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"To a trader the presence of good liquidity in a market signifies an important reassurance that he is not alone, that he will be able to find a counterparty when he needs to adjust his position, that the bid to offer price spread will be manageable and that the reference or index price used in that market is credible."

"[...] Indeed strong liquidity is the very best evidence of a robust wholesale market in a commodity (such as electricity or gas),[...] the very best guarantor of efficiently selected and correctly priced sources of supply for consumers."

Peter Styles, Chairman of Electricity Committee at European Federation of Energy Traders (EFET). 14 February 2013⁴

In Search of Liquidity

Figure: Monthly NBP traded volumes and churn ratio. Source data: Ofgem
In Search of Liquidity
"If the job has been correctly done when a common stock is purchased, the time to sell it is – almost never."

– Philip Fisher

*Common Stocks and Uncommon Profits* (1958), John Wiley & Sons, Inc. (Eds. 2003), p.113
Liquidity encompasses a number of transactional properties of markets (Kyle, 1985)
Liquidity is a cost carried by investors to complete a transaction,

yet

Lack of liquidity creates market instability and inefficiencies

Dark Side of Liquidity
Market Microstructure Theory

Field of research devoted to the economics of securities markets, including the measurement and identification of the determinants of liquidity and transactions costs, and their implications for the efficiency and regulation of trading mechanisms and market structures. (NBER 5)

5 http://www.nber.org/workinggroups/mm/mm.html
Market Microstructure Theory

Transaction costs:

- Order processing costs
- Inventory costs
- Asymmetric-information costs
- Linked to transactional properties of markets, i.e. to liquidity
Inventory costs (Demsetz, 1968):

- Inventory risk
- Immediacy

[e.g. Stoll (1978), Amihud and Mendelson (1980), Amihud and Mendelson (1986), Grossman and Miller (1988)]
Asymmetric-information costs (O’Hara, 1995):

“[…] reflect a balancing of losses to the informed with gains from the uninformed.” (p. 54)

[e.g. Bagehot (1971), Garman (1976), Glosten and Milgrom (1985), Easley and O’Hara (1987), Stoll (1989)]
Market Microstructure Theory

⇒ Trading activity is the way information on asset fair value is disseminated in a market:

- provides price signals

- can reduce market liquidity temporarily (inventory costs) and may move asset prices permanently (asymmetric-informational costs)

Liquidity Measures and Statistic/Econometric approaches to:

- Transactional properties of markets
  - (i) spread (tightness)
    [e.g. Goyenko et al. (2009)]
  - (ii) price impact (depth, resilience)
    [e.g. Goyenko et al. (2009)]
  - (iii) inventory costs and asymmetric-information costs of liquidity
    [e.g. Roll (1984), Huang and Stoll (1997), Goyenko et al. (2009)]

- Price pressure
  [e.g. Pastor and Stambaugh (2003), Hasbrouck (2009)]

- Relationships between liquidity and prices, price volatility and trading activity
  [e.g. Hasbrouck (1991), Dufour and Engle (2000), Chordia et al. (2005)]
Liquidity and Market Microstructure in Financial Markets

(i) Does liquidity change over time?
[e.g. Kyle (1985), Easley and O’Hara (1987), Huang and Stoll (1997), Goyenko et al. (2009)]

(ii) Which are the relative contributions of transaction costs to liquidity?
[e.g. Huang and Stoll (1997), Chordia et al. (2001)]

(iii) What is the impact of trading activity on prices?
[e.g. Easley and O’Hara (1987), Pastor and Stambaugh (2003), Hasbrouck (2009), Evans and Lyons (2002), Banti et al. (2012)]

(iv) What are the determinants of liquidity and the associations between liquidity, prices, price volatility and trading activity?
[e.g. Bessembinder (1994), Chordia et al. (2005), Danielsson and Payne (2012)]
(i) *Does liquidity change over time?*
*Europe? Natural gas markets? Evolution?*

(ii) *Which are the relative contributions of transaction costs to liquidity?*
[Marshall et al. (2012)]
*European energy markets?*

(iii) *What is the impact of trading activity on prices?*

(iv) *What are the determinants of liquidity and the associations between liquidity, prices, price volatility and trading activity?*
By adopting the perspective of the financial market microstructure theory and a time-varying approach, this research assesses:

- Evolution of liquidity:
  - Liquidity measurement
  - Relative contributions of transaction costs

- Impact of trading activity on prices

- Drivers of liquidity

in the **NBP forward market**
One-month-ahead (1MA) NBP forward contracts (Source: Tullett Prebon Information)

Tick-by-tick indicative quotes (bid and ask), and transaction prices and volumes, May 2010-December 2014

After cleaning: $T=78,019$

Resampling: 60-minutes; $T=10,580$ or 1,058 trading days/10 daily observations

Deseasonalized and detrended data: Focus on the irregular component of the time series
Liquidity Measurement: Tightness

Measures of spread

Effective half spread \( \tau = D_{\tau} \left( \frac{P_{\tau} - M_{\tau}}{M_{\tau}} \right) \) (1)

Realized half spread \( \tau = D_{\tau} \left( \frac{P_{\tau} - M_{\tau+1}}{M_{\tau}} \right) \) (2)

\( P_{\tau} = \text{transaction price at trading time } \tau \)
\( M_{\tau} = \text{midquote (average bid and ask quotes)} \)
\( M_{\tau+1} = \text{midquote after the transaction} \)
\( D_{\tau} = \text{trade indicator (1 buyer-initiated, -1 seller-initiated, Lee and Ready (1991))} \)
Liquidity Measurement: Depth and Resilience

Measure of price impact

\[ \text{Price impact}_\tau = D_\tau \left( \frac{M_{\tau+1} - M_\tau}{M_\tau} \right) \]

Effective half spread\(_\tau\) – Realized half spread\(_\tau\)

\[ \Rightarrow \text{Effective half spread} = \]

Inventory costs + Asymmetric-information costs

Effective half spread \(\Rightarrow\) More reliable in OTC markets
Three-way decomposition of transaction costs

\[ D_t = \varphi D_{t-1} + \eta_t \quad (4) \]

\[ r_t = \gamma \Delta D_t + (\alpha + \beta) \gamma D_t - \alpha \gamma \varphi D_{t-1} + \varepsilon_t \quad (5) \]

\[ r_t = \log \left( \frac{P_t}{P_{t-1}} \right) \text{ over 60-minute intervals} \]

\[ D_t = \pm 1 \]

\[ \gamma \Rightarrow \text{order-processing costs} \]

\[ \alpha \Rightarrow \text{asymmetric-information costs} \]

\[ \beta \Rightarrow \text{inventory costs} \]
Impact of Trading Activity on Prices

Price pressure \( r_{n,t} = \lambda_n S_{n,t} + u_{n,t} \) \hspace{1cm} (6)

\[
\begin{align*}
    r_{n,t} &= \log \left( \frac{P_{n,t}}{P_{n,t-1}} \right) \text{ over 60-minute intervals} \\
    S_{n,t} &= \sum_{\tau} D_{n,t,\tau} \sqrt{v_{n,t,\tau}}, \text{ measure of order flow}
\end{align*}
\]

\( \lambda_n \) estimated over \( N=5,581 \) rolling windows of size \( m=5,000 \) and increments of 1 period \( (N = T - m + 1, \text{ with } T=10,580) \)

\( \Rightarrow \frac{1}{\lambda_n} \) is a time-varying measure of market depth
Drivers of Liquidity

Structural VAR models

\[ V_t = \sum_{i=1}^{p} \alpha_{V,i} V_{t-i} + \sum_{i=1}^{p} \beta_{V,i} R_{t-i} + \sum_{i=1}^{p} \gamma_{V,i} |R|_{t-i} + \sum_{i=1}^{p} \delta_{V,i} S_{t-i} + \varepsilon_{V,t} \]

\[ R_t = \sum_{i=0}^{p} \alpha_{R,i} V_{t-i} + \sum_{i=1}^{p} \beta_{R,i} R_{t-i} + \sum_{i=1}^{p} \gamma_{R,i} |R|_{t-i} + \sum_{i=1}^{p} \delta_{R,i} S_{t-i} + \varepsilon_{R,t} \]

\[ |R|^t = \sum_{i=0}^{p} \alpha_{|R|,i} V_{t-i} + \sum_{i=1}^{p} \beta_{|R|,i} R_{t-i} + \sum_{i=1}^{p} \gamma_{|R|,i} |R|_{t-i} + \sum_{i=1}^{p} \delta_{|R|,i} S_{t-i} + \varepsilon_{|R|,t} \]

\[ S_t = \sum_{i=0}^{p} \alpha_{S,i} V_{t-i} + \sum_{i=0}^{p} \beta_{S,i} R_{t-i} + \sum_{i=0}^{p} \gamma_{S,i} |R|_{t-i} + \sum_{i=1}^{p} \delta_{S,i} S_{t-i} + \varepsilon_{S,t} \]

\( V_t = T_{V,t}, \ T_{N,t} \) or \( T_{OF,t} \), trading activity (volume, \# of trades, order flow)
\( R_t = \log \left( \frac{P_t}{P_{t-1}} \right) \), transaction price returns
\( |R_t| = abs \left[ \log \left( \frac{P_t}{P_{t-1}