The Reformed EU ETS:

Intertemporal Emission Trading with Restricted Banking

16th IAEE European Conference, Ljubljana, 27th August 2019

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Energy Economics, 2019 forthcoming

Co-researched by **J. Bocklet, M. Hintermayer, L. Schmidt** and **T. Wildgrube**

The EU ETS is a prominent example of a cap and trade system to internalize the external costs of greenhouse gas(GHG) emissions

Factsheet:

- Participating countries: EU28 + EEA (Norway, Iceland and Liechtenstein)
- Includes electricity sector, energy-intensive industry and inner-European aviation accounting for 45% of GHG emissions
- Target of at least 40% GHG reduction in 2030 compared to 1990

Economic classification:

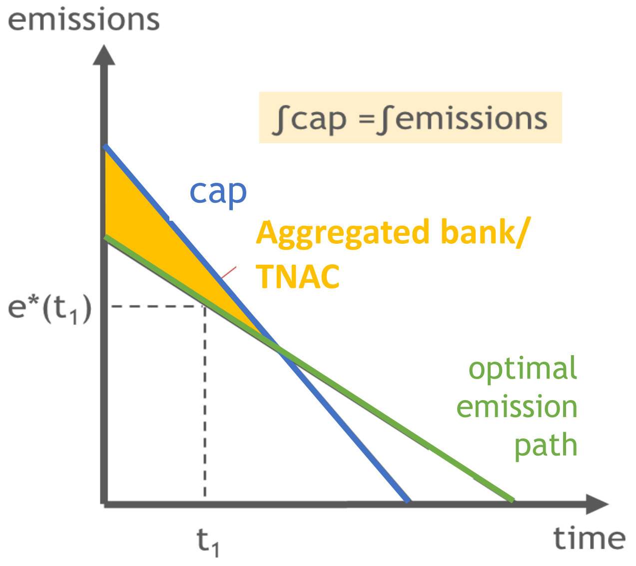
- Cap and trade system efficiently coordinates abatement among polluters
- Initial issuance of allowances through free allocation and weekly auctions
- Intertemporal optimization of firms through banking of allowances

Latest reform:

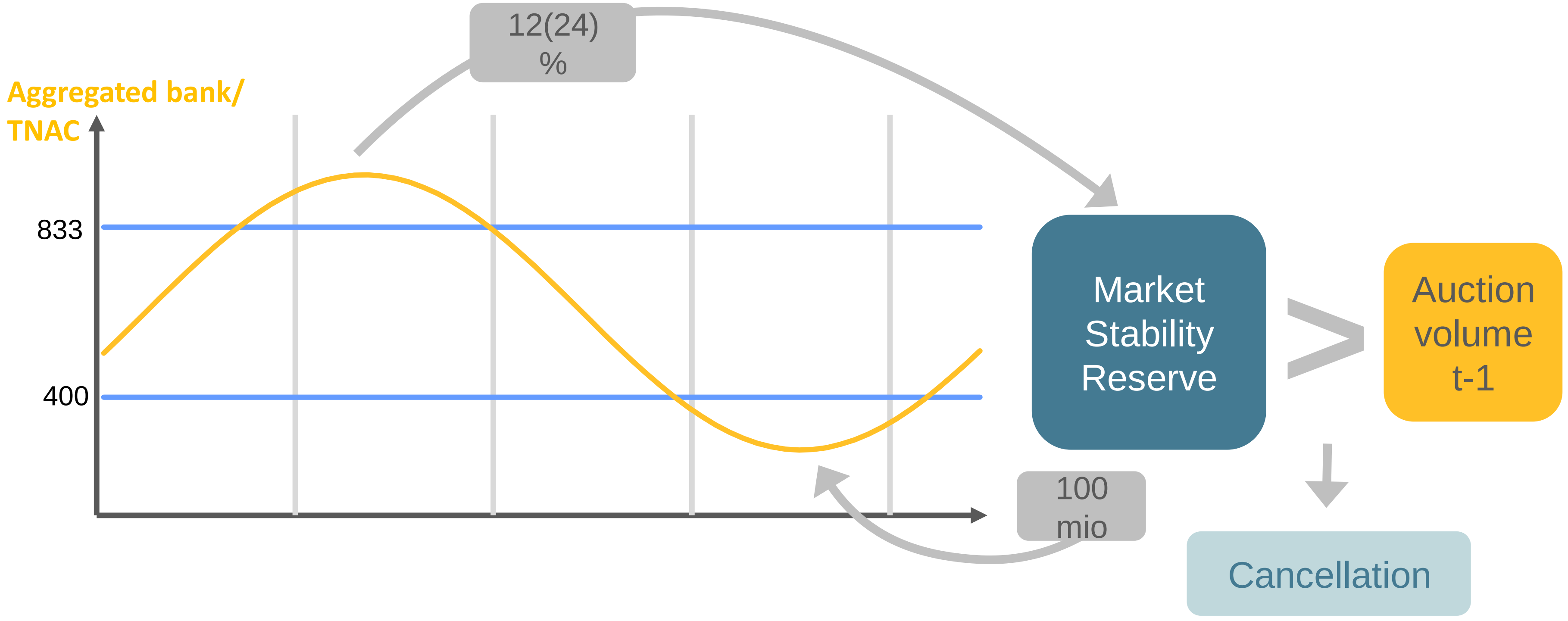
- Linear reduction factor (LRF): overall emission cap is reduced
- Market stability reserve (MSR): Delay of allowance supply
- Cancellation mechanism (CM): Restriction of the size of the MSR

