Redistribution Effects of Energy and Climate Policy

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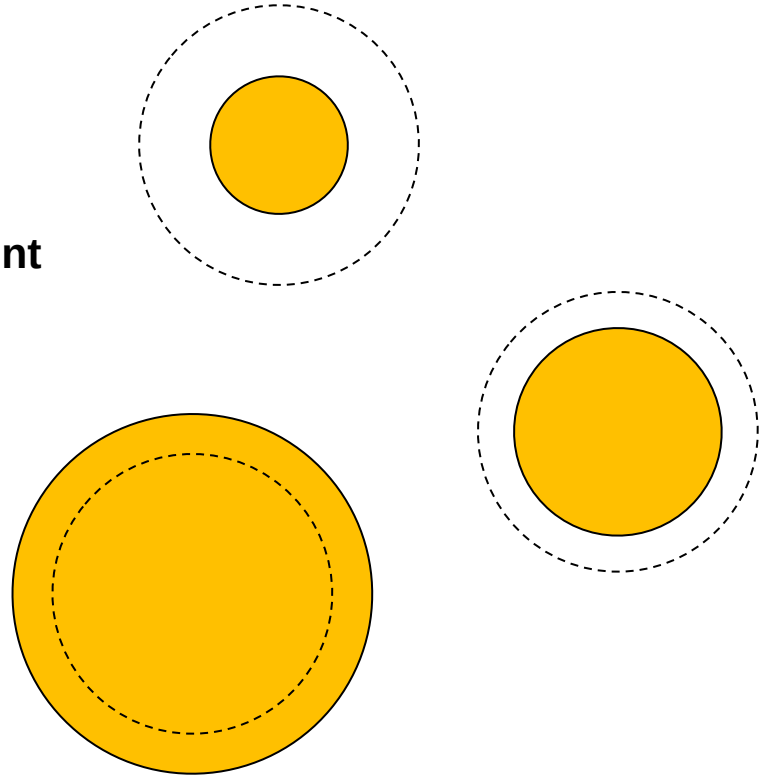
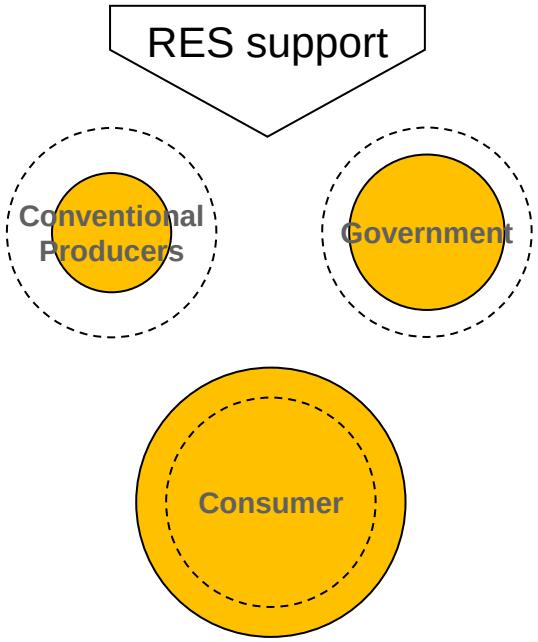
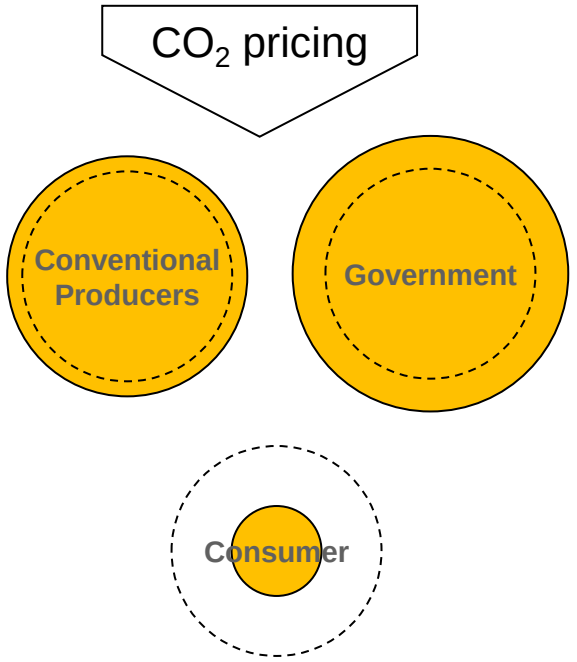


Redistribution Effects of Energy and Climate Policy



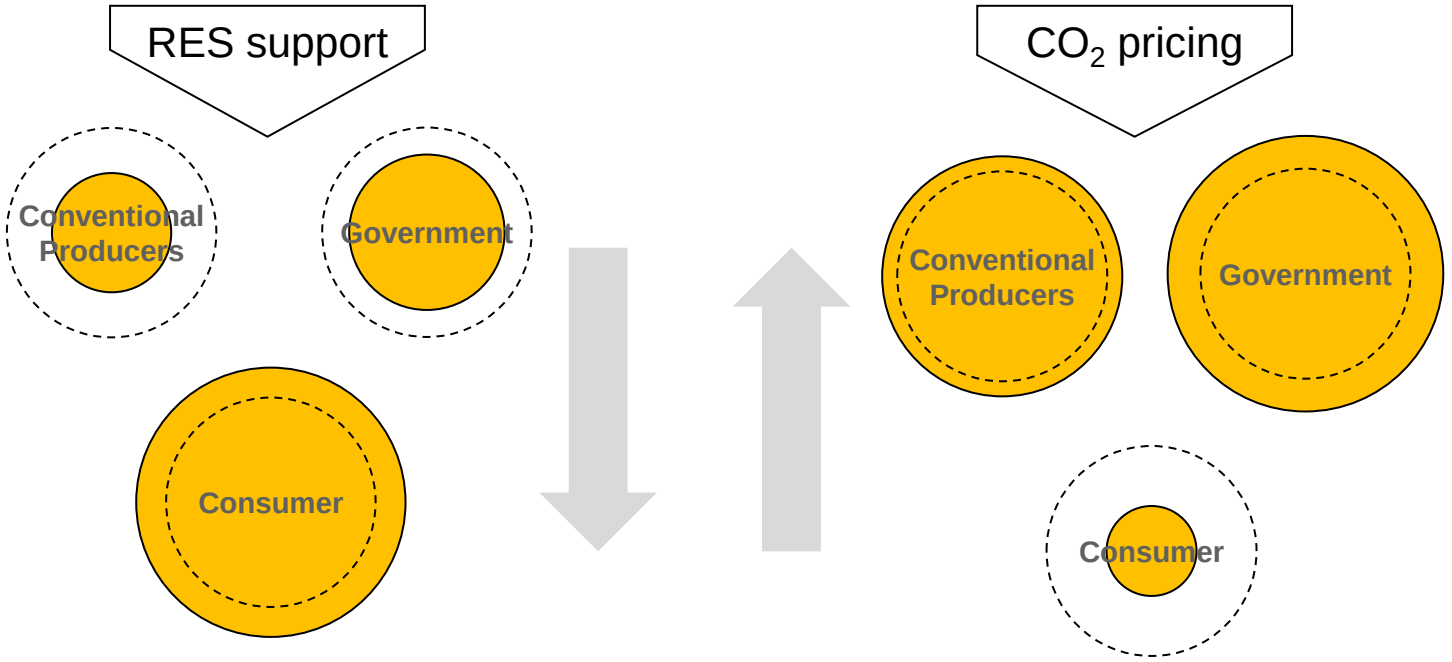


Theoretical model and numerical model use the same framework

- **Long-term** economic equilibrium (benchmark) → producers do not earn profits*
- **Short term** perspective: investment costs are sunk → producers can earn profits
- Profits change with economic shocks → redistribution (of all surpluses)
- Long lifetimes and construction times in power sector → long transition to (new) equilibrium

