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Fit for 55? An assessment of the effectiveness of the EU COM's reform proposal for the EU ETS[⋆]

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Abstract

To achieve the EU's new climate target of reducing emissions by at least 55% until 2030, the European Commission proposed a reform of the EU ETS in its 'Fit for 55' legislative package. The reform entails an increase of the linear reduction factor (LRF), an adjustment of the intake rules for the Market Stability Reserve (MSR) and the introduction of a fixed threshold for the cancellation of allowances. A numerical discrete-time optimization model of the EU ETS assesses the impact of the reform as a whole and decomposes this impact into the effects caused by the three individual reform elements. The results show a significant impact of the reform with 48% higher prices in 2021 compared to the current regulation. Among other factors, the reform proposal has thereby significantly driven the observed price increase in 2021. The impact of the increased LRF is substantial, while the adjustments of MSR and Cancellation Mechanism are less important. While the proposed reform strengthens the EU ETS, the increased LRF and the adjusted MSR rules do not fully achieve their intended goals. The increased LRF may not reach the intended emissions reduction of 61% for emissions covered under the EU ETS. The adjusted MSR regulation may increase resilience to shocks. Yet, it may also decrease MSR intake, reducing the MSR's ability to regulate allowance supply. The fixed cancellation threshold increases the predictability of the mechanism as intended. However, the changed cancellation volume has repercussions on the achievement of the emission reduction target.

Keywords: Fit for 55, EU ETS, Linear reduction factor, Market Stability Reserve, Cancellation Mechanism

JEL classification: C61, D25, Q48, Q54, Q58

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1. Introduction

Since its establishment in 2005, the European Emissions Trading System (EU ETS)[1] has been reformed multiple times, changing its underlying incentive structure. The reformed and strengthened EU ETS currently reaches price levels of about 90 Euro per EU allowance (EUA) in February 2022, compared to an average of 24.9 Euro in 2020 and 5.8 Euro in 2017 (ICE, 2022). While other factors may influence EUA prices, the EU ETS experienced a significant price increase after its latest reform in 2018. Similarly, the EUA price increased after the European Commission (EU COM) announced its 'Fit for 55' legislative package in July 2021 that proposes measures to achieve the increased EU climate targets to at least 55% reduction until 2030 compared to 1990 levels and climate neutrality until 2050 set in the European Climate Law (European Parliament and the Council of the European Union, 2021). The 'Fit fir 55' package contains a substantive reform proposal for the EU ETS with three key reform elements that aim at strengthening the existing EU ETS: an increase of the linear reduction factor (LRF), an adjustment of the intake rules of the Market Stability Reserve (MSR) and an adjustment of the threshold for the Cancellation Mechanism (CM) (European Commission, 2021e).

The first element, the increase of the LRF, i.e., the rate at which the EU ETS cap decreases each year, aims at achieving the new, more ambitious climate target of at least 55% reduction until 2030. In accordance with the impact assessment for the 'Fit-for-55' package, the EC proposes an increase of the LRF to achieve a 61% reduction of EU ETS emissions compared to 2005 (European Commission, 2021b).

In 2015, the EU introduced the MSR with the aim of addressing imbalances of supply and demand of allowances and increasing the market's resilience to shocks (European Commission, 2021d). It adjusts the annual supply of allowances in response of the total number of allowances in circulation (TNAC), transferring excess allowances into a public reserve or reinjecting allowances from the MSR back into the market (European Parliament and the Council of the European Union, 2015). In 2018, the EU complemented the MSR with a CM rendering allowances invalid if the MSR volume exceeds a pre-determined threshold (European Parliament and the Council of the European Union, 2018). It was further established that the EU COM should review the MSR within the first three year after it entered into force in 2019 (European Parliament and the Council of the European Union, 2015).

[1]This article uses the following abbreviations: EU ETS: European Emissions Trading System; EUA: EU allowance; EU COM: European Commission; LRF: linear reduction factor; MSR: Market Stability Reserve; CM: Cancellation Mechanism; TNAC: total number of allowances in circulation.

The second element of the proposed EU ETS reform is the two-fold adjustment of the MSR intake rules. First, an increase of the MSR intake rate is proposed to reduce the number of allowances in the market that potentially cause a surplus of allowances (European Commission, 2021d). Second, a buffer zone shall reduce threshold effects potentially caused by the regulation in place. The aim of the buffer zone is hence to decrease price volatility (European Commission, 2021e). Price volatility is, among others, induced by abrupt shifts in allowance demand or supply that may lead to sudden changes in the EUA price levels.

The third proposed change to the mechanisms of the EU ETS is the adjustment of the CM that limits the amount of allowances in the MSR. The EU COM aims at increasing the predictability of the CM by proposing a fixed threshold for cancellation instead of the currently flexible threshold (European Parliament and the Council of the European Union (2018) and European Commission (2021e)).[2]

The research at hand analyzes the effects of the reform proposal on the price and abatement paths in the EU ETS. In particular, it aims to understand how the reform proposal could have contributed to the price increase and how the relative impact of the individual reform elements on price levels is. A focus of the analysis is on whether the individual reform elements effectively achieve their intended goals: The increase of the LRF aims at achieving the new, more ambitious climate target. The adjustment of the MSR rules with the introduction of a buffer zone and a long-term higher MSR intake rate aims to tackle market imbalances as well as to reduce price volatility in the EU ETS. The proposal for a fixed cancellation threshold targets the predictability of the CM.

For this purpose, the research extends a model of the EU ETS developed in Bocklet et al. (2019) with the latest reform proposal. The discrete-time numerical model optimizes firms' abatement in response to their expectation of the allowance price path in the EU ETS. It accurately depicts the EU ETS in its current regulation including the MSR and CM as well as the proposed adjustments. Different scenarios that integrate only one additional reform element help to decompose the aggregate impact of the reform into the effects of the individual reform elements. By comparing the scenarios with and without the individual

[2]In addition to the outlined adjustments, the EC proposes an extension of the EU ETS to the maritime and aviation sectors into the main EU ETS (European Commission, 2021e). While both sectors only have a limited amount of emissions (the aviation and maritime caps are approx. 24 and resp. 79 million allowances (European Commission (2020) and European Commission (2021e)), the complex provisions for their integration into the EU ETS would impact the market outcome in hard to disentangle ways. For the purpose of clearly decomposing the individual effects of the three reform amendments outlined above, the research refrains from including these provisions.

reform element, the analysis assesses the effectiveness of the element; i.e., whether it achieves its intended goal.

The analysis finds that while the proposed reform achieves a higher predictability of the CM, it does not ensure reaching the new climate target for 2030. Moreover, the impact of the proposed adjustment of the MSR intake on reducing allowance surplus and decreasing price volatility is ambiguous. The model results show how the existing mechanism for MSR intake induces sudden increases or decreases in the allowance supply, thereby potentially destabilizing the EUA price. The introduction of the buffer zone smooths allowance supply as it prevents threshold effects caused by the current regulation. It hence reduced the probability of supply-induced shocks but does not address price variability caused by the MSR. Moreover, it may also reduce MSR intake and cancellation volumes which is in conflict with the other MSR goal of reducing the number of allowances in circulation. In any case, the model results also show that the overall impact of the proposed change in the MSR intake rules may be low.

The analysis of emissions trading systems builds on the seminal work of Hotelling (1931) on the optimal extraction path of finite resources. Hotelling (1931) shows that, in an ideal setting, extraction adjusts such that gains from extraction develop with the same rate as gains from alternative investments, that is the interest rate of capital. Rubin (1996) is the first to apply this finding to an ETS. His work is fundamental to understand the nature of an ETS based on an intertemporal allocation of an overall emissions budget.

Recently, research using numerical models of the EU ETS emerged that analyzes the dynamics of the regulatory system and draws conclusions on the efficiency and effectiveness of the EU ETS and its different reforms. Richstein et al. (2015) and Perino and Willner (2016) evaluate how the MSR affects price and abatement paths and find that the MSR does not fulfil its intended purpose of increasing market stability. Instead, it increases price variability. Bocklet et al. (2019) and Quemin and Trotignon (2019a) analyze the impact of the Cancellation Mechanism. Beck and Kruse-Andersen (2018) and Schmidt (2020) show that the CM changes the impact of overlapping national policies which can reduce emissions in the reformed EU ETS, if implemented early on. Bocklet (2020) analyzes the impact of crises on the EU ETS and finds that MSR and CM can decrease price volatility in times of crisis.

