A Combined Merchant-Regulatory Mechanism for Electricity Transmission in Europe

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INFRADAY

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Agenda

1. **Introduction**
2. **State of the literature**
3. **Model approaches:**
    1. Cost function analysis
    2. Two part tariff model
    3. Application
4. **Conclusion**
5. **Literature**

Two Part Tariff

Vogelsang (2001) proposes the following approach:

1. The Transco should be allowed to price in a way that capacity is best utilized

2. The Transco should rise enough money to invest

$$\frac{p^t q^w + F^t N^w}{p^{t-1} q^w + F^{t-1} N^w} \leq 1 + i - X$$

p	**transmission price**	q	**transmission output**
F	**fixed fee**	N	**number of consumers**
i	**interest rate**	X	**regulatory X-factor**

→ Aim: Test the Vogelsang approach on meshed electricity networks

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Approaches to transmission investment

Long term FTRs:

- **Auction of FTRs by an ISO**
- **Participation voluntary → merchant mechanism**

e.g. Kristiansen and Rosellon (2006), Bushnell and Stoft (1997)

Regulatory approach:

- **transmission firm is regulated through benchmark regulation or price regulation**

e.g. Léautier (2000), Joskow and Tirole (2002)

Hogan-Rosellón-Vogelsang (2007) combine the merchant and regulatory approaches in an environment of price-taking generators and loads

Extension of the Vogelsang (2001) approach for meshed projects

Designed for Transcos but also applicable for ISOs

Preliminary results of the HRV profit-maximizing regulatory model show convergence to marginal-cost pricing

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General Outline

3 basic research questions:

1. Impact of loop flows on global extension cost functions
2. Implementation of the HRV regulatory model to meshed electricity networks
3. Application to an exiting network

Models are based on:

- numerical simulations using GAMS
- power flows are calculated with a DC Load Flow model based on voltage angle difference
- several scenarios have been simulated including asymmetric line costs, varying starting values

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Model formulation

Minimization of the global extension costs:

$$C(FTR) = \min_{k_i} \sum_{i,j} f_{ij}(k_{ji})$$

s.t.

$$-H * q \leq k$$ **Line capacity constraint**

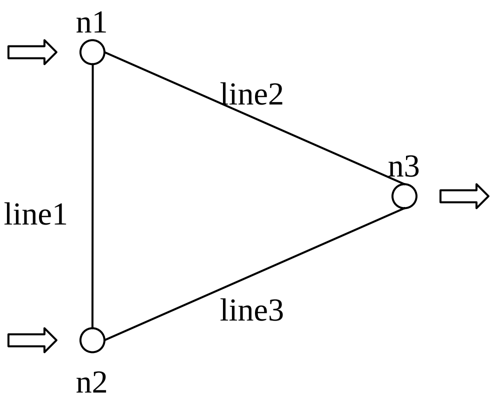
$$q = FTR * e$$ **Linkage between FTRs and net injections**

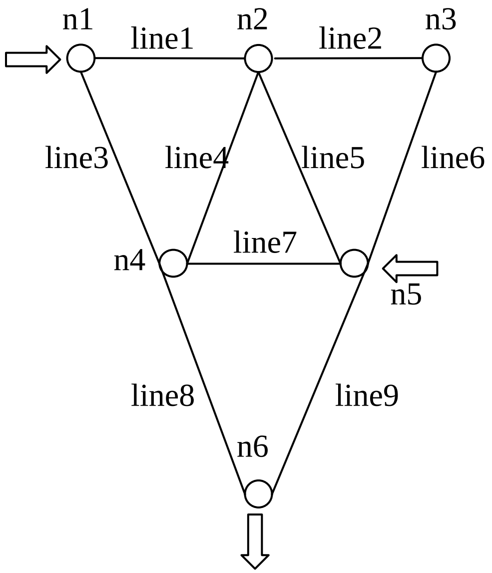
With

H	**PTDF-Matrix**	***f(k)***	**line extension cost function**
q	**net injections**	***FTR***	**FTR between two nodes**
k	**line capacities**	***e***	**vector of ones**

Data

2 basic grid settings are tested:





3 line extension functions are tested:

$$f_{ij} = a_{ij} k_{ij} + c$$

Linear extension costs

$$f_{ij} = a_{ij} k_{ij}^2 + c$$

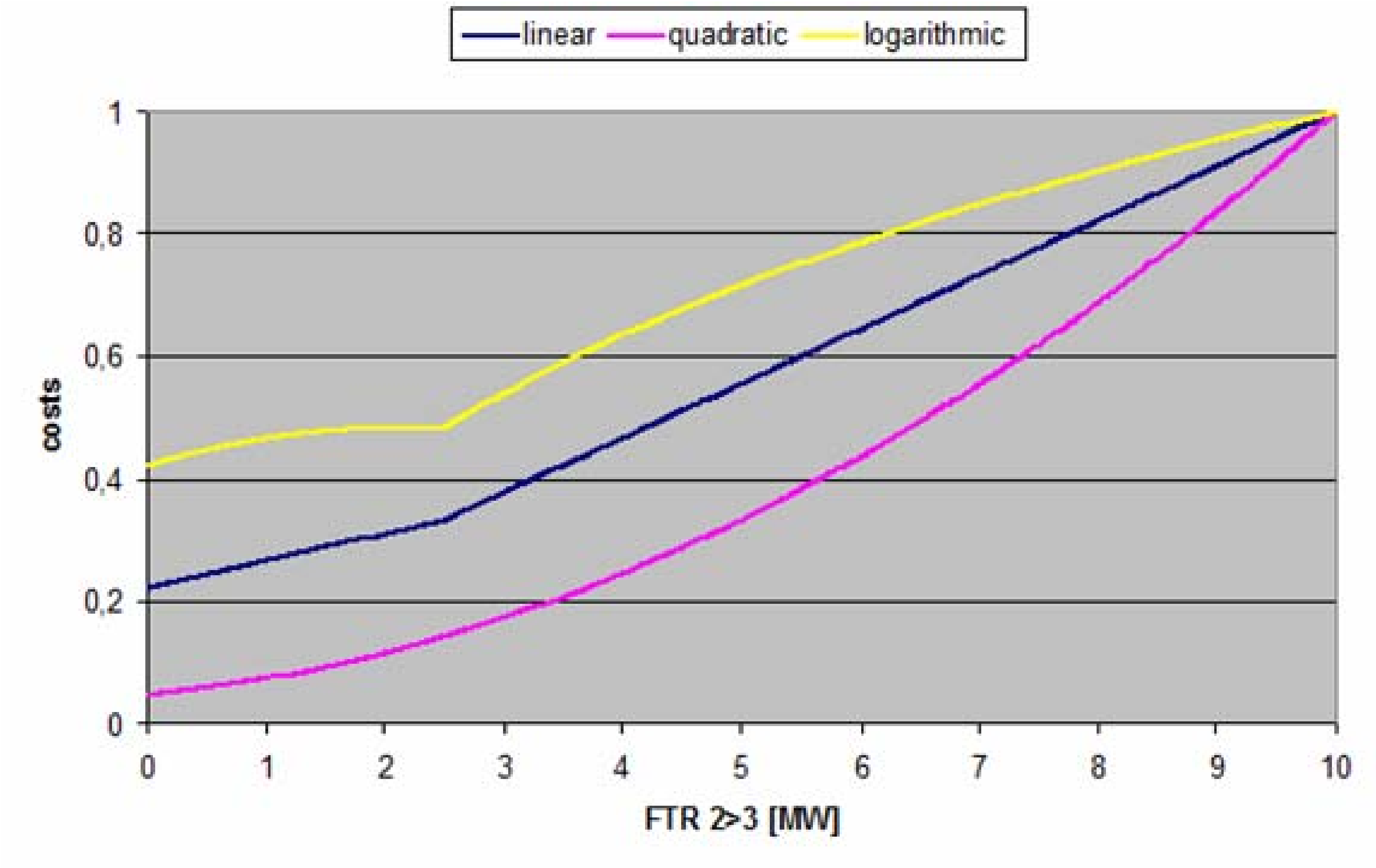
Quadratic extension costs

$$f_{ij} = \ln\left(a_{ij} + b_{ij} k_{ij}\right) + c$$