The framework for intertemporal trading changed

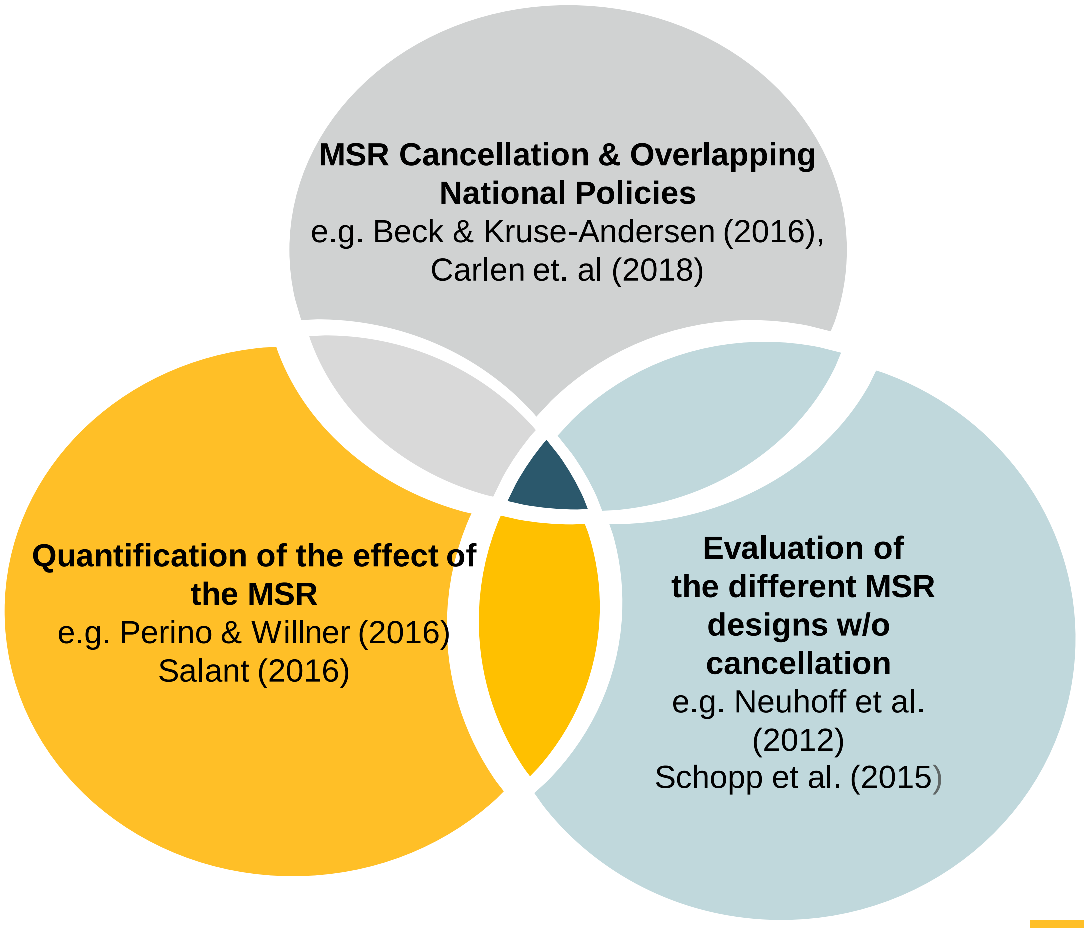
Unrestricted banking



Banking is restricted – the supply becomes partly endogenuous



Our research combines Hotelling model with the reformed EU ETS



Theoretical foundation for intertemporal trading
Hotelling (1931)
Rubin (1995)
Chevallier (2012)

