



# **Pricing Carbon Effectively: Lessons from the European Emissions Trading System**

**Dallas Burtraw<sup>1</sup>**

**Resources for the Future**

and

**Michael Themann<sup>2</sup>**

**RWI - Leibniz Institute for Economic Research**

**March 2018**

Policy Brief produced for the *Jean Monnet Network on EU-Canada Relations: The EU and Canada in Dialogue*, which is supported by a grant from the Erasmus+ Programme of the European Union. The Network is housed at Carleton University in Ottawa, Canada, <https://carleton.ca/caneunet/>.



Co-funded by the  
Erasmus+ Programme  
of the European Union

*The content of this policy brief does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in therein lies entirely with the author(s).*

---

<sup>1</sup> Dallas Burtraw is Darius Gaskins Senior Fellow in the Energy and Climate Program at Resources for the Future (RFF), 1616 P Street NW Washington, DC 20036, USA. E-mail: [Burtraw@rff.org](mailto:Burtraw@rff.org)

<sup>2</sup> Michael Themann is Researcher in the Environment and Resources Department at RWI - Leibniz Institute for Economic Research (RWI), Invalidenstrasse 112, 10115 Berlin, Germany. E-mail: [Michael.Themann@rwi-essen.de](mailto:Michael.Themann@rwi-essen.de)

## Summary

The EU Emissions Trading System (EU ETS) is the world's largest carbon market and has become a model for market-based approaches to reduce greenhouse gas emissions in other world regions. Evaluating and improving its effectiveness has thus not only been a concern for European policymakers, but for the success of carbon pricing policies at a global level.

Conventional wisdom is that the environmental effectiveness of a cap-and-trade system like the EU ETS is guaranteed. This expectation is based on its design, which limits total emissions to a specific level (the emissions cap), and the expectation is supported by the observation that compliance with cap-and-trade programs is virtually 100 percent, meaning the emissions target is achieved.

Nonetheless, many observers have challenged the role of cap and trade. The major concern is that prices for emissions allowances (EUAs) are typically too low to incent innovation and investment in low-carbon technology that is necessary to comply with the EU's long-term emissions reduction goals for 2030 and 2050. A second concern is that the emissions cap also serves as an emissions floor; that is, it is not only a maximum level of emissions, but specifies the actual level of emissions that will result. This appears to hamstring the ability of independent actors or subsidiary jurisdictions such as member states in the EU to pursue emissions reductions beyond the EU's own goals. These challenges have led to calls for a thorough reform of the EU ETS.

In contrast, objections are voiced from those who feel that the ETS price on carbon already imposes an unfair cost on industry in the EU, which has to compete with unregulated industries in other countries. Even at present low prices, industry groups have stressed that the economic impacts of the trading scheme may undermine their ability to compete in international markets.

This policy brief begins with a review of the empirical evidence on the accomplishments of the EU ETS and concerns about industry competitiveness. We discuss various drivers of current and future EUA price development. While the EU ETS undeniably has had some success in reducing emissions and alleviating economic costs in the short term, the current policy design raises concerns about its success in the long run. The persistent low allowance prices introduce the risk that high-carbon infrastructure and industrial assets will become locked in, making it expensive to achieve long-term carbon reduction goals.

To address these structural flaws, we argue for a comprehensive carbon price signal supported by a minimum price floor in the EU ETS. Such a measure would stimulate the demand for low-carbon technologies. This reform is also essential to mitigate the economic and political costs of carbon pricing that may otherwise rise steeply in the future and become detrimental to achieving the climate goals under the Paris Agreement. A recent reform in the EU – the Market Stability Reserve – takes a step in the right direction; however, it appears insufficient to arrest our concern fully. We look to the North American carbon trading programs, which all have a minimum price floor, as models that can influence the EU's program design. In this regard, the lessons obtained from the European experience have important implications for the functioning and expansion of carbon markets worldwide.

## **Reviewing the evidence: how is the EU ETS doing?**

Since the inception of the EU ETS in 2005, European energy and manufacturing industries face a yearly decreasing cap on their total amount of greenhouse gas emissions. The trading scheme represents a central pillar of the European Union's effort to comply with its commitments under the Paris agreement. For the year 2030, the EU's objective states that emissions are to be reduced by 40% compared to 1990 levels. In accordance with the 2030 Climate and Energy Framework, the EU ETS regulated sectors will contribute to this by a 43% reduction, whereas non EU ETS sectors, mainly heat and mobility, will provide a 30% reduction, both of which relative to 2005 levels (EU 2018).

The trading program has gone through three phases and will begin a fourth in the next decade, each with various reforms aimed in large part at increasing the allowance price. Still, the EU ETS continues to exhibit EUA prices well below the levels that were originally anticipated.

