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Agreeing on an EU ETS Price Floor to Foster Solidarity, Subsidiarity and Efficiency in the EU[1]

Ottmar Edenhofer, Christina Roolfs, Beatriz Gaitan, Paul Nahmmacher, Christian Flachsland

Key Points for Policymakers

- The EU Emissions Trading System (EU ETS) has provided neither credible incentives for long-term investments in low-carbon technologies nor strong near-term mitigation incentives.
- Low EU ETS allowance (EUA) prices and the heterogeneity of the EU Member States (MS) have led to a patchwork of national climate policy across MS, with variable and unequal policy stringency.
- Under the current EU ETS design these national policies do not achieve additional emission reductions within ETS sectors. Instead, they reduce the EU ETS carbon price and reallocate carbon emissions to MS with weaker national climate policies.
- A price floor for EUAs combined with appropriate transfers (the redistribution of EU ETS revenues) allows for the heterogeneity of MS within the multilevel policy structure of the EU to be addressed.
- While the economic literature suggests using optimal transfers across MS to achieve efficiency when a quantity (ETS) or price instrument is employed, the implementation of optimal transfers may not be feasible. Nevertheless, there are other transfer schemes that can improve upon the EU's solidarity and subsidiarity—two well-established EU normative design principles—and the EU ETS' economic efficiency.
- A numerical exercise is provided to quantify the cost effects of the EU ETS price floor proposal within the European power sector.

1. Introduction

Taking into account the heterogeneity of EU Member States (MS), this chapter proposes an EU ETS price floor as a key element of an EU ETS reform. It links economic efficiency to the EU's principles of solidarity and subsidiarity, and illustrates the cushioning effect of an ETS price floor on intra-ETS leakage. While the price floor's stabilization effect is also identified in chapter 1, this chapter provides an analysis of the role of fiscal transfers to enhance the MS' agreeability of introducing a price floor.

The EU Emissions Trading System (EU ETS) has not yet provided credible incentives for long-term investments in low-carbon technologies. Its credibility has suffered since the year 2008 because the emission cap has been consistently above the EU-ETS sectors' carbon emissions for which the financial crises that started in the second half of the 2000s are blamed for. The subsequent decline in EU ETS allowance (EUA) prices from mid-2008 onward, as depicted in figure 2.1, triggered an ongoing and remarkable debate about reforming the EU ETS. EU policymakers attempted to fix the EU ETS by implementing a back loading provision[2] and the market stability reserve (MSR).[3] Both measures focus on shortsighted fixes of the carbon price decline: they temporarily remove EUA surpluses from the market. However, the EUAs that were temporarily removed will be returned to the market at some point in the future, leaving the cumulative cap (the aggregate supply of permits) unchanged. It was also decided to increase the Linear Reduction Factor (LRF)—reflecting the annual reduction of the cap—from 1.74 percent to 2.2 percent per year, thereby reducing the cumulative EU ETS cap. This has not had a major effect on the EUA price. While there is no clear consensus about the core problems of the EU ETS and the best response options to effectively address them, it is likely that back loading and the MSR will be insufficient (Knopf et al. 2014). The debate on structural EU ETS measures launched by the European Commission (EC 2012) is still unresolved and opens a window of opportunity for a debate on long-term reform.

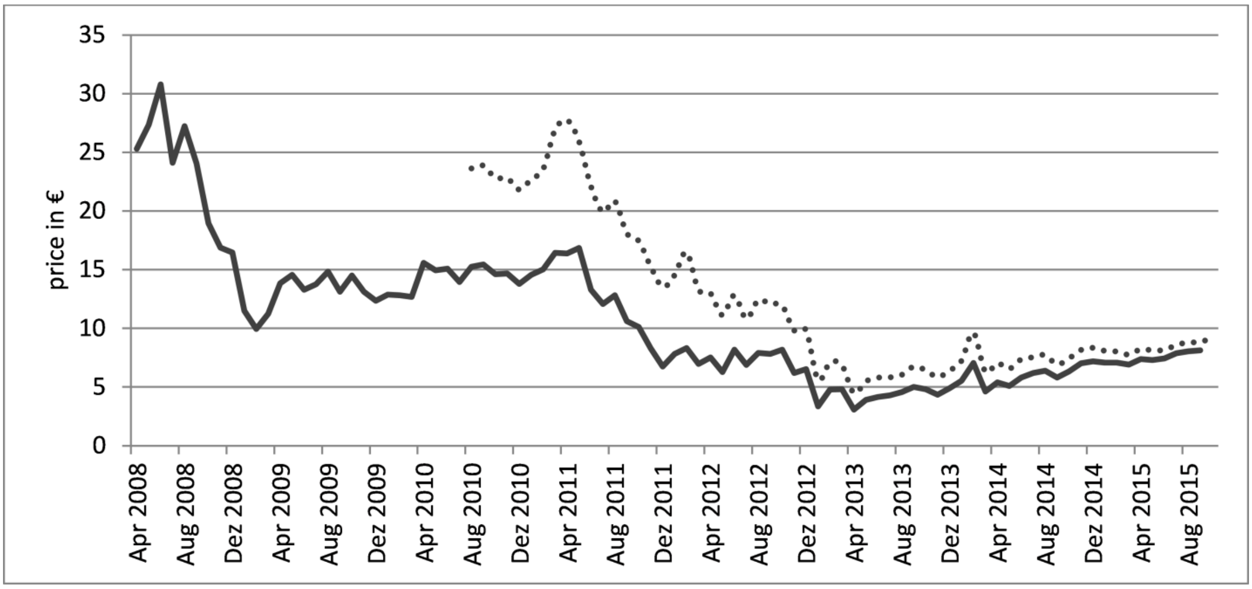

Figure 2.1: Evolution of EUA price (solid line) and EUA future contracts for the year 2020

(dotted line).[4]

In addition to concerns about a lack of the EU ETS' credibility, fundamental questions about the coordination of regulatory authorities have been raised. In particular, there is a lively debate about whether MS' climate polices undermine the cost effectiveness of the EU ETS (IPCC 2014). EU MS have implemented diverse national climate and energy polices[5] with varying stringencies, which affect carbon emissions. To illustrate these different stringencies, we derive an aggregate effective carbon price using the OECD's estimated effective carbon prices for Denmark, France, Germany and the UK for different sectors.[6] Based on climate and energy policies, the OECD's study estimates the net social cost paid for each unit of emissions abated for various sectors and countries.[7] We weight the OECD's estimated sectoral prices according to the given sector's share of aggregate emissions in each country. Data on sectoral emission shares is taken from the European Environment Agency (EEA 2013). The result is depicted in figure 2.2. For the sectors and countries we consider, Germany has the highest effective carbon price of 53€/tCO_2e, followed by Denmark, the UK and France with respective effective carbon prices of 46, 42 and 25€/tCO_2e. The variety of instruments implemented across MS and the effective carbon prices presented here indicate that MS prioritize emission mitigation objectives differently and prefer distinct means to pursue those objectives.[8]

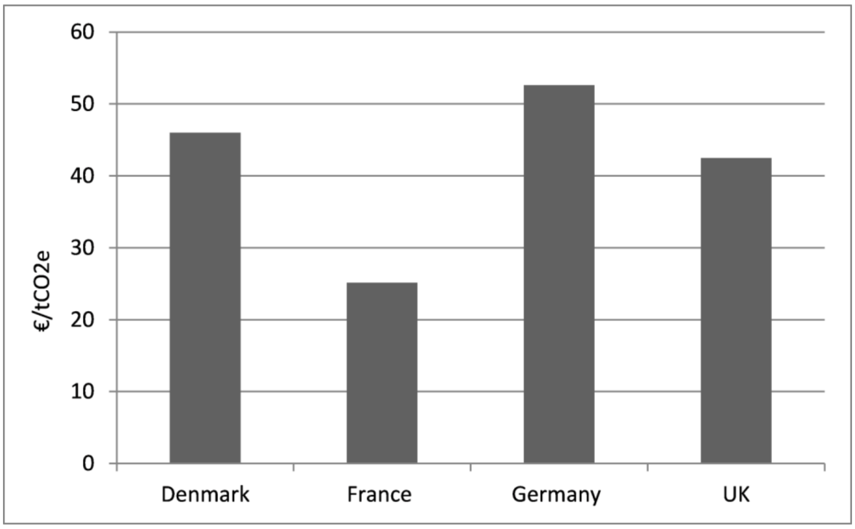

Figure 2.2: Estimated effective carbon prices by country derived from the electricity, transport, pulp and paper and cement sectors. Calculation based on a study by the OECD (2013) and weighted according to the sectoral share of emissions data from the year 2010 (EEA 2015).

The heterogeneity of the EU MS[9] has led to different willingness to pay (WTP) for abatement as reflected in national climate policies. If the different WTP for abatement had been anticipated and taken into account in the design of the EU ETS, current national polices would not have a weakening effect on the EU ETS. Given the evolution of MS policy choices and lessons learned on the interaction among the EU ETS and national policies, it is pressing to revisit and discuss fundamental EU ETS design features.

We base our analysis on two normative design principles that are well established within the EU—the principle of solidarity[10] and the principle of subsidiarity.[11] We use well-known theoretical arguments to conclude that the current EU ETS does not satisfy these principles. We point to solutions provided by economic theory that would help to make the EU ETS more compatible with these principles. We claim that a price floor for EUAs combined with appropriate transfers enables the heterogeneity of MS within the multilevel policy structure of the EU to be accounted for, while also allowing the principles of subsidiarity and solidarity to prevail. A first-best outcome and an optimal policy design will not be implemented by self-interested MS. It is therefore used as the socially optimal benchmark—a normative focal point—for our analysis. However, an EU ETS supplemented with a carbon price floor and an appropriate transfer scheme[12] is consistent with the self-interests of the MS such that no Member State is harmed and at least some MS are made better off. This policy design approach promises to be a win-win strategy for all MS.

