LIFE COASE

Collaborative Observatory for ASsessment of the EU ETS

Providing knowledge for improved emissions trading

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Table of Contents

Introduction

This document summarises the insights collected during the third conference on the ex-post evaluation of emissions trading and the third workshop on ex-ante assessments of emissions trading, which both took place in June 2025.[1] As required in the context of the LIFE COASE project, the conference included presentations of papers that provided an ex-post evaluation of emissions trading systems (ETS), and the workshop included presentations that focused on ex-ante assessments of ETS.[2] The main topics addressed in the workshop were scope expansion of emissions trading, negative emissions, future allowance prices and modelling, market oversight and trading and carbon leakage. The summaries below reflect the insights collected by the Life COASE external collaborators Paul Ekins and Sebastian Osorio.

These two summaries will be the base for the background report shared with to the participants of the second Net Zero Carbon Market Policy Dialogue (NZCMPD), which will take place in October 2025.

Summary of the Third International Conference on Ex-Post Evaluation of Emissions Trading

The EU ETS

Effect of selling emission allowances to firms instead of giving them out for free

Emissions trading systems (ETSs) have now become the main policy instrument globally for mitigating climate change. The recent implementation of emissions trading systems in more countries means that they now cover around 20% of global greenhouse gas emissions. A key consideration in terms of their effectiveness is their design.

In terms of the allocation of emission allowances, there are two main methods: free allocation, which is typically the means of allocation in new systems, and the sale of allowances. The main differences between these two allocation mechanisms are that selling allowances raises public revenue, but also may have effects on the competitiveness of the covered industries. Alder et al. (2025) focused on the economic and environmental implications of the two allocation mechanisms.

The EU ETS has been moving away from free allocation of allowances towards their sale. In 2018 the EU announced which sectors would lose some or all of their free allocation in the fourth emissions trading period, which would start in 2021. Before the change, installations qualified for free allowances if the emission or trade intensities were above 30%, or their emission intensity was greater

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[1] The Conference and the Workshop programmes can be found in Appendix I and Appendix II respectively.

[2] LIFE COASE – Collaborative Observatory for the ASsessment of the EU ETS – is a project co-funded by the EU Life Programme of the European Union. More information: https://lifecoase.eui.eu

than or equal to 5% and their trade intensity was greater than 10%. After the change, the qualification criterion for free allowances was a product of emission and trade intensity that was greater than 30%.

The share of free allowances dropped precipitately from above 80% in 2020 to below 40% in 2021. Using manufacturing firm-level panel data over 2014-2022, Alder et al. (2025) carried out difference-in-differences (DiD) estimation to explore the environmental and economic implications of this change in the allocation rule of free allowances. After 2021, there was a noticeable drop in the emissions from the installations that then had to pay for their allowances, compared to those that continued to get their allowances for free.

The DiD estimation showed clearly that paying for allowances decreases emissions by more than 10%, but that on the economic side, there is a similar decrease in turnover, employment and total assets.

Effect on climate-related investments

Rochlitz (2025) investigated the effect of the EU ETS on firm investment, specifically asking the question whether firms increased spending on climate investments after stricter EU ETS regulation. Reasons given in the literature why this might be so include fuel or product switching, a greater focus on innovation, and possible impacts on competitiveness, the latter of which could result in carbon leakage.

Rochlitz (2025) used data from manufacturing firms in Germany, with climate investments defined as investments in increased energy efficiency (e.g. heat pumps, insulation), emission reduction and renewable energy. As in Alder et al. (2025), this research used DiD estimation of investments between a treatment group of firms that newly entered EU ETS at the beginning of its third phase in 2013, and a control group of firms that were never covered by the EU ETS. The estimation was implemented for the period 2006-2017, i.e. before and after the entrance of installations into the third phase of the EU ETS in 2013, although it sought also to account for anticipation effects, given that the third phase of the EU ETS was announced in 2009. The study sought to identify whether there was a change in total climate investments across all firms, whether there were higher total climate investments per firm that invested, and whether relatively more firms invested.

Simple trend analysis showed that over 2006-2017, climate investments increased for both groups, but that these investments increased more for the treated group, starting in 2011, suggesting some anticipation effect, and this overall effect was confirmed by the DiD estimation. However, the DiD estimation also found that the higher overall level of investment was due to more firms investing, rather than individual firms investing more. Around 85% of the climate investments were in energy efficiency. Future research will seek to determine whether these results were maintained post-2017.

Relationship between lobbying, free emission allowance, allocation and firm outcomes

ETSs around the world routinely allocate free emission allowances to carbon- and trade-intensive sectors in order to reduce the impacts of an ETS on competitiveness and carbon leakage. However, free allowance allocations are broadly declining along with emission caps. Winkler (2022) investigates whether the extent of free allowances does protect the sectors that receive them, by estimating their effect on firm profits, and whether firm lobbying in the maintenance of free allowances is cost-effective. The paper uses a range of data from different sources: firm-level lobbying spending from the EU Transparency Register, which gives daily meetings data over 2014-21; plant-level emissions data from the EU Transaction Log; firm-level data from Orbis; free allocation from sector-level carbon leakage lists; and time series of daily EU ETS prices from Bloomberg.

Free allowance allocation is broadly based on trade and emission intensity, with a cut-off around a trade intensity of 0.3, but there is scope for exemptions on the basis of qualitative criteria, and the data shows that spending on lobbying is higher in sectors with a trade intensity lower than 0.3.

A first regression result suggests that free allowance allocation does increase profitability, and therefore protects competitiveness and reduces carbon leakage. The regression suggests that there is a break at trade intensity of 0.3, and that receiving free allowances increases net profits by €902 million Euro sector-wide, at the 1% significance level. This is 0.16% of average EU GDP. A further result is that lobbying expenditure, and the average returns on such expenditure, increase with the price of allowances, ranging from €1/€ spent in 2016-17, when allowance prices were relatively low, to €4.6/€ spent in 2019, when allowance prices were much higher. However, some sectors received much greater returns: crude oil extraction getting €35, electricity production getting €25 and plastics manufacture getting around €8, per €1 of lobbying spend.

The results suggest that free allowances do increase firm profitability and therefore protect competitiveness and reduce carbon leakage, and that lobbying for such allowances is cost-effective. It will be interesting to see how the situation changes with the introduction of the Carbon Border Adjustment Mechanism (CBAM), which is likely to change free allowance allocation further.