Osorio et al. (2021) and Pietzcker et al. (2021) analyze the EU ETS in the context of more ambitious EU climate targets. Both articles do not consider the 2021 reform proposal. Pietzcker et al. (2021) assess the impact of a 63% reduction sector of the European power sector and find that coal-fired electricity generation would phase out until 2030. Osorio et al. (2021) analyze market outcomes under a range of MSR parameters (auction share, thresholds and intake rate) and LRF options with a focus on the interactions between both reform elements. They find that an MSR reform can both lead to significantly more or less cancellation and that the increased LRF may lead to up to twice the cancellation volume depending on the applied MSR parameters. In contrast to Bocklet (2020), they find that cancellation volumes are hard to predict which leads to high price uncertainty.

There is so far no scientific analysis of the EU ETS reform proposal within the 'Fit for 55' package. In preparation of the proposal, the EU COM conducted an impact assessment analyzing different options for reforming the MSR and CM (European Commission, 2021b). The impact assessment uses a model developed in Quemin and Trotignon (2019b) that is similar to the model applied in the research at hand. However, the analyzed options differ from the actual EU COM proposal and the combination of different reform elements inhibits developing a clear understanding of which effects can be attributed to which individual reform element. The think tank Sandbag (Sandbag (2021a) and Sandbag (2021b)) has engaged in analyses of the EU ETS reform but use simulation with fixed assumption of emissions levels. The contribution of the research at hand to the existing literature is a comprehensive and transparent analysis of the proposed reform based on most recent data of the EU ETS using 2020 values of TNAC and MSR volume. The research analyzes the overall impact of the proposed reform on abatement and prices as well as the effectiveness of the individual elements. For this, an optimization model of the EU ETS is used to decompose the total impact of the reform into the impact of the individual elements, comparing their effects against their intended aim.

The remainder of this paper is organized as follows: Section 2 outlines the content of the current EU ETS reform proposal in detail. Section 3 extends the model developed in Bocklet et al. (2019) with the proposal. Section 4 introduces scenarios that decompose the impact of the reform into the effects of the individual reform elements and presents the model results. Section 5 discusses critical assumptions of the applied model and potential shortcomings of the individual reform elements. Section 6 concludes.

2. The EU ETS in its current regulation and with the reform proposal

This section explains the EU ETS regulation in detail, contrasting the rules for LRF, MSR and CM in the regulation in place with the EU COM's reform proposal.

2.1. Linear reduction factor

The EU ETS cap in its current form applies a LRF of 2.2% meant to achieve an emission reduction of 43% for EU ETS emissions compared to 2005 levels and a 40% climate target for overall emissions in the EU compared to 1990 levels for the year 2030 (European Parliament and the Council of the European Union, 2018). The LRF is not a percentage rate for the cap to decline but rather a share of initial emissions, i.e., a fixed number of allowances, by which the cap decreases each year. For an increased EU climate target of at least 55% reduction until 2030 compared to 1990 levels, the EU COM proposes a 61% reduction of EU ETS emissions compared to 2005, in accordance with the impact assessment for the 'Fit-for-55' package (European Commission, 2021b). This is equivalent to an increase of the linear reduction factor from 2.2% to 4.2% from 2021 onwards (European Commission (2021e)).[3] The EC proposes an one-off reduction of 117 million allowances to accommodate the possible timeline of changes to the EU ETS Directive assuming a late implementation in 2024.[4] To achieve the EU's new long-term target of climate neutrality in 2050, the EU ETS needs a LRF of 2.0% from 2031 onward. An extrapolation of the current linear reduction factor of 2.2%, as applied in Bocklet et al. (2019), leads to zero supply of emissions only in 2058.

2.2. Market Stability Reserve

In 2015, the EU introduced the MSR with the aim of stabilizing the market by addressing imbalances of supply and demand of allowances and increasing the EU ETS's resilience to shocks (European Commission, 2021d). The MSR started operating in 2019. It adjusts the annual supply of allowances in response of the TNAC volume. If the TNAC is higher than 833 million allowances, the auction volume of a year is reduced by a share of the TNAC. This share is stored in the MSR (European Parliament and the Council of the European Union, 2015). From 2019 to 2023, this share is set to 24%. After 2023, it should decrease to 12% under the current regulation (European Parliament and the Council of the European Union, 2018).

[3]In fact, the proposed LRF slightly overachieves the target leading to a emissions reduction of 62% compared to 2005 levels.

[4]European Commission (2021e) leaves the exact value for the one-off reduction option to the year the proposal enters into force but European Commission (2021c) states a reduction of 117 allowances. This, in turn, indicates a target year 2024 for the proposal to enter into force with 39 million allowances for every year from 2021 to 2023 in which the increased LRF is not applied.

The EU COM proposes a two-fold adjustment of the MSR intake rule. First, draft directive 2021/0202 proposes that the intake rate from 2024 to 2030 should continue to be at 24%. The preamble of the proposal for the directive states that the current intake rate of 12% after 2023 may cause a harmful surplus of allowances. The aim of the increased MSR intake rate is to reduce the number of allowances in the market. After 2030, the proposal suggests reverting the intake rate from 24% to 12% (European Commission, 2021d). Second, the EC identifies a threshold effect caused by the MSR regulation in place: Once the TNAC is at 833 million allowances, MSR intake jumps from zero to 100 (at a 12% intake rate) or 200 million allowances (at a 24% intake rate). The EU COM proposes a smoother intake rule: Within a buffer zone between a TNAC of 833 and 1096 million allowances, only the difference between 833 million allowances and the actual TNAC is transferred to the MSR. At a TNAC of 834 million allowances, that is only one allowance. At a TNAC of 1096 millions allowances, it is 263, which is exactly 24% of the TNAC. In this way, the buffer zone provision reduces MSR intake for a general intake rate of 24%. The aim of the buffer zone is to prevent abrupt spikes in allowance supply, thereby stabilizing EUA prices (European Commission, 2021e).

2.3. Cancellation Mechanism

In 2018, Directive 2018/410 introduced a CM rendering allowances in the MSR invalid if the MSR volume exceeds a predetermined threshold. This mechanism endogenizes allowance supply. While the MSR by itself only shifts abatement in time, the CM changes the overall allowance budget available to the market based on the firms' abatement behaviour. The current regulation sets the cancellation threshold to the previous year's auction volume (European Parliament and the Council of the European Union, 2018). In its reform proposal, the EC states that the current mechanism is not predictable enough as the cancellation threshold depends on the auction level and in consequence also on the MSR intake as MSR intake reduces the number of allowances that is auctioned. With the proposed reform, the EC aims at increasing the predictability of the CM by setting a fixed threshold for cancellation of an MSR volume of 400 million allowances (European Commission, 2021e).

3. Modeling the EU ETS reform proposal

To assess the impact of the proposed EU ETS reform, the research extends a numerical optimization model of the EU ETS developed in Bocklet et al. (2019) which is based on the model of an intertemporal allowance market in Rubin (1996). The EU ETS model uses discrete time steps $t = 1, 2, \ldots T$ and accurately depicts the EU ETS including the Market

Stability Reserve and the Cancellation Mechanism. The updated model compares the 2018 regulation with the EU COM's proposal from July 2021 as described in section 2.
This section sets up the optimization problem of firms in a multi-period emission trading system and derives the market clearing condition. It further sets up model equations for the MSR and CM according to the current regulation and the EC's reform proposal. The section concludes with remarks on the model implementation and the applied parameters.

3.1. Firms' decision

In the model, N polluting firms have to buy allowances for their emissions and hence decide on their level of abatement $a(t)$ or the number of allowances they buy in each period $x(t)$, respectively. Firms act rationally and have perfect foresight. Extending the original model in Bocklet et al. (2019), Bocklet and Hintermayer (2020) show that hedging of allowances and myopic behavior influenced the EU ETS outcome in the past. While these factors probably continue to play a role in the market behavior, the research at hand refrains from transferring the model results of Bocklet and Hintermayer (2020) to the here applied model for two reasons. First, it is likely that the impact of bounded rationality decreases in market prices and the EU ETS has seen a remarkable increase of prices in the past years (ICE, 2022). With higher stakes in the market, firms should take a longer-term perspective and reduce hedging if it induces additional costs on them. Moreover, the increasing participation of financial actors should likewise have decreased the impact of hedging and myopia. Quemin and Pahle (2021) show that the number of investment funds in the EUA market increased from under 100 in January 2018 to almost 350 in November 2021. Second, the consideration of bounded rationality elements in firms' behavior increases the model complexity at the cost of losing transparency and the ability to disentangle the effects of individual model elements and assumptions. Section 5.1 discusses the impact the assumptions of perfect rationality and foresight have on the model results.
Each firm minimizes the present value of its total expenditure which is the sum of abatement costs $C(a(t))$ and payments for $x(t)$ allowances at price $p(t)$ discounted at interest rate r.

