Preparing the 2021 EU ETS MSR Review and the Road to Greater EU Climate Ambition

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Coordinating the Next Wave of EU Climate Policies
PIK-MCC-Hertie-CEC-GRI | Berlin, 20 November 2019

This paper

- Evaluate options for 2021 review with focus on raising ambition
- Raising ambition is at the core of current policy debate
  - national level: implement demand-reducing or cancellation policies, price floor
  - EU level: reinforce companion or non-ETS sector policies, ETS review
  - Parry (2019, EER): ↑ EUA prices create larger welfare gains (Pareto improv)
- ETS review: changes in LRF & MSR (rate, thresholds, cancellation)
  - these elements interact + hinge on firms' behavior (horizon, responsiveness)
  - (model: other policies embedded in yearly revised EUA demand forecasts)
- Plug & play analysis based on: Emissions Trading with Rolling Horizons
  - competitive intertemporal ETS model under uncertainty with supply control
  - firms can utilize rolling horizon and have bounded responsiveness to control
  - RH reconciles 2008-17 bank dynamics w/ implicit discount rates (better on price)
  - perform detailed analysis of 2018 EU ETS reform

Modeling framework

- Usual intertemporal ETS model in discrete time $t = 1, 2, \ldots$ with ▸ more
  - stochastic future baseline emissions (Borenstein et al., 2019)
  - representative firm approach (Rubin, 1996; Cantillon & Slechten, 2018)
  - unlimited banking, limited borrowing (non-linearity à la Deaton & Laroque)
  - minimize expected NPV of costs & quasi Hotelling's rule $p_t - \beta \mathbb{E}_t\{p_{t+1}\} \geq 0$

- Supply-side control via MSR: supply schedule is endogenized

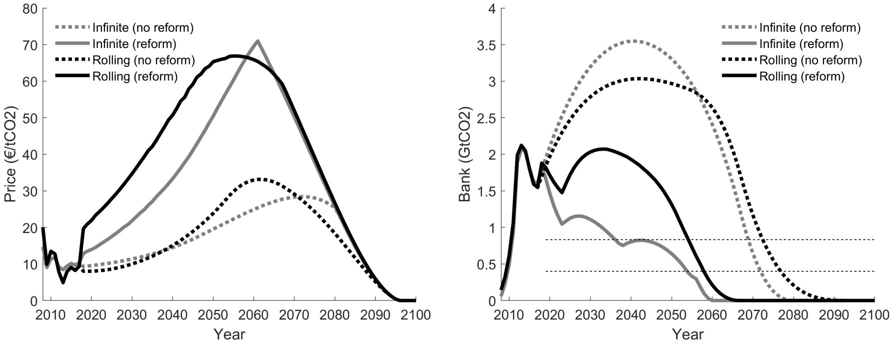
- Representative firm utilizes infinite or rolling horizon (Goldman, 1968)
  - RH: optimize over h years given realistic supply and demand forecasts + only implements date-t optimal outputs and moves to $t+1$ with updated forecasts

- Key quantity for firm: expected cumulative abatement effort over horizon $\rightarrow$ interplay between decisions in equilibrium and MSR actions over time
  - zero responsiveness: firm discovers MSR impacts each year w/o anticipation
  - full responsiveness: firm perfectly perceives and accounts for interplay $\rightarrow$ implement fixed-point approach in spirit of Lucas & Prescott (1971)

Calibration

- Rich variety of observed trading and compliance behaviors ▸ more
  - autarkic compliance via banking & borrowing, active non-compliance entities
  - difficult to elicit firms' degree of and horizon for intertemporal optimization
  - various risk and managerial preferences to handle compliance and trading
  - rolling horizons are a reality (std mgt process, fut maturities, reg uncertainty)
- Lack of conclusive evidence → Friedman's black box type of approach
  - infinite vs rolling horizons in how well they replicate 2008-17 outcomes
  - calibrate resultant of all firms' behaviors with usual representative firm model
- Two-step calibration in spirit of standard least squares MLE ▸ more
  - parametrize historical and forecasted supply and demand conditions ▸ more
  - infinite: $h = \infty^\star$ $r = 7.06\%$ vs rolling: $h = 12$y and $r = 3\%^\star$
  - RH reconciles bank dynamics with implicit discount rates (+better on price)
    - $r \approx 7\%$ in line with general returns on risky assets (Jordà et al., 2019)
    - $r \approx 3\%$ central value for rates implied from futures' yield curves

Infinite vs rolling horizons (in status quo)

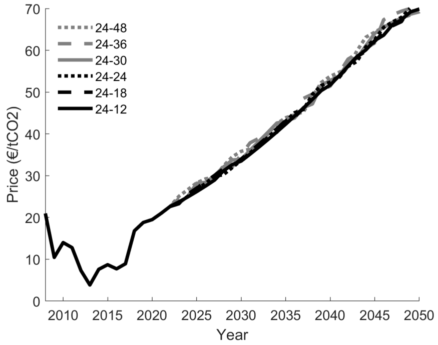


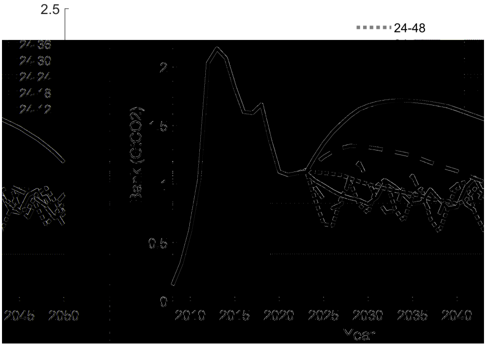
- Case with cancellation mechanism and full responsiveness of firms
  - reform impacts depend on firms' behavior (horizon and responsiveness)
  - 2018 price jump partly recovered by a rolling horizon
  - cumulative cancellations: 5 (infinite) vs 10 (rolling) $GtCO_2$
  - in WP: decompose impacts of (interaction between) LRF ↑, MSR, cancellation