At first glance, low prices should appear to be good news, because it implies that emissions reduction goals are not expensive to achieve. Also, from a technical point of view, the environmental effectiveness of a cap-and-trade system like the EU ETS is guaranteed: by design the emissions can never be above the cap and the reduction targets will be automatically reached. As long as the level of the cap is sufficiently ambitious, the policy will be effective. However, the concern about low prices takes shape in a long-run perspective. It appears that the price level today is not sufficient to initiate innovation and investment that are necessary to achieve long-run goals, and thereby undermines the credibility of those long-run goals.

There is evidence of success in the short run. In recent years, emissions have fallen sharply in European industry and energy sectors. Empirical studies suggest that, to a degree, this development can be attributed directly to the EU ETS.<sup>3</sup> Estimates based on aggregate data show that in the very moderate trial phase (2005-2007) emissions decreased by about 3% (Anderson and Di Maria 2011; Ellerman and Buchner 2008; Ellerman et al. 2016). Micro-data studies on German and French EU ETS firms suggest a 10-28% emissions reduction when compared to non-regulated firms (Petrick and Wagner 2014; Wagner et al. 2014). Most of the effects found in these studies are directly related to the stringency in Phase II (2008-2012), especially the early years of that period, when the EUA price was around 15€. However, effects on innovation appear to have been more moderate; a mere 1% increase in total European low-carbon patenting can be attributed to the policy (Calel and Dechezleprêtre, 2016).

In terms of total EU ETS emissions, reduction targets have in fact been overachieved. In late Phase II (2008-2012) and the currently running Phase III (2013-2020), total emissions have been consistently below the cap. Such an outcome might be consistent with banking of allowances at the beginning of the program in order to reduce the costs of compliance later. However, to an important degree, this development can be attributed to other emission reduction factors such as the effect of the economic crisis and policies aimed at increasing the share of renewable energy and the degree of energy efficiency (Gloaguen and Alberola 2013; Bel et al. 2015).

---

<sup>3</sup> We refer the reader to Ellerman et al. (2016) and Martin et al. (2016) for more comprehensive reviews.

## **Has the EU ETS harmed the competitiveness of industry?**

The transition towards a low-carbon economy will undeniably affect decisions on production, factor allocation and investment. Unsurprisingly, these economic impacts of the EU ETS have received a lot of attention from economists, policymakers and industry representatives. A major concern has been that during this adjustment, increased production costs might impede regulated companies from competing successfully in international markets. Eventually, firms might even relocate their carbon-intensive production to countries with less ambitious carbon regulation – a process that could severely undermine the ambition to curb emissions at the global level.

Empirical evidence suggests that, until now, this threat has clearly been overstated. Regulated firms have not shown any indication of relocating their production. The average risk to downsize European operations in response to the EU ETS has been low with most firms reporting no plans to considerably cut production or employment (Martin et al. 2014). Companies are found to be committed to their European asset bases and do not show any signs of downsizing (aus dem Moore et al. 2017). EU ETS firms instead increased their fixed assets (machinery, equipment) in the first two trading periods on average by 11 to 15 percent compared to a control group. Empirical studies have also unequivocally rejected the idea of an increase of foreign direct investments (FDI) or a shift of emissions towards non-EU regions by regulated companies in response to the carbon policy (Koch and Basse Mama 2016; Dechezleprêtre et al. 2015).

These studies also find some variation in the response to the EU ETS among sectors and firm types. Some multinational companies apparently did invest in their European asset bases to a lesser degree or did notably increase their outward FDI. However, these firms represent a negligible share of the respective EU ETS emissions (less than 4%) and stem from comparatively clean industries that are more geographically mobile due to low capital intensities (aus dem Moore et al. 2017; Koch and Basse Mama 2016).

A recent study uses total factor productivity as a comprehensive measure of costs and benefits induced by the EU ETS and shows that the effect depends on the level of a firm's technological advancement (Themann and Koch 2018). Technologically more advanced firms are more likely to cope with the costs of a carbon price or even increase their productivity. In contrast, firms operating behind the technology frontier are more likely to face a productivity slowdown.

