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Abstract

From 2023 onwards, allowances held in the market stability reserve above the number of allowances auctioned the previous year will be cancelled. In this paper, we analyse what consequences additional national emission reductions in the EU ETS sector will have on total emissions given this new cancellation mechanism. We show that additional national abatement measures now have the potential to reduce total EU ETS emissions. However, for this to happen, the emission reductions must take place early – before 2023 in our base case. To provide an understanding of this complex system, we present a series of extensions to show how the results are affected by, for example, future emission levels, technological development, optimising agents and speculative trading in allowances.

Keywords: EU ETS, cancellation mechanism, numerical analysis, national emission reductions.

1. Introduction

The EU aims to reduce greenhouse gas emissions from its emissions trading system (EU ETS) by 43 per cent by 2030 compared to 2005. To facilitate this, a series of revisions to the EU ETS directive entered into force on 8 April 2018 after "extensive negotiations"[1]. We focus on the consequences of one short passage in the directive. It reads:

"[…] *from 2023 allowances held in the reserve above the total number of allowances auctioned during the previous year should no longer be valid*" (recital 23, Directive (EU) 2018/410)

This creates what we refer to as a "cancellation mechanism" which will have a great impact on EU climate policy. Not only will it cancel a large number of allowances, but if an individual member state induces additional emission reductions from its domestic EU ETS, this may now affect total emissions. This fundamentally changes the role of national (EU ETS) overlapping policies. Previously, such policies might have had an influence on prices, but not on total emissions.

The revision of the EU ETS creates a complex system. It is by no means obvious how or to what extent domestic emission reductions will reduce total emissions. The purpose of this paper is to analyse how the system operates and thereby help policy makers make well-founded decisions. In particular, we:

a) analyse whether national measures will influence total emissions in the EU ETS sector, and, if so,
b) discuss what factors will influence the magnitude of the effect and through what mechanisms the effect will operate.

The paper is organised as follows. Section 2 provides a background and briefly comments on the system and its components. Section 3 analyses possible impacts from national measures, first by assuming that the system does not influence agents' intertemporal optimisation and then by suggesting instead that the agents are responsive. Section 4 concludes.

2. Background

The EU ETS was introduced in 2005 and is currently reaching the end of its third trading period (2013-2020). It covers energy-intensive industries and large electricity and heat producers. The system has been evaluated on several occasions, and amendments to the original directive (Directive 2003/87/EC) have been adopted, such as Directive 2009/29/EC and Directive (EU) 2018/410.

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[1] ec.europa.eu/clima/policies/ets/revision_en.

The latter was preceded in 2017 by the EU member states formally approving a set of new rules for the EU ETS (Council of the European Union, 2017a and 2017b).

Persistently low prices for allowances since 2008 prompted the European Commission in 2012 to suggest a revision of the EU ETS. As a result, the European Parliament and the Council decided in 2015 to establish a market stability reserve (MSR) (European Commission, 2012; Decision (EU) 2015/1814). The reserve will come into force in 2019.[2]

The reserve will reduce the current amount of allowances in circulation by limiting auction volumes. The Total Number of Allowances in Circulation (TNAC) is defined by the European Commission (2017) as follows:

$$TNAC = Supply - Demand - Allowances\ in\ the\ MSR$$

The supply of allowances includes banked allowances from phase 2 of the EU ETS (2008-12) and allowances allocated to the market from the start of phase 3 (1 January 2013). Demand consists of the total verified emissions from installations and allowances cancelled from 2013. As allowances held in the MSR are not included in the TNAC it may, somewhat simplified, be viewed as the number of allowances held by actors on the market.

When the TNAC is above 833 million, the number of allowances auctioned will be reduced by 24 per cent of the TNAC (12 per cent from 2024). These allowances are placed in the reserve. When the TNAC is below 400 million, a total of 100 million allowances will be withdrawn from the reserve and auctioned to the market (200 million until 2024).

The stated purpose of the reserve is to stabilise and raise the allowance price. However, previous studies, such as Perino and Willner (2016), suggest that the reserve, contrary to its purpose, will increase price volatility. In addition, Salant (2016), focusing on political risk, shows that political interference will cause a deviation from the cost-effective price path within the system.

In line with what was suggested in Kollenberg and Taschini (2016), the European Parliament and the Council decided in 2017 to complement the reserve with a cancellation mechanism.[3] Starting in 2023, the cancellation mechanism means that the reserve cannot contain more allowances than

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[2] Other changes include increasing the linear factor by which the allocated allowances are reduced each year, from 1.74 to 2.2 per cent of the allocation in 2005.

[3] Alternative ways of revising the system are discussed in, e.g., Andor et al. (2016). Factors influencing allowance prices are presented in, e.g., Koch et al. (2014), Ellerman et al. (2015 and 2016), and Hintermann et al. (2016).

were auctioned the previous year. Any allowances above that number will become invalid. This implies that, from 2023, a significant number of allowances will be cancelled (Council of the European Union, 2017a and 2017b).

3. Impact of additional national measures

In this section, we analyse what the cancellation mechanism means for the effect of additional national EU ETS emission reductions on total EU ETS emissions[4]. It is well-known that, without the cancellation mechanism, the impact of such additional policy measures on total emissions is zero. This is because total emissions are given by the number of allowances allocated. Implementing a national measure will have no effect on that number, hence it will only result in emissions being reallocated geographically and/or over time.[5] With the introduction of the MSR, this conclusion remains.

The cancellation mechanism may change this. Additional national measures that reduce domestic emissions in a given year imply that allowances, otherwise needed to cover these emissions, may not be used. Thus, the total number of allowances in circulation that year will increase. This will, subject to the TNAC being larger than 833 million, mean that the number of allowances auctioned the following year will be reduced further and more allowances will be transferred to the MSR, after which they may – due to the cancellation mechanism – leave the system.

To study the effects of the cancellation mechanism in more detail, we present a numerical analysis. We start in a simple setting and consider a case where a small country unilaterally implements a temporary tax[6] on its EU ETS firms that reduces the sector's emissions by 1 million tons in 2019, the same year the MSR becomes operational and four years before the cancellation mechanism comes into force.

Some assumptions are required. First, we assume that the MSR in 2019 holds 1 000 million allowances. This seems plausible: a total of 900 million allowances previously withdrawn from auctioning will be placed in the reserve at this time, together with a limited number of allowances that, for various reasons, have not been allocated to the market. Second, we postulate that the TNAC is 2 500 million in 2019. In 2016, the number was 1.7 billion, and it was virtually unchanged in 2017 (European Commission, 2017 and 2018). It is not unlikely that this amount will increase until 2019.

