

Happy Birthday: Twenty Years of the EU ETS

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Sterner, T., Burtraw, D., Delbeke, J. et al (2026). Happy Birthday: Twenty Years of the EU ETS. Annual Review of Resource Economics, 18(1): 195-217.
http://dx.doi.org/10.1146/annurev-resource-112624-115720

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ANNUAL REVIEWS

Annual Review of Resource Economics

Happy Birthday: Twenty Years of the EU ETS

Thomas Sterner,[1] Dallas Burtraw,[2] Jos Delbeke,[3] Filip Johnsson,[4] Åsa Löfgren,[1] and Lars Zetterberg[5]

[1]Department of Economics, University of Gothenburg, Gothenburg, Sweden; email: thomas.sterner@economics.gu.se, asa.lofgren@economics.gu.se

[2]Resources for the Future, Washington, DC, USA; email: burtraw@rff.org

[3]School of Transnational Governance, European University Institute, Florence, Italy; email: jos.delbeke@eui.eu

[4]Department of Environmental and Energy Science, Chalmers University of Technology, Gothenburg, Sweden; email: filip.johnsson@chalmers.se

[5]IVL Swedish Environmental Research Institute, Stockholm, Sweden; email: lars.zetterberg@ivl.se

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Annu. Rev. Resour. Econ. 2026. 18:195–217

First published as a Review in Advance on April 15, 2026

The *Annual Review of Resource Economics* is online at resource.annualreviews.org

https://doi.org/10.1146/annurev-resource-112624-115720

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JEL codes: F18, H23, O44, P48, Q54, Q56

OPEN ACCESS

Keywords

EU ETS, carbon pricing, climate policy, emissions trading, environmental taxation

Abstract

Twenty years after its launch, the European Union Emissions Trading System (EU ETS) stands as the world's largest and most mature carbon market. The ETS has developed, from generous allowance allocation and initial price collapse to the introduction of the Market Stability Reserve, enabling more effective emissions reductions. Drawing on major reviews and recent empirical studies shows that the system decreased emissions, limited carbon leakage, and facilitated low-carbon innovation, especially in the power sector. The system evolved from a pure cap-and-trade to a hybrid instrument that adjusted the allowance supply to stabilize prices and functions within a broader policy ecosystem, which influences its effectiveness. However, the EU ETS still faces challenges: decarbonizing heavy industry, considering transport and building, phasing out free allocation, managing social impacts, and more. The EU ETS can teach us to design politically feasible carbon pricing systems that are durable.

1. ESSENTIAL FEATURES OF THE EUROPEAN UNION EMISSIONS TRADING SYSTEM

The European Union Emissions Trading System (EU ETS), launched in 2005, is widely regarded as a cornerstone of EU climate policy. Covering 30 countries, including all EU Member States as well as Norway, Iceland, and Liechtenstein, it is the world's largest ETS in value. The EU ETS regulates approximately 10,000 installations across sectors such as electricity and heat production, cement, steel and metals, pulp and paper, and oil refineries. Intra-EU aviation was included in 2012, and shipping from 2024. The system consists mainly of carbon dioxide (CO_2) emissions and includes some emissions of nitrous oxide (N_2O), methane (CH_4), and perfluorocarbons (PFCs) from specific sources. Currently, the EU ETS covers about 40% of EU greenhouse gas emissions, totaling approximately 1.4 billion tons of carbon dioxide equivalents (CO_{2e}) in 2024.

Over the past 20 years, the emissions of the sectors covered by the EU ETS have been almost halved. Emissions from the power sector declined the most because of a fuel switch away from coal to natural gas and renewable energy sources. Allowance prices today hover around €75 per ton of CO_{2e} and raise an annual revenue of some €40 billion. The system has been well-received by regulators, as it provided certainty regarding future emissions. It was also welcomed by industry for its flexibility, enabling companies to either reduce emissions or purchase allowances. Carbon pricing has an advantage over prescriptive regulation in that regulators typically have difficulties identifying the least-cost opportunities to reduce emissions.

The EU ETS evolved over time, with legislative reviews linked to four distinct periods that were characterized by a gradual strengthening of targets in line with the EU's commitments under the United Nations Framework Convention on Climate Change (UNFCCC): The first phase (2005–2008) was a pilot scheme without banking of allowances; the second and third phases corresponded to the two commitment periods under the Kyoto Protocol, namely 2008–2012 and 2013–2020; and the fourth phase (2021–2030) corresponded to the first period under the Paris Agreement. The latter period coincides with the European Green Deal in which the EU ETS was confirmed as a core element in a package of policies with a view to delivering a 55% emission reduction by 2030 as a milestone toward climate neutrality by 2050. The primary method of distributing emissions allowances, especially for electricity, is with a revenue-raising auction. A Carbon Border Adjustment Mechanism (CBAM) establishes a carbon charge on imported goods equivalent to the EU ETS price and starts replacing free allowances for industry as of 2026. In addition, an adjacent ETS2 will start in 2028 to include emissions from the use of fossil fuels in transport and heating of buildings.

How did all this come about? In the 1990s, emissions trading was seen as an American policy following the United States's successful experiences on the tradable performance standard for the lead phaseout in motor fuels and the cap-and-trade acid rain program for the removal of sulfur in electricity generation. European policy makers tend to favor taxation as the prime instrument for dealing with lead or sulfur in fuels, as well as the use of gasoline and diesel in transport. Carbon taxation in the EU was challenging because taxation is the prerogative of the EU's Member States and thus requires unanimity. A switch was made to emissions trading, as this is a quantitative policy instrument falling under the environmental chapter of the Treaty of Rome. Proposals to introduce price management mechanisms, such as price floors or corridors, were met with resistance and ultimately dismissed to avoid any resemblance to taxation that could politically trigger decision-making through unanimity.

1.1. Setting an Absolute Emissions Cap

Right from its first stage, the EU ETS faced a significant challenge due to a generous initial surplus of allowances and hence a low market price threatening its effectiveness. Empirically, price

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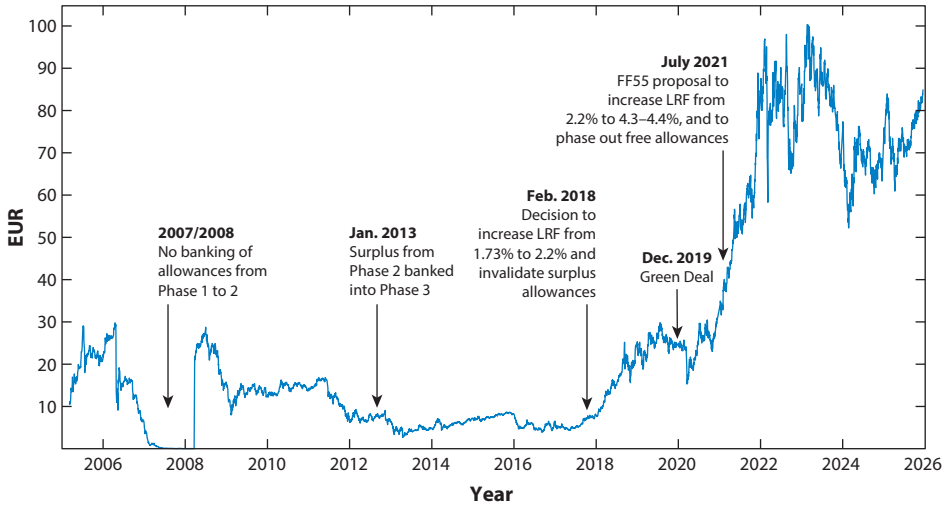