*Assuming perfect markets

Conclusions



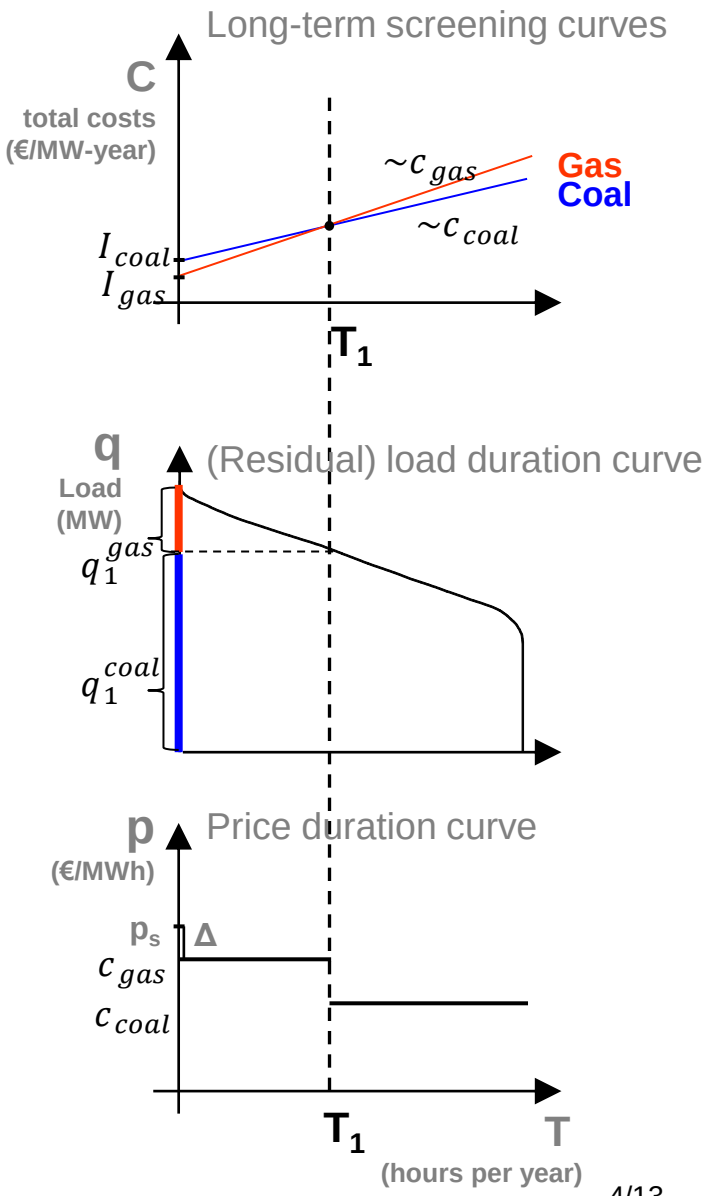
- Redistribution large relative to welfare effects
- Different policies induce diametrically opposed redistribution flows:
  - RES support transfers welfare from producers and the state to consumers
  - CO_2 pricing shifts welfare from consumers to producers and state (depends on CO_2 price and capacities)
- Complementary explanation for attractiveness of renewables support to policy makers

Theoretical model: Long-term equilibrium easily derived

- We extend a method from (Green 2005)
  - Screening curve: total costs per kW-year of one technology as a function of its full load hours
  - RLDC shows the sorted hourly residual load of one year starting with the highest load hour
  - Price duration curve shows the sorted hourly prices of one year starting with the highest.

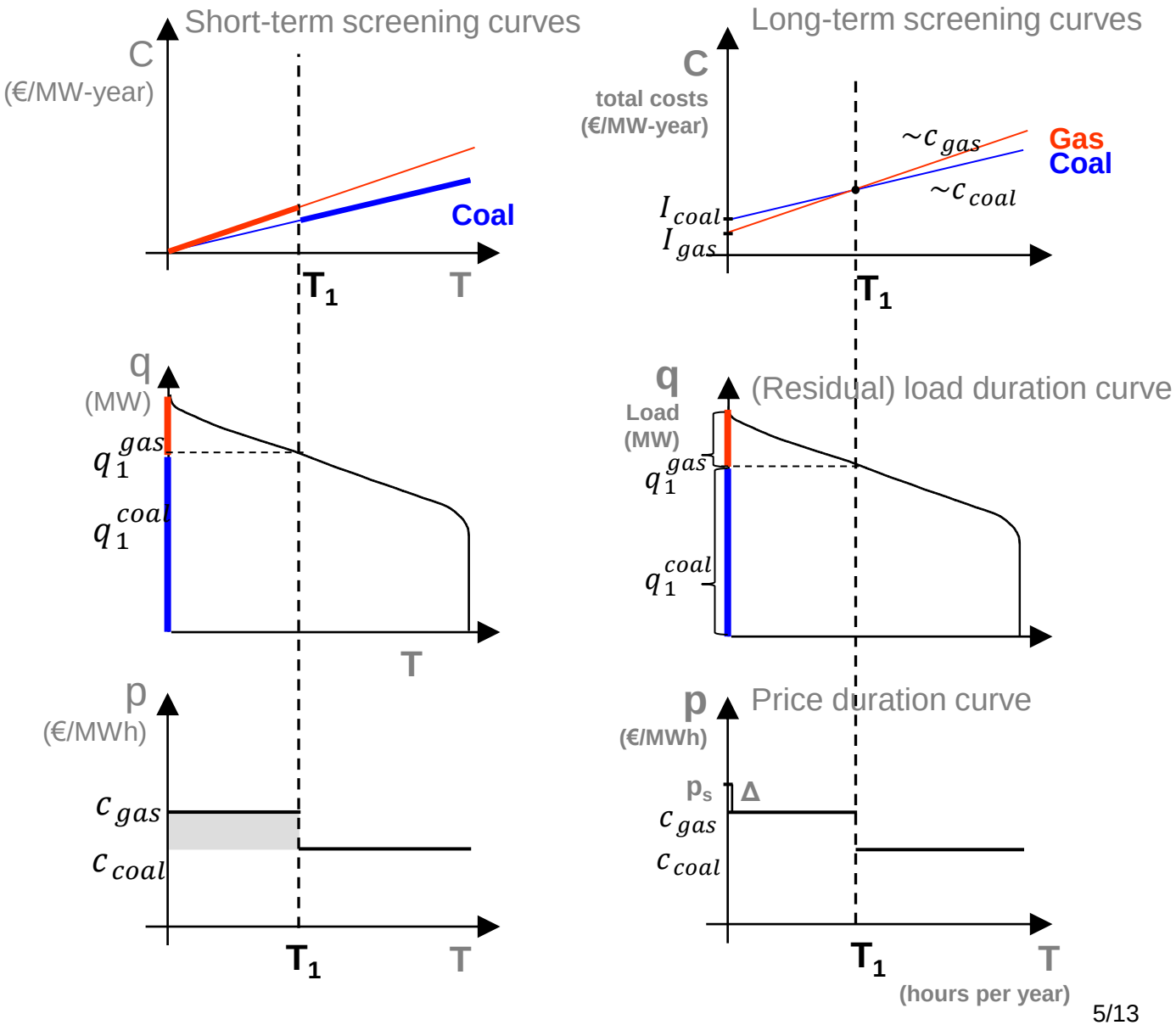
- Theoretical model assumptions
  - Two generation technologies
  - Producers: fully competitive, perfect foresight.
  - Electricity demand: price-inelastic, deterministic
  - Dynamic aspects, like ramping constraints or electricity storage, are neglected as well as international trade and grid constraints.
  - Externalities are assumed to be absent.
  - Energy only markets with marginal pricing.