$$PV = \sum_{t=0}^{T} \frac{1}{(1+r)^t}[C(a(t)) + p(t)x(t)]. \tag{1}$$

The firm can bank the allowances in order to use them at a later point in time. The individual bank of the firm $b(t)$ cannot be lower than zero; that means, a firm cannot emit more than it owns in allowances. The firm has a constant level of baseline emissions u that the firm would have in a hypothetical setup without an emission trading system. Combined with the intertemporal constraint on banking, the minimization problem of the firm is

$$\begin{aligned} \min_{a(t),x(t)} \quad & \sum_{t=0}^{T} \frac{1}{(1+r)^t}[C(a(t)) + p(t)x(t)] \\ s.t.\ b(t) - b(t-1) &= x(t) - u + a(t) \quad \text{for all} \quad t = 1, 2, \ldots, T \\ b(t) &\geq 0 \\ x(t),\, a(t) &\gtrless 0. \end{aligned} \tag{2}$$

The Lagrangean optimization yields the equilibrium condition

$$C_a(a(t)) = p(t). \tag{3}$$

The firm sets its abatement level $a(t)$ such that the marginal abatement costs equal the allowance price $p(t)$.
The model assumes a marginal abatement cost (MAC) function $C_a(a(t))$ that increases linearly in abatement a_t with an exogenous cost parameter c:

$$C_a(a(t)) = c\, a(t) \tag{4}$$

3.2. Market equilibrium

The market determines the allowance price such that the demand of the N identical firms and the supply of allowances are in equilibrium. Supply can come from the private bank b_t or the issuance of allowances I_t. The path of issued allowances decreases with a linear reduction factor $\alpha(t)$, i.e. $I(t) = I(t-1) - \alpha(t)I_0$. The regulator issues a share of allowances through auctions $I_{auct}(t)$ and the remaining allowances for free.
It must hold that aggregated emissions, that is baseline emissions minus abatement, over time are smaller than aggregated issued allowances plus the initial bank:

$$\sum_{\tilde{t}=0}^{t}[u - a(\tilde{t})] \leq \sum_{\tilde{t}=0}^{t} I(\tilde{t}) + b_0 \text{ for all } t = 0, 1, \ldots, T. \tag{5}$$

The allowance price develops over time according to the following rule, derived from the firm's optimization problem in equation 2.

$$\frac{p(t+1) - p(t)}{p(t)} = r - (1+r)^{t+1}\frac{\mu_b(t)}{p(t)}. \tag{6}$$

In a setup in which the total number of allowances is available at all points in time, the price would increase with the interest r in line with Hotelling (1931). In the setup of the EU ETS borrowing is not allowed. $\mu_b(t)$ can be interpreted as the shadow costs of the borrowing constraint. If firms would optimally abate less than allowances are available, then the constraint on borrowing is binding. This occurs when the private bank is empty, i.e. $b_t = 0$. In this case the price increases at a lower rate than r.

3.3. Market Stability Reserve and Cancellation Mechanism

The EU introduced the Market Stability Reserve and the Cancellation Mechanism with the aim to stabilize allowances supply in the EU ETS. The combined mechanism of MSR and CM adjusts the allowances supply as reaction to the total number of allowances in circulation $TNAC(t) = Nb(t)$.

According to the EC's reform proposal, if at any point of time t the TNAC is higher than a threshold ℓ_{zone}, allowances enter the MSR in the following year instead of being auctioned. Under the 2018 regulation, MSR intake is a share $\gamma(t)$ of the TNAC. The EC reform proposal suggests introducing a buffer zone such that if the TNAC is in a range between ℓ_{zone} and ℓ_{up}, the MSR intake only amounts to the difference between the TNAC and ℓ_{zone}. Above ℓ_{up}, the intake increases to a share $\gamma(t)$ of the TNAC for both the 2018 regulation and the reform proposal. The auction volume $I_{auct}(t)$ decreases by the same amount of allowances. Under both regulations, if $TNAC(t)$ is below a lower threshold ℓ_{low}, R allowances from the MSR are added to the auction volume of the following year (European Parliament and the Council of the European Union (2015) and European Commission (2021d)).[5]

The CM determines that allowances are cancelled from the MSR, i.e. are rendered invalid, if the MSR exceeds a limit of ℓ_{cancel}. Under the regulation in place, ℓ_{cancel} is set at the previous year's auction volume. The proposed reform fixes the threshold ℓ_{cancel} at 400 million allowances (European Parliament and the Council of the European Union (2018) and European Commission (2021d)).

In the model, the endogenous supply of allowances is expressed by

$$I(t) = I(t-1) - \alpha(t)I_0 - Intake(t) + Reinjection(t). \tag{7}$$

[5] The threshold for MSR intake ℓ_{zone} is 833 million and the upper threshold ℓ_{up} under the reform proposal is 1096 million allowances. The intake share $\gamma(t)$ is 24% until 2023 and 12% afterwards under the regulation in place. The EC proposes maintaining $\gamma(t)$ at a level of 24% until 2030. The reinjection is triggered at a lower threshold ℓ_{low} of 400 million allowances and comes at yearly tranches R of 100 million allowances (European Parliament and the Council of the European Union (2015) and European Commission (2021d)).

The MSR volume is then given by

$$MSR(t) = MSR(t-1) + Intake(t) - Reinjection(t) - Cancel(t), \tag{8}$$

with

$$Intake(t) = \begin{cases} \gamma(t) * TNAC(t-1) & \text{if } TNAC(t-1) \geq \ell_{up}, \\ 0 & \text{else,} \end{cases} \tag{9}$$

for the 2018 regulation and

$$Intake(t) = \begin{cases} \gamma(t) * TNAC(t-1) & \text{if } TNAC(t-1) \geq \ell_{up}, \\ TNAC(t-1) - \ell_{zone} & \text{if } \ell_{up} > TNAC(t-1) \geq \ell_{zone}, \\ 0 & \text{else,} \end{cases} \tag{10}$$

for the reform proposal as well as rules for reinjection and CM of

$$Reinjection(t) = \begin{cases} R & \text{if } TNAC(t-1) < \ell_{low} \wedge MSR(t) \geq R, \\ MSR(t) & \text{if } TNAC(t-1) < \ell_{low} \wedge MSR(t) < R, \\ 0 & \text{else,} \end{cases} \tag{11}$$

$$Cancel(t) = \begin{cases} MSR(t) - \ell_{cancel} & \text{if } MSR(t) \geq \ell_{cancel}, \\ 0 & \text{otherwise.} \end{cases} \tag{12}$$

3.4. Model implementation and parametrization

The model is implemented and solved by GAMS and CPLEX as a mixed-integer linear program. The non-linear regulatory decision rules in both the regulation in place and the reform proposal are linearized using binary variables and the big-M method.

Following Bocklet et al. (2019), the numerical model uses an interest rate of $r = 8\%$, baseline emissions of $u = 2000$ million $CO_2eq.$ and a cost parameter $c = 0.75$ that leads to costs of the backstop technology of 150 Euro per ton.

The updated model starts in 2021 for both regulations and adjusts the cap to account for the withdrawal of installations from the United Kingdom. The 2021 cap therefore decreases to 1,572 million allowances (European Commission, 2021e).

The MSR started in 2019 with an initial endowment of 900 million allowances from back-loading between 2014 and 2016 (European Parliament and the Council of the European Union, 2015) and 600 million not allocated allowances from phase III of the EU ETS (European Commission, 2015). The starting value for the MSR volume in 2021 is 1925 million allowances (European Commission, 2021a). In 2021, the MSR intake is 333 million allowances.[6]

4. Results

This section decomposes the overall effects of the reform into the individual effects of the different amendments. For this purpose, the research sets up four different scenarios, depicted in table 1. The *2018 regulation* scenario represents the current status of the EU ETS with a LRF of 2.2% and the existing implementation of the MSR and CM as outlined in section 2. The *Increased LRF* scenario updates the climate target of the *2018 regulation* scenario to a LRF of 4.2% until 2030 and of 2.0% afterwards. The *New MSR* scenario extends the *Increased LRF* scenario by including the new MSR intake rules in accordance with the 'Fit-for-55' proposal described in section 2. The *Fit for 55* scenario includes all three reform elements and thus entails a CM with a fixed cancellation threshold of an MSR volume above 400 million allowances.

4.1. Increased linear reduction factor

To assess the impact of the increased LRF on its own, the *Increased LRF* scenario is compared to the *2018 regulation* scenario. The increased LRF applied ex-ante, i.e. without MSR movements and cancellations, leads to a 62% emissions reduction in 2030 and climate neutrality in 2050. In total, it causes a reduction of overall allowance supply by 10,100 million allowances, or 34.2%, compared to the counterfactual *2018 regulation* scenario in which the 2.2% LRF is extrapolated until allowance supply becomes zero. Figure 1 contrasts the ex-ante allowance supply of the two scenarios. It becomes apparent that while the existing regulation achieves climate neutrality in the EU ETS sectors in 2058, climate neutrality in

[6] In reality, MSR intake is determined for a period from September of one year to August of the next year. However, MSR volume for the cancellation mechanism is the end value of each year. To adjust this MSR intake to a yearly basis, the model uses for 2021 the January to August 2021 value from 2020's Communication C(2020) 2835 adjusted by Notice 2020/C 428 I/01 plus an estimate for MSR intake from 2021's Communication C(2021)3266. The estimate uses the 2020 share of the September to December intake from the 2020's Communication total intake.

