Model-based analysis of market integration and congestion in the European gas market

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Motivation

- Potentially large investment requirements in the European gas market
  
  (1) Rising import dependency requires additional capacities
  
  (2) Third Energy Package: Improving competition requires enhancing physical market integration
  
  (3) Security of supply scares: Mitigation of risks through increased interconnection

- European Recovery Plan, Trans-European Networks, 10Year-Network Development plans by TSOs & ENTSO-G

- Lack of coherent investigation of investment requirements
Motivation

• Study initiated by European Regulators’ Group for Electricity and Gas (ERGEG), prepared by the Institute of Energy Economics at the University of Cologne (EWI):

  *Model-based Analysis of Infrastructure Projects and Market Integration in Europe with Special Focus on Security of Supply Scenarios*

• European-wide, model-based, top-down approach

*http://www.ewi.uni-koeln.de/ERGEG-Study.303.0.html*
Agenda

1. Theoretical Background

2. Model-based Approach

3. Selected Results
Literature

Capacity Valuation and Investments in Gas Markets:

- Small literature on infrastructure valuation in interconnected gas grids (Cremer/Laffont EER 2002)
- Generally based on approaches from electricity grids:
  - LMP (Schweppe 1988)
  - Congestion Pricing (Hogan, J Reg Econ 1992)
- EWI Working Paper: Extension of Cremer/Laffont approach with inclusion of temporality / storages
Simple grid with storages – Problem Setup

Welfare Optimization Problem:

\[
SW = \sum_{t=0}^{1} \frac{1}{(1+i)^t} \left[ \right.
\begin{align*}
&+ (S(d_3^{t}) - p_3(d_3^{t})d_3^{t}) \\
&+ (p_3(d_3^{t})d_3^{t} - p_1(q_1^{t})q_1^{t} - p_2(q_2^{t})q_2^{t} - c_{13}(z_{13}^{t})l_{13} - c_{21}(z_{21}^{t})l_{21} - c_{23}(z_{23}^{t})l_{23}) \\
&+ (p_1(q_1^{t})q_1^{t} - C_1(q_1^{t}) + p_2(q_2^{t})q_2^{t} - C_2(q_2^{t})) \\
&+ \left. \right] - c_{storage}(s_3) - G - H
\end{align*}
\]
Optimality conditions:

\[ P_3^t \leq P_2^t + c_{23}^{\text{transport}} + \eta_{23}^t \]

\[ P_3^{t+1} \leq (P_3^t + c_{3}^{\text{storage}})(1 + i) + \lambda \]

Shadow cost of the pipeline capacity constraint

Shadow cost of the storage capacity constraint
Application to Analysis of Transport Infrastructures

- Investigation of physical market integration / investment requirements -> Where do we identify congestion?

\[ P_B^t \leq P_A^t + c_{AB}^{\text{transport}} + \eta_{AB}^t \]

i. Capacity Constraint not binding:

\[ \eta_{AB}^t = 0 \iff P_B^t - P_A^t \leq c_{AB}^{\text{transport}} \]

ii. Capacity Constraint associated with shadow cost:

\[ \eta_{AB}^t > 0 \iff P_B^t - P_A^t > c_{AB}^{\text{transport}} \]
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European Infrastructure Model

Infrastructure: Pipes, LNG, Storages
Natural Gas Demand
Natural Gas Supply

TIGER Model Optimisation
Minimisation of Gas Supply Costs subject to infrastructure, supply and demand assumptions

Natural Gas Flows
Utilisation of Infrastructure
Locational Marginal Supply Costs

Geocoded Database:
Coverage >EU-27
>600 Nodes
European Infrastructure Model

**Geocoded Database:**
Coverage >EU-27

>600 Nodes

>900 Pipelinesections*
- Based on TSO Maps
- Capacity / Pressure / Diameter
- Nearly all Entry-Points
- Major Exit Points
- Border point capacities

*including projects
European Infrastructure Model

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>200 Storages*
- Type
- Max. injection / withdrawal
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>200 Storages*
  • Type
  • Max. injection / withdrawal
  • Working Gas Volume

>30 Terminals*
  • Max. hourly / annual capacity
  • LNG Storage Capacity

*including projects
Approach for Analysis

- Scenario(s) on gas supply / demand / infrastructures:
  - Based on data from European Commission / ERGEG / TSOs

- Scenario Variations:
  - Major Pipeline Projects (Nord Stream II, South Stream, Nabucco)
  - Relative LNG Prices: LT equilibrium vs. “LNG Glut”
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Approach for Analysis

- Computation of Locational Marginal Supply Costs
- Investigation of existence of congestion between selected nodes (pipeline routes / between countries)
Identified Congestion in Reference Scenario

Bottleneck in direction of arrow in:
- Winter (high demand)
- Winter (low demand)
- Summer
- Peak demand day
Effects of Nabucco?

Bottleneck in direction of arrow in:
- Winter (high demand)
- Winter (low demand)
- Summer
- Peak demand day
Effects of South Stream?

Bottleneck in direction of arrow in:
- Winter (high demand)
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Findings

• Generally, with all assumed infrastructure projects being included (TYNDP by TSOs), European gas market, especially in Western Europe, well integrated physically

• Some severe bottlenecks (into Denmark, Eastern Europe, especially import capacity into Hungary)

• Further congestion in Western Europe, especially into France, Belgium, Netherlands on days of very high demand due to limited peak storage capacities (and potentially very high demand volatility) there

• Nabucco and South Stream increase physical market integration in Eastern Europe significantly

• Full results on Security of Supply Simulations

  -> Study Download: http://www.ewi.uni-koeln.de/ERGEG-Study.303.0.html
Conclusion

- Theoretical framework from electricity grid analysis suitable starting point for valuation of infrastructures in gas markets

- Model-based approach with Europe-wide infrastructure model allows analysis for European gas market

- Identification of possible congestion in simulated efficient market -> possibly further congestion caused by market inefficiencies (especially congestion management and capacity allocation)

- Study focused on congestion identification -> question of efficient amount of investment? (scope for further research)
Thank you for your attention!
Selected EWI publications on natural gas topics