Preparing and informing the 2021 review process

- From now on: assume firms use RH and exhibit full responsiveness
- Review elements include changes in
  - cap linear reduction factor (LRF)
  - MSR intake rate (and fixed re-injection quantity)
  - MSR thresholds' positions (height, width) and slopes
- Cancellation mechanism taken as granted though need be enshrined
  - small impacts with RH: re-injections are far off, mostly outside horizon
- Evaluate changes in isolation: combinations are likely but numerous
- Focus on MSR-induced resilience to future shocks (2nd reform objective)
- Assume that agreement on review takes time (as for 2015-18 reform)
  - regulatory changes are implemented in 2024 and maintained thereafter
  - voted/agreed upon in – and thus anticipated from – 2023

Changing the intake rate

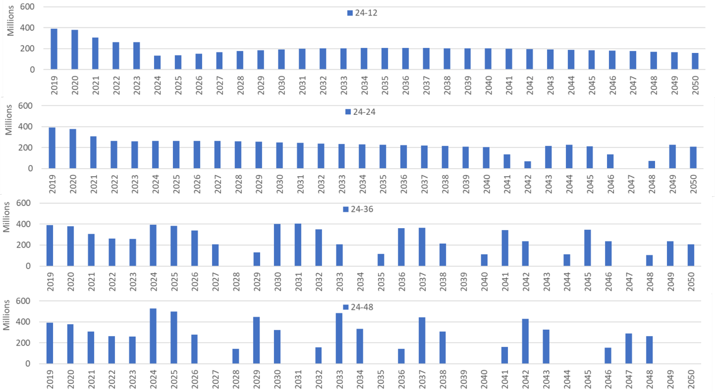




- A higher intake rate magnifies threshold effects of a trigger mechanism
  - does not bring stability to market: conditions harder to gauge for participants
  - interacts with banking motives: drag vs restoring force around upper threshold
  - prices slightly higher on average, but more volatile
  - slightly larger cumulative cancellations: 8.71 (12%) to 9.15 (48%) $GtCO_2$

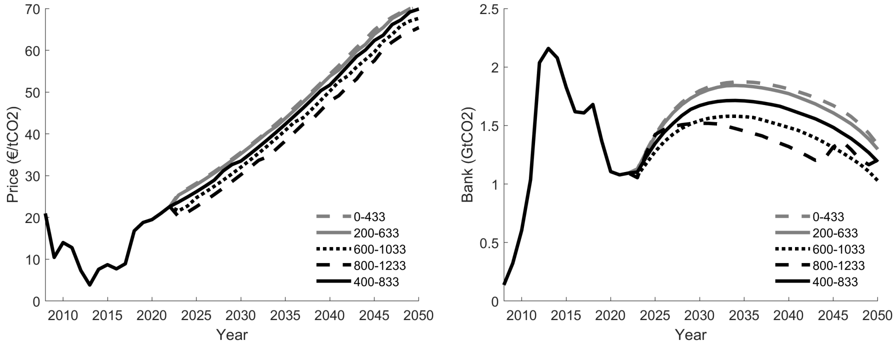
Changing the intake rate

Annual MSR intakes with different intake rates



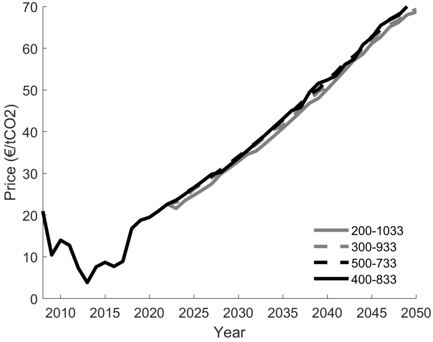
- Cumulative MSR intakes are similar but time profiles vary:
  - low rate: annual intakes quite stable over time
  - high rate: annual intakes more erratic (roller coaster) + shorter intake period

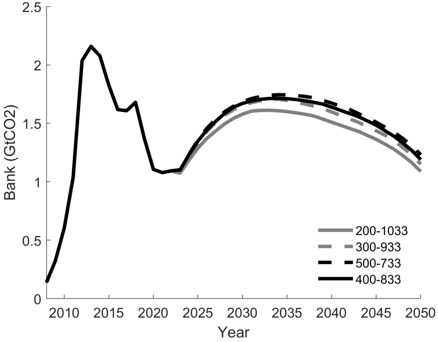
Changing the height of the thresholds



- Higher thresholds imply lower prices and smaller cumulative removals
  - height of upper threshold matters the most with cancellation mechanism
  - if one seeks to curtail TNAC, implement high thresholds!
  - prices ordered by decreasing upper threshold height (range of 5-10€/tCO_2)
  - cumulative cancellations can vary more: 6.86 (1233) to 9.26 (433) GtCO_2

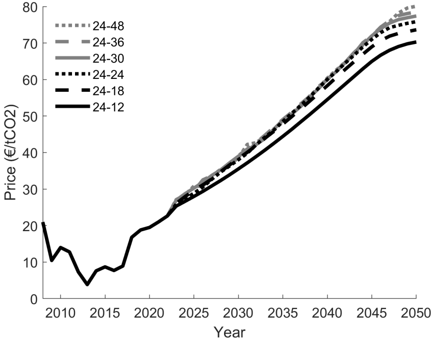
Changing the width between the thresholds