	LRF	MSR	CM
2018 regulation	2.2 until 2057	$\ell_{up} = 833$ million EUA $\gamma = 0.12$ after 2023	MSR > TNAC(t-1)
Increased LRF	4.2 until 2030 2.0 until 2050	"	"
New MSR	"	$\ell_{zone} = 833$ million EUA $\ell_{up} = 1{,}096$ million EUA $\gamma = 0.24$ after 2023	"
Fit for 55	"	"	MSR > 400 million EUA

Table 1: Scenario overview

2050 requires a significant reduction of the allowance cap. With a LRF of 4.2% until 2030, the climate neutrality target for 2050 can be achieved with a lower LRF of 2.0% after 2030.

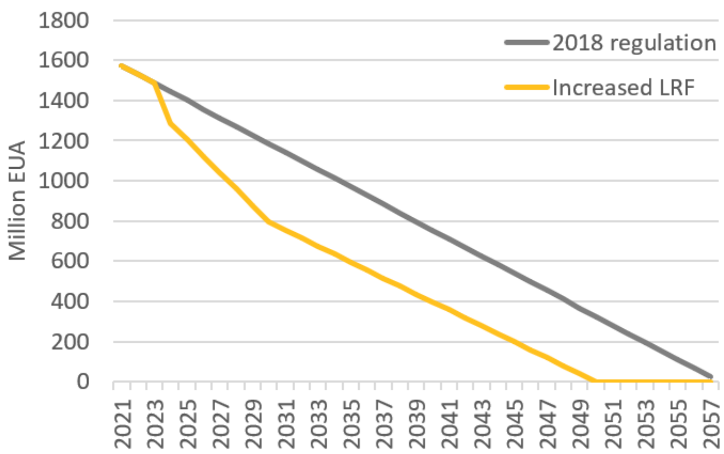
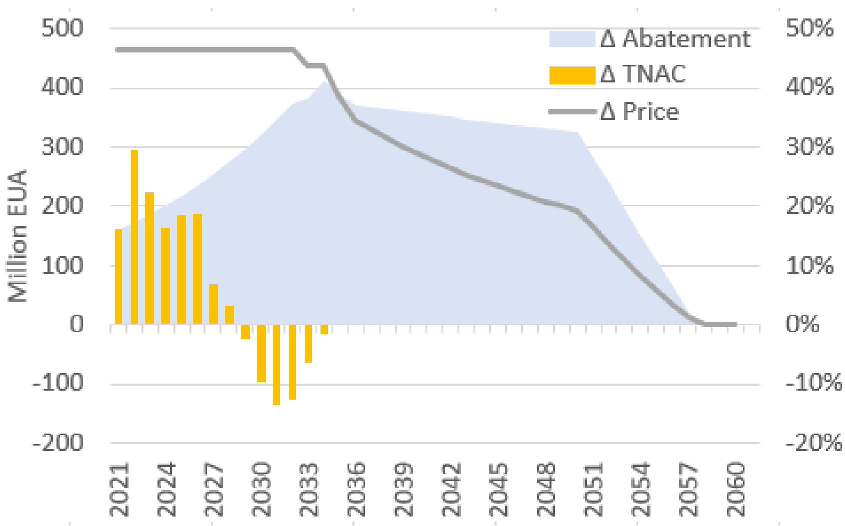


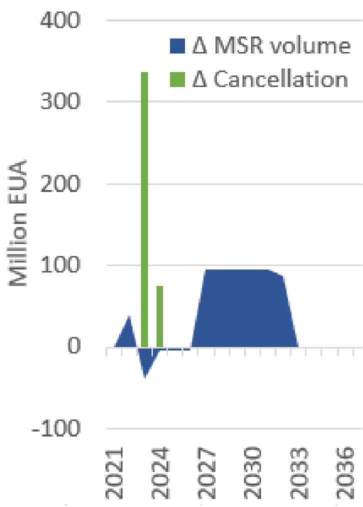
Figure 1: Ex-ante allowance supply under the 2018 regulation and the Fit for 55-proposal

Figure 2 highlights the differences in the model results of the two scenarios. The tightening of allowance supply leads to an increase of the allowance price over the model horizon. The 2021 price level is 46.4% higher with the new target. Accordingly, abatement is shifted forward and increases proportionally to the price increase. The emission level reduces to zero already in 2050 under the increased LRF; i.e., firms do not bank allowances for the time the allowance supply is zero.

The higher price and, hence, abatement level lead to a higher TNAC from 2021 to 2028. This, in turn, triggers more and longer MSR intake. While under *2018 regulation* intake takes only place in 2021 and 2022, it is prolonged until 2024 in the *Increased LRF* scenario. This leads to a higher cancellation volume with the new target. Notably, the longer intake period leads to lower auction levels in 2023, thus triggering additional cancellation in 2024. The aggregate cancellation volume increases from 1,945 to 2,355 million EUA, i.e. by 21%. As the rules for MSR intake and cancellation do not change between the two scenarios, the MSR volumes after the cancellation in 2023 do not vary significantly. The higher TNAC in the *Increased LRF* scenario leads to a later start of reinjection of MSR allowances into the market in 2028 compared to 2027 in the *2018 regulation* scenario. In the long run, the lower allowance supply leads to a quicker depletion of the TNAC such that, after 2028, its level is lower under *Increased LRF* than under *2018 regulation*.



(a) Allowance market



(b) MSR movements

Figure 2: Results of *Increased LRF* minus *2018 regulation*

The increased LRF ex-post misses its aim of a 61% emission reduction compared to 2005 levels. While the ex-ante cap overachieves the targets with a 62% reduction, the resulting emission level in 2030 only achieves a 58% emission reduction. Not only use firms allowances from the TNAC in 2030 but the climate target year lies moreover in the period of MSR reinjection. In other words, the MSR impedes the achievement of the climate target for 2030. This confirm the results from Osorio et al. (2021) that a LRF of 5.1% would be needed to achieve an emission reduction of 63% under the EU ETS.

4.2. Revised MSR regulation

As explained in detail in section 2, the reform proposal suggests to adjust the current MSR regulation in two ways: First, a buffer zone shall be introduced to reduce price volatility by enabling a smooth increase of the intake level instead of the hard threshold of the 2018 regulation. Under the 2018 regulation, MSR intake increases for an additional unit of TNAC above the threshold from zero to a significant number. Under the 'Fit for 55' proposal, intake is in the same case only one allowance - the difference between the threshold and the TNAC. Second, the reform proposes to increase the MSR intake rate from 12 to 24% with the aim to reduce the number of allowances in the market.

The model results show that the proposed *New MSR* regulation does not significantly change the MSR intake compared to the 2018 regulation ceteris paribus. Figure 3 presents the difference in MSR intake between the *Increased LRF* and the *New MSR* scenarios. The intake values under the *New MSR* decrease by 0.2% for 2022 and by 0.5% for 2023 as the reform proposal only takes effect in 2024. Even if the reform proposal took effect in 2021, MSR intake would only change negligibly as the TNAC in 2021 is above and in 2022 only slightly under the upper threshold of TNAC. Above this threshold, the two MSR designs do not differ at a given intake rate. Despite the same intake rule in both scenarios for 2022 and 2023, there is a slight difference in the intake values that is caused by the firms' expectation of the change in regulation after 2023.

In 2024, the model estimates a decrease from 108 to 57 million allowances intake in the MSR induced by the proposed change in the regulation. At a TNAC of 897 or 890 million allowances, respectively, in 2023, intake at a rate of 12% in line with the regulation in place is significantly higher than with an intake under *New MSR* (of the difference of the previous year's TNAC and 833 million allowances). We can, however, not conclude that the proposed MSR will in all cases lead to less intake. For a TNAC above 947 million allowances, the proposed regulation leads to more intake than the current regulation with a 12% intake rate.[7] The increase of the intake rate from 12 to 24% from 2024 onward has in the model no effect as intake in any case ceases after 2024 due to the low level of TNAC associated with the more ambitious climate target.

Figure 3 presents the differences between the *Increased LRF* and the *New MSR* scenarios in detail. As the cancellation mechanism does not vary between the two scenarios, the lower MSR intake presented in Figure 3 translates directly into a cancellation volume that is by

[7] At an intake rate of 24% under the regulation in place, in contrast, the proposed transition zones leads in all cases to a lower intake.

