Globalization of Natural Gas Markets Working Papers

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A Strategic Model of European Gas Supply

(GASMOD)

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A Strategic Model of European Gas Supply (Gasmod)

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Agenda

1. Context: The European Natural Gas Sector
2. Literature: Partial Equilibrium Gas Models
3. Model
4. Aggregation and Data
5. Results
6. Outlook
7. References
1. Context: The European Natural Gas Sector

- Liberalization and Regulation by European Commission (Acceleration Directive (2003/55/EC)) have led to changes in market structure and of the institutional framework:
  - Intensification of competition within Europe (end of “destination clause“ and of national monopolies)
  - Regulated third party access
  - Legal unbundling
- Diversification of suppliers: from current triad (Russia, Norway, Algeria) towards a larger number of exporting countries (including Libya, Egypt, Middle East and overseas LNG)
- Modeling approach to investigate two questions for the (future) European natural gas market:
  - Which countries will be important for natural gas supplies to Europe?
  - Does infrastructure influence natural gas trade, and if so which infrastructure extensions would be needed for the new market patterns to evolve?

Sources: www.hydrowingas.co.uk
www.naturalgas.org
2. Literature: Partial Equilibrium Gas Models

- **Golombek et al. (1995, 1998):**
  Effects on upstream competition of liberalized downstream markets in some European countries, producer cost function.

- **EUGAS model (e.g. Perner, 2002, Perner and Seeliger, 2003):**
  Linear optimization of European gas supply in a long term perspective (implicit assumption of competitive markets), many exogenous variables: demand, prices, indigenous production etc., takes into account infrastructure (LNG, terminals).

- **GASTALE model (e.g. Boots, Rijkers, Hobbs, 2004):**
  Double marginalization approach of two successive markets but with simplifying assumptions (e.g. symmetry of traders), linear demand function and marginal cost curves from Golombek et al. (1995), transmission and storage sector. Intention to include infrastructure.
3. Model: The Value-Added Chain in the Gas Sector

- Production
  - Natural Gas Reservoir
  - Wellhead
  - Processing Plant
  - Raw Gas Gathering System

- Transmission
  - Mainline Transmission System
  - Intra-European Transmission System

- Wholesale trade
  - International trade
  - National trade

- Large Customer
  - Intra-European customers
  - Domestic customers

- Distribution
  - Transmission (low pressure)
  - Distribution (high pressure)

- Final Customer
  - Large customers
  - Wholesale customers
  - Retail customers

Upstream Market
  - Production
  - Transmission

Downstream Market
  - Wholesale trade
  - Large Customer
  - Distribution
  - Final Customer
Model Structure

Wholesale Trader $r_{France}$

Final market $m_{France}$

Intra-EU-cap$_{r,m}$

Final market $m_{Germany}$

Wholesale Trader $r_{Germany}$

Upstream Producer $f_{Russia}$

exp-cap$_f$

cap$_{f,r}$

cap$_{f,r}$

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4. Model

- Two successive markets: upstream and downstream market
  - Producer countries upstream export to downstream traders in Europe
  - Downstream (wholesale) traders buy either imported gas or domestically produced gas
  - Traders then sell natural gas to all European countries, including their home country

⇒ Double marginalization if imperfect competition on both markets

⇒ Characteristics of double marginalization: overall welfare reducing, penalizing the upstream producer by further reducing their sales and hence their profits

Assumptions:
- Producers know the final demand addressed to the wholesale traders
- Traders are price takers of the import price set on the upstream market
Model Specification (1)

- Profit maximization program:

\[
\max_{x_{f,r}} \Pi(x_{f,r}) = \left( pe_r(X_r) - mc_{f,r} \right) x_{f,r}
\]

- FOC (assuming Cournot competition):

\[
mc_{f,r} = pe_r(X_r) + \frac{\partial pe(X_r)}{\partial x_{f,r}} \frac{X_r}{pe_r(X_r)} \frac{X_r}{pe_r(X_r)} \frac{pe_r(X_r)}{x_{f,r}}
\]