Relationship between actual GHG emissions and carbon prices

Firms covered by the EU ETS have to disclose their greenhouse gas (GHG) emissions each year. And these disclosed emissions suggest that these emissions are reduced by carbon pricing. However, it is possible that this emission reduction is a function of under-disclosure of emissions by firms, rather than a real emission reduction. Chan & Wan (2025) sought to cast light on this issue by exploring the difference under carbon pricing between emissions disclosed by firms in the EU ETS, compared with the emissions estimated by environmentally extended input-output tables (EEIO). If under-disclosure is shown to be a major cause of apparent emissions reduction, a further question is whether this is due to the capacity of firms to make the low-carbon transition.

In terms of data, the study proceeded by generating both disclosed and estimated Scope 1 emissions for firms covered by EU ETS, and by constructing variables of disclosure quality (a weighted GHG emissions ratio consisting of the external cost of disclosed emissions, divided by the external cost of all Scope 1 emissions), transition capacity and other issues related to climate change exposure. Separate regressions were carried out between these and other control variables and the carbon price, lagged by one period.

The result of the first regression suggests that there is indeed a significant negative relationship between carbon prices and disclosed emissions, but that this significance disappears in respect of estimated emissions (which the paper calls ‘actual’ emissions). If indeed it is the case that the estimated emissions are closer to actual emissions than the disclosed emissions, then this suggests that carbon pricing is not effective in reducing actual emissions.

With regard to the weighted GHG emissions ratio, the regression shows that this is negatively and significantly related to the carbon price, suggesting that disclosure quality decreases at higher carbon prices (i.e. there is an increased gap between estimated and disclosed emissions).

When the regression is expanded to include transition and other climate change exposure, it shows that firms with a greater transition capacity tend to decarbonise more and have a higher disclosure quality. There are no significant coefficients between Scope 1 emissions or disclosure quality with regard to climate change exposure.

According to Chan & Wan (2025), carbon pricing might be ineffective if the apparent reduction in emissions is due to under-disclosure rather than real emission reduction; GHG abatement may depend on firms having sufficiently strong transition capacity; and weaker transition capacity may lead firms to under-disclose their emissions rather than abating them. To combat this effect policy makers could introduce measures to ensure high-quality GHG disclosure and, in the longer term, increase investment to boost transition capacity.

Carbon pricing at the international level

Impact of UK ETS on firms' carbon intensity

In 2020, as a result of the vote in 2016 to leave the EU, the UK exited the EU ETS and set up its own ETS, the UK ETS. Data shows that up to about 2023 the UK and EU emissions allowance prices stayed broadly the same, but diverged significantly after 2023, with the UK price becoming significantly lower (with the early 2024 EU/UK prices being around GBP60/GBP40, and the early 2025 prices being around GBP60/GBP35, but with considerable volatility over these years)(Chiappari et al., 2025).

Many firms transitioned from the EU ETS to the UK ETS, providing an opportunity for empirical investigation as to whether this had an effect on their carbon intensity, compared to those firms that remained in the EU ETS, and whether this effect differed for different firms in different sectors, given differences in the EU and UK allowance allocations and pricing mechanisms.

Chiappari et al. (2025) started from installation level data, aggregated at the account holder level, from the EU Transaction Log over 2013-2022 for the EU ETS, and from the UK Emissions Trading Registry over 2021-2022 (i.e. before the EU and UK allowance prices had started to diverge) for the UK ETS. This data has information on annual allowance allocations and verified emissions. The EU (control group) and UK firms (treatment group) were matched according to accounting and other corporate information. A difference in differences regression was carried out of the carbon intensity of the whole sample on various firm-level factors, including whether they belonged to the energy, manufacturing or other sectors, and a range of other variables (ISO certification, territorial variables showing the Brexit vote in different areas (for UK companies) and areas of environmental conservation).

As expected, both UK and EU-matched firms exhibited a general decline in emissions and carbon intensity in 2021 and 2022. The matching of firms was shown to be robust, with no statistically significant difference in emissions between matched UK and EU companies before Brexit. Both before and after the introduction of the UK ETS, the emissions levels and carbon intensities of UK and EU companies remain statistically comparable, and in the whole sample of matched companies after Brexit there seems to be no statistically significant difference in impact on verified emissions and carbon intensity between UK and EU companies. Allocated allowances, environmental certifications, and regional factors seem all to play a role in shaping emissions outcomes.

Impact of EU ETS on Türkiye

Jensen (2025) seeks to determine whether there is an impact of the EU ETS on third countries, specifically countries in the Middle East and North Africa (MENA) region. The research questions were whether the EU ETS led to carbon leakage in those regions, whether there might be a trade policy spillover and what the overall impact was for different MENA countries.

The data used for the regression came from the World Bank Enterprise Survey, the Green Module+.It differentiates between the 'green behaviour' of firms according to whether they are subject to formal influences, such as taxes and public standards, informal influences such as pressure from customers, or engage in self-management of emissions through monitoring or the adoption of targets.

The research demonstrates that the effect of the EU ETS on larger third countries in the MENA region seems to be larger than the general impact of introducing energy conserving measures but the impact differs in sign between countries – for Turkey there is an average positive trade policy spillover, while for Egypt the average trade policy spillover of carbon leakage is negative. For the smaller countries (e.g. Morocco and Tunisia) the results are inconclusive.

Impact of California's carbon pricing policies on renewables deployment

Dilek et al. (2025) focused on the long run effect of carbon pricing in the California ETS, and on the effect on neighbouring states of the introduction of a CBAM in California. Specifically it asked whether the California cap-and-trade scheme caused an energy transition in the California electricity market, and whether the California CBAM caused positive spillover effects into neighbouring states.

The California ETS with a CBAM for the electricity market started in January 2013. The study used a synthetic difference in differences (DiD) methodology, with emissions data from the Energy Information Administration (EIA). Economic, population, climate and state level data came from the Bureau of Economic Analysis, the Census Bureau, the National Oceanic and Atmospheric Administration and different state institutions respectively.