Figure 1

EU ETS allowance prices from March 2005 to December 2025. Price data from the International Carbon Action Partnership (**https://icapcarbonaction.com/en/ets-prices**). Data visualized by the authors. Abbreviations: EU ETS, European Union Emissions Trading System; FF55, Fit for 55; LRF, linear reduction factor.

volatility and prices below ex ante forecasts have been common in emissions markets unless supply adjusts dynamically, for example, with a price floor (Burtraw & Keyes 2018). In contrast, a tax will apply an emissions price independent of the level of emissions. Authorities setting a quantity will also consider the likely cost and emissions outcomes but with considerable uncertainty. If they set very ambitious targets and allocate too few allowances, allowance prices could end up so high that industry and politicians would protest vigorously and perhaps even close the system. Other ETSs are more careful, using a system of relative caps that adapt to circumstances such as economic growth. The EU ETS, however, defines an absolute cap for a predefined trading period, which led authorities to start the system with loose caps and a generous allocation of allowances.

Generous emissions caps characterized the first and second trading phases (2005–2007 and 2008–2012). More than 90% of allowances were allocated for free, managed in a decentralized approach at the Member State level. The financial crisis of 2008 ended in a recession and, concurrent with regulations that supported decarbonization of the electricity sector, led to much less demand for allowances; this got combined with a significant influx of foreign carbon credits from the Clean Development Mechanism (CDM), sanctioned under the Kyoto Protocol.[1] The result was a substantial allowance surplus that caused very low allowance prices ranging between €3 to €8 per tonne between 2012 and 2017 (**Figure 1**), undermining the capacity to incentivize the adoption and deployment of low-carbon technologies.

In recent years, emissions trading schemes and carbon taxes have expanded worldwide to account for approximately 28% of global CO_{2e} emissions in 2024 (World Bank 2025). However, these schemes have so far exhibited a low average price (US$7.9 per ton in 2026) (**https://worldcarbonpricing.org/**). In the EU, as carbon taxation and detailed command-and-control

[1]The EU ETS imported some 1.6 billion certified emissions reductions from the CDM (Meadows & Yordi 2024, p. 108).

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technical regulation were dismissed as alternative options, the prolonged period of low carbon prices created the political space to get serious with setting a more stringent cap for the ETS.

1.2. The Market Stability Reserve

In response to the allowance surplus and low carbon prices in Phase 3, the European Commission assessed six options including (*a*) increasing the reduction target, (*b*) retiring allowances, (*c*) early revision of the annual reduction factor, (*d*) extension of the ETS to other sectors, (*e*) limiting access to international credits, and (*f*) introducing discretionary price management mechanisms (European Commission 2012). As a short-term solution, 900 million allowances were backloaded, meaning they were temporarily withheld from auction and stored for future use. The scholarly literature argued that, because cumulative supply was unchanged, this would have a minor effect on allowance prices, which appeared true (Fell 2016, Hepburn et al. 2016, Holt & Shobe 2016, Kollenberg & Taschini 2016, Perino & Willner 2016, Salant 2016). Following extensive negotiations, it was decided in 2015 to halt the import of international CDM credits and to establish a Market Stability Reserve (MSR). The MSR became operational in 2019, with the backloaded allowances placed in the reserve.

The MSR monitors the total number of allowances in circulation (TNAC) and automatically adjusts the issuance of new allowances to stabilize the market in response. When the TNAC exceeds a specified threshold, a portion of allowances to be auctioned is instead placed into the MSR. Conversely, if the TNAC falls below a certain level, allowances are released from the reserve to the auction. There is a rule that limits the total number of allowances the MSR can hold, set at the volume auctioned in the previous year. In 2018, it was decided that from the year 2023, any allowances exceeding this cap are invalidated, and in 2023, 2.5 billion allowances were invalidated under this rule.

Each year, the emissions cap (total volume of allowances issued annually) is reduced by the linear reduction factor (LRF). The reduction factor is determined as a percentage of the average cap under the system over the 2008–2012 period. Initially, the LRF was 1.74%, but starting in 2021, the factor was changed to 2.2% per year, limiting allowance supply. The announced change in the LRF and the invalidation of surplus allowances had an immediate impact. Allowance prices rose to around €20–30 per ton in 2018. In the 2023 review of the EU ETS, it was decided to strengthen the LRF further to 4.4% by 2030. In February 2023 prices reached a peak of €100 per ton and went down to the range of some €75 in mid-2025 (**Figure 1**).

Since its launch, the EU ETS has evolved significantly through various adaptations, and the creation of the MSR is probably the most important one. Twenty years of the EU ETS offers valuable insights for other regions seeking to implement or enhance carbon pricing mechanisms. In the following sections, we explore these lessons in greater detail. One key element is that the textbook definition of a cap-and-trade system is hard to implement. The generous initial cap in the EU ETS was not equipped to confront unforeseen circumstances like an economic recession or the massive influx of foreign carbon credits. Through the MSR, the absolute cap was gradually tightened and made sensitive to the supply of allowances in circulation involving elements of both cap and tax instruments.

2. DESIGNING THE KEY ELEMENTS OF AN EMISSIONS TRADING SYSTEM

Based on experiences from the EU ETS and North American cap-and-trade systems, this section presents and discusses two key design elements: allowance allocation and cost containment

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mechanisms. We also briefly present how cap and trade systems outside the United States and the EU have incorporated these elements.

2.1. Auctioning and Free Allocation

At its inception, the EU ETS was the world's first carbon market and covered electricity and industrial emissions. To accommodate business interests, the EU initially distributed almost all its emissions allowances for free to incumbent emitters, often in proportion to historic use, known as grandfathering. Coincidentally, in the early 2000s, much of the electricity sector was being restructured into competitive electricity markets, and the infusion of free allowances into competitive electricity markets led to windfall profits because unregulated firms would include the allowances in their power bids and value them at their (carbon market) opportunity cost, rather than their (zero) original cost (Burtraw et al. 2010). This meant companies could charge consumers for something they had received for free. Several scholarly findings and formal investigations identified billions of euros of excess profits (Fell et al. 2015, Lise et al. 2010, Pahle et al. 2011, Sijm et al. 2008), which triggered a move to auctioning in the electricity sector.[2] As of 2013, free allocation to the power sector was abolished with small exceptions.

In Europe's emerging competitive electricity markets, electricity generation companies with carbon-intensive generation assets often continued to profit under carbon pricing with auctions, depending on their portfolio of nonemitting and emitting generation technologies, because the allowance price raised the electricity price when emitting generation was the price-setting technology in the power market. Companies with a relatively greater share of nonemitting generation benefit most, although sometimes carbon costs from inframarginal coal-fired generation outweigh the increase in revenues (Burtraw & Palmer 2008, Möst et al. 2016).

