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POLICY BRIEF

THE ROAD TO GREATER EU CLIMATE AMBITION

Aligning the carbon market and the market stability reserve with medium to long term climate targets

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Regulatory changes are on the horizon to align the EU carbon market with the EU's Paris commitments, the goals of the upcoming European Green Deal (e.g. carbon neutrality by 2050), and the achievements of other pieces of the climate and energy policy landscape which were recently – or are about to be – reinforced.

Discussions in Brussels on raising ambition within the carbon market revolve around a more stringent cap trajectory (LRF increase) and a revision of the Market Stability Reserve (MSR) and its parameters. These elements are not independent, and their interaction need be considered. With our simulation model we evaluate and quantify various options for 2021 review package. We highlight our key results below:

- **Transitional stringency matters:** Past market developments suggest that market actors tend to focus on the short to mid term and do not fully account for the long-term ambition target embedded in the cap trajectory. While the impact of an LRF increase is more salient in the long term, the MSR has potential to make the long-term ambition more tangible earlier on by frontloading abatement efforts.

- **Informing the MSR review:** With the MSR thresholds constant over time, a higher intake rate causes higher volatility without leading to higher ambition. The position of the intake threshold matters relatively more than that of the release threshold: a lower intake threshold sustains higher price and ambition levels. As an important avenue for the review, combining declining thresholds (e.g. based on the LRF) with a higher intake rate is conducive to higher prices and ambition without destabilizing the market. This notwithstanding, even after changes in its parameters, the ability of the MSR to improve market resilience to future shocks remains limited by design.

- **How to raise ambition?** Since the MSR joint with cancellations has potential to permanently curb supply, it could be utilized hand in hand with an LRF increase to raise ambition. With the current LRF (2.2%) and MSR parameters, our simulations indicate that the current 2030 target will be overachieved (-48% w.r.t. -43% relative to 2005). If we consider that the ambition target is ramped up to -62%, the required LRF lies between 2.6 and 3.0% depending on the MSR parameters – but it is not sufficient for delivering carbon neutrality by 2050. Our analysis further explores the complex interaction between the chosen LRF and the MSR parameters which need be carefully assessed as part of the 2021 review process.

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In the wake of the latest reforms, the carbon price on the European carbon market (EU ETS) witnessed a fourfold increase and now hovers around 25€/tCO_2. The driving factor behind this recovery is the tightening of the cap on emissions, which was achieved through a strengthening in the rate at which the cap declines over time (LRF) and the establishment of a market stability reserve (MSR) equipped with a cancellation mechanism (CM). This has brought scarcity back to the market earlier than what was originally anticipated by market actors.

This notwithstanding, additional regulatory changes are still on the horizon, essentially as part of the 2021 review. The underlying motivation is the alignment of the EU ETS with (1) the EU's Paris commitments as well as the objectives of the upcoming European Green Deal to reach carbon neutrality by 2050 (2) the achievements of other pieces of the European climate and energy policy landscape, i.e. EU-wide renewable and energy efficiency measures and a range of national policies which were all recently – or are about to be – reinforced.

Discussions in Brussels on raising ambition within the EU ETS revolve around a more stringent cap trajectory (LRF increase) and a revision of the MSR and its parameters. These elements are not independent, and their interaction need be considered. With our simulation model we evaluate and quantify various options in revising the MSR parameters and the cap trajectory. We highlight our key results below:

- Past market developments suggest that market actors tend to focus on the short to mid term and do not fully account for the scheme's long-term ambition target: only the years ahead with greater visibility and political credibility matter the most for their decisions.

- *Transitional stringency matters*. In this context, the MSR has potential to make the long-term ambition embedded in the cap trajectory more tangible in the short to mid term by frontloading abatement efforts – and coupled with the CM, it also increases long-term scarcity. In fact, the 2018 price rally is largely attributable to market actors expecting a sizable MSR-induced supply cutback in the coming years rather than to the companion LRF increase, whose induced scarcity increase is more salient in the long term. In sum, transitional stringency is as important as cumulative stringency for policy design.

- *Informing the MSR review*. With the current thresholds (400-833 MtCO_2) constant over time, a higher intake rate generates higher volatility due to more pronounced oscillatory behavior around the thresholds, but without leading to higher ambition. The position of the intake threshold matters relatively more than that of the release threshold in terms of market outcomes: a lower intake threshold sustains higher price and ambition levels. As an interesting avenue for the review, combining declining thresholds (e.g. based on the LRF) with a higher intake rate is conducive to higher prices and ambition without destabilizing the market. Despite this, even after changes in its parameters, the ability of the MSR to improve market resilience to future shocks remains limited by design.

- *How to raise ambition?* Since the MSR + CM has potential to permanently curb supply, it could be utilized hand in hand with an LRF increase to raise ambition. With the current LRF (2.2%) and MSR parameters, our simulations indicate that the current 2030 target will be overachieved (-48% w.r.t. -43% relative to 2005). If we consider that the ambition target is ramped up to -62%, the required LRF lies between 2.6 and 3.0% depending on the MSR parameters – but it is not sufficient for delivering carbon neutrality by 2050. Our analysis further explores the complex interaction between the chosen LRF and the MSR parameters which need be carefully assessed as part of the 2021 review process.