Logarithmic extension costs

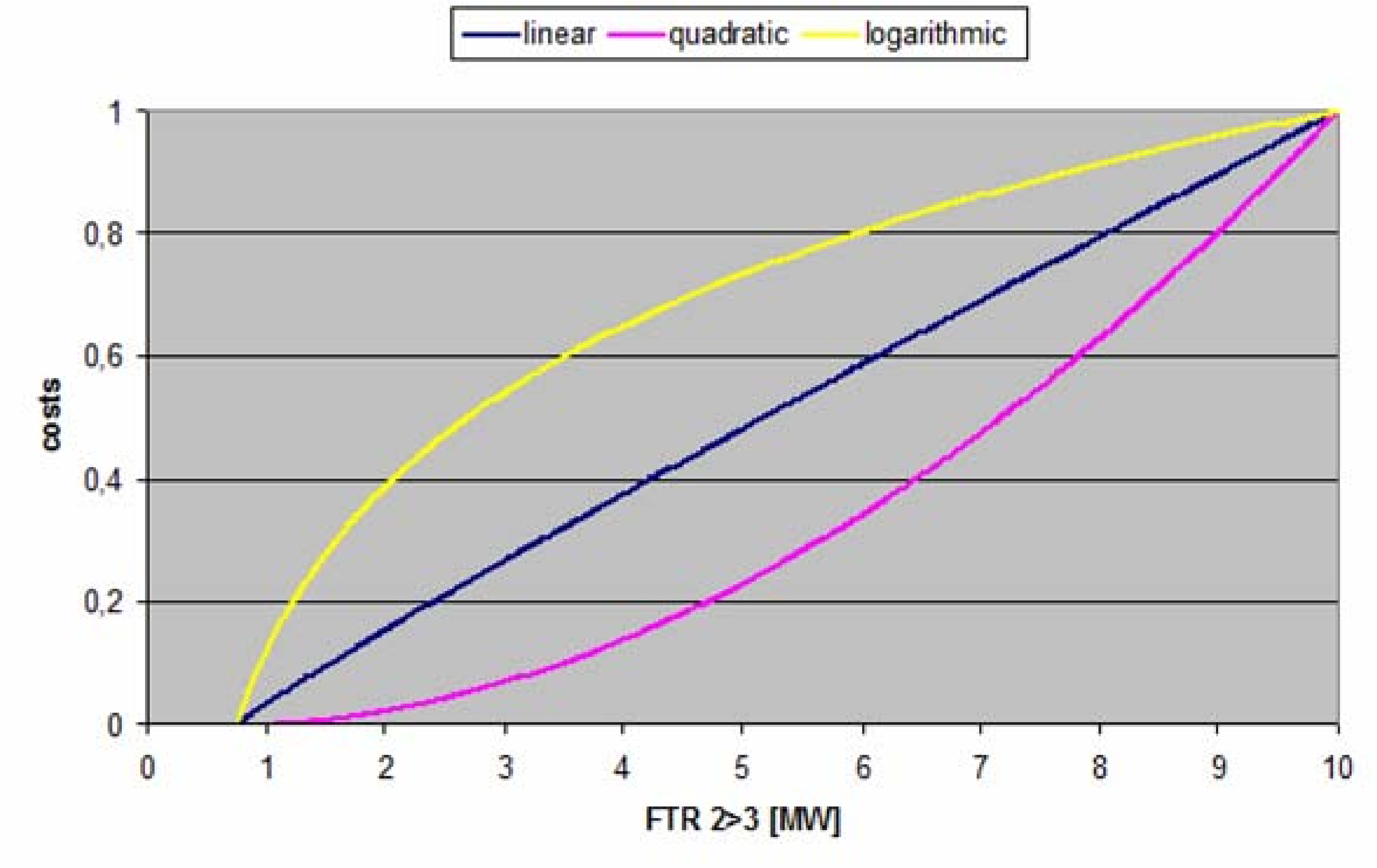
Results with fixed PTDF

Global cost function correlates to the number of loop flow lines:



Results with variable PTDF

Global cost function does not correlate to the number of loop flow lines:



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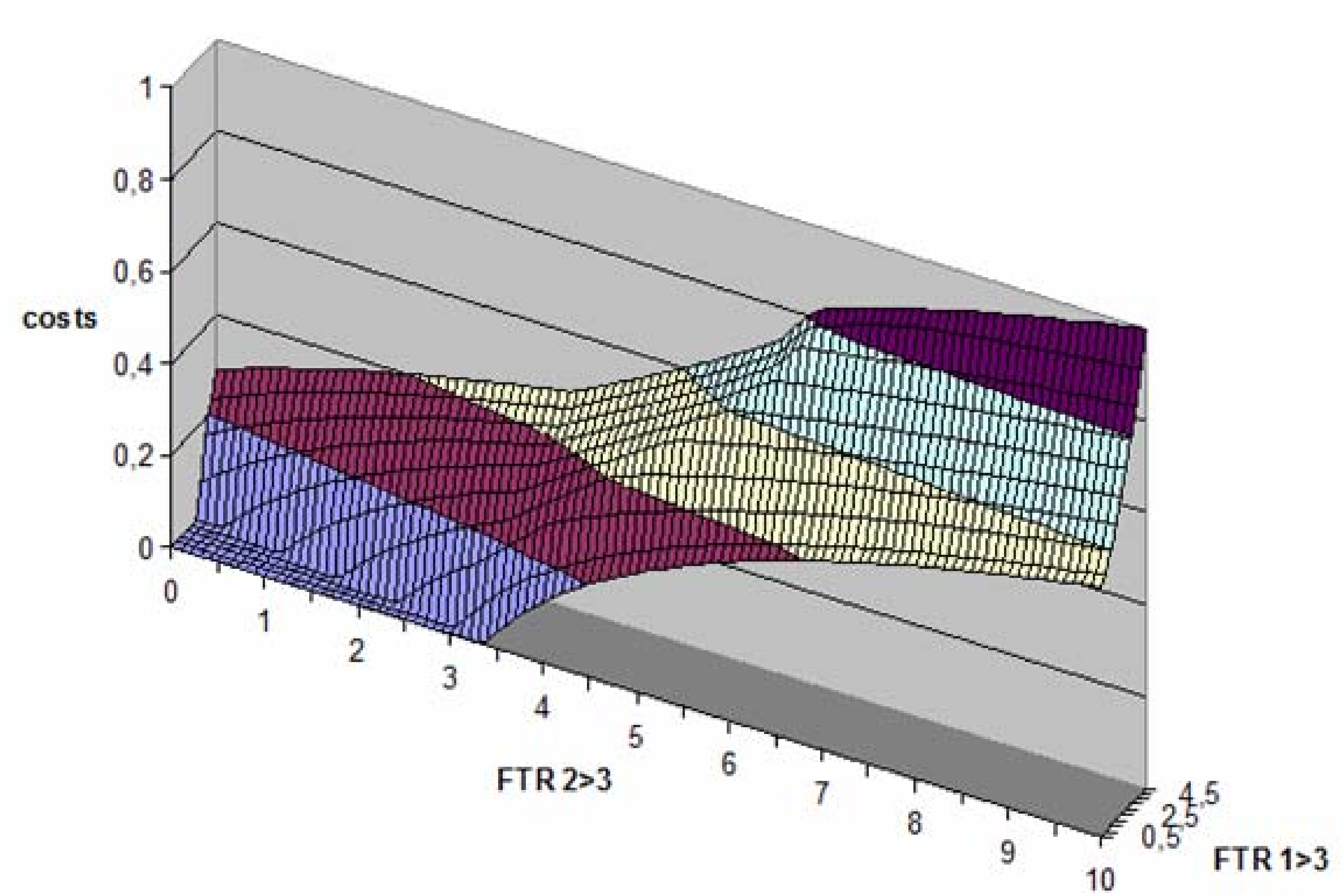
Results with variable PTDF and six nodes logarithmic extension

Shifting between different extension schemes leads to sharp slope changes



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Model formulation as MPEC

Profit maximizing Transco:

$$\max_{k,F} \quad \pi = \sum_t \Delta p_{ij}^t q_{ij}^t + F^t N^t - c\left(k_{ij}^t\right)$$

s.t.

$$\Delta p_{ij}^t q_{ij}^t + F^t N^t \leq \Delta p_{ij}^{t-1} q_{ij}^t + F^{t-1} N^t \qquad \textbf{Regulatory constraint}$$

Lower level problem:

Welfare maximization:

$$\max \ W = \sum_{n,t} \int_0^{d_{n,t}^*} p(d_{n,t}) \, \mathrm{d}d_{n,t} - \sum_{n,t} \left(c(g_{n,t}) g_{n,t} \right)$$

s.t.

