringent climate policies than in the case in which domestic efforts to reduce emissions would face the risk of firms relocating to areas with less stringent climate policies (Jakob et al. 2022). Nevertheless, anti-leakage policies can also have detrimental effects for the transformation of the EU economy towards net-zero. A salient example is the free allocation of emission permits, which reduces carbon leakage, but also incentivizes additional production of emission-intensive goods (Martin et al. 2014). It is hence desirable to devise measures against export-related leakage in a way that has synergies with the broader goals of decarbonization. As policies adopted by the EU to address export-related leakage can be expected to have different implications domestically and in third countries, we discuss both aspects separately.

Third, to ensure that available financial resources are employed in the most efficient manner, it is crucial to limit **costs** for public budgets and thus taxpayers. This also includes transaction costs for the **administrative effort** to ensure that public authorities can effectively implement and firms can access measures designed to address export-related leakage. Moreover, complex regulation might create legal uncertainty and deter firms from investing. This is of particular importance in situations in which large up-front investments need to be undertaken, such as the net-zero transformation of energy-intensive industries (Steckel and Jakob 2018).

Fourth, it is desirable that the adopted measures be in **conformity with international trade agreements**, especially WTO provisions, to signal continued commitment to the multilateral rules-based economic order. A WTO-consistent design would also avoid legal uncertainty for investments by EU firms and the risk of retaliatory measures by trade partners, such as tariffs on imports from the EU. Despite increasing geopolitical tensions that also affect international trade relations, the EU Commission has consistently emphasized its commitment to the global trade regime by seeking a CBAM design that conforms to WTO rules (European Commission 2019; 2021b). It is impossible to have full certainty that a newly implemented measure will be approved by the WTO. Nevertheless, there is ample analysis of previous jurisprudence that allows to assess the likelihood with which a proposed measure will be (successfully) challenged under the dispute settlement mechanism. Most importantly, existing experience yields important information on design features that are likely to violate WTO rules – such as direct support to exports – and can thus point to the most important pitfalls when designing instruments to tackle export-related leakage. Reducing legal uncertainty can also lower the risk of delayed investments if firms hold back with investments until the WTO has conclusively ruled on the matter.

Fifth, **international acceptance** of EU policies is crucial for maintaining international climate cooperation. Strong external pushback against an envisaged or implemented policy can force the EU to withdraw or scale back the policy (Jakob 2023). A salient example is the attempt to include international flights in the EU ETS, where the EU backtracked in response to massive protests from key countries such as the US and China, as well as threats of economic and political retaliation (Hartmann 2013). Even if the policy is upheld despite international pressure, other countries could adopt countervailing trade measures. Additional trade barriers could slow down the diffusion of clean technologies, and increase the cost of the low-carbon transformation (Helveston, He, and Davidson 2022). Furthermore, conflicts on climate-related trade measures entail the risk of spilling over to international climate negotiations, thus further slowing down progress.

2.2 Policy Options and Initial Evaluation

As mentioned in the introductory section, concern about emissions leakage in relation to exports has proven one of the most controversial issues in the political and legislative discussion debate about industrial decarbonization and the CBAM (Kuehner, Jakob, and Flachsland 2022). Given the high level of attention to the topic, several proposals have been brought forward to provide relief for exporters. Often described as “export rebates”, these proposals tend to consist of a partial or full waiver of the costs faced by exported goods to comply with the EU ETS, either in the form of free allocation of allowances or equivalent financial compensation. An additional approach entails offering targeted innovation support to exporting producers to assist them with the decarbonization of production technologies and processes, lowering the costs they face under the EU ETS. In our baseline scenario we assess the current approach agreed under the CBAM, i.e., a complete phaseout of free allocation by 2034, and no alternative protection against export leakage.

2.2.1 Baseline Scenario

In the baseline scenario, **free allocation of allowances declines to zero by 2034**, but does so in a non-linear way, starting slowly during this decade and then accelerating after 2030.[2] By backloading the phase-out of free allocation, affected producers and administrative authorities are afforded more time to prepare for the application of the CBAM, and continued innovation and technology cost declines will make it easier to decarbonize industrial production processes. By 2034, however, producers will face the full cost of complying with the EU ETS, regardless of whether their products are consumed domestically or exported. Ending free allocation or any other policy mechanism that lowers the carbon cost faced by European producers has the benefit of strengthening the price signal and thus the incentive for decarbonization, which should, in turn, accelerate the transformation of industry to climate neutrality. Doing so is also advantageous under international trade law, because it ends a practice – the issuance of free

[2] The rate of reduction in free allocation is as follows: 2026: 2.5%; 2027: 5%; 2028: 10%; 2029: 22.5%; 2030: 48.5%; 2031: 61%; 2032: 73.5%; 2033: 86%; 2034: 100%.

allocations under the EU ETS – that has already been considered a countervailable subsidy by the United States Department of Commerce (Department of Commerce 2020).

Since the rules and timeline of this phase-out have already been agreed, the baseline scenario is assumed to represent an administratively feasible option. Where this default option falls short, however, is in the leakage protection afforded to exported goods and their producers. **For the domestic market, the CBAM levels the playing field by extending the carbon price under the EU ETS to imported goods. No such safeguard benefits European products exported into third countries**, giving rise to concerns about export leakage once free allocation of allowances begins to decline. Politically, by contrast, international trade partners should welcome the phase-out of free allowances, as the increasing carbon cost makes products manufactured in the EU less competitive than products manufactured elsewhere.