- We show that profits are zero in the long-run



In the short term investments are sunk

- No investment costs
- No scarcity prices



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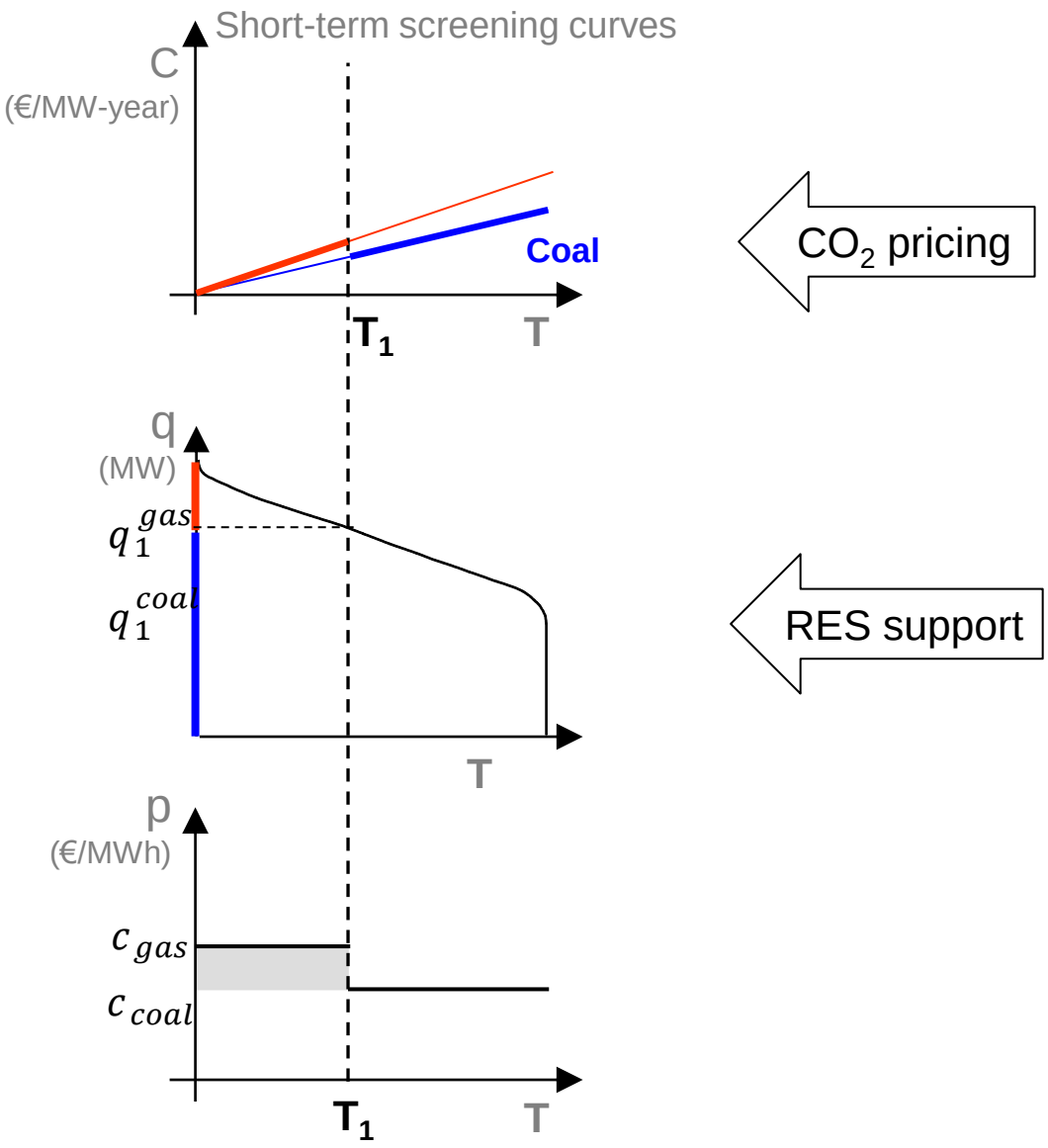
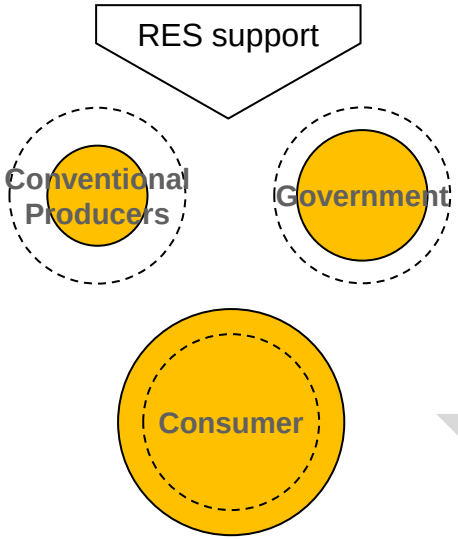
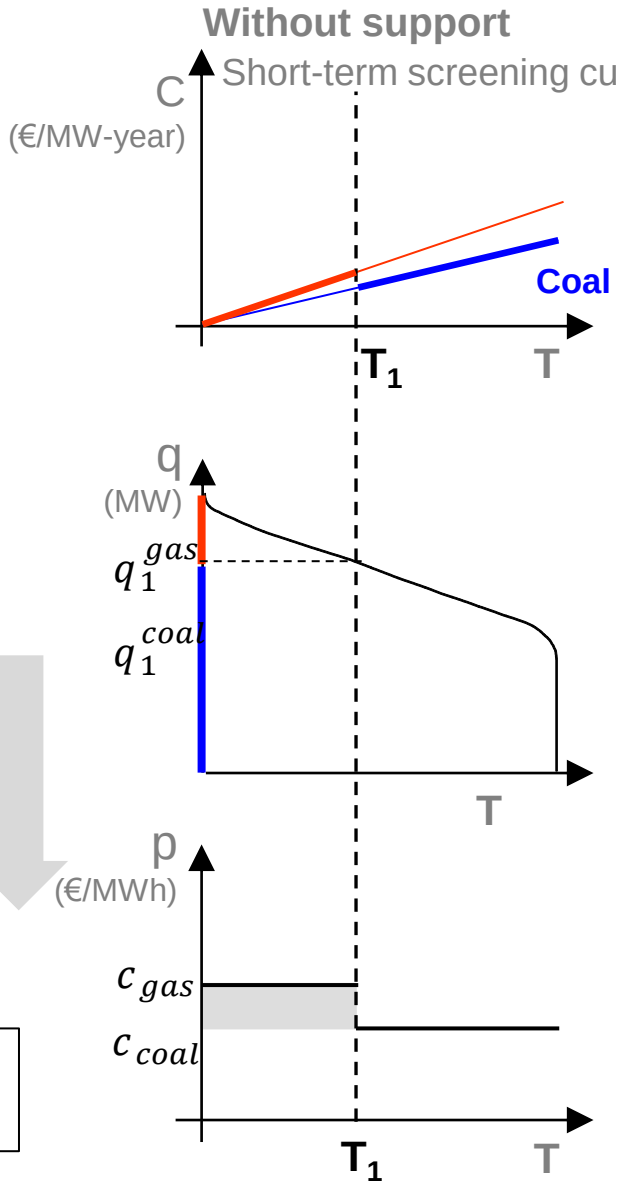