In an effort to mitigate any adverse effects, the EU has set up a program of granting free allocation of EUAs to companies in energy- and trade-intensive industries that are perceived to be at a considerable risk of downsizing and/or relocating their production. The main issue is that the criteria currently used do not capture this risk well. The practice has thus led to substantial overcompensation. An alternative, more cost-effective allocation scheme based on more refined criteria would instead reduce the aggregate risk of downsizing by more than half compared to the current practice – without increasing the public cost of compensation (Martin et al. 2014, 2015).<sup>4</sup>

---

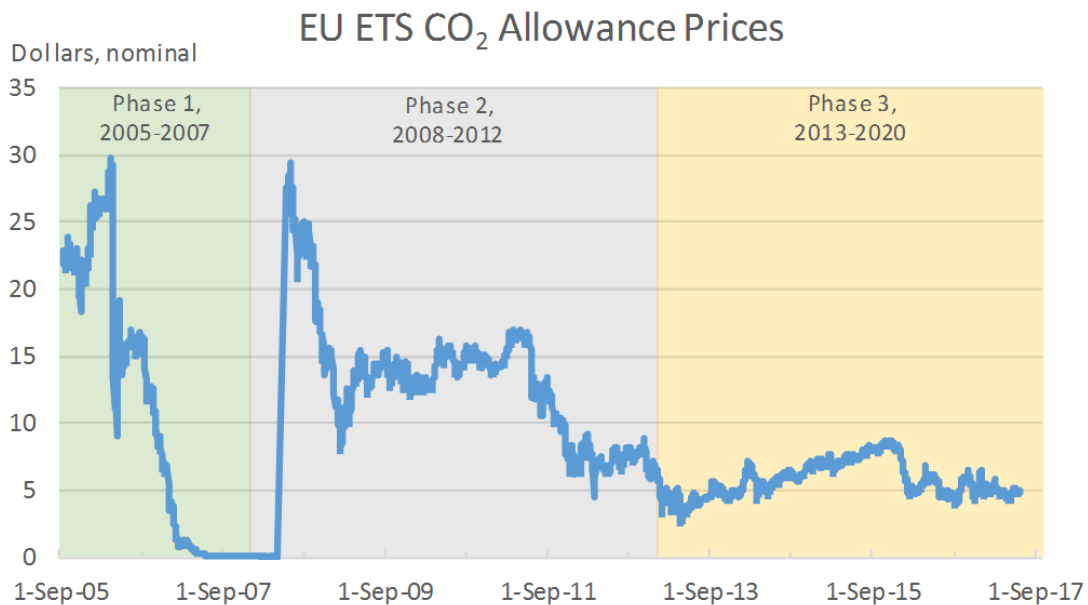
<sup>4</sup> For instance, trade intensity per se is not related to relocation propensity, although many firms become eligible for free allocation due to this. In contrast, emissions intensity, characteristics of firm size (e.g., output, assets) and trade-intensity with respect to less developed countries are very good predictors. A more cost-effective approach would redirect resources to firms at actual risk based on these criteria.

Overall, in the first two trading phases (2005-2012) the EU ETS appears to have had some success in reducing emissions in accordance with EU reduction objectives – all while keeping adverse economic effects largely at bay. The reasons may be manifold: First, firms operating capital-intensive assets may prefer a carbon price over high costs of relocating production. Second, the extensive compensation mechanism may have alleviated regulatory costs. Third, firms may have been able to pass down these costs to consumers (Fabra and Reguant 2014). Fourth, the economic recession and companion policies may have contributed to emission reduction thus easing the regulatory pressure stemming from the EU ETS.

**Structural design flaws put decarbonization at risk**

Despite some early successes in European climate policy, major uncertainties on the future of carbon pricing remain. Most prominently, many observers stress that the consistently low price of allowances indicates a severe lack of stringency that puts the successful decarbonization of the European energy system at risk. As can be seen in Figure 1, from 2005 to 2017 the price of an EUA, the equivalent of one ton of CO<sub>2</sub>, traded on the European carbon market has fluctuated between 0 and 30 US Dollars, most of the time in the lower range of this interval.

**Figure 1** EUA prices in US Dollar, 2005-2017



Source: Thomson Reuters 2018.

This is surprising given the specific architecture of the cap-and-trade system. The reformed design of the EU ETS stipulates a yearly reduction factor of 2.2% that would lead to a cap of zero emissions by 2057 (Edenhofer et al. 2017). Rational market participants, in apprehension of this scarcity, should have a strong incentive to pursue more expensive mitigation measures and to purchase carbon allowances from others to build up a bank that would be available when the program is more stringent in the future. This rational behavior should be evident in a price path

that increases steadily over time, roughly in line with the opportunity cost of holding financial resources tied up in the form of banked emissions allowances. However, allowance prices remain stubbornly low. One interpretation of this is that market participants lack confidence that the program will be in place in the long run, or in the possibility that emissions allowances will be scarcer in the future. The experience of lower than expected prices for allowances in cap-and-trade programs is not unique to Europe. Every emissions market around the world, for every type of atmosphere resource, has witnessed price paths that are below expectations, with only a few short-run exceptions where prices rose before falling again to low levels (Burtraw and Keyes, 2018).<sup>5</sup>

There are many reasons why prices in emissions allowance markets like the EU ETS frequently fall short of expectations. One is potentially overly generous initial allocation, which is common because the regulated parties are influential in the policy discussions that organize these markets. Second, the economic downturn in the last decade led to a reduction in energy use and associated emissions. Third, incentives associated with carbon pricing may in fact have their intended effect by accelerating a process of innovation that finds low cost ways to comply with the emissions cap. However, in the EU, these market fundamentals have been shown to explain only a fraction (10%) of historical EUA downward price movements (Koch et al. 2014).