Since 2013, auctioning has been the default method for distributing allowances in the EU ETS, but a large share of allowances is still allocated for free to industry. Initially, grandfathered allocation provided economic rents because facilities would continue to receive generous allocations even if productivity increased or production levels fell. Allocation to industry has since then transitioned from grandfathering to benchmarking, i.e., levels that are set by an emissions rate benchmark and scaled with the level of production. This greatly reduced economic rents and provided an incentive for abatement, but unlike auctioning it suppresses the change in product prices and does not provide incentives to economize on output.[3]

2.2. Cost Containment: Quantity Versus Price Interventions

The EU experience has had global influence on, and, in turn, been influenced by, other market designs. Common across all national systems globally is inclusion of the electricity sector, which generally has proven to be the most responsive sector to a carbon price. Following the EU, the Regional Greenhouse Gas Initiative (RGGI) was the second carbon market to begin operation in 2009, regulating the electricity sector in (currently) 10 eastern US states. The windfall profits associated with free allowance distribution in the EU electricity sector led the RGGI to implement an allowance auction that quickly expanded to include virtually 100% of allowances. In a leapfrog fashion, the success of the RGGI's auction helped legitimize the expanded use of auctions in the EU.

[2]Keppler & Cruciani (2010) estimate windfall profits between 2005 and 2007 to more than €19 billion.

[3]Some have argued for coupling output-based allocation with the inclusion of consumption in the ETS to send a price signal throughout the product value chain (Grubb et al. 2022, Ismer et al. 2016). The main thrust of reform issues is, however, on abolishing free allocation and introducing a CBAM.

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The RGGI was also influenced when prices in the EU fell toward zero toward the end of 2007. In contrast to the EU's later adoption of a quantity-based adjustment to allowance supply, the RGGI adopted an automatic price-triggered adjustment to allowance supply using a price floor in their quarterly auctions, which became a template for auction design in the economy-wide carbon markets in California, Quebec, and Washington state.

Hence, the EU and North American programs both deviate from the textbook definition of a cap-and-trade by dynamically adjusting allowance supply to manage costs, but they use different approaches to do so. The EU's MSR is triggered by the quantity of allowances in circulation in contrast with the price-triggered approach in the North American programs. Reforms, as the ones in the EU ETS in 2018 and 2021, have also offered opportunities to adjust allowance supply, taking into account macroeconomic events and to what extent emissions are actually being reduced.

As in the EU today, allocation to industry in the North American economy-wide programs is based on productive output, providing incentives to maintain economic activity in the state or province. California tethered allocation more tightly to production levels, providing a template for doing the same in the EU. However, the state has a unique approach of free allocation of allowances to electricity and natural gas utilities, who must consign their allocation to the auction with revenues from their sale returned to the utilities to be used for the benefit of ratepayers (Burtraw & McCormack 2017). Most of the value has been returned as a climate dividend to households on an equal-per-residential account basis. However, 2025 program reauthorization redirects all the consignment proceeds to residential electricity ratepayers to explicitly couple carbon pricing with electrification.

Several other features play a role in helping authorities manage costs. The ability to bank allowances for use in future compliance periods to smooth investment decisions and reduce price volatility was copied in the North American programs. The carbon markets exhibit a very limited element of borrowing enabled by overlapping compliance periods and auctions. Unlike the EU, which terminated the use of CDM credits as emissions offsets, the California, Quebec, and Washington programs continue to allow regulated entities to use offsets for a limited share of their compliance obligations. Recent legislation in California aligns it with Washington by requiring that the number of allowances issued under the emissions cap be reduced to balance offset use by regulated entities.

2.3. Carbon Markets Outside the United States and European Union

Important markets are emerging in Asia and elsewhere. The Korean ETS that began operation in 2015 is an economy-wide program. New Zealand's ETS is quite different in scope, as it covers forestry and aims to include agriculture in the not-too-distant future. The China ETS is an intensity-based program and currently covers only the power sector but is planned to be extended to include cement, steel, and aluminum. Today it represents the biggest ETS in volume and is planned to grow from approximately 5 to 8 billion tons of CO_{2e}. Japan has had an ETS in Tokyo since 2010 (Arimura & Matsumoto 2020), and in 2026 a national ETS will be launched (Kyodo News 2025). More countries such as Brazil, Indonesia, and Turkey are preparing ETSs.

The EU and US experiences served as useful blueprints for these schemes, while local circumstances, different economic structures, and political realities determined the final outcomes of their legislation. However, they all face similar issues and challenges, including cap-setting through absolute or intensity-based targets, allocation for free or through auctioning, and flexibilities through price or quantity interventions.

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3. EVALUATING THE EUROPEAN UNION EMISSIONS TRADING SYSTEM

As the world's first and largest carbon market, the EU ETS has attracted significant academic attention, particularly in evaluating its effectiveness and impact on emissions reduction and other economic factors. Its unique approach, combining market-based mechanisms with stringent environmental goals, has made it a focal point for studies seeking to understand its broader implications.

Early reflections on the scheme's initial implementation and challenges were developed by, for example, Convery (2009), Egenhofer (2007), and Ellerman & Buchner (2007). Zhang & Wei (2010) and Venmans (2012) presented early overviews of the emerging empirical research on the EU ETS. A decade after the launch, the *Review of Environmental Economics and Policy* featured a set of 10-year retrospective articles on the EU ETS in which Ellerman et al. (2016) offered a broad look back on the EU ETS, Hintermann et al. (2016) reviewed the literature on market and price behavior, and Martin et al. (2016) synthesized evidence on how firms regulated by the EU ETS have responded in terms of abatement, competitiveness, and innovation. Comparative perspectives have also emerged, such as Narassimhan et al. (2018), who assess eight ETSs, including the EU ETS, highlighting differences in design, implementation, and effectiveness.

In this section, we aim to complement the insights from these earlier reviews with findings from more recent studies, as the EU ETS has now been in operation for 20 years, while also referencing older literature where relevant. However, we do not aim to offer a comprehensive or systematic review. Rather, by highlighting these more recent studies, we hope to provide a useful entry point for readers interested in exploring literature further.

We organize findings from the literature into three distinct areas: (*a*) the EU ETS's contribution to emissions reductions, (*b*) potential carbon leakage and impacts on the competitiveness of regulated sectors, and (*c*) the scheme's influence on innovation and adoption of low-carbon technologies. This division reflects important dimensions along which the EU ETS has been evaluated in earlier literature. Notably, it aligns with the structure used in the review by Martin et al. (2016).

3.1. The EU ETS Contribution to Emissions Reductions

Figure 2*a* illustrates the development of verified emissions from installations covered by the EU ETS since its start, showing a clear downward trend. As shown in **Figure 2*b***, however, this trend varies across sectors. Nonetheless, raw emissions data alone make it difficult to draw causal conclusions about the EU ETS's impact on firm outcomes, as doing so requires disentangling its effects from other influencing factors such as macroeconomic trends, external shocks, and complementary policies.

Two key obstacles are (*a*) the limited availability of reliable CO_2 emissions data for unregulated firms, both before and after the implementation of the EU ETS, as well as baseline (pre-EU ETS) emissions data for regulated firms; and (*b*) the difficulty of establishing a credible counterfactual, i.e., what would have happened if a firm had not been regulated by the EU ETS. Without high-quality data and a convincing counterfactual, it is difficult to make credible causal claims. However, methodological advances have enabled studies to apply quasi-experimental methods and provide causal evidence of the EU ETS's effect on emissions. We highlight six key contributions below.