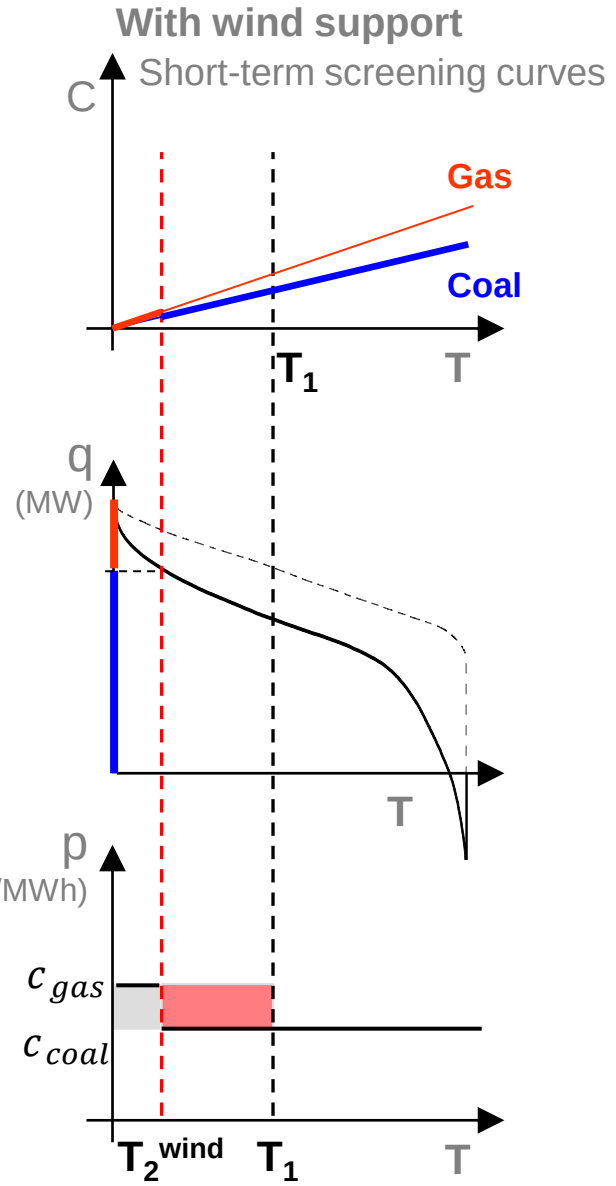
Wind reduces the producer profits

- Producers earn less profits
- Decrease of spot market price → consumers savings
- The state pays RES support



