National-strategic transmission investment and zonal pricing

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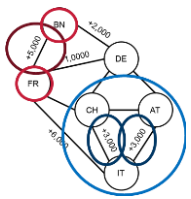
Overview

1. National-strategic investment in cross-zonal capacity
2. Implication of bidding zones on investment in cross-zonal capacity

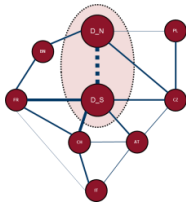
National-strategic cross-border transmission investment



Individual countries could be in favor or against stronger cross-border/(zonal) integration for welfare considerations

- Price and welfare implications
- Allocation of investment costs for network investment

Bidding zones and investment in cross-zonal capacity

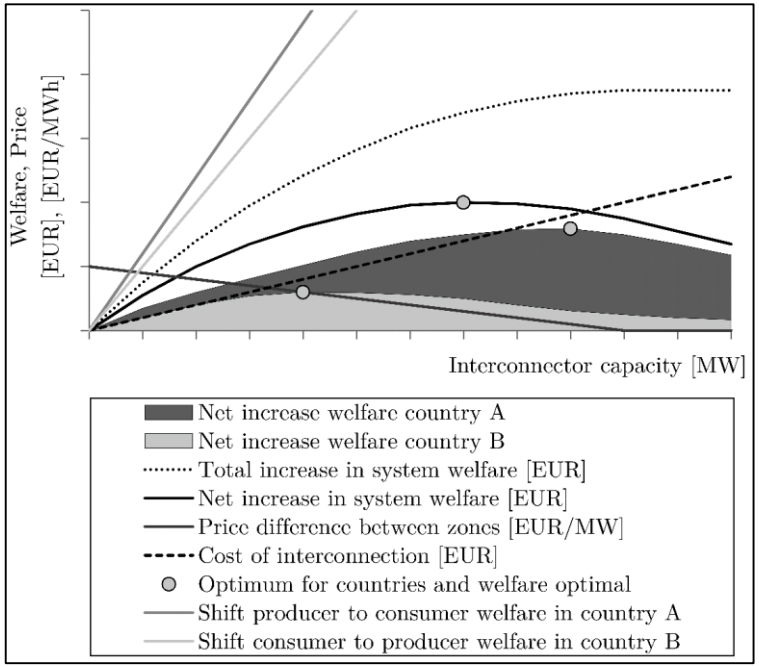


Bidding zones affect market outcome and cross-zonal investments

- Change in market dispatch, trade flows, and price differences between zones (and countries)
- Distributional implications (on status-quo) but also on (optimal/national-strategic) cross-zonal investment

National-strategic investment in cross-zonal capacity

Assumption:
There are different national (zonal) preferences for cross-zonal investment



Allocation of costs and benefits

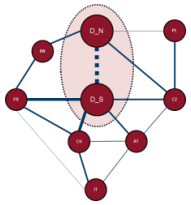
1st best: sharing of welfare benefits
Achieve welfare optimal investment by perfect cost-benefit mechanism with compensation payment

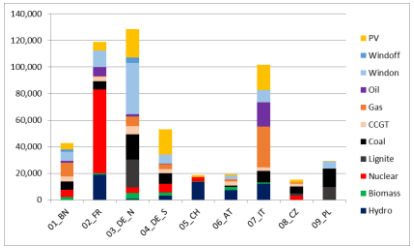
Alternative → allocation of investment costs

A) Bilateral 50:50 sharing	B) Proportional cost sharing
Status-quo for most cross-border projects	Costs are split according to benefits

1) Electricity sector model

Calculation of the welfare distribution for all possible combinations of line investment with equal cost allocation





National-strategic investment in cross-zona capacity

Methodology: National decisions on investment

1. Assumptions on the local objective function
   - Countries (players) are rational and seek to maximize their own national welfare
   - Welfare is defined as the sum of consumer surplus, producer surplus and congestion rents minus costs for transmission investments. The congestion rent is shared equally between the two adjacent players
2. Assumptions on the market design
   - Short-term marginal pricing with implicit auctioning of exchange capacity defines the market outcome
   - Static setting for generation capacities, their variable costs, and the demand functions.
   - Trade flows in **zonal market setting**

National-strategic investment in cross-border capacity

Game description:

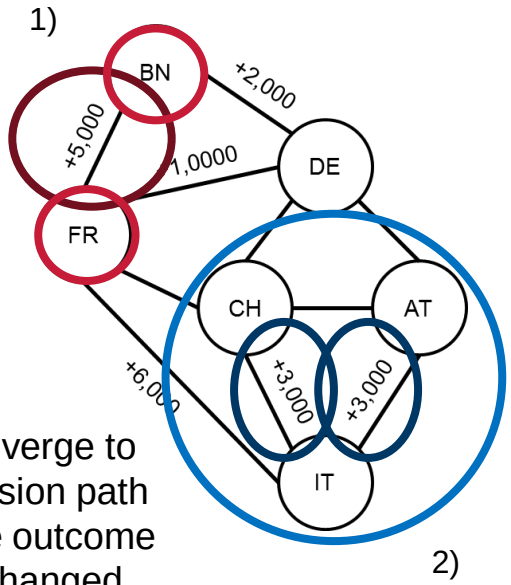
- Simultaneous moves (one time decision)
- Players = Countries
- Strategies = Transmission expansion choices
- Payoffs = national welfare
- Complete information for all countries (payoff matrix is known)
- Countries have exclusive decision power on investment in transmission lines on own territory
- Finite number of expansion options

Strategic considerations:

- Local objective function: Countries trying to maximize own welfare = CS + PS + CR - Line invest cost
- Countries can
  1) block investments on their territory
  2) decide on additional investments together with other countries

Stable strategies:

1) If any player has the power to increase its own welfare, given a particular outcome, by reducing investment on one of its own lines the outcome is not considered to be stable.



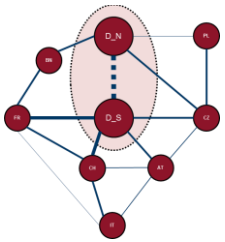
2) Also the incentive to diverge to a different (stable) expansion path can result in a non-stable outcome if all players involved in changed planning are better off compared to the initial outcome.

Finite strategies are combinations of investment in cross-zonal capacity in steps of 1000 MW

Bidding zones and investment in cross-zonal capacity

Additional bidding zones (can) provide:

1. Price signals for transmission investment
2. More decision power for certain countries allowing them more influence by national-strategic decision on trade capacity



	System-optimal	National-strategic
One price zone		
Two price zones		

Implication of bidding zones on investment in cross-zonal capacity

Assumptions:

- D_N and D_S decide as one country in the scenario with two bidding zones

Input data (network):

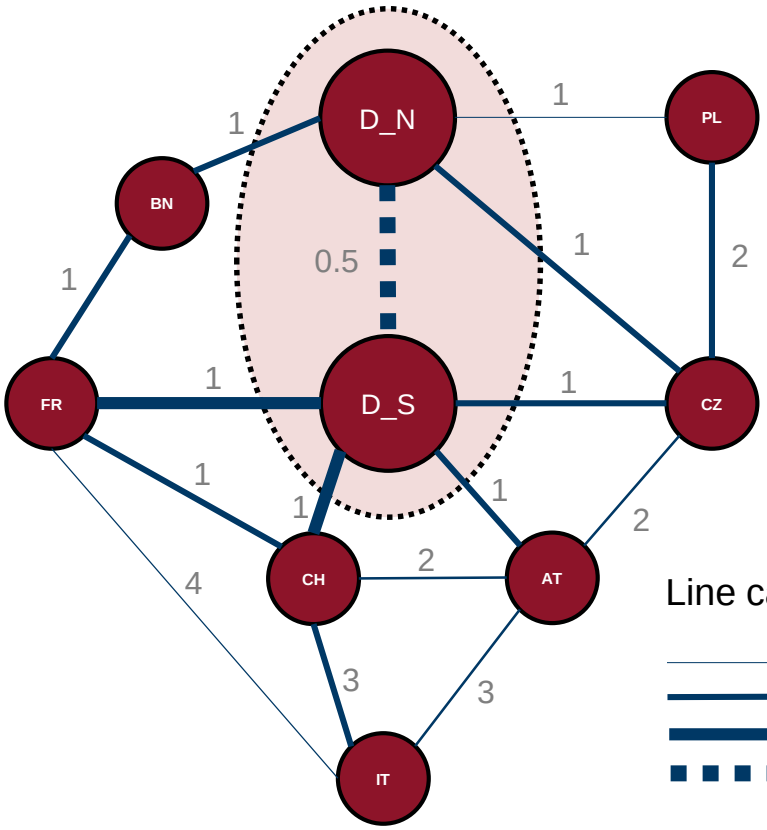
- Germany and neighboring countries
- Cross-zonal capacity
- Line length (multiplier on invest cost)
- Possible split in northern and southern bidding zone within Germany