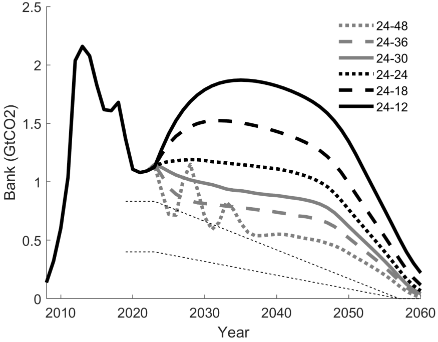




- SIMILAR STORY: position of upper threshold matters the most
  - similar ordering of price and banking paths (less visible)
  - cumulative cancellations vary less: 8.04 (1033) to 8.85 (733) $GtCO_2$

Declining thresholds





- Declining thresholds stabilize impacts of higher intake rates
  - accompany the natural (bell-shaped) trajectory of the bank
  - TNAC never falls within the desired range but is 'stabilized'
  - relative to constant thresholds (and fixed re-injection quantity):
    - prices are higher and less volatile for all intake rates
    - cumulative cancellations are larger: 9.27 (12%) to 11.1 (48%) $GtCO_2$

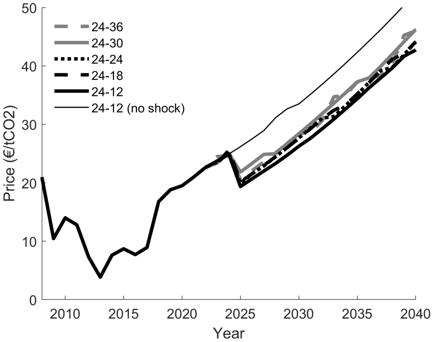
Declining thresholds

Annual MSR intakes with different intake rates and declining thresholds

- Annual MSR intakes quite stable over time (except for 48% at first)
  - similar in size across intake rates: higher rate compensated by lower bank

MSR-induced resilience to future ‘imbalances’?

Unanticipated permanent negative demand shock (-150MtCO_2 from 2025)



- Shock not entirely cushioned + price not ‘put back on track’
  - price response and shock absorption not monotonic in the intake rate
    - price drop maximal with 12% (5.6€) minimal with 30% (3.2€)
    - crucially hinges on TNAC the year before the shock occurs (relevant indicator?)
  - modest cumulative absorption: 10-17% of cumulative shock
  - see WP for small one-off shocks preserving intake cut-off dates results

How to raise (ETS) ambition?

- General remark: How to express targets?
  - annual targets are tricky/misleading given intertemporal trading
    e.g. reaching 0 emission in 2050 requires that the cap be zero before 2050
  - even more so true now that the MSR is in place
- Two ways of raising ambition within ETS perimeter
  - higher *Linear* Reduction Factor
  - reinforced MSR (augmented intake rate and thresholds)
- Not equivalent when firms utilize rolling horizons (inter alia)
  - transitional stringency as important as cumulative stringency if not more
  - MSR frontloads abatement effort: more effort perceived early on w.r.t. LRF_{eq}
  - WP: 2018 reform LRF_{eq}=2.95 but not least-cost (+2.2% w.r.t. MSR) results
- LRF-MSR interaction: complements or substitutes?
  - ambiguous: higher LRF induces shorter banking (and thus MSR intake) period

Interaction between LRF and MSR design

Intake rate	LRF	Emissions (Mt) 2030	2040	2050	Intakes end	Removals (Gt)
No MSR	2.20	1,281	848	419	–	0
	4.15	882*	405	148	–	0
12%	2.20	1,109	674	285	2055	8.71
	2.96	882*	401	145	2048	8.51
	2.20[d]	1084	644	282	2057	9.27
	2.94[d]	882*	409	149	2048	8.60
24%	2.20	1,106	666	279	2051	8.89
	2.89	882*	390	120	2044	9.51
	2.20[d]	1054	587	232	2057	11.0
	2.63[d]	882*	399	142	2051	11.3
36%	2.20	1,098	676	280	2050	8.97
	2.83	882*	419	129	2045	9.77
	2.20[d]	1040	588	208	2057	11.6
	2.62[d]	882*	382	118	2052	11.8

Thanks for listening

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Link to LSE WP: Emissions Trading with Rolling Horizons

Emissions Trading with Rolling Horizons

Model

- Competitive intertemporal ETS under uncertainty with supply control
- Firms can use rolling horizon and have bounded responsiveness to control

Calibration

- Parametrization to EU ETS: Supply, demand and market design
- Aim: Match observed annual price and banking levels over 2008-17
- RH reconciles observed bank with implicit discount rates (+better on price)

Simulations (EU ETS Reform)

- 2018 price jump consistent with RH and MSR (irresp. of cancel)
- MSR reduces cumulative cap (even w/o cancel) up to 10GtCO_2 under RH
- Cancellations reduce efficiency loss due to MSR (improvement under RH)
- MSR punctures less of the 'waterbed over time' under RH (but for longer)

Model Structure

- Intertemporal permit market: compliance required at times $t = 1, 2, \ldots$
  - with unlimited banking and limited borrowing (up to next year's free alloc)
- Competitive trading and firms' production decisions are ignored
  - decentralized market equilibrium $\equiv$ joint cost minimization (Rubin, 1996)
- Stochasticity: future baseline emissions are uncertain
  - business cycles, reach of companion policies (e.g. Borenstein et al., 2019)
- Arbitrage $\rightarrow p_t - \beta \mathbb{E}_t\{p_{t+1}\} \geq 0$ in equilibrium (quasi Hotelling's rule)
  - minimization of expected NPV of abatement costs
  - limited borrowing $\rightarrow$ non-linearity, no closed-form sol. (Deaton & Laroque)
- Representative firm has infinite or rolling horizon (RH) alternatively
  - RH to deal with uncertainty (use of realistic forecasts) Literature EU ETS evidence
  - Spiro (2014), van Veldhuisen & Sonnemans (2018) with exhaustible resource

