What Drives Natural Gas Prices?

- A Structural VAR Approach -

Enerday Conference I 19th April I Sebastian Nick I Stefan Thoenes
Agenda

1. Research Questions
2. Methodological Approach
3. The Model
4. Results
5. Illustrative Examples
6. Conclusion
Research Questions

What are the fundamental drivers of natural gas prices?

Which price movements can be assigned to supply shocks?

- Liberalized wholesale market
- Decline in oil-indexation
- Significant supply shocks

NCG Day-Ahead Price

EUR/MWh

0 5 10 15 20 25 30 35 40

02.01.2008 02.01.2009 02.01.2010 02.01.2011 02.01.2012

NCG Day Ahead in EUR/MWh
Methodology: Requirements and Choice

Characteristics of German Gas Market

- Interdependencies between gas prices, storages, LNG, substitution among alternative commodities
- Exogenous shocks both on supply and demand side of the market

Required Model Features

- Modelling of the interaction among various variables (no a priori assumptions of exogeneity)
- Simulation of one-off impacts (via multiplier)

Vector Autoregressive Model (VAR) as proposed by Sims (1980)

\[
\begin{align*}
    y_{1t} &= v + A_{11}y_{1t-1} + \ldots + A_{1p}y_{1t-p} + u_{1t} \\
    y_{nt} &= v + A_{n1}y_{1t-1} + \ldots + A_{np}y_{nt-p} + u_{nt}
\end{align*}
\]

Instantaneous Interaction reflected in reduced form errors:

\[
\sum_{i=1}^{j=n} \text{cov}(u_{it}, u_{jt}) \neq 0
\]

- Lack of economic interpretation
- Need for structural representation

Impulse Response Analysis and Forecast Error Variance Decomposition
The Model: Data

<table>
<thead>
<tr>
<th>Fundamental Influence</th>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature induced demand shocks</td>
<td>HDD-deviation from historical average</td>
<td>GMS (DWD)</td>
</tr>
<tr>
<td>Supply shortfalls</td>
<td>Gas volumes not available to the EU</td>
<td>Own calculation</td>
</tr>
<tr>
<td>Business cycle</td>
<td>Brent Spot Crude Price</td>
<td>EIA</td>
</tr>
<tr>
<td>Fuel-substitution</td>
<td>ARA Spot Coal Price</td>
<td>McCloskey</td>
</tr>
<tr>
<td>Global market integration</td>
<td>LNG-Imports of EU-27</td>
<td>Eurostat</td>
</tr>
<tr>
<td>Flexibility in demand and supply</td>
<td>Deviation from historical changes in utilization rates</td>
<td>Gas Storage Europe</td>
</tr>
<tr>
<td>German natural gas price</td>
<td>NCG Day Ahead Price</td>
<td>EEX</td>
</tr>
</tbody>
</table>

Sample period: January 2008 – June 2012
Frequency: Weekly
→ 228 observations for each series
Results: Impulse Response Analysis

Figure 1: Responses of the Natural Gas Price
Results: Impulse Response Analysis

• Storage flows adjust quickly to changing market conditions
• Hypothesis of competitive storage operation can not be rejected
## Results: Forecast Error Variance Decomposition

<table>
<thead>
<tr>
<th>Forecast Horizon</th>
<th>HDD Dev.</th>
<th>Supply Shortfall</th>
<th>Crude Price</th>
<th>Coal Price</th>
<th>LNG</th>
<th>Storage</th>
<th>Gas Price</th>
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<tbody>
<tr>
<td>1</td>
<td>0.26</td>
<td>0.08</td>
<td>0.00</td>
<td>0.15</td>
<td>0.03</td>
<td>0.24</td>
<td>0.24</td>
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<tr>
<td>2</td>
<td>0.23</td>
<td>0.05</td>
<td>0.00</td>
<td>0.17</td>
<td>0.03</td>
<td>0.26</td>
<td>0.25</td>
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<td>4</td>
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<td>0.07</td>
<td>0.00</td>
<td>0.22</td>
<td>0.03</td>
<td>0.26</td>
<td>0.26</td>
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<tr>
<td>8</td>
<td>0.11</td>
<td>0.06</td>
<td>0.02</td>
<td>0.33</td>
<td>0.02</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>12</td>
<td>0.09</td>
<td>0.05</td>
<td>0.07</td>
<td>0.39</td>
<td>0.02</td>
<td>0.19</td>
<td>0.19</td>
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<td>26</td>
<td>0.05</td>
<td>0.02</td>
<td>0.30</td>
<td>0.37</td>
<td>0.02</td>
<td>0.12</td>
<td>0.12</td>
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<tr>
<td>52</td>
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<td>0.02</td>
<td>0.39</td>
<td>0.26</td>
<td>0.01</td>
<td>0.14</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Enerday | 19th April 2013 | Sebastian Nick**
Illustrative Example I: Russian-Ukrainian Crisis


Notes: Week 1 refers to the week ending on Friday 1/9/2009
Notes: Week 1 refers to the week ending on Friday 9/19/2008. The price increase in week 17 reflects the beginning of the Russian-Ukrainian gas dispute in January 2009.
Illustrative Example II: February 2012 Cold Spell

Notes: Week 1 refers to the week ending on Friday 1/27/2012
Conclusions

What are the fundamental drivers of natural gas prices in Germany?