I – The carbon price is driven by expected future stringency

Initially at around 25€/tCO_2, the price on the European carbon market (EU ETS) collapsed and remained at low levels for nearly a decade thereafter (Figure 1). The main factors behind this drop and subsequent stagnation are now well identified: the lasting repercussions of the 2008 economic recession, a massive of surrender of Kyoto offsets, the achievements of companion climate and energy policies (i.e. a rapid deployment of renewables, energy efficiency measures and a patchwork of other national policies) as well as regulatory uncertainty.

These factors reduced current and anticipated future emissions independently of the permit price, thereby eroding the stringency of the emissions cap. At the time, the system was not equipped with supply-side control mechanisms, nor had the regulatory authority the legal mandate to quickly adjust supply downward. Because permits are bankable (i.e. storable) this contributed to the accumulation of a sizable quantity of unused permits, oft referred to as the "surplus". This also reduced the need to curb emissions in the short term as well as the longer-term stringency relative to initial expectations, undermining low-carbon investment incentives.

After long negotiations and a multi-step reform, the system was amended to both tighten supply and make it more responsive. This took the form of an increase in the annual linear reduction factor (LRF) of the cap and the introduction of a supply control instrument, the market stability reserve (MSR), later reinforced with an add-on cancellation mechanism (CM).

The LRF specifies the year-on-year change in supply so that the cap decreases linearly toward a certain target. Initially aiming at reducing emissions by 21% in 2020 relative to 2005 (1.74% LRF) it was raissed to ratchet up the target to -43% in 2030 (2.2% LRF).[1] In parallel, the MSR is a reserve which automatically adjusts the number of permits to be auctioned in a given year as a function of the bank of permits in the previous year: downward (upward) if past banking is above (below) a given intake (release) threshold (and the MSR stock allows).[2] On top of this, the CM permanently invalidates those permits stored in the MSR in excess of auctions in the previous year, substantially tilting the system toward permanent supply contraction.

The twin objective of the MSR is to address (i.e. absorb) the current "surplus" and introduce some supply responsiveness in the system to pre-empt "surplus" formation in the future should similar demand-curbing circumstances happen again. Despite a lack of economic guidance in this respect, the implicit rationale behind the MSR is that too high a "surplus" of unused permits weighs negatively on prices. As Figure 1 shows, the "surplus" formation indeed coincided with the price decline, which contributed to the establishment of this line of thought.

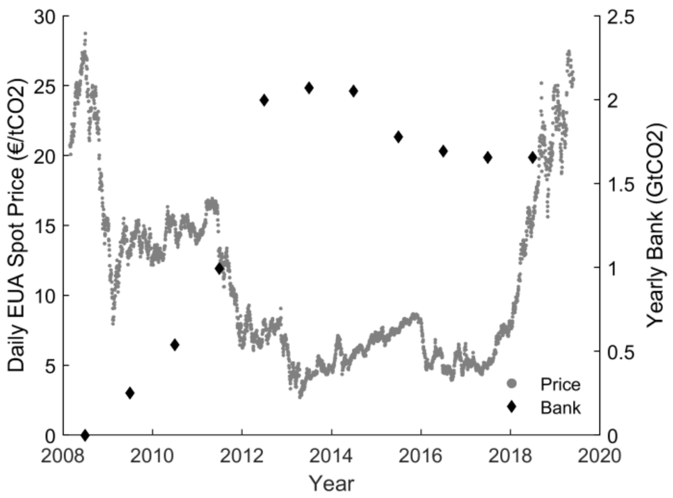
While something is undoubtedly true in this reasoning, it is only part of the story – crucially, it misses out on the system's intertemporal dimension incentives. Specifically, because banking is a naturally occurring feature in any intertemporal system with a declining cap trajectory, one may conceptually delineate 'bad' and 'good' types of "surplus" (resp. passive carryover due to excess net supply vs. active hedging to manage risks and banking to smooth compliance costs over time). However, the MSR somewhat conflates these two aspects of banking and treats them alike. This is not a bad thing per se, but rather something one should keep in mind.

As a case in point, note that while prices have quadrupled over the last couple of years, the bank has stayed constant, calling into question the purported causal link between the "surplus" and price levels. In fact, because market actors can bank permits for future use (when the cap

[1] Supply decreases annually by the amount LRF $\times$ reconstructed emissions for the regulated perimeter in 2010, specifically by 38.3 and 48.4 MtCO_2 with an LRF of 1.74 and 2.20%, respectively.
[2] See Appendix A for a detailed description of the MSR functioning and its parameters.

becomes more stringent), one could even argue that the "surplus" was not sufficiently high to sustain a price level that was reflective of the long-term constraint implied by the cap.

Figure 1 – Evolution of EUA price and banking over 2008-2019



Sources: ICE and European Commission, compiled by the authors.

Indeed, the permit price reflects the expected shortage of permits relative to emissions over time – as far ahead as market actors can perceive it. The larger the expected shortage, the higher the price today as a result of higher abatement and banking, and vice versa. Therefore, what drove the recent price rally was the expectation of a larger shortage consecutive to the reform, in a context where all other price determinants (e.g. economic conjuncture, fossil fuel prices) have not witnessed similar evolutions.[3] As we further discuss in the next sections, the reform indeed increased expected shortage in the short and long terms alike.