Another potential explanation for relatively low allowance prices is the interaction of different market and regulatory imperfections (Edenhofer et al. 2017): (i) Market actors may be myopic and systematically disregard the long time horizon of decarbonization. EUA future markets cover a time span of only a few years and market participants may have a low willingness to hold EUAs for longer periods of time. By itself, though, this explanation is not satisfying because if prices are expected to rise in the future, there should be an opportunity for speculators to enter the market to capture substantial returns, and that speculation should drive up prices in the present. (ii) EUA prices have been shown to be sensitive to political events (Koch et al. 2015). This suggests that market actors do not perceive the cap as an exogenous event, but rather the result of a political process that is regularly adjusted. Low prices may indicate that market actors are not confident in the stringency of the future cap and bet on the possibility that policymakers might eventually relax the cap.

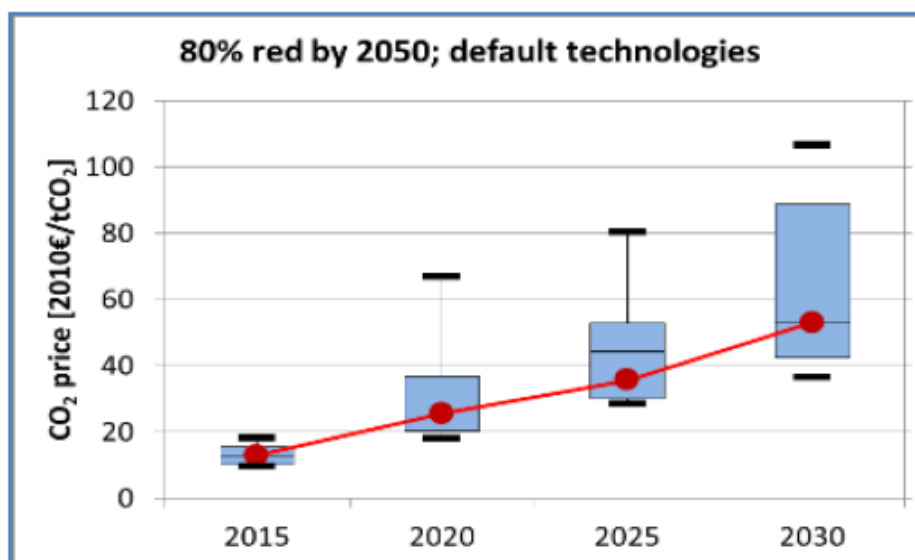
Without a thorough reform of the European carbon market, a combination of these factors may keep demand and thus EUA prices persistently below the benchmark of a cost-effective price path towards 2050 in the next years. Figure 2 summarizes the results of different modeling studies and shows that the price should be increasing steadily for a cost-effective decarbonization to work.<sup>6</sup>

---

<sup>5</sup> This includes markets for sulfur dioxide, nitrogen oxides, volatile organic carbon and carbon dioxide.

<sup>6</sup> Boxes: 50% interval; whiskers: 90% interval. The straight line refers to the median over 12 different energy-economy models. The red line refers to results from the PRIMES model used in the EU's "Energy Roadmap 2050" (Edenhofer et al. 2017).

**Figure 2** CO<sub>2</sub> price paths for cost effective long-term emissions reduction in Europe by 2050 (-80% relative to 2005)



Source: Edenhofer et al. 2017.

Given the persistently low EUA prices, EU member states with more ambitious climate goals may choose to pursue national policies to curb carbon emissions. However, under a fixed emissions cap that gradually decreases, any additional reduction in one country or industry enables emissions increases in another without any change in overall emissions. This mechanism is coined “the waterbed effect” because it leads to a rearrangement of where emissions occur, but no change in total emissions (Burtraw et al., 2017).