2.2.2 Full Export Rebate

The current approach to address carbon leakage under the EU ETS consists of muting the compliance cost incurred by covered facilities in energy-intensive or trade-exposed sectors. While this could also be achieved in the form of a financial transfer based on the documented cost of allowance purchases, it has taken the form of free allocation of emission allowances to producers of goods deemed at risk of carbon leakage, based on their energy intensity, trade exposure, or a combination of both. So far, the free allocation has been partial, based on product benchmarks (see Section 2.2.3 below). As free allocation is phased out, however, it could be retained for exporters to cover the full reported emissions associated with products destined for third countries. Alternatively, the rebate could take the form of a financial transfer to compensate the full carbon cost incurred by producers of exported goods.

As a policy option, this is **the least likely to generate a robust decarbonization incentive** for exporters in the EU because it intentionally mutes the carbon price signal. If the rebate is proportional to the quantity of exported goods, it would provide an incentive to increase the production of emissions-intensive goods. If the rebate is instead based on historical export levels, producers would face an incentive to reduce emissions due to the opportunity cost of allowances or financial compensation, but the incentive would still be weaker than under alternative policy options. It is also unclear how an export rebate based on continued allocation of free allowances would align with the decarbonization trajectory under the EU ETS, in which the overall number of allowances will decline rapidly and reach zero around 2040. Finally, an export rebate also incurs a fiscal cost, because revenue that would otherwise be generated from the auctioning of allowances to exporters would be foregone in the case of free allocation, or expended again to fund the financial transfer.

Both solutions would be **vulnerable to judicial challenges** because they both represent subsidies under the Agreement on Subsidies and Countervailing Measures (ASCM), which defines subsidies as a financial contribution by a government that confers a benefit. Financial contributions here include both a direct transfer, but also foregone revenue that would otherwise be due. The solution is legally vulnerable since this particular subsidy would be contingent on export performance, that is, it would display a relationship of conditionality or dependence between its award and the exportation of the relevant goods. While interpretations are conceivable that would avoid classification of export rebates as a prohibited export subsidy (Marcu, Mehling, and Cosbey 2022), considerable legal risks remain, which also explains why the EU chose not to include such an export rebate in the CBAM.

This option scores highly, however, in the protection it affords against leakage, and its ability to level the competitive playing field for domestic and foreign producers in export markets. No other policy option fully mitigates the compliance cost faced by European exporters under the

EU ETS. That same strength will also likely **render a full export rebate politically unpopular among trade partners**, as it fully offsets European exporters' disadvantage from carbon pricing, while their domestic producers selling into the EU market are subjected to the full carbon price. The ongoing transatlantic tensions over the Inflation Reduction Act and a long history of contentious trade defence proceedings – resulting in antidumping measures and countervailing duties – underscore the high level of concern elicited by perceived competitive advantages resulting from foreign subsidies. Finally, while the award of subsidies – especially if linked to the carbon content of exported goods and export performance – entails some technical and administrative hurdles, its implementation is likely to be feasible because relevant data is already collected and requisite infrastructure is in place.

2.2.3 Partial Export Rebate

Under the EU ETS, industrial emitters – even those considered to be at risk of carbon leakage – generally do not receive free allocation at a level that covers their emissions. Instead, the number of free allowances is based on historical production levels multiplied by a product benchmark, which reflects the average carbon intensity of the 10% best performing installations producing the goods included in the leakage list.3 While these 10% best performers thus obtain sufficient free allowances to cover the entirety of their emissions, the remaining producers need to purchase additional allowances, with the periodically updated product benchmarks creating an **additional incentive to reduce carbon intensity**. Such a partial approach could also be retained for export rebates, where the number of free allowances or the level of financial compensation could be based on product benchmarks that are based on the performance of the most efficient producers. Additionally, or alternatively, free allocation or financial transfers could be curtailed by a certain share to create a further incentive for emission reductions and lower the risk of overcompensation.

While such a partial export rebate would still suffer from many of the same problems identified in the previous section with regard to how it still, at least partially, mutes the carbon price signal, how it is misaligned with the rapid decline in the number of allowances under the EU ETS, and how it burdens public budgets, it **scores better in terms of the decarbonization incentive it provides to exporters** due to the residual compliance burden. Conversely, this residual compliance burden also lessens the ability of a partial export rebate to fully avert carbon leakage and level the playing field. Legally and politically, while incrementally preferable, such a partial rebate is still likely to elicit many of the same concerns that a full export rebate faces, although the greater environmental benefits may help to justify the rebate.

2.2.4 Innovation support

Technological innovation can lower the costs of emission abatement, and thus also the compliance costs facing exporters covered by the EU ETS. Many support mechanisms to advance research, development, and deployment of new technologies affect a broad set of industries and are hence also relevant for addressing carbon leakage. These support mechanisms are distinct from the export rebates described above in that they do not remit all or part of the costs accruing to producers from complying with the EU ETS, but instead **seek to incentivize the diffusion of abatement technologies by lowering their cost or reducing the financial risk of related investments**. One way to provide targeted innovation support for exporters could be to target the carbon content of production, for instance by dividing a predetermined financial contribution between the 10% cleanest exporters in a specific sector. The prospect of financial support would provide a motivation for investment in novel production technologies beyond the

[3] The preliminary carbon leakage list for the period 2021-2030 is available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018XC0508(01).

incentive from the carbon price. A similar approach to implementing innovation support could consist in awarding subsidies for specific production technologies and making the award contingent on the export of products.