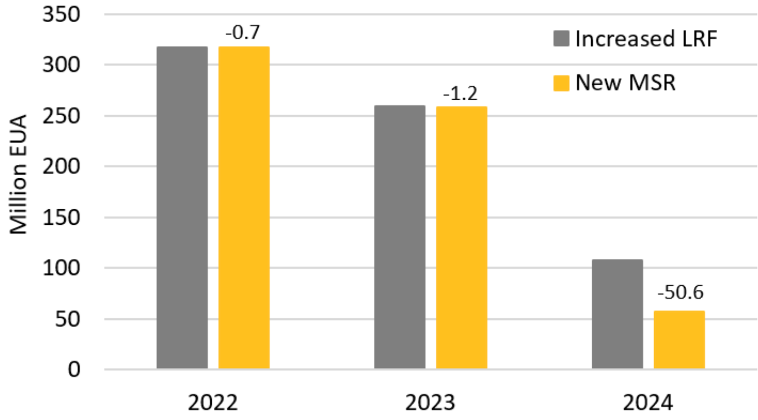
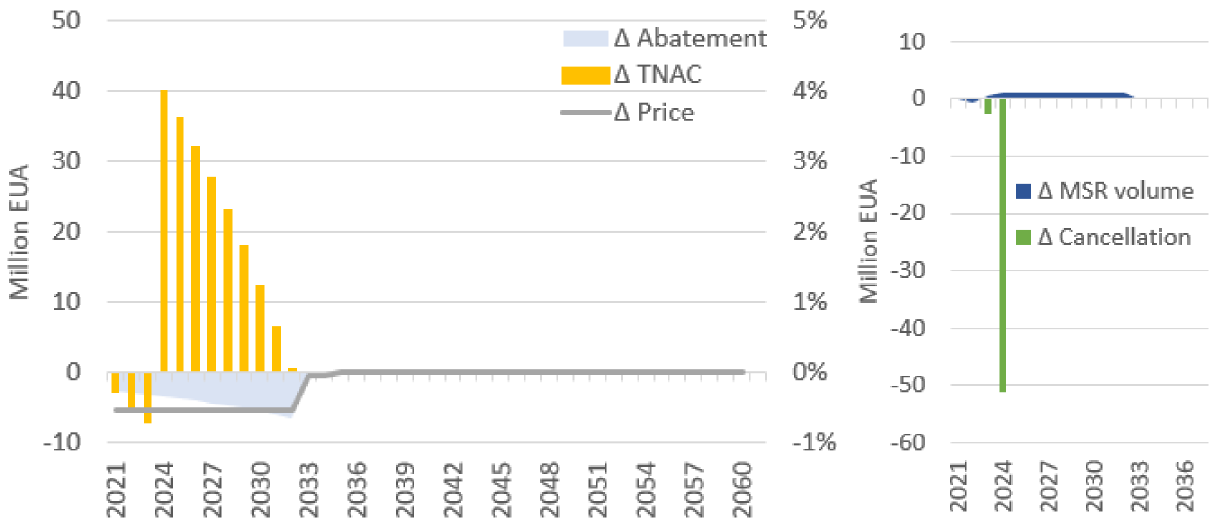


Figure 3: MSR intake under *Increased LRF* and *New MSR*

53.7 million allowances lower in *New MSR* than in the *Increased LRF* scenario. In perfect foresight of the higher allowance supply in *New MSR*, the price starts at a slightly lower level. The lower price induces lower abatement in *New MSR* compared to *Increased LRF* in all years. Less abatement leads to a lower TNAC from 2021 to 2023. In 2024, the changed MSR intake rules with less intake in *New MSR* boost the TNAC level compared to the *Increased LRF* but the higher TNAC levels deplete in the following years because of the lower abatement. Price levels are identical again once the TNAC and MSR become zero in 2034 in both scenarios as the abatement and price levels are determined by the allowance supply. While the direction of change induced by the proposed adjustment of the MSR is ambiguous, it is worth noting that the difference in the results of the two scenarios are lower than 1% and hence negligible. The adjusted MSR intake rules have no significant impact on the EU ETS market outcome.



(a) Allowance market

(b) MSR movements

Figure 4: Results of *New MSR* minus *Increased LRF*

The EU COM describes the aim of the buffer zone as reducing price volatility. Price volatility describes historical price movements over a longer period that cannot be assessed in a simulation model. We follow the interpretation of Perino and Willner (2016) that the EU COM's concept of market stability rather refers to the absolute price change in response to shocks, i.e., price variability. We can further say that an unexpected change in allowance supply constitutes a system-inherent shock. Figure 5 provides a first idea of the impact of the buffer zone on allowances supply. It shows that, while its introduction in *New MSR* smooths allowance supply and hence should reduce price variability, the effect is only visible in 2024.

To further assess the MSR reform's impact on price variability, we can extend the findings of Perino and Willner (2016) to the proposed regulation. The authors find that the MSR in its current regulation increases price variability in case of a shock. The MSR has accordingly a destabilizing effect on the allowance market. Independent of our model results, we can conclude from the findings of Perino and Willner (2016) that a reform reducing the impact of the MSR must increase the market's resilience, while the destabilizing effect is more pronounced if the impact of the MSR is stronger. The impact of the reform proposal is hence ambiguous as the MSR intake is lower for a TNAC between 833 and 947 million allowances and higher above this level.

Perino and Willner (2016) focus on demand-induced shocks, e.g., economic crises or overlapping policies. The MSR reform proposal, however, is not directed at addressing this type of

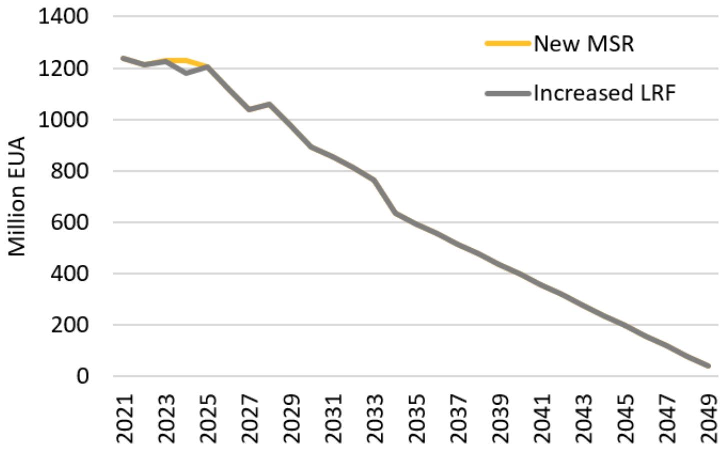


Figure 5: Ex-post allowance supply under *Increased LRF* and *New MSR*

shocks. Its intention is rather to reduce the uncertainty regarding the level of MSR intake and this objective is achieved. We can therefore conclude that while the reform proposal may not increase the general resilience to shocks and even deteriorate it, it reduces price variability induced by uncertainty regarding the MSR intake and hence increases market stability.

We find this ambiguous impact also for the second aim of the MSR adjustment, the reduction of allowance supply. Introducing a buffer zone increases allowance supply. This effect may be offset and even overcompensated by the increase of the intake rate from 12% to 24%.

4.3. Revised Cancellation Mechanism

Regarding the revision of the cancellation mechanism, economic intuition suggests that a cancellation threshold of 400 million allowances compared to the previous year's auction volume from the current regulation would significantly increase the cancellation volume. However, the increase induced by the revised cancellation mechanism only amounts to 3.2% of the total cancellation volume. Figure 6 shows that while in the *Fit for 55* scenario cancellation volumes increase in 2023 and 2024 compared to the *New MSR* scenario, the cancellation in 2025 decreases to zero in both scenarios. With a fixed cancellation threshold, the first cancellation limits the MSR volume to 400 million allowances and, in consequence, further cancellation only takes place in years with MSR intake. As the last year of MSR intake in *Fit for 55* is 2024, there is no cancellation after this year. A sensitivity analysis in Appendix A shows that even an extreme threshold of zero would not have a significantly higher cancellation volume, as the 'Fit for 55' proposal can only enter into force by 2024 and the cancellation volume depends more on the MSR intake than on the cancellation threshold.