In Jaraitė & Di Maria (2016), firm-level data from Lithuania covering Phases 1 and 2 (2004–2010) are used to assess the EU ETS's effects on emissions and firm performance.[4] Using a

[4]Sampled firms in the study belong to NACE (Nomenclature statistique des activités économiques dans la Communauté européenne) sectors 10–40 but exclude firms that are service providers.

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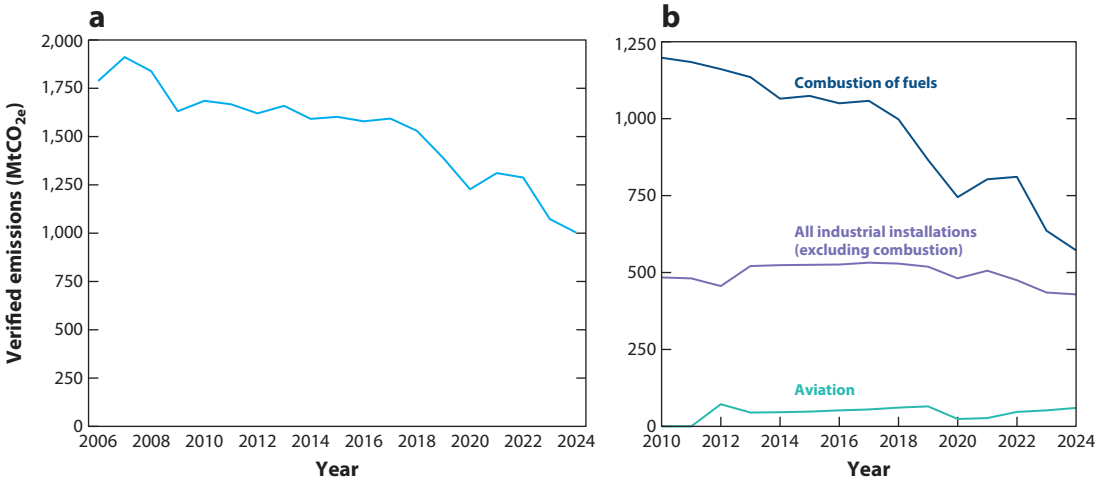


Figure 2

(*a*) Verified $MtCO_{2e}$ (EU27), all stationary installations in the European Union Emissions Trading System (EU ETS), 2005–2024. (*b*) Verified $MtCO_{2e}$ (EU27), by sector, 2010–2024. Data from European Environment Agency EU ETS data viewer (EEA 2025). Visualization by the authors.

matching estimator combined with difference-in-differences (DiD), the authors find no evidence that the ETS reduced overall CO_2 emissions, though they report modest improvements in emissions intensity.

In a study of Norwegian manufacturing plants, Klemetsen et al. (2020) use a matching strategy and DiD to estimate the impact of the EU ETS across Phases 1 to 3, with Phase 3 represented only by 2013 data. They report a large but weakly significant 30% emissions reduction in Phase 2, while cautioning that the estimate should be interpreted carefully due to high standard errors and mixed robustness results. No significant effects are found in the other phases, nor is there evidence of changes in emissions intensity.

Bayer & Aklin (2020) use a generalized synthetic control approach to estimate counterfactual emissions trajectories for EU ETS–covered sectors, using both 2005 and 2008 as alternative treatment start dates. They find that emissions in ETS sectors were approximately 8.1% to 11.5% lower than their counterfactual levels, indicating that the EU ETS caused significant additional emissions reductions beyond those observed in non-ETS sectors. Their results suggest that the EU ETS achieved substantial abatement despite low carbon prices in the early phases.

Dechezleprêtre et al. (2023) examine regulated installations covered by the EU ETS across four countries (France, the Netherlands, Norway, and United Kingdom) using a matched DiD design and estimate that the ETS reduced emissions by around 10% over Phases 1 and 2, with larger reductions in Phase 2 (15%) than in Phase 1 (6%). Their results also suggest that tighter allowance allocation strengthened abatement incentives.

Using French administrative data and a matched DiD framework, Colmer et al. (2025) estimate that the EU ETS led to a 14% reduction in emissions in Phase 1 and 16% in Phase 2 among regulated manufacturing firms relative to comparable unregulated firms.

Finally, Biancalani et al. (2024) adopt a matrix completion method with fixed effects estimation, a recent machine learning–based quasi-experimental technique, as an alternative to DiD approaches to estimate counterfactual emissions trajectories for 17 EU countries in ETS-relevant sectors from 2005 to 2020 (using comparable non-EU countries to construct the counterfactual). Their results suggest that emissions were approximately 15.4% lower than their estimated

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no-ETS counterfactual levels. This alternative strategy provides further evidence of a significant policy impact of the EU ETS and expands the set of tools available for causal evaluation in climate policy.

The estimated emissions reductions in these studies, with the latter four reporting reductions of around 10–16% in the later phases and limited effects in Phase 1, are broadly consistent with those reported by Martin et al. (2016), who report a 3% reduction for sector-level studies in Phase 1, and 10–26% for studies using firm-level data during Phase 2. Taken together, the evidence after two decades indicates that the EU ETS has achieved meaningful emissions reductions, despite relatively low carbon prices in the early phases.

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3.2. Leakage and Competitiveness

Verde (2020) reviews the empirical literature on the competitiveness effects and potential carbon leakage associated with the EU ETS. The overall conclusion is that there is no consistent evidence of significant negative or positive impacts on firm competitiveness, nor of substantial carbon leakage, based on studies covering Phases 1 and 2. This is consistent with several more recent studies. Dechezleprêtre et al. (2022) investigate how the EU ETS influences the spatial allocation of carbon emissions among multinational firms. Their analysis reveals no indication that the EU ETS has triggered a relocation of emissions from Europe to other regions, including those with less-stringent climate regulations or within firms operating in energy-intensive sectors. Naegele & Zaklan (2019) examine how the EU ETS has influenced both the carbon footprint embedded in traded products and overall trade values. Their findings indicate no observable effect of the EU ETS on net import levels, in terms of either trade value or carbon emissions associated. Furthermore, Dechezleprêtre et al. (2023) find that, contrary to concerns about competitiveness, the EU ETS is associated with increased revenue and investment, without adverse effects on profits or employment. That there is no effect on competitiveness or leakage also aligns with Colmer et al. (2025), who find that emissions reductions were achieved without observable declines in output or employment, and with no evidence of leakage through outsourcing. One should note, however, that allowance prices were low in Phases 1 and 2, reducing the incentives to outsource production.

In contrast, a recent study by Wang & Kuusi (2024), drawing on more recent data and higher allowance prices, finds some evidence of carbon leakage associated with the EU ETS. Specifically, the authors show that the policy has contributed to an increase in the carbon intensity of imports into the EU, while simultaneously reducing the carbon content of EU exports. Their overall conclusion is that the EU ETS has led to a moderate rise in the carbon embedded in the EU's trade flows. Finally, D'Arcangelo & Galeotti (2025) investigate how the EU ETS influences cross-country investment decisions, showing that carbon pricing discourages investment within Europe, particularly for energy-intensive firms, although the overall effect on investment relocation appears economically modest.