Although the emissions outcome may not be affected by the actions of individual member states, the demand for allowances would be, and this puts downward pressure on allowance prices. In turn, the low prices caused by the waterbed effect creates the appearance that the ETS is not incentivizing actions necessary for long-term decarbonization and undermines the confidence in the EU ETS as an effective way to reduce emissions. In turn, this may lead to calls for even more ambitious companion policies, creating a spiral that could severely impair the signal strength of the European carbon market for emissions abatement. The application of companion policies that directly or indirectly address greenhouse gas emissions in EU ETS sectors (such as renewable feed-in-tariffs or air quality standards) has already become common practice among EU member states. Although the contribution of these policies to EUA price declines has been limited so far (Koch et al. 2014), this mechanism may pose an increasing threat to the effectiveness of carbon pricing under a scenario of continuously depressed prices.

In the EU and elsewhere, the realization of falling prices is further amplified by the reinvestment of allowance value revenues in program-related activities. The EU provides guidance to each member state to invest at least fifty percent of the revenue from allowance auctions in climate and energy related projects (Löfgren et al. 2018). In the North American carbon markets, the share

tends to be even greater (Burtraw and Keyes 2018). Hence, these programs have a built-in design that exacerbates the trend toward low prices.

The European carbon market needs a relatively stable price trajectory very soon, and a sufficiently high price floor is one way to achieve that while leaving the actual determination of the price to market dynamics. If this is not achieved, it becomes likely that carbon-intensive assets would not be replaced by low-carbon technology, but rather are locked in and reinforced by additional investments in high-carbon technology. Projections for Germany demonstrate that the risk of such a lock-in may increase critically within the next years. Due to technical lifetimes and investment cycles, the year 2030 represents a critical juncture (German Academies of Science 2017). The threat of a lock-in is not only limited to EU ETS sectors. The energy transformation requires substantial investments into renewable technologies in the heat and mobility sectors, potentially doubling electricity demand and increasing the need for renewable capacities by up to factor 7.<sup>7</sup>

In the absence of a more robust and comprehensive EU ETS that incentivizes a switch to low-carbon technologies, the economic costs of climate policy may otherwise increase dramatically in the future. Demand for EUAs would possibly remain at a similar level as today, while the cap will continue to decline by 2.2%. In such a scenario, given the sustained investments in high-carbon assets, companies would be able to readjust towards abatement only at a high cost. Eventually, the economic costs of carbon-trading would increase steeply and a large part of asset portfolios would need to be devalued (Edenhofer et al. 2017). Such a crisis would clearly squander the relative success of the EU ETS in coupling emissions reduction with the mitigation of adverse economic effects. The economic dislocation and the threat of industrial relocation would likely increase the pressure on policymakers to relax the cap and put the European effort to curb emissions in jeopardy.

### **Pricing carbon effectively**

We propose the introduction of a minimum price for emissions allowances as an approach to make the EU ETS more robust to the market and regulatory issues described above and to accelerate the decarbonization of the European economy (Burtraw et al. 2010, Grull et al. 2011, Wood and Jotzo 2011, Fell et al. 2012). A price floor has been a feature since the inception of all the North American programs – the Regional Greenhouse Gas Initiative (nine northeast US states) and the Western Climate Initiative (California, Quebec and Ontario). The price floor is implemented through a reserve price in the auction of allowances, below which allowances will not sell (Burtraw et al. 2017).

The main contributions of a price floor to the stability and effectiveness of cap-and-trade systems are twofold. A price floor would partially remedy the waterbed effect because when the price is at the floor, as has been the case for some periods of time in the North American programs, measures by subsidiary jurisdictions yield real additional emissions reductions. The reason for this is that these local emissions reduction do not depress the price and thus provide no incentive to increase

---

<sup>7</sup> For instance, a scenario of 85 percent reduction in German emissions by 2050 could require an increase in wind and solar capacity by the factor 5-7, mirrored by a doubling in electricity consumption. The scenario accounts for investments into energy efficiency.



emissions elsewhere. However, when the price is above the price floor then the waterbed effect remains an influence on the emissions outcome.

Perhaps more importantly, the price floor would send a signal to market participants with respect to the minimum value of emissions reductions over time and increases the expected value of the future market price (Burtraw, Palmer and Kahn 2010). Hence, the introduction of a price floor helps to avoid a lock in of low carbon technologies and reduce the risk of escalating economic and political costs associated with it.

### **Recent reforms in the EU ETS**

The EU has instituted various reforms in an effort to boost the allowance price, including most recently the Market Stability Reserve (MSR). Instead of constraining prices directly, the MSR adjusts the issuance of new allowances in response to the volume of unused allowances in circulation (the allowance bank). Beginning in 2019, if the allowance bank exceeds a specified ceiling quantity, then the issuance of new allowances through auction is reduced every year by 24% of the excess. The withheld allowances enter the MSR. The allowances begin to re-enter the market from the MSR through a subsequent auction when the volume of banked allowances falls below a threshold quantity.<sup>8</sup>

In November 2017, the EU augmented the MSR with an important provision allowing for the cancellation of some of the allowances held in the MSR. Starting in 2023, the number of allowances in the MSR must not exceed the number of allowances auctioned in the previous year – any remaining allowances are cancelled. Also, voluntary cancellations by member states are possible (FME 2017).