Dilek et al. (2025) found that the ETS significantly increased the percentage of renewable energy in California's energy system. Specifically there was a 143 MW renewable capacity increase in the average Californian county, engendering a 5.18 percentage point rise in California's renewable electricity share. The study also showed that the effect of the California CBAM on the neighbouring states of Arizona and Nevada was substantial, increasing their renewable capacity by 53 MW and 107 MW respectively. The results suggest that carbon pricing can have effects beyond consumption reduction and fuel-switching, incentivising investment in renewables, and that a CBAM can also encourage trade partners to invest cleaner technologies.

Carbon pricing research review

Information about carbon pricing appears in research papers, policy makers reports and economic analysis, reviews of which, Dong et al. (2025)postulate, has led to a corpus of knowledge that is scattered, isolated and redundant. Instead the paper advocates for a 'living ecosystem' on carbon pricing that links together the isolated reviews on different issues related to carbon pricing. The issues include effectiveness, on which a 'living ecosystem' review paper has already been published; innovation, carbon intensity, market efficiency and the labour market, on which similar papers are in progress; and carbon leakage, distribution, public perception and competitiveness, for which authors are still being sought.

The reviews will be 'living evidence': continuously updated, machine assisted and stakeholder-responsive, in order to facilitate faster policy learning and up-to-date decisions. Policy makers will raise questions and define needs, while machine-learning will help researchers with the search and screening of the literature, data extraction, synthesis of results and updating as new studies appear, in order to deliver to policy makers timely and relevant insights.

Policy roundtable: "What future for international climate cooperation?"

Chantal Carpentier opened the debate stating that it is clear that the world is not on track to keep global warming to 1.5^{o}C above average global pre-industrial temperature levels. Rather it is currently heading towards around 2.6^{o}C, with potentially very high climate damage costs. And yet it is also clear that the low-carbon transition offers many business opportunities. However, realising these opportunities, and achieving the target commitments of the SDGs, requires considerable investment, and there is currently a substantial gap between what is required and what has been committed. At least part of the investment challenge could be addressed if developing countries reduced the high tariff barriers that many of them impose on, for example, the import of renewable energy technologies. Climate-aligned foreign direct investment could be attracted by reducing these tariffs through the development of green free economic zones, and by other measures, including support for sustainable finance, knowledge-sharing on green technologies, access to clean technology and innovation and capacity building. UNCTAD has produced a trade and investment guide to help developing countries deliver on these policies.

Catherine Leining discussed how New Zealand currently faces a significant gap between the carbon reduction likely to be delivered by its current policies and its NDC commitment. Closing that gap through domestic action alone would be excessively expensive and disruptive, which is why it is worthwhile looking to Article 6 of the Paris Agreement to facilitate carbon emission reductions in developing countries, where about three quarters of the cost-effective abatement measures to meet the 1.5°C target are to be found. However, a number of 'mindsets' are obstructing New Zealand from making progress on delivering emission reduction in other countries, from 'dismissive detractors', who believe that such expenditures would disadvantage New Zealand, to those arguing for 'least-cost compliance' who seek to maximise offshore carbon abatement, if that is where the cheapest opportunities for such abatement lies. Between these views are those who fear that offshore mitigation will lead to 'carbon colonialism', and those who want to drive as much domestic abatement as possible. Attempts to move forward on this issue of making abatement investments outside New Zealand are impeded by stalled carbon abatement at home (in New Zealand), an excessive focus on immediate costs rather than strategic benefits, a bad experience with the offsetting opportunities under the Kyoto Protocol, and a failure to recognise offshore carbon mitigation as helping the development of the relevant countries. A new mindset of 'climate cooperation' could perhaps help resolve the impasse between the earlier views, reconciling the goals of developing country progress through climate action and attainment of New Zealand's NDC, that also maintains a strong commitment to domestic carbon abatement, delivers cost-effective abatement abroad and promotes global equity. Such an approach could accelerate global progress with both carbon markets and climate finance.

Jos Delbeke presented three issues that can help take forward the discussion on progressing carbon markets: cooperation between ETSs; carbon credits, including through Article 6 and voluntary carbon markets (VCMs); and developments in the EU, which in many ways resemble the discussions in New Zealand. With ETSs proliferating around the world, partly at least in response to the EU CBAM, what is now needed is cooperation between them, moving towards the economists' goal of a global carbon price. There are some positive signs of this cooperation, for example between the EU ETS and the ETSs in Switzerland and the UK, but an interim step may need to be mutual recognition of different countries' ETSs, given the differences between them. On carbon credits the VCM is struggling because of the perceived lack of integrity of many of its credits. It may be that, with some regulation through Article 6 of the Paris Agreement, this situation improves. These developments, together with considerations of limiting the cost of reducing its own emissions and the obvious need of increased climate finance for developing countries, have caused the EU to look more favourably on incorporating very high-integrity carbon credits in its own NDC for 2040, but only to a limited extent (3% of its 2040 NDC) and only from 2036.

In the discussion the first point that came up was how the UN system and other countries should react to the tariffs being imposed by the US. The point was made that the US was only involved in around 20% of world trade, and other countries should continue and cooperate to support the orderly global trading system established under the WTO. Discussion moved on to the issue of monitoring, reporting and verification (MRV) of carbon credits. It was felt that a number of issues need to be addressed right across the issues of positive and negative spillovers related to carbon credits, including the cost of MRV, which would need to be included in the price of the credits. MRV should also be looked on as an opportunity to deepen partnerships between developed and developing countries. A further thought was that full use should be made of new MRV opportunities offered by technologies such as space observation by satellites. It should also be borne in mind that many credits are likely to become available through Article 6 projects, which will have their own MRV requirements. On low-carbon technology more broadly, it was recognised that China was a leader in this field, and there needed to be an approach to trade in these technologies that links it to investment, so that other regions develop their own technical capacity in clean technology. In the EU this could take place through its Clean Trade and Investment Partnerships. In developing countries carbon credits financed through more than one single country could go beyond a project approach and shift whole sectors in a low-carbon direction (i.e., by helping them install the necessary technologies), through 'mini-lateral' agreements. The issue of the extent of credits also came up, with the fears of some NGOs that this would take the form of some sort of neo-colonialism and exploitation of developing country land and other resources, and also the possible effects of massive crediting on the carbon price in developed country ETSs, such as the EU ETS, as happened with the CDM investments. However, the fact remains that trade and investment will be crucial to achieve large-scale carbon abatement and low-carbon development in developing countries, and there could be new initiatives both through Article 6, and through technology transfer between countries with surplus capacity in renewables technologies, such as China, and resource-rich countries that supply many of the minerals on which these technologies depend.

