THE INTERPLAY BETWEEN LOW CARBON INNOVATION AND CARBON MARKETS DYNAMICS

CoE & CEC event, Brugge, 18 november 2019
"Carbon pricing: the silver bullet for energy transition?"

Marc Baudry

University Paris Nanterre – EconomiX-CNRS

&

Climate Economics Chair

Motivations for a dynamic approach of the EU-ETS

- An Emission Trading System (ETS) is a quantity oriented policy mechanism that incentives firms to internalise in their economic decisions the pollution that their activity generates

- A global cap is imposed on polluting firms, but flexibility is introduced to satisfy the cap at the least cost
  - Emission allowances are allocated to firms
  - Firms can either abate their emission level and/or trade allowances on the ETS
  - Trading reallocates the abatement effort from firms with high marginal abatement cost to those with low marginal abatement cost

- For a stock pollutant, two cases have to be distinguished
  - 1) Pollution damages are a continuous function of the cumulated emissions
    - Example: Water pollution due to the use of chemicals in agriculture
  - 2) Only the stock of pollution at some time horizon matters (pollution threshold effect)
    - Example: the 2° scenario for GHG

Motivations for a dynamic approach of ETS

- In case 1, the marginal benefits and marginal damages of cumulated emissions have to be equalised at each period
  - => Flexibility is limited to intra-period trading and space (market linkage)
  - => There is no time flexibility, a specific value of the cap characterises each date
- In case 2, the marginal benefit of emissions at each period has to be equalised with the marginal damage of the stock at the time horizon
  - => inter-temporal flexibility can be introduced
  - But generally limited to banking/storageof allowances
    - Help firms smooth their abatement effort when facing a stochastic activity level
  - Borrowing makes an ETS inefficient in the presence of risk and information asymmetries
    - Firms facing a higher risk of bankruptcy have a stronger incentive to borrow
    - => commitment to comply is not credible

Motivations for a dynamic approach of ETS

- The EU-ETS is illustrative of case 2
  - https://ec.europa.eu/clima/sites/clima/files/docs/ets_handbook_en.pdf
- Characterised by different "phases"

  - Within phase banking is allowed
  - Between phase banking is also allowed
    - Except from phase 1 (experimental) to phase 2
- In 2008, the objective was to reduce GHG emissions covered by the EU-ETS by 21% in 2020 compared to 1990
- In 2014, the objective has been revised to a 40% reduction in 2030 compared to 1990

Motivations for a dynamic approach of ETS

- Such an objective requires to go beyond abatement of emissions
  - Abatement results from the reduction of the quantity of polluting inputs or outputs without modifying the technology used
    - The pricing of carbon emissions induces an increase in the private marginal cost of production and leads to a realignment of production decisions with collective interest
    - Abatement may be viewed as a **short term and reversible** response by firms
  - The price signal provided by the EU-ETS is also expected to impulse technological change
    - Adoption of a low carbon technology induces a **long term irreversible** decrease of the baseline of emissions
    - Irreversibility comes from the sunk cost nature of the investment made
    - The switch from fossil fuels to renewables in the power industry is illustrative of a technological change that lowers GHG emissions
      - Apart peak load management
      - Does not presume that the development of renewables in Europe is imputable to the EU-ETS!

Motivations for a dynamic approach of ETS

- There is a complex interplay between technological change and the price signal of an ETS
  - 1) The price signal is supposed to drive the adoption of low carbon technologies
    - But an ETS is a quantity oriented policy instrument => the price signal is not the instrument but an outcome and is therefore subject to uncertain adjustments
    - Uncertainty + irreversibility : an optimal strategy for firms is to postpone irreversible investments (real option theory => there is a “irreversibility premium”)
      - The “irreversibility premium” implies a potential misalignment of firms interest on collective interest
    - **=> does it justify increasing the share of auctioned allowances (instead of free allocation) and recycling the revenue from auction in the form of subsidies to low carbon technologies adoption?**
  - 2) The adoption of low carbon technologies intrinsically reduces the baseline of emissions and thus the net demand for allowances on the ETS
    - => technological change may make the price fall!
    - has be accounted for when setting the cap (more stringent cap reduction)
  - **The ongoing research presented thereafter aims at tackling this complex interplay and guiding public policy**