Generation and demand:

- Generation capacity for different conventional and renewable technologies with variable costs and availability
- Inverse demand function in each zone

Market design:

- Zonal dispatch with trade capacity (no loop-flows)
- At this point only one exemplary hour



Line capacity:

- 1 GW
- 2 GW
- 3 GW
- 8 GW

Capacity cost factor:

- 0.5 / 1 / 2 / 3 / 4

Zonal pricing and transmission investment

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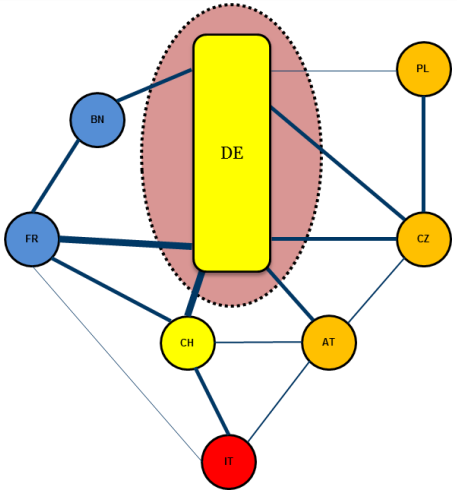
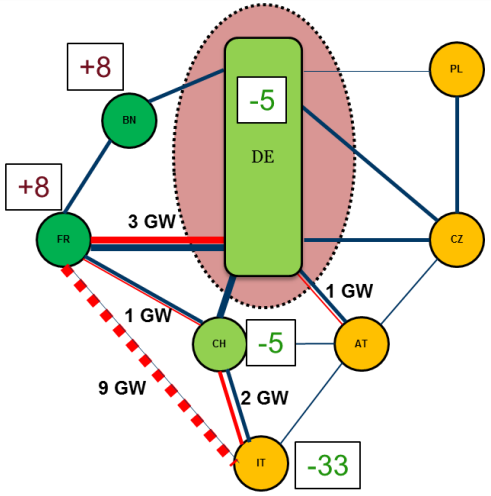
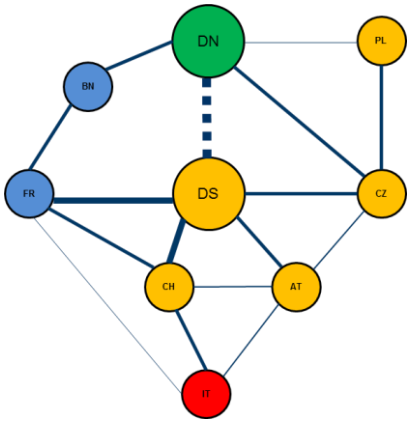
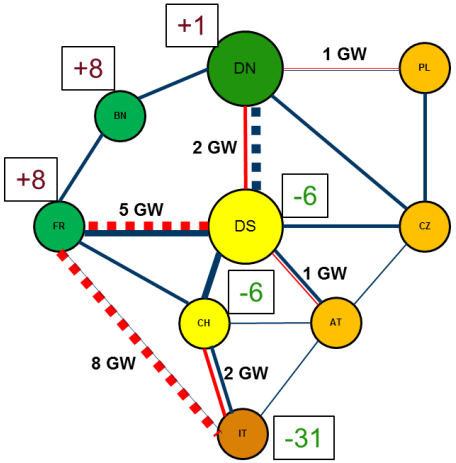
	Initial market result	Optimal network investment
One price zones		
Two price zones		

Impact of zonal design on network:

- New price signals from two zones
- Diversion of network investment to new zone with higher price
- Internal signals for investments after zonal splitting

Invest capacity:
- 1 GW
- 2 GW
- 3 GW
- >3 GW

Price:
- 12 EUR/MWh
- 20 EUR/MWh
- 21 EUR/MWh
- 23 EUR/MWh
- 26/28 EUR/MWh
- 32 EUR/MWh
- 35 EUR/MWh