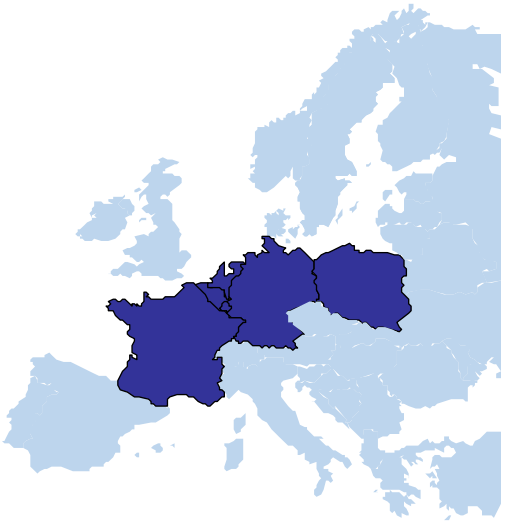
Quantification?
→ Numerical model

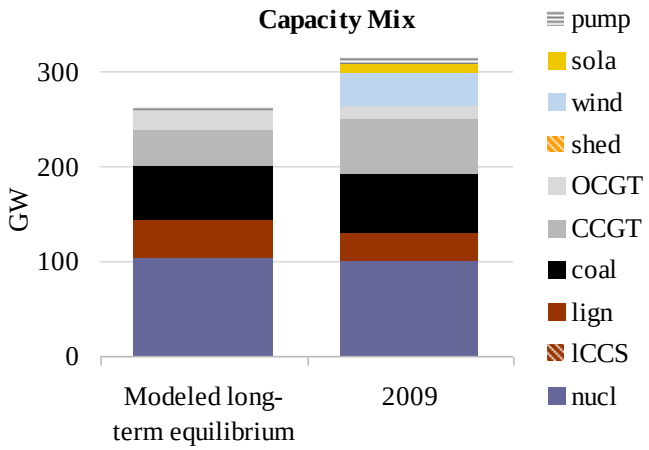




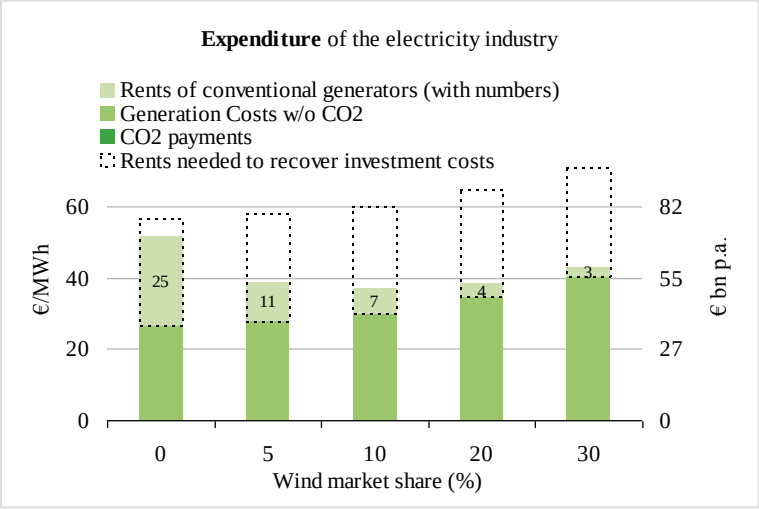
Model & scenario setup

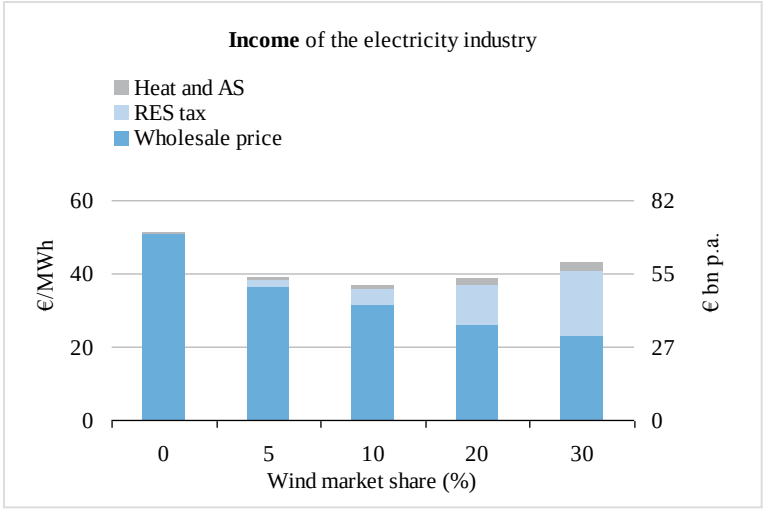
- why numerical modelling?
  - quantitative estimates (orders of magnitude)
  - more technologies, North-Western Europe
  - interconnectors, storage, CHP, ancillary services
- model
  - stylized electricity market model
  - total system costs are minimized with respect to investment and dispatch decisions under a large set of technical constraints
  - ten technologies (wind, solar, eight dispatchable, pump hydro)
  - no market power, externalities or other market imperfections
    → cost minimization is equivalent to profit-maximizing firms
  - electricity price is set by variable cost of marginal plant
  - no load flow, NTCs between market areas
- integrated dispatch and investment
  - hourly time steps for a full year
  - existing plant stack, storage and interconnectors
  - endogenous (dis-)investments in generation, storage and interconnectors via annualized investment costs
- back-tested and calibrated to market prices
- 1M equations, 4M non-zeros, solving time ½ h
- scenario setup
  - first: long-term equilibrium
  - then: policy shocks





Wind support: theoretical results are confirmed





- Confirms theoretical results: producers pay, consumers benefit, government pays
- Wind support reduces the wholesale price (merit-order effect), thereby reducing conventional generators' rents
- Consumer payments are reduced even if they would pay RES support (Sensfuss et al. 2008, de Miera et al 2008)
- Redistribution effects are large compared to welfare effect

PANEL 1: REDISTRIBUTION (€/MWH) WHEN INCREASING THE WIND SHARE FROM ZERO TO 30 %.

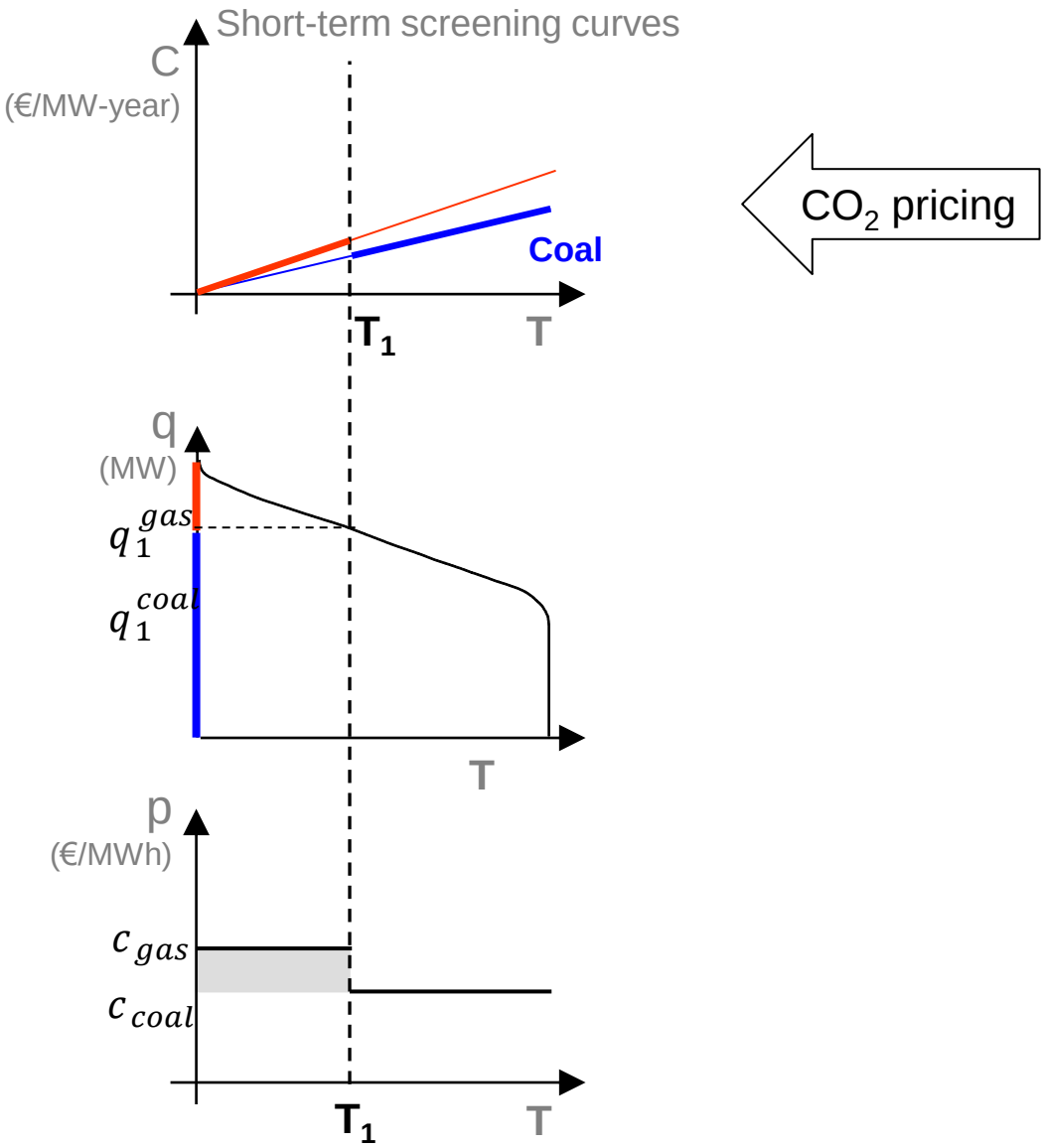
Conv Producers	
Nuclear Rents	- 13
Coal Rents	- 9
Gas Rents	- 1
Producer Surplus	- 22

Effect on Government Budget	
CO_2	/
Wind	- 18
Gov't Budget	- 18

Consumer Surplus	
Electricity market	+ 28
Heat market	- 2
AS market	- 0
Interconnectors	- 0
Cons Surplus	+ 25

Welfare	
Consumers	+ 25
Producers	- 22
Government	- 18
Welfare	- 15

CO2 pricing: short-term screening curves pivot



CO2 pricing: short-term screening curves pivot

(a) Rents are generated by coal power plants when gas power plants are price-setting.