Line capacity restriction $\left| P_{ij}^t \right| \leq P_{ij}^{\max}$

Energy balance $g_i^t - d_i^t - q_i^t = 0$

Plant capacity restriction $g_i^t \leq g_n^{\max}$

Results

For fixed PTDF:

• **results do not indicate a proper movement, rather a single extension resulting in one price change**

• **sensitivities (starting values, asymmetric cost functions) do not result in a continuous price movement**

→ Not accounting of discounting may bias the outcome

• **the starting value for fixed part has no influence**

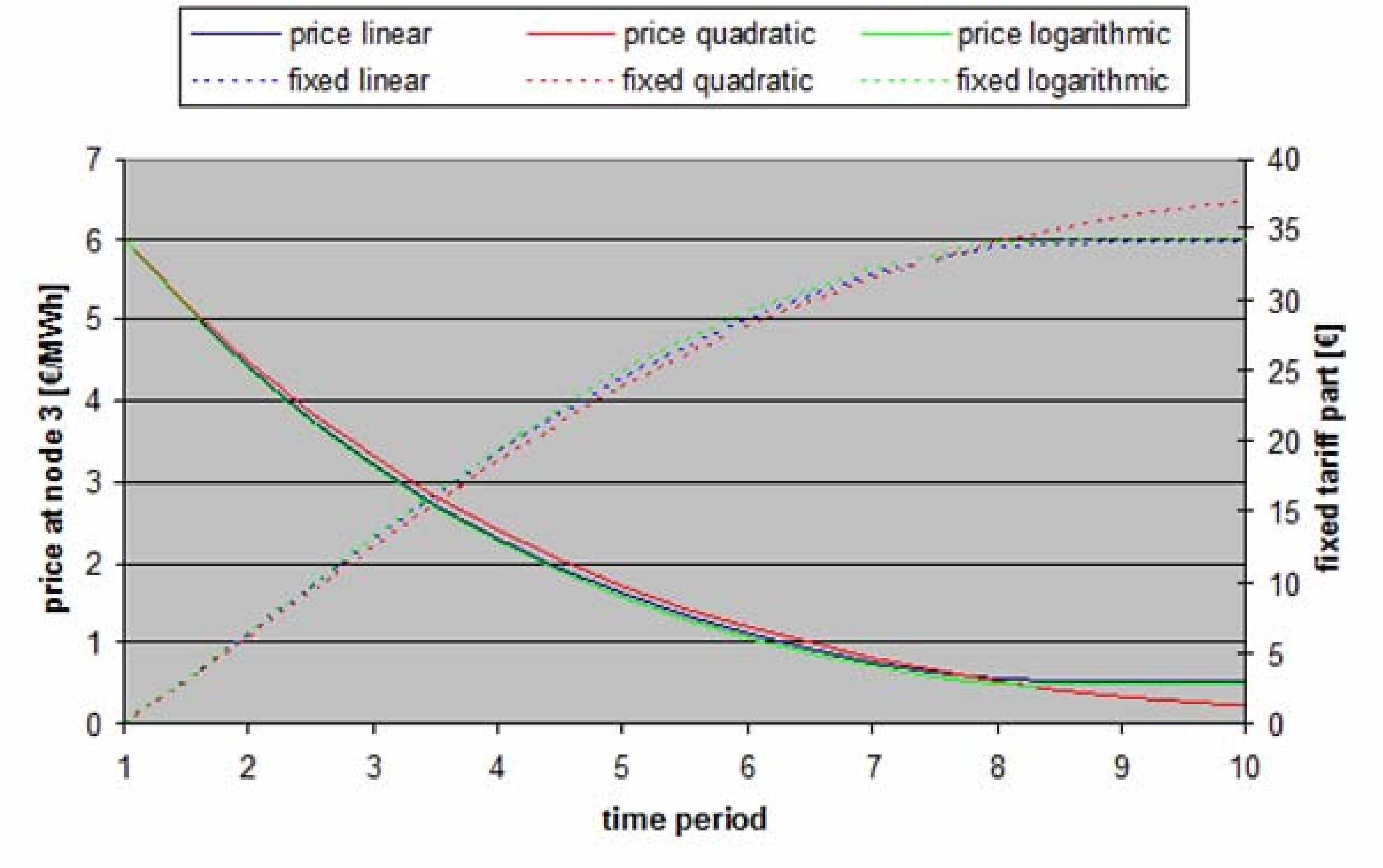
For variable PTDF:

• **continuous price movement towards marginal generation costs → continuous grid extension**

• **starting value for fixed part still irrelevant**

Results with variable PTDF

Price decrease towards marginal costs of generation



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Test Model

Simplified model of the BENELUX:

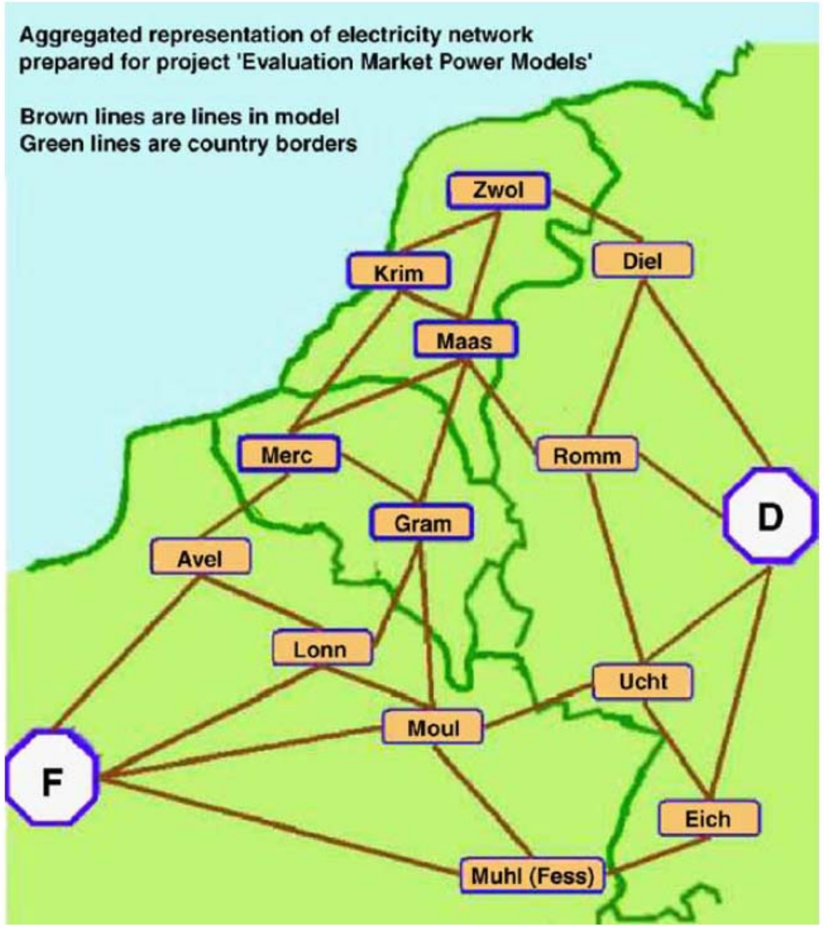
- **Covering 7 nodes and 8 auxiliary nodes**

- **Including 8 plant types (nuclear, lignite, coal, CCGT, gas/oil, hydro, pump) with fixed marginal costs**

- **Neglecting wind capacities**

- **Ten periods with fixed values for the first period**

- **Only network upgrades possible at linear extension costs of 100 € per km per MW capacity**