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[4] The term "total emissions" refers here and henceforth to all CO_2e emissions from the entire EU ETS sector aggregated over the system's life span. We do not allow for the possibility that additional emission reductions in the EU ETS sector may result in upward calibration of the ESR target, or any other form of carbon leakage effects.

[5] One may argue that national measures could lead to future policy shifts, which in turn could reduce the total number of allowances to be allocated. This indirect effect will not be addressed further here.

[6] The qualitative results of the analysis presented below are valid for a wide range of policy measures.

Third, the number of allowances intended for auctioning in 2019 is assumed to be 1 000 million. This might be somewhat on the high side. In 2018, around 800 million allowances are intended to be auctioned, excluding allowances auctioned in EEA EFTA countries. Fourth, the number of auctioned permits is assumed to decrease by 25 million allowances per year. In reality, a linear factor annually reduces the allocation by 48 million allowances. Since about 55 per cent of the total allocation is auctioned, the assumed path seems realistic. We only address EU ETS allowances that are allocated through auctions and ignore those allocated for free. The implicit assumption is that the allowances allocated for free each year are all used to cover emissions that year, i.e. they will not affect the TNAC. This simplification does not influence the qualitative results.

NON-RESPONSIVE AGENTS

In this section, we assume that the system does not influence the intertemporal optimisation of the agents. Although this is unrealistic, it allows us to focus on the "technical" consequences of the system. Later, we introduce agents that optimise their behaviour over time. Here, we view the market as one coordinated agent that follows a simple rule of emitting a certain amount each year (the "target emission level") if there are allowances available to cover that emission level. When there is a shortage of allowances, the market emits as much as possible given the number of allowances available.

In the base case, we set the target emission level at 900 million tons.[7] Also, the target emission level is initially assumed to be constant over time. Later, we address a decrease in the target level over time due to technological development.

Influence of the cancellation mechanism on TNAC, MSR and auction volumes

Before considering how additional domestic emission reductions will affect total emissions, we briefly address how the cancellation mechanism will influence the TNAC, the MSR and the volumes being auctioned. Figure 1a shows how the TNAC (base case) evolves over time, with (dashed line) and without (solid line) the cancellation mechanism.

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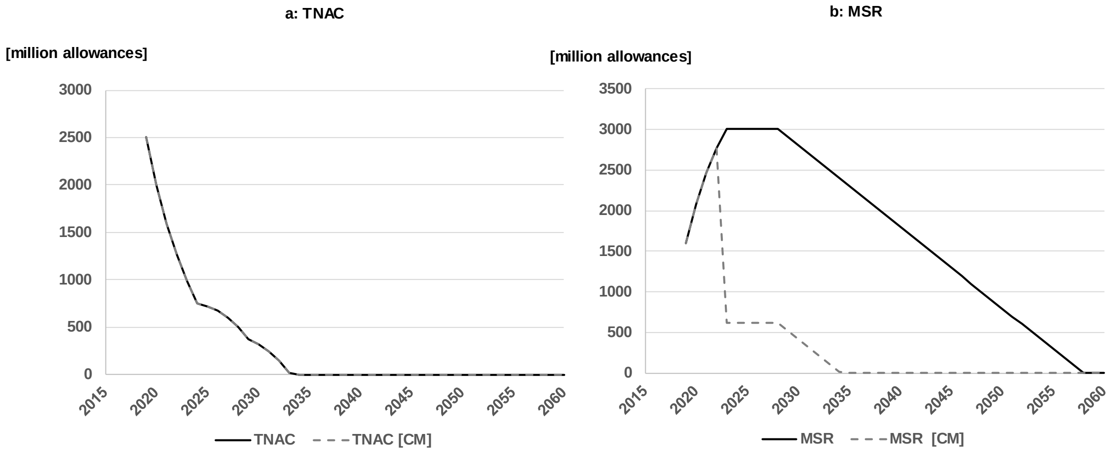
[7] We assume an initial auction volume of 1 000 million allowances. In recent years, total emissions from the EU ETS have amounted to approximately 90 per cent of the annual allocation. As we focus only on the auctioned share, the target emission level we employ is 90 per cent of 1 000 million.

Figure 1 *TNAC and MSR over time in the base case, with and without the cancellation mechanism*



Two things are worth noting in Figure 1a. First, it shows a rapid initial decrease in the TNAC. The 2 500 million allowances in 2019 are reduced to 748 million allowances in 2024. Second, the two lines coincide, i.e. the cancellation mechanism does not affect the reduction of the TNAC. This implies that changes in the TNAC are driven by the MSR, not the cancellation mechanism. The cancellation mechanism, however, has a major impact on the number of allowances that will be held in the MSR, as seen from Figure 1b. When the mechanism first becomes operational in 2023, it will, given the setting in the base case, make almost 2 400 million allowances invalid. Both with and without the cancellation mechanism, the number of allowances in the MSR is constant between 2023 and 2029 due to the TNAC then being below 833 million but above 400 million. From 2029 onwards, the TNAC is below 400 million, and allowances are fed back to the market until the MSR is emptied. This occurs in 2059 without the cancellation mechanism, but as early as in 2035 with the cancellation mechanism in force.[8]

Figure 2 illustrates the yearly auction volume, with and without the cancellation mechanism. Up until 2035, there is no difference between the two. In both cases, there is an initial high reduction in auction volumes. For instance, in 2019, the planned auction volume is assumed to be 1 000 million allowances. Due to the large number of allowances in the TNAC, the auction volume is reduced by 600 million (24 per cent of 2 500 million). As the TNAC decreases, so does the reduction in auction volumes.