The chapter is organized as follows. In section two we review previous findings about shortcomings of the current EU ETS price. In section three the interaction between heterogeneous MS and EU policies is discussed, in particular the effect on carbon prices. Two normative design principles and one implementation rule are subsequently suggested, taking into account the second-best reality of EU policy-making. In particular, we argue that the introduction of a carbon price floor is a promising proposal for EU ETS reform. Section four illustrates the effects of an EU ETS price floor by means of numerical simulations for the EU power sector. Section five states our conclusions.

2. The main shortcomings of the current EU ETS price signal

Recent economic literature on climate change favors the use of a carbon tax (price) or hybrid system (a quantity-based instrument with price stability provisions) over a pure quantity-based instrument such as an ETS without price stability provisions (e.g., Cramton et al. 2015). Those kinds of policy instruments are expected to deliver a more stable price signal and are economically superior to a pure ETS in terms of the ability to avoid price volatility, emission leakage effects and uncertainty about economic costs (Goulder, Schein 2013; Philibert 2009). However, taxation power in the EU is limited—the collection and redistribution of direct taxation is a sovereign right of MS.[13] If an EU carbon tax were going to be implemented, it would require a unanimous vote, whereas an ETS requires a two-thirds majority vote (Talus 2013). In practice, this has meant that the quantity-based ETS was the only politically feasible carbon-pricing instrument at the time of its inception (Skjærseth, Wettestad 2010; Talus 2013).[14] An ETS price floor implemented as an auction reserve price (as done in the Californian ETS) should not be considered a tax in legal terms but builds upon the ETS' political feasibility.

Another line of argumentation focuses on the ongoing price decline of the EU ETS which causes specific credibility challenges. Reasons for the EUA price decline are analyzed by Koch et al. (2014; 2016). They find that the global economic recession, renewable support schemes, the inflow of carbon credits, and gas and coal prices can only explain about 10 percent of the price decline in the EU ETS over the period of 2008–2013. They conclude that policy events have a strong influence on EUA price formation and suggest that controversial debates by EU policymakers as well as EU parliament votes—particularly over back-loading—have destabilized the long-term expectations of investors.

Not surprisingly, the low price of futures contracts for the year 2020 indicates that traders anticipate only a modest long-term scarcity of emission permits in the market (see figure 2.1). Neither back-loading nor structural reform proposals like the MSR promise to change this expectation, as they only shift the release schedule of a constant cumulative EUA budget over time. Elsewhere it has been extensively discussed why a price floor—potentially complemented by a price ceiling, thus yielding a price corridor—at the EU level would help to stabilize price expectations and support long-term credibility (Knopf et al. 2014; Philibert 2006; Wood, Jotzo 2011). Since carbon and energy pricing have a positive impact on clean technology investments (Copenhagen Economics 2010; Eyraud et al. 2011), the low EUA prices from mid-2008 onward together with low prices for future contracts lack the intended incentives for EU-wide clean technology investments.

Even in the presence of the EU ETS, MS continue to implement and modify various forms of national energy and climate policies (Strunz et al. 2015; Talus 2013). These additional policies suggest that some MS would rather pursue either a less or more stringent climate policy than is available through the EU ETS. For example, Poland threatened to withdraw from EU climate policy altogether[15] demonstrating its wish for less stringent climate policy. On the other hand, Germany, the UK and Sweden have implemented policies demonstrating a wish for more stringent climate policy. Germany implemented the Renewable Energy Sources Act to foster the German energy transition (*Energiewende*). The UK established the Climate Change Levy consisting of inter alia a carbon price support rate for EUA. It functions as a national price floor with a current level of 18£/CO_2e (HM Revenue & Customs 2014).[16] Sweden established a general carbon tax in 1991, but it made exemptions to some sectors after the EU ETS implementation (OECD 2014).[17] Despite these efforts towards more stringent climate policies, national climate policies act to weaken the EUA price as the demand for allowances from MS with more ambitious climate polices decreases (Böhringer et al. 2008).

In the following section, we extend the debate about EU ETS reform by considering the heterogeneity of MS. The current EU ETS is supposed to equalize marginal abatement costs[18] across MS. This can only be efficient without the presence of any unilateral MS policies (Williams 2012). Additionally, the equalization of marginal abatement costs among MS does not account for the federal-like structure between the EU and its heterogeneous MS, in which EU and MS policies coexist. Instead, climate policy at the EU-level could be set in a similar fashion as the EU tax minima for VAT in alcohol, tobacco, and energy products. For these, the EU sets required minimum rates for MS, but they have the flexibility to set higher rates if they wish to for fiscal or other reasons (EP 2014). In the climate context an EU ETS price floor would not hold back those MS who wish to price emissions more aggressively.

The existence of EU minimum rates in other regulatory domains raises the question of whether the EU's vertically divided regulatory regime and the MS' heterogeneity are sufficiently considered in the design of the EU ETS, and if improvements are conceivable. The

MS' heterogeneity has largely been ignored in the EU ETS design, though income heterogeneity is addressed to some extent by certificate allocation provisions.[19] As a result, the simultaneous interaction between the EU ETS and MS climate policies will continue to distort the functioning of the EU ETS. The policies implemented by individual MS reduce the EUA price and increase the effective national carbon price in the respective MS. Because the cap remains constant, they do not achieve emission reductions. Fixing the EU ETS will be required to ensure an effective, efficient and ambitious European climate policy. Otherwise there is a risk that EU climate policy will become further fragmented, ineffective and costly, and consequently, it might deteriorate over time.

3. Guiding principles for EU ETS design with heterogeneous Member States

In this section we explore the implications of MS' heterogeneity on the EU ETS price design. For this purpose we consider two types of MS' heterogeneities. First, MS can differ in income levels. This can stem from differences in factor endowments such as physical capital and human capital, access to fossil resources, and technological differences. In the face of income disparities, the optimal provision of climate change mitigation requires specific transfers (see section 3.1). The use of transfers within the context of climate change has a direct link to the principle of solidarity as described by Hilpold (2015). He relates the EU solidarity principle to the use of transfers to achieve a common goal. Second, MS can be heterogeneous in terms of their preferences for environmental quality and/or how they are affected by climate change. For example, EU countries might expect different impacts on their populations from climate change-induced heat waves, droughts and flooding. Taking these preferences into account plays a fundamental role in the fulfillment of the EU subsidiarity principle (see section 3.2).

3.1 Efficiency, transfers and solidarity

Traditional wisdom suggests that, by equalizing the cost increase from reducing a unit of emissions (marginal abatement cost, MAC) across emission sources, emissions trading always achieves efficiency[20] (Coase 1960). However, in the presence of unequal income across countries, a uniform carbon price that equalizes MACs across countries may not be efficient. For example, richer countries may be able to afford more stringent national climate policies. The efficiency of MAC equalization across countries was first challenged and refuted by Chichilnisky, Heal (1994), who showed that if a poor country gains more from increases in private consumption than a rich country, the poor country's willingness to pay (WTP)[21] for mitigation is lower relative to that of the rich country. For expository reasons, let us consider the case of a poor country in Asia in which a large portion of its population suffers from malnutrition. In that country the gain from increasing private consumption (in particular food) should be much higher than the gain of a developed country in Europe from increasing private consumption. In such a case, the poor country's WTP for mitigation is lower and hence it should pay less for emissions mitigation than a developed country in Europe. Despite smaller income gaps among EU MS, similar effects resulting from unequal income levels across countries matter within the EU. Crucially, Chichilnisky and Heal (1994) demonstrate that an efficient solution to this situation features different MACs across countries. If, however, MACs across countries were to be equalized under an ETS, optimality would require specific transfers from richer to poorer countries.

Optimal abatement

If the optimal transfers are not implemented, Chichilnisky and Heal (1994) show that poorer countries should set lower MACs than richer countries. They find that an efficient outcome is one in which a country's MAC equals the ratio of the sum of social gains from emission reductions across all countries relative to the social gain from larger private consumption in the respective country. Since countries benefit differently from increasing private consumption, MACs must not necessarily be equalized to achieve efficiency. In such a situation, different carbon prices for each country are an institutional pre-condition for social optimality. However, national carbon prices could lead to a more nationalized and fragmented European climate policy, which would undermine future cooperation within Europe.

Optimality under an emissions trading system (ETS)

To counteract the fragmentation of European climate policy, a uniform carbon price seems preferable to differentiated national carbon prices. However, a uniform carbon price requires a specific transfer scheme since, without transfers, an ETS imposes MAC equalization across countries but is not efficient. As indicated above, this equalization is not efficient as long as the social gain from increasing private consumption is not equal across countries. Chichilnisky and Heal (1994) point out that optimality within an ETS that employs a uniform carbon price can only be fulfilled by using a transfer scheme that equalizes the social gain from increasing private consumption (*SGIPC*) across countries. Thus, since poorer countries gain more than richer countries from increasing private consumption, poorer countries must receive transfers leading to the equalization of the *SGIPC* for all countries. In the face of large income differences across countries, significant transfers must occur.