Such approaches in which support is directly coupled to export performance would, however, likely be considered a prohibited export subsidy under the ASCM. To lower the likelihood that innovation support measures violate international law, they could instead be broadly targeted at sectors which are prone to export leakage, **without however distinguishing between goods that are produced for the domestic or for foreign markets**. Measures adopted to foster the decarbonization of exported products would not only help accelerate the transformation in the EU, but would also reduce carbon leakage on the export side. Accordingly, innovation support scores favourably in both its ability to support industrial decarbonization and also – by **also accelerating the decarbonization of foreign producers** who benefit from technological learning – its ability to limit leakage and level the competitive playing field. Since it does not directly alter the competitive playing field in which domestic and foreign producers operate – and indeed technological advances would also benefit producers abroad – it also should encounter significantly less political resistance from trade partners. Finally, there are many established instruments through which innovation support can be operationalized, making this an administratively viable option.

A broad set of instruments can be recruited to this end. For instance, green lead markets that award a premium for certain goods (in addition to the savings related to avoided costs of emission permits) could provide an important incentive for carbon-neutral production. Carbon Contracts for Difference (CCfDs) could guarantee producers that adopt novel technologies, such as investments in capacities to generate renewable or low-carbon hydrogen, a minimum carbon price that would render investments in the technology profitable. Other options include financial de-risking through preferential access to or concessional loans and support for R&D. Long-standing experience with such instruments and the existing institutional infrastructure would likely facilitate the implementation of targeted innovation support to address export-related leakage.

A broad approach of supporting innovation has the advantage of **relatively straightforward administrative implementation**, and would avoid being contingent on export performance, **reducing the likelihood of a violation of the ASCM**. As its impact on producers in other countries occurs only indirectly, it can also be expected to arouse less political resistance than e.g. the CBAM, of which the costs for trade partners are directly visible.

2.3 Comparing the Options

Based on the above analysis, we compare the discussed policy options in terms of their potential to reduce export-related carbon leakage, contribution to the transformation to net-zero, conformity with international trade law, administrative feasibility and political acceptance by the EU's main trade partners (see Table 1).

No single option outperforms the alternatives on all accounts. Yet, some of the options face serious obstacles. For instance, ending free allocation of emission permits without providing any support for exports from CBAM-relevant sectors can be done in a straightforward fashion without provoking resistance by trade partners, but will do little to prevent export-related leakage. By contrast, full export rebates have a high potential to reduce leakage, but would likely violate WTO provisions and are unlikely to be accepted internationally. Partial export rebates might have a higher chance of being compatible with WTO rules and would at the same time entail lower costs than full rebates. However, they would still be likely to face political opposition from trade partners and might be challenged under the WTO dispute settlement mechanism. **The only option that does not display any negative effects is targeted innovation support.**

The decision which option to address export-related leakage **ultimately depends on political preferences**. From our analysis, we consider targeted innovation support a promising option that has the potential to successfully reduce export-related leakage in a way that is administratively feasible, compliant with existing legal provisions, and acceptable for the EU's trade partners. In addition, innovation support could have important implications for the transformation in the EU that go beyond leakage protection. For this reason, we will examine innovation support in more detail in the next section.

Table 1: Comparison of different options to address export-related carbon leakage

Dimension \ Option	End of free allocation, no support for exports	Full export rebate (free allocation or financial compensation)	Partial export rebate (free allocation or financial compensation) based on benchmark	Targeted innovation support
Supporting the transformation in the EU and globally; 2030 targets reached	+	–	o	++
Leakage protection and maintaining competitiveness of EITE industries	– –	++	+	+
Conformity with international and EU law	++	– –	–	+
Costs and administrative effort	++	o	+	o
International political feasibility	++	–	–	+

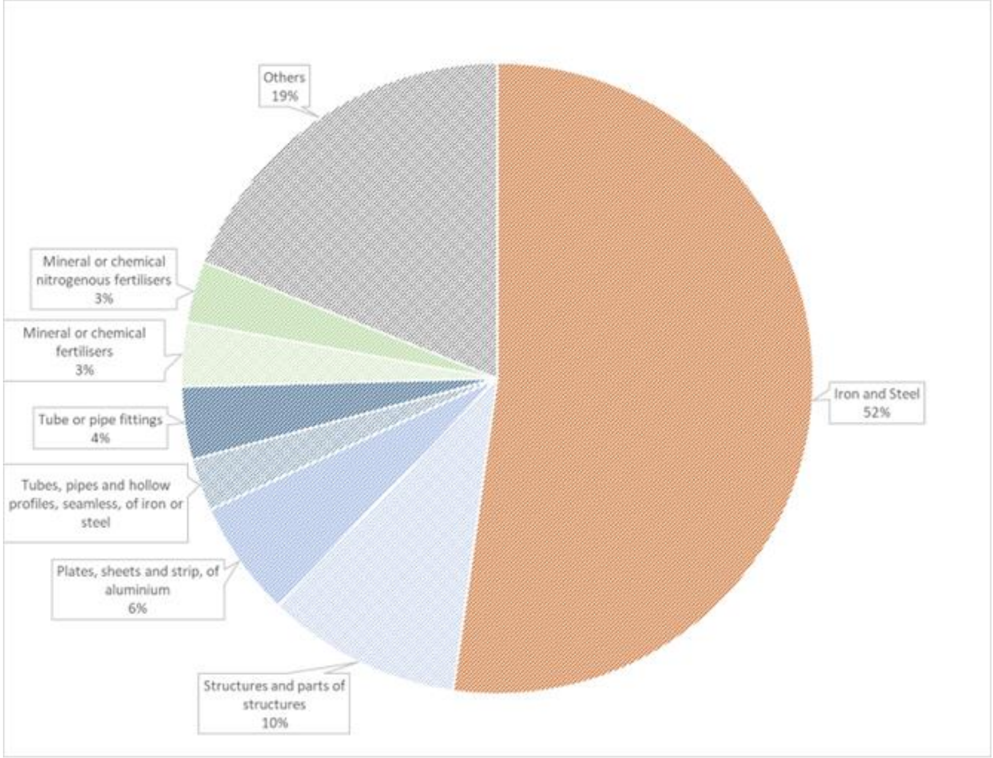
3 In-depth Assessment of Innovation Support