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Solution Paths

- Infinite horizon (IH): given b_{t-1}, firm minimizes expected NPV of costs

$$\min_{\{e_\tau\}_{\tau \geq t}} \mathbb{E}_t \Big\{ \sum_{\tau \geq t} \beta^{\tau - t} C_\tau(\tilde{u}_\tau - e_\tau) \Big\}$$

subject to $0 \leq e_\tau \leq \tilde{u}_\tau$ and $b_\tau = b_{\tau-1} + \tilde{f}_\tau + \tilde{a}_\tau + \tilde{o}_\tau - e_\tau \geq -\tilde{f}_{\tau+1}$

- Rolling horizon (RH): optimizes over h years given forecasts $\hat{x}^t_{\tau \geq t}$ and only implements date-t optimal outputs and then moves to $t+1$

$$\min_{\{e_\tau\}_{\tau=t}^{t+h}} \sum_{\tau=t}^{t+h} \beta^{\tau-t} C_\tau(\hat{u}^t_\tau - e_\tau)$$

subject to $0 \leq e_\tau \leq \hat{u}^t_\tau, \; b_\tau = b_{\tau-1} + \hat{f}^t_\tau + \hat{a}^t_\tau + \hat{o}^t_\tau - e_\tau \geq -\hat{f}_{\tau+1},$

$$\text{and} \quad \sum_{\tau=t}^{t+h} \left[\hat{u}^t_\tau - e_\tau\right] = \sum_{\tau=t}^{t+h} \left[\hat{u}^t_\tau - (\hat{f}^t_\tau + \hat{a}^t_\tau + \hat{o}^t_\tau)\right] - b_{t-1}$$

- To ensure comparability between IH and RH as h grows: graphs
  - solve IH expected equilibrium path in the first order (Schennach, 2000)
  - certainty-equivalent x-paths coincide with forecasts: $\hat{x}^t_\tau = \mathbb{E}_t\{\tilde{x}_\tau\}$ back

Interplay between MSR & Competitive Equilibrium

- Key quantity for firm: expected cumulative abatement effort over horizon

- Interplay between decisions in equilibrium and MSR actions over time
  - zero responsiveness: firm discovers MSR impacts each year w/o anticipation
  - full responsiveness: firm perfectly perceives and accounts for interplay

- Indirect approach is viable without supply control (Samuelson, 1971)
  - MSR only affects market clearing, not intertemporal efficiency (Salant, 1983)

- Fixed-point approach for firm to derive interplay and adjust decisions
  - Equilibrium $\equiv$ fixed point of a mapping between firm's beliefs about MSR impact profile and optimal beliefs (in spirit of Lucas & Prescott (1971))
  - Recursive procedure as firm controls for its truncated horizon (Goldman, 1968) $\rightarrow$ corrected solution path $\equiv$ sequence of first-year optimal outputs

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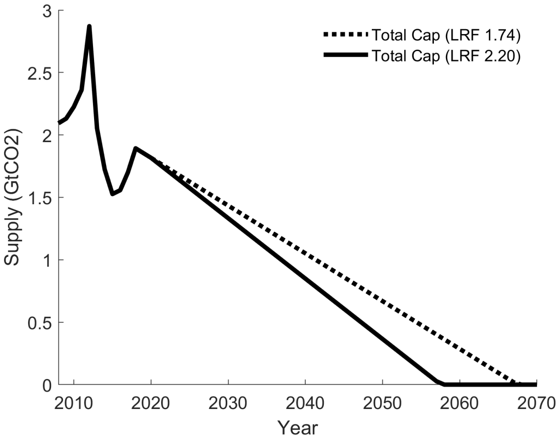
Cap Trajectory (Supply)



- cap slope: – 38.3 or 48.4 $MtCO_2$ p.a. under an LRF of 1.74 or 2.20%

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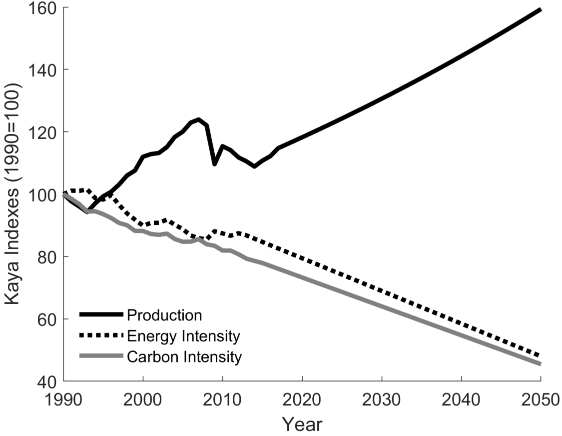
Baseline CO_2 Emissions (Demand)



$$CO_2 \ emissions = Production \times \frac{Energy}{Production} \times \frac{CO_2 \ emissions}{Energy}$$