In the current EU ETS, two general types of transfers exist. First is the redistribution of EU ETS auction revenues to MS. In the year 2013 40 percent of all EUA were auctioned for a total auction revenue of about 3.6bn€ (EC 2015d). Of these revenues, 88 percent were distributed in proportion to historical emissions across MS. Ten percent of the auction revenues were channeled to less wealthy EU MS to promote investments dedicated to carbon intensity reduction and for adaptation to climate change (EC 2013, 2015a, 2015a). The remaining 2 percent (the 'Kyoto bonus') were allocated to nine EU MS that had reduced their emissions by at least 20 percent of their Kyoto Protocol base year or period level by 2005[22]. Second, the value of the remaining 60 percent of all EUAs were transferred to firms. If firms are transnational, then it is not clear whether the MS' population is the full beneficiary of this type of transfer, nor whether the transfer can address differences in wealth as would be needed to equalize the social gains from increased consumption across countries.[23]

If we consider the EU MS' per capita gross domestic products as a wealth indicator, we can conclude that differences across MS are rather large. Thus, transfers of 12 percent of the total EUA auction revenues to less wealthy MS are probably insufficient to achieve optimality. In section 3.3, we provide estimates for transfers that would lead to EU ETS optimality (the equalization of the gain from increasing private consumption across EU MS) based on Chichilnisky and Heal's analysis.

Design Principle 1. Efficiency, transfers and solidarity

A uniform emissions price at the EU-level must be supplemented with appropriate transfers to ensure economic efficiency. The current EU ETS design in which marginal abatement costs are equalized across all Member States is not per se efficient. Efficiency is only obtained if rich Member States provide sufficiently large transfers to poorer Member States. Such transfers enable higher levels of consumption in poorer States— hence complying with the EU's solidarity principle— while significantly increasing the poorer States' willingness to pay for mitigation. If the transfers cannot be implemented, rich Member States need to have higher marginal abatement costs and therefore abate relatively more than poor Member States.

3.2 National preferences and subsidiarity

The analysis in the previous section focused on income differences and on one common goal (climate change mitigation). We now address the use of multilevel climate policies driven by heterogeneous MS' preferences. Heterogeneous preferences can arise due to differing effects from multiple emission externalities, i.e., climate change and air pollution, as well as differing priorities for environmental quality. Even if information about transboundary and global impacts of carbon emissions were perfectly available to regulators at all regulatory levels, MS authorities typically only care for the well-being of national inhabitants. By contrast, an overarching regulating layer, such as the EU, considers the well-being of all inhabitants of all MS, and it is better equipped to provide global public goods such as climate change mitigation. In the following section, we focus on the interaction of multilevel regulation for cases in which MS have heterogeneous preferences. Addressing this type of heterogeneity in the context of multilevel policies is important because, as clarified below, it plays a fundamental role in the fulfillment of the EU subsidiarity principle (see also Oates 1972, 2011).[24]

Heterogeneous preferences and strategic Member States

A study by Williams (2012) analyzes interactions between government layers in which both sub-level (MS) and top-level (EU) regulating authorities are allowed to regulate emissions simultaneously. He finds that if the top-level regulator implements an ETS, additional MS' climate policies become either ineffective or may even result in additional costs for the multilevel regulatory system. To attain efficiency with an over-arching ETS, MACs across MS must be equalized and optimal transfers have to be set. However, if MS implement additional policies, MACs can differ. Williams shows that within an over-arching ETS there is no transfer from the top-level regulator to the MS that can achieve efficiency as long as MS policies are present. Instead, since the ETS cap is fixed and the ETS price adjusts as MS unilaterally cut emissions leading to increased emissions in other MS (intra-ETS leakage), the top-level ETS cancels out all unilateral abatement efforts. [25] Williams also finds that a carbon tax implemented by the top-level regulator is superior to an ETS. This occurs because the top-level and sub-level prices are additive, while quantity instruments are not as the stricter cap is always binding.[26]

More specifically, it would be preferable for the EU to implement an EU-wide carbon tax to address emission leakage effects among MS, and for MS to set national taxes for regulating local emissions externalities and/or local preferences. Reflecting Chichilnisky and Heal's (1994) findings, the multilevel system eventually achieves optimality if the carbon taxes at the two different levels are supplemented by optimal transfers. Based on Williams's argument, a uniform EU carbon price combined with MS' carbon prices and optimal transfers can lead to an efficient outcome. On the contrary, the use of a pure ETS—as opposed to one with a binding price floor—precludes the achievement of an efficient outcome, because MS cannot be prevented from implementing national climate polices.

In a similar line of research, Roolfs et al. (2016) find that a carbon price set by the top-level regulator in addition to MS' policies can approximate the first-best outcome, if the top-level regulator employs optimal transfers. They analyze the potential of a top-level regulator to set a union-wide carbon price in coexistence with strategic MS policies while the top-level regulator anticipates how MS' carbon prices react to the top-level's carbon price. If non-optimal transfers are available, they identify the price floor level that at least comes closer to the first-best outcome while making all MS better off.

Design Principle 2. Member States' preferences and subsidiarity

Implementing an emissions' price instrument at the EU-level— either by an EU ETS price floor or a EU carbon tax— is consistent with the principle of subsidiarity. With a price based instrument at the EU-level national policies can prosper as companion policies of the EU ETS. It allows effectively accounting for the Member States' heterogeneous preferences without undermining the EU policy. In contrast, purely quantity-based instruments at the EU-level—such as the current EU ETS— would not only make it harder for ambitious Member States to become frontrunners with respect to climate policy but would even render their national efforts fruitless.

Design Principle 1 and 2 consider different bases for the heterogeneity of MS (income levels and preferences) but lead to a common result: In a multilayered policy regime, a price instrument implemented at the top-level more efficiently allows for heterogeneity to be addressed as long as optimal transfers are employed. However, optimal transfers derived from economic theory are often unviable for policymakers. In the next section we propose a pragmatic rule that does not achieve the first-best outcome, but can find consensus across MS such that some MS are better off, while also ensuring that other MS' well-being remains at least at their original level (Pareto-improvements).

3.3. Institutional design in a non-optimal world

The aforementioned design principles are normative focal points derived within an economic, theoretical setting. However, the optimal implementation of both principles may prove difficult in the real world. This may be due to enforcement constraints, to the difficulty or impossibility of overcoming the free-rider behavior of self-interested actors, and/or—as will be discussed next—to the political infeasibility of the transfers that would be necessary to lead to the optimality of an EU ETS.

Building upon Chichilnisky and Heal's (1994) findings, we derive the optimal transfers needed to make the EU ETS efficient. To do so, we assume that a) each country's well-being is influenced similarly by private consumption; and b) an upper-level regulator such as the EU weighs all countries equally.[27] Given these assumptions, equalizing the social gain from increasing private consumption across countries requires that all countries have an equal level of private consumption. To estimate the transfers needed to equalize consumption levels across EU MS, we use private consumption expenditure data (WDI, 2015) in purchasing power parity US dollars (PPP$) for the year 2010. Our objective is to find transfers that enable the EU's population the same level of per-capita consumption, while making aggregate consumption equal to observed in the data. The transfer per person in each Member State is the gap between the EU's and each Member State's per-capita consumption levels. Based on consumption data in the year 2010, figure 2.3 shows optimal per-capita transfers (per person) across all EU MS that would equalize EU per capita consumption. A negative number indicates that a respective country is not a receiver but it is instead a donor. The population of Luxembourg, as the richest in the EU, would be the largest donor (with a negative transfer, a net payment, of PPP$7,819 per person. Luxembourg's population is followed by the populations of Austria, the UK and Germany, with respective negative per-capita transfers of PPP$4,370, PPP$3,470 and PPP$3,101. The populations receiving the largest transfers would be those living in Bulgaria, Latvia, Estonia and Romania. The estimated optimal transfers serve to demonstrate the magnitude of the difference in consumption levels across MS. The difference in consumption levels has a large implication for the individual WTP for climate change mitigation.

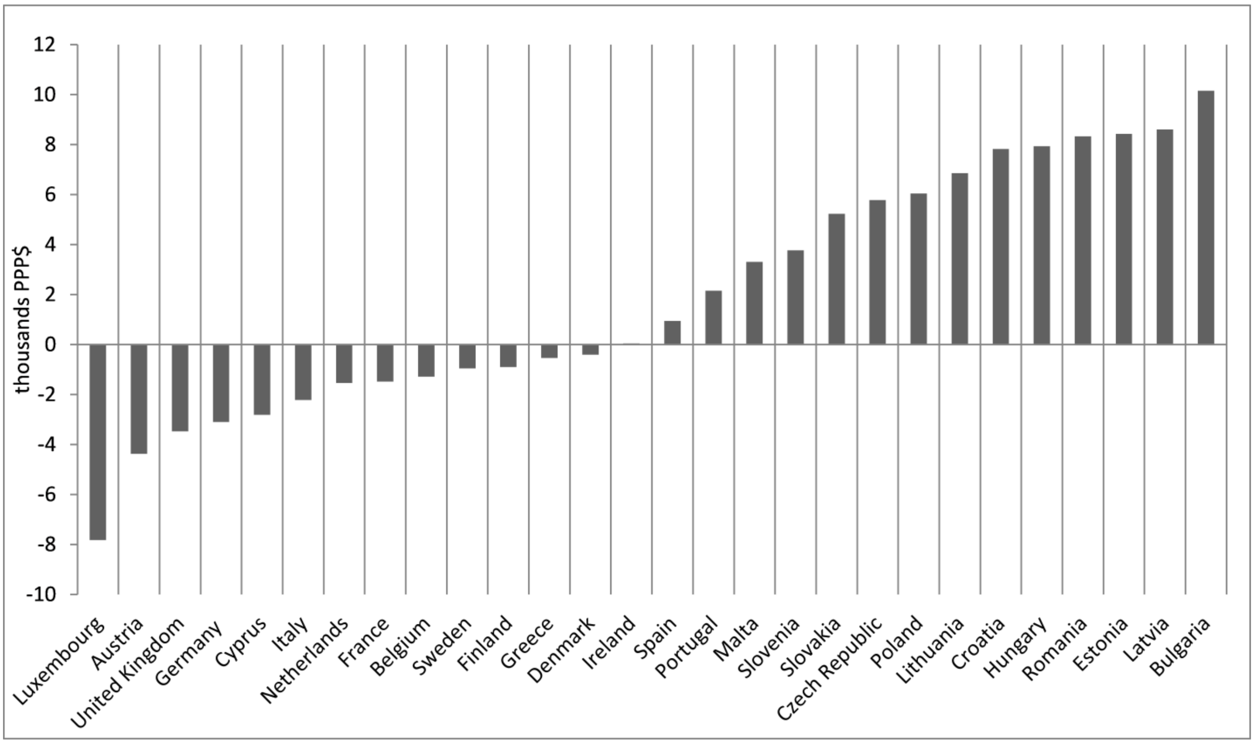

Figure 2.3: Optimal transfers per person according to private consumption in the year 2010 in thousands of $ of purchasing power parity (PPP$).