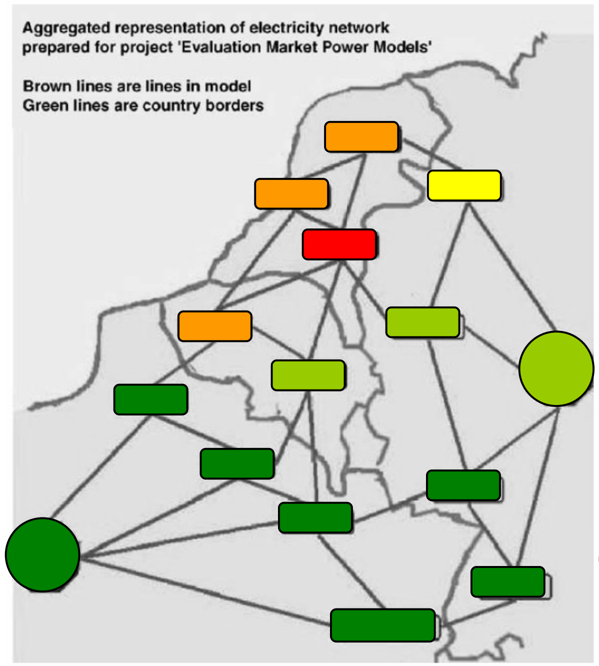
Results

Extension schedule leads to prices convergence at a level of coal units

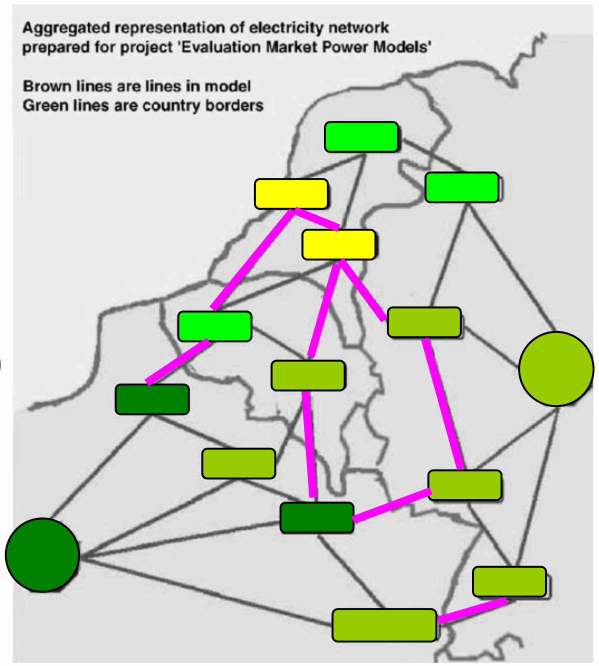
Overall welfare increases, significant profit increase for the Transco

< =15 | 15-20 | 20-25 | 25-30 | 30-40 | >=40 | Prices [€/MWh]

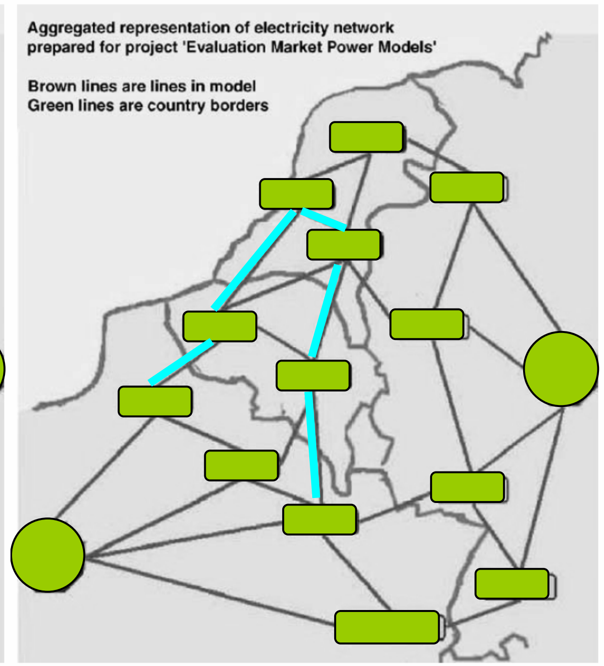
Extension between t5 and t1 | Extension between t10 and t5



t1



t5



t10

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Conclusion

• A combination of the merchant-FTR approach with the regulatory approach to electricity transmission expansion

• 3 distinguish topics (cost functions, HRV approach implementation, application)

• Develop first results towards a more detailed analysis

→ Results indicate that the two part approach may be a proper tool for fostering efficient grid extensions in meshed electricity networks

Lookout:

• Further research necessary to verify results and extend the approaches

• Additional non modeling related topics are relevant too (property rights, implementation)

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