Dynamic equilibrium modelling

- **Basic setting**
  - Market dynamics is inherited from the stochasticity of baseline emissions
    - Individual baseline emissions are assumed to follow a random walk
      - The key idea is to capture shocks affecting the economic activity
      - The growth rate of baselines can go upwards or downwards between 2 successive dates with exogenous time invariant probabilities
      - This is a basic setting for valuation of financial assets
        - **Binomial tree model by Cox, Ross and Rubinstein**
      - It is also used for real asset valuation, more specifically in real options
        - In real options, the question addressed is typically "*invest now or postpone the investment project*"
          - Postponement allows to benefit from additional information and avoids making irreversible unprofitable choice, but at the cost of delaying gains if the project is profitable

Dynamic equilibrium modelling

- **Basic setting**
  - Scarcity of allowances implies that are treated as an asset
    - They can be used immediately or banked
      - Selling an allowance in t generates a gain of p_t at date t and $p_t\ (1+r)$ at date $t+1$ if firms are risk neutral, where r is the risk free interest rate
      - Banking an allowance from t to $t+1$ generates an expected gain $E_t[p_{t+1}]$ at date $t+1$
      - **Hotelling's rule applies**:
        - Market equilibrium requires that

$$E_t[p_{t+1}]=p_t\ (1+r)$$

        - Expectation is conditional on information available at date t => observed shocks on current baseline emissions induce a revision of expectations

Dynamic equilibrium modelling

- **Basic setting**
  - Firms are assumed to minimize their expected intertemporal cost of compliance
    - At each date they have **two decision variables**
      - By how much they abate their emissions
      - Do they sell (reduce their banking) or buy (increase their banking) allowances
    - They are facing **two kinds of constraints**
      - A) The ETS ends at the time horizon T
        - Banked allowance will be worth zero after T => the optimal banking at the end of T is zero
      - B) At each intermediate compliance date they have to exhibit a non negative banking
  - Firms are heterogeneous in terms of
    - Marginal cost of abatement (assumed to be linear)
    - Magnitude of shocks affecting their baseline emissions

Dynamic equilibrium modelling

- **Basic setting**
  - In the absence of constraint of type B, a recursive solving method yields the analytical expression of the equilibrium price at each period

Expected sum of current and future baseline emissions

Allowances auctionned by the regulator at date t

Sum of allowances freely granted to firms at date t

Current total banking of allowances

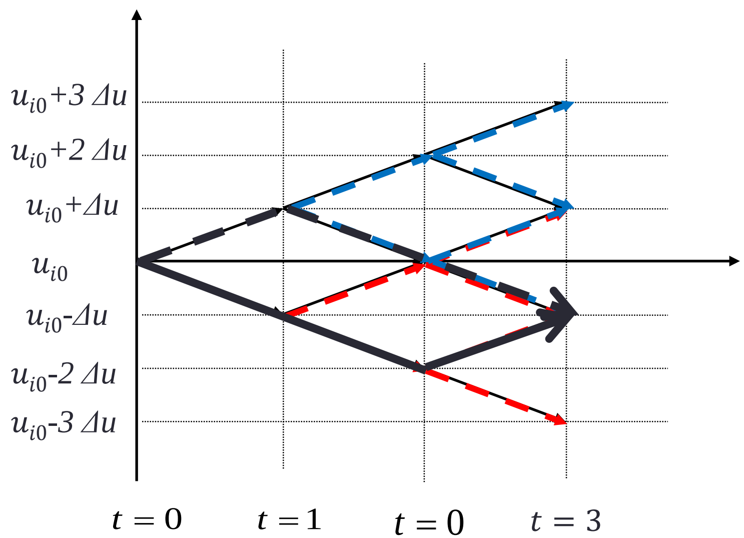
$$p_t = \frac{\sum_{s=t}^{T} \sum_i E_t[u_{i\,s}] - \sum_{s=t}^{T} \left(Q_t + \sum_i E_t[q_{i\,s}]\right) - \sum_i b_{i\,t}}{\left(\sum_i \frac{1}{c_i}\right)\left(\sum_{s=0}^{T} (1+r)^s\right)}$$