Calculating the amount of finance that would be required to ensure that EU firms are competitive on the global market is a challenging enterprise, which is beyond the scope of this paper. Nevertheless, we perform a simple back-of-the-envelope calculation to be able to assess the order of magnitude of costs that exporters in CBAM-relevant sectors need to bear to employ carbon-free technologies. A straightforward approach to ensure that EU firms can maintain their competitiveness vis-à-vis firms that do not face such costs then consists in **awarding an amount**

of financial support to EU firms that equals their full incremental costs of EU climate regulation.

For the case of steel, which constitutes a sizable portion of exports from CBAM-relevant sectors (see **Error! Reference source not found.**), BCG (2022) estimates that carbon-free production by means of carbon capture and sequestration (CCS) or direct reduction of iron using hydrogen would **increase costs by 175 € and 225 € per ton** of output, respectively. This is very similar to the costs of emission permits required to produce steel in a conventional way, which according to recent estimates produces between 1.6 and 2 tCO_2 per ton of steel, and thus carbon costs ranging between roughly 150 € to 200 € per ton of CO_2. Given that in 2022 steel in the EU traded at around 800 and 1,000 € per ton (Focus Economics 2023), these price increases correspond to relative increases of 15% to 28%. We use **the mean of 22%** and assume that this figure can also be applied as a ballpark estimate for the cost-increase of CBAM-relevant sectors other than steel. Applying this figure to the overall export volume in CBAM-relevant sectors of 65 bn € yields **a cost increase of about 14 bn € per year.**

Figure 1: Share of industries in exports from CBAM sectors



Source: Eurostat (2023)

In the following, we structure our in-depth assessment of approaches to support innovation in sectors that are covered by the CBAM and for which export-related leakage is a serious concern in three central questions: first, which industries should receive which amount of funding? Second, from which sources should the required financial means be acquired? Third, by which instruments should the financial support disbursed? We then elicit guiding principles of how to disburse innovation support in a way that yields the greatest benefit for the transformation of carbon-intensive industries in Europe and beyond.

3.1 Funding: For Which Industries?

With a (hypothetical) export rebate in place, financial flows accruing to different industries would be determined by the benchmark used to calculate emissions and the prevailing carbon price. For innovation support, however, a method to determine which industries should receive which amount of support will be required.

There are two basic approaches to target financial support to the respective industries. The first consists in directly tying support to exports in key sectors by providing a specified payment for e.g. each ton of steel exported from the EU. This approach is straightforward and intuitive but would likely violate provisions of the WTO'S ASCM. Even though one could argue that WTO consistency should not be the highest goal of EU policy making in face of a climate emergency, measures that could be regarded by trade partners as industrial policies primarily designed to advance EU interests in the disguise of climate measures might be politically contentious. Indeed, the Commission has repeatedly emphasized that it is seeking a CBAM design that is aligned with international trade rules. Furthermore, violating WTO rules could lead to retaliation by trading partners, such as the imposition of punitive tariffs, which could undo the gain in competitive advantage for EU firms on the global market resulting from innovation support (Jakob 2021a).

For this reason, it seems preferable to target innovation support to industries that export large quantities of their products but **make the support available regardless of whether the produced goods are exported or consumed within the EU**. Innovation support disbursed in this manner will not achieve the optimal degree of protection against export-related leakage. It will, however, have the additional benefit of fostering the transformation of the respective industries as a whole, which is also a main objective for EU climate policy.

For the output from these industries that is sold on the domestic market, specific support schemes are envisaged to accelerate the transformation of the economy to net-zero. These support schemes are **necessary as a complement to the carbon price** (which ensures that private actors account for the social costs of greenhouse gas emissions) to **address additional market barriers**, such as credit constraints, lack of long-term credibility of climate commitments and myopia in decision-making by private actors (Staub-Kaminski et al. 2014).

Such an approach can be expected to **work best in industries that exhibit substantial economies of scale**, i.e. for which production costs per unit decline with the volume produced. That is, the incentives to adopt cleaner technologies and the decision to export are intrinsically linked. As cleaner technologies can be expected to have lower production costs per unit (if the carbon price is factored in), they can make exporting worthwhile in settings in which production with conventional technologies would only have been profitable for the domestic EU market, where firms can get higher prices due to the protection granted by CBAM. **Also serving the export market could then become worthwhile even at lower prices than those on the EU market as it allows to spread the initial investment costs for clean technologies over a larger output.** Industries that display such economies of scale typically require large-scale initial investments, e.g. to build up production plants, that need to be recovered by charging a mark-up to the costs of producing a unit of output. The emission-intensive industries relevant for CBAM are considered to display such economies of scale, in particular iron and steel (Crompton and Lesourd 2008).[4]

[4] For industries without scale economies, in which costs total production costs are closely in line with the produced volume, support that cannot be specifically targeted at exports needs to bring down costs of each unit and thus also dilute the incentive for saving resource on the domestic market.