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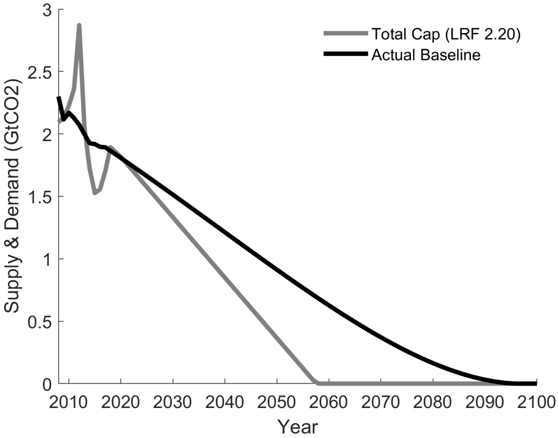
Supply & Demand



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Future Demand Forecasts

- Future baseline forecast $\equiv$ deterministic part of AR(1) process ▸ graph

$$\hat{u}^t_{t+1} = \varphi(1+\gamma_t)u_t + (1-\varphi)\bar{u}^t_{t+1}$$

- persistence: $\varphi = 0.9$ (Fell, 2016)
- expected future GDP growth rate γ_t (past: EC forecasts; future: 2%/y)
- trend $\bar{u}$ declining over time, in line with companion policies

Forecast period	Climate Energy Package	$\bar{u}_{2050}/e_{2008}$	$\bar{u}_t = 0$ in
2008-2013	CEP#1	57.5%	2115
2013-2017	CEP#2	50.7%	2105
2018-2100	Reinforced CEP#2	39.7%	2096

◂ back

Ex-Post Calibration (2008-17)

- Assume $C_t'' = c > 0$ (recall: linear MACC intercept declining over time)
- Two-step calibration in spirit of std. least squares MLE: graphs
  - calibrate r given h or h given r to replicate observed bank
  - calibrate c given r and h to replicate observed yearly-averaged spot price

Horizon type	Horizon & discount rate	Marginal abatement cost
Infinite	$h = \infty^\star$ $r = 7.06\%$ (std.dev $= 52.9$ $MtCO_2$)	$c = 5.53 \cdot 10^{-8}$ €$/(tCO_2)^2$ (std.dev $= 4.04$ €$/tCO_2$)
Rolling	$h = 13$ $r = 3\%^\star$ (std.dev $= 64.9$ $MtCO_2$)	$c = 5.72 \cdot 10^{-8}$ €$/(tCO_2)^2$ (std.dev $= 2.12$ €$/tCO_2$)

- RH reconciles observed bank with implied discount rates (+better on price)
  - $r \approx 7\%$ in line with general returns on risky assets (Jordà et al., 2019)
  - $r \approx 3\%$ central value for rates implied from futures' yield curves data

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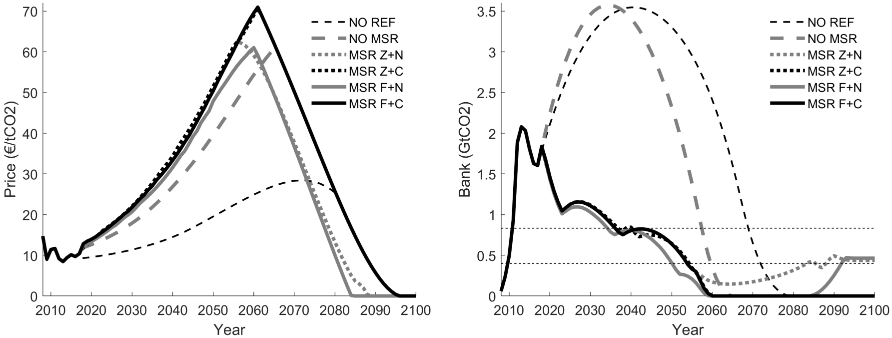
Appraising the EU ETS Reform

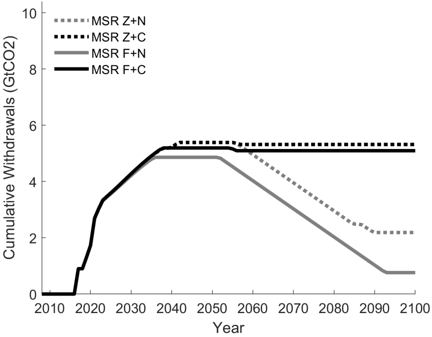
- Evaluate reform impacts on price/bank paths & cumulative emissions
  - up to 2100 (market terminates before, all permits used well before)
- Reform impacts with infinite vs. rolling horizons
  - No reform/status quo: LRF of 1.74% (NO REF)
  - Without MSR: sole increase in LRF from 1.74 to 2.20% (NO MSR)
  - With MSR but without cancellations:
    - with full (MSR F+N) or zero responsiveness (MSR Z+N)
  - With MSR and with cancellations:
    - with full (MSR F+C) or zero responsiveness (MSR Z+C)
- Focus on cumulative emissions and cost efficiency
- Focus on cumulative emissions and exogenous abatement

Reform Impacts with Infinite Horizon



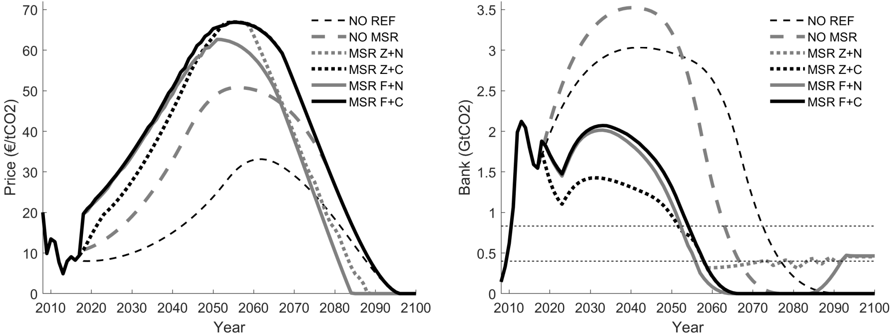
- Reform hikes prices and reduces banking
  - Small impacts from responsiveness and cancellations
  - MSR intakes stop just before 2040 (followed by ∼15 years of inactivity)