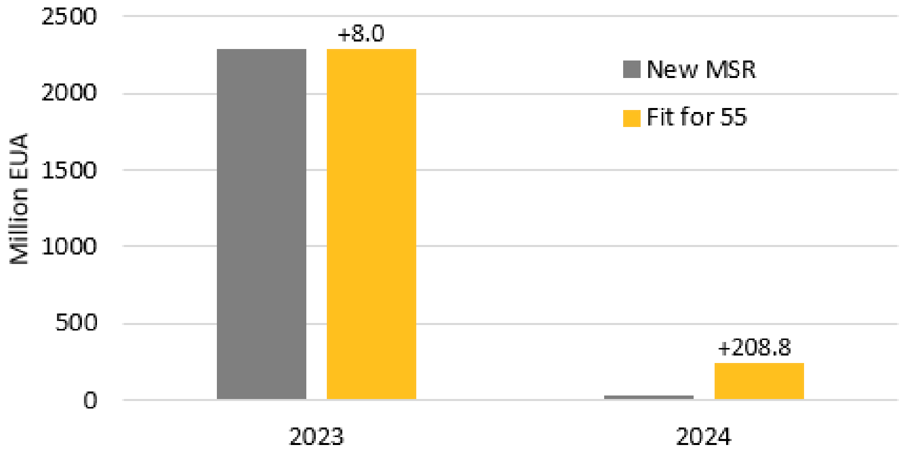


Figure 6: Cancellation volume under 2018 regulation and Fit for 55-proposal

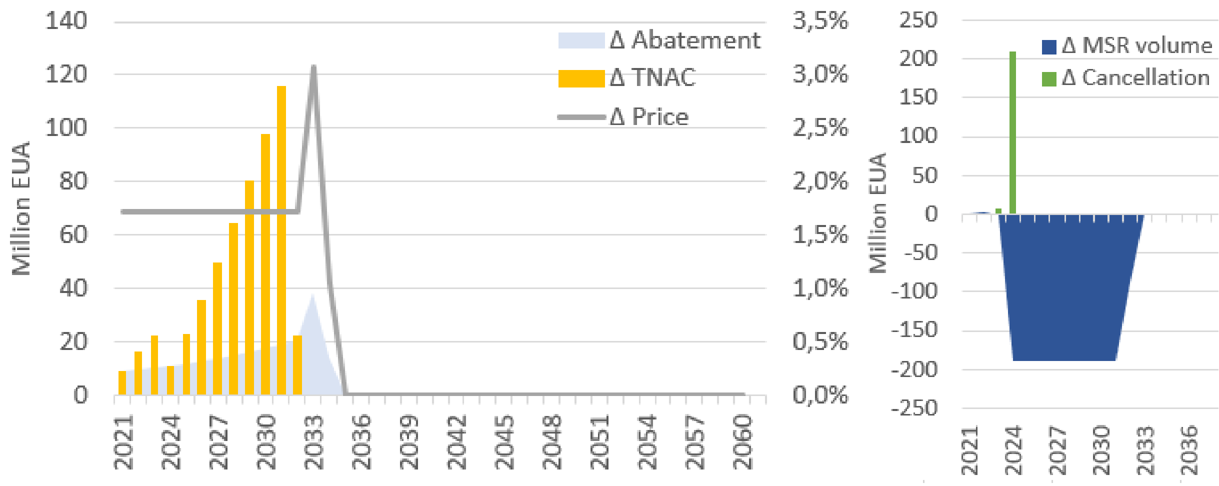
Figure 7 presents the differences between the *New MSR* and the *Fit for 55* scenarios in detail. The expectation of a higher cancellation volume leads to higher prices and consequently more abatement in the *Fit for 55* scenario. The lower cancellation in *New MSR* leads to a higher remaining MSR volume after the cancellation and allows for a two years longer reinjection period from 2028 to 2033, instead of 2031 in *Fit for 55*.[8]

The model results show that the proposed fixed cancellation threshold of 400 million allowances leads to a higher cancellation volume compared to the current threshold which is defined by the previous year's auction level. This is not necessarily the case under other circumstances. In the model setup, there is no additional MSR intake after 2024 and, hence, cancellation only takes place in 2023 and 2024, both under the 2018 regulation and the proposed reform. While the cancellation volume in the first years is in all cases higher under the proposed fixed cancellation threshold of 400 million allowances, there could be additional cancellation under the 2018 regulation but not under the proposed reform later in the case of an MSR volume below 400 and a previous year's auction level that is even lower.

4.4. Scenario comparison

To understand the impact of the individual reform elements, this subsection compares the four scenarios regarding the model results for emission reduction, EUA prices and cancel-

[8]This explains the spike in the price difference as the reinjection allows for a longer maintenance of a Hotelling price path in *New MSR*.



(a) Allowance market

(b) MSR movements

Figure 7: Results of *Fit for 55* minus *New MSR*

lation volume. Figure 8 shows that all scenarios significantly fall short of the 61% climate target of 2030. While this is not surprising for the *2018 regulation* scenario that aims at a reduction of 43%, the increased LRF can only partially close the gap. The adjusted MSR and CM have only a minor additional impact on the 2030 abatement level.

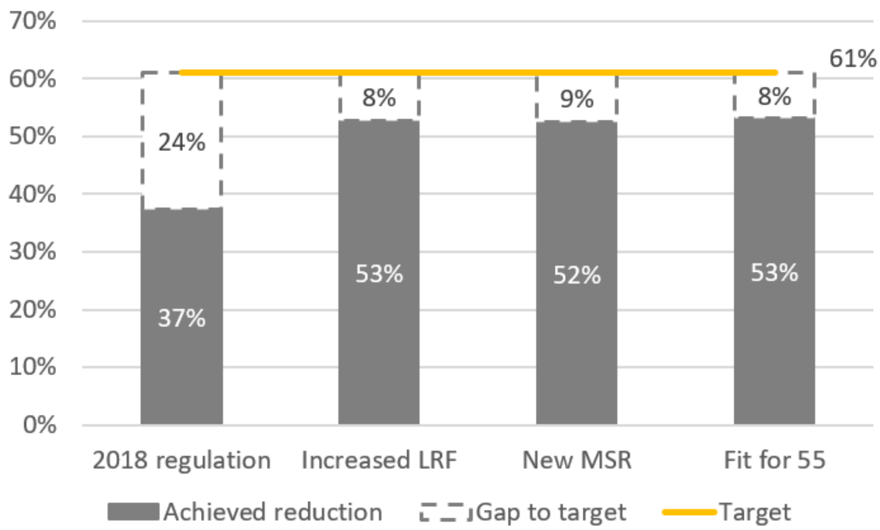


Figure 8: Achieved versus target reduction for 2030 in the four scenarios

Figure 9 indicates the impact of the reform elements on the 2021 allowance price level. While the reform as a whole increases price levels by 48%, 46 percentage points of these can be attributed to the increased LRF. In *New MSR*, the proposed MSR rules decrease the price level by one percentage point as the MSR intake is lower than in *Increased LRF*. The increased cancellation volume in the *Fit for 55* scenario increases the 2021 price level by only 3 percentage points.

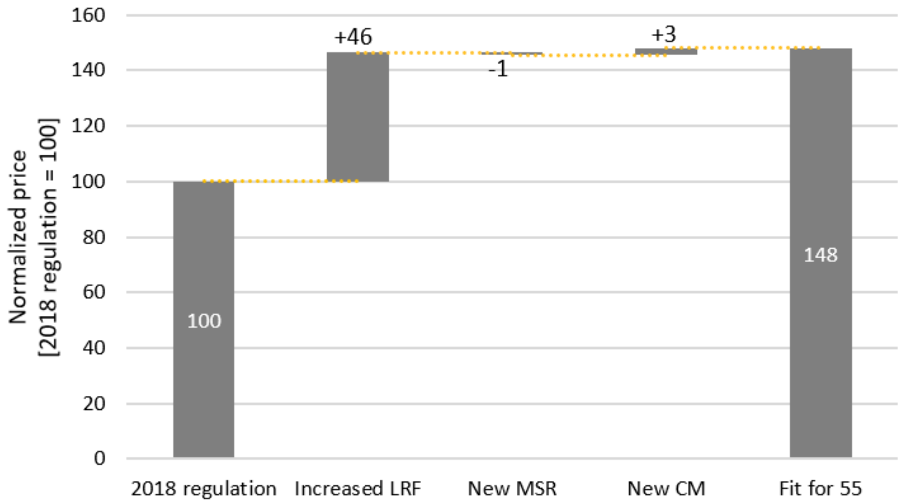


Figure 9: Decomposition of changes in 2021 price level into the individual reform elements

While the impact of the MSR and CM adjustments on abatement and price levels are minor compared to the impact of the increased LRF, all three reform elements have significant effects on the aggregate cancellation volumes. Figure 10 shows how the total increase in cancellation volume of 563 million allowances can be attributed to the different elements of the reform proposal. The main share of the increase (410 million allowances) stems from the increased LRF. The proposal for an adjusted MSR regulation, in contrast, reduces the overall cancellation by 54 million and the new CM rules lead to an increase of 217 million allowances. Analogously, Appendix B presents a decomposition of the impact of the reform proposal into the three reform elements regarding total emissions and the 2021 abatement level.