Slope of the inverse aggregate marginal abatement cost curve (sum of slopes of individual inverse MAC)

Total discounting factor (results from Hotelling's rule)

Dynamic equilibrium modelling

- **Basic setting**
  - This price is forward looking
    - It depends of expected future cumulated baselines which themselves depends on the current state of baselines (for instance from $\boldsymbol{u_{i0}+\Delta u}$ or $\boldsymbol{u_{i0}-\Delta u}$ at date $t+1$)
  - And path dependent
    - Abatement do not exactly compensate the upward or downward shocks on baselines so that banking at each node of the binomial tree depends on the past (for instance banking with u_{i0}-Δu at date $t=3$ with path ⟶ or path - - →)

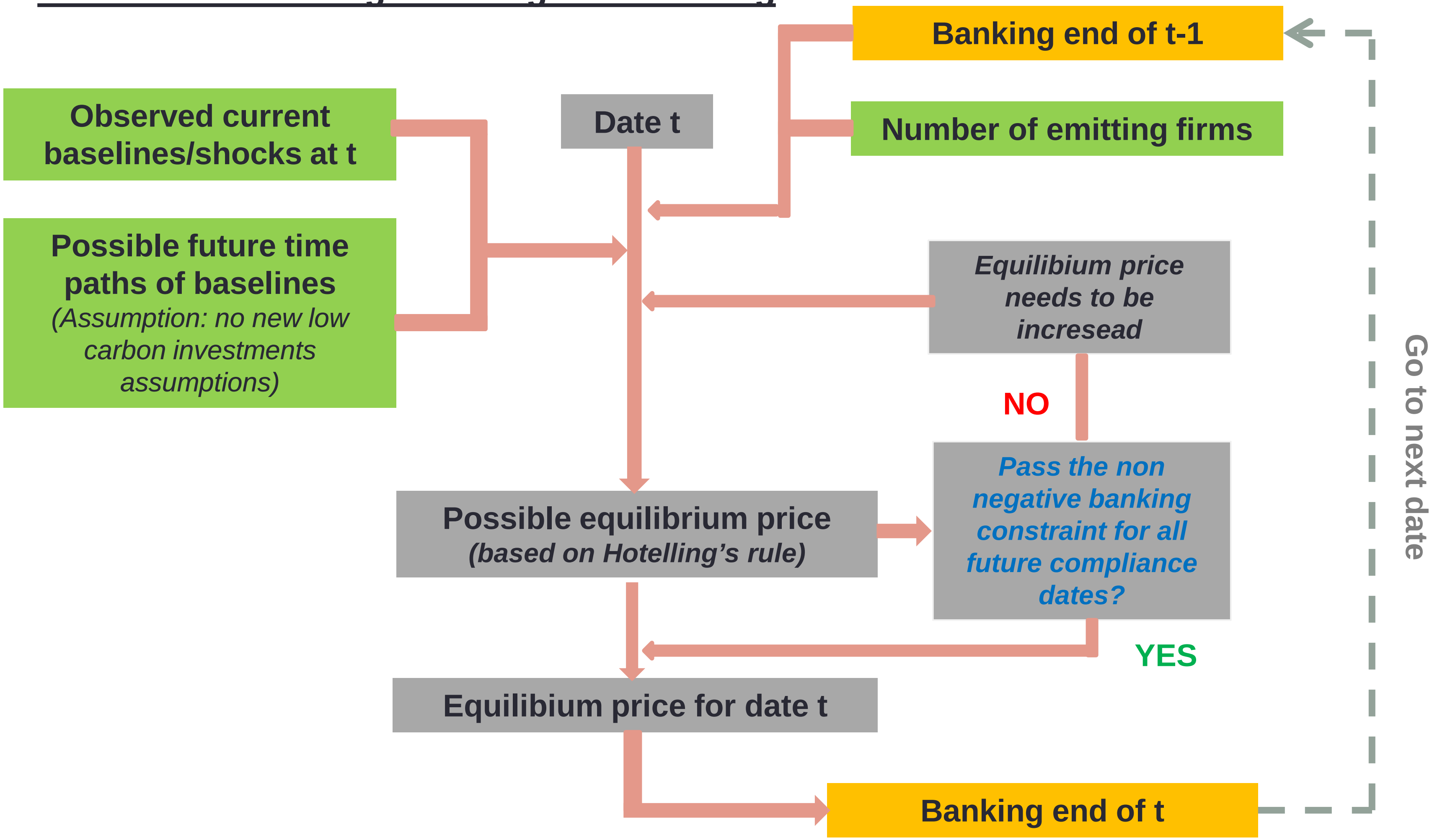


Dynamic equilibrium modelling

- **Advanced modelling**
  - Taking account of the **non negative banking** constraint at intermediate compliance dates:
    - The price signal in the basic model drives the allocation abatement to the lower MAC firms and compensates them for this effort
      - It is not incompatible with some firms having a negative banking, except at T
      - In order to rule out the existence of negative banking at intermediate compliance dates whatever the shocks in the future, the price signal has to be higher
        - **This adjustment of price has to be made at each node of the tree form representation of the dynamics**

Dynamic equilibrium modelling

- **Advanced modelling: non negative banking**



Dynamic equilibrium modelling

- **Advanced modelling**
  - Taking account of the **option to invest** in low carbon technologies:
    - The model focuses on the drastic case of investment in a zero carbon emitting technology (sunk investment cost K is the same for all firms)
      - Avoids having to consider repeated investment decisions for a same firm
        - Consistent for instance with the switch from fossil fuel to renewable energy in the power industry
      - It is thus assumed that firms make a conjecture (linear decrease up to T) on total banking and on their own banking and reassess the dynamics of the price at each date on the basis of this conjecture
        - The decision to invest in the zero emitting technology can be analysed with a standard real option approach (the feedback effect between banking and price is supressed)
        - Once the investment made, a firm has a zero emission baseline forever but still receives allowances
          - Firms that have invested are systematically net suppliers of allowances on the market

Dynamic equilibrium modelling

- **Advanced modelling**
  - A consequence of the option to invest is that the number of firms emitting carbon potentially decreases at each date
    - The dynamics of the price (to be adjusted to fullfil the non negative banking constraint) is now given by

The drop of the number of firms emitting carbon implies a drop of the expected sum of future baselines and a subsequent ***downward effect on the price***