Narrowing the focus to specific industries, Boutabba & Lardic (2017) find that the EU ETS has had only a minimal effect on carbon leakage and competitiveness in the cement and steel sectors. However, they observe that the steel industry appears more sensitive to carbon pricing than the cement industry, as higher carbon prices were associated with increased net imports in both sectors. This confirms earlier results for the cement and steel industries (Branger et al. 2016), as well as findings for the cement, steel, and aluminum sectors found by Sartor (2013).

3.3. Effect of the EU ETS on Innovation and Adoption of Low-Carbon Technologies

An important aspect of evaluating the EU ETS is its role in driving the development and adoption of low-carbon technologies that can lower the cost of abatement in both the short and long

term. Moreover, if these technologies spill over to firms not directly subject to the ETS, they may contribute to additional emissions reductions beyond the scope of the system.

Several studies have examined the impact of the EU ETS on technological change, with recent literature reviews suggesting overall positive effects, albeit with important caveats. Chen et al. (2025) find that the EU ETS has generally stimulated technological investment, patenting, and the adoption of new technologies, although some studies report null or even negative effects. They note that the results from quantitative studies are generally more positive than those from qualitative studies and also highlight that variation across sectors and regions is an important factor behind these mixed findings. Similarly, Teixidó et al. (2019) conclude that while the ETS has been relatively effective in promoting low-carbon innovation, it has been less successful in encouraging technology adoption, particularly during Phases 1 and 2 when free allocation of allowances dampened investment incentives. The authors note that while empirical evidence for Phase 3 (2013–2020) is still limited, the shift toward auctioning and benchmark-based allocation has enhanced incentives for low-carbon investments.

Individual studies provide more detailed evidence, although most were conducted before allowance prices rose substantially in Phase 3. For example, early empirical work by Delarue et al. (2010) shows that initial emissions reductions in the power sector were largely driven by fuel switching from coal to natural gas. In later years, electricity generation has seen substantial emissions reductions, with carbon intensity falling by 26% between 2019 and 2024 (Rosslowe & Petrovich 2025), largely due to cost-driven adoption of wind and solar technologies that have seen large cost reductions. In contrast, decarbonization in industry, particularly in energy-intensive sectors such as steel, cement, and fertilizers, seem to have been limited. Firm-level studies on the industrial sector, for example, in Sweden (Löfgren et al. 2014), Italy (Borghesi et al. 2015) and Lithuania (Jaraitė & Di Maria 2016), provide limited evidence of the ETS inducing adoption of low-carbon technologies and innovation. This is partly because cutting emissions in industry requires large investments with substantial process interventions and long lead times. These studies illustrate the sectoral and regional heterogeneity emphasized by Chen et al. (2025).

Among the empirical contributions, a few studies stand out for their rigorous identification of the EU ETS's causal effects on low-carbon innovation and technology adoption. Specifically focusing on innovation, Calel & Dechezleprêtre (2016) estimate the EU ETS's causal impact on firm-level patenting, and the authors find that the ETS increased low-carbon innovation among regulated firms by up to 10%, without displacing patenting in other technological areas. The authors also investigate the types of technologies these patents cover, finding that most additional low-carbon patents among regulated firms relate to alternative energy, energy storage, and energy efficiency (although the findings are based on conditional estimates and warrant further investigation). They also find no evidence that the EU ETS influenced patenting activity beyond the group of regulated firms. Further, in a more recent study, Calel (2020) examines both innovation and adoption among British firms, finding that regulated firms increased patenting and R&D expenditure in low-carbon technologies. Specifically, growth in low-carbon patenting and low-carbon R&D outpaced other technologies, rising by approximately 20–30% compared to 3–5% for other technologies. However, the author also shows that regulated firms have not widely adopted technologies to reduce CO_2 intensity, underscoring the importance of distinguishing between innovation and the actual adoption of low-carbon technologies in policy evaluations.

There is also growing attention to the interaction between carbon pricing and technology-push policies. Scotti et al. (2025) find that the combination of the EU ETS and complementary policies and research programs like Horizon 2020 contributed to measurable emissions reductions among energy firms during Phase 3. However, a recent study by Coria & Jaraitė (2026), based on Swedish firm-level data, finds no evidence of synergies between the EU ETS and innovation subsidies:

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Firms subject to both policies do not outperform subsidy-only firms in green patenting, citations, or technological scope, while subsidies increase green innovation, particularly when firms receive larger subsidies.

Although the abovementioned studies primarily examine retrospective effects, assessing the EU ETS's potential to drive future technological transformation, particularly in the industrial sector, requires attention to additional market failures and barriers that may hamper innovation and adoption of low-carbon technologies. In addition to standard learning-by-doing effects, research points to two aspects that are particularly important for industrial decarbonization. The first concerns financial constraints and capital market imperfections (Armitage et al. 2024). Early deployment of capital-intensive technologies such as hydrogen-based steelmaking or carbon capture and storage (CCS) involves large irreversible investments in technologies that are not yet commercially mature and for which early installations often entail costs substantially above engineering cost estimates (Beiron & Johnsson 2024, Emanuelsson et al. 2025), implying significant exposure to downside risk that may exceed firms' financing capacity or risk tolerance even when expected future carbon prices are high.

The second challenge relates to coordination failures, which have been highlighted as a significant hurdle for decarbonizing the industrial sector (see, e.g., Davis et al. 2018, Kushnir et al. 2020, Löfgren & Rootzén 2021). Profitable adoption of low-carbon industrial technologies, such as hydrogen-based steel production and cement production using CCS, often depends on complementary investments in infrastructure, including hydrogen supply and low-carbon electricity (Kushnir et al. 2020) or CO_2 transport and storage networks (Golombek et al. 2023). This interdependence gives rise to coordination problems that may prevent otherwise profitable investments from being realized. Similar challenges may also arise in other energy-intensive sectors such as petrochemicals and fertilizers. Importantly, it is not obvious that higher EU ETS allowance prices (or expectations thereof) will, by themselves, resolve such coordination problems.

In addition, due to long lead times associated with investments in capital-intensive technologies, investment decisions must often be taken well in advance of price realizations. This timing mismatch, combined with capital market imperfections and coordination failures, may limit the ability of carbon pricing alone to induce socially desirable early adoption. Targeted support mechanisms may therefore play a role in accelerating diffusion and overcoming these transitional barriers (Blanchard et al. 2023, Scotti et al. 2025).

In summary, while the EU ETS appears to have played a meaningful role in incentivizing innovation and the adoption of low-carbon technologies, particularly in the electricity sector, the scale and nature of industrial transformation required to meet the 2050 climate targets is unlikely to be achieved through carbon pricing alone. Complementary instruments may be justified in sectors characterized by large indivisible investments, infrastructure dependence, and persistent coordination failures. Recent policy designs, such as the German carbon contracts for difference (Richstein et al. 2024), illustrate attempts to target marginal abatement by conditioning support on realized cost gaps, thereby mitigating concerns about limited additionality and rent extraction. These considerations point to the importance of a coherent and credible policy mix in which carbon pricing is combined with carefully designed technology-push and risk-sharing instruments.

4. REGULATORY POLICIES AS COMPLEMENTS TO EMISSIONS TRADING

Contrary to economic theories, carbon pricing is commonly added to an already existing policy mix and is de facto a companion of regulatory policies. This leads to the question of whether regulatory policies are complementary to the carbon market, or whether the reverse is closer to

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the reality. In any case, the significant emissions reductions achieved under the European Green Deal suggest that both pricing and regulatory policies played successfully together and may well have reinforced one another.