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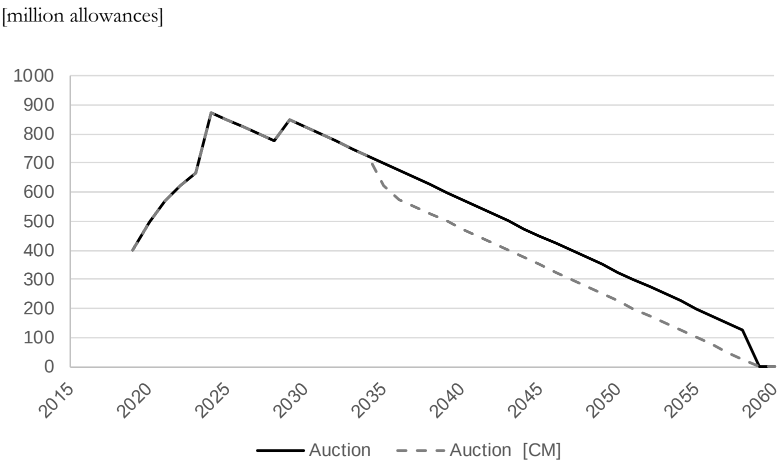
[8] As a comparison, Perino and Willner (2017) find that the MSR is emptied in 2037.

Figure 2 *Number of allowances auctioned in the base case, with and without the cancellation mechanism*



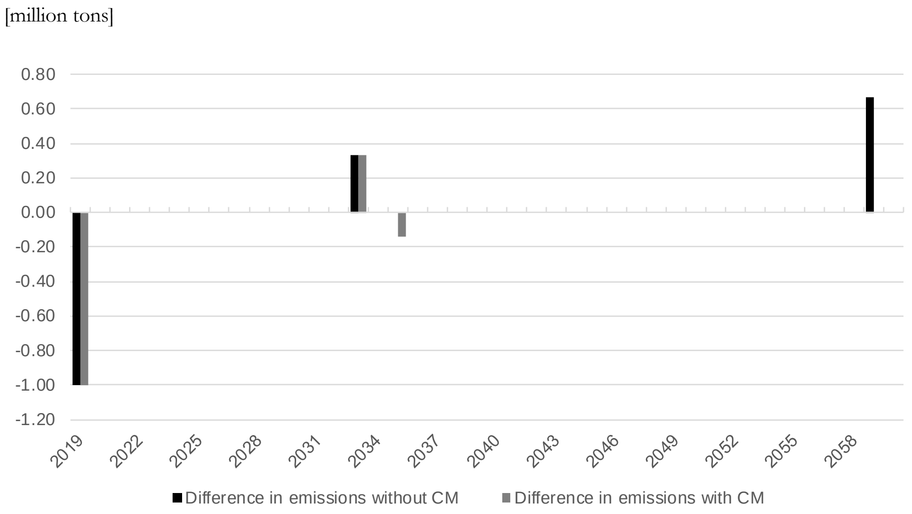
The first kink in the curves in Figure 2 (in 2023) is due to a reduced feed-in rate (from 24 to 12 per cent). The second kink (in 2024) reflects a drop in the TNAC to below 833 million, after which the system reverts to the original allocation plan (until 2029). The TNAC then drops below 400 million, and 100 million extra allowances are fed back from the MSR to the market each year and added to the annual allocation. When the cancellation mechanism is in force, the feedback of allowances stops in 2035, as the MSR is then emptied.

Effects of national measures on total emissions

The discussion above briefly illustrates the impact of the cancellation mechanism. We now turn to the main objective of this study: to address what the cancellation mechanism means for the effects of additional overlapping national policies.

Consider a small country that implements a measure that results in a one-shot reduction in domestic EU ETS industry emissions of an additional 1 million tons in 2019. Figure 3 illustrates how EU ETS emissions are affected by that measure, with and without the cancellation mechanism.

Figure 3 *Impact on emissions from national measure, with and without the cancellation mechanism*



The initial reduction in emissions by 1 million tons is shown by the negative bars in 2019 in Figure 3. During most other years, the initial reduction will not have any impact on emission levels. However, there are three exceptions: 2033, 2035 and 2059.

Without the cancellation mechanism (black bars), emissions in 2033 increase by 0.33 million tons compared to the case without the additional initial emission reduction. In 2059, another emission increase, amounting to 0.67 million tons, occurs. The total emission increase is thus exactly equal to the initial reduction. This is not surprising: without the cancellation mechanism, the MSR will only reallocate emissions over time.

With the cancellation mechanism, the outcome is different. Again, there is an emission increase in 2033 of 0.33 million tons. However, an emission reduction of 0.14 million tons will now occur in 2035. Thus, in this example, an initial emission reduction of 1 million tons results in total emissions falling by 0.81 million tons (1 million - 0.33 million + 0.14 million) when the cancellation mechanism is operational.[9]

The effects in 2033, 2035 and 2059 all have different explanations. In 2033, there are not enough allowances available for the market to emit as much as it would otherwise have done. Hence, emissions fall below the assumed annual target level of 900 million tons for the first time. However, the initial reduction causes the TNAC in 2033 to be 0.33 million tons larger than it would otherwise have been. These additional allowances enable increased emissions that year.

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[9] Similar results are found in Kruse-Andersen and Beck (2018).

Furthermore, the number of allowances in the MSR will be greatly reduced when the cancellation mechanism is first applied in 2023. In 2035, the TNAC is below 400 million, and thus 100 million allowances should be fed back to the market through increased auction volume. But there are not that many allowances in the MSR in 2035. The initial 1 million reduction will make the 2022 auction a little lower, hence the number of allowances left in the MSR after the 2023 cancellation will also be lower. Thus, when the MSR is emptied in 2035, it contains fewer allowances than had the initial emission reduction not occurred. The difference amounts to 0.14 million. Thus, emissions will be 0.14 million tons lower in 2035 due to the initial emission reduction.

The increased emissions in 2059 follow from the initial further reduction increasing the number of allowances in the MSR, which will be allocated to the market when the MSR is emptied. Here, this occurs in 2059.[10]

The example illustrates that overlapping policies will, given the cancellation mechanism, affect total emissions. The reduction in total emissions will, with one exception discussed below, never exceed the initial reduction. In the above example, the total reduction in emissions amounts to 81 per cent of the initial reduction. That figure is specific to the assumptions we make. It depends on how much of the initial reduction may be fed into the MSR before the TNAC falls below 833 million. We study this and other aspects in more detail in a series of extensions below.

Extension 1 – Varying the market's emission levels

In the base case, the target emission level is assumed to be constant at 900 million tons per year. With a higher (lower) target level for emissions, the TNAC will decrease at a faster (slower) rate. As this will influence the number of years during which the TNAC exceeds 833 million, and hence allowances are fed into the MSR and may be subject to the cancellation mechanism, it will influence the impact that additional national measures have on the system's total emissions.