Keynote lecture: "A New Hope? Carbon Market Integration in an Evolving Global Context", Michael Mehling

An early ambition for carbon pricing was for a single global carbon tax or emission trading system. With the former quickly proving unobtainable, the focus shifted to the centralised setting of Quantified Emission Limitation and Reduction Obligations (QELROS), with international emission trading and the 'flexibility' mechanisms of Joint Implementation and the Clean Development Mechanism. These were embodied in the Kyoto Protocol of 1997.

While the implementation of the Kyoto Protocol mechanisms was mixed, the whole approach of the Kyoto Protocol proved unsustainable at the Copenhagen COP in 2009, as a result of which a more decentralised approach was adopted, with countries agreeing to put forward their own Nationally Determined Contributions (NDCs), with the possibility of setting up their own ETSs to help achieve them. The possibility of linking these carbon markets was envisaged as early as 2009, and there were accelerated efforts to build domestic market readiness and bilateral cooperation through such institutions as the International Carbon Action Partnership (ICAP). Several successful linkages between ETSs emerged, but there were also setbacks, most obviously the failure of the USA ever to adopt a national ETS.

More recently there is a new momentum in respect of carbon pricing, with the rapid proliferation of ETSs in different countries. The economic burden of deep decarbonization and pressure to scale up climate finance transfers has also driven the completion at COP29 of Article 6 of the Paris Agreement, which has put in place accounting frameworks that facilitate linkage between emission reductions in different countries. The development of ETSs has also been stimulated by the announcement and imminent implementation by the European Union of its CBAM. At the same time the increasing complexity and anticipated trade implications of the burgeoning ETSs has led to growing interest in harmonization, through such programmes as the OECD's International Forum on Carbon Mitigation Approaches (IFCMA).

2025 has so far seen this momentum maintained: in April the International Maritime Organisation (IMO) agreed on a carbon pricing framework that allowed use of 'surplus' and 'remedial' credits; in

May the EU and the UK agreed an intention to link their ETSs; in June the Brazilian Presidency declared the "harmonization of carbon markets" as one of the key objectives for COP30; and in July the EU announced its willingness to consider use of international credits towards its 2040 mitigation target. However, the carbon pricing momentum is vulnerable to geostrategic rivalries and competing priorities, which impede cooperation, to compliance challenges to measures such as CBAM, and to the perceived stalling of climate leadership. Of course, it may be the case that CBAM is considered compliant with the WTO rules, and that this may lead to a renewed perception of a rules-based trade order, though perhaps also one which is flexible to the requirement of deep decarbonization.

On the economics of abatement it is true that this has led to further political debate about the political desirability and even feasibility of decarbonization, but one response to this issue is that it is well established that carbon pricing is the least-cost means of carbon abatement in many sectors – some calculations suggest that substantial use of carbon trading through Article 6 could reduce mitigation costs by 50% - so that any approach to net zero by the middle of the century should include it in order to get costs down. Both current climate impacts and projections of climate damage costs in the future suggest that the costs of mitigation are, in any case, far less than the costs of unmitigated climate change.

Summary of the third Workshop on Ex-Ante Assessments of Emissions Trading

As emissions trading systems (ETSs) continue to expand globally and confront many of the same challenges, systematic ex-ante model comparisons remain relatively rare. The third edition of the *"LIFE COASE Workshop on ex-ante assessments of emissions trading"* featured several modelling contributions, including the third ex-ante comparison of ETS models. This initiative aimed to enhance knowledge sharing and mutual learning by compiling scientific insights from a diverse set of ETS frameworks around the world (see figure below). In addition to the comparative analysis, this section highlights key takeaways from selected applications of ex-ante models presented during the workshop. As a result, the examples included here reflect a subset of modelling applications rather than a comprehensive review.

EU
Centre for Climate and Energy Analyses (CAKE/KOBiZE) - d-PLACE integrated with other models
ClearBlue Markets - CBM EU ETS Fundamental Model
UK
Department of Energy Security and Net Zero (formerly BEIS) - Carbon Market Model (CMM)
EU / UK
BloombergNEF
Potsdam Institute for Climate Impact Research (PIK) - LIMES-EU
New Zealand
Ministry for the Environment New Zealand - New Zealand Emissions Trading Scheme Market Model

China
Institute of Energy, Environment, and Economy, Tsinghua University - China in Global Energy Model (C-GEM)
ClearBlue Markets - CBM China ETS model
California-Quebec
The Ministère des Finances du Québec (MFQ) and the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP) - Carbon market model
California Air Resources Board and University of California, Davis (Regulator) -
Several jurisdictions
Cambridge Econometrics - E3ME
E3Modelling/Ricardo - GEM-E3

Figure 1. Model's geographical scope and participating institutions in the Workshop.

Model assumptions and carbon prices

The ETS modelling frameworks surveyed demonstrate significant diversity in structure, reflecting different purposes and design trade-offs. Most models adopt a hybrid structure, combining top-down macroeconomic modelling with bottom-up or technology-rich modules for key sectors such as power, industry, transport, or buildings. Specifically, 6 models are hybrid, 3 bottom-up, and 2 top-down.

Temporal granularity is typically yearly (6 models), though many economy-wide CGE or integrated assessment models use 5-year time steps (5 models) to balance detail with computational efficiency. In some cases (e.g., CAKE), seasonal or sub-annual detail is added within key modules like power sector.

Foresight assumptions tend towards limited foresight, applied in 8 models. This usually means actors are assumed to base decisions on 3- to 5-year outlooks (e.g. forward prices, banking). Only one model (LIMES-EU) systematically applies perfect foresight by default, but also has a myopic version. Some models (e.g., CAKE, GEM-E3) apply both types depending on the module — e.g., perfect foresight for energy system optimisation, limited foresight for macroeconomic components.

All models cover the power sector and industry, as central components of ETS modelling. Coverage of buildings, transport, aviation, maritime, waste, and forestry varies, typically included in models with full economy-wide scope or where required by ETS design.