Regulations have their own justifications such as removing barriers to decarbonization by driving innovation and commercializing technology. Many relevant policies are motivated by independent concerns about environmental and public health, economic efficiency, and energy security. Importantly, regulatory policies effectively build economic constituencies that become champions of greater climate policy stringency (Meckling et al. 2017). Altogether this may describe a policy sequence that enables dynamic ratcheting up of stringency (Pahle et al. 2018). The combination of a transparent carbon price with regulatory policies that have less visible costs to consumers seems to allow for the political acceptance of higher climate ambitions.

The electricity sector has been especially affected by regulations aimed at reducing long-range air pollution stemming initially from the acid rain agenda. Regulation of air pollution was combined with climate concerns leading to the planned closure of all coal-fired electricity plants throughout western Europe in the near future and a phaseout of coal for electricity generation by 2038 or sooner in Germany and elsewhere. Coincidentally, generous feed-in tariffs to incentivize nonemitting generation spawned firm-level innovation and spillovers, for example, enabling a dramatic rise in solar energy globally (Gerarden 2023).

The introduction of ETS2 for transportation and buildings will build on many existing regulations, and the interaction of regulations with the market will influence allowances prices. In road transport, Europe has also been a climate pioneer with high fuel taxes that have reduced emissions significantly for decades (Sterner 2007). Going forward, electrification and vehicle efficiency standards may be increasingly relevant. The EU fleet-wide targets for CO_2 emissions from new passenger vehicles will fall by nearly 60% within this decade and aim for a 90% reduction in 2035. When it comes to buildings, there is considerable diversity, but regulation through building codes and subsidies are expected to play major roles in shaping energy use (and supply) in buildings; however, pricing also plays a role (Ewald et al. 2021). In the future, with changing climate, renewables and artificial intelligence, many buildings are likely to become prosumers (both producers and consumers). End-use energy labeling, performance standards, and other policies cover products that consume 50% of EU final energy consumption and collectively are expected to reduce associated consumption by 17% by 2030 (Gonzalez-Torres et al. 2023).

Regulatory policies do not guarantee that a specific emissions target will be achieved. In contrast, a declining ETS emissions cap identifies a numerically specific goal to be delivered, and this can boost confidence that emissions reductions by the covered sources will be achieved over time (unless policies are changed). Further, the expanding influence of the carbon market infuses cost-effectiveness into the climate policy portfolio. In tandem with regulations, the market helps establish the credibility of the emissions target that is necessary to form expectations about the future scarcity of emissions and draw forward private capital to enable the energy transformation (Dolphin et al. 2023, Thibault & Lefèvre 2024).

The expanding influence of carbon markets highlights a dilemma not sufficiently underscored in textbook implementations of cap-and-trade systems. When regulations and other emissions reductions measures by local government, firms, and individuals are effective, they reduce the demand for emissions allowances. If the quantity of available allowances is not adjusted accordingly, successful regulations fail to deliver the emissions reductions. The primary effect is that a reduction in allowance price will unleash a vicious cycle that reduces the market-driven incentive for investment and erodes the credibility of climate policy (Flachsland et al. 2020). This phenomenon is known as the waterbed effect because the emissions cap acts like the volume in a waterbed; that is, when regulatory policies push emissions down in one place, emissions rise at a

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covered entity somewhere else in the market. The price is affected by regulatory activities outside the market, but the emissions outcome is not affected, thus eroding the contribution from regulations.

The waterbed effect can be addressed through a specific quantitative adjustment, which is foreseen by the EU ETS legislation, for example, in case Member States take decisions to accelerate the closure of coal-fired power plants. The EU ETS also has general measures limiting the waterbed effect such as the increased annual reduction percentage or the functioning of the MSR that triggers an automatic adjustment of the allowance supply in response to the number of allowances in circulation. These modalities generated a substantial increase in allowance prices in the EU.

Unlike a price-responsive adjustment to allowance supply (unless it were implemented as a continuous function), the MSR is incrementally responsive over a continuum of market scenarios. Compared to a price-responsive approach, which is instantaneously implemented in the auction, the MSR adjustment is delayed in response to changes in market equilibrium. Consequently, some argue that the market under the MSR approach may be destabilized compared to a price-based adjustment such as a price floor and price steps, and hence the allowance price outcome of the MSR is difficult to predict (Burtraw et al. 2022, Perino et al. 2022). Quantity- and price-triggered mechanisms are different approaches to dynamic adjustment of allowance supply, implementing a hybrid approach suggested by Roberts & Spence (1976) to resolve the seminal problem posed by Weitzman (1974) of the choice between inflexible quantity regulation (caps) and inflexible price regulation (taxes) of an isolated economic variable such as emissions.

5. THE FUTURE OF THE EUROPEAN UNION EMISSIONS TRADING SYSTEM: POLICY DEVELOPMENTS AND POLITICAL REALITIES

After having reviewed the past 20 years of real-life EU ETS, this section looks forward to the next 20 years. The EU ETS has become a hybrid system that is different from what textbooks originally recommended, and its evolution is unlikely to come to a halt.

Further major transformations of the EU ETS can be expected for two fundamental reasons. The first is that the EU is almost halfway through its journey toward climate neutrality. That implies that many emissions reductions, particularly those at the lower end of the cost curve, have been realized. Further emissions reductions are situated higher on the cost abatement curve, and this is reflected in the carbon price that is currently high compared to the past. Although research did not indicate leakage was a substantial problem, the period studied was mostly before 2020. Since then, the ambition gap with Europe's trading partners not implementing comparable carbon pricing widened significantly. Moving closer to climate neutrality also raises the debate about climate mitigation beyond emissions reductions in the form of carbon removals.

Secondly, the political debate related to climate change has become more complicated. A degree of climate policy fatigue appears to be emerging within the EU, a trend that may become more pronounced with the introduction of EU ETS2, which directly exposes households to carbon pricing. However, the most significant development currently underway is the diminishing role of multilateral agreements. This trend extends beyond international trade to climate policy, exemplified by the United States withdrawing from the international climate regime for the third time.

This section covers four issues: the use of EU ETS revenues and the social dimension, the decarbonization of industry, international carbon market cooperation, and the governance of a system that becomes more complicated with every review.

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5.1. Increased EU ETS Revenues and the Social Dimension

Economic textbooks deal with emissions trading almost exclusively from a price perspective and equally advocate for the use of auctioning as an attractive way of allocating allowances. Within the economics literature, relatively little attention has been paid to the use of revenues generated through carbon pricing, although interest in this area is growing, particularly with regard to the redistribution of carbon tax revenues (see, e.g., Douenne & Fabre 2022, Ewald et al. 2022, Hammerle et al. 2021, Sommer et al. 2022). It is worth noting that a related body of literature in political science also addresses these issues (see, e.g., Jagers et al. 2021, Levi 2021, Mildenberger & Leiserowitz 2017, Nowlin et al. 2020).