Continuous time Hotelling model

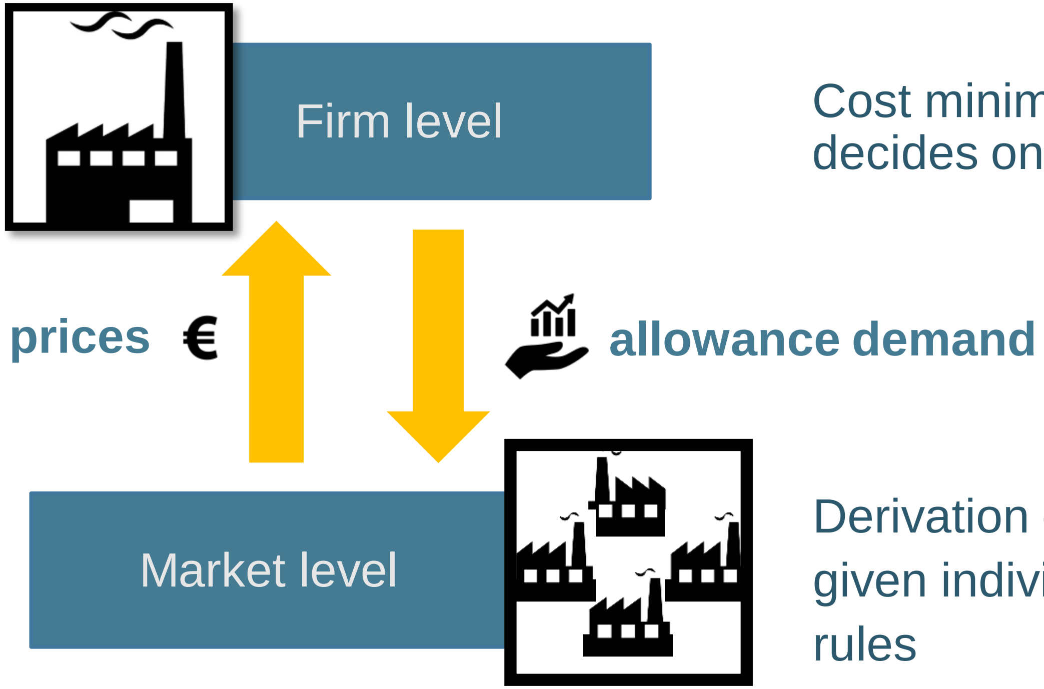
Dynamic cost effectiveness

Discrete time, qualitative analysis and iterative models

Research question

- What are the economic effects of the increase of the LRF and the introduction of the MSR and the cancellation mechanism?
- How do those amendments impact the dynamic cost effectiveness of the market?

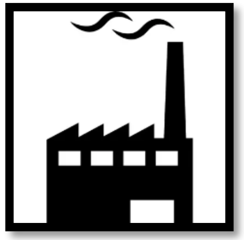
A market equilibrium is derived where firms minimize their costs given the new market rules



Cost minimizing, price-taking firm with perfect foresight decides on emissions, abatement and banking

Derivation of market equilibrium conditions and price path given individual optimality conditions, supply and regulatory rules

Price-taking firms minimize costs under perfect foresight



Abatement costs — **Costs/Revenues from allowance trading**

$$\min \quad \sum_{t=0}^{T} \frac{1}{(1+r)^t}\Big[\underbrace{\frac{c}{2}(u-e(t))^2}_{\text{Abatement costs}} + \underbrace{p(t)x(t)}_{\text{Costs/Revenues from allowance trading}}\Big]$$

$$s.t.\; b(t) - b(t-1) = x(t) - e(t) \quad \text{for all} \quad t = 1, 2, \ldots, T$$

$$b(t) \geq 0$$

$$x(t),\, e(t) \gtrless 0.$$

Decision variables of the firm

- $e(t)$ emissions
- $x(t)$ net acquired allowances
- $b(t)$ banked allowances

Exogenuous parameters to the firm

- $p(t)$ allowance market price
- r interest
- u baseline emissions
- c cost parameter

Price-taking firms with perfect foresight minimize costs for abatement and allowance trading by decision on emissions, abatement and banking.

We assume N homogeneous firms and derive equilibrium conditions from the individual KKT conditions.

Market prices develop according to the Hotelling rule as long as firms bank allowances

Input

- Interest rate
- Baseline emissions
- Abatement costs

Market equilibrium

→ Firms choose emissions such that **Carbon price equals Marginal Abatement Costs**:
p(t) = c(u-e(t))

→ Price follows **Hotelling rule**:
- Price increases with interest rate as long as firms bank allowances (TNAC>0)
- As borrowing is not allowed, price increase is reduced after TNAC is empty

Regulatory Framework

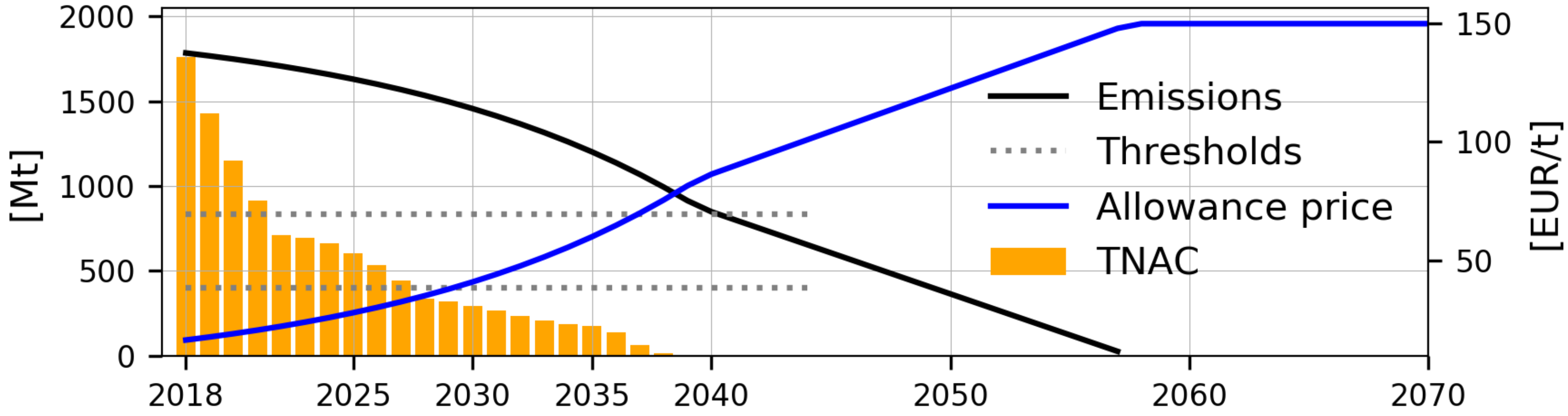
→ First model with closed-form solution for endogenous MSR reaction and cancellation