National welfare implications of investment

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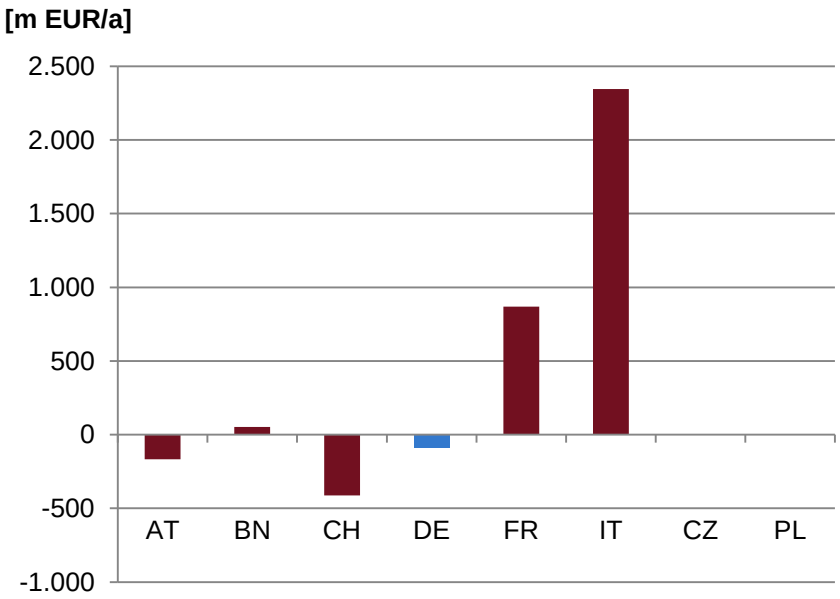
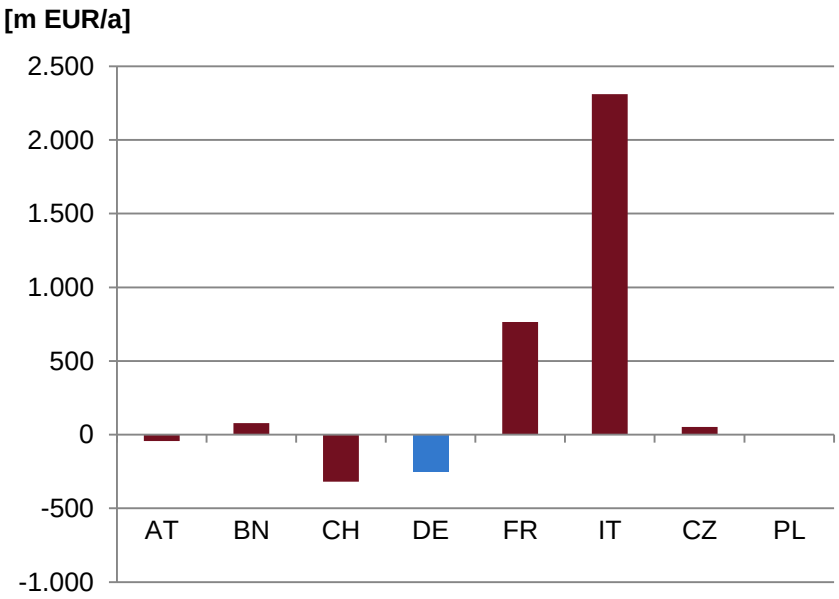
One zone

- Main benefits from cross-border network investment for large exporting/importing countries
- Transit countries with benefits from price differences lose from capacity increase



Two zones

- (Small welfare increase from two price zones in Germany)
- Implications of optimal network investment show similar picture with two price zones
- But: higher welfare losses in Germany (RD)



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National perspective on investment