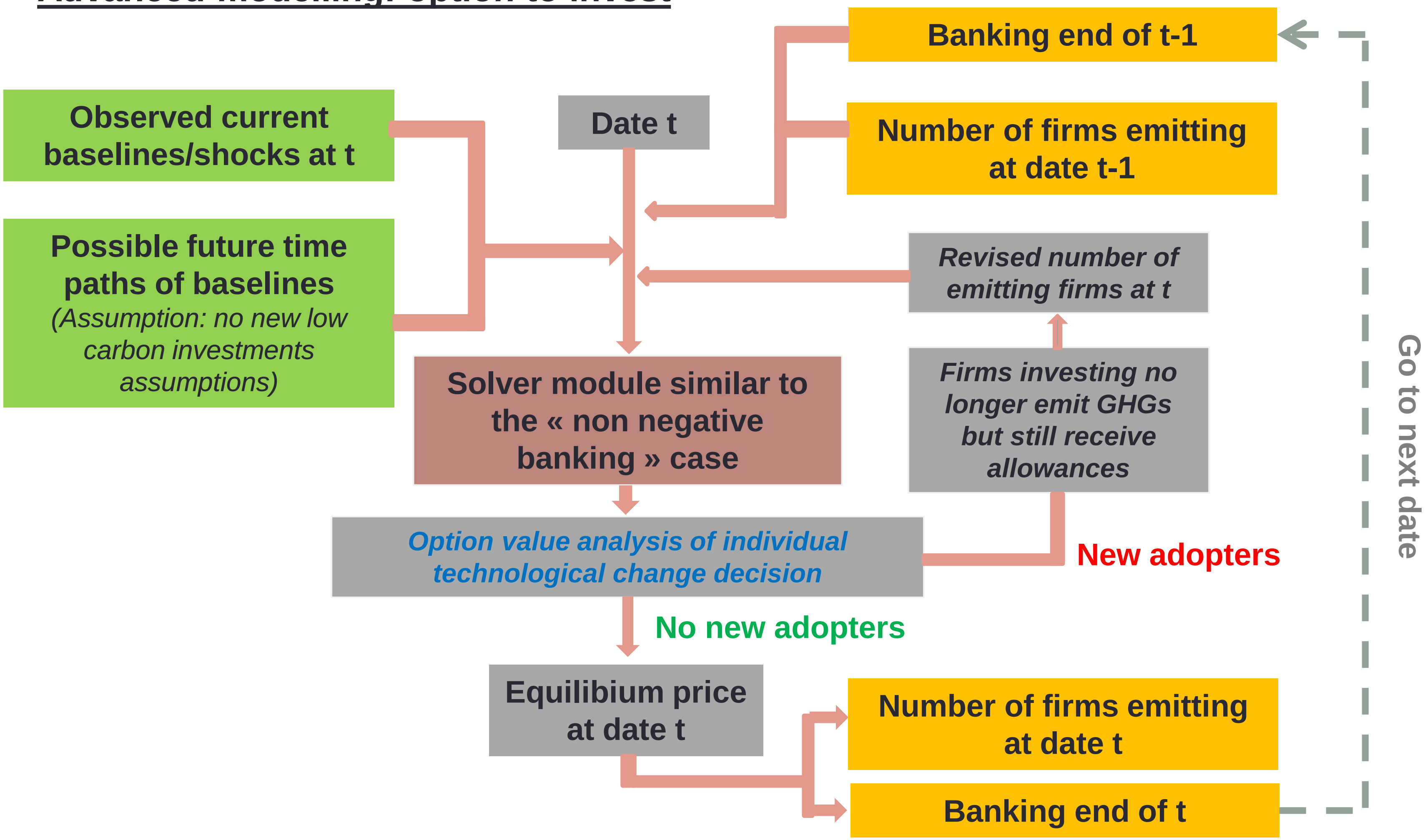
$$p_t = \frac{\sum_{s=t}^{T} \sum_{i\epsilon\Omega} E_t[u_{i\,s}] - \sum_{s=t}^{T}(Q_t + \sum_i E_t[q_{i\,s}]) - \sum_i b_{i\,t}}{\left(\sum_{i\epsilon\Omega} \frac{1}{c_i}\right)(\sum_{s=0}^{T}(1+r)^s)}$$

The drop of the number of firms emitting carbon implies a drop of the slope of the inverse aggregated MAC and a subsequent ***upward effect on the price***

- Thus, there is two opposite effects on the price
- Calls for simulation to assess the net effect

Dynamic equilibrium modelling

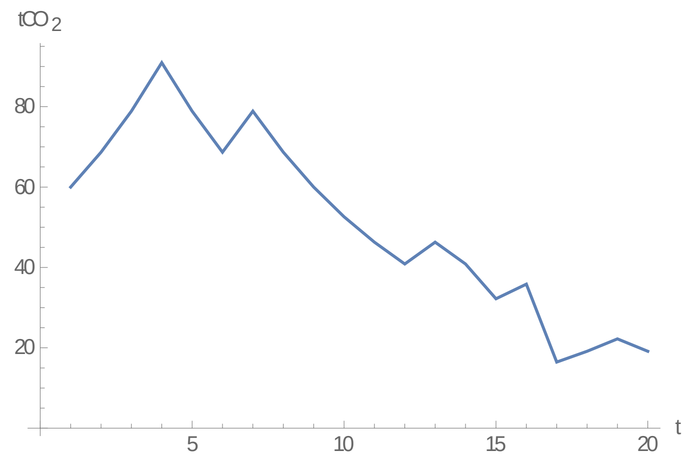
- **Advanced modelling: option to invest**