II – Transitional stringency is as important as cumulative stringency

In principle, through the system's intertemporal dimension, the permit price is the vehicle that balances expected long-term permit supply and demand. The long-term ambition embedded in the cap trajectory via the LRF (i.e. the cumulative stringency) is hence a key element of the policy and should be reflected in today's prices. However, if market participants are boundedly farsighted, thereby failing to recognize the policy's cumulative stringency to its full extent, then prices may reflect the short- to mid-term ambition (transitional stringency) and fall short of the actual underlying long-term ambition.

There are good empirical reasons to think that market actors do not fully account for the long-term stringency implied by the cap trajectory, for instance:

- utilities and industrials precisely plan their production schedules, sales and investments from a few months to a few years ahead, while their longer-term strategies remain less concrete and fixed in nature to gain flexibility and adapt to changes as they occur;
- organized trading for forward and futures contracts, which aims at (partly) remedying markets' inherent myopia,[4] only comprises maturities of up to ten years ahead at most;

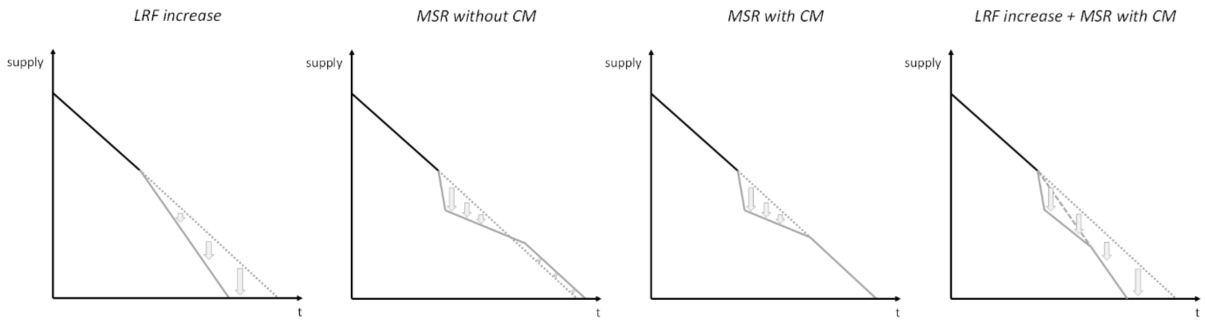
[3] See Marina Friedrich & Michael Pahle (2019), Allowances Prices in the EU ETS – Fundamental Price Drivers and the Recent Upward Trend (PIK) and references therein.
[4] See Robert M. Solow (1974)'s Richard T. Ely Lecture, American Economic Review, Papers and Proceedings.

- political decisions regarding long-term targets are unclear or subject to change, or both: as they are not set in stone and their implications are harder to fathom, they can appear less credible than those that have binding and more tangible impacts in the short term.

Therefore, a natural way for actors to deal with these uncertainties is to focus on a shorter time frame over which (1a) supply and demand conditions are clearer, (1b) political credibility and visibility is greater and (2) to update expectations and associated decisions on a regular basis. In a recent working paper developing a representation of market actors' expectations, we show that such a rolling horizon procedure can replicate past annual price and banking dynamics with interest rates in line with observed rates implied from futures' yield curves.[5]

If agents tend to focus more on the short to mid term than on the long term, this has important ramifications for policy design and outcomes, e.g. inefficiently low price levels might not trigger adequate investments with a risk of lock-in. Crucially, the system's transitional stringency is as important as its cumulative stringency – if not more. For instance, the left graph in Figure 2 shows that an LRF increase is more salient in the long term than in the short term. Even though the reduction in cumulative supply induced the change in the LRF from 1.74 to 2.2% as part of the 2018 reform is substantial (9 $GtCO_2$) market prices may be less than commensurate since the impact on transitional scarcity is less marked and agents are boundedly farsighted.

Figure 2 – Stylized representation of LRF vs MSR impacts on supply over time



The MSR has potential to raise both transitional and cumulative stringency. The former aspect occurs as the MSR is set to postpone some auctions, i.e. it frontloads abatement efforts and makes longer-term scarcity more tangible for boundedly farsighted agents. The latter aspect occurs as the CM will cancel the bulk of the permits the MSR is set to withdraw (and is seeded with).[6] These two properties are depicted on Figure 2. Had the 2018 reform only comprised the LRF increase from 1.74 to 2.2%, our calibrated model suggests that the price would have increased to 10€/tCO_2 only.[7] This is because the MSR brings into present times – as well as augments through the CM – the scheme's long-term scarcity.