5. Discussion

5.1. Critical model assumptions

The model results show a limited impact of the proposed change in MSR and CM rules. However, this may to a large extent depend on the model assumptions of constant baseline emission level and a linear MAC curve. Moreover, the research assumes rational firms with perfect foresight, neglecting the potential influence of bounded rationality aspects, like

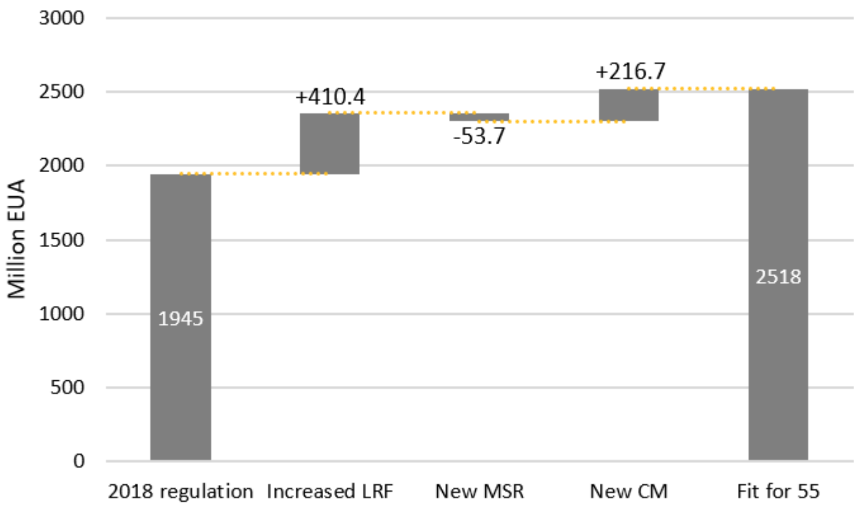


Figure 10: Decomposition of changes in cancellation volume into the individual reform elements

hedging behavior or myopia. The following subsection discusses how model results would change if these assumptions were relaxed and under which real-world circumstances this might be the case.

Baseline emissions may change over time in response to the development of the economy or to overlapping policies. The impact of these changes in baseline emissions on the outcome of the EU ETS and the effect of the reform proposal depends on two factors: the duration of the change in baseline emissions (temporary or permanent) and the market's anticipation of these changes. For instance, in the case of a sudden economic crisis or a similar shock to emissions baseline emissions may drop abruptly but also recover quickly.[9] In consequence, the TNAC might increase to levels above 833 million allowances and there might be an additional phase of MSR intake. In this case, all allowances transferred to the MSR are automatically cancelled under the proposed CM. Under the existing regulation, the impact of a short-term crisis is less clear as the cancellation depends on the previous year's auction level, i.e., the timing of the demand shock. Thus, the proposed adjustment increases predictability of the cancellation mechanism also in this case.

Overlapping policies or long-term changes in the structure of the economy may affect the level of baseline emissions more permanently than economic crises. For instance, higher levels of RES or lower electricity demand reduce baseline emissions and vice versa. The outlined effects would be more pronounced but go in the same direction as for a temporary

[9]More generally speaking, economic crises can take different shapes of recovery. See Bocklet (2020) for an analysis of different types in the context of the EU ETS.

baseline emissions shock. However, particularly with overlapping policies, it is likely that market agents anticipate these changes of baseline emissions. In this case, the price and abatement paths would adjust already before the change occurs. Anticipated overlapping policies that reduce baseline emissions can therefore decrease price and abatement levels along the entire EU ETS horizon and even lower the cancellation volume compared to a benchmark without the overlapping policies. Rosendahl (2019) and Schmidt (2020) provide analyses of this so-called New Green Paradox. The proposed adjustment of the MSR and CM rules cannot overcome this problem.

The model results further depend critically on the assumption of the functional form of the MAC curve. The slope of the MAC curve determines how abatement is distributed over time. The model uses a smooth synthetic MAC curve with a linear slope. This assumption may not hold in reality, as Hintermayer et al. (2020) indicate. We can qualitatively assess the impact deviations from this assumption. An overall steeper or flatter linear MAC curve is equivalent to a change in backstop costs and has no impact on the distribution of abatement over time, as Bocklet et al. (2019) show. If, however, only the low-cost segment of the MAC curve becomes flatter, for instance induced by a smaller gas-coal-spread for electricity generation, while the costs of abatement options in the high-cost MACC segment are unchanged, firms would shift abatement efforts forward. This, in turn, would increase TNAC, MSR intake and cancellation volumes.

Considering elements of bounded rationality like hedging of allowances and myopic behavior would influence the model results. Hedging means that firms hold a certain share of allowances in their private bank to protect themselves against EUA price increases. This behavior increases the TNAC levels. As Bocklet and Hintermayer (2020) show, this leads to a higher intake into the MSR and a higher cancellation volume. Hedging behavior thus increases the impact of the increased LRF. Myopic behavior, in turn, leads to more emissions in the short run as firms do not take into account future scarcity of allowances. This potentially dampens the impact of an increased LRF with fewer MSR intake and cancellation volume. Both elements of bounded rationality should not change the findings regarding the effectiveness of the reform elements. Hedging or myopia do not affect the achievement of climate targets neither the level of (short-term) predictability of the CM. It could have a small effect on the level of MSR intake or the change in price variability induced my the proposed MSR reform but the change could go in both directions.

5.2. Potential shortcomings of the proposed reform elements

The model results in section 4 indicate that the individual reform elements may not fully achieve but work towards reaching their goals and are thus largely effective. Altogether, the proposed EU ETS reform should therefore strengthen the EU ETS as key instrument of EU climate policy. This subsection discusses potential shortcomings of the reform regarding the efficiency of its intended goals.

For the (over)achievement of a 61% climate target by 2030, the LRF increases from 2.2% to 4.2%. To achieve climate neutrality by 2050, the LRF would again decrease from 4.2% to 2.0%. Whether it is optimal that the allowance supply starts to decrease at a high rate and then to slow down ambition depends on various factors and cannot be determined within the analysis at hand. As illustrated in Bocklet et al. (2019), the optimal timeline for allowance supply would be to issue all allowances at the beginning of an ETS. This approach allows firms to allocate the emissions budget freely over time. Setting up an annual cap, in turn, leads to a significant loss of cost-effectiveness as it restricts the allocation of emissions over time. However, issuing all allowances at the beginning of an ETS is a theoretical benchmark that can only be effective if a government can fully commit to an ETS and firms believe that there will not be further interventions. In reality, a cap with a predetermined cap reduction is likely to be the more effective policy approach.

The MSR reform proposal smooths the intake rules and effectively eliminates threshold effects, thereby decreasing price variability. However, there is an inherent trade-off between the two goals of the MSR, low price volatility and regulation of allowance supply. Any deviation from the predetermined allowance cap that is not fully predictable for market participants may constitute a supply shock that increases price variability. Osorio et al. (2021) confirm this by computing MSR and cancellation volumes for a range of parameter constellations. They find that the results are highly uncertain and that thus these instruments induce uncertainty regarding the allowance price. The proposed adjustment can mitigate but not overcome this trade-off. In the same vein, Salant (2016) discusses that any sort of additional regulatory intervention in an ETS has a destabilizing effect leading to inefficiently high total abatement costs. In this sense, there is a trade-off between the small overall positive impact of the proposed adjustments to the MSR and CM mechanisms and the negative impact of potentially increasing regulatory risk in the market by again changing the regulation in place.

In a similar way, the proposed reform falls shorts of addressing the inconsistency of the current hybrid approach of the EU ETS with an orientation towards both an emissions budget over the system's overall time horizon and annual climate targets. The EU ETS is budget-oriented as it provides the option to bank allowances but it also aims at fixed annual climate targets. Banking provisions increase the economic efficiency of emissions trading system. However, they explicitly allow for emissions to be higher than a fixed annual cap.[10] Likewise, the MSR and CM focus on allowance supply in specific years and aim to limit banking of allowances. Osorio et al. (2021) propose that the adjustment of the LRF should take into account MSR and CM movements in order to achieve the 2030 emission target. However, the most accurate models can never predict the exact emission level of a specific year and hence even meticulous adjustments of the LRF, MSR and CM rules cannot guarantee that the 2030 climate target is achieved.

6. Conclusion

The research at hand applied a discrete-time optimization model of the EU ETS to assess the impact of the EU ETS reform proposed in the 'Fit for 55' package of the European Commission as a whole and to decompose the effects of the three main reform elements. The model results indicate a significant impact of the reform with 48% higher prices in 2021 under the proposed reform than under the 2018 regulation. While this is clearly not the only factor that has influenced 2021 price levels, the model results suggest that market participants expect the reform to enter into force and significantly influence EU ETS market outcomes. The results further show that the increased linear reduction factor has by far the largest impact on the EU ETS market outcome, driving 46 percentage points of the 48% price increase. In comparison, the adjustment of the MSR intake rules and the CM has only a smaller impact of together two percentage points.