Across the models surveyed, key results reveal both common trends and notable differences in projected ETS outcomes. One consistent finding is that carbon prices generally increase over time in all scenarios, driven by tightening caps, rising abatement costs, and (where relevant) expanding sectoral coverage. However, the pace and magnitude of price increases vary considerably between models, reflecting differences in assumptions about policy stringency, technological progress, and market flexibility.

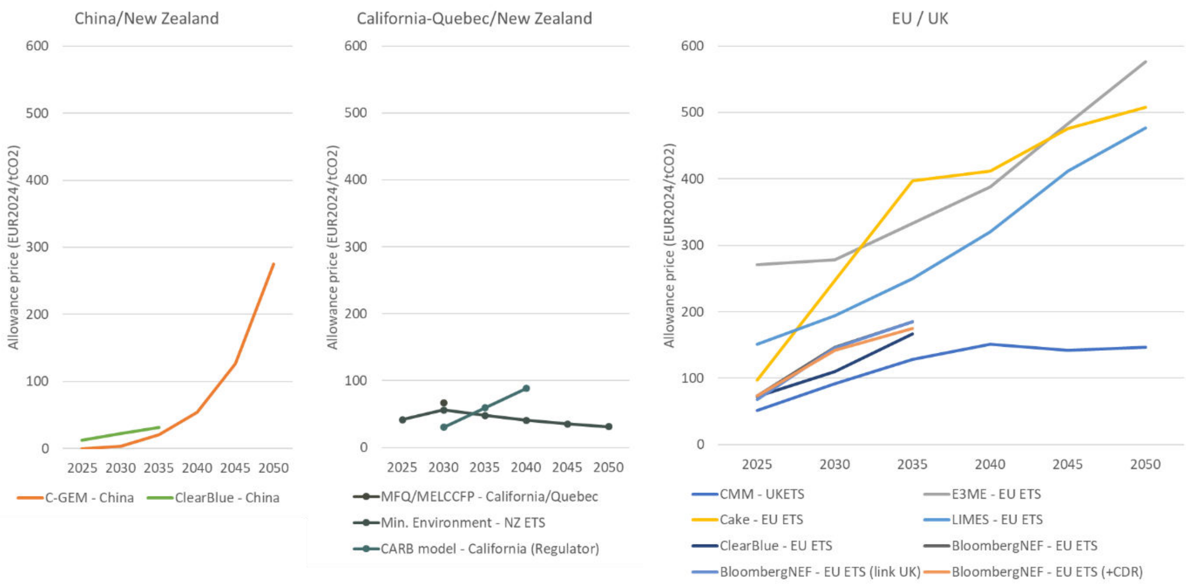

Figure 2. Carbon price estimations for different jurisdictions.

Carbon market linking

Carbon market linking is explored in many models, but it is not a central feature in most baseline scenarios. Instead, it typically appears in sensitivity analyses or scenario explorations, reflecting the current reality that operational linkages are rare or limited. Where linking is represented, it is most often between systems that are already connected or under discussion for linkage — such as the California-Québec partnership, or possible connections between the EU ETS and UK ETS.

The structure of linking varies across models. In most cases where linking is included, models retain separate ETS caps or targets, even when allowances are fungible or pooled. For example, in the California-Québec linked system, models represent a shared pool of allowances and joint auctions, while maintaining separate jurisdictional caps aligned to their targets. Similarly, EU-UK linking scenarios typically assume that allowances are fungible for compliance but that separate caps and price management mechanisms continue to apply.

There is also variation in the scope of linking. Some models focus on full linking of systems, while others explore partial linking, such as limiting linkage to specific sectors (e.g., those covered by the Carbon Border Adjustment Mechanism in EU-UK scenarios). The treatment of price control mechanisms reflects this fragmentation: models generally retain jurisdiction-specific price floors, ceilings, or market stability mechanisms, even in linked scenarios.

Overall, linking is seen as a feature that could provide flexibility and price convergence between markets, but its treatment in models reflects both political uncertainties and the complexity of designing fully harmonised linked systems. Aside from a few operational examples (e.g. California–Québec), most proposed linkages (e.g. EU–UK, China–international) have either stalled or been kept deliberately shallow. As a result, many models treat linking as a hypothetical scenario, rather than a core or likely outcome. Besides this, linking two ETSs with different levels of ambition can create distributional tensions. Even if their ambition is similar, linking is politically sensitive. Countries or regions may be reluctant to surrender control over carbon pricing, especially if linkage might expose them to price volatility, reduce domestic policy flexibility or reduce their revenues (see example of potential linking between Washington to California-Quebec). These political risks are difficult to quantify, making it hard for modellers design robust assumptions for linked scenarios.

Emission Reduction Credits

The inclusion of emission reduction credits (ERCs) in ETS models is generally limited, with most models either not integrating credits at all or doing so only in specific scenarios. Where ERCs are included, they are usually domestic in origin, reflecting either current regulatory frameworks or caution about the quality and monitoring of international credits.

Integration approaches differ. Some models, like CARB's, treat ERCs as fully fungible within compliance, but subject to strict usage limits (e.g. a cap on offset use). Others, such as BloombergNEF or E3ME, include credits indirectly — for example, modelling removals or reductions that reduce compliance costs or carbon taxes rather than acting as tradable substitutes for allowances. Where limits apply, these typically reflect existing policy: for example, the California system caps offset use at 4% through 2025 and 6% after. In China, the ClearBlue model reflects the current 5% cap on the China Certified Emission Reduction (CCER) scheme use in the national ETS.

Most models that include ERCs find that their impact on ETS prices is modest in the near term, largely due to tight limits on credit use or limited credit supply. However, in longer-term scenarios or under assumptions of expanded credit availability, ERCs can provide meaningful cost relief and increase compliance flexibility.

Carbon Dioxide Removals

Carbon dioxide removals (CDR) play a role in most of the models included in the survey, though their treatment and integration into the ETS differ substantially. Across models, CDR is typically considered as a compliance option aimed at balancing residual emissions where abatement becomes costly or technically limited. The technologies most commonly represented are bioenergy with carbon capture and storage (BECCS), direct air carbon capture and storage (DACCS), and afforestation. Unlike the latter, BECCS and DACCS provide permanent storage, allowing them to contribute towards long-term decarbonization goals.