• In the short-run, gas price crucially affected by weather conditions
• Gas prices in medium-term horizon driven by business cycle and cross-commodity effects: Coal prices (at least) equally important as crude prices
• Evidence of efficient storage operations (i.e. smoothing prices)

Which price movements can be assigned to supply shocks?

• Price impact of supply shocks may be overestimated since major shares of price spikes in the respective periods can be accounted for by demand sided variables

Further Research

• Extension to a European scale / other national gas hubs
• Enrich the model with more accurate data on LNG-imports
Thank you for participation!

Any Questions or Remarks?

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Appendix
Previous Econometric Research on Gas Prices

Two main branches of research:

1) Oil-Gas price relation
   Caveat:
   • Low explanatory power in the short-run
   
   2) Alternative Price Determinants
   Mu (2007)
   Brown and Yücel (2008)
   
   Caveat:
   • Exogeneity assumptions → inconsistent with liberalized and efficient gas markets

Crude Oil and Natural Gas Spot Prices

Econometric framework that allows a more realistic approach on gas price determinants
Methodology: SVAR and Structural Analysis

Structural VAR-Representation

\[ Ay_t = v + A^*_1 y_{t-1} + \ldots + A^*_p y_{t-p} + \varepsilon_t \]

Structural MA-Representation

\[ y_t = \sum_{i=0}^{\infty} \theta_i \varepsilon_{t-i} \]

- Allows for an economic analysis, since instantaneous correlation is accounted for by \( A \)
- However, \( A \) has to be identified (see e.g. Lütkepohl (2005))

Impulse Response Analysis

- \( \theta_i \rightarrow \) elements can be interpreted as responses of the system to structural innovations
- the \( jk \)-th element of \( \theta_i \) represents the effect on variable \( j \) of a shock in the \( k \)-th variable that has occurred \( i \) periods ago

Forecast Error Variance Decomposition

\[ \omega_{jk,h} = \sum_{i=0}^{h-1} \theta^2_{jk,i} / MSE[y_{j,t}(h)] \]

with \( MSE[y_{j,t}(h)] = \sum_{i=0}^{h-1} \theta^2_{jk,i} \)
The Model: Methodological Challenges

**Challenge**
- Different regressors in reduced-form equations
- Weak finite sample properties of irf-standard errors

**Approach**
- Estimation via FGLS
- Bootstrap of confidence bands
The Model: Identification

<table>
<thead>
<tr>
<th></th>
<th>HDD Dev.</th>
<th>Supply Shortfall</th>
<th>Crude Price</th>
<th>Coal Price</th>
<th>LNG</th>
<th>Storage</th>
<th>Gas Price</th>
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</thead>
<tbody>
<tr>
<td>HDD Dev.</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Supply Shortfall</td>
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<td>*</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Crude Price</td>
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<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coal Price</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>*</td>
</tr>
<tr>
<td>LNG</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Storage</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Gas Price</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Notes: Each row of this table indicates an equation in the VAR model with the respective variable as dependent variables and each column indicates the instantaneous impact of the variable in each equation. The * denotes that a parameter is estimated from the data and that the model allows for an instantaneous relationship, while a 0 indicates that the according parameter is restricted to zero.
## The Model: Lagged Restrictions

<table>
<thead>
<tr>
<th></th>
<th>HDD Dev.</th>
<th>Supply Shortfall</th>
<th>Crude Price</th>
<th>Coal Price</th>
<th>LNG</th>
<th>Storage</th>
<th>Gas Price</th>
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<td>0</td>
<td>0</td>
</tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>Crude Price</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>*</td>
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<tr>
<td>Coal Price</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>*</td>
</tr>
<tr>
<td>LNG</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Storage</td>
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<td>*</td>
<td>*</td>
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<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Gas Price</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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</table>

*Notes:* Each row of this table indicates an equation in the VAR model with the respective variable as dependent variables and each column indicates the instantaneous impact of the variable in each equation. The * denotes that a parameter is estimated from the data and that the model allows for an instantaneous relationship, while a 0 indicates that the according parameter is restricted to zero.
Illustrative Example III: Libyan Civil War

Impact of the Libyan Supply Shortfall on the Natural Gas Price in Spring 2011

Notes: Week 1 refers to the week ending on Friday 2/18/2011
Appendix: Data

Deviation From Historical Heating Degree Days

Supply Shortfall

Brent Crude Oil Price

Coal Price

Detrended LNG Supply

Storage

Natural Gas Price
Appendix: Impulse Responses

[Graphs showing impulse responses for LNG, storage, and gas price, with axes for time in weeks and various shocks as variables.]
The Model: Construction of Storage Variable