Consider a low target emission level of, say, 600 million tons. A national measure that reduces domestic EU ETS emissions by 1 million tons in 2019 will, as above, momentarily increase the TNAC by 1 million. Thus, the number of allowances fed into the MSR will be larger, and the auction volume will be correspondingly lower. In the first year, the difference will be 24 per cent of 1 million. Consequently, the TNAC will be 0.76 million larger in the second year due to overlapping policies. Again, 24 per cent of this constitutes the difference in auction volume compared to no additional domestic reduction. Thus, 0.18 (= 0.24 * 0.76) million fewer allowances will be allocated to the market in the second year. This process continues as long as the TNAC contains more than 833 million allowances. As the target emission level is low, the TNAC will stay above 833 million for a

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[10] As allowances are scarce, these additional allowances will result in increased emissions in 2059.

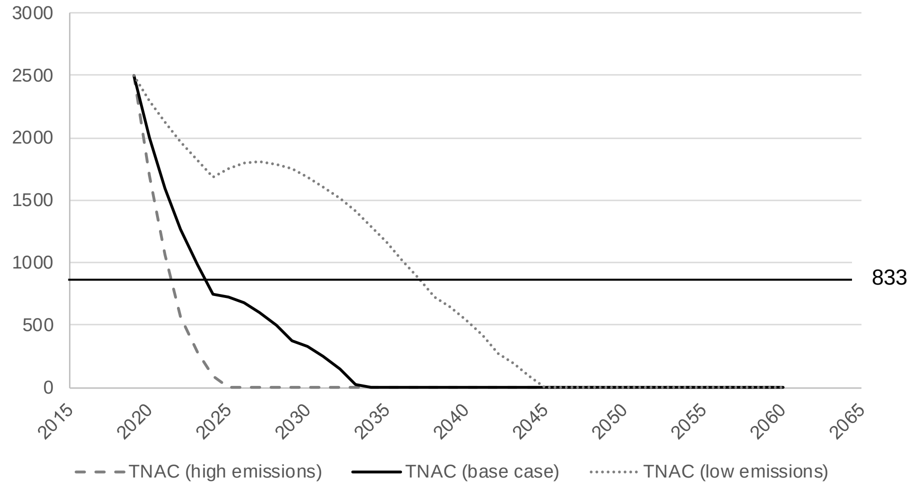
longer period (until 2038, as opposed to 2024 in the base case). The result, in this example, is that a 1 million additional emission reduction yields a reduction in total emissions of 0.95 million. That is, almost a one-to-one relationship.

With a higher target emission level, the opposite result will emerge. Consider the case where the target level is 1 200 million tons per year. The TNAC will then fall below 833 million as early as 2022. The shorter time span during which allowances are fed into the MSR (rather than being auctioned) means that the initial national measure to reduce domestic emissions by 1 million tons only yields a reduction in total emissions of 0.42 million tons.

Thus, how high the demand for allowances is has a substantial impact on the effect of additional national domestic reductions in the EU ETS. This is because lower emissions imply a longer period during which allowances are fed into the MSR. How the TNAC develops over time is illustrated for the three cases – base, low and high – in Figure 4.

Figure 4 *The TNAC over time for the three cases*

[million allowances]



Extension 2 – Varying when the domestic emission reduction occurs

Since allowances must be fed into the MSR before they may be cancelled, it becomes important *when* the national measure results in emission reductions. Consider again the base case. Above, we found that when the national measure yields emission reductions in 2019, the decrease in total emissions amounts to 81 per cent of the domestic reduction. If the domestic emission reduction were to occur in 2021 instead, the impact on total emissions would drop to 66 per cent.

There are two counteracting effects at work. The first is that a 2021 emission reduction is closer to when the TNAC drops below 833 million. An emission reduction in 2019 decreases the auction volume for four years given the assumptions in the base case. If the reduction occurs in 2021, there are only two years during which it may influence the auction volumes, and thus ultimately total emissions. This effect reduces the impact from 81 per cent to 56 per cent. However, as the emission reduction now occurs closer in time to when the cancellation mechanism first comes into effect, it will have a greater impact on how many allowances are left in the MSR after 2023. Due to this, there will be fewer allowances left in the MSR when it is emptied in 2035. This counteracts the initial effect and slightly increases the impact on total emissions to 66 per cent.

Repeating this exercise for the three cases – base, high and low – and varying during which year the emission reduction due to the national measure occurs, we obtain Figure 5. The figure clearly shows that, for all three cases, the later the national measure becomes effective in reducing domestic emissions, the smaller the effect on total emissions. To have a large effect, it is thus important to strive for measures that yield early domestic emission reductions.

Figure 5 *Effect on total emissions from a domestic emission reduction of 1 million tons depending on when it occurs*

[million tons]