Figure 2.4 indicates the aggregate optimal transfers per Member State (the per-capita transfers multiplied by the population of each Member State). Transfers of the size depicted in figure 2.4 are very unlikely to be politically feasible. At the same time, current EU ETS transfers equal to 12 percent of the revenues from the EUA auction (0.432bn€ in 2013) seem insufficient.

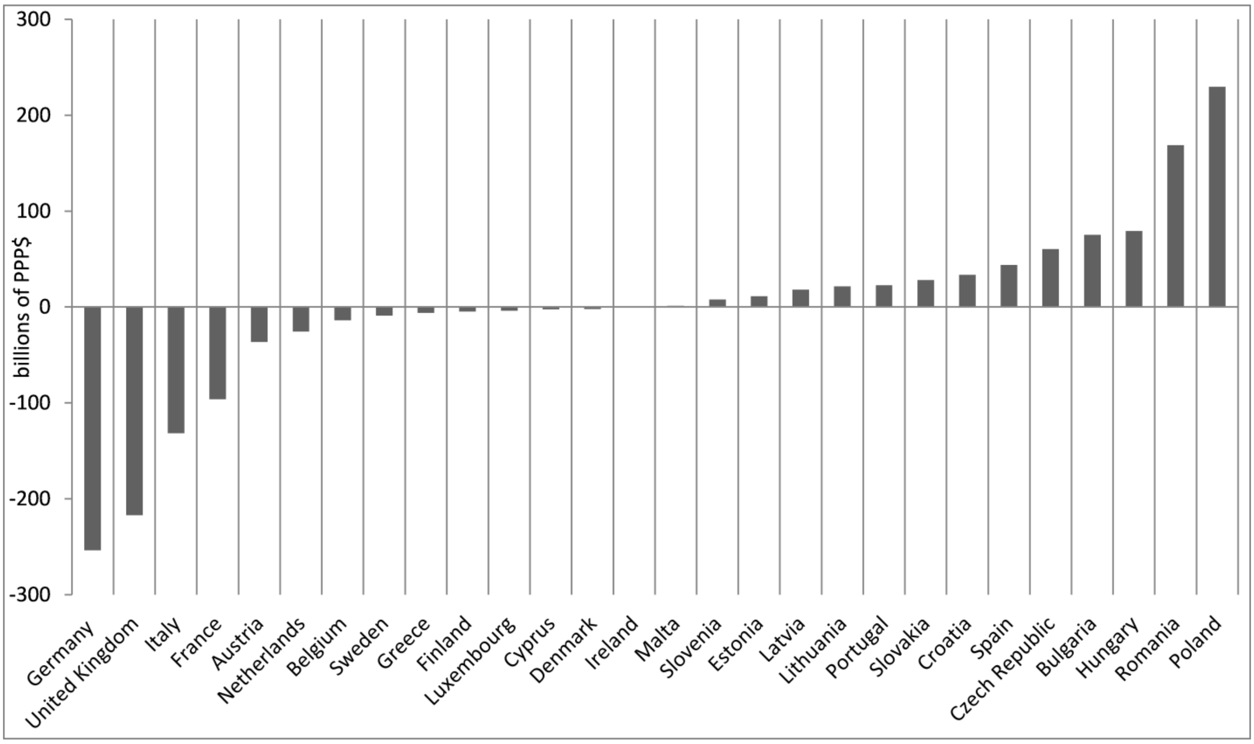

Figure 2.4: Optimal transfers per country according to private consumption in the year 2010 in billions of $ of purchasing power parity (PPP$).

Since a theoretical, first-best outcome of a pure ETS with optimal transfers is very likely to be politically infeasible, we propose the consideration of second-best options.[28] One such case that is particularly useful is a second-best world in which changes in the EU ETS design make a Member State better off, while also ensuring that other MS' well-being remain at least at their original level (this is compared to a case in which only MS implement climate policies in a decentralized, uncoordinated setting). From a welfare perspective, this ensures that the joint implementation of climate policies creates winners, while also guaranteeing that there are no losers.

In contrast to the normative framework described in sections 3.1 and 3.2, we now consider results from a study which analyzes a setting in which: a) optimal transfers are not viable; b) a multilevel policy regime is already established; and c) a uniform price signal is set at the top-level and each Member State sets its own carbon price. This starting point is more similar to the current EU ETS in which the EUA market intends to deliver a uniform price signal to all MS, while MS set additional climate policies and transfers are given as discussed in section 2. In a comparable set-up and with heterogeneous MS, Roolfs et al. (2016) identify MS' carbon prices and a range of top-level uniform carbon prices, including a price floor level, combined with simple transfers[29] that make all countries better off compared to a decentralized setting.

When income heterogeneity is considered, Roolfs et al. find that equity-based transfers can put a disproportionate cost burden on the richest Member State. The richest Member State agrees to bear the cost burden of the top-level policy as long as its gain outweighs its costs. Based on the nature of the equity-based transfers, poorer MS carry no burden but benefit by internalizing the emission externalities and by a net income gain. Therefore, the tipping point for the feasibility of top-level policy becomes the consent of the richest Member State and is represented by a carbon price floor. Here, the carbon price floor is the carbon price level that leads to the highest well-being of the richest Member State. As long as the top-level regulator considers the carbon price floor, the top-level policy is compatible with the self-interest of all MS in the sense that all MS are better off.

Within the context of their model, Roolfs et al. show that the price floor based on the richest Member State's utility and in combination with equity-based transfers works as long as the wealth gap among poor and rich MS is not extreme. Since the price floor ensures that no Member State falls below the welfare level of the decentralized outcome, it also satisfies the principle of subsidiarity. Analogously, Roolfs et al. find that a price floor works for transfers based on the MS' historical emission levels. However, this transfer scheme—in contrast to equity transfers—can make all MS better off and it does not always impose restrictions on wealth gaps. They conduct a similar analysis on heterogeneous preferences for emissions' externalities on MS' well-being, and find similar results.

Implementation Rule: Set a price floor and provide appropriate transfers.
A carbon price floor can help to address the challenges associated with the heterogeneity of Member States while accepting a non-optimal world. With an EU ETS carbon price floor, transfers must not necessarily be optimal to lead to welfare improvements for all Member States.

4. Illustration of the effects of an EU ETS price floor

In this section we provide a twofold sketch demonstrating that national climate policies will not undermine the efficiency of the EU ETS when a price floor is implemented (see also IPCC 2014; Goulder, Stavins 2011). We first give an illustrative description of the cushioning effect of a price floor. We then present results from the European power sector model LIMES-EU.

4.1. Cushioning intra-ETS leakage with a carbon price floor

Consider a multinational ETS without MS policies. The ETS allowance price (p_{ETS}) is determined endogenously by the ETS market, such that MACs are equalized across all participants. Thus, the MS' emission levels (E_i, E_j) are determined by p_{ETS} (see figure 2.5). If Member State *i* prefers a lower national emission level E_i^* than the level that results from the ETS alone, its WTP for mitigation is above p_{ETS}. In order to obtain E_i^* Member State *i* sets an additional national policy τ, which results in an effective national carbon price of p_{MS}, such that $p_{MS}= p_{ETS}+ \tau$.

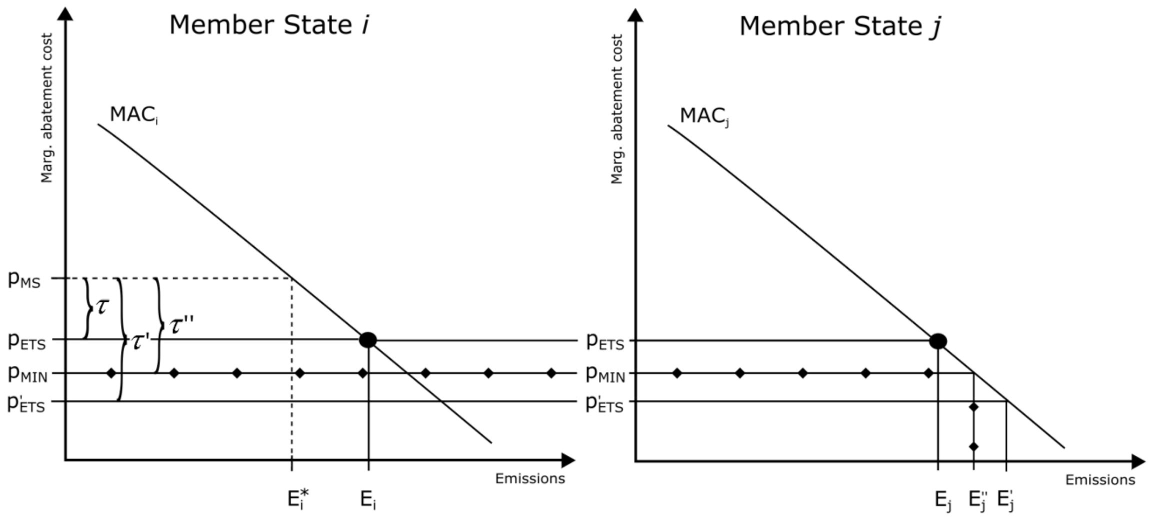

Figure 2.5: Illustration of the cushioning-effect of intra-ETS leakage with a carbon price floor (p_{MIN}).