Support for innovation, investment, and social compensation is often treated as complementary policy, yet these measures are, in many cases, integral to the design and functioning of ETSs. With EU ETS allowance prices currently ranging between €70 and €100, political attention is increasingly turning to the use of the substantial revenues generated. With the introduction of auctioning, Member States were encouraged to spend at least 50% of revenues for climate action and energy transformation, and many exceeded that target (Löfgren et al. 2018). From June 2023, all proceeds (or an equivalent amount) must be spent on climate- and energy-related actions. In 2024, auctioned allowances provided roughly €25 billion in proceeds to national governments for climate-related investments and €9 billion for the Innovation and Modernization Funds (European Commission 2025). The ETS has hence provided billions of euros in climate-related investments. In the future, more political debate can be expected for the use of the substantially increased ETS revenues, as there are many competing demands: social, industry, and climate (e.g., CO_2 removals).

With the introduction of ETS2, the issue of the social dimension came to the fore, as households are directly exposed insofar as they consume fossil fuels to heat their houses and drive their cars. Ninety percent of allowances that are auctioned by Member States are apportioned by Member States' share of historical emissions, and 10% are distributed to lower-income Member States to enable investment and provide compensation. Like energy taxes, the carbon price is often considered regressive, although this is not necessarily true (Feindt et al. 2021). Research has shown that fairness and the effect on low-income households are integral for public acceptance of climate policies (Bergquist et al. 2022, Dechezleprêtre et al. 2025). There is broad consensus that revenues from ETS2 should be earmarked for social purposes, which has led to the establishment of the Social Climate Fund. A key challenge will be addressing the needs of lower-income households, particularly in relation to capital-intensive investments such as home renovations. This is especially pertinent given that clean technologies tend to be more costly during the early stages of their diffusion.

5.2. The Decarbonization of the Manufacturing Industry

Most emissions reductions under the EU ETS have been realized in the electricity sector. The current trend would lead the sector to become almost carbon free over the next decade, but expected increases in electricity use in other sectors and by data centers increase the challenge. As discussed earlier, what made this possible has been the switch from coal to gas and renewables in power generation. The Russian invasion of Ukraine exposed the gas vulnerability of the EU, and the ensuing sanctions regime led to a significant reduction in imports. This was partly compensated for by higher investments in renewable energy, not least in photovoltaics and wind, with the target of 42% for 2030 currently achieved. However, massive investment is still needed not only in more renewable capacity but also in grid expansion and flexibility through storage and demand-side management. Nuclear power may also come into play, but current projects have seen large delays in construction with high cost overruns.

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Further progress will have to include emissions reductions from industry. In response, the European Commission reaffirmed its commitment to achieving climate targets and introduced the Clean Industrial Deal as part of its broader strategy to accelerate industrial decarbonization. Decarbonization appears to be the only structural way to reduce Europe's energy costs and increase its energy security in an increasingly volatile international context. A strengthening of the competitiveness of the EU's industry is being sought through electrification, while prices for this source of energy remain high. The Clean Industrial Deal made clear that the EU wants to reach its climate targets and at the same time maintain its traditional energy-intensive industry, not least in the metals and chemicals sectors. The clean tech industry is expected to further develop and enhance the economic resilience of the EU through strengthening circularity and diversification of critical raw material imports. This could be linked to the creation of so-called lead markets for green products.

A major issue is how to scale-up capital-intensive and risky investment in industrial decarbonization. A strengthened Innovation Fund, along with the proposed establishment of a new Industrial Decarbonization Bank, is intended to scale-up low-carbon investment, with a provisional budgetary envelope of €100 billion (Cornillie et al. 2025). These investment incentives are likely to be funded with EU ETS revenues. This approach mirrors the rebranding of carbon markets in North America from cap-and-trade into cap-and-invest systems, aiming to overcome the mistrust some people have in the role of markets for climate purposes.

Dealing with carbon leakage remains an important issue, particularly in a world where disparities in climate policy become more important. One of the key issues is how to contain circumvention and resource shuffling and how to promote exports, issues that were only marginally addressed in the EU's CBAM legislation in light of keeping the system within World Trade Organization (WTO) rules. The CBAM will apply an import tariff according to the estimated carbon intensity of six product categories: aluminum, cement, fertilizer, steel, hydrogen, and electricity. An issue will be extending the scope of the CBAM. One of the key modalities of the CBAM is the coincidental gradual phase-out of free allowances by 2034, which is a development with significant implications for the metals sectors and one likely to become the subject of more political debate.

5.3. International Cooperation Between Carbon Markets

The CBAM is to be phased in from 2026 and represents an interesting starting point for more international cooperation on carbon markets. A key feature of the CBAM is that importing companies may deduct verified carbon costs incurred in their country of origin from their CBAM duties. This is a major reason for several countries, such as Japan, Brazil, and Turkey, to introduce ETSs and promotes the international diffusion of carbon pricing. It aligns with research suggesting that the introduction of carbon pricing in one jurisdiction can incentivize adoption in others, thereby contributing to broader global emissions reductions (Dolphin & Pollitt 2021). Moreover, Linsenmeier et al. (2023) find that the greatest global benefits from such policy diffusion arise in countries that have not yet implemented carbon pricing mechanisms.

Since Brexit, the United Kingdom has exited the EU ETS, but the political prospects for an explicit linkage between the UK and EU systems are increasing. Notably, the EU has already established a successful linkage with the Swiss ETS. Economic evidence shows that ETSs with many participants from different sectors improve the overall cost-effectiveness of the common system. Linking with more countries could be advisable from an economic perspective but could also be faced with political challenges. Linking between two different constituencies such as the EU and China, for example, would generate major financial streams, making it politically difficult to sustain. Nevertheless, there is scope for bringing design elements of ETSs closer together, for example, in the context of Carbon Clubs (Clausing & Wolfram 2023, Nordhaus 2015).

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The launch of ETSs is politically and administratively demanding. A comprehensive governance system needs to be developed encompassing monitoring/reporting/verification (MRV), registries, compliance, and enforcement provisions, in light of creating trust in the market system. Political decision-making is equally challenging. Instead of engaging in emissions trading, many countries prefer to engage in carbon credits and rely on private actors for several governance tasks. Developing countries may hope to sell carbon credits to developed countries and create an additional form of climate finance. This debate is reinforced because the implementation of Article 6 of the Paris Agreement was adopted in 2024. It may also emerge as part of a cost-containment strategy in industrialized regions such as the EU as ambitious climate targets imply rising costs of abatement. Moreover, carbon credits may represent a way of linking ETSs indirectly with one another. For these reasons, the EU has decided to accept international credits to deliver 5% of its 90% emissions reductions target for 2040. Such international carbon credits will not be allowed directly into the EU ETS and will only be accepted if they meet stringent criteria regarding environmental integrity.

The EU ultimately refrained from including international aviation emissions within the scope of the EU ETS, instead accepting the establishment of an international offset mechanism known as CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation). The system is planned to become mandatory as of 2027. However, the ambition level is weak, and the carbon prices paid are very low. Looking ahead, more substantive action on international aviation can be anticipated, given that it remains a rapidly growing source of emissions, in contrast to the continued decline in the EU's territorial emissions. The EU may take up a leading role on this issue, as it successfully did on maritime emissions as part of the 2023 review of the EU ETS Directive.