Another important related aspect is the interaction between the LRF and the MSR:

- for a given LRF, changing the MSR (and CM) parametrization will change the resulting stringency, both in transitional and cumulative terms;

[5] See Simon Quemin & Raphaël Trotignon (2019), Emissions Trading with Rolling Horizons (LSE).
[6] Cumulative cancellations are in order of 8.7 $GtCO_2$ in the status quo (current MSR design and LRF, see Table 1) but note they can be twice as small depending on assumed firms' behavior (see supra footnote 5).
[7] In our model, this represents 13% of the price rise witnessed in conjunction with the MSR and the CM. Crucially, the CM is not instrumental in supporting the price rally as it cancels reinjections in the mid to long term (i.e. beyond agents' horizon) relative to the short to mid term auction backloading operated by the MSR. That being said, the CM has undoubtedly contributed to making the bite of the reform more concrete and credible for market actors.

- for a given MSR (and CM) parametrization, changing the LRF will change the resulting stringency, both in transitional and cumulative terms.

This interplay is not trivial and need be assessed, especially in the current context of ratcheting up the 2030 target in alignment with the 2050 carbon-neutrality objective. This will be the topic of Section IV. We now turn to the investigation of the price and ambition impacts of changing the MSR parameters in the context of the upcoming review.

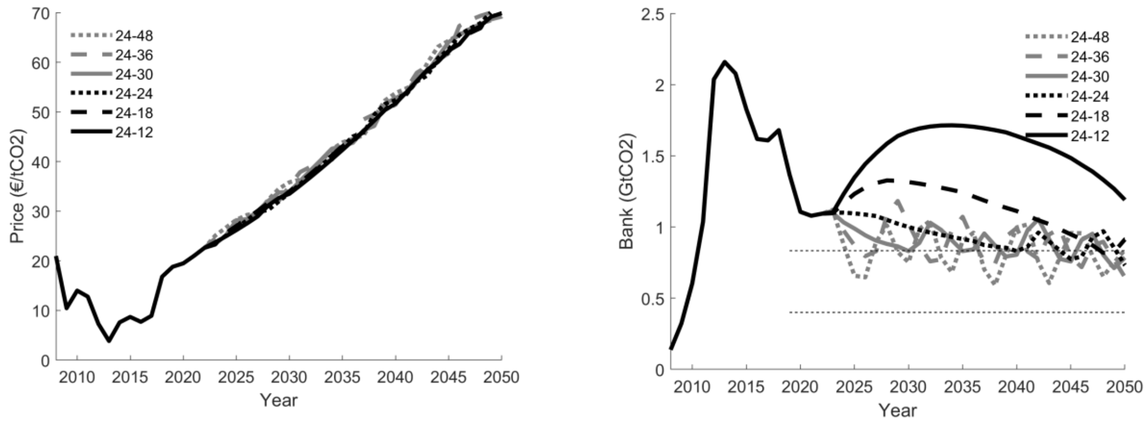
III – Informing the review: Impact assessment of changes in MSR parameters

We use our calibrated model to assess the impacts of a set of changes in the MSR parameters. Specifically, we take the MSR setup as given and vary each of its main parameters in isolation (i.e. the intake rate, the intake and release thresholds) relative to the status quo (see Appendix A). We thus single out their respective impacts on market outcomes. As the review package is likely to comprise a combination of such changes, we also discuss their interaction. Moreover, we evaluate the MSR-induced resilience to future demand shocks in an illustrative example.

We take the CM as granted (and its trigger as currently set out) although we underline it need be enshrined as part of the review process. Moreover, we assume that agreement on the 2021 review package takes time. Specifically, following the 2015-2018 reform timeline, we consider that regulatory changes are voted in – and thus anticipated from – 2023 for implementation in 2024 and maintained unchanged thereafter.

With constant thresholds, a higher intake rate increases volatility but not ambition

Figure 3 – Price and bank paths for different intake rates from 2024 onward



Note: Intake rate of 24% between 2019 and 2023. From 2024 onward, we compare the impacts of intake rates of 12, 18, 24, 30, 36 and 48% alternatively with constant release-intake thresholds over time (400-833 $MtCO_2$).

A large intake rate magnifies the threshold effects (or discontinuities) induced by the MSR – a trigger mechanism by design.[8] Mechanically, it causes banking oscillations around the intake threshold as a result of a conflict between the downward dragging force exerted by the MSR

[8] That is, realized supply is highly sensitive to when the MSR is active or inactive. For instance, when the bank in year t is 834 $MtCO_2$ auctions in year $t+1$ are curtailed by 100 up to 400 $MtCO_2$ with an intake rate of 12 and 48% respectively, while they are unaltered when the bank in year t is 832 $MtCO_2$ (the current threshold is 833 $MtCO_2$).