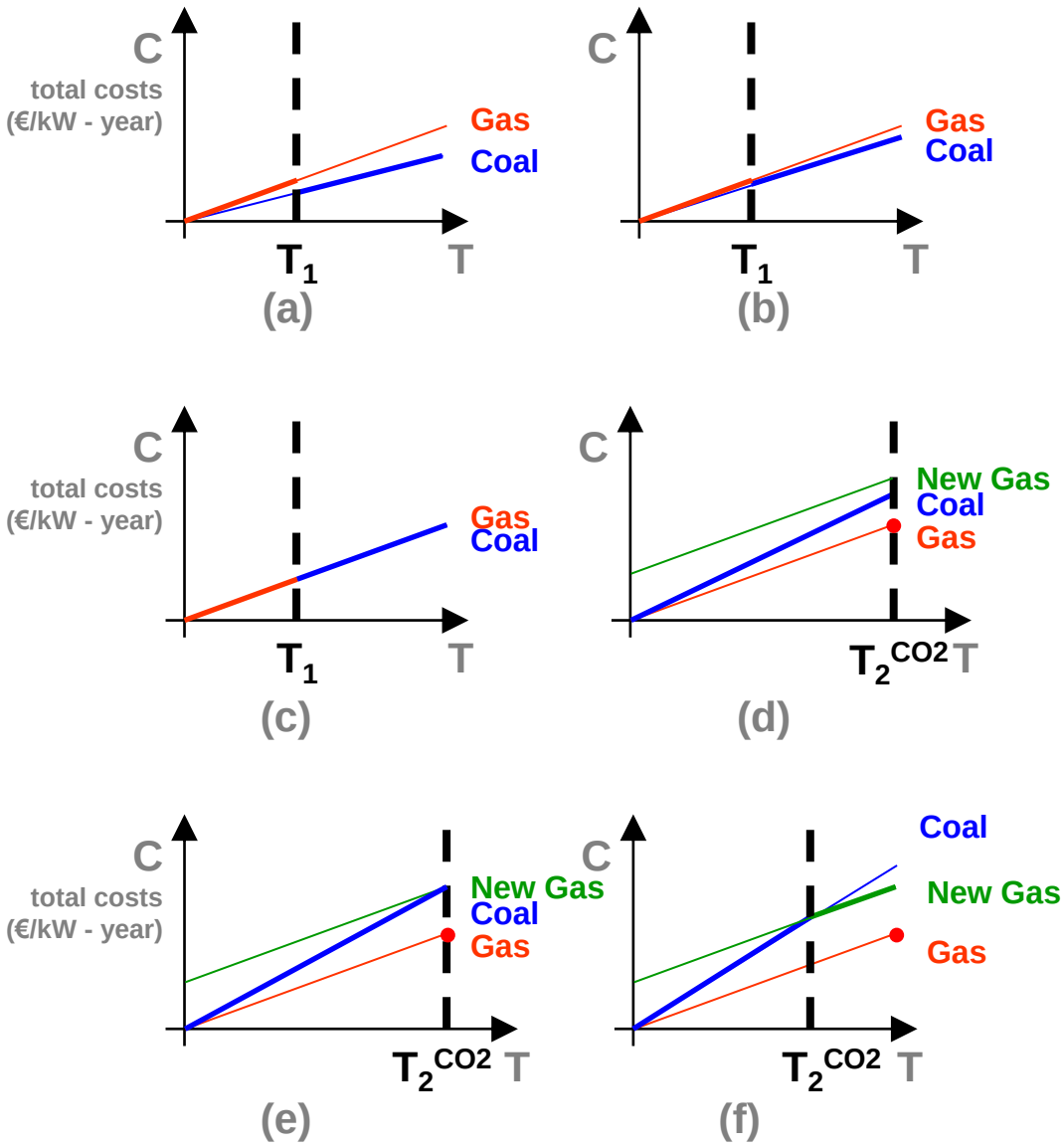
(b) The difference of variable costs decreases, thus the coal rents decrease. The dispatch remains unchanged.

(c) No rents occur because variable costs of coal and gas power plants are equal. (65€/t CO_2)

(d) Now the dispatch changes: Gas power plants now have least variable costs and cover base load. Coal power plants only cover the remaining base, mid and peak load. Gas power plants generate rents when coal power plants are price-setting.

(e) The screening curve of coal touches the screening curve of new gas power plants. The rents of gas power plants reach a maximum. (80€/t CO_2)

(f) Now, new investments in gas power plants lead to decommissioning of existing coal capacity. Old gas power plants are the only plants that generate rents. These rents remain at their maximum value.



Assuming variable costs of 25 €/MWhth (gas) and 12 €/MWhth (coal), efficiencies of 48% (gas) and 39% (coal), carbon intensities of 0,24 t/MWhth (gas) and 0,32 t/MWhth (coal) and investment costs of 100€/kWa (gas).