The model results indicate that the proposed adjustment of the EU ETS mechanisms strengthen the EU ETS as key instrument of EU climate policy. The reform raises the climate ambition of the EU ETS, increases the predictability of the cancellation mechanism and eliminates threshold effects in the MSR intake under the regulation in place that may destabilize the market outcome. Nevertheless, the achieved improvements may be of limited impact. The adjusted MSR intake leads to a significant change only in 2024 as there is no further MSR intake afterwards under the old and new MSR rules. Similarly, the fixed threshold for cancellation leads only to a higher cancellation volume in its introduction year

[10] Note that the contribution of the EU ETS to EU climate targets is further uncertain as the EU ETS covers not only the EU but also Norway, Liechtenstein and Iceland.

2024. Further cancellation would only take place if there was additional MSR intake. This is not the case under the model configurations. The increased LRF reinforces the low impact of the MSR and CM it decreases TNAC levels. The increased climate targets may render the other proposed reform elements unnecessary.

The reform may not fully achieve its goals. The model results show that the increased linear reduction factor does not ensure the achievement of the new climate target for 2030. The emissions level in the target year may be higher as firms may use their banked allowances and allowances from the MSR may be reinjected into the market. While this may not be a serious flaw of the EU ETS from an economic point of view, it is a drawback for a reform labeled 'Fit for 55'. Furthermore, the impact of the proposed adjustment of the MSR intake on reducing allowance surplus and decreasing price volatility is ambiguous. The introduction of the buffer zone smooths allowance supply as it prevents threshold effects caused by the current regulation. However, it may also reduce MSR intake and cancellation. Decreasing price volatility through the buffer zone may hence be in conflict with the other MSR goal of reducing the number of allowances in circulation.

The underlying reason of the inability of the reform to achieve its goals is the hybrid nature of the EU ETS combining elements that orient towards an overall emissions budget and others that focus on the achievement of annual emissions targets. While the intertemporal nature of emissions trading system inhibit precisely targeting annual emissions reductions, the uncertainty induced by the MSR and Cancellation Mechanism further complicates this endeavour. EU ETS reforms need to constantly balance both approaches that are partially in conflict. While economic theory favors a budget approach, political commitment problems as well as providing optimal incentives for innovation and learning by doing favor a system with annual targets. Further research is needed to understand the optimal balance between the two approaches. In particular, there is still a lack of understanding how allowance supply in emissions trading systems should be regulated in order to ensure optimal abatement paths beyond the Hotelling rule of resource extraction.

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Appendix A. Sensitivity analysis of the cancellation threshold

Figure A.11 shows that the finding, that a CM based on fixed threshold of 400 million allowances does not significantly change the cancelled volume compared to the regulation in place, also holds for other threshold levels. As the *Fit for 55* proposal can only enter into force by 2024, the new rule would not be valid for the first cancellation in 2023. For cancellation thresholds lower than 400 million allowances, the cancellation volume in 2023 and 2024 increases slightly more than proportionally to the threshold increase as more cancellation induces a feedback with higher prices and even more abatement, a higher TNAC and more MSR intake and cancellation. However, a tighter threshold does not induce cancellation in 2025 as long as there is no additional MSR intake. In this way, even an extreme threshold of zero, i.e., all MSR allowances are automatically rendered invalid after 2023, leads to an increase of the overall cancellation volume of only 475 million allowances or 18.9% compared to the thresholds in the *Fit for 55* scenario. While the cancellation volume analogously decreases for higher thresholds, it remains unchanged for thresholds above 700 million allowances as at this threshold there is no cancellation triggered in 2024 when the proposed regulation could enter into force.

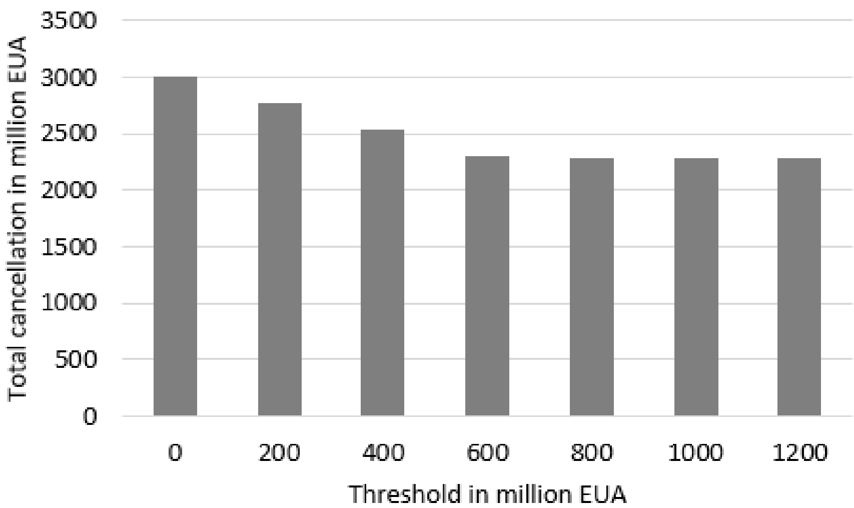

Figure A.11: Cancellation volume under different cancellation thresholds

Appendix B. Further scenario comparison

Analogously to the decomposition of cancellation volumes presented in Figure 10, Figure B.12 presents the change of total emission levels in the EU ETS (over the entire model horizon) induced by the three reform elements. The impact of the MSR and CM adjustments on total emission levels is negligible.

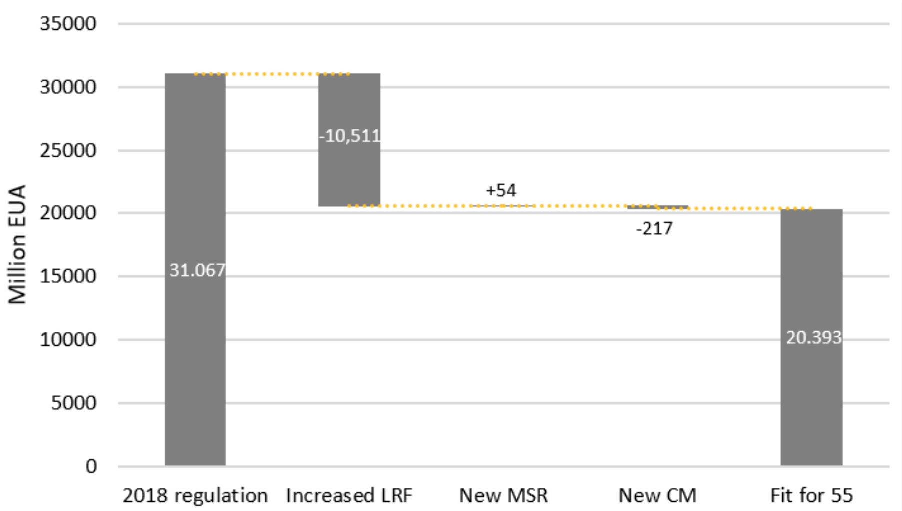

Figure B.12: Decomposition of changes in total emissions into the individual reform elements

Similarly, change in the 2021 abatement level is mainly induced by the increased LRF, while MSR and CM adjustments play a minor role, as figure B.13 shows.

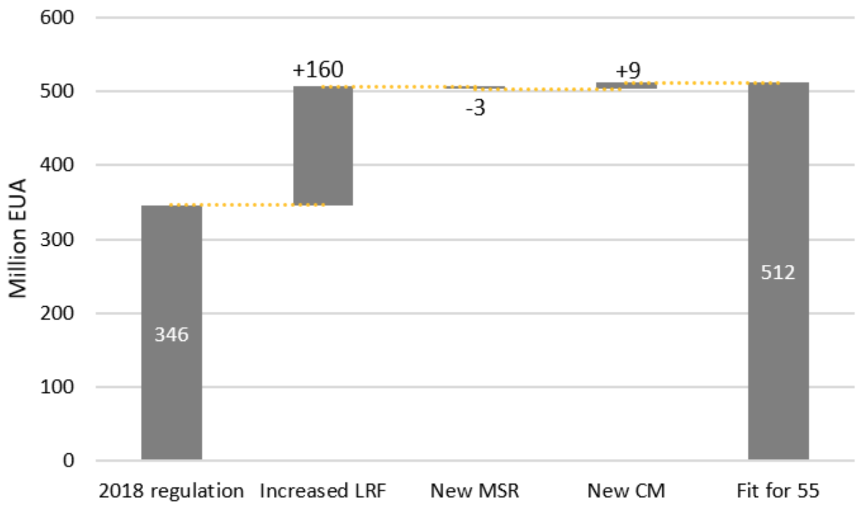

Figure B.13: Decomposition of changes in 2021 abatement levels into the individual reform elements