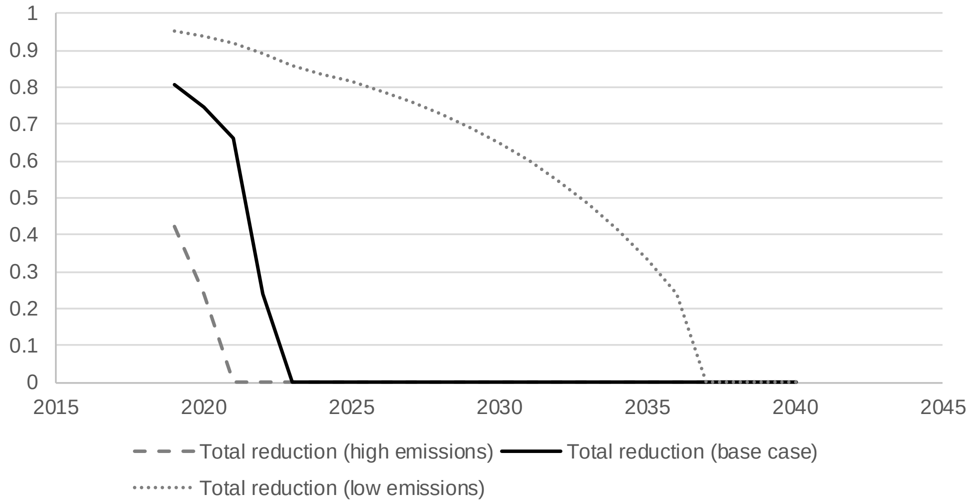


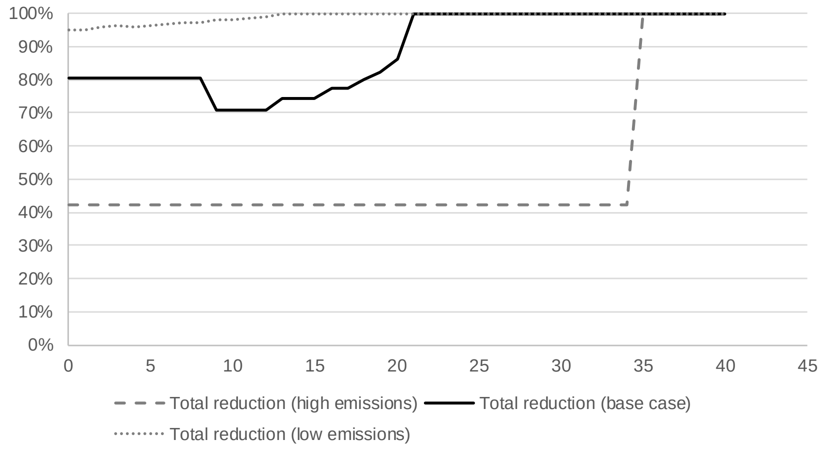
Figure 5 also illustrates that there are large differences depending on future emission levels. When emissions are high, the window of opportunity during which national measures have an impact on total emissions is short. Given our assumptions, measures that yield domestic reductions have no impact on total emissions if they occur after 2021 in the high emissions case.

In the low emissions case, the window of opportunity is substantially wider. Then, national measures have an impact on total emissions even if they produce domestic reductions as late as 2037. However, the impact will still be lower, the later the domestic reduction occurs. Thus, early domestic reductions are, in that sense, still preferable.

Extension 3 – Decreasing market emissions, technological development

Above, we assumed that the market's emission target is constant over time. A more realistic assumption may be that the target level decreases over time due to the likes of technological development. We capture this by letting the target emission level in 2019 be the same as in the three cases above respectively, and then fall linearly by a fixed annual amount. Figure 6 illustrates the outcome. On the horizontal axis is the annual linear decrease in target emissions, measured in million tons. On the vertical axis is the percentage impact on total emissions from a one-shot domestic emission reduction occurring in 2019.

Figure 6 *Impact on total emissions (as a percentage of domestic reduction in 2019) as a function of rate of decrease in target emissions*



The overall message from Figure 6 is that, for all three cases, a sufficiently fast annual reduction in the target emission level will result in a one-to-one relationship between the initial domestic reduction and the reduction in total emissions. However, the path differs between the three cases.

For a one-to-one relationship to occur, the target emission level must reach zero before the TNAC does. In other words, the technological development must be fast enough that not all allowances will be needed to cover emissions. The extra allowances freed up by the national measure, but not cancelled by the cancellation mechanism, will then not be used later in the period. However, this must be considered a special case, as the technological development in this situation is fast enough to make the cancellation mechanism unnecessary.

Both in the base case and the case with high target emissions, there is a segment at which a faster annual decrease in the target emission level has no influence on the impact from the initial domestic reduction on total emissions (the horizontal part of each line in Figure 6). In this segment, the interaction between the MSR, the planned auction volumes (annually decreasing by the linear reduction factor) and the TNAC is such that allowances will become invalid due to the cancellation mechanism only in 2023 – there is no other year during the period when the MSR contains more allowances than are auctioned the previous year. This changes with higher rates of decrease in target emissions.[11] Then, the cancellation mechanism will also be activated in at least one year after 2023.

The setting discussed above may mean that the TNAC is below 833 million one year, and above it the next. However, it is difficult to construct a case where it returns to being above 833 million for a sustained period using linear reductions of both auction volumes and target emissions. This would require a more substantial technology shift.

To study this, let us return to the base case and introduce a technology shift occurring in 2030 that reduces the target emission level from 900 to 450. The effects on the TNAC are illustrated in Figure 7.

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[11] The drop seen for the base case when the annual decrease in target emissions goes from 8 to 9 in Figure 6 follows from the disappearance of the reinforcing effect from the MSR containing fewer allowances the last time allowances should be fed back to the market, as these allowances now become subject to cancellation instead.

Figure 7 *The TNAC over time, with and without technology shift in 2030*

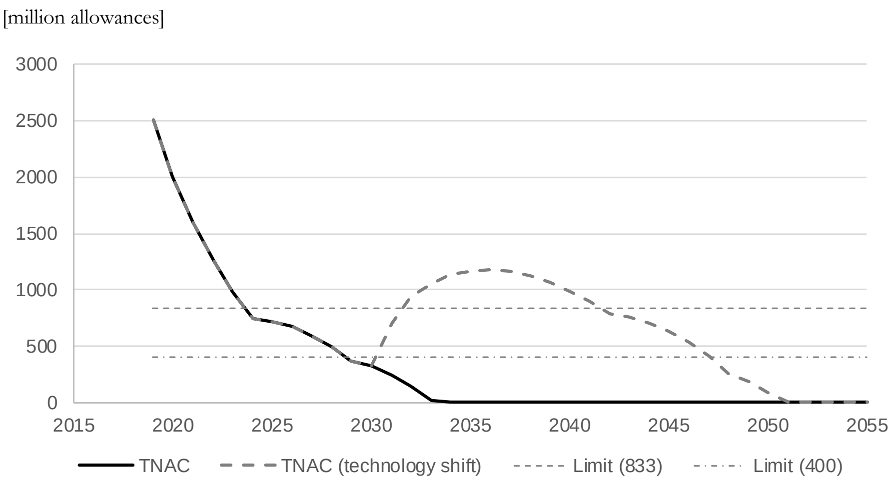

Figure 7 shows that the technology shift means that the TNAC exceeds 833 million again in 2033 and remains above that level until 2041. The technology shift creates a second opportunity for the freed-up allowances to be fed into the MSR. Consequently, the effect of national measures will be greater given the technology shift. A measure that yields a 1 million ton reduction in domestic emissions in 2019 results in a 0.81 million ton decrease without the shift (see above), but a 0.91 million ton reduction with the shift.

The technology shift also allows later domestic reductions to have an effect on total emissions. Without the shift, any domestic reduction occurring after 2022 in the base case has no influence on total emissions. With the shift, however, it does. In this example, a 1 million ton domestic reduction that occurs after 2022 but before 2031 will result in total emissions falling by 0.72 million tons.