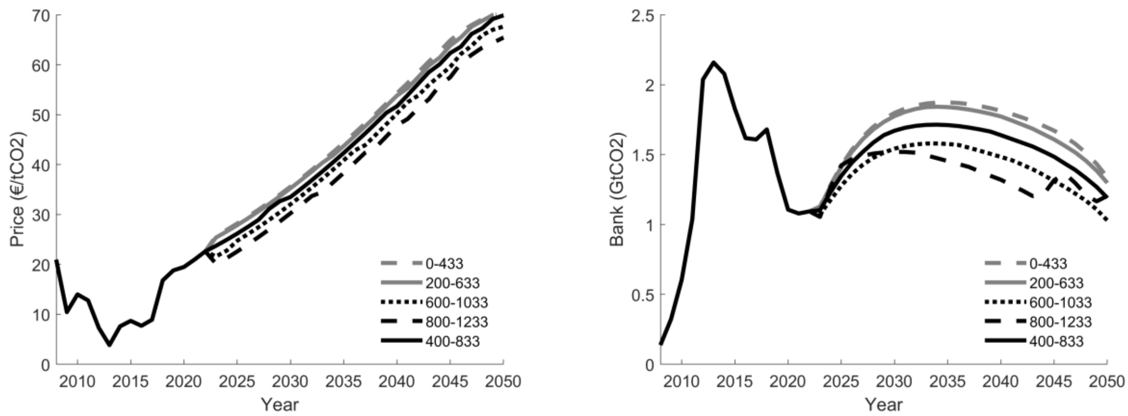
on the bank[9] and the upward restoring force stemming from banking incentives faced by firms as they cost minimize over time. This conflict, and hence induced oscillations, are more salient the higher the intake rate (Figure 3, right panel). Crucially, the more banking oscillates around the intake threshold, the more erratic the MSR intake and auction streams (see Appendix B).

As induced oscillations in banking and annual supply are transmitted to prices, a higher intake rate is conducive to larger price volatility with only a marginal price increase on average (Figure 3, left panel). This is in stark contrast with the second objective of the 2018 reform to improve the resilience of the market, and ultimately of the price signal. The slight increases in average price levels are attributable to slightly larger cumulative cancellations, ranging from 8.7 to 9.2 $GtCO_2$ with an intake rate of 12 and 48% respectively (see Appendix B).

In short, with the current thresholds (400-833 $MtCO_2$, constant over time), a higher intake rate than in the status quo (12% from 2024 on) does not increase ambition and tends to destabilize the market by making prices more volatile and annual supply more irregular. In practice, higher intake rates entail that future market conditions are harder to gauge for market participants and could also be prone to manipulation or strategic arbitrage not related to fundamentals.

Given an intake rate, a lower intake threshold yields higher price and ambition levels

Figure 4 – Price and bank paths for different threshold positions from 2024 onward



Note: Release-intake thresholds of 400-833 $MtCO_2$ between 2019 and 2023, whose position we vary afterward with width kept constant. Intake rate of 24% between 2019 and 2023 and of 12% afterward.

With a given intake rate, the lower the intake threshold, the longer the intake period and thus the larger the cumulative intakes and attendant cancellations. In consequence, price paths are ordered by decreasing height of the intake threshold, with a maximal wedge of about 7€/tCO_2 between intake thresholds set at 433 and 1233 $MtCO_2$ (Figure 4, left panel) which is reflected by cumulative cancellations of 9.3 and 6.9 $GtCO_2$ respectively.

Lowering the intake threshold allows an increase in price and ambition levels without inducing volatility, but there are decreasing returns. For instance, a lowering from 1233 to 1033 $MtCO_2$ increases cumulative cancellations by 1 $GtCO_2$, but only by 0.1 $GtCO_2$ from 633 to 433 $MtCO_2$. This is because a lower intake threshold essentially prolongs the intake period at a time when the bank is relatively low – i.e. at the end of the banking period. Additionally, as firms anticipate longer and larger intakes with a lower intake threshold, they tend to accumulate a larger bank

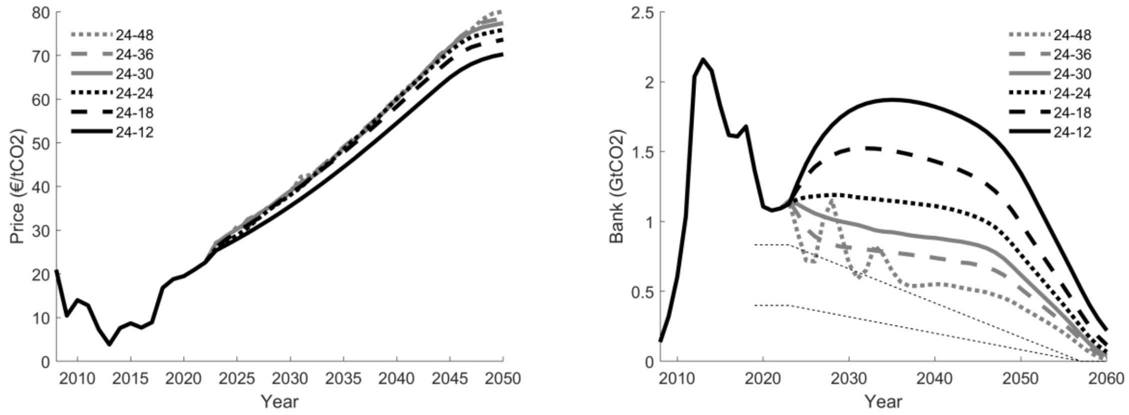
[9] More precisely, as the MSR takes in permits and cuts back on annual auction volumes, it forces firms to tap into their private banks of permits to compensate for reduced contemporaneous supply.

(Figure 4, right panel) which translates into larger intakes early on. Decreasing returns obtain because (1) this anticipation effect saturates for low intake threshold levels and (2) the intake period is upper bounded by the banking period so it cannot be prolonged indefinitely.

