Degrees of Coordination in Market Coupling and Counter-Trading

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Outline

1. The context: Market Integration in the European Community
2. Illustration
3. Case Study
4. Results
5. Conclusions

The context: Market Integration in the European Community

- Day ahead and real time markets:
  1. Market coupling deals with the day-ahead market;
  2. Real time is seen as a deviation management mechanism and agents are incentivised not to resort to it.
- Integration of energy and transmission:
  1. Market coupling partially integrates energy and transmission;
  2. The zonal energy market clears on an ATC representation of the network;
  3. Counter-trading takes care of the real network.
- Counter-trading:
  1. Counter-trading is operated by zonal System Operators;
  2. Without clear indication on how they coordinate.

Organisation of Cross-zonal Trade of Electricity (1)

The energy market

- Two groups of agents:
  1. Zonal (national) Power Exchanges (PXs) that clear the intra and inter zone energy markets;
  2. Zonal (national) Transmission System Operators (TSOs) that guarantee the security of the transmission system.

Market coupling concentrates on the energy market and is organized as follows:

- TSOs provide the energy market with a simplified representation of the grid;
- PXs jointly clear the energy markets taking into account this simplified representation of the grid received from the TSOs;
- PXs find the equilibrium electricity quantities and prices;
- In presence of grid congestion, electricity prices differ per zone.

- **The Regional Initiative (2006)**

  Several regions: each must remove barriers to trade;

  A challenge: Regions do not necessarily have to do the same thing but what they are doing must fit at the end (2015)!!

  A country can be part of several regions (e.g. France is part of four regions) and hence implement different systems at different borders!!

- **The third legislative package (2009)**

  Is potentially a progress
  More coordination: ACER (regulators coordinate) and ENTSO-E (grid operators coordinate). More common guidelines and codes.

- **And: allocation of grid capacities will eventually be based on Kirchhoff's laws (flow based)!!!**

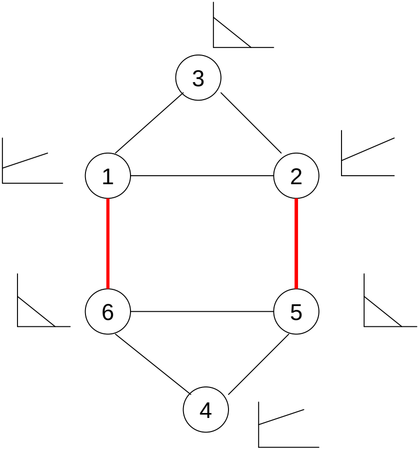
FOCUS OF THE TALK: The flows resulting from the PXs' market clearing may not be feasible for the grid:

- TSOs restore feasibility by buying and selling incremental or decremental injections at the different nodes, while maintaining the zonal electricity demand and production levels unchanged.

This operation is known as counter-trading or re-dispatching and it can be conducted with different degrees of coordination depending on the organization of the market.

The question is to assess the impact of these different degrees of coordination.

Illustration



SOURCE: Chao, H.P., S.C. Peck. 1998. Reliability Management in Competitive Electricity Markets. *Journal of Regulatory Economics*, **14**, 198-200.

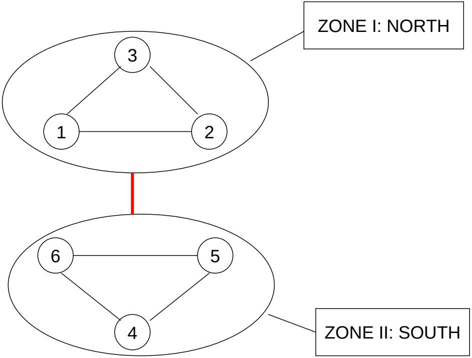
Different Degrees of Coordination

1. **Full integration of energy and transmission markets:**
   - Flowgate model: an optimization problem (Model 1)

2. **Imperfect integration of energy and transmission markets: Market Coupling and Counter-Trading**
   - National TSOs operate in a fully coordinated way: A NEP (Model 2)
   - National TSOs are not or imperfectly coordinated: GNEPs (Model 3):
     A. National TSOs have full access to all re-dispatching resources: an internal market of counter-trading resources (Model 3.1);
     B. National TSOs have only a limited access to all re-dispatching resources: a limited internal market of counter-trading resources (Model 3.2)
     C. National TSOs manage only the re-dispatching resources in their control area: national markets of counter-trading resources (Model 3.3)

Market Coupling: PX's Model

Under market coupling assumptions, the market is subdivided into two zones (North and South), controlled by a TSO each:



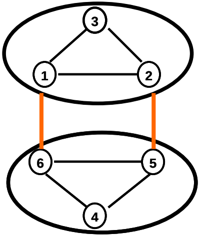
The TSOs provide this simplified representation of the network to the PXs.