→ Binary decision variables are used to restate MSR and CM conditions in a MILP

Output

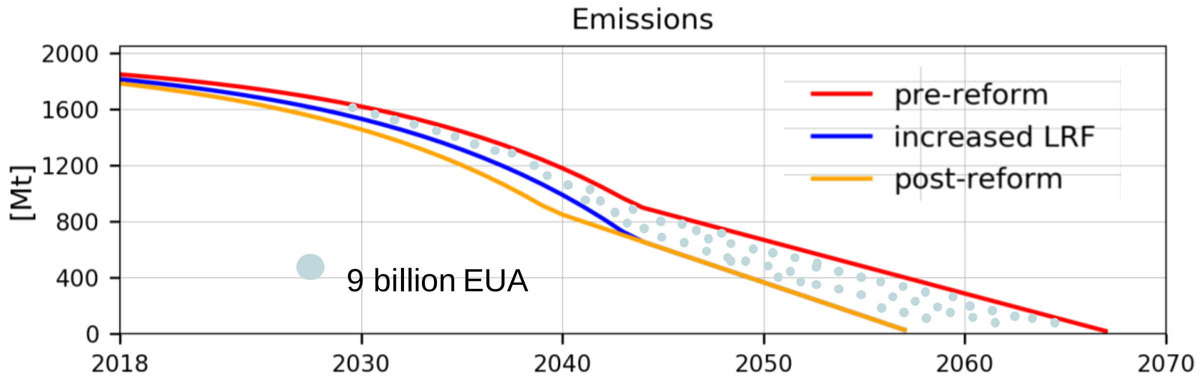
- Prices
- Emissions
- TNAC
- MSR
- Cancellation

The price develops with the interest rate until 2038 (Hotelling rule)



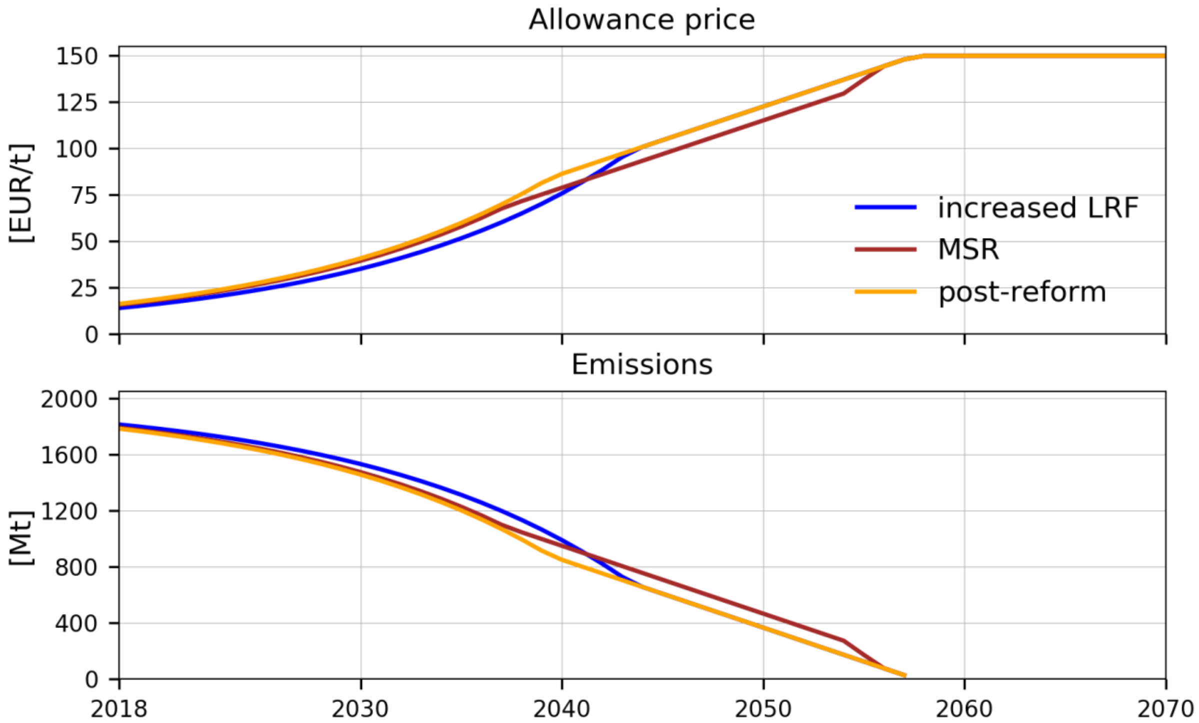
The reform impacts prices and emissions mostly in the long run