As soon as τ is implemented, Member State *i*'s firms reduce their demand for allowances subject to p_{MS} and the ETS allowance price falls from p_{ETS} to p'_{ETS}. If Member State *i* wants to ensure that its preferred emission level (E_i^*) is reached, it can do so by adjusting its national policy (τ') by means of a so-called variable fee.[30,31] However, Member State *j,* which has implemented no additional national policy, also faces a decrease on the ETS price (from p_{ETS} to p'_{ETS}). This results in an increase in Member State *j*'s emission level from E_j to E_j'. In effect, since the ETS cap is set exogenously, the additional national policy of Member State *i* has no effect on overall emissions as the emission allowances are used by Member State *j*'s emitters (100 percent emission leakage[32]). From a multinational perspective, the national policy can be considered a disturbance. From a national perspective, the national policy may have beneficial side-effects (e.g., increased national revenues, reduction of local air pollution). However, it fails to reach the goal of total emission reduction due to the intra-ETS leakage effect.

The problem of the ETS price decline and the ineffectiveness of national policies can be cushioned by the implementation of an ETS-wide price floor, p_{MIN} (Refer to figure 2.5 in which Member State *i* now implements the variable policy τ''). Since the ETS price decrease is cushioned, Member State *j* faces p_{MIN} which is lower than the initial ETS price (p_{ETS}) but above p'_{ETS}. Therefore, Member State *j* implicitly benefits from Member State *i*'s policy due to the price decrease. However, the emission leakage effect triggered by the national policy disturbance in the ETS is weakened. The effective emission level of Member State *j* (E_j'') is above the initial emission level (E_j), but below the emission level without a price floor (E_j'). In the end, Member State *i* and *j* are both better off.

4.2. Implications for the European power sector: Numerical simulation

In this section our theoretical analysis is complemented with quantitative results from the long-term investment model for the electricity system of Europe (LIMES-EU). The model is a multi-country model [33] that simultaneously determines cost-minimizing investment and dispatch decisions for generation, storage and transmission technologies needed to serve future electricity demand and to comply with future energy and climate policies. Its integrated approach, together with an intertemporal optimization in five-year steps from today until 2050, allows for the analysis of consistent and cost-efficient pathways for the future development of the European power system on both aggregate and national levels.

The optimal deployment of different electricity generation options strongly depends on future climate and energy policies at EU and national levels. We illustrate the effect of a European price floor plus additional emission reduction efforts in Germany. This is motivated by the current German discussion about how to reach national 2020 climate targets using additional unilateral policies (see, e.g., BMWi 2015). Our analysis is focused on the time span of 2015 to 2030, assuming a common European carbon price from 2030 onwards. In the present model framework, a price floor on carbon emissions leads to additional costs for the energy system. The revenues and redistribution (transfers) from carbon pricing are not considered in our numerical exercise.

Table 2.1 provides an overview of the policy scenarios analyzed. Three different European carbon price floors until 2030 are considered. In the baseline scenarios, the carbon price in Germany is equal to the level of an EU carbon price floor. For the policy scenarios we implement a variable fee in Germany that raises the effective German carbon price to 20€/tCO_2, a price that is in line with the long-term EU decarbonization targets (EC 2011; Knopf et al. 2014).[34] In all scenarios, aggregate European emissions are constrained to be less than or equal to the emission budget that results from the different EU carbon prices (5, 10 and 15 €/tCO_2) without an additional Germany policy. From 2030 onwards, we consider four scenarios with carbon prices of 20, 25, 30 and 35 €/tCO_2 that are effective for all European countries.

Table 2.1 Policy scenarios (all prices in € per tCO_2)

until 2030	Europe	carbon price floor of 5€ / 10€ / 15€
	Germany	no additional policy* or effective carbon price of 20€
after 2030	Europe	common European carbon price of 20€ / 25€ / 30€ / 35€ in 2030, subsequently rising by 5% per year until 2050
	Germany	no additional policy*

*If no additional policy is set, the German carbon price is equal to the European carbon price.

In order to reflect the energy policies currently in place, the nuclear phase-out in Belgium, Germany and Switzerland as well as the German renewable energy expansion target are taken into account. Nuclear power investments in other countries are constrained to the expansions already under construction or planned and to the investments needed to replace depreciating capacities. As the future of carbon capture and storage (CCS) is highly uncertain, our policy scenarios are run both with and without the possibility of CCS investments. In total, this leads to 24 baseline scenarios without and 24 policy scenarios with an additional emission policy in Germany. Figure 2.6 summarizes the effects of such an additional policy on carbon emissions in Germany and in Europe on the whole.

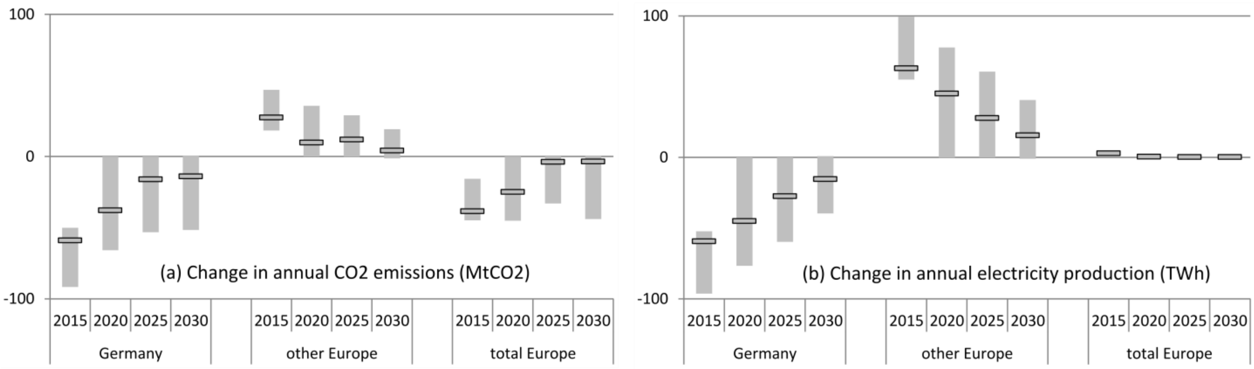

Figure 2.6: Change in (a) annual CO_2 emissions and (b) electricity production due to a higher CO_2 price in Germany. The grey bar indicates the range over all scenarios and the outlined box indicates the median over all scenarios.

The results show that an elevated German carbon price reduces German emissions in all policy scenarios (Figure 2.6 a). This is mostly due to an overall reduction in German electricity production (Figure 2.6 b). Replacing the missing domestic supply with electricity imports from neighboring countries results in an increase of emissions abroad. In most cases, however, the emission reductions in Germany outweigh the emission increases abroad, leading to an overall reduction of emissions across Europe—implying that it is the EU-wide price floor and not the cap that becomes binding. Figure 2.7 illustrates this effect in the year 2020 for a scenario with a common European carbon price of 30€/tCO_2 in 2030 and different price floors in the years prior to 2030. In these scenarios, the European-wide emission reductions vary between 0 and 0.67tCO_2 per ton of emission reduction in Germany. The reductions in German electricity production when there is a EU price floor of 5 or 10€/tCO_2 result from reductions in the use of lignite and hard coal, while the increase in neighboring countries is predominantly based on natural gas and renewables. The lower emission intensity of newly installed foreign power plants reduces the total European emissions. When there is a 15€/tCO_2 European price floor, the German carbon price of 20€/tCO_2 is not high enough to induce a considerable change in the electricity production pattern, nor in CO_2 emissions.

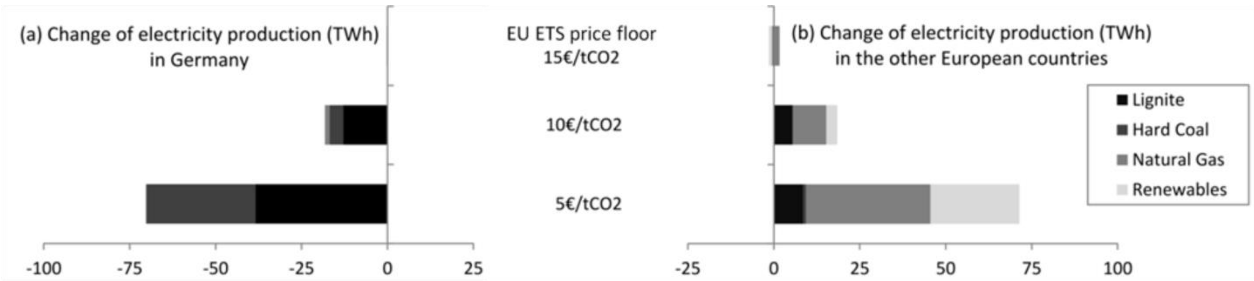

Figure 2.7: Change in annual electricity production (a) in Germany and (b) the other European countries in the year 2020 due to a higher CO_2 price in Germany. Though the use of CCS is possible, it is not yet deployed in 2020 in these scenarios. The annual electricity production of nuclear power plants does not change in any of the three scenarios.

Overall, the results suggest that an EU-wide carbon price floor allows for the introduction of more ambitious national carbon prices with a net reduction effect on overall emissions. In our numerical model framework, such additional efforts increase total system costs. This increase in costs[35] depends heavily on the level of the European price floor. It varies between 12bn€ (in the case of a 15€/tCO_2 price floor) and 36bn€ (in the case of a 5€/tCO_2 price floor). For a price floor of 10€/tCO_2, costs incurred by the additional German climate policy are around 24bn€. Other scenario variations, e.g., the level of the common carbon price after 2030, have only a very limited effect on overall costs (i.e., +/-1bn€), with lower cost differences for higher future carbon prices. Our analysis for the German case can only serve as an illustration. Additional analyses focusing on other countries are needed and should be an interesting subject for further research.