Together with the intake rate, the position of the intake threshold is a key policy handle.[10] The latter specifies the trigger condition for the MSR to take in permits while the former dictates the share of the bank that is withdrawn from auctions and placed in the reserve. In comparison, the position of the release threshold has a marginal impact on price and ambition outcomes. Indeed, reinjections only occur for a few years in the 2050's in relatively small fixed chunks of 100 $MtCO_2$ per annum when the reserve is almost empty anyway (due to cancellations).

With declining thresholds, a higher intake rate raises ambition without more volatility

Figure 5 – Price and bank paths with linearly declining thresholds from 2024 onward



Note: Release-Intake thresholds of 400-833 $MtCO_2$ between 2019 and 2023, which then linearly decline to reach 0 in the same year as the cap (in 2058). Intake rate of 24% between 2019 and 2023 and of 12 to 48 % afterward.

Because banking will eventually decrease as time progresses and the cap declines, the MSR thresholds could be aligned accordingly, i.e. gradually adjusted downward. There are different ways of implementing declining thresholds, but one sensible approach could be to align them with the LRF. Here, intake and release thresholds are assumed to be decreasing linearly over time to become nil in the same year as the cap (in 2058 with an LRF of 2.2%).[11]

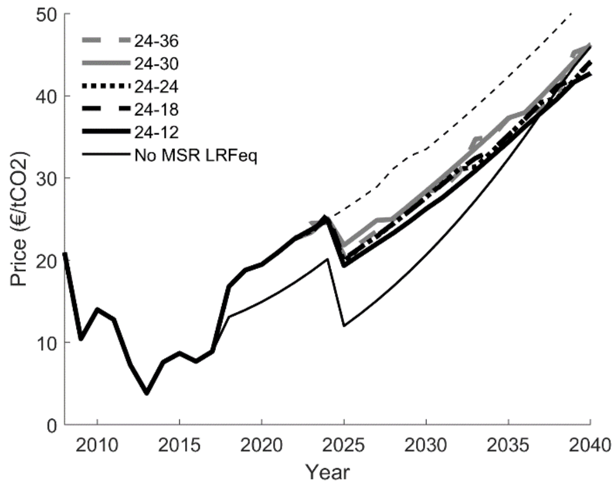
Intuitively, relative to constant thresholds, one can expect that (1) the intake period is longer, which in turn leads to higher ambition and price levels and (2) threshold effects and induced oscillatory behaviours are less likely, hence mitigated. This is readily apparent when comparing Figures 3 and 5. For a given intake rate, the price is higher and less volatile, and cumulative cancellations are larger, ranging from +0.5 $GtCO_2$ with a 12% rate to +2 $GtCO_2$ with a 48% rate. Of course, undesirable oscillations and associated volatility may still materialize when the intake rate is large enough. Here, this happens only with a 48% intake rate over the first decade – otherwise, the intake and auction streams are more regular (see Appendix B) and the end of the intake period coincides with that of the banking period (i.e. banking de facto never crosses the intake threshold, see Table 2).

[10] We also varied the width between thresholds and obtained similar results – specifically, the position of the intake threshold matters more than that of the release threshold in terms of price and ambition outcomes.
[11] We also consider that the fixed reinjection quantity (100 $MtCO_2$) declines similarly, but this has negligible impacts given the relatively marginal role of this parameter.

Combining an increase in the intake rate with declining thresholds appears promising as this allows raising ambition without inducing volatility. Note that the increase in the intake rate need not be significant as there are again decreasing returns. Specifically, an increase from 12% to 18% already reaps the bulk of the higher ambition potential (+1.3 $GtCO_2$ in terms of cumulative cancellations). This can readily be seen by comparing price paths on Figure 5 (left panel), i.e. those with a rate of or above 18% are grouped together above that with a 12% rate.

The MSR induces some, but limited, resilience to future demand shocks

Figure 6 – Price impacts of a permanent negative demand shock with and without MSR



Note: Case of an unanticipated permanent negative (-150 $MtCO_2$) shock on yearly demand for permits from 2025 onward. Constant release-intake thresholds of 400-833 $MtCO_2$. Intake rate of 24% between 2019 and 2023, and of 12 to 36% afterward. LRFeq (2.8%) is the LRF that generates the same average cumulative emissions without MSR as an LRF of 2.2% in the presence of the MSR and CM (with the various intake rates, without the shock).

The MSR exhibits limited shock cushioning capacity. In the year of the shock it can contain the price drop by 30% to 60% relative to a case without MSR. This cushioning effect depends on, but is crucially not monotonic in, the intake rate (it is maximal for a 30% rate). Indeed, the MSR can at best respond with a one-year lag: its impacts on supply when the shock happens depend on banking the year before, so crucially are independent of the shock. As time progresses, we note that the intake rate does not make much of a difference in terms of price path.