- The increase in the LRF reduces the overall emission cap substantially (9 billion EUA)
- The last allowance will be issued in 2057 and hence 10 years earlier

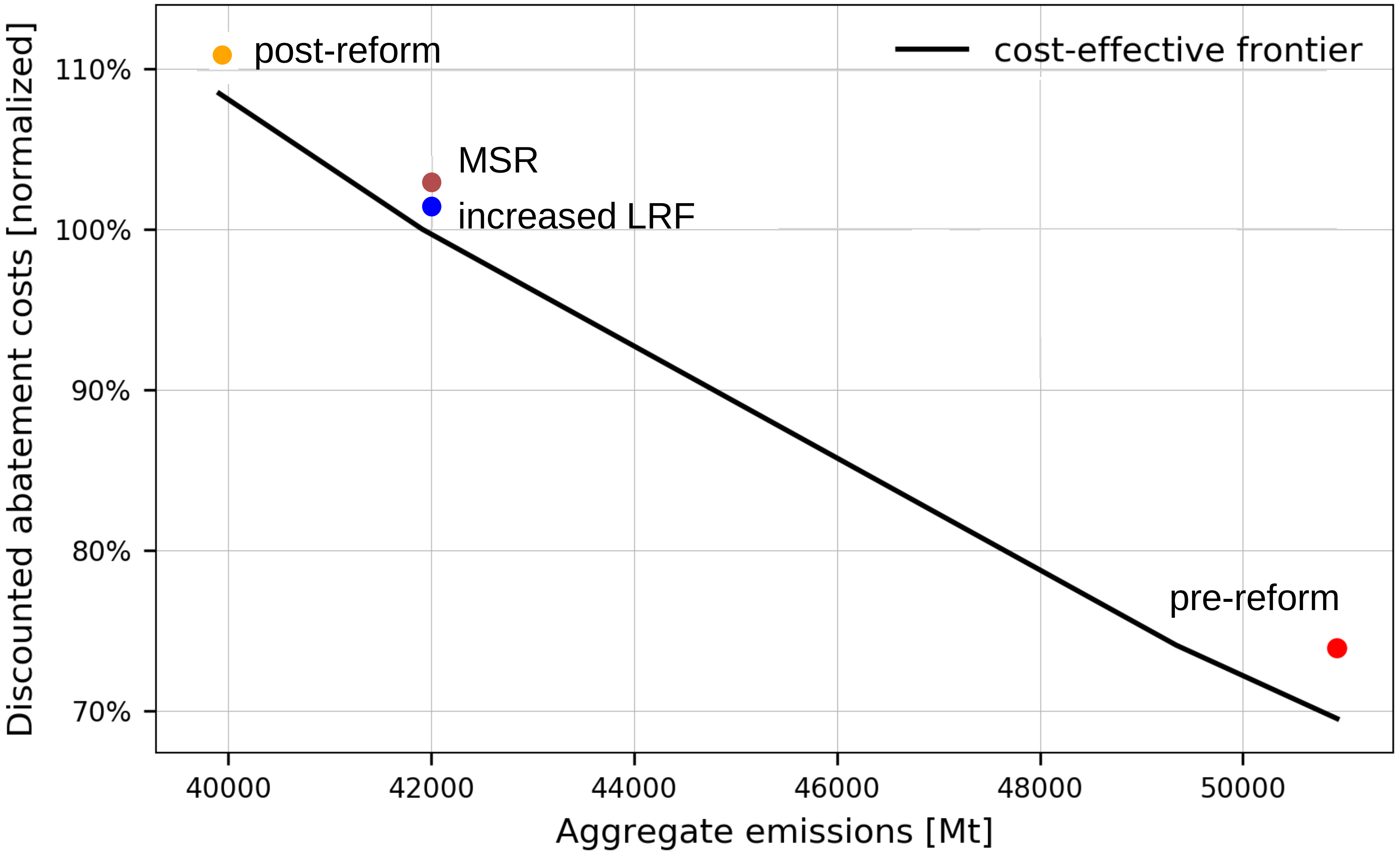


- The MSR is allowance preserving but shifts allowances from the present to the future

- The CM reduces 2 billion EUA



The amendments decrease emissions substantially, the MSR deteriorates dynamic cost effectiveness