Reform Impacts with Infinite Horizon



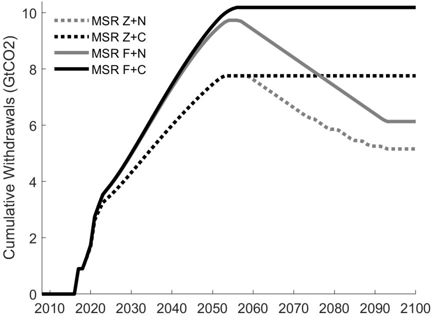
- Reform endogenizes and reduces cumulative emissions
  - With cancellations: cumulative emissions reduced by 5 $GtCO_2$
  - Without cancellations: MSR doesn't have time to empty before market ends

Reform Impacts with Rolling Horizon



- Reform **further** hikes prices and reduces banking **less sharply**
  - Responsiveness has greater impacts than cancellations
  - MSR intakes stop just after 2050 + price jump in 2018

Reform Impacts with Rolling Horizon



- Reform endogenizes and **further** reduces cumulative emissions
  - Cumulative emissions reduced by 6 (w/o cancel) to 10 $GtCO_2$ (w/ cancel)
  - Larger MSR intakes due to responsiveness coupled with RH

Focus on Cumulative Emissions & Cost Efficiency

- Reform → cumulative emissions cap becomes a market outcome
  - LRF_{eq}: yields same cumulative emissions w/o MSR as w/ MSR (ref: 2.20%)
  - Efficiency loss: additional total compliance costs under MSR w.r.t. LRF_{eq}?
  - (Interaction: are LRF increase and MSR independent reform features?)

Horizon	Respons.	Cancel.	LRF_{eq}	Efficiency loss	Interaction
Infinite	Zero	Off	2.28%	9.0%	16.4%
		On	2.48%	0.2%	4.6%
	Full	Off	2.18%	11.5%	11.1%
		On	2.46%	0.2%	3.1%
Rolling	Zero	Off	2.50%	9.0%	11.7%
		On	2.70%	0.6%	0.6%
	Full	Off	2.59%	7.9%	1.7%
		On	2.95%	-2.2%	-5.2%

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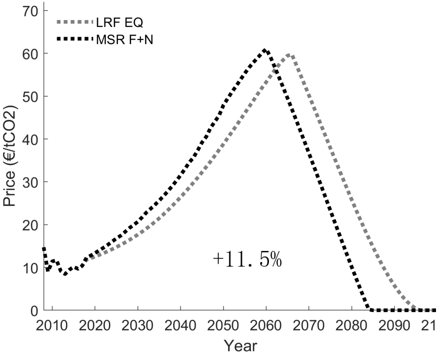
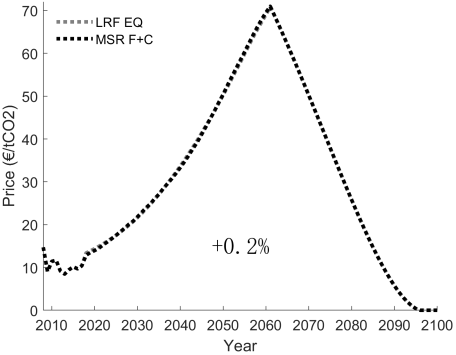
Focus on Cumulative Emissions & Cost Efficiency

- Reform → cumulative emissions cap becomes a market outcome
  - $\mathrm{LRF}_{\mathrm{eq}}$: yields same cumulative emissions without MSR as with MSR
  - Equilibrium price paths under MSR w.r.t. $\mathrm{LRF}_{\mathrm{eq}}$?





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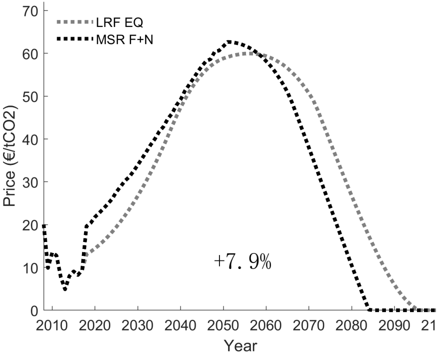
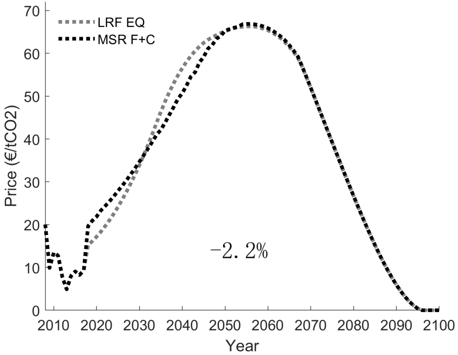
Focus on Cumulative Emissions & Cost Efficiency

- Reform → cumulative emissions cap becomes a market outcome
  - LRF_{eq}: yields same cumulative emissions without MSR as with MSR
  - Equilibrium price paths under MSR w.r.t. LRF_{eq}?