Whatever the intake rate, price recovery over time is limited. This is because in terms of supply-demand balance, the MSR can only absorb between 10 and 17% of the cumulative shock. In turn, prices never return to the levels that would have prevailed absent the shock. Interestingly, the price obtained with a higher but sole LRF (2.8%) catches up with those obtained under the MSR and a 2.2% LRF after a dozen of years despite the absence of supply-side control.[12]

The above contrasts with the second 2018 reform's objective to increase market resilience to future supply-demand imbalances. Critiques that the MSR is by design ill-equipped to act as a buffer are by no means new. These include inter alia (1) the embedded asymmetry in the MSR

[12] This catch-up effect occurs as boundedly farsighted firms gradually come to perceive the actual underlying long-term ambition associated with the 2.8% LRF, which is similar to that obtained under a 2.2% LRF + MSR and CM. Importantly, it materializes independently of, and not in response to, the shock.

ability to absorb or inject permits, (2) questions about the bank being the relevant index for this purpose[13] and (3) the minimum one-year lag before a possible MSR response.

IV – Raising ambition with the MSR in place

There are two ways of raising ambition within the ETS perimeter: (1) increasing the LRF and (2) augmenting the MSR.[14] As discussed in Section II, they are not equivalent in that scarcity induced by the former is more prevalent in the long term while that induced by the latter prevails in the short to mid term (and the CM also works to raise long-term scarcity). This has important ramifications, especially in terms of ambition, if market actors are boundedly farsighted.

These two options can be utilized hand in hand. Indeed, because the MSR equipped with the CM endogenizes the effective cumulative cap, it has potential to raise ambition.[15] Therefore, attaining a given emission target (specified in cumulative or annual terms[16]) requires a smaller LRF with the MSR and the CM in place.

The current ambition target is to decrease covered emissions by 43% in 2030 relative to 2005 (2320 $MtCO_2$). In the status quo, our simulations suggest that the ETS is going toward a 48% cut in emissions, thereby overachieving its target (see Table 1). As an illustration, we consider an increase in ambition in line with emissions reduced by 62% in 2030 relative to 2005.[17]

As Tables 1 and 2 show, the LRF required to attain this hypothetical target is always lower with the MSR than without (4.15%) although it varies with the MSR parameters. Specifically, with constant 400-833 $MtCO_2$ thresholds, the required LRF is around 2.9% and slightly decreases with the intake rate. With linearly declining thresholds, it is even lower, especially with a 24 or 36% intake rate where it lies around 2.6%.[18] Note that in all cases this higher target does not lead to carbon neutrality in 2050 (with always more than 100 $MtCO_2$ of residual emissions).[19]

Not only do MSR impacts hinge on its selected parameter values, but also on the LRF. Indeed, all else constant, the higher the LRF the shorter the banking period, but the higher the banking levels early on when the bank is accumulating. With the MSR in place, this implies that MSR intakes are larger early on (short-term effect) but smaller later on (long-term effect) since the intake period is shorter. Depending on which effect dominates, increasing in the LRF can either reinforce or undermine the MSR's ability to raise ambition.

Intuitively, the larger the intake rate, the larger annual MSR intakes early on (and the shorter the intake period anyway). Ignoring the induced oscillations in banking, one may hence expect that the short-term effect is more likely to dominate with a higher the intake rate. As Tables 1 and 2 show, this is indeed the case with constant and declining thresholds. Specifically, while cumulative cancellations are lower with a higher LRF for a 12% intake rate, the opposite holds

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[13] Because of the MSR-induced shortening of the banking period and frontloading of abatement efforts, firms have less flexibility in spreading shocks over time and smoothing compliance costs. Therefore, prices tend to reflect and respond more to contemporaneous shortage and demand shocks.
[14] It is unclear for now whether an increase in the LRF can be negotiated as part of the review process.
[15] The fact that the MSR frontloads abatement efforts and raises prices in the short to mid term can trigger long-lived investments in low-carbon technologies, thereby reducing long-term demand and raising ambition – a positive feedback our model does not capture.
[16] As a general remark, setting an emission target for a given year is tricky given the intertemporal dimension of the market. For instance, a zero target for 2050 requires that the cap be zero before 2050 as some banked permits can still be used to cover emissions after the cap is nil. This issue is even more convoluted now that the MSR is in place.
[17] This is more ambitious than what is currently on the discussion table (50-55%). This assumption does not change the qualitative nature of our results while making the case for setting a higher ambition target.
[18] This was to be expected since declining thresholds allow for higher ambition (see Section III). Note the decreasing returns in raising the intake rate, e.g. the required LRF is lowered by .01% only when the rate goes from 24 to 36%.
[19] Reaching exactly zero emissions by 2050 would require a much higher LRF, above 4% in all cases.

for 24 and 36% intake rates. In total, cumulative emissions are an intricate function of the mix of LRF and MSR parameter values, and their interaction need be carefully assessed.