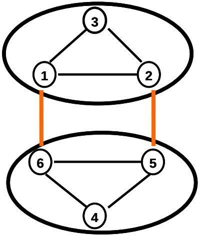
Four Models of Counter-Trading

We consider four different counter-trading organizations:

Coordinated Counter-Trading:

TSO^N and TSO^S **coordinate** counter-trading operations in their control area



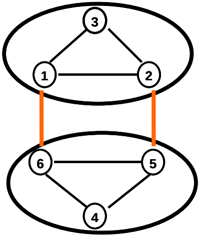


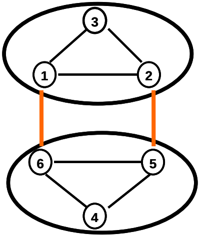
Un-coordinated Counter-Trading Case I:

Both TSO^N and TSO^S operate counter-trading **in all nodes**

Un-coordinated Counter-Trading Case II:

TSO^N operate counter-trading in its control area and have limited action in nodes 4,5,6. TSO^S does the vice-versa.





Un-coordinated Counter-Trading Case III:

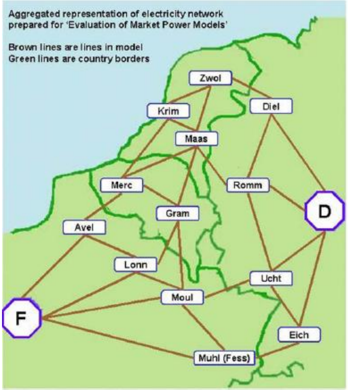
Both TSO^N and TSO^S operate counter-trading **only** in their control area.

Methodology

- From an economic point of view: lack of coordination of counter-trading is modeled as Generalized Nash Equilibrium (where the re-dispatch by a TSO constrains the re-dispatch of other TSOs);
- From a mathematical point of view: the Generalized Nash Equilibrium is modeled as a Quasi-Variational Inequality problem;
- From a numerical point of view: we sample the set of solutions through a price-directed parametrization of Variational Inequalities (Nabetani, Tseng, Fukushima (2009))

Case Study

Market coupling is currently operated between Belgium, France and the Netherlands, but it should be soon extended to Germany.



Flowgate	Reactance	Max Capacity [MW]
AVEL_LONN	22,2	2762
D_DIEL	45,9	20000
D_EICH	45,9	20000
D_ROMM	45,9	20000
D_UCHT	45,9	20000
DIEL_ROMM	69,2	1842
DIEL_ZWOL	12,2	2971
EICH_UCHT	41,3	3329
F_AVEL	45,9	20000
F_LONN	45,9	20000
F_MOUL	45,9	20000
F_MUHL	45,9	20000
GRAM_LONN	45,2	1207
GRAM_MOUL	156,5	267
KRIM_MERC	34,2	936
LONN_MOUL	27,1	1842
MAAS_GRAM	41,8	641
MAAS_KRIM	29,1	1842
MAAS_MERC	61,0	641
MERC_AVEL	55,4	898
MERC_GRAM	31,1	1842
MOUL_MUHL	38,2	3329
MUHL_EICH	11,5	1282
ROMM_MAAS	28,3	896
ROMM_UCHT	43,0	1842
UCHT_MOUL	25,4	1326
ZWOL_KRIM	33,1	1842
ZWOL_MAAS	50,0	1842

SOURCE: Energy research Centre of the Netherlands (ECN) website

Results

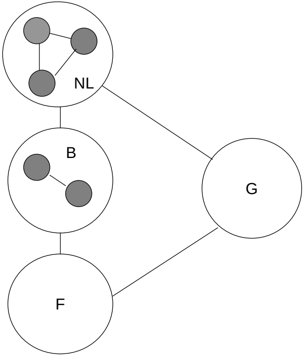
MAIN RESULTS

Considering different scenarios of the flowgate model, applied to an integrated energy and transmission market of the Central Western European market, we obtain the following results:

Demand level	Social Welfare (€)
Reference	267,124,462,455
Increase 5%	279,254,121,514
Increase 10%	291,080,340,843
Increase 20%	313,591,708,405

Table: Welfare of different flowgate model scenarios

PXs' solve a welfare maximization problem while taking into account the following stylized representation of the transmission network:



The social welfare resulting from the clearing of the energy market, before removing violations of line constraints, amounts to 267,570,731,848 €.

MAIN RESULTS

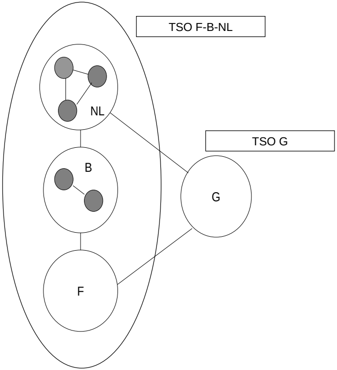
In this case, when all TSOs conduct a coordinated counter-trading, we get the following results under different energy demand scenarios:

Demand level	Total Re-dispatching costs (€/MWh)	Average Re-dispatching costs (€)	Welfare (PX) (€)
Reference	450,335,061	0.374	267,120,396,787
Increase 5%	431,283,689	0.346	279,249,137,781
Increase 10%	549,816,403	0.426	291,066,310,376
Increase 20%	321,992,912	0.240	313,589,922,952

Table: Welfare and re-dispatching costs

Welfare losses computed w.r.t. the corresponding cases of the Flowgate Model 1 are 4.8, 14 and 1.7 million €/year.