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Focus on Cumulative Emissions and Exogenous Abatement

- Reform → non-price driven emission reductions can be made permanent
  - i.e. partial puncture of a 'waterbed effect over time'
  - long-term impacts on cumulative emissions of one-shot marginal shifts in baseline emissions (small enough to avoid changes in cut-off intake date)

			Year of shift				
Horizon	Respons.	Cancel.	2020	2025	2030	2035	2040
Infinite	Zero	Off/On	53%	42%	33%	19%	6%
	Full	Off	49%	38%	24%	0%	0%
		On	54%	43%	32%	12%	0%
Rolling	Zero	Off/On	14%	14%	15%	17%	20%
	Full	Off	22%	24%	25%	27%	28%
		On	23%	24%	26%	27%	28%

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Focus on Cumulative Emissions & Exogenous Abatement

$$\overbrace{-X_t}^{\text{baseline shift}} \longrightarrow \overbrace{Y_t \cdot X_t}^{\text{bank increment}} \longrightarrow \overbrace{W_{cumul} \cdot Y_t \cdot X_t}^{\text{cumulative withdrawals}},$$

		Year of shift				
Horizon	Share	2020	2025	2030	2035	2040
Infinite	Y_t	60%	57%	54%	53%	52%
	W_{cumul}	90%	76%	59%	23%	0%
Rolling	Y_t	24%	28%	31%	34%	40%
	W_{cumul}	92%	87%	85%	80%	70%

Note: Case with the cancellation mechanism and full responsiveness.

- $Y_t^{RH} < Y_t^{IH}$: less room to spread X_t and higher bank to start with
- $W_{cumul}^{RH} > W_{cumul}^{IH}$: more time to absorb bank increment

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Planning with Rolling Horizons (Literature 1)

- The more distant future is more uncertain in terms of
  - possible outcomes, their probabilities and how to incorporate them in planning
- Rolling horizons to deal with increasing uncertainty, informational constraints/requirements and cognitive limitations
  - Agents resort to heuristics or rules of thumb (e.g. Gigerenzer & Selten, 2003)
- Concept of RH first formalized by Goldman (1968), extended to
  - stochasticity and stationarity (Easley & Spulber, 1981)
  - capital accumulation (Kaganovitch, 1985)
  - strategic interactions (Jehiel, 1995)
  - nonlinear model predictive control (Grüne et al., 2015)
- RH = crude but simple way of modeling behavior in face of ambiguity
  - ambiguity aversion with maxmin decision rule (Gilboa & Schmeidler, 1989)
  - spasity-based bounded rationality (Gabaix, 2014)
  - rational inattentivess (Reis, 2006; Sims, 2006)

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Planning with Rolling Horizons (Literature 2)

- RH used in production planning and supply chain (Sahin et al., 2013)
  - permits are one factor of production (Zhang & Xu, 2013)
- RH help rationalize quantitative puzzles
  - saving behaviors (Caliendo & Aadland, 2007)
  - social security choices (Findley & Caliendo, 2009)
  - long-run price dynamics of exhaustible resources not conforming to Hotelling's rule (Spiro, 2014; van Veldhuizen & Sonnemans, 2018)
- Rich experimental literature on dynamic decision problems:
  - deviations from rational expectations (Carbone & Hey, 2001)
  - behavioral expectations & adaptive heuristic switching (Hommes et al., 2019)
  - limitations on how far ahead people can plan (Hey & Knoll, 2007)
  - traders myopic (Smith et al., 1988) or use past trends (Haruvy et al., 2007)

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Planning with Rolling Horizons (EU ETS)

- Intra-firm constraints restrict reach of intertemporal considerations
  - standard in-house risk management procedures apply
    $\rightarrow$ power firms partially hedge future prod. up to 3 years (Eurelectric, 2009)
    $\rightarrow$ beyond hedging target, banking only at much higher rate (Schopp et al. 2015)
  - stockpiling limited by willingness to tie up capital (Dardati & Riutort, 2016)
  - banking justifiable when carbon trading is not one's core activity?
  - hoarding permits can trigger concerns about cornering and manipulation

- Futures markets provide proxies for foresight and discount rates
  - maturities up to 10 years ahead & liquidity quickly $\downarrow$ with time-to-maturity
  - discount rates implied from futures' yield curves are 'low' data

- Regulatory uncertainty: firms may excessively focus on the short term
  - regulation is changing and only set for a dozen years ahead timeline
  - credibility of the regulator to intervene to 'fix the market' (ETS, RIP?)
  - vagueness of the regulatory language example:cancellations

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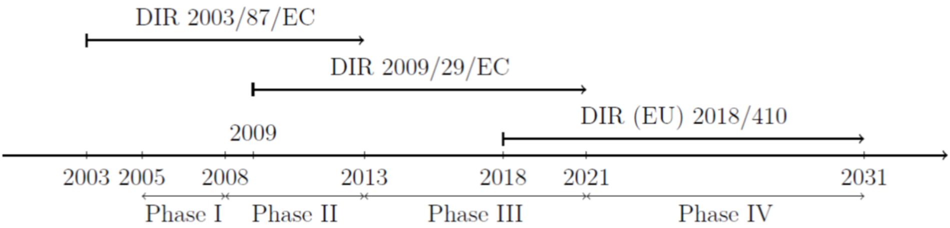
EU ETS Regulatory Timeline



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Market Stability Reserve (Soft Banking Collar)

- From 2019 on: automatically adjusts a_t based on past banking
  - if $b_{t-2} > 833$ million: $0.24 \cdot b_{t-2}$ withheld from auctions (0.12 after 2023)
  - if $b_{t-2} < 400$ million: 200 million added to auctions (100 after 2023)
  - stock of permits in MSR satisfies complementary dynamics (+initial seed)
- In principle: cumulative cap preserved ($\sim$auction schedule reshuffling)
  - provided that the MSR has time to release all set-aside permits
- From 2023 on: add-on cancellation mechanism breaks neutrality for sure
  - any permits in reserve in excess of previous year's auctions are cancelled
  - endogenizes the cumulative cap: depends on past & future market outcomes
  - regulatory vagueness: validity, should vs. shall vs. will, pending 2021 review