Table 1 – LRF-MSR interaction with constant thresholds (400-833 $MtCO_2$)

		Emissions (Mt)					
Intake rate	LRF	2030	2040	2050	Intakes end	Removals (Gt)	Cumul. Em (Gt)
No MSR	2.20	1,281	848	419	–	0	58.6
	4.15	882*	405	148	–	0	45.1
12%	2.20	1,109	674	285	2053	8.7	51.5
	2.96	882*	401	145	2047	8.5	44.2
24%	2.20	1,106	666	279	2049	8.9	51.3
	2.89	882*	390	120	2042	9.5	43.8
36%	2.20	1,098	676	280	2048	9.0	51.2
	2.83	882*	419	129	2043	9.8	44.0

Note: Constant release-intake thresholds of 400-833 $MtCO_2$ over time. Intake rate of 24% between 2019 and 2023 and of 12, 24 or 36% afterward. The star superscript denotes the increased 2030 target (-62%) relative to the current target (-43%, with an LRF of 2.2%). The last column contains cumulative realized emissions over 2008-2100.

Table 2 – LRF-MSR interaction with linearly declining thresholds (in line with LRF)

		Emissions (Mt)					
Intake rate	LRF	2030	2040	2050	Intakes end	Removals (Gt)	Cumul. Em (Gt)
No MSR	2.20	1,281	848	419	–	0	58.6
	4.15	882*	405	148	–	0	45.1
12%	2.20[d]	1084	644	282	2066[b]	9.3	50.9
	2.94[d]	882*	409	149	2058[b]	8.6	44.3
24%	2.20[d]	1054	587	232	2063[b]	11.0	49.1
	2.63[d]	882*	399	142	2058[b]	11.3	44.2
36%	2.20[d]	1040	588	208	2061[b]	11.6	48.6
	2.62[d]	882*	382	118	2056[b]	11.8	43.7

Note: Release-intake thresholds of 400-833 $MtCO_2$ between 2019 and 2023, which then linearly decline to reach 0 in the same year as the cap given the LRF (indicated by the superscript d). Intake rate of 24% between 2019 and 2023 and of 12, 24 or 36% afterward. The superscript b indicates that intakes stop only when the bank becomes nil, i.e. the bank never passes below the intake threshold and the MSR always withdraws permits.

Appendix A – The Market Stability Reserve and the Cancellation Mechanism

The MSR consists of (1) a reserve of permits whose stock in year t we denote S_t and (2) a set of parameters: an intake rate IR_t, a release quantity RQ_t and intake-release thresholds IT_t and RT_t. It adjusts annual auctions A_t as a function of the bank in the year before B_{t-1} as follows:[20]

- if $B_{t-1} > IT_t$ then $A_t \leftarrow \max\{A_t - IR_t \times B_{t-1}, 0\}$ and $S_{t+1} = S_t + \min\{IR_t \times B_{t-1}, A_t\}$;
- else if $B_{t-1} < RT_t$ then $A_t \leftarrow A_t + \min\{RQ_t, S_t\}$ and $S_{t+1} = \max\{S_t - RQ_t, 0\}$;
- else the MSR is inactive.

In the status quo (current design), the MSR parameters are set such as:

- $IT_t =$ 833 $MtCO_2$, constant over time;
- $RT_t =$ 400 $MtCO_2$, constant over time;
- $IR_t =$ 24% between 2019 and 2023 and 12% afterward;
- $RQ_t =$ 100 $MtCO_2$, constant over time.

The MSR endogenizes the auction schedule $\{A_t\}_t$, i.e. it rearranges annual auctions over time based on market outcomes. In principle, it leaves the cumulative supply as defined by the cap trajectory unchanged, i.e. it essentially operates an autonomous auction backloading.

From 2023 on, the add-on CM further adjusts the MSR stock as follows:

- $S_t \leftarrow S_t - \max\{S_t - RC_t, 0\}$,

where RC_t is the maximum number of permits (a cap) allowed in the MSR. In the status quo:

- $RC_t = A_{t-1}$.

That is, the CM shaves off the difference between the current MSR stock and realized auctions in the previous year from the MSR stock, and permanently cancels these “excess” permits. This implies that cumulative emissions allowed under the system are now endogenous – the extent to which they will be reduced has de facto become a market outcome.

[20] Because of a mismatch between the compliance and auction calendars (i.e. the official figure for the bank in year $t-1$ can only be used from September of year t on) MSR operations in year t are actually based on $\frac{2}{3}B_{t-2} + \frac{1}{3}B_{t-1}$.

Appendix B – Streams of annual MSR intakes (2019-2050)

Figure B – Annual MSR intakes with different intake rates

Note: Intake rate of 24% between 2019 and 2023, and alternatively of 12, 24, 36 or 48% afterward. (upper) Constant 400-833 $MtCO_2$ thresholds; (lower) linearly declining thresholds from 400-833 in 2023 to 0-0 $MtCO_2$ in 2058.

With constant thresholds, cumulative MSR intakes and therefore cumulative cancellations are similar (only marginally increasing with the intake rate). Flows, however, differ substantially with the intake rate. With a 12% intake rate, annual intakes are quite stable over time. As the intake rate increases, annual intakes become more erratic (mimicking a roller coaster) and the intake period is shorter – but overall, cumulative impacts are similar across intake rates.

In comparison, with declining thresholds, annual intake rates are more evenly distributed over time for all intake rates (except for a 48% rate between 2024-34). Although intake rates vary by a factor of 4, annual intakes only vary in size by a factor of 2 at most. This is because lower bank levels (see Figure 5, right panel) mitigate the absolute impacts of higher intake rates.

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