There is uncertainty as to how the MSR will actually perform. Various estimates suggest that in 2023 the MSR may cancel 1.7 billion allowances (cited in Perino 2018) to 2.4 billion allowances (ICIS 2017). In contrast, emissions from covered sources in 2016 were 1.75 billion tons, declining each year thereafter. The cancellation of this substantial volume of allowances in the MSR will place upward pressure on the allowance price. It will also temporarily puncture the waterbed effect, meaning that for the next few years, actions taken by member states to reduce emissions will lead to cancellations of allowances in the ETS. However, the effect is temporary, and the waterbed effect is expected to return later in the next decade as the MSR is depleted (Perino 2018).

Further, the reduction in the bank does not necessarily have a direct effect on the allowance price if there are other structural problems such as a lack of long-run confidence in the program. The MSR process is difficult to predict and not transparent, which may feed into a lack of confidence in the program. Hence, while it appears to be a valuable step in the right direction, it does not seem to have solved the problem.

---

<sup>8</sup> After 2023 that amount is reduced to 12%.

## **A general approach to managing prices**

We argue that the most transparent approach to addressing the problem of low prices would be to implement a price floor. However, as mentioned above, this does not address the waterbed effect when prices are above the price floor.

Progress toward a more general approach was taken by the Regional Greenhouse Gas Initiative (RGGI) northeast US states in their 2016 program review (finalized in 2017), with the implementation of a second price step that applies to a portion (10 percent) of the allowances. This price step is above the price floor, which applies to all the remaining allowances. The price step is a minimum price for those specific allowances, so that if the price falls to below the price step, the supply of allowances sold in the auction is reduced by about ten percent. However, if the price keeps falling because demand for allowances is very low, the price can still fall below that price step until it finally reaches the price floor.

One appeal of this approach, which RGGI calls an “emissions containment reserve,” is that as in other commodity markets, the supply of allowances responds to the price (Burtraw et al. 2018). In general, if a price of a good is less, one expects to see less of that good coming into the market. This helps the market to achieve equilibrium and leads to less price volatility than in a market with a vertical supply curve with a fixed, unchanging supply of the good.

Another virtue of the price-responsive supply of allowances is that it addresses a concern of some observers that a minimum price would be used by governments to gradually convert a market into a tax. If one or potentially several price steps are included, that price can fall below the price step if demand is very low. Hence, the step cannot determine the market price. EU governments would not be able to steer the price in an attempt to maximize revenues from the auctioning of EUAs. A series of steps could easily approximate a continuous supply of allowances that responds when demand falls. In this way this important reform can strengthen the role of markets in carbon mitigation.

## **Elements for future reform in the EU ETS**

A minimum price, or better, a price-responsive supply of emissions allowances, would introduce a valuable improvement to the EU ETS. This approach could be coupled with the MSR, which is already in place, but we expect would emerge as the more useful mechanism. A price floor or price schedule for the supply of allowances to be introduced to the market would provide substantial benefits through improved transparency and predictability.

A suitable level for the price floor to start could be in the range of 20 to 40 Euro (25-50 USD) per ton of CO<sub>2</sub>-equivalent in the year 2020, which is in line with most scenarios that model the EU climate objectives until 2050 (Knopf et al. 2013). Such a starting point is already being envisioned by the Pan-Canadian Framework that aims at a price of around 32 Euro (50 CAD) in 2022 (Government of Canada 2017). The High-Level Commission on Carbon Prices reviewed evidence from different mitigation pathways, technological roadmaps and global integrated assessment models and concluded that a more ambitious range of 40 to 80 dollars (32-65 Euro) in 2020 and

50 to 100 USD (40-80 Euro) in 2030 would be needed to drive abatement efforts (Stiglitz et al. 2017).

However, we emphasize that consideration of a minimum price or a price-responsive supply of allowances should not be precluded by differences of opinion about the price levels to be implemented. The introduction of a price floor, or price schedule, is a strong positive feature of program design. Even at low levels, these features have the effect of censoring the range of potential price outcomes and thereby affect the expected price. The feature would boost confidence in the program.