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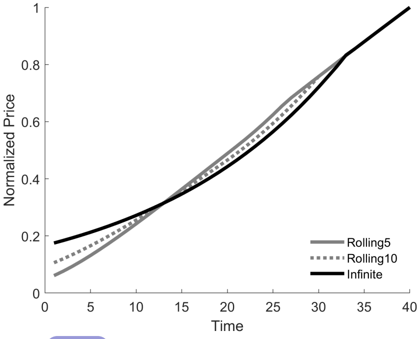
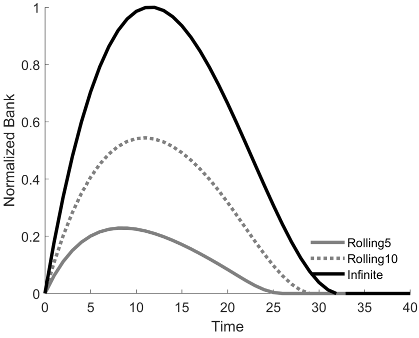
Infinite vs. Rolling Horizons

- Under perfect foresight, no supply control and yearly binding caps
  - Qualitatively: shorter horizon $\sim$ larger discount rate





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Infinite vs. Rolling Horizons

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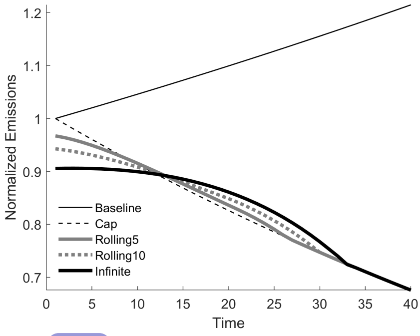

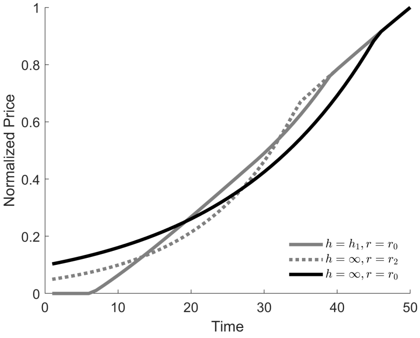

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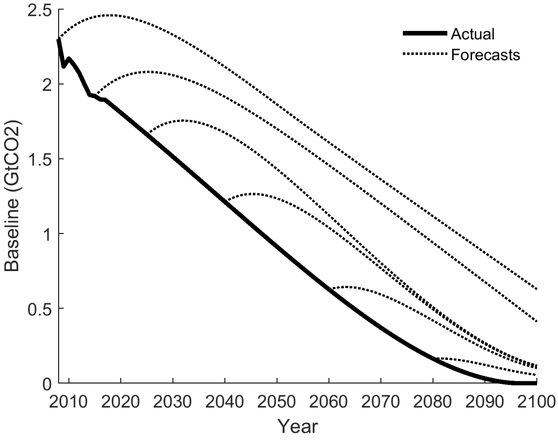
Actual Baseline vs. Forecasts



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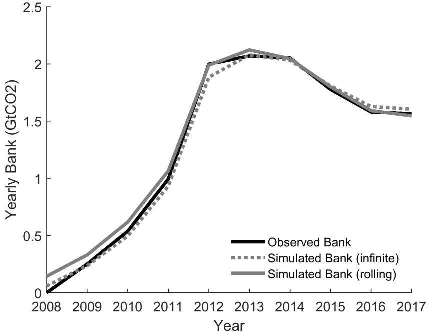
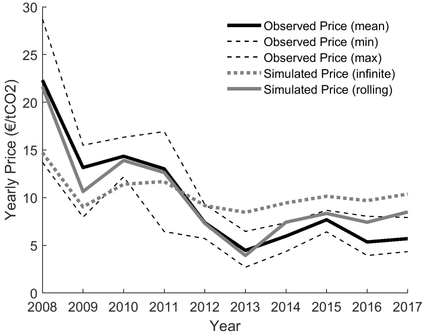
Calibration Results





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Implied Discount Rates (2008-17)

Daily yield curve	Mean	Median	Std.Dev	Min	Max
Fut. Dec Y+1 / Spot	2.4%	2.5%	1.5%	0.2%	7.0%
Fut. Dec Y+1 / Fut. Dec Y	2.9%	2.6%	1.8%	0.3%	8.7%
Fut. Dec Y+2 / Fut. Dec Y+1	3.6%	3.7%	2.0%	0.2%	8.7%
Fut. Dec Y+3 / Fut. Dec Y+2	4.1%	2.5%	2.0%	0.6%	9.2%

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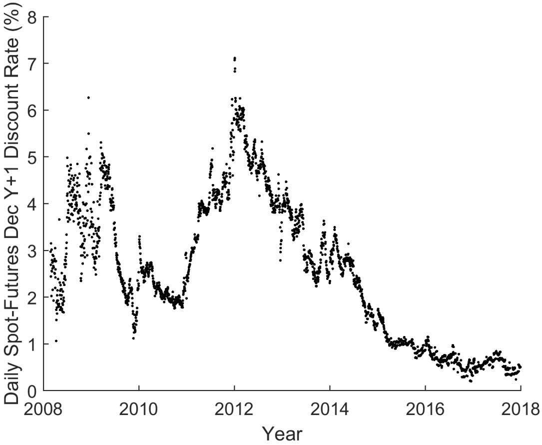
Yield Curve: Fut. Dec Y+1 / Daily Spot (2008-17)



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