Contributions of the paper

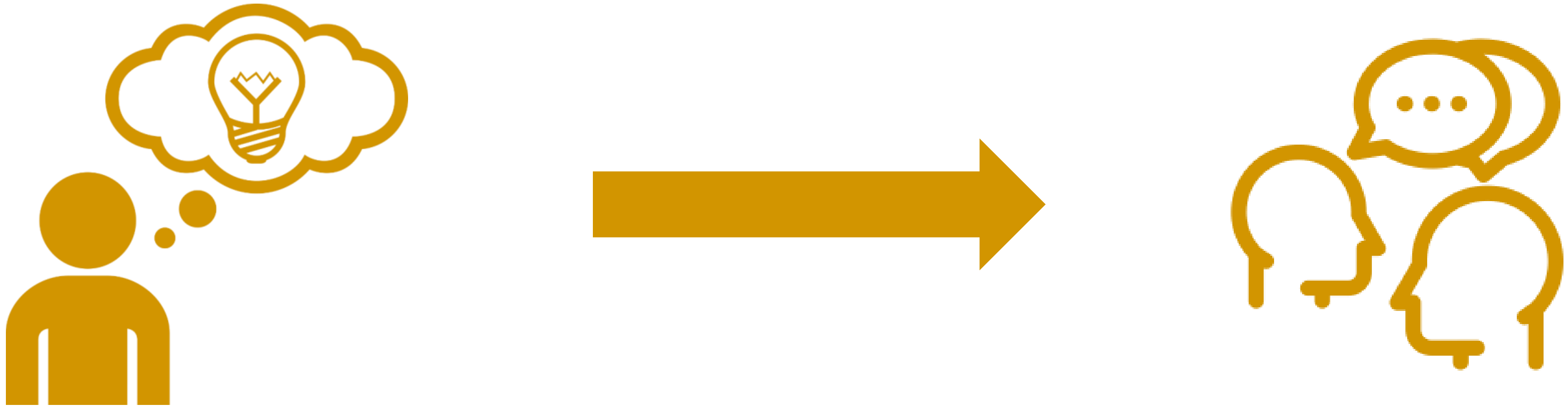
- Accurate depiction of latest EU ETS regulation within a discrete time model with endogenous cap
- Modelling and quantification of the impact of LRF, MSR and CM
- Decomposition of the price effects of the latest EU ETS amendments as well as their impact on dynamic cost effectiveness

What we further look at

Ongoing work

- **Temporary allowance demand shocks (e.g. economic crisis)**
- **Permanent allowance demand change (e.g. renewable policy)**
- **Carbon price floor**

- **hedging requirements** of large energy companies
- **myopic market participants in contrast to perfect foresight**
- **uncertainty in the market**



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Thank you for your attention!

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Back-up

Individual KKT conditions

stationarity conditions:

$$\frac{\partial \mathcal{L}}{\partial x(t)} = \frac{1}{(1+r)^t} p(t) - \lambda(t) = 0 \quad \forall t = 1, 2, \ldots, T$$

$$\frac{\partial \mathcal{L}}{\partial e(t)} = (-1)\frac{1}{(1+r)^t} c(u - e(t)) + \lambda(t) = 0 \quad \forall t = 1, 2, \ldots, T$$

p=MAC

$$\frac{\partial \mathcal{L}}{\partial b(t)} = \lambda(t) - \lambda(t+1) - \mu_b(t) = 0 \quad \forall t = 1, 2, \ldots, T$$

~ p(t)=(1+r) p(t-1)

primal feasibility

Banking flow constraint

$$b(t) - b(t-1) - x(t) + e(t) = 0 \quad \forall t = 1, 2, \ldots, T$$

$$x(t),\ e(t) \gtrless 0 \quad \forall t = 1, 2, \ldots, T$$

dual feasibility and complementarity

Shadow costs

$$0 \le b(t) \perp \mu_b(t) \ge 0 \quad \forall t = 1, 2, \ldots, T$$

$$\lambda(t) \gtrless 0 \quad \forall t = 1, 2, \ldots, T$$

$p(t)$ allowance market price
$e(t)$ emissions
$x(t)$ net acquired allowances
$b(t)$ banked allowances

$\lambda(t)$ dual variables of flow constraint
$\mu_e(t)$ complementary variable of emissions
$\mu_b(t)$ complementary variable of banking

r interest
u baseline emissions
c cost parameter

The supply is partly endogenously determined given the new regulatory market rules

$$TNAC(t) = \sum_{i=1}^{N} b_i(t)$$

$$S_{auct}(t) = 0.57\, S(t) - Intake(t) + Reinjection(t)$$

$$MSR(t) = MSR(t-1) + Intake(t) - Reinjection(t) - Cancel(t)$$

Defining regulatory quantities

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

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

MSR rules

$$Cancel(t) = \begin{cases} MSR(t) - S_{auct}(t-1) & \text{if } MSR(t) \geq S_{auct}(t-1), \\ 0 & \text{otherwise.} \end{cases}$$

Cancellation Mechanism

Model parametrization

Regulatory parameters fed to the model:

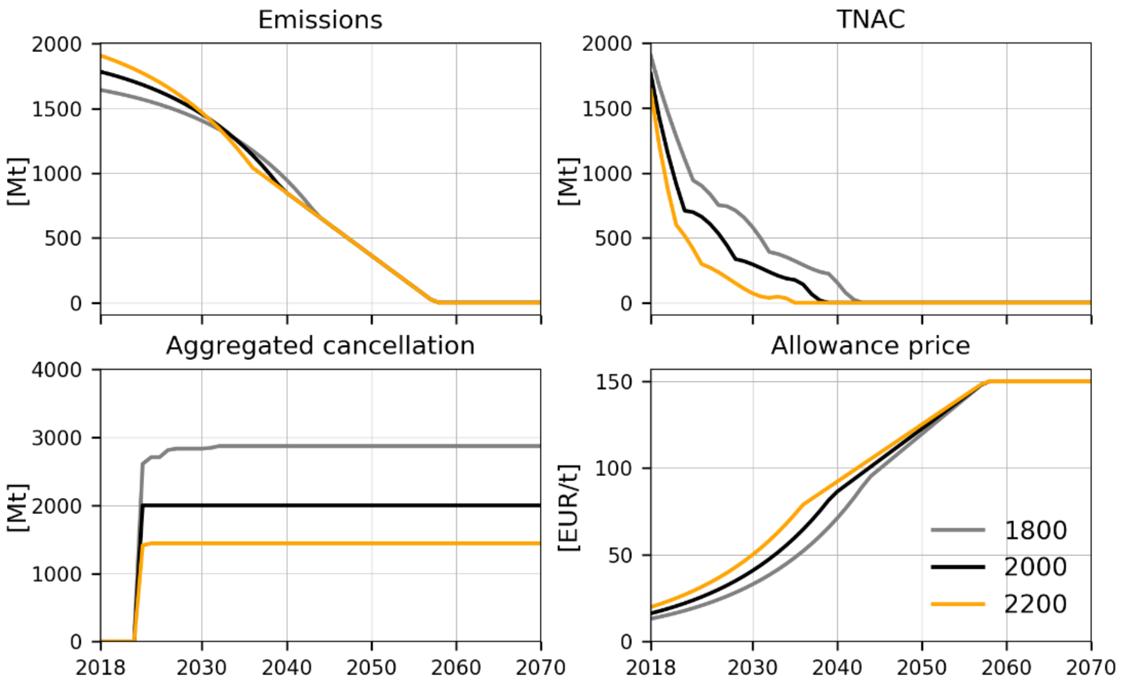
- **MSR** in 2019 initially endowed with 900m allowances (backloaded allowances) and in 2020 with another 600m allowances (unallocated allowances)
- Starting Value **TNAC** 2017: 1645m allowances
- **Issued allowances** in 2010: 2199m allowances which are linearly reduced every year with a linear reduction factor of 2.2% (1.74% before 2020).
- Share of auctioned allowances constant at 57%.

Exogenous parameters in the reference scenario:

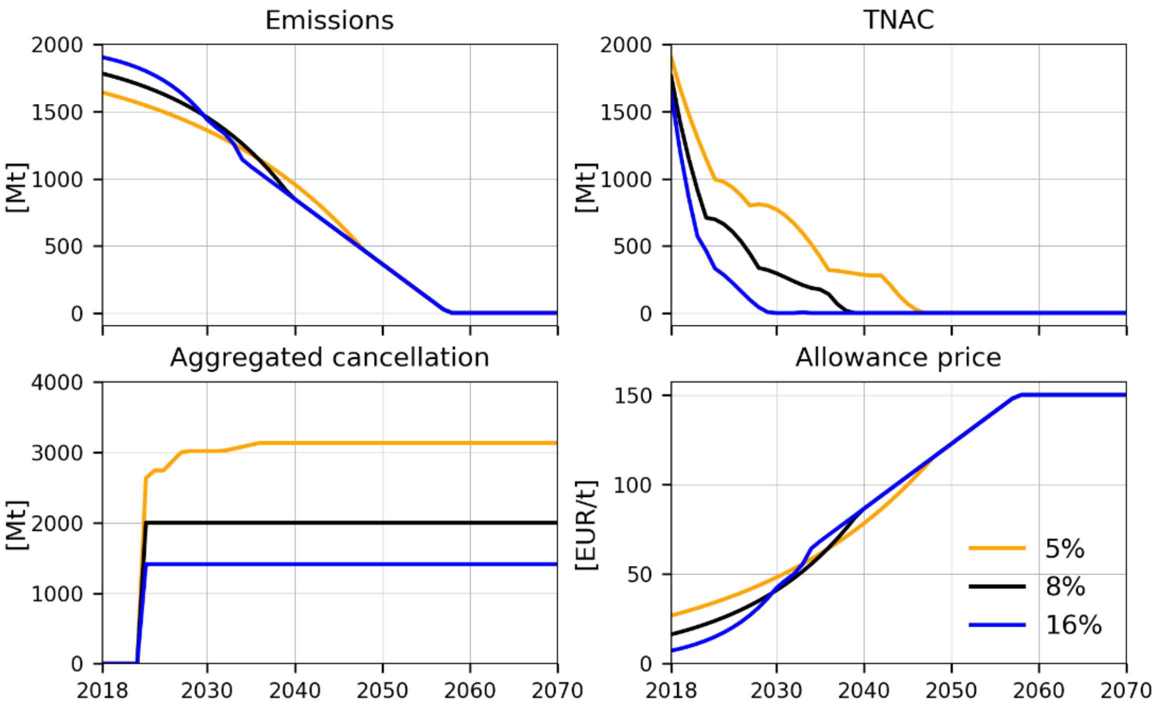
- **Interest rate**: 8% (approx. WACC for energy intense industries)
- **Counterfactual emissions:** assumed to be constant at 2000 Mt CO_2 eqv. [Neuhaus et al. 15]: 2200, [Perino/Willner 16]: 1900
- **Backstop technology**: CCS as assumed as backstop technology at 150 Euro/t CO_2 eqv. The backstop technology is used to calculate the cost parameter c. → **Backstop costs only scale prices up and down**