Objective:
Capture only flows that short-term price sensitive

Utilization

Deviation from Historical Average (%-points)

Utilization - Historical Average (left y-axis)
Utilization - Actual (left y-axis)
Utilization - Deviation from Historical Average (right y-axis)

Change in Utilization (%-points)

Change in Utilization - Historical Average
Change in Utilization - Actual
Change in Utilization - Deviation from Historical Average
Appendix: Calculation of Supply Shortfall 2009


Appendix: Calculation of Supply Shortfall 2011


Proceeding:

Linear interpolation of Libyan exports to Italy

\[ \downarrow \]

Shut equals difference to pre-crisis level
### Appendix: Calculation of Supply Shortfall 2012

#### Table A.5: Summary of Sources for the Russian Supply Shortfall in February 2012

<table>
<thead>
<tr>
<th>Source</th>
<th>Publication Date</th>
<th>Time Period</th>
<th>Affected Location</th>
<th>Supply Disruption</th>
<th>Original Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJ Tradenews</td>
<td>02/02/12</td>
<td>01/31/12</td>
<td>Europe</td>
<td>1.5% less</td>
<td>Gazprom Employee</td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>E.ON Ruhrgas, Germany</td>
<td>None</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>Italy</td>
<td>11.6% less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>Italy, Poland, Slovakia</td>
<td>8% to 10% less</td>
<td>Oettinger, European Commission</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>Hungary, Czech Republic</td>
<td>Less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>RWE Supply &amp; Trading, Germany</td>
<td>30% less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>OMV, Hub Baumgarten, Austria</td>
<td>Less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/03/12</td>
<td>Wingas, Germany</td>
<td>30% less expected</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>PGNiG, Poland</td>
<td>7% less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>E.ON Ruhrgas, Germany</td>
<td>Approximately one third less</td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>Austria</td>
<td>30% less</td>
<td>Speaker of Günther Oettinger, European Commission</td>
<td></td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>Italy</td>
<td>24% less</td>
<td>Speaker of Günther Oettinger, European Commission</td>
<td></td>
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<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>Poland</td>
<td>8% less</td>
<td>Speaker of Günther Oettinger, European Commission</td>
<td></td>
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<tr>
<td>DJ Tradenews</td>
<td>02/06/12</td>
<td>Currently</td>
<td>Italy, Greece, Austria, Poland, Slovakia, Hungary, Bulgaria, Romania, Germany, Romania, Italy</td>
<td>Less</td>
<td>Speaker of Günther Oettinger, European Commission</td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/07/12</td>
<td></td>
<td>Bulgaria, Slovakia, Hungary, Poland, Austria, Greece, Europe</td>
<td>No disruptions</td>
<td>Speaker of Günther Oettinger, European Commission</td>
</tr>
<tr>
<td>DJ Tradenews</td>
<td>02/08/12</td>
<td>Previous week</td>
<td>Europe</td>
<td>15% less</td>
<td>Alexander Medvedev, Gazprom</td>
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<tr>
<td>DJ Tradenews</td>
<td>02/13/12</td>
<td></td>
<td>E.ON Ruhrgas, RWE and Wingas, Germany, Europe</td>
<td>Less deliveries, but rising</td>
<td>Company</td>
</tr>
<tr>
<td>ICIS Heren</td>
<td>02/15/12</td>
<td>Beginning of February</td>
<td>GDF Suez, France</td>
<td>About 10% below contractual levels</td>
<td>Gazprom</td>
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<tr>
<td>EGM</td>
<td></td>
<td>02/06/12</td>
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<td>30% less</td>
<td>Company</td>
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<tr>
<td>ICIS Heren</td>
<td>02/15/12</td>
<td>Beginning of February</td>
<td>GDF Suez, France</td>
<td>20% less</td>
<td>Company</td>
</tr>
<tr>
<td>EGM</td>
<td></td>
<td></td>
<td>Slovakia</td>
<td>8% to 10% less</td>
<td>Company</td>
</tr>
<tr>
<td>ICIS Heren</td>
<td>02/15/12</td>
<td>01/31/12</td>
<td>SPP, Slovakia</td>
<td>36% less</td>
<td>Company</td>
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<td>EGM</td>
<td></td>
<td></td>
<td>Europe</td>
<td>No disruptions anymore</td>
<td>Alexander Medvedev, Gazprom</td>
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<td>EGM</td>
<td></td>
<td></td>
<td>Snam Rete Gas</td>
<td></td>
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<td>Henderson and Heather (2012)</td>
<td>April 2012</td>
<td></td>
<td></td>
<td></td>
<td>schnaidergas.com</td>
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