It should be noted that a rather substantial technology shift is required and/or it must occur early for the TNAC to again rise over 833 million. In Figure 7, the shift amounts to a 50 per cent reduction. If instead it were to yield a 33 per cent reduction in target emissions, that would not be enough to push the TNAC back above 833 million. Similarly, if the 50 per cent reduction were to occur in 2034 rather than 2030, the TNAC would not revert to above 833 million.

Extension 4 – Larger than one-to-one ratio

In all the examples above, the TNAC falls below 833 million in the same year regardless of the national measure (which year depends on the setting). It is possible to construct examples where the national measure prolongs the period during which the TNAC exceeds 833 million. Then, the overlapping policies may have an impact on total emissions that exceeds one-to-one.

Consider a setting where the national measure results in a large domestic emission reduction, say 100 million tons in 2019. Further, let us assume that the emission target is 960 million tons per year and non-decreasing. Given this setting, the TNAC falls below 833 million in 2023 if the national measure is not introduced. If it is, the TNAC stays above 833 million one year longer. Thus, the national measure results in a reduced auction volume, in this case by some 200 million allowances, also in 2023. The consequence is that the 100 million ton domestic reduction results in a reduction in total emissions of 277 million tons. That is, the total reductions are more than double the domestic reduction.

It must be noted that, even though a ratio of more than one-to-one is possible, it requires rather specific assumptions to occur.[12]

Extension 5 – Cost-effective policy option

The discussion above shows that national measures geared towards the domestic EU ETS sector's emissions may decrease total emissions. However, such measures are not cost-effective. The marginal abatement cost in the country where the measures are applied will exceed the allowance price. The total cost of reaching the resultant level of total emissions is thus higher than for a policy that achieved the same emission level and equalises the marginal abatement costs across all firms within the EU ETS.

If a national government strives to decrease total EU ETS emissions unilaterally, it could, before the cancellation mechanism was introduced, buy allowances and cancel them. The cancellation mechanism makes that a less effective option.[13] When the government removes allowances from the market in this way, it reduces the TNAC, and so fewer allowances will be transferred to the MSR and potentially be subject to the cancellation mechanism. In other words, some of the purchased allowances would be cancelled anyway.

A slight modification of strategy solves the problem. The government could still buy allowances, but not cancel them until the TNAC falls below 833 million (by some margin). Such a strategy has two advantages over the kinds of national measures discussed above. First, it is cost-effective, as it will not force marginal abatement costs to differ between countries. Second, it achieves a one-to-one ratio, something that other national measures typically do not do.

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[12] In addition, Kruse-Andersen and Beck (2018) study the flexibility mechanism that allows (a certain share of) emissions to be transferred from the ETS to the ESR sector. An agreement between the European Parliament and the Council declares that the transferred allowances are still to be counted as part of the TNAC. This means that the transfer does not affect the number of allowances to be placed in the reserve, or hence the cancelled amount. In practice, however, the number of allowances on the ETS market will fall, and the price of allowances will rise, which makes it more profitable to reduce ETS emissions in addition to the transfer. These reductions will increase the number of allowances in the TNAC, the number of allowances to be placed in the reserve, and the number cancelled. Hence, all in all, a larger number of allowances will be placed in the MSR and cancelled. Therefore, the effect on total emissions is large (around 150 percent).

[13] See, for instance, the simulation in Kruse-Andersen and Beck (2018).

RESPONSIVE AGENTS

Thus far, the agents in our examples do not optimise their behaviour in response to the system, but only decrease their emissions when forced to do so due to a scarcity of available allowances. This simplifies the presentation and understanding of how the system works. However, it is not very realistic. In this section, we introduce agents that optimise, in the sense that they reallocate their emissions over time to minimise (discounted) abatement costs.

A coordinated market

We start with a setting where the market acts as one coordinated entity that uses allowances only to cover its emissions. Later in this section, we introduce the possibility of investing in allowances for speculative purposes.

A slightly modified version of the numerical model used above is applied. The base case is our point of departure, but we reinterpret the target emission level of 900 million tons per year to be instead the business-as-usual (BAU) level. That is, we assume that the market would emit 900 million tons per year in the absence of any policy measures. Further, we assume the BAU level to be constant over time, i.e. there is no technical development. This simplifies the interpretation of the results.

The abatement cost is assumed to be a quadratic function of the abatement level:

$$\frac{\alpha}{2}(e_{BAU} - e_t)^2 \tag{1}$$

where α is a scaling parameter, e_{BAU} denotes BAU emissions, and e_t denotes actual emissions in year *t*.

The objective function for the (coordinated) market is to find the future emission path that minimises the sum of discounted abatement costs, given the total number of allowances available (currently and in the future). We apply a discount rate of 3.5 per cent. The choice of discount rate will change the results, but not the qualitative insights.

In order for the numerical model to be solvable, we apply a simplifying approach where the choice is limited to deciding on the emission level in 2019 (e_1) and an annual increase in abatement for the following years expressed as a percentage change. The two choices are made simultaneously. The market will follow the path induced by e_t and the annual abatement increase if there are enough allowances available to do so, otherwise it will emit as much as possible.

Three policy regimes are compared:

1. MSR with the cancellation mechanism
2. MSR without the cancellation mechanism
3. An aggregate emission cap allocated to the firms the initial year

The first two correspond to the settings in the previous section. The third is included as it is – at least in this setting where we ignore bankruptcy and non-compliant behaviour – the most cost-effective approach. By allocating all allowances to the market in the initial year, it is left to the market to choose how to allocate emissions, and thus the use of the allowances, over time without any further restrictions being imposed.

For the three regimes to be comparable, they must yield equal total emissions. Under the cancellation mechanism, total emissions are endogenous. The market knows how the mechanism works, and that its choices influence how many allowances will be cancelled, and takes this into consideration when it optimises its behaviour. Thus, we first optimise given an operational cancellation mechanism and calculate what this implies in terms of total emissions. We then calibrate the two other regimes such that total emissions will be the same in those.

For the aggregate emission cap, this is straightforward: simply allocate the same number of allowances to the market in the initial year as the amount of emissions made under the cancellation mechanism (given that the market has optimised). For the MSR without cancellation, there are different ways of calibrating the regime such that the total emissions will be the same as with cancellation. The one used here is to decrease the initial auction volume, i.e. the number of allowances being auctioned in 2019, but keep the same linear reduction factor as in the base case.