Only one TSO operates in the market. This coordinates the re-dispatching activities inside and on the interconnections of France, Belgium and the Netherlands. This market organization is depicted as follows:



MAIN RESULTS

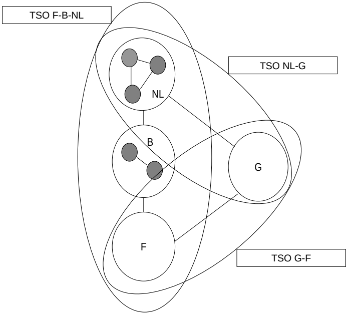
Total Re-dispatching costs (€)	**Average Re-dispatching costs (€/MWh)**	**Welfare (PX)** (€)
454,589,603	0.378	267,116,142,245

Table: Welfare and re-dispatching costs

Welfare losses amount to 4.2 and 8.3 million €/year w.r.t. the values obtained in Models 1 and 2 respectively.

Three TSOs operate in the markets:

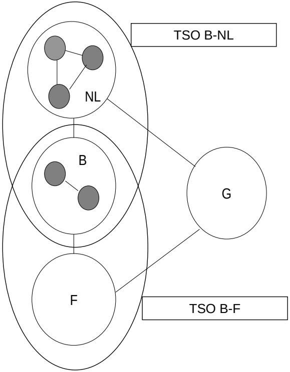
- (F-B-NL) TSO manages the re-dispatching activities in France, Belgium and the Netherlands;
- (G-NL) TSO manages the re-dispatching activities in Germany and in the Netherlands;
- (G-F) TSO manages the re-dispatching activities in Germany and in France



MAIN RESULT: one restores the efficiency of an integrated counter-trading

This model creates arbitrage possibilities between TSOs that have un-discriminatory access to common counter-trading resources. This assumption allows TSOs to implicitly coordinate their action: we fall back on the results of Model 2 where we consider an explicit coordination.

Two TSOs operate in the market. They manage congestion on the interconnection lines between France and Belgium (note as is the case between RTE (F) and Elia (B)) and Belgium and the Netherlands (as is not the case between Elia (B) and TenneT (NL)). One is the (F-B) TSO and the other is the (B-NL) TSO. They share counter-trading resources in Belgium as illustrated in the following picture:



MAIN RESULTS

Variation limits for (B-NL) TSO	Total Re-dispatching cost (€)	Average Re-dispatching costs (€/MWh)	Welfare (PX) (€)
936	454,591,481	0.377904	267,116,140,367
936*0.5	454,591,481	0.377904	267,116,140,367
936*0.1	460,145,326	0.382521	267,110,586,522

Table: (B-NL) has limited action in Belgium: degradation with respect to Model 2

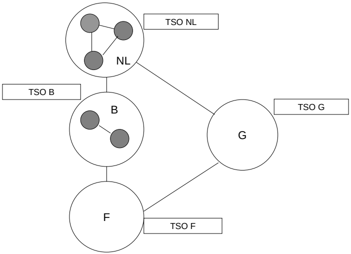
Variation limits for (F-B) TSO	Total Re-dispatching cost (€)	Average Re-dispatching costs (€/MWh)	Welfare (PX) (€)
898	454,592,586	0.377905	267,116,139,261
898*0.5	454,878,412	0.378143	267,115,853,435
898*0.1	656,384,167	0.545655	266,914,347,681

Table: (F-B) has limited action in Belgium: degradation with respect to Model 2

Welfare losses amount to 5,5 and 202 million € for the cases "936*0.1" and "898*0.1" w.r.t. Model 3.1.

An Uncoordinated Counter-Trading with Four TSOs: Model 3.4 (1)

There are four TSOs: one per each national market. None of the TSOs controls the interconnection lines:



This problem is infeasible, but feasibility can be restored with a significant investment in the grid (in practice by reducing ATC for the PXs).

MAIN RESULTS

This segmentation of the TSOs' action implies market inefficiencies as results show:

- Welfare amounts to 264,181,743,898 € (loss of 2.9 billion €/year w.r.t. the welfare of Model 1);
- High average re-dispatching costs in Belgium (4.32 €/MWh) and in the Netherlands (35.67 €/MWh);
- No re-dispatching costs in France and in Germany

Conclusions

Conclusions

1. Counter-trading can be costly: this has indeed been observed in practice e.g. ERCOT;
2. As expected the less coordination, the more costly it can be;
3. Counter-trading can even be impossible (also observed in practice (e.g. PECO, Sweden))