The effect of CO2 pricing

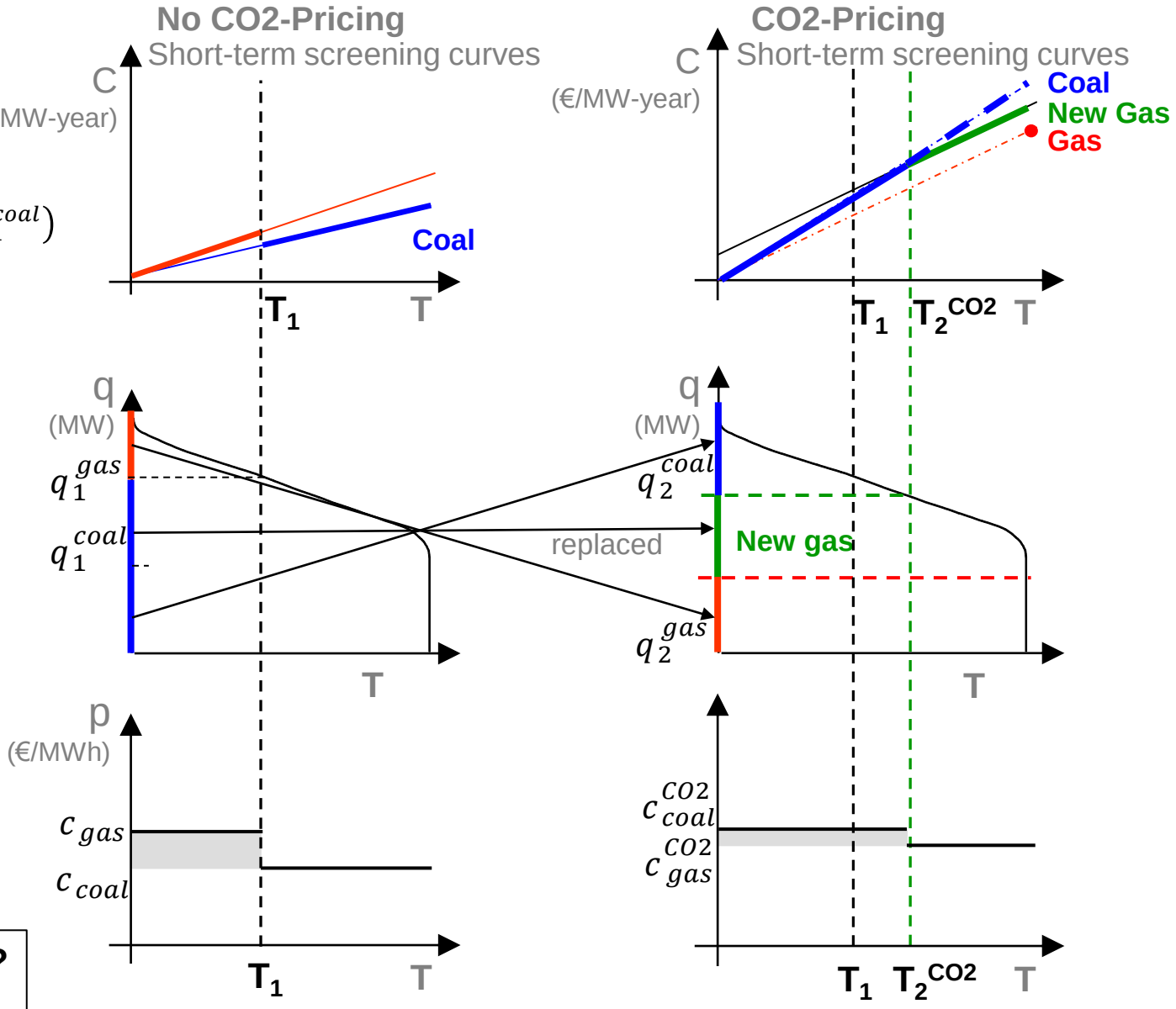
- With high CO2 price: Shift of rents only depends on the initial long-term capacity mix

$$R_2^{gas} - R_1^{coal} = I_{gas}\left(q_1^{gas} - q_1^{coal}\right)$$

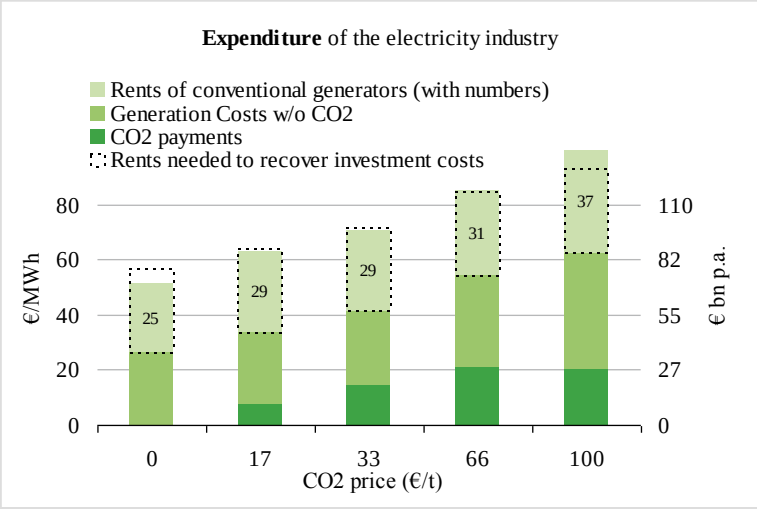
General results

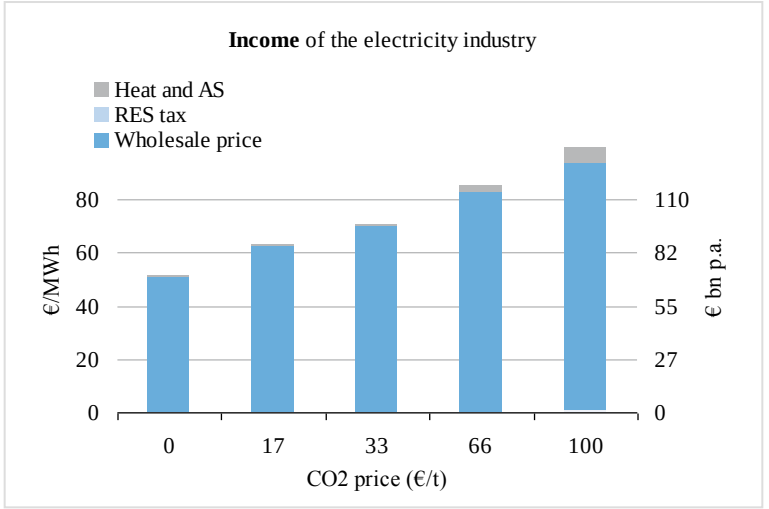
- Total producer profits depend on long-term capacities and CO2 price
  - Large redistribution within producers depending on technologies
  - More low-carbon technology → total producer rents tend to increase
- Consumers pay
- State benefits

North-Western Europe?
→ Numerical model



CO_2 Pricing: in North-Western Europe producers benefit





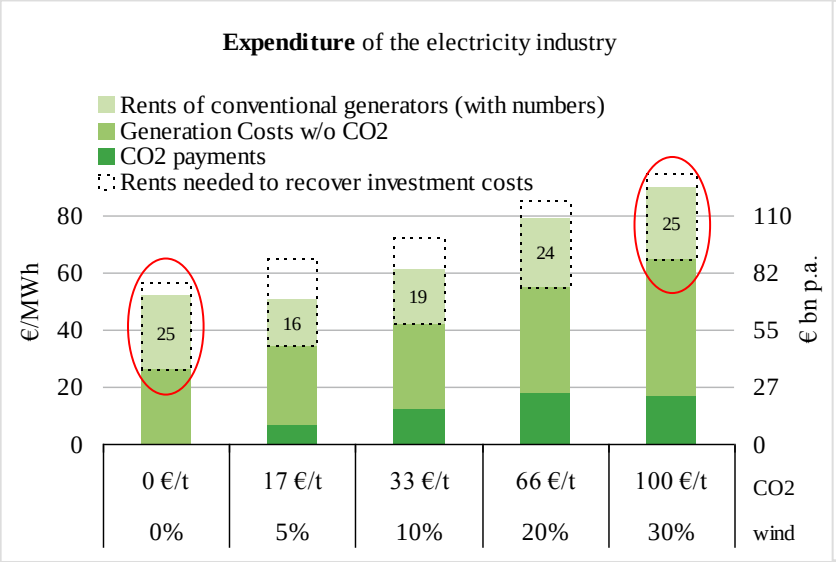
- North-Western Europe: Producers benefit, government benefits, consumers pay
- CO_2 pricing increases wholesale price, increasing the rents of low-carbon generators (Martinez & Neuhoff 2005, Chen et al. 2008)
- Producer rents are comparable to „windfall profits“ due to grandfathering (20 €/MWh)
- Redistribution also between existing generators from lignite and hard coal to nuclear
- Large differences across markets (producers in countries with low-carbon base load gain more)