Parameter assumptions change numerical assumptions but not the modus operandi of the model

Counterfactual emissions



Interest rate



The amendments decrease emissions substantially but the dynamic cost effectiveness could be improved

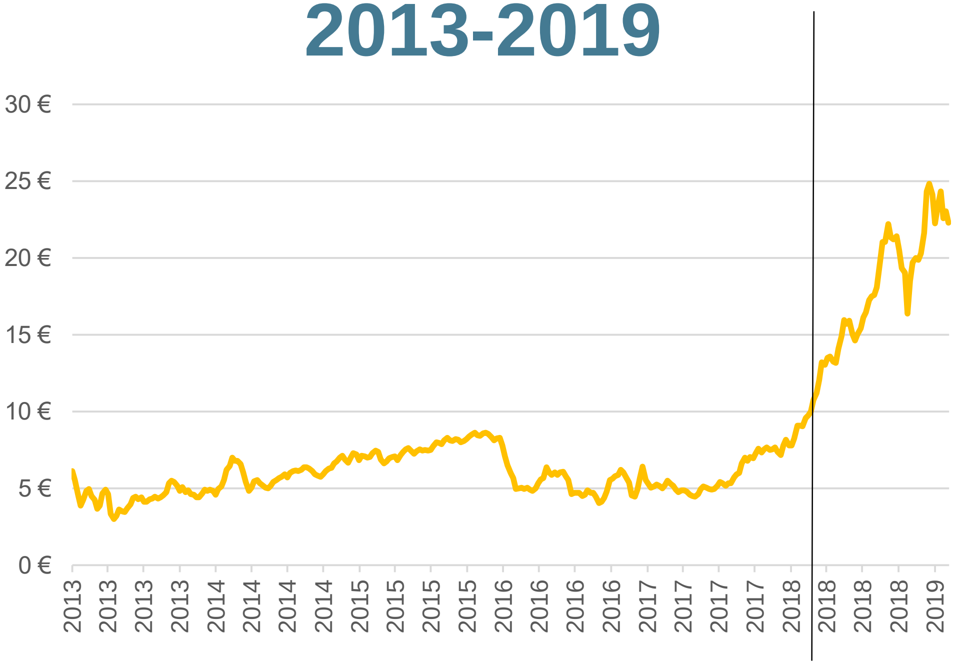
- MSR adds a restriction on banking and thus decreases dynamic efficiency (antagonistic to firms time preferences)
- CM slightly increases dynamic efficiency since fewer allowances are available in later periods (shadow costs of non-borrowing constraints are low)

Late cancellation as an alternative design choice:

- Allowances are cut from the long end leaving the MSR untouched and thus more available allowances before 2050
- design allows firm to harmonize their abatement path with their time preferences

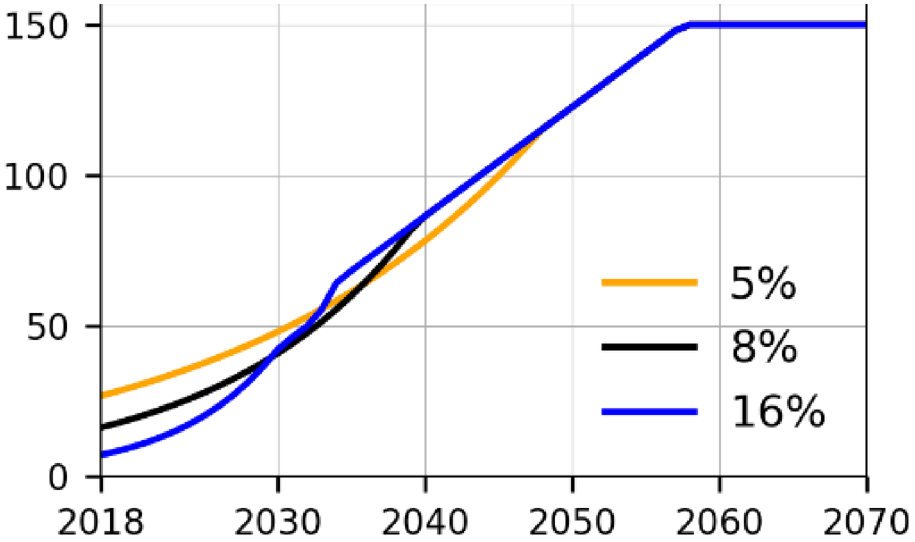
Our model does not depict the sudden price increase in the EU ETS

Real EUA prices 2013-2019



Latest reforms

Modelled EUA prices 2018-2070



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