One might argue that ramping up the production of e.g. green steel from the EU would lower the world market price and increase consumption, as investments from producers in other countries are sunk and these firms will produce as long as the world market price covers their marginal costs, i.e. even if they are unable to recover their initial investment costs. Nevertheless, **the prospect of not being able to cover investment costs would avoid building up of new conventional capacities and thus help prevent the lock-in that arises from newly built plants** that can be expected to emit for a substantial time period. For the steel industry, delaying decarbonization efforts would use 12% of the remaining carbon budget to reach the 1.5°C target, according to Vogl et al. (2021).

A recent study estimates investment costs for green steel based on direct reduction with hydrogen of around 600 € per ton of capacity (Vogl, Åhman, and Nilsson 2018). Given a total capacity of roughly 200 million tons of steel per year in the EU, **overall investment costs for carbon-neutral steel production can be expected to amount to 120 bn €** (the aforementioned study also estimates that investment costs for direct reduction steelmaking are about 30-40% above the costs of conventional blast furnaces, so that incremental investments costs range from 36 to 48 bn €). For this reason, providing financial support that covers the additional costs for exports from CBAM sectors, which we have estimated to be around 14 € bn per year, **over the course of a decade would be sufficient to cover the entire investment costs of the steel industry to become carbon-neutral**. As costs of clean production can be expected to decline with technological maturity, overall funding needs will likely be substantially lower.

3.2 Funding: Through What Instruments?

An important question for the choice of support instrument is whether the up-front investments or rather the output of specific products should be targeted. **Adopting new production technologies requires large-scale investments.** Firms have an incentive to carry out these investments if they can expect to recover the associated costs in the future as a result of financial support for green products. Nevertheless, with capital market frictions, myopic decision-making and lack of credible commitment, the prospect of future revenues may not provide sufficient incentive for the required large-scale investments. Therefore, innovation support will likely be needed to support initial investments in climate-neutral production methods and also at later stages to account for higher marginal production costs while markets develop.

Instruments to grant preferential access to financial markets can go a long way to decrease investment costs. This is of particular importance for industries that face large capital requirements for up-front investments, such as steel producers. These industries could benefit from e.g. credit lines at rates below market rates or de-risking instruments, such as credit guarantees (Steckel and Jakob 2018). Inclusion of technologies to decarbonize emission-intensive industries in the EU Taxonomy for Sustainable Finance could be an important step to make these technologies eligible for preferential funding, either for private or institutional investors aiming at sustainable asset classes, or for public spending, which is increasingly tied to sustainability criteria (Schütze and Stede 2021).

Whether covering the full (and not only the incremental) investment costs for all steel produced in the EU (not just exported one) would pose a sufficient incentive to produce for the export market **likely depends on the degree of future cost reductions due to technological learning**. According to Richstein and Neuhoff (2022), the 600 € of investment costs estimated by Vogl et al. (2018) can be translated into about 60 € of annualized costs. With current steel prices in the EU of about 800 € per ton, covering this would amount to support of about 7.5% of production costs. We have estimated the costs of clean production to be about 22% percent above the costs of conventional technologies. Hence, if technological learning achieves cost reductions for carbon-free production in CBAM sectors of 15% or more, EU producers whose investment costs are covered by public finance would be cost competitive on the global market. As the respective technologies are still at a very early stage, there is little reliable evidence on cost reductions dur to leaning by doing. Yet, the experience with solar PV suggests learning rates (defined as the rate at which unit costs decline if output doubles) of more than 20%, which has led to cost reductions for panels of more than 90% over the last decade (Nemet 2019).

There are already numerous instruments to accelerate the transformation of carbon-intensive industries in place or under deliberation. **These existing or envisaged instruments could also be used to address export-related leakage** by supporting export-intensive CBAM sectors. Support for the transformation of specific sectors is less well targeted than an approach that explicitly addresses exports. Still, it has three important advantages: first, it has a higher chance of being in line with WTO rules. Second, it can build on an existing institutional setting and does not require establishing new mechanisms. Third, it accelerates the transformation of emission-intensive sectors in general, which is a key goal for EU climate policy. That is, even spending that does not reach its intended target of leveling the playing field for EU exports on the global market is not wasted – rather, it promotes a different desirable social objective.

To support the ramp-up of clean production technologies, a large variety of support schemes exists. For decarbonizing the industrial sectors, an **output subsidy** – e.g. a predetermined payment per ton of green steel produced – is a straightforward approach. From its design, it very much resembles the feed-in-tariffs which have proven a successful instrument to promote the roll-out of renewable energy in the power sector. The logic of this instrument consists in **rewarding learning effects related to the deployment of new technologies** (often called 'technology spillovers') that are not captured by market prices (Jaffe, Newell, and Stavins 2005). These subsidies can be differentiated by technologies to account for different degrees of learning and provide lower rewards for more mature technologies. As an alternative strategy, quantitative targets, e.g. defined as the share of a certain product that needs to be produced in a carbon-neutral way could be adopted. In this case, tenders assigning funding to those firms that bid to achieve a specific output at the lowest costs in a competitive auction (which have gained prominence for new renewable energy sources) might be considered.