Table 1 summarises the results. Abatements in the first year, 2019, are largest under an aggregate cap and somewhat lower under the MSR without the cancellation mechanism. Abatements in 2019 with the cancellation mechanism are substantially lower – half the level under the MSR alone.

The annual increase in abatement is equal to the discount rate, 3.5 per cent, under an aggregate cap. This is what should be expected from theory, e.g. Hotelling's rule (1931) regarding at what rate to fully extract a non-renewable natural resource. For the MSR, the annual abatement increase is somewhat larger. Under the cancellation mechanism, the annual increase is substantially larger, almost twice the discount rate. The last row in Table 1 provides an illustration of the relative costs of the regimes. The total discounted costs[14] are lowest under an aggregate cap. We see that the MSR

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[14] From 2019 to 2080. After 2080, emissions are zero for all regimes.

regime results in slightly higher costs. The cancellation mechanism increases costs much more than the MSR in isolation, exhibiting a cost increase of 24 per cent over the aggregate cap regime.

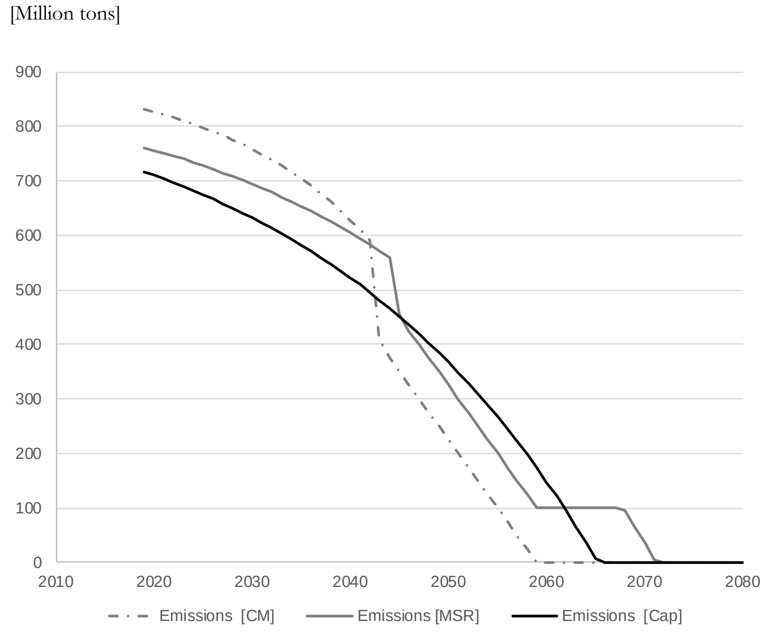
Table 1 *Cost-minimising initial abatement, rate of increase, and relative costs*

	Aggregate emission cap	MSR	MSR+CM
Initial abatement (2019)	183	139	69
Rate of increase (%)	3.50	3.65	6.73
Relative cost (present value)	1.00	1.02	1.24

Figure 8 illustrates the cost-minimizing emission paths for the three regimes. We see that emissions under the MSR, but without the cancellation mechanism, are larger than under the aggregate cap until 2040. Then, there are no longer enough allowances available to follow the path given by annual emission reductions of 3.65 per cent. Thus, the market must drastically decrease its emissions at that point. From 2040 onwards, emissions follow a linear reduction path given by the auction volumes.

A similar pattern is visible for the case with the cancellation mechanism. The early emissions are even higher. The reduction rate is, however, larger (6.73 per cent), and so is the required decrease when allowances become scarce in 2041. In the second half of the period, emissions are lower under the cancellation mechanism than under the other two regimes. Also, emissions reach zero earlier under the cancellation mechanism. After the last auction, which in our setting occurs in 2058, there are no allowances available.

Figure 8 *Optimal emission paths under three regimes*



It is not surprising that emissions early in the period are higher under the cancellation mechanism than under the other regimes. Under an aggregate cap, early emission reductions mean that more allowances are available to cover future emissions. The cancellation mechanism, at least partly, removes this effect. The value of early emission reductions is thus reduced and, hence, less early emission reductions will be conducted in optimum.

A similar story explains why early emissions are larger under the MSR than under the aggregate cap. Under the MSR, no allowances will leave the system. Thus, an early emission reduction will provide room for more emissions later in the period when allowances are fed back to the market from the MSR. However, the market will still be constrained, as the feedback is limited to 100 million allowances per year. Total discounted costs are thus reduced by increasing emissions early in the period. This will increase the abatement costs later in the period, but the fact that costs are decreased early outweighs this.

The cost-minimising approach above is not directly comparable to the earlier setting where the agents did not respond to the system. For instance, total emissions are lower under the cost-minimising approach – an additional 0.5 billion allowances are removed by the cancellation mechanism. As the emissions are lower, the TNAC will remain above 833 million for a longer period. Thus, more allowances are fed into the MSR and may be subject to the cancellation mechanism.

Figure 9 illustrates the impact from a national measure that reduces domestic emissions depending on which year the reduction occurs. The diagram is constructed by starting with the optimal path under the cancellation mechanism, illustrated in Figure 8, and letting one additional unit of emission reduction occur in a given year. We vary the year of occurrence from 2019 to 2045, calculate the resulting difference in total emissions, and relate this to the size of the additional emission reduction following from the national measure. The vertical axis thus shows the effect as a percentage of the additional reduction.[15]

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[15] The system is not reoptimised. To avoid any errors due to this, we use a small value for the additional reduction: 100 tons.

Figure 9 *Impact on total emissions from a national measure depending on which year the resulting emission reduction occurs*

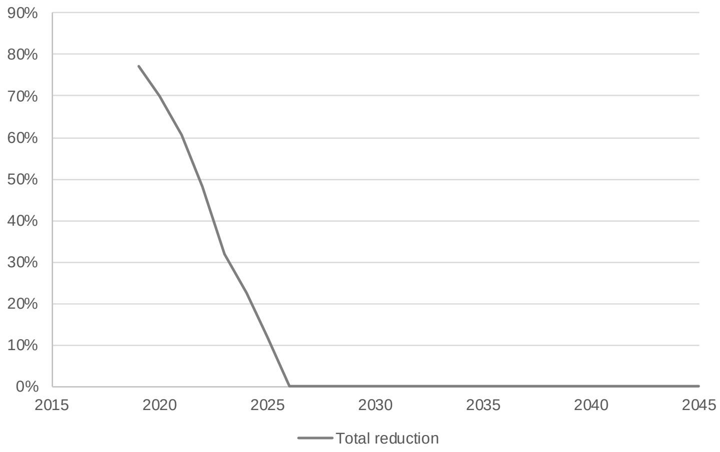


Figure 9 shows a similar pattern to that in the case of non-responsive agents. Early additional emission reductions have a larger impact on total emissions. In this example, the impact becomes zero for emission reductions occurring in 2026 or later. The size of the effect lies between that found in the base case and the case with low emissions in the previous section. This seems reasonable, as the initial emission levels in the cost-minimising case are close to those in the base case (831 million and 900 million tons respectively) but decrease to 600 million tons (i.e. the target emission level in the low-emission case) around 2040.