Despite the wide acknowledgement of the need to integrate CDR in the long term, the degree and manner of integration into the ETS vary. In some models, removals are fully integrated into the ETS cap, treated as equivalent to emission allowances. For example, in models like LIMES-EU and BloombergNEF, CDR technologies directly offset emissions within the market, with removal units substituting for allowances on a one-to-one basis. In contrast, other models reflect CDR through offset mechanisms or cost savings rather than as full allowance equivalents. CARB's model, for instance, includes removal credits within California's offset program, where they can be used for compliance but only within defined caps. Similarly, the NZ ETS model integrates afforestation directly by generating allowances tied to forest removals, where supply is driven by the ETS price and land use assumptions.

A key point of divergence among models concerns the constraints applied to CDR deployment. Many models apply explicit limits on potential removals, reflecting assumptions about land availability, biomass supply, or technological readiness. For example, models like LIMES-EU or GEM-E3 impose restrictions linked to sustainable resource use or cost thresholds. Others, such as BloombergNEF, acknowledge that CDR supply will be limited in the near term due to technical constraints, meaning that removals play only a minor role in such a horizon. Where constraints are looser or long-term scenarios are considered, CDR emerges as a more significant driver of price moderation and emissions balancing, particularly in the period after 2040.

There is also variation in how models treat the geographical origin of removals. Such as ERCs, most focus primarily on domestic removals, reflecting current policy frameworks or practical limitations. While a few models explore potential international crediting (e.g. through Article 6 mechanisms), these are generally framed as future possibilities rather than current model features. The size of deployment also varies greatly depending on the jurisdiction: from up to 25 MtCO2/yr in NZ to up to 1300 MtCO2 in China. Furthermore, dependency also seems to vary substantially among them: maximum estimated removals would account for roughly 10% of current emissions in China and the EU, and 33% in NZ[3]. This highlights the very high reliance of NZ on CDR to achieve climate neutrality.

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[3] Estimations based on 2023 emissions: 12.6 GtCO2 in China (https://www.iea.org/reports/co2-emissions-in-2023/energy-intensive-economic-growth-compounded-by-unfavourable-weather-pushed-emissions-up-in-china-and-india), 3175 MtCO2 in the EU (https://climate.ec.europa.eu/document/download/7bd19c68-b179-4f3f-af75-4e309ec0646f_en?filename=CAPR-report2024-web.pdf), and 76 MtCO2 in NZ (https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-19902023-snapshot/).

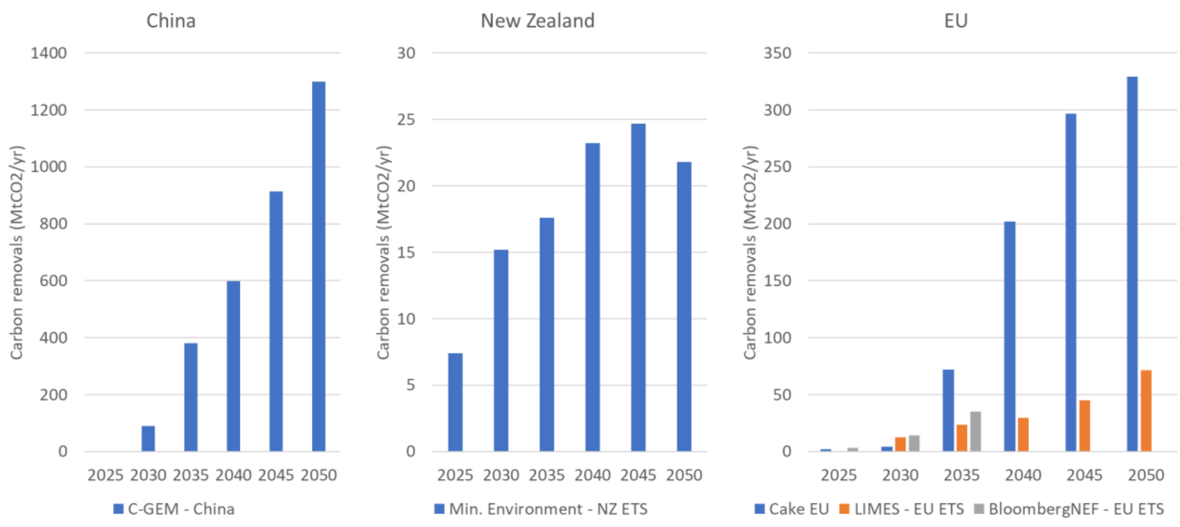

Figure 3. Estimations on carbon removals from different models. Note: Not all model provided figures on their estimations.

Overall, the role of CDR in ETS modelling appears to be both widely acknowledged and highly scenario-dependent. While models consistently show that removals can provide compliance flexibility and help reduce costs, their system-wide impact depends heavily on assumptions about availability, integration rules, and policy design. In most cases, CDR is expected to play a growing role in long-term decarbonisation, but one that is shaped by uncertainties around deployment scale and governance.

Overall, while model details differ, the broad picture is of a carbon market where prices rise over time, compliance costs increase, and flexibility mechanisms like ERCs or CDR can help smooth price paths and support cost-effective decarbonisation.

Additional insights from modelling presentations

In addition to the questionnaire-based analysis, the workshop featured presentations offering deeper dives into regional ETS developments, linkage implications, and the interaction between compliance and voluntary markets. These studies highlight recurring themes found in the survey — such as the role of offsets, price dynamics in linked markets, and institutional design challenges — while also expanding the perspective to include new modelling frameworks and emerging market structures.

The presentation from the LIFE VIIEW 2050 project provided a global perspective, focusing on the macroeconomic impacts of linking the EU ETS to other carbon pricing systems (e.g., China, Korea, UK, USA) and on incorporating offsets from Global South countries. Using a global CGE model (CREAM), the study found that linking can significantly lower EU allowance prices (by 40–60 EUR/t), with modest GDP gains (0.2–0.3%) but limited effects on consumption. Offsets also lower EU prices (by 25–55 EUR/t), with consumption gains across all regions, albeit with GDP losses in the Global South. The study raises questions about welfare distribution and macroeconomic balance, particularly for lower-income regions. The findings stress the importance of balancing cost-effectiveness with equity and broader welfare outcomes, especially as international carbon flows increase.