Carbon Contracts for Differences (CCfDs) have also received considerable attention in the debate on industrial decarbonization. **CCfDs basically guarantee a certain price for the price of carbon**, so that the respective industries can assess the likelihood that their investment in clean technology will pay off (Sartor and Bataille 2019). If the actual carbon price under the EU ETS falls below that agreed 'strike price', a payment from the public budget would cover the difference. To account for technological learning over time and incentivize early action by first movers, the strike price for the carbon price needs to decline over time. This instrument is mainly designed to reduce uncertainty for investors. As CCfDs usually assume a single strike price that applies to each specific technology, this instrument is less well equipped to account for different learning rates. Yet, that facilitates implementation and makes the instrument less prone to regulatory capture than direct subsidies.

Finally, **increased spending on research and development (R&D) also constitutes an important aspect of innovation support**. Rewards are not constrained to the entity carrying out the R&D and are subject to a high degree of uncertainty. For this reason, R&D is undersupplied by the market and merits public support. Due to the substantial time-lag from research to commercialization, R&D funding should be regarded a long-term strategy that should be part of the portfolio of policies for innovations support, without neglecting other support schemes that are relevant for the short- and mid-term.

To disburse funds, **EU Member States could grant tax credits for firms**. Tax credits are at the heart of the IRA. This instrument is less well-targeted than dedicated support for clean technologies and hence more expensive to deploy at a level that allows exports in CBAM sectors to be competitive on the global market. However, it has the substantial advantage of administrative simplicity and predictability for beneficiary industries. It might also entail lower informational requirements to identify the technologies that should receive support and be less prone to regulatory capture by vested interests.

3.3 Funding: From What Sources?

A straightforward way to source funding for innovation support consists in **using revenues from the auctioning of emission permits**. With the gradual phase-out of free allocation of allowances (which hitherto has constituted the main instrument to address carbon leakage on the domestic as well as the global market), additional revenues will become available that can be channeled into investment support. Recent estimates put the value of emission permits that have been handed out to firms in the EU in 2022 at around 20 bn € (World Bank 2023). That is, **additional revenues from auctioning permits can be expected to be more than sufficient to cover the incremental costs relative to conventional production technologies of exports from CBAM sectors**.

Investments by the private sector will **need to occur before the free allocation of emission permits is phased out**. Hence, it will be necessary to provide financial support that will only be later matched by additional revenues from permit auctions. Such a 'front-loading' of financial support can be achieved by reallocating revenues, e.g. by allocating a smaller share of auction revenues to Member States' budgets for a transitional period. An alternative option is to issue public debt that is jointly guaranteed by all EU Member States and that will later be repaid by additional revenues from permit auctions.

With gradual progression to net-zero, the amount of emission permits will decline over time. Even though permits will likely be available for residual emissions that are offset by negative emissions in other sectors (i.e. carbon dioxide removal, e.g. through afforestation or direct air capture), **auction revenues can be expected to decline in the long run**. In an optimistic scenario, financial support for climate-neutral production technologies would only be required in a transitional period until the costs of these new technologies have declined sufficiently to make them competitive with conventional ones. However, it is also conceivable that costs of clean production will remain higher than those of conventional technologies. In this case (assuming that climate policy ambition in other countries keeps lagging behind that of the EU) continued financial support will be required to ensure the competitiveness of EU producers on the world market, and auction revenues might not be sufficient to cover the associated financial needs. CBAM revenues could then be used to meet the financial shortfall. The European Commission expects that revenues will amount to about 1 bn € per year in the starting period of the scheme. However, it can be expected that revenues will be an order of magnitude higher once the scheme is fully phased in by 2034 (and in parallel free allowances are phased out). In principle one should expect that, as imports and export values in these sectors are of comparable magnitudes, CBAM revenues should be fully sufficient to finance innovation support to an extent that covers the cost difference to conventional production technologies for exports in CBAM-relevant sectors. Nevertheless, to ensure that the CBAM does not lead to adverse effects on low-income countries, a substantial part of the associated revenues should – directly, or through a commensurate increase in international climate finance transfers – serve to support these countries, e.g. to promote the transformation of emission-intensive industries (Beaufils et al. 2023; Springmann 2013). If CBAM revenues are directly and fully recycled back to trade partners with low per-capita incomes, only those revenues collected from countries with relatively high incomes would be available for innovation support. As an alternative, EU Member States could increase their budgets for climate finance in proportion to additional CBAM revenue. In this case, the entire CBAM revenue would be available for innovation support, but Member States would need to establish income streams to meet the additional commitments for their national budgets.

There are several mechanisms that could be used to deploy financial support on the EU level, such as the **Innovation Fund**, the **Recovery and Resilience Facility** or the proposed **Sovereignty Fund**. The Innovation Fund supports innovative technologies and flagship projects to reduce investment risks for the private sector. As the Innovation Fund[5] relies on revenues from permit auctions, the available financial means depend on the carbon price, and disbursements depend on tenders, which creates uncertainty for firms whether they will receive support. Projections assuming a carbon price of 75 € per ton of CO_2 arrive at an overall volume of about 38 bn € in the time period 2020-2030. Even though higher carbon prices seem likely, probably a higher share of auction revenues would need to be channeled to the Innovation Fund if policy makers intend to fully offset the higher costs of exports from CBAM sectors relative to competitors on the global market. The Recovery and Resilience Facility was launched in mid-2021 to help Member States deal with the risk of economic contraction in the wake of the COVID-19 pandemic. It is financed by EU debt and has a financial volume of 723.8 € bn, of which are 338 € bn are grants and 385.8 € bn are loans. These sums, of which to date only a minor fraction has been used, could go a long way to support the transformation of emissions-intensive industries. Funding policies that are adopted by Member States on the national level seems to be the most straightforward approach to use these financial resources within the architecture of the Recovery and Resilience Facility. Finally, the Sovereignty Fund[6] has been announced as a reaction to the US IRA, and concrete proposals for its design are expected in the second half of 2023. This fund could be an entry point to advance joint EU projects instead of redistributing finance between member states.