Simulation results

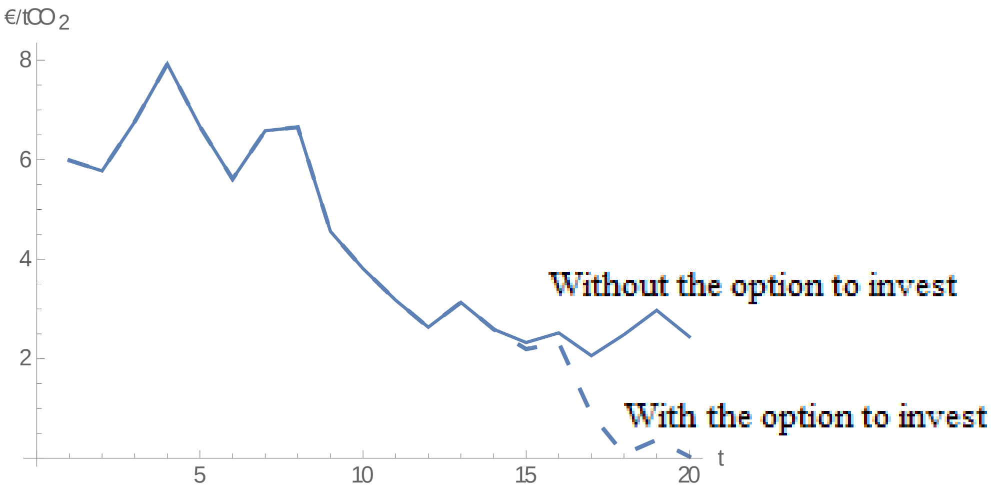
- Consider 3 firms with the following parameters:
  - Abatement cost parameters $c_1=0{,}1$ $c_2=2$ $c_3=6$
  - Initial baseline $u_{10}=30$ $u_{20}=20$ $u_{30}=10$
  - Magnitude of shocks on baseline $\Delta u_1=0{,}15$ $\Delta u_2=0{,}06$ $\Delta u_3=0{,}23$
  - Probability of a positive shock $\theta=0{,}5$
  - Sunk cost of investment in the zero carbon technology $k=100$
  - Allowances freely allocated at the start of each year $q=16$
  - Discount rate $r=0{,}03$

- Consider 5 years of 4 trimester (unit of time) and compliance at the end of each year
  - The simulated time path of baseline emissions exibits an initial and then a drop
  - Very similar to phase 2 of the EU-ETS with the economic crisis in 2008

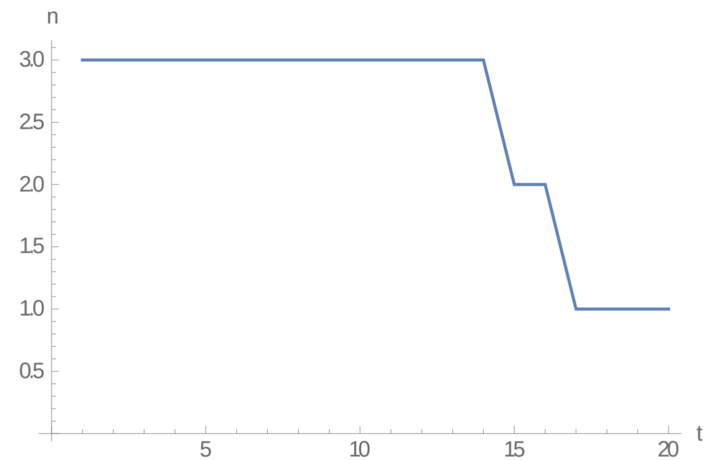


Simulation results

- Investment implies a end-of-phase drop of the price (in this simulation)



- Firms invest late: they seems to postpone the investment decision due to the drop in the price



- **Further work aims at calibrating the model on data from the EU-ETS (EU transaction log) and examining the consequences of developing auctions and reclycing of revenue from auctions in the form of subsidies to technological change**

Thank you
for
your attention