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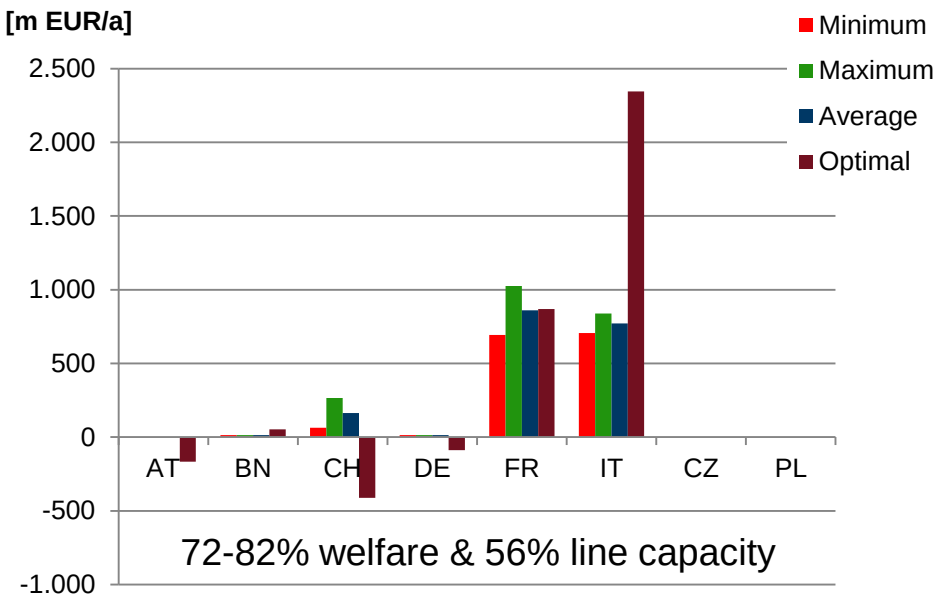
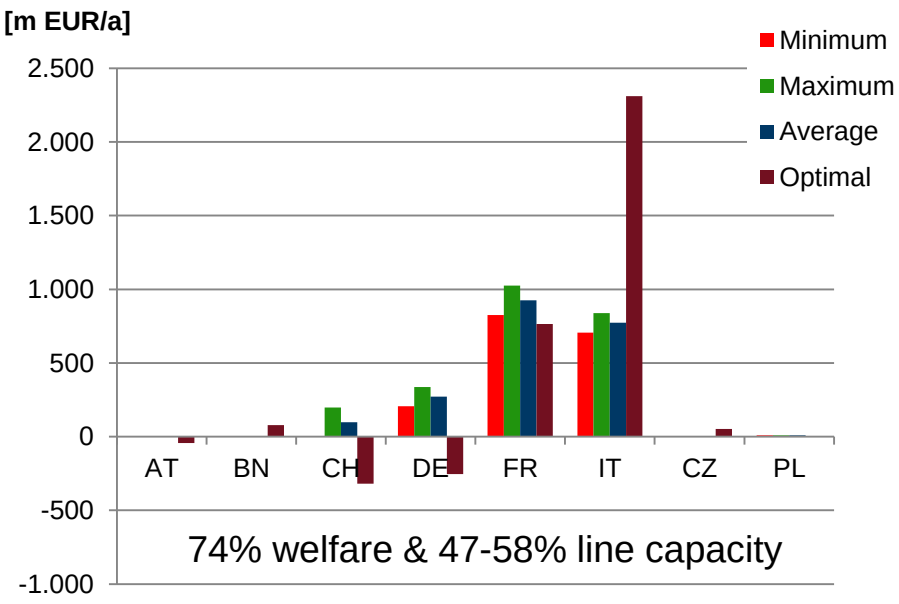
One zone

- Optimal: FR & IT gain / CH transit without benefit
  CH -450
  FR +900 / IT +2,400
- Strategic: three stable solutions
  CH +500-700 // FR congestion rent // IT less
  - No line AT-DE
  - 5 GW FR – (CH) – IT (compared to 11 GW)



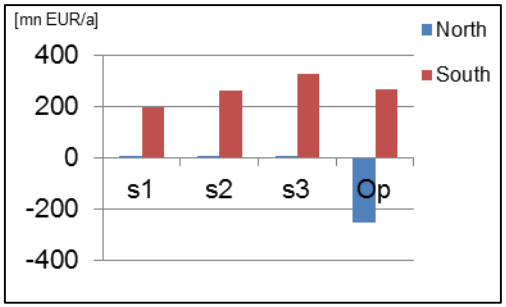
Two zones

- Optimal: (compared to one zone)
  DE -170 / FR -100
  CH +100 / AT +120 / CZ +50 / BN +25
- Strategic: three stable solutions
  DE +450-600 // CH +300-500 // FR +50-250
  - No line within DE
  - FR – DE_S 3-5 GW
  - 5 GW FR – CH – IT (compared to 10 GW)



Discussion

- Evaluation of zonal pricing from German perspective:
  a) Welfare gains in static case
  b) Losses in dynamic case with network integration (internal lines in zones & RD!)
  c) Additional benefits by larger strategy space in national-strategic case
     → Preference for higher national price difference
     → North: no loss of CS // South: CS gains from capacity to FR higher internal congestion rent // lower investment costs
     → +450-600m EUR/year higher national welfare



- Results might change if considering different allocation schemes for investment costs

- Some shortcomings in representation of system operation (re-dispatch, etc.) and very simple example (correlation of renewable generation and demand, etc.)