Further funding can come from EU Member States. Again, the revenue from auctioning emission permits that currently accrues to Member States could be used for this. The Temporary Crisis and Transition Framework has relaxed state aid rules to allow Member States to match subsidies in other jurisdictions, such as those introduced in the US as part of the IRA. A contentious issue in this regard will be the asymmetry in incomes and the challenge that richer Member States prop up their green industries, thus undermining the competitive position of Member States which lack the financial resources to follow suit. For this reason, **innovation support will likely require a blend of finance disbursed on the level of Member States and on the EU level**, respectively, with the latter predominantly targeted at Member States with low per-capita incomes.

Such a scheme could be used in a way that provides incentives to ratchet up funding on the national level by **making financial resources from an EU fund available to support schemes to which Member States make an own contribution**. The Social Climate Fund, which specifies the maximum amounts that Member States can access conditional on co-financing of 25% of the measure from the national budget, could serve as a blueprint for such an approach. To ensure equitable distribution of the funding for innovation support, **the volume of financial resources that a given Member State can claim would need to decrease with per-capita income but increase with the value of CBAM-relevant exports**. In addition, the

[5] See https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund_en

[6] See https://ec.europa.eu/commission/presscorner/api/files/document/print/en/statement_22_5543/STATEMENT_22_5543_EN.pdf.

required own contribution needs to be chosen in a way that allows Member States with low per-capita income to meet the spending needed to access their allotted innovation support.

3.4 Guiding principles for technology support measures

The question of which industries should receive innovation support, from which sources funding should be taken, and through which instruments it should be deployed are tightly related. Firstly, **there are certain issues that are outside the jurisdiction of the EU**. A salient example is tax policy. Thus, measures that involve changes in tax rules, such as the provision of tax breaks, can probably only be implemented on the level of individual Member States. Policies that are harmonized EU-wide will likely have to take on the form of funds. It seems reasonable that these funds should accrue to Member States' budgets and be used for national policies. Secondly, **the preferable policy instrument probably differs between industries and technologies**. Whereas novel approaches might benefit most from funding for R&D or pilot projects to show their feasibility, for technologies at more advanced stages, alternative policies such as financial de-risking through CCfDs or preferential access to credit, which allow them to pass the 'valley of death' from feasibility to market readiness, might be most appropriate to accelerate their commercialization. Policies to support specific technologies have frequently been criticized as economically inefficient and subject to regulatory capture. Nevertheless, it is commonly acknowledged that **transformative change is subject to multiple barriers** (Staub-Kaminski et al. 2014), many of which cannot be addressed directly by appropriate policies, e.g. because of lack of information or institutional constraints. For this reason, there is a role for **policies that alleviate these barriers by providing support for specific technologies in a way that allows for flexibility and experimentation** (Rodrik 2014) – for instance by subsidizing the production of carbon-neutral steel without requiring that a specific technology is used.

To prevent that support schemes lock in public budgets for an indefinite time horizon and use up funds even if the respective technologies have reached maturity, it will be essential to **establish sunset clauses to terminate support**. Hence, funding should follow a clearly defined path. Due to declining costs and to incentivize early action, decreasing financial commitments over time seem reasonable. For instance, financial support could start with an initial volume of 14 bn € (i.e. the estimated additional costs for clean production of exports from CBAM sectors) and decline by 1.4 bn € per year, thus being phased out after a decade. In this manner, the total financial commitment would amount to 70 bn €. Whether this amount of support will be sufficient depends on how quickly technological learning will bring down production costs. Furthermore, financial support granted in other areas, for instance for the production of green hydrogen, will have a crucial impact on the costs of decarbonization faced by firms in carbon-intensive industries. To assess whether support schemes achieve their intended goal and identify cases in which overly generous subsidies are provided and should be gradually reduced, such schemes **require a transparent monitoring process**. An approach in this direction is outlined by Sartor et al. (2022), who propose that by 2029, a review of climate measures adopted in other countries and global market conditions should be carried out to determine whether instruments to support EU exports are still required.

On the global market, the competitive disadvantage of EU firms is the larger the less stringent regulations their competitors face in other jurisdictions. That is, non-EU firms can then produce at lower costs because they are subject to less stringent environmental standards. **Ratcheting up standards in other countries can thus not only help to directly reduce emissions in these countries but would also improve the position of EU producers on the world market**. Support for the transformation of emission-intensive industries in other countries could be financed by recycling CBAM revenues, either directly, or via a commensurate increase in climate finance by EU Member States. This approach would likely **ease political resistance from the EU's trade partners against the CBAM while at the same time lowering the support that will be required to make EU producers competitive on the world market**.