4.3. Some implementation issues

There are several challenges that go beyond the scope of this chapter that are associated with the implementation and operation of a price floor in terms of the detailed design. An extensive analysis can be found in Wood, Jotzo (2011). For the operational implementation of a price floor, they suggest an auction reserve price (which is implemented in the California and Regional Greenhouse Gas Initiative ETSs), a variable fee (as implemented in the UK), or the buy-back of allowances by the regulating authority. To avoid excess allowances being sold at a price below the price floor, the regulator should be willing to buy-back and cancel excess allowances at the level of the price floor, as pointed out by Goulder, Schein (2013). This would imply additional costs for the regulator. Another option to avoid buy-back necessities would be to use a price instrument only (no ETS) (Goulder, Schein 2013). For a detailed discussion on cancelling allowances, see, e.g., Kollmuss, Lazarus (2010). In terms of the newly proposed MSR, a price floor could also be used as a signal indicating when allowances should be withdrawn—i.e., when the ETS price floor is binding.

Some analysts might argue that an EU ETS price floor is unnecessary. Another decentralized alternative for MS with higher WTP for mitigation reduction is the unilateral purchase and retirement of allowances (P&RA). This procedure could be carried out in the current legal EU structure as EU responsibilities and the ETS design would remain unchanged.

To express a significantly higher WTP for mitigation, MS (such as Germany or the UK) would need to purchase and retire significant amounts of EUAs. If huge amounts of EUAs were withdrawn and retired, the first effect that would be observed on the ETS market is an EU ETS price increase, due to a reduction in the total EUA effectively available. This procedure could result in dissent from other MS as they may face a higher ETS price that might not be compatible with their (comparably lower) WTP for mitigation. Therefore, compensation or side-payments may become necessary. This brings back the question of transfer design and the role of transfer coordination. The role of coordination could be effectively carried out at the EU-level if an EU ETS price floor and appropriate transfers are set. There are consequently two drawbacks to the P&RA. First, national funds need to be used as side-payments to generate agreeability among MS on the use of P&RA. Second, the Member State that purchase and retires EUAs must use national revenues that could otherwise be used in other programs, including climate programs (Bianco et al. 2009), thereby causing budgetary disturbances. Given current fiscal pressures it seems unlikely that a country would do this. A case in point is the UK, whose government is under intense political pressure to moderate fiscal austerity.[36] Therefore, it seems politically infeasible to divert revenues from the national budget to purchase EUAs, which would effectively divert revenues from the UK Treasury to allowance holders in other EU MS. In order to avoid the use of governmental revenues, a country could force companies to retire allowances as Germany attempted through the implementation of a "climate levy" (BMWi 2015). This might not impact the national budget but it hurts some MS due to a higher EU ETS price and causes the same problems as discussed above.

From an individual government's perspective, there are additional potential advantages of a price floor. A price floor not only ensures a more stable price signal for market-participants, but also more stable revenue flows for MS and EU ETS funds. If the carbon price floor is binding in the longer term, it can be a substitute for income and corporate taxation, ameliorating the effect on government revenues derived from tax competition (Heinemann et al. 2009) and counteracting distortionary effects of taxation. It can therefore be used as a more efficient source of public finance (Edenhofer et al. 2015). Sweden's environmental national policies exemplify the successful implementation of a carbon price[37] and the shift of the fiscal burden from labor to carbon emissions (OECD 2014). Parry et al. (2014) present an extensive analysis of multiple incentives—besides climate change mitigation—for countries to put a price on carbon emissions, subsequently extended to a discussion of climate regime design based on co-benefits by Edenhofer et al. (2015). Cramton et al. (2015) highlight that the commitment to a uniform multinational carbon price is less risky for individual countries than the commitment to a quantity instrument. They argue that future business-as-usual emissions and abatement costs are both highly uncertain. Due to these uncertainties, the financial risk for countries agreeing on quantity commitments becomes much larger than commitments to a price.

A carbon price floor can also entail benefits for the operation of the EU ETS market. Burtraw (2014), for example, emphasizes that a carbon price floor is a non-discretionary and transparent signal by policymakers about the level of climate policy ambition, which allows market participants to better anticipate future developments. Burtraw also points out that a price floor may be used as a signal for cap adjustments. The more often the price floor binds, the higher the likelihood that the cap was set too loose. As a result, the regulator would need to withdraw and retire allowances or tighten the future cap schedule more often. Therefore, a price floor explicitly and transparently addresses the objective implicitly intended by the MSR— stabilizing the ETS market. More importantly, if credibility about an ETS is lacking, as is the case in the EU ETS, the use of a carbon price floor would increase policy credibility as an additional signal and commitment by policymakers to a certain level of policy ambition.

5. Concluding remarks

This chapter proposes a price floor, in combination with appropriate—not necessarily socially optimal—transfers, as a key reform option for the EU ETS. A carbon price floor has additional advantages to stabilization effects. One such advantage that is often overlooked is the ability to address heterogeneity and the policies of MS in vertical regulatory structures like the EU.

There may be gains from multinational climate policy when there is a multilayered governmental structure such as in the EU. A pure ETS without optimal transfers cannot correctly accommodate MS' heterogeneity as it neglects differences in income and preferences on carbon emissions. The multilayered structure, however, facilitates a solution. An EU ETS carbon price floor, combined with appropriate transfers, can enable MS to implement national climate policies that are indeed effective. This does not necessarily imply additional changes in EU legislation in terms of an EU revenue system. For example, if allowances are auctioned at a price floor, MS can remain in charge of revenue collection. Transfer payments could be coordinated at the EU-level while actual payments could be made bilaterally.

To conclude, this chapter identifies guiding design principles to reform the EU ETS and depicts why and how the heterogeneity of the MS should be considered. We point out efficiency shortcomings in the EU ETS design particularly in light of the heterogeneity of the MS. We connect economic theory to the solidarity principle and discuss why the traditional EU ETS as a pure cap-and-trade system—in which MACs are equalized—is not efficient per se. A higher WTP by MS and subsequent transfers from richer to poorer MS should play a role. To achieve social optimality, significant explicit transfers from richer to poorer MS would need to be deployed. In a model that departs from an EU ETS, differentiated carbon prices could be implemented in each MS, which would implicitly function as transfers. However, different national carbon prices could lead to a fragmentation of the EU climate policy damaging the cooperation among MS.

When embedded in a multilevel governmental system a quantity-based instrument (such as an ETS) at the upper governmental layer leads to inefficient outcomes if it coexists with MS' policies. Hence, the current EU ETS is inconsistent with the principle of subsidiarity. The MS' policies distort the long-term optimal carbon price within the EU ETS. Therefore, we have suggested that an EU-wide price floor combined with optimal transfers for the EU ETS could approximate efficiency.

To cope with the MS’ heterogeneity if neither optimal prices nor optimal transfers are attainable, we propose an EU ETS price floor as a useful tool. Besides the price stabilization effect, an EU ETS price floor allows willing MS to implement national climate policies without decreasing the dynamic efficiency of the EU ETS. It allows MS’ policies to be integrated without undermining EU ETS-wide emission reductions. Our numerical simulations of the European power sector indicate that an EU ETS price floor ameliorates leakage within MS and can achieve additional EU-wide emission reductions of up to 50MtCO_2, if a Member State, such as Germany, also implements a carbon price.

Regardless of the benefits of carbon pricing, the window of opportunity for a debate on long-term reform has more far-reaching implications. The EU can be considered a laboratory for multilateralism and lessons can be learned for implementing global climate policies (Goulder, Stavins 2011; Grubb et al. 2014). If the EU succeeds with its EU ETS reform, it may prove wrong the accusations of “blame-and-burden” and instead shift attention toward the design of a common climate policy with mutual gains (Grubb, Coninck et al. 2014). A failure of the EU ETS may send a negative signal about the plausibility of multinational cooperation to non-EU countries trying to implement an ETS.

The debate about EU climate policy and the EU ETS reform also interacts with the international climate policy process beyond the twenty-first Conference of the Parties (COP 21) in Paris. At the COP 21 the EU and its MS committed to a 40 percent EU-wide GHG emission reduction by the year 2030 compared to 1990 levels (UNFCCC 2015). According to the EC’s Impact Assessment document of alternative EU ETS reform options, these EU-wide GHG emission reductions would require EUA prices of 40€/tCO_2e in the year 2030, and 264€/tCO_2e in the year 2050 (EC 2014).

The agreement of the COP 21 feeds back into the need to reform the EU ETS. An improved coordination between EU and MS' climate policies is required to meet the EU’s and MS’ pledge of EU-wide GHG emission reduction. MS that currently seek to phase out coal-fired power plants, e.g., by unilateral carbon pricing schemes, do not achieve any additional emission reductions beyond the EU ETS cap (pricing schemes are already implemented in the UK and under consideration in Germany). Since coal phase-outs are pressing measures to meet the EU's reduction target, unilateral MS' initiatives should be empowered to accompany EU policy. Currently, MS policies function in the opposite direction. They weaken the EU ETS by lowering EUA prices. Low EUA prices jeopardize the achievement of the EU’s GHG emission reduction target. As this chapter describes, an EU ETS reform that implements a price floor would allow the policies of ambitious Member States to prosper as companion policies to the EU ETS and contribute to the EU-reduction target instead of weakening the EU ETS.