Focusing specifically on linking, Roy et al (RFF) examined the economic and environmental effects of linking the California-Quebec established cap-and-trade system with Washington's newer program. They emphasised the trade-offs between cost efficiency and revenue distribution, showing how dynamic allowance supply tools could mitigate downside risks. Using the Haiku emissions market model, the authors showed that linking would result in a converged allowance price across jurisdictions, lowering prices in Washington and raising them in California. While this reduces aggregate compliance costs and reduces further emissions, slower emissions reductions in Washington could affect communities. It also leads to revenue redistribution—with California gaining and Washington potentially losing revenue under current rules. The authors emphasised how design features like an Emissions Containment Reserve (ECR) -designed to remove allowances when they are below a trigger price, and add allowances to the market when hitting different price ceilings- can help stabilise revenues and address environmental justice concerns. Overall, the analysis demonstrated how linking can enhance system efficiency while highlighting the need for adaptive program design to manage trade-offs.

In contrast, ClearBlue Markets' work on China's integrated compliance and voluntary markets. It described the expansion of coverage in the Chinese ETS, a steady rise in allowance prices since 2023, and the 2024 relaunch of the CCER program with updated methodologies. Given the difficulty in modelling offsets due to their many different types and costs, technology uncertain evolution, and longer investment horizon, their modelling approach combines bottom-up ETS projections with a forward-looking power system model, and it introduces a novel cyber-physical-social system (CPSSE) to simulate regulatory behaviour under uncertainty. One innovation is the introduction of a regulator-defined exchange rate between allowances and offsets, allowing for differentiated incentives. The approach highlights how dynamic interactions between compliance and voluntary markets—and the regulators who manage them—could shape long-term carbon price trajectories and investment patterns in China. More generally, this study highlights the complexity of governing overlapping markets with evolving targets.

Collectively, these contributions underscore the importance of adaptive, well-governed market frameworks that consider both economic efficiency and distributional outcomes, especially as carbon markets expand and interact more closely at the international level.

Concluding remarks

Although more and more countries implement their ETS keep progressively expanding their scope, they also face increasing pressure due to their impact on the economy. Unlike commodity markets, ETS need to be understood as political markets which are particularly vulnerable to discretionary decisions and political backlash. The challenge is to ensure the credibility of ETSs while maintaining enough flexibility to trigger a decarbonisation pathway that is both stringent and politically acceptable — essential for the system's long-term survival.

Article 6 might play a big role in addressing this challenge, as it can provide the required flexibility to established ETS. However, it can also undermine the system's credibility as it can be seen as a mechanism to water down the system's ambition. How to ensure both flexibility and credibility? Although evidence from the Workshop is limited in this regard due to the nascent nature of expanding ETSs scope, there is increasing interest in the topic. A first glimpse of solutions is on the table, and there is plenty of awareness on the need to address distributional issues as well as adapt the systems based on their particularities.

References

Alder, M., Franzmeyer, E., & Hattemer, B. (2025). *From Free to Fee: How Allowance Allocation Affects ETS Performance*.

Chan, K. J. D., & Wan, W. T. S. (2025). *Beyond Reported Emissions: Carbon Pricing, Disclosure Quality, and Financial Stability in the European Union Emissions Trading Scheme*.

Chiappari, M., Flori, A., Giansante, S., & Zalewska, A. (2025). *Assessing the Impact of the United Kingdom's Withdrawal from the European Union Emissions Trading System on Firms' Carbon Intensity*. https://icapcarbonaction.com/en/ets.

Dilek, G., Teixidó, J. J., & Serrano, M. (2025). *Carbon pricing effects on renewables: evidence from California's electricity market*.

Dong, T.-K.-T., Lim Kim, M., Miersch, K., Banik, B., Repke, T., Mey, B., Gechert, S., Stern, D., Tarun, K., Bruns, S., & Minx, J. (2025). *Toward a Living Ecosystem of Reviews for Evaluating the Impacts of Carbon Pricing*.

Jensen, C. (2025). *The EU's Emissions Trading System and 3rd Countries. -Calibrating a Structural Equation Model with Enterprise Survey Data for Türkiye*.

Rochlitz, F. (2025, July 7). *The Effect of the EU Emissions Trading System on Climate Investments*. [Conference presentation]

Winkler, D. (2022). *Pollution for Sale: Lobbying, allowance allocation and firm outcomes in the EU ETS*. https://ssrn.com/abstract=4114641

Appendix I – Ex-Post Conference Programme

International conference on the ex-post evaluation of emissions trading, 7 July 2025

8:50 – 9:00 | **Welcome**

- Simone Borghesi (EUI, University of Siena)

9:00 – 10:20 | **Session 1: The EU ETS**

- *From Free to Fee: How Allowance Allocation Affects ETS Performance,* **Marie Alder**, **Eva Franzmeyer**, **Benjamin Hattemer** (European University Institute); [Slides]
- *The Effect of the EU Emissions Trading System on Climate Investments,* **Felix Rochlitz** (University of Basel); [Slides]
- *Pollution for Sale: Lobbying, allowance allocation and firm outcomes in the EU ETS,* **David Winkler** (London School of Economics, UC Berkeley)
- *Beyond Reported Emissions: Carbon Pricing, Disclosure Quality, and Financial Stability in the European Union Emissions Trading Scheme,* **Wilson Tsz Shing Wan** (Hong Kong University of Science and Technology), Keith Jin Deng Chan (Hong Kong University of Science and Technology); [Slides]

10:20 – 10:30 | *Coffee break*

10:30 – 11:50 | **Session 2: Carbon pricing at the international level**

- *Assessing the Impact of the United Kingdom's Withdrawal from the European Union Emissions Trading System on Firms' Carbon Intensity,* **Mattia Chiappari** (Politecnico di Milano), Andrea Flori (Politecnico di Milano), Simone Giansante (Università degli Studi di Palermo), Ania Zalewska (University of Leicester School of Business)
- *The EU's Emissions Trading System and 3rd Countries – Calibrating a Structural Equation Model with Enterprise Survey Data for Türkiye,* **Camilla Jensen** (Roskilde University); [Slides]
- *Carbon pricing effects on renewables: evidence from California's electricity market,* **Gökhan Dilek** (University of Barcelona), Jordi J. Teixidó (University of Barcelona), Mònica Serrano (University of Barcelona); [Slides]
- *Toward a Living Ecosystem of Reviews for Evaluating the Impacts of Carbon Pricing,* **Thi-Kieu-Trang Dong** (Hasselt University), Mi Lim Kim (ANU), Klass Miersch (PIK), Banna Banik (ANU), Tim Repke (PIK), Bianka Mey (Chemnitz University of Technology), Sebastian Gechert (Chemnitz University of Technology), David Stern (ANU), Khanna Tarun (SPPGA), Stephan Bruns (Hasselt University, METRCIS, INCHER), and Jan Minx (PIK); [Slides]