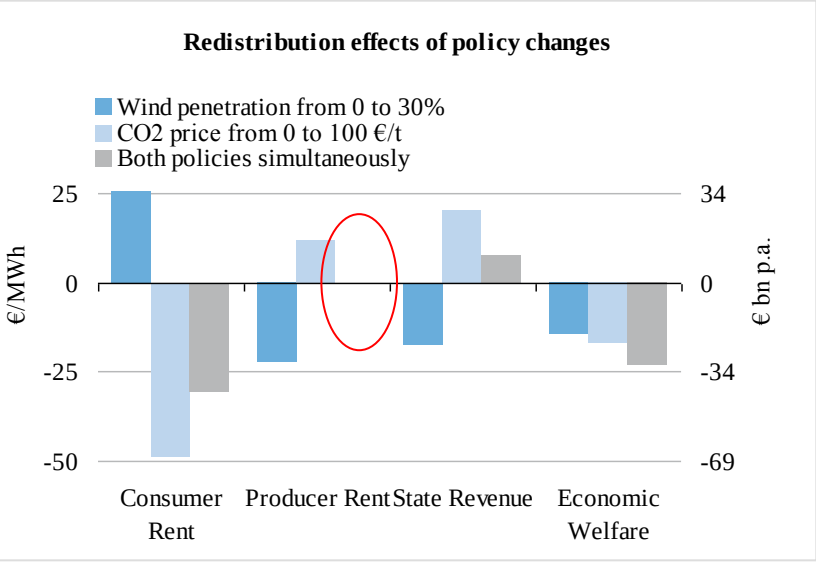
PANEL 2: REDISTRIBUTION (€/MWH) WHEN INCREASING THE CO_2 PRICE FROM ZERO TO 100 €/T

Conv Producers		**Government**	
Nuclear Rents	+ 21	CO_2	+ 20
Coal Rents	- 10	Wind	/
Gas Rents	+ 0		
Prod Surplus	+ 12	Gov't Budget	+ 20

Consumer Surplus		**Welfare**	
Electricity market	- 43	Consumers	- 49
Heat market	- 6	Producers	+ 12
AS market	- 0	Government	+ 20
Interconnectors	- 0		
Cons Surplus	- 49	Welfare	- 17

Policy Mix: redistribution can be minimized





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This paper brings together two branches of literature

Merit-order literature

- Decrease of spot market prices due to renewable electricity generation → savings for the consumer
- Sensfuss 2007, 2008, de Miera et al. 2008, Munksgaard & Morthorst 2008

CO2 pricing literature

- How do producer profits change (depending on different allocation rules for emissions allowances)?
- To what extend CO_2 costs can be passed through to consumers?
- Martinez & Neuhoff 2005, Chen et al. 2008, Burtraw et al. 2002

Our work adds to the literature in three ways.

- effects of both policies in a consistent framework with the long-term equilibrium as benchmark
- focus on redistribution effects: evolution of effects at different levels of policy intervention and comprehensive accounting of all flows
- analytical model to trace causal mechanisms and numerical model for quantifications

CO2 pricing within a nuclear system tends to increase conventional rents

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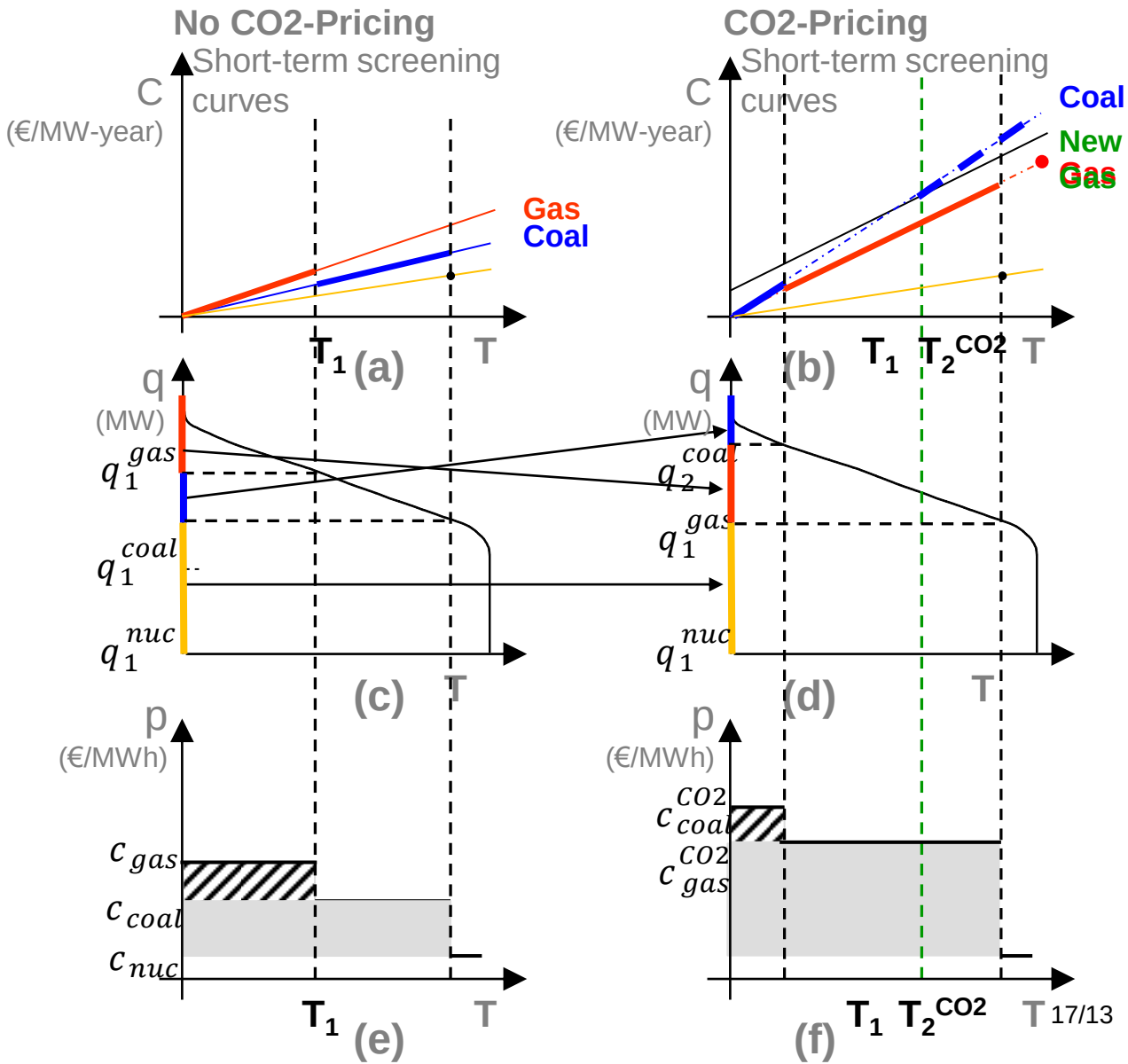

Long-term equilibrium with nuclear

- Back-up slide