Market Arbitrage:
European and North American Natural Gas Prices

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Henry Hub and NBP Prices
Henry Hub and WTI Prices
NBP and Brent Prices
Does LNG facilitate arbitrage across the Atlantic?

- Movements of natural gas prices in Europe and North America are linked to each other
- Movements of natural gas prices on both sides of the Atlantic are linked to those for crude oil
- Our econometric tests: is co-movement of natural gas prices is mediated through crude oil prices?
The Data

- **Weekly data**: June 13, 1997 - May 9, 2008
- **Natural Gas**: Henry Hub (United States) and National Balancing Point (United Kingdom)
- **Crude Oil**: WTI (United States) and Brent (Northern Europe)

- All four price series are difference stationary.
- HH is cointegrated with NBP, WTI and Brent.
- NBP is cointegrated with HH, Brent and WTI.
Bivariate Causality Testing
(error-correction models)

HH ← NBP
HH ← WTI
HH ← BRENT

NBP ← HH
NBP ← WTI
NBP ← BRENT
Multivariate Causality Testing

• Henry Hub
  – WTI and NBP as explanatory variables
  – Brent and NBP as explanatory variables

• NBP
  – WTI and HH as explanatory variables
  – Brent and HH as explanatory variables
## Multivariate Causality Testing

<table>
<thead>
<tr>
<th>explanatory variables</th>
<th>Significance of Joint F-tests $^\dagger$</th>
<th>Significance of Joint F-tests $^\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH lags</td>
<td>0.0533</td>
<td>0.1284</td>
</tr>
<tr>
<td>NBP lags &amp; CI$_{HH,NBP}$</td>
<td>0.0723</td>
<td>0.1284</td>
</tr>
<tr>
<td>WTI lags &amp; CI$_{HH,WTI}$</td>
<td>0.0207</td>
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<tr>
<td>Brent lags &amp; CI$_{HH,Brent}$</td>
<td></td>
<td>0.2151</td>
</tr>
<tr>
<td>Optimal Lags</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>$R^2=.07$ Adj $R^2=.04$</td>
<td>$R^2=.05$ Adj $R^2=.03$</td>
<td></td>
</tr>
<tr>
<td>Significance of Overall F-Statistic: 0.0005 $^\dagger$</td>
<td>Significance of Overall F-Statistic: 0.0166 $^\dagger$</td>
<td></td>
</tr>
</tbody>
</table>
Multivariate Causality Testing

<table>
<thead>
<tr>
<th>explanatory variables</th>
<th>Significance of Joint F-tests‡</th>
<th>Significance of Joint F-tests‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBP lags</td>
<td>0.0029</td>
<td>0.0083</td>
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<tr>
<td>HH lags &amp; CI_{HH,NBP}</td>
<td>0.7015</td>
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<tr>
<td>WTI lags &amp; CI_{NBP,WTI}</td>
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<tr>
<td>Brent lags &amp; CI_{NBP,Brent}</td>
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<td>0.2430</td>
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<tr>
<td>Optimal Lags</td>
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</tr>
</tbody>
</table>

\[ \text{R}^2 = 0.11 \quad \text{Adj R}^2 = 0.09 \]

Significance of Overall F-Statistic: 0.0000‡

\[ \text{R}^2 = 0.10 \quad \text{Adj R}^2 = 0.08 \]

Significance of Overall F-Statistic: 0.0000‡
Multivariate Causality Testing

• Henry Hub
  – with WTI in the model, NBP is marginally significant
  – with Brent in the model, NBP is insignificant

• NBP
  – with WTI in the model, HH is insignificant
  – with Brent in the model, HH is insignificant
Exogenous Variables Affecting Henry Hub

- Heating degree days
- Deviations from normal heating degree days
- Cooling degree days
- Deviations from normal cooling degree days
- U.S. natural gas storage
- Shut-in production in the Gulf of Mexico.
Multivariate Causality Testing with exogenous variables

<table>
<thead>
<tr>
<th>explanatory variables</th>
<th>Dependent Variable</th>
<th>HH</th>
<th>NBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBP lags</td>
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<td>0.0653</td>
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<tr>
<td>HH lags</td>
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<td>0.1597</td>
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<tr>
<td>HH lags &amp; CI_{HH,NBP}</td>
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<td>0.3158</td>
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<tr>
<td>NBP lags &amp; CI_{HH,NBP}</td>
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<tr>
<td>WTI lags &amp; CI_{HH,WTI}</td>
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<td>0.0000</td>
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<tr>
<td>WTI lags &amp; CI_{NBP,WTI}</td>
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<td>0.0376</td>
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<tr>
<td>Exogenous Variables</td>
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<tr>
<td>Exogenous Variables, HH lags &amp; CI_{HH,NBP}</td>
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<td>0.1450</td>
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<tr>
<td>Optimal Lags</td>
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<td>4</td>
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</tr>
</tbody>
</table>

R^2 = .18  Adj R^2 = .15  Significance of Overall F-Statistic: 0.0000⁷
R^2 = .13  Adj R^2 = .10  Significance of Overall F-Statistic: 0.0000⁷
Multivariate Causality Testing with exogenous variables

• Henry Hub
  – With WTI and the exogenous variables in the model, NBP is insignificant

• NBP
  – With WTI and the exogenous variables in the model, HH is insignificant
Conclusions

• Bivariate testing shows coordinated movement of HH and NBP

• Natural gas prices on both sides of the Atlantic adjust to crude oil prices in an error-correction process

• Multivariate testing shows coordinated movement of HH and NBP may be mediated through crude oil prices

• The extensive pricing of LNG against crude oil in Europe could statistically reinforce the relationship between crude oil and natural gas prices