Socially optimal targets and policies may not be attainable, but as this chapter points out, coordination around an EU ETS price floor and appropriate transfers could at least enable policy reforms that support consensus across MS and increase the level of success of climate policy ambitions. These findings, just as they apply to a regional ETS, can also apply to international instruments for climate change mitigation.

References

Bianco, Nicholas; Monast, Jonas; Profeta, Tim; Litz, Franz (2009): Allowing States to Retire Allowances without Affecting National Allowance Prices: A Straw Proposal (Working Paper, World Resources Institute/Duke University Nicholas Institute for Environmental Policy Solutions). https://nicholasinstitute.duke.edu/sites/default/files/publications/allowing-states-to-retire- allowances-without-affecting-national-allowance-prices-a-straw-proposal-paper.pdf (accessed 10/23/2015).

BMWi, Bundesministerium für Wirtschaft und Energie (2015): Eckpunkte-Papier „Strommarkt". *Bundesministerium für Wirtschaft und Energie.* http://www.bmwi.de/BMWi/Redaktion/PDF/E/eckpunkte-papier-strommarkt,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf (accessed 10/31/2015).

Böhringer, Christoph; Koschel, Henrike; Moslener, Ulf (2008): Efficiency Losses from Overlapping Regulation of EU Carbon Emissions. *Journal of Regulatory Economics* 33(3), 299–317.

Burtraw, Dallas (2014): "Commentary: Saving Europe's Key Weapon against Climate Change, 2014." *Resources for the Future.* http://www.rff.org/research/publications/commentary-saving-europe-s-key-weapon- against-climate-change (accessed 9/10/2015).

Chichilnisky, Graciela; Heal, Geoffrey (1994): Who Should Abate Carbon Emissions? *Economics Letters* 44, 443–449.

Chichilnisky, Graciela; Heal, Geoffrey; Starrett, David (2000): Equity and Efficiency in Environmental Markets: Global Trade in Carbon Dioxide Emissions. In *Environmental Markets. Equity and Efficiency,* ed. Chichilnisky and Heal. Chichester, West Sussex: Columbia University Press, 46–67.

Coase, Ronald H. (1960): The Problem of Social Cost. *Journal of Law and Economics* 3, 1–44.

Copenhagen Economics (2010): Innovation of Energy Technologies: The Role of Taxes, No 0036 (Taxation Studies, Directorate General Taxation and Customs Union, European Commission). http://ec.europa.eu/taxation_customs/resources/documents/common/publications/studies/t axation_energy_innov.pdf (accessed 10/29/2015).

Cramton, Peter; Ockenfels, Axel; Stoft, Steven (2015): An International Carbon-Price Commitment Promotes Cooperation. *Economics of Energy & Environmental Policy* 4 (2), 51–64.

EC, European Commission (2011): "Energy Roadmap 2050 - Impact assessment and scenario analysis." *European Commission: Energy.* https://ec.europa.eu/energy/en/topics/energy-strategy/2050-energy-strategy (accessed 9/10/2015).

——— (2012): "The state of the European carbon market in 2012." COM(2012) 652 final. http://ec.europa.eu/clima/policies/ets/reform/docs/com_2012_652_en.pdf (accessed 10/28/2015).

——— (2013): "The EU Emissions Trading System (EU ETS) Factsheet." http://ec.europa.eu/clima/publications/docs/factsheet_ets_en.pdf (updated 2013, accessed 9/10/2015).

———(2014): A policy framework for climate and energy in the period from 2020 up to 2030. SWD(2014) 15 final. Available online at http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0015_en.pdf, (accessed 9/10/2015).

——— (2015a): "EU ETS Auctioning." *European Commission: Climate Action.* http://ec.europa.eu/clima/policies/ets/cap/auctioning/index_en.htm (accessed 9/10/2015).

——— (2015b): "EU Tax Policy Strategy." *European Commission: Taxation and Customs Union.* http://ec.europa.eu/taxation_customs/taxation/gen_info/tax_policy/index_en.htm (updated 2015, accessed 9/10/2015).

——— (2015c): "The Lisbon Treaty and tax legislation in the EU." *European Commission: Taxation and Customs Union.* http://ec.europa.eu/taxation_customs/taxation/gen_info/tax_policy/article_6759_en.htm (updated 2015, accessed 9/10/2015).

——— (2015d): "Allowances and Caps." *European Commission: Climate Action.* http://ec.europa.eu/clima/policies/ets/cap/index_en.htm (accessed 10/20/2015).

Edenhofer, Ottmar; Jakob, Michael; Creutzig, Felix; Flachsland, Christian; Fuss, Sabine; Kowarsch, Martin et al. (2015): Closing the Emission Price Gap. *Global Environmental Change* 31, 132–143.

EEA, European Environment Agency (2013): *Trends and projections in Europe 2013 — Tracking progress towards Europe's climate and energy targets until 2020.* Luxembourg: Publications Office of the European Union. http://www.eea.europa.eu//publications/trends-and-projections-2013.

——— (2015): "EEA greenhouse gas - data viewer." *European Environment Agency: Data and Maps.* http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer (accessed 10/20/2015).

EEX, European Energy Exchange (2015): "Emissions Secondary Market." *European Energy Exchange: Environmental Markets.* https://www.eex.com/en/products/environmental-markets/emissions-secondary-market (accessed 10/30/2015).

EP, European Parliament (2014): "Indirect taxation." *European Parliament: Fact Sheets on the European Union.* http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU_5.11.3.html (updated 10/26/2015).

——— (2015): "The principle of subsidiarity." *European Parliament: Fact Sheets on the European Union.* http://www.europarl.europa.eu/ftu/pdf/en/FTU_1.2.2.pdf (accessed

9/10/2015).

Eyraud, Luc; Wane, Abdoul; Zhang, Changchang; Clements, Benedict (2011): Who's Going Green and Why? Trends and Determinants of Green Investment (IMF Working Paper 11/296). https://www.imf.org/external/pubs/ft/wp/2011/wp11296.pdf.

Garside, Ben (2015a): BRIEFING: In or Out? Poland Approaches EU Climate Crossroads. Published August 5, 2015. *Carbon Pulse.* http://carbon-pulse.com/briefing-in-or-out-poland-approaches-eu-climate-crossroads (accessed 9/10/2015).

——— (2015b): Poland's surging opposition seeks talks on EU emission opt-out. Published June 22, 2015. *Carbon Pulse*. http://carbon-pulse.com/polands-surging-opposition-seeks- talks-on-eu-emission-opt-out-bloomberg (accessed 9/10/2015).

Goulder, Larry; Schein, Andrew R. (2013): Carbon Taxes versus Cap and Trade: A Critical Review. *Climate Change Economics* 4(3).

Goulder, Lawrence H.; Stavins, Robert N. (2011): Challenges from State-Federal Interactions in US Climate Change Policy. *American Economic Review* 101(3), 253–257.

Grubb, Michael; Coninck, Heleen de; Sagar, Ambuj D. (2014): From Lima to Paris, Part 2: Injecting Ambition. *Climate Policy* 15(4), 413–416.

Heinemann, Friedrich; Mohl, Philipp; Osterloh, Steffen (2009): Who's afraid of an EU tax and why?—revenue system preferences in the European Parliament. *The Review of International Organizations* 4(1), 73–99.

Hilpold, Peter (2015): Understanding Solidarity within EU Law: An Analysis of the 'Islands of Solidarity' with Particular Regard to Monetary Union (April 27, 2015). 34 *Yearbook of European Law* 2015, pp. 257-285. Available at SSRN: https://ssrn.com/abstract=2599725 or http://dx.doi.org/10.2139/ssrn.2599725

HM Revenue & Customs (2014): "Carbon price floor: reform and other technical amendments." *Gov.UK: Business tax - policy paper.* https://www.gov.uk/government/publications/carbon-price-floor-reform (accessed05/11/2016).

Inman, Philip (2015): "UK deficit rises steeply after surprise fall in tax receipts." Published Sept 22 2015. *The Guardian*. http://www.theguardian.com/business/2015/sep/22/uk-deficit-rises-steeply-after-surprise- fall-in-tax-receipts (accessed 10/28/2015).

IPCC (2014): *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA.

Kahn, Debra (2015): "California engaging in carbon-trading discussions with other Western states." Published Aug 21 2015. *E&E Publishing*. http://www.eenews.net/stories/1060023751 (accessed 9/10/2015).

Knopf, Brigitte; Koch, Nicolas; Grosjean, Godefroy; Fuss, Sabine; Flachsland, Christian; Pahle, Michael et al. (2014): The European Emissions Trading System (EU ETS): ex-post analysis, the market stability reserve and options for a comprehensive reform. *Nota* *di Lavoro* 79(2014). Milan, Italy: Fondazione Eni Enrico Mattei.

Koch, Nicolas; Fuss, Sabine; Grosjean, Godefroy; Edenhofer, Ottmar (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, Nicolas; Grosjean, Godefroy; Fuss, Sabine; Edenhofer, Ottmar (2016): Politics matters: Regulatory events as catalysts for price formation under cap-and-trade. *Journal of Environmental Economics and Management* 78, 121–139.

Kollmuss, Anja; Lazarus, Michael (2010): Buying and cancelling allowances as an alternative to offsets for the voluntary market: A preliminary review of issues and options (OECD. Environment Working Paper No. 21).

Landis, Florian; Schenker, Oliver; Reanos, Miguel Angel Toar; Vonnahme, Christina, Zitzelsberger, Sonja (2012): An Overview on Current Climate Policies in the European Union and its Member States. Centre for European Economic Research, ZEW Mannheim.

Nahmmacher, Paul; Schmid, Eva; Knopf, Brigitte (2014): Documentation of LIMES-EU - A long-term electricity system model for Europe. Potsdam Institute for Climate Impact Research, Potsdam, Germany. https://www.pik-potsdam.de/members/paulnah/limes-eu-documentation-2014.pdf.