Variables:

- \( f \) exporting firm, i.e. upstream producer
- \( r \) importing firm, i.e. downstream trader (here: one firm per country)
- \( m \) final consumer market, by assumption equivalent to the importing regions
- \( mc_{f,r} \) marginal production cost of the producer \( f \) (incl. transport costs to trader \( r \))
- \( pe_r \) equilibrium import price for the trader \( r \) (border price)
- \( p0_m \) reference market price on final market \( m \)
- \( d0_m \) reference demand on final market \( m \)
- \( \theta_{f,r} \) market share of exporter \( f \) with trader \( r \)
- \( \sigma_r \) price elasticity of \( r \)
- \( x_{f,r} \) supply by exporter \( f \) to trader \( r \)
- \( y_{r,m} \) supply by trader \( r \) to end-market \( m \)
- \( domprod_r \) domestic production in European countries
Model Specification (2)

Iso-elastic demand function
(with a constant elasticity of demand):

\[ de_r = de_0 \cdot \left[ \frac{pe_r}{pe_0_r} \right]^{-\sigma_r} \]

MCP Program (solved simultaneously):

- FOC Exporters:

\[ mc_{f,r} = pe_r(x) \left( 1 + \frac{\theta_{f,r}}{\sigma_r} \right) \]

- FOC domestic producers:

\[ mc_{r,dom} = pe_r(x_{f,r}) \left( 1 + \frac{\theta_r}{\sigma_r} \right) \]

- FOC Traders:
  (taking into account the final demand)

\[ pe_r = p_0 \cdot \left( 1 + \frac{\theta_{r,m}}{\sigma_m} \right) \cdot \sqrt{\frac{y_{r,m}}{d_0_{r,m}} - t_{r,m}} \]

- Market Balance:

\[ \sum_f x_{f,r} + domprod_r = \sum_m y_{r,m} \]

+ capacity restrictions for transport and production capacities on both markets
3. Aggregation and Data

Large number of exporting and European importing countries / regions (including domestic production of each European country)

- **Exporters**: Algeria, Libya, Egypt, Iraq, Iran, Middle East (Qatar, Oman, UAE, Yemen), FSU, Norway, Netherlands, UK, Nigeria, Trinidad, Venezuela

- **Importers**: UK, Netherlands, Spain/Port, France, Italy/Switzerland, Belgium/Luxembourg, Germany, DK, Sweden/Finnland, Austria, Czech/Slovak Rep./Hungary, Former Yugoslavia, Romania/Bulgaria, Baltic, Greece, Turkey

- Preliminary assumption of one gas company per country / region

- Capacity data from GTE, OME (2001)

- Production and transport cost data (LRMC) to the EU by OME (2001)

- Trade data (flows, prices) by IEA and BP for 2003

- Assumptions on price elasticities (differing between Western and Eastern Europe, and between countries with high/low part of natural gas in energy consumption): between -0,6 and -0,75
5. Results

- 3 scenarios are compared:
  - Cournot competition on both markets
  - Perfect competition on both markets
  - Cournot competition on the upstream market, perfect competition on the downstream market (“Competition 2”)

- Two main questions to be answered:
  - Who are the – most important – exporters of natural gas to Europe?
  - Are the – limited – infrastructure capacities influencing the equilibrium quantities and which infrastructure is congested?
**Results: Export quantities**  
- more diversity!