5.4. Toward a European Carbon Central Bank?

As the EU ETS is closely linked to the target of climate neutrality by 2050, the volume of emission allowances available on the market is expected to decline sharply, reaching zero around 2040, a dynamic often referred to as the end game (Pahle et al. 2025). That means that in the next 20 years most emissions reductions will have been realized, and that the removal of carbon from the atmosphere may become a more important issue. In the immediate future, carbon removals will accommodate emissions from those activities that take more time to decarbonize or are considered hard to abate. This begs the question of whether the EU ETS should be gradually be opened to credits generated from CO_2 removal activities, from either domestic or international origin or both. This would prepare for a future in which the EU will have to consider a net-negative climate target. In such a scenario, the EU ETS would evolve from a system reducing emissions to a system removing carbon.

Another major issue looming in the background is the merger of the EU ETS for power and industry with the adjacent system of ETS2 for buildings and transport. ETS2 is conceived as a separate system to ensure a secure launch and to limit any negative impact to the well-functioning EU ETS. However, over time one might expect the two systems could be merged, as transportation is being increasingly electrified. Such a merger would subject some three-quarters of the EU economy and its related emissions to a carbon pricing signal originating from the EU ETS.

As discussed earlier, a key feature of the EU ETS is the MSR. While the MSR was crucial to neutralize the oversupply of allowances, the reverse may be needed for the future, as allowances will become scarce. In light of avoiding volatility, or carbon price levels that may be difficult to sustain politically, managing liquidity on the carbon market may become a critical task. Proposals have been formulated to create a European Central Carbon Bank, analogous to how a central bank is managing monetary liquidity (Edenhofer et al. 2024). Such a carbon bank could then also

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oversee other processes such as the convergence between the EU ETS and the EU ETS2, or quality and quantity control on carbon credits.

6. CONCLUDING REMARKS

The EU ETS is now halfway through its fourth phase (2021–2030), marking 20 years since it was first implemented. In this article, we have examined the evolution, impact, and lessons learned from the EU ETS, highlighting its role as a pioneering carbon pricing mechanism. Research indicates that the EU ETS was helpful in reducing emissions, that carbon leakage was not a major problem in the early phases, and that the use of low-carbon technology was stimulated. It was also underlined how well-designed climate policies combine carbon pricing with specific regulatory instruments. However, there remains significant scope for further investigation. The experiences from the EU ETS not only guide European policy makers but also provide valuable insights for other regions aiming to implement effective carbon pricing strategies.

Future research could provide deeper insights into the long-term impacts of the EU ETS and its interaction with complementary policies, not least in the field of energy. Comparative analyses with other ETSs, such as the ones of California, RGGI, China, and New Zealand, as well as newly emerging systems, can also yield valuable lessons for improving the EU ETS and fostering international cooperation.

Over time, ETSs could be linked to one another, thereby letting allowances be traded across different constituencies, while a uniform global carbon price emerges. This is generally easiest between systems that have a similar level of ambition because the trading will imply a de facto mutual recognition of allowances. However, a major challenge for further research lies in balancing the efficiency of such a global uniform carbon price with the political feasibility and flexibility of differentiated prices. A potential approach to achieve this balance is for ETSs to engage in mutual recognition and accept the temporary existence of different carbon prices while gradually working toward convergences in their setup. This could also allow for the integration of emerging carbon credit markets in low-income countries where financial flows are limited. This strategy could facilitate a gradual convergence toward a unified carbon price in the long run.

Furthermore, the diverse interests of countries and regions, shaped by their natural resource endowments and technological capabilities, present both challenges and opportunities for international climate policy. For example, we see currently that fossil fuel–rich regions like North America, Russia, and the Middle East may decide to abandon international climate goals and openly promote fossil fuels. Even when they do collaborate and work toward climate goals, they are likely to favor softer policies like subsidies for emerging low-carbon technologies as their primary climate strategy. In contrast, regions with fewer fossil resources, such as India, Europe, and China, might be more inclined to adopt carbon pricing mechanisms and prioritize technological innovation. Even in Europe we see that the Fit for 55 strategy is being questioned by some parties. These complexities underscore the need for nuanced policy approaches that account for diverse economic contexts and strategic interests of countries with varying resource endowments, while striving to achieve global climate mitigation goals (Wei et al. 2012).

SUMMARY POINTS

1. Over two decades, the European Union Emissions Trading System (EU ETS) has evolved through successive reforms and institutional learning that made the system

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more robust and credible. Its effectiveness rests on the capacity to adjust design features in response to changing economic conditions, political constraints, and surplus accumulation.

2. The EU ETS has gradually moved away from a textbook cap-and-trade design toward a hybrid system that combines elements of quantity and price control. The establishment of the Market Stability Reserve made the cap responsive to the total number of allowances in circulation, adding flexibility and strengthening market stability.
3. Dynamic control of allowance supply has played an important role in improving price stability and strengthening expectations of long-term scarcity, contributing to more credible carbon pricing signals.
4. Empirical research shows that the EU ETS achieved meaningful emissions reductions, with most studies finding limited or no significant adverse effects on competitiveness, employment, or overall economic performance, although effects may vary across sectors and firms.
5. Carbon pricing has driven decarbonization in the power sector, while heavy industry requires complementary policies such as innovation funding, infrastructure investment, and long-term risk sharing.
6. The EU experience underscores the importance of policy sequencing: Early leniency built acceptance, while gradual tightening of the cap and expanded auctioning established trust and political durability.
7. Revenues from EU ETS allowance auctions contribute to the Innovation Fund and Modernization Fund, while the Social Climate Fund, linked primarily to ETS2, aims to address distributional concerns and support public acceptance as carbon pricing expands to households and transport.
8. The EU ETS illustrates how carbon markets can coexist with regulatory and technology-push policies within a broader policy mix and provides important lessons for the design and political feasibility of carbon pricing systems in other regions.

FUTURE ISSUES

1. Greater public investment and coordinated infrastructure planning are needed to help energy-intensive industries such as steel, cement, and chemicals deploy low-carbon technologies including hydrogen, electrification, and carbon capture and storage.
2. As the cap on emissions approaches zero, the EU ETS will need transparent and stringent certification rules for carbon-removal credits to ensure that only permanent and verifiable removals are counted, prevent market distortion, and maintain trust in the integrity of the system.
3. The ETS2 has been somewhat controversial, and as of 2026 its start has been delayed from 2027 to 2028. As ETS2 extends carbon pricing to household fuels for heating and transport, rising energy costs will place a heavier burden on low-income families. Addressing these impacts through targeted support and an appropriate use of the Social

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Climate Fund will be essential to maintain public acceptance and political durability of EU climate policy.

4. Because all EU ETS revenues (or an equivalent amount) are intended to support the green transition under current legislation, future spending should balance investments in emissions reductions, energy system transformation, industrial innovation, and social compensation, as these areas are essential for achieving climate neutrality, strengthening competitiveness, and maintaining public acceptance of carbon pricing.
5. The EU should establish transparent carbon-accounting standards and bilateral agreements that allow importers to deduct verified foreign carbon costs under the Carbon Border Adjustment Mechanism, preventing double charges and building trust with trading partners.

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DISCLOSURE STATEMENT

J.D. was Director-General of the European Commission's Directorate-General for Climate Action from 2010 to 2018. The other authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

Support from Mistra Carbon Exit is gratefully acknowledged. T.S. also acknowledges support from the Kamprad Foundation (project 20230142). Thanks to Hide-Fumi Yokoo, referees, and editors for valuable comments and to Harald Bergh for efficient research assistance.

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