Ideally, the reform of introducing a price floor would comprise all EU member states. A politically more viable approach could instead let states with ambitious climate goals agree on such a mechanism. In a second step, more reluctant members could be persuaded to join, e.g., by dedicating more revenues from EUA auctions to low-carbon investments in these regions (German Academies of Science 2015).

### **Other recommendations**

There are several other reforms that could strengthen the EU ETS. One avenue to further improve policy outcomes is to blend in adequate support policies. Ideally, these policies should directly address market failures that are not properly resolved by carbon trading.

For instance, support for research and development policies could bolster the moderate impacts of carbon trading on innovation. This is especially fruitful since innovations can produce positive spillovers for other branches of the economy. In a similar vein, measures with a focus on technology transfer could be applied. These policies would enable particularly less technologically advanced firms to adopt more efficient technology and thus distribute the benefits and costs of carbon regulation more evenly.

Other market failures may occur with respect to a lack of financing and access to infrastructure (e.g., grids). Also, certain technology standards may help to further ingrain confidence among market actors that policymakers are committed to achieving the international goals under the Paris agreement. Further, more refined compensation methods (e.g., free allocation or border tax adjustments) based on more detailed data on actual relocation risk and economic vulnerability would provide a more cost-effective way of mitigating any threat of relocation.

The next big step for the EU to consider should be the extension of carbon pricing to non-ETS sectors of the economy. The non-ETS sectors currently face a similar threat of credibility because the cost of emissions reductions is expected to increase, and this may be difficult to defend politically. In an effort to avoid a lock-in of infrastructure in the mobility and heat sectors, the EU should consider extending the ETS to these sectors, ideally by stepwise converting it into an upstream system (German Academies of Science 2017).<sup>9</sup> The introduction of a cost-effective policy through carbon pricing could help improve credibility of policy goals, and incentivize innovation and investment that will help reduce costs, which is necessary to make these goals a reality.

---

<sup>9</sup> An upstream system would oblige businesses that extract, refine and trade fossil energy sources to hold EUAs (e.g., refineries) rather than the myriad of actors downstream (e.g., the millions of private car users).

## References

- acatech/Leopoldina/Akademienunion (German Academies of Science), 2015: Incorporating the German Energiewende into a comprehensive European approach. Series on science based policy advice. ISBN: 978-3-8047-3430-2.
- acatech/Leopoldina/Akademienunion (German Academies of Science), 2017: Coupling of Energy Sectors – Options for the next phase of the German Energy Transition. Series on science based policy advice. ISBN: 978-3-8047-3672-6.
- Anderson, B., and Di Maria, C., 2011. Abatement and Allocation in the Pilot Phase of the EU ETS. *Environmental and Resource Economics* 48(1): 83–103.
- aus dem Moore, N., Großkurth, P., Themann, M., 2017. Multinational corporations and the EU Emissions Trading System: Asset erosion and creeping deindustrialization? *Ruhr Economic Papers*, No. 719.
- Bel, G., and Joseph, S., 2015. Emission abatement: Untangling the impacts of the EU ETS and the economic crisis. *Energy Economics* 49: 531–539.
- Brunner, S., Flachsland, C., and Marschinski, R., 2012. Credible Commitment in Carbon Policy. *Climate Policy* (12): 255–271.
- Burtraw, D., Palmer, K., and Kahn, D. 2010. A Symmetric Safety Valve, *Energy Policy*, 38(9): 4921-4932.
- Burtraw, D., and Keyes, A. 2018. Recognizing Gravity as the Strong Force in Atmosphere Emissions Markets, *Agricultural and Resource Economics Review*, (forthcoming).
- Burtraw, D., Holt, C., Palmer, K., Paul, A., and Shobe, W., 2017. Expanding the Toolkit: The Potential Role for an Emissions Containment Reserve in RGGI. RFF Report.
- Burtraw, D., Holt, C., Palmer, K., Paul, A., and Shobe, W., 2018. Quantities with Prices. RFF Working Paper 18-08.
- Calel, R. and Dechezleprêtre, A., 2016. Environmental policy and directed technological change: Evidence from the European carbon market. *Review of Economics and Statistics*, 98(1): 173–191.
- Dechezleprêtre, A., Gennaioli, C., Martin, R., and Muûls, M., 2015. Searching for carbon leaks in multinational companies. Grantham Research Institute on Climate Change and the Environment Working Paper 165, Centre for Climate Change Economics and Policy.
- Edenhofer, O., C. Flachsland, C. Wolff, L. K. Schmid, A. Leipprand, N. Koch, U. Kornek, M. Pahle. 2017: Decarbonization and EU ETS Reform: Introducing a price floor to drive low-carbon investments. MCC Policy Paper, 24.11.2017.