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Cournot Competition</th>
<th>Perfect Competition</th>
<th>Competition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exports (bcm/y.)</td>
<td>Market share</td>
<td>Exports (bcm/y.)</td>
</tr>
<tr>
<td>Algeria</td>
<td>14,66</td>
<td>4,40%</td>
<td>66,00</td>
</tr>
<tr>
<td>Libya</td>
<td>4,80</td>
<td>1,44%</td>
<td>14,50</td>
</tr>
<tr>
<td>Egypt</td>
<td>5,04</td>
<td>1,51%</td>
<td>11,87</td>
</tr>
<tr>
<td>Iraq</td>
<td>0,00</td>
<td>0,00%</td>
<td>0,00</td>
</tr>
<tr>
<td>Iran</td>
<td>0,00</td>
<td>0,00%</td>
<td>10,00</td>
</tr>
<tr>
<td>Middle East</td>
<td>13,32</td>
<td>4,00%</td>
<td>26,60</td>
</tr>
<tr>
<td>Russia</td>
<td>58,79</td>
<td>17,65%</td>
<td>196,00</td>
</tr>
<tr>
<td>Norway</td>
<td>86,00</td>
<td>25,82%</td>
<td>86,00</td>
</tr>
<tr>
<td>Netherlands*</td>
<td>66,59</td>
<td>19,99%</td>
<td>0,00</td>
</tr>
<tr>
<td>UK*</td>
<td>59,41</td>
<td>17,83%</td>
<td>0,00</td>
</tr>
<tr>
<td>Nigeria</td>
<td>12,56</td>
<td>3,77%</td>
<td>22,70</td>
</tr>
<tr>
<td>Trinidad</td>
<td>11,96</td>
<td>3,59%</td>
<td>18,70</td>
</tr>
<tr>
<td>Venezuela</td>
<td>0,00</td>
<td>0,00%</td>
<td>0,00</td>
</tr>
<tr>
<td>Total</td>
<td>333,12</td>
<td>100,00%</td>
<td>452,37</td>
</tr>
</tbody>
</table>

*excluding domestic consumption

Reference exports to Europe 2003: 57,77 17,58%
Reference market share 2003: 0,75 0,23%
Exports from non-traditional producers increase

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Cournot Competition</th>
<th>Competition2</th>
<th>Reference exports to Europe</th>
<th>Reference market share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exports (bcm/y.)</td>
<td>Exports (bcm/y.)</td>
<td>Market share</td>
<td>Market share</td>
</tr>
<tr>
<td>Libya</td>
<td>4.80</td>
<td>14.50</td>
<td>1.44%</td>
<td>2.62%</td>
</tr>
<tr>
<td>Egypt</td>
<td>5.04</td>
<td>11.87</td>
<td>1.51%</td>
<td>2.15%</td>
</tr>
<tr>
<td>Iran</td>
<td>0.00</td>
<td>10.00</td>
<td>0.00%</td>
<td>1.81%</td>
</tr>
<tr>
<td>Middle East</td>
<td>13.32</td>
<td>26.60</td>
<td>4.00%</td>
<td>4.81%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>12.56</td>
<td>22.70</td>
<td>3.77%</td>
<td>4.11%</td>
</tr>
<tr>
<td>Trinidad</td>
<td>11.96</td>
<td>18.70</td>
<td>3.59%</td>
<td>3.38%</td>
</tr>
</tbody>
</table>

- Long-term contracts not considered here, geo-political and other reasons for supplies from a region not taken into account

- Formulation as oligopolistic players on the same “level” as traditional players gives traditional, large suppliers a smaller “weight” in the strategic game and reduces their market share (esp. Russia, to a lesser extent Algeria)

- Strategic withholding of traders (in Cournot scenario) reduces total exports and excludes producers with higher costs from the market (Iran)
Results: Final Consumption
- oligopolistic scenario is most likely

<table>
<thead>
<tr>
<th>Markets</th>
<th>Cournot Competition</th>
<th>Perfect Competition</th>
<th>Competition 2</th>
<th>Consumption 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>49,55</td>
<td>113,29</td>
<td>95,95</td>
<td>95,40</td>
</tr>
<tr>
<td>Netherlands</td>
<td>38,89</td>
<td>69,58</td>
<td>56,87</td>
<td>40,30</td>
</tr>
<tr>
<td>Spain/Port.</td>
<td>27,49</td>
<td>39,81</td>
<td>39,38</td>
<td>26,60</td>
</tr>
<tr>
<td>France</td>
<td>50,71</td>
<td>60,17</td>
<td>63,33</td>
<td>43,30</td>
</tr>
<tr>
<td>Italy/Switz.</td>
<td>96,05</td>
<td>115,89</td>
<td>121,09</td>
<td>73,60</td>
</tr>
<tr>
<td>Belgium/Lux.</td>
<td>16,06</td>
<td>21,31</td>
<td>21,43</td>
<td>16,00</td>
</tr>
<tr>
<td>Germany</td>
<td>100,69</td>
<td>147,41</td>
<td>138,31</td>
<td>85,50</td>
</tr>
<tr>
<td>Denmark</td>
<td>0,00</td>
<td>6,23</td>
<td>5,66</td>
<td>5,40</td>
</tr>
<tr>
<td>Sweden/Fin.</td>
<td>2,00</td>
<td>6,29</td>
<td>2,24</td>
<td>5,30</td>
</tr>
<tr>
<td>Austria</td>
<td>11,94</td>
<td>15,46</td>
<td>14,59</td>
<td>9,40</td>
</tr>
<tr>
<td>Poland</td>
<td>12,61</td>
<td>17,63</td>
<td>16,17</td>
<td>11,20</td>
</tr>
<tr>
<td>CSH</td>
<td>26,25</td>
<td>41,76</td>
<td>36,45</td>
<td>28,80</td>
</tr>
<tr>
<td>Balkan</td>
<td>9,73</td>
<td>10,05</td>
<td>10,53</td>
<td>7,69</td>
</tr>
<tr>
<td>Bulg./Rom.</td>
<td>13,29</td>
<td>29,23</td>
<td>28,94</td>
<td>20,90</td>
</tr>
<tr>
<td>Baltic</td>
<td>0,00</td>
<td>3,30</td>
<td>5,70</td>
<td>5,04</td>
</tr>
<tr>
<td>Greece</td>
<td>2,34</td>
<td>3,70</td>
<td>3,61</td>
<td>2,30</td>
</tr>
<tr>
<td>Turkey</td>
<td>0,00</td>
<td>33,60</td>
<td>33,09</td>
<td>20,90</td>
</tr>
<tr>
<td>TOTAL</td>
<td>457,62</td>
<td>734,71</td>
<td>693,36</td>
<td>497,64</td>
</tr>
</tbody>
</table>

In bcm per year

- Cournot Scenario confirms base year patterns for most countries and for total Europe
- exception: UK where Competition scenario(s) fit(s) most
- Final consumption in Perfect Competition Scenario(s) unrealistically high
- Surprising results of no gas consumption in Denmark, the Baltic States and Turkey due to model formulation and data insufficiencies (transport capacities)
Results: Capacity bottlenecks
- mainly for intra-European trade

- France → Spain
- UK ↔ Continent
- Norway → Europe
- Between BL, NL, GER and Fr
6. Conclusions

- Gasmod confirms certain results observed in reality, e.g. that natural gas markets are characterized by an oligopolistic structure, where prices significantly deviate from long-run marginal costs.

- Competition on the European downstream market leads to higher quantities (and thus lower prices) for the European consumer, close to the scenario of perfect competition on both markets.

- Substantial changes in market shares can be expected: “globalisation” of European natural gas supply with increasing supplies from non-traditional producers.

- Infrastructure capacity constraints do influence the natural gas trade, especially within Europe.
Globalization of Natural Gas Markets

Research Program “Global Gas”:

http://www.tu-dresden.de/wwbwleeg/projekte/gg/gg.html

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cvh@mailbox.tu-dresden.de

c kemfert@diw.de
Selected References


OME, 2001: Assessment of internal and external gas supply options for the EU - Evaluation of the supply costs of new natural gas supply projects to the EU and an investigation of related financial requirements and tools, Observatoire Méditerranéen de l’Energie.