Oates, Wallace E. (1972): An Essay on Fiscal Federalism. *Journal of Economic Literature* 37, 1120–1149.

——— (2011): *Fiscal Federalism*. Cheltenham: Edward Elgar Publishing Ltd.

OECD (2013): *Effective Carbon Prices*. Paris, France: OECD Publishing. http://dx.doi.org/10.1787/9789264196964-en.

——— (2014): "Sweden - Highlights." *OECD: Environmental Country Reviews.* http://www.oecd.org/env/country- reviews/highlights.htm

Parry, Ian; Veung, Chandara; Heine, Dirk (2014): How Much Carbon Pricing is in Countries' Own Interests? The Critical Role of Co-Benefits (CESifo Working Paper No. 5015). https://www.cesifo-group.de/DocDL/cesifo1_wp5015.pdf.

Philibert, Cédric (2006): Certainty versus Ambition. Economic Efficiency in Mitigation Climate Change (International Energy Agency Working Paper Series). http://philibert.cedric.free.fr/Downloads/rb_certainty_ambition.pdf.

——— (2009): Assessing the value of price caps and floors. *Climate Policy* 9 (6), 612–633.

Quandl (2015a): ICE Futures Europe. ECX EUA Futures, Continuous Contract #2. https://www.quandl.com/data/CHRIS/ICE_C2-ECX-EUA-Futures-Continuous-Contract-2-C2 (accessed 10/30/2015).

——— (2015b): ICE Futures Europe. ECX EUA Futures, December 2020. https://www.quandl.com/data/ICE/CZ2020-ECX-EUA-Futures-December-2020-CZ2020 (accessed 10/31/2015).

Roolfs, Christina; Gaitan, Beatriz; Edenhofer, Ottmar (2016): The richest wins them all: Triggering benevolent hegemony by federal transfers. (*Mimeo*).

Santore, Rudy; Robison, H.David; Klein, Yehuda (2001): Strategic state-level environmental policy with asymmetric pollution spillovers. *Journal of Public Economics* 80(2), 199–224.

Sheeran, Kristen A. (2006): Who Should Abate Carbon Emissions? A Note. *Environmental and Resource Economics* 35(2), 89–98.

Shiell, Leslie (2003): Equity and efficiency in international markets for pollution permits. *Journal of Environmental Economics and Management* 46(1), 38–51.

Shobe, William M.; Burtraw, Dallas (2012): Rethinking Environmental Federalism in a Warming World. In *Climate Change Economics* 3(4), 33.

Skjærseth, Jon Birger; Wettestad, Jørgen (2010): Making the EU Emissions Trading System: The European Commission as an entrepreneurial epistemic leader. *Global Environmental Change* 20(2), 314–321.

Strunz, Sebastian; Gawel, Erik; Lehmann, Paul (2015): Towards a general "Europeanization" of EU Member States' energy policies? *Economics of Energy & Environmental Policy* 4 (2).

Talus, Kim (2013): *EU Energy Law and Policy: A Critical Account.* Oxford: Oxford University Press.

UNFCCC (2015): EU Submits its Climate Action Plan ahead of Paris 2015 Agreement. Available online at http://www4.unfccc.int/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf, updated on 10/6/2015, (accessed 10/6/2015)

Williams, Roberton C. (2012): Growing state–federal conflicts in environmental policy: The role of market-based regulation. *Journal of Public Economics* 96(11-12), 1092–1099.

Wood, Peter John; Jotzo, Frank (2011): Price floors for emissions trading. *Energy Policy* 39 (3), 1746–1753.

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2. Auctioning of 900 million EUAs was postponed from the years 2014/2016 to 2019/2020.

3. The MSR mechanism withdraws EUAs from auctioning when a certain upper threshold of unused EUAs in circulation (allowance surplus) is exceeded and feeds these into the "Market Stability Reserve." Once a lower threshold is triggered, these EUAs are re-released from the MSR.

4. Data for EUA prices for the year 2008 are taken from ECX EUA Futures, Continuous Contract #2, ICE (Quandl 2015b). EUA prices from 2009-2015 are based on the settlement prices at the secondary market, EEX (2015). Future contract prices for the year 2020 are taken from the settlement prices in December 2020, ICE (Quandl 2015a).

5. For example, the UK's climate change levy, the German Renewable Energy Act (which includes subsidies to renewable energy production) and eco-tax, the Danish and Swedish fuel and carbon taxes and a variety of funds for energy efficiency measures in various MS (Landis et al. 2012).

6. The sectors considered by the OECD study are electricity generation, road transport, pulp and paper, cement, and households' domestic energy use.

7. Note that the OECD's estimated effective carbon prices are based on specific calculations for different policies. It implies neither that all instruments considered (like carbon taxes and feed-in tariffs) function in the same way, nor that they have the same effect on emission mitigation.

8. We stress that the estimates based on the OECD (2013) serve for illustrative purpose only. There are different methodologies available to calculate implicit carbon prices. A discussion of alternative estimates of effective carbon prices can be found in OECD (2013).

9. The heterogeneity of the EU MS can be in terms of, e.g., economic development, environmental objectives, dependency on domestic polluting fuels, and concerns about vulnerability related to the import of energy fuels.

10. According to Hilpold (2015) the EU solidarity principle means that contributions (transfers) across MS or from the EU budget to MS are given with either a) the hope of receiving counter-contributions at some point in the future or b) the intent to pursue a common goal.

11. The subsidiarity principle defines the exercise of the EU's competences to be justifiable only if the EU can improve on the MS' action (EP 2015).

12. We will specify how we define "appropriateness" later in this chapter.

13. See Lisbon Treaty and tax legislation in the EU (EC 2015c, EC 2015b).

14. The claim that allowing special treatments, such as grandfathering, is only possible within an ETS is questioned by Goulder and Schein (2013), who argue that when

using a carbon tax-price, tax exemptions can achieve similar effects as those from grandfathering.

15. See, e.g., Ben Garside (2015b; 2015a).

16. At the current exchange rate of 1.35, this accounts to approx. 25€/tCO_2e in the year 2015 and 40€/tCO_2e in the year 2020.

17. Under the Swedish carbon tax program, small industrial producers and agriculture and forestry sectors pay lower carbon taxes than do households (OECD 2014).

18. Roughly defined, the marginal abatement cost is the cost increase from reducing a unit of emissions.

19. For example, by assigning a higher proportion of certificates to Eastern European countries, in particularly Poland (Garside 2015b; EC 2013).

20. We refer to "efficiency" in terms of allocative efficiency, not to be confused with cost-effectiveness, which is sometimes also called "cost-efficiency."

21. See Sheeran (2006) for intuitive details on the modelling work of Chichilnisky and Heal (1994) and their consecutive work in Chichilnisky et al. (2000).

22. The beneficiaries of the "Kyoto bonus" are Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia.

23. During phase I and II of the EU ETS, EUAs were granted for free (grandfathered) to industry and power companies. Many of these power companies are fully or partially state-owned. In such cases, it is likely that domestic consumers indirectly benefited from these free allowances. Additionally, a proportion of EU ETS emissions are generated by non-domestic and/or transnational firms, inside and outside of electricity production, in which case it is not necessarily the domestic consumers who benefited from the grandfathered

allowances.

24. In addition to climate change externality considerations, there are other reasons why a uniform carbon price—which equalizes MACs across countries—may not be efficient. For example, some countries may wish to price emissions more aggressively for fiscal reasons. If a country has a relatively mobile tax base with respect to broader fiscal instruments (e.g., due to a prevalence of informal markets, tax evasion), then implementing carbon prices may be a fiscal alternative to other taxes.

25. In a comparable setup, Santore et al. (2001) arrive at similar findings.

26. See also Goulder, Schein (2013) and Shobe, Burtraw (2012).

27. In technical terms we impose a separable utility function in which the consumption component is identical across countries. We also assume that an upper regulator such as the EU equally weighs each country within a social welfare function.

28. Within this essay the EU ETS-transfer estimation only depicts *optimal* transfers. Estimates for other *appropriate* EU ETS transfers—those transfers that achieve (Pareto) improvements for all MS but not necessarily optimality—are subject to our ongoing research.

29. I.e., equity-based transfers and transfers based on historical emissions.

30. If the Member State would not use a variable but a fixed fee, its price would drop below p_{MS}. We suppose that a Member State may anticipate the price drop effect and therefore adjust its policy to meet its preferred emission level. However, both instruments—a variable and a fixed fee—in general generate the same effects in this exercise. For a detailed discussion of a variable fee as a national price floor see Wood, Jotzo (2011).

31. The mechanism is similar to the UK's carbon price floor for the EU ETS.

32. See also Goulder and Stavins (2012), who discuss the leakage effect in more detail.

33. The model version applied in this paper comprises 26 of the 28 EU Member States plus Switzerland, Norway and the Balkan region, and excludes Malta and Cyprus. Except for the Balkan region, all countries are represented as individual model regions. Transmission is modelled as a transport problem from the center of one region to the center of a neighboring region, with the maximum transmissible amount of electricity being restricted by the installed net transfer capacity. There are 14 different generation technologies and two different storage technologies represented in LIMES-EU. See Nahmmacher et al. (2014) for detailed model documentation.

34. The large model comparison exercise presented in Knopf et al. (2014) showed that a carbon price of at least 20€/tCO_2 is needed before 2030 in order to cost-efficiently reach the long-term decarbonization targets by 2050.

35. The total system costs comprise the dispatch and investment costs of all generation, storage and transmission technologies until 2050. They are discounted to today's values with a discount factor of 5 percent per year.

36. See for example, Inman (2015).

37. In this case it is a tax. However, it is a constant revenue stream—a feature of both a tax and a price floor.