The market's ability to respond to the system by reallocating its emissions over time clearly influences the impact from national measures. However, it appears that the impact is primarily driven by the system's design. Even when the agents respond optimally to the system, allowances will be fed into the MSR and become subject to the cancellation mechanism. The insights from the examples with non-responsive agents thus explain a large part of what influences the impact of national measures.

Non-coordinated market with speculation

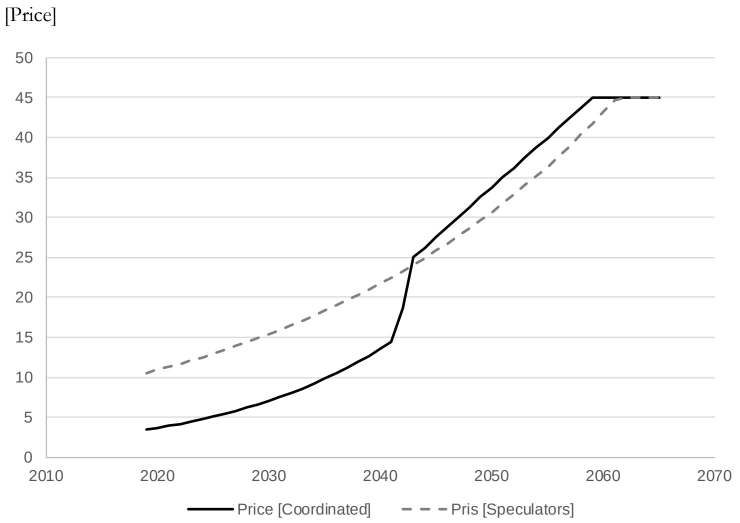
The analysis above assumes a coordinated market and no speculation in allowances. However, the outcome leaves room for profits to be made from borrowing money to buy allowances early and sell them at a later stage. Such potential profits should all be exploited by the market.

Two conditions must be fulfilled. First, no agent should have a marginal abatement cost that differs from the allowance price. If the marginal abatement cost exceeds the allowance price, the agent would be better off increasing emissions, thus avoiding the marginal abatement cost, and purchasing allowances to cover the increase. On the other hand, if the allowance price exceeds the marginal abatement cost, the agent should decrease its emissions and sell the freed allowances.

Second, it should not be possible to purchase allowances today and sell them tomorrow so as to make a profit larger than the (risk-adjusted) discount rate. If such profits are possible, agents would buy allowances, driving up allowance prices. This should continue until all potential profits are exhausted.

Using the first condition, we can plot the allowance price path that would follow from the cost-minimising emissions path in the previous section, illustrated by the solid line in Figure 10. Note that the cost function we use is not calibrated to real data; what is important in Figure 10 is thus the shape, not the level, of the curve. If we keep the assumption that the agents employ a discount rate of 3.5 per cent, it is obvious that the second condition is violated. For instance, an agent may purchase allowances in 2040 for a price of around 13 and sell them three years later for a price of 25, earning an annual profit of 15 per cent – far above the assumed 3.5 per cent. A similar strategy is possible even before 2040, as the prices then increase annually by 6.73 per cent.

Figure 10 *Price path with a coordinated market (solid line) and speculation (dashed line)*



When all potential speculation gains are exhausted, a path is established where the price increases with the discount rate, illustrated by the dashed line in Figure 10. We see substantially higher prices until 2040 compared to the coordinated case. After 2043, prices are lower than in the coordinated case, but the difference is not as large as in the early years. One explanation for this is that the strategy of purchasing and holding allowances will keep the TNAC at a higher level. Therefore, more allowances will be fed into the MSR. The additional supply created after 2043 when speculators sell allowances will thus be counteracted by more allowances becoming invalid due to the cancellation mechanism. Some 0.5 billion allowances more will be cancelled in this setting as compared to the coordinated case. Speculators thus considerably reduce total emissions because of their profit-maximising behaviour.

As the speculative behaviour keeps TNAC above 833 million longer (in the example above, it stays above the threshold until 2039), the impact of national measures becomes larger. Total emissions will decrease by 96 per cent of a domestic reduction that occurs in 2019. The exact number relies on an assumption that the rate of return required by speculators is the same as the discount rate used by emitters, i.e. 3.5 per cent in this example. Given the substantial, not least political, risks surrounding the investment, this is likely an unrealistically low required rate of return. Even so, the qualitative result is solid: speculative behaviour is likely to keep the TNAC above 833 million longer and thereby increase the impact of national measures on total emissions.

4. Conclusion and Policy Implications

This paper shows when, and how, a unilateral overlapping policy in a member state have the potential to lower total EU ETS emissions. A key insight is that these domestic emission reductions must take place early. This significantly affects the number of allowances in the reserve, and as such the number of allowances cancelled. Hence, whilst long-term climate goals require long-term cost-effective policies, the design of the cancellation mechanism instead favours short-term measures that reduce national emissions in early periods. Still, national measures of the sort discussed in this paper are not likely to have a decisive impact on total EU ETS emissions or the price level of allowances. To achieve that requires EU wide coordinated measures.

Furthermore, the cancellation mechanism will in itself reduce cumulative emissions and raise the price of allowances. Hence, the introduction of a cancellation mechanism will in fact reduce the need for politicians to impose additional national measures to meet ambitious national climate targets. Still, if there is a political desire to impose additional national measures, some recommendations can be made. In particular, we find that:

1. The focus should be on broad, multi-sectoral measures rather than (sector-)specific ones.
2. Early emission reductions are always better than those that occur late. The effect on total emissions decreases with late reductions.
3. A single member state may buy allowances, store them and postpone the cancellation of these allowances (until the time is right). Such a unilateral measure, if not counteracted by other member states, may reduce total EU ETS emissions in a cost-effective way.

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