As due to the CBAM prices are higher in the EU than on the global market, **EU producers in carbon-intensive sectors would always prefer to sell on the domestic market**. Innovation support then puts them in a favorable position vis-à-vis foreign competitors that also face the carbon costs because of the CBAM, but do not benefit from innovation support. As a consequence, political pressure could arise in other countries for comparable support schemes to decarbonize industries covered by the CBAM (Jakob 2023). In combination with technology spill-overs that reduce production costs of carbon-neutral alternatives, the EU acting as a first mover could unfold a dynamic that speeds up the transformation of carbon-intensive industries across the globe, and policy makers could build on this momentum with **additional support with regard to finance, technology transfer and capacity building for third countries**. The EU and its Member States have, for instance, recently engaged in Just Energy Transition Partnerships (JETPs) to support coal phase-outs in South Africa, Indonesia and Vietnam (further JETPs with India and Senegal are under consideration). These JETPs aim to mobilize US$ 9, 20 and 15 billion, mainly via loans, but also include some grants. These financial commitments could further be strengthened by the **creation of lead markets for green basic materials in the EU**. That is, the EU could require a certain share of basic materials, such as iron or steel, to be produced in a carbon-free way. Such a policy would provide additional support beyond the carbon price (in the EU ETS and CBAM for domestic and foreign producers, respectively) to deploy novel technologies. Another lever is public procurement, e.g. requirements for green materials used in public infrastructure. Such programs **should be open to all producers, regardless of their geographical origin**, to ensure non-discriminatory treatment that allows to source these materials at the lowest economic costs. Lead markets could provide an important incentive for firms in other countries to change their production technologies. This might also lead them to adopt clean production technologies for other markets that do not reward clean production. For some cases, such as vehicle emission standards or renewable energy subsidies, this 'standard pull' is well-documented in the scientific literature (Buchholz, Dippl, and Eichenseer 2019; Ghisetti 2017). EU initiatives to decarbonize key industries in other countries could benefit from international coordination. Recent proposals to establish a 'Climate Club' might be a promising way to advance industrial decarbonization, and some authors have suggested to put decarbonization of carbon-intensive industries at the heart of such efforts (Hermwille et al. 2022).

4 Conclusions and Outlook

Recent policies to gradually substitute the current practice of free allocation of emission permits by a CBAM to counter the risk of carbon leakage hold great potential to ensure that on the domestic market EU producers face a level playing field vis-à-vis foreign firms that are subject to less stringent climate regulations. However, **export-related leakage, which is not addressed by the CBAM in its current form, remains a serious concern for EU climate policy**.

In this paper we have discussed several options to address export-related leakage. We have argued that all forms of export rebates, regardless of whether they are implemented by means of free allocation for export sectors or direct payments, face serious legal and political constraints. For this reason, **targeted innovation support seems to be a promising option to**

ensure the competitiveness of CBAM-relevant sectors on the global market. In this context, it will be crucial to strike the right balance between targeting support to climate-neutral production and providing sufficient flexibility for innovative approaches. This could be achieved by providing investment support as well as output-based support (e.g. for zero-carbon steel), instead of subsidizing specific production methods. Introducing elements of competition, for instance by competitive tenders, can help to seek out the most promising solutions and ensure that scarce financial resources are used efficiently.

A rough estimate suggests that **about 14 bn € per year might be required for such innovation support**, which could be mainly sourced from auctioning additional emission permits. Financial resources could be disbursed via EU funds, possibly with a requirement for own contributions by Member States to crowd in additional support and take into account countries' financial means. To ensure that innovation support does not violate WTO provisions, it should be **targeted at firms in industries that are export-intensive, regardless of whether these firms produce for the domestic or foreign markets**. This approach would have the additional benefit of promoting the transformation of key industries in the EU. Finally, innovation support for industries in non-EU countries could further help to achieve a more level playing field on the global market for EU producers.

The implementation of such policies will likely be **heavily influenced by recent efforts to employ industrial policies to spur green industries**. The US Inflation Reduction Act (IRA), which is expected to mobilize at least 369 bn US$ for green industries, is a landmark policy in this regard. Recent estimates suggest that public support implied by the IRA could be substantially larger than projected and even surpass 1 trn US$ (Bistline, Mehrotra, and Wolfram 2023). The EU has responded with its Green Industry Plan, which inter alia contains provisions to relax state-aid rules and the Net-Zero Industry Act (NZIA). Even though most of the provisions of the IRA and the NZIA do not directly address CBAM-relevant sectors, they nevertheless might be of crucial importance by, for instance, affecting the costs of key inputs, such as green hydrogen.

Obviously, approaches that directly target exports, such as (partial) export rebates, would be more effective in addressing export-related leakage. Innovation support that targets all production in CBAM sectors as described in this paper, by contrast, has the advantage of a higher likelihood of WTO consistency and a lower potential of political resistance by key trade partners. As it **can build on measures that either already exist or will be introduced anyway to transform carbon-intensive sectors**, the approach discussed here could be implemented in a straightforward manner without significant administrative effort and complexity. Innovation support has the potential to spark the transformation of carbon-intensive industries in the EU and address export-related leakage. It can also **contribute to emission reductions in other countries by buying down the costs of clean production and providing strategic incentives to also adopt innovation support measures** to enable their firms to produce carbon-neutral goods that are competitive on the EU market.

Policy makers can use this window of opportunity to shape emerging industrial policies in ways that yield important synergies between the goals of decarbonizing hard-to-abate sectors in the EU and abroad while at the same time reducing the risk of export-related carbon leakage. The issues discussed in this paper could inform the design of policies that meet these goals.

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