Ongoing work…

Methodological extension

Green field model:

1. Supra-national or national planner decides on zonal setting and trade capacity (which first?)
2. Endogenous investment in conventional and renewable generation capacity and storage for spot market outcome
3. Re-dispatch costs within country and costs for reserve capacity

Policy application to Europe

Zonal European model:

1. Zonal hourly data and several time steps (years) with national scenarios
2. Starting from status-quo: allow de-investment in cross-border capacity, e.g., with phase shifters
3. Address externality of loop flows
4. Include re-dispatch requirements for scenarios combining bidding zones (e.g., uniform price zone in Germany)
5. Allow for cross-border bidding zones

Thank you for your attention!

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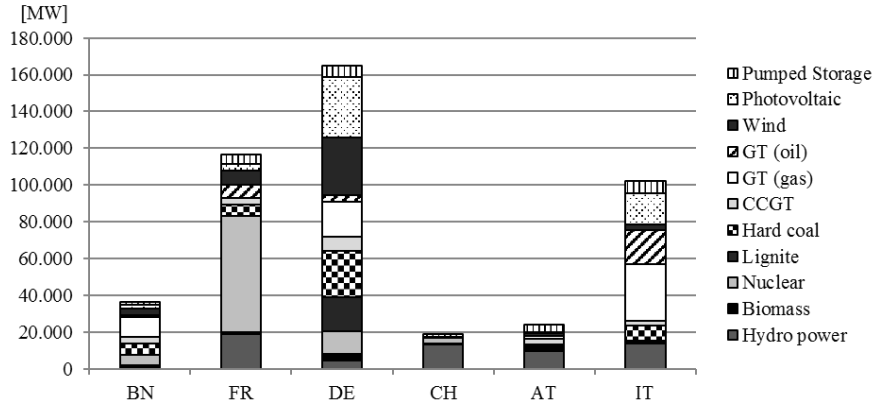
Backup

National-strategic investment in cross-border capacity

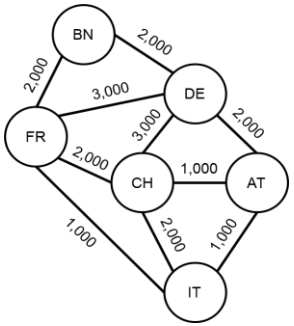
Application: Non-Cooperative Transmission Planning

Simple system representation:

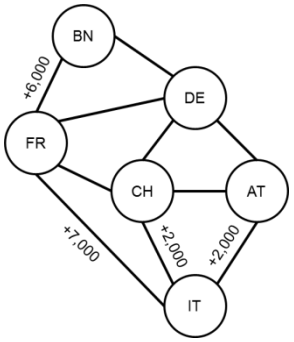
- 6 nodes / 10 cross-border lines
- 11 technologies
- 2012 quantities and price:
  - 4 x 168 hours, elasticity demand -0.25
  - Time series for renewable generation and demand
- Transmission expansion in steps of 1,000 MW



Initial Network:



System optimal:



National-strategic investment in cross-border capacity

Application: Non-Cooperative Transmission Planning

with bilateral cost sharing:

- 28 stable solutions
- avg. 79% of optimal welfare gains
- avg. 70% of optimal capacity expansion

[M€]	AT	BN	CH	DE	FR	IT
Minimum	137	-112	122	-801	475	84
Maximum	440	772	710	-293	1,451	1,139
Average	323	363	362	-559	925	703
Optimum	239	410	390	-754	1,380	985

with regional cost sharing:

- 8 stable solutions
- avg. 94% of optimal welfare gains
- avg. 117% of optimal capacity expansion

[M€]	AT	BN	CH	DE	FR	IT
Minimum	118	462	310	-837	1,164	876
Maximum	282	551	373	-690	1,378	1,051
Average	233	505	346	-786	1,286	959
Optimum	227	468	332	-754	1,356	1,021