- Ellerman, A. D., Marcantonini, C., and Zaklan, A., 2016. The European Union Emissions Trading System: Ten years and counting. *Review of Environmental Economics and Policy*, 10(1): 89–107.
- Ellerman, A. D., and Buchner, B. K., 2008. Over-Allocation or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005-06 Emissions Data. *Environmental and Resource Economics*, 41(2): 267–287.
- European Union (EU), 2018. Emissions Trading System (EU ETS). Revision for phase 4 (2021-2030). Retrieved on 03/20/2018 from: [https://ec.europa.eu/clima/policies/ets/revision\\_en](https://ec.europa.eu/clima/policies/ets/revision_en).
- Fabra, N. and Reguant, M., 2014. Pass-Through of Emissions Costs in Electricity Markets. *American Economic Review* 104(9): 2872–2899.
- Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (FME), 2017. EU Parliament and Council agree comprehensive reform package. Retrieved on 03/20/2018 from: <https://www.bmub.bund.de/en/pressrelease/hendricks-emissionshandel-kann-endlich-wirkung-entfalten/>.
- Fell, H., Burtraw, D., Morgenstern, R.D., Palmer, K.L.. 2012. Soft and Hard Price Collars in a Cap-and-Trade System: A Comparative Analysis,” *Journal of Environmental Economics and Management*, 64(2): 183-198.
- Gloaguen, O. and Alberola, E., 2013. Assessing the factors behind CO2 emissions changes over the phases 1 and 2 of the EU ETS: an econometric analysis. CDC Climat Research Working Paper 2013-15.
- Government of Canada, 2017. Technical paper on the federal carbon pricing backstop. Retrieved on 03/20/2018 from: <https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html>.
- Grüll, G., Taschini, L. 2011. Cap-and-trade properties under different hybrid scheme designs. *Journal of Environmental Economics and Management*, 61(1): 107-118.
- ICIS 2017. EU ETS post-2020 reform: status quo or seismic shift? Marcus Ferdinand, Stefan Feuchtinger and Florian Rothenberg, analysts. December 11.
- Knopf, B., Chen, Y. H. H., De Cian, E., Förster, H., Kanudia, A., Karkatsouli, I., Keppo, I., Koljonen, T., Schumacher, K. and Van Vuuren, D. P., 2013. Beyond 2020 – Strategies and costs for transforming the European energy system. *Climate Change Economics* 4 (1).
- Koch, N., Fuss, S., Grosjean, G., Edenhofer, O., 2014. Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything? *New evidence, Energy Policy*, 73, 676-685.

- Koch, N., Grosjean, G., Fuss, S., Edenhofer, O., 2015. Politics matters: Regulatory events as catalysts for price formation under cap-and-trade, *Journal of Environmental Economics and Management*, 78, 121-139.
- Koch, N., Basse Mama, H., 2016. European climate policy and industrial relocation: Evidence from German multinational firms, SSRN Working Paper, 2868283.
- Martin, R., Muûls, M., Preux, Laure B. de, Wagner, U. J., 2014. Industry compensation under relocation risk: A firm-level analysis of the EU Emissions Trading Scheme. *American Economic Review*, 104(8):2482–2508.
- Martin, R., Muûls, M., de Preux, Laure B., Wagner, U. J., 2015. On the empirical content of carbon leakage criteria in the EU Emissions Trading Scheme. *Ecological Economics*, 105:78–88.
- Martin, R., Muûls, M., Wagner, U. J., 2016. The impact of the European Union Emissions Trading Scheme on regulated firms: What is the evidence after ten years? *Review of Environmental Economics and Policy*, 10(1): 129–148.
- Perino, G. 2018. New Phase 4 – EU ETS Rules Temporarily Puncture Waterbed, *Nature Climate Change*, (forthcoming).
- Petrick, S. and Wagner, U. J., 2014. The impact of carbon trading on industry: Evidence from German manufacturing firms. Kiel Working Papers 1912, Kiel Institute for the World Economy.
- Stiglitz, J.E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G., Rovere, E.L. la, Moyer, E., Pangestu, M., Shukla, P.R., Sokona, Y. and Winkler, H., 2017. Report of the High-Level Commission on Carbon Prices. Carbon Pricing Leadership Coalition.
- Themann, M., Koch, N., 2018: Catching up and falling behind: Cross-country evidence on the impact of the EU ETS on productivity growth. mimeo.
- Wagner, U. J., Muûls, M., Martin, R., and Colmer, J., 2014. The causal effects of the European Union Emissions Trading Scheme - evidence from French manufacturing plants. mimeo.
- Wood, J., Jotzo, F. 2011. Price floors for emissions trading. *Energy Policy*, 39(3): 1746-1753.