11:50 – 12:00 | *Coffee break*

12:00 – 13:00 | **Policy Roundtable: "What future for international climate cooperation?"**

Moderated by Paul Ekins (UCL)

- Chantal Line Carpentier (UNCTAD)
- Catherine Leining (Motu Economic and Public Policy Research)
- Jos Delbeke (EUI)

13:00 – 14:00 | *Lunch break*

14:00 – 14:40 | **Keynote lecture: "A New Hope? Carbon Market Integration in an Evolving Global Context"**

- Michael Mehling (Massachusetts Institute of Technology)

14:40 – 14:45 | **Closing remarks**

- Simone Borghesi (EUI, University of Siena)

Appendix II – Ex-ante Workshop Programme

Workshop on the ex-ante assessment of emissions trading 2025

Programme

9:55 – 10:00 | **Welcome**

- Simone Borghesi (EUI, University of Siena)

10:00 – 11:00 | **Overview of results from survey on ex-ante modelling of ETSs**

- Sebastian Osorio (Potsdam Institute of Climate Impact Research)

11:00 – 11:25 | *Coffee break*

11:25 – 13:05 | **Modelling economic implications of Article 6 and ETS linking – recent evidence**

- 'VIIEW on EU ETS 2050: Linking EU ETS with other carbon pricing mechanisms', Jakub Boratyński (Cake/KOBiZE)
- 'Modelling the interplay between compliance and voluntary carbon markets: a case study of China', Yan Qin (Clearblue Markets)
- 'Considerations for Washington's linkage negotiations with California and Québec', Nicholas Roy (Resources for the Future, USA)

13:05 – 14:00 | *Lunch break*

14:00 -15:15 | **Open discussion on modelling of carbon market integration**

15:15 – 15:30 | **Conclusions**

Programme

9:55 – 10:00 | **Welcome**

- Simone Borghesi (EUI, University of Siena)

10:00 – 11:00 | **Overview of results from survey on ex-ante modelling of ETSs**

- Sebastian Osorio (Potsdam Institute of Climate Impact Research)

11:00 – 11:25 | *Coffee break*

11:25 – 13:05 | **Modelling economic implications of Article 6 and ETS linking – recent evidence**

- 'VIIEW on EU ETS 2050: Linking EU ETS with other carbon pricing mechanisms', Jakub Boratyński (Cake/KOBiZE)
- 'Modelling the interplay between compliance and voluntary carbon markets: a case study of China', Yan Qin (Clearblue Markets)
- 'Considerations for Washington's linkage negotiations with California and Québec', Nicholas Roy (Resources for the Future, USA)

13:05 – 14:00 | *Lunch break*

14:00 -15:15 | **Open discussion on modelling of carbon market integration**

15:15 – 15:30 | **Conclusions**

Appendix III – Ex-ante model features

Table 1 Overview of surveyed model features

Responding organisation	Acronym	Model (suite) name	Approach	Linkage to other ETS	Sectors covered and modelling detail	Start date	End date	Time granularity	Representation of foresight	Inclusion of emission reduction credits	Inclusion CDR
Department of Energy Security and Net Zero (formerly BEIS)	CMM - UKETS	Carbon Market Model (CMM)	Top down	No	Power sector, Industry, Aviation	2024	2050	Yearly	Limited	No	No
Institute of Energy, Environment, and Economy, Tsinghua University	C-GEM - China	China in Global Energy Model (C-GEM)	Top down	Yes	Power sector, industry, Buildings, Road transport, Aviation, Maritime, Waste, other sectors	2020	2060	Other	Limited	No	Yes
Cambridge Econometrics	E3ME - EU ETS	E3ME	Hybrid	Yes	Power sector, industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, other sectors	2010	2100	Yearly	Limited	Yes	Yes
Centre for Climate and Energy Analyses (CAKE/KOBiZE)	Cake - EU ETS	d-PLACE - Computable General Equilibrium model (CGE), MEESA - energy model, TR3E - transport model and EPICA - agriculture model	Hybrid	No	Power sector, industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, other sectors	2020	2050	Other	Both	Yes	Yes
Potsdam Institute for Climate Impact Research (PIK)	LIMES - EU ETS	LIMES-EU	Bottom-up	No	Power sector, Industry, Aviation, Maritime	2010	2070	Other	Perfect	No	Yes

ClearBlue Markets	ClearBlue - China	CBM China ETS model	Bottom-up	No	Power sector, industry, Aviation	2019	2035	Yearly	Limited	Yes	No
ClearBlue Markets	ClearBlue - EU ETS	CBM EU ETS Fundamental Model	Bottom-up	Yes	Power sector, industry, Buildings, Road transport, Aviation, Maritime	2008	2035	Yearly	Limited	Yes	No
E3Modelling/RICARDO	E3M/Ricardo - GEM-E3	GEM-E3	Hybrid	Yes	Power sector, industry, Buildings, Road transport, Aviation, Maritime	2017	2100	Other	Limited	Yes	Yes
BloombergNEF	BloombergNEF - EU ETS	BloombergNEF - EU ETS	--	Yes	--	--	--	--	--	Yes	Yes
The Ministère des Finances du Québec (MFQ) and the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	MFQ/MELCCFP - California/Quebec	Carbon market model	Hybrid	Yes	Power sector, industry, Buildings, Road transport, Aviation, Maritime	2024	2050	Yearly	Limited	Yes	Yes
Ministry for the Environment New Zealand	Min. Environment - NZ ETS	New Zealand Emissions Trading Scheme Market Model	Hybrid	No	Power sector, industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, other sectors	2020	2050	Yearly	Limited	No	Yes
California Air Resources Board and University of California, Davis (Regulator)	CARB model - California (Regulator)	--	Hybrid	Yes	Power sector, industry, Road transport, other sectors	Historical data from 1990 through 2022	Either 2030 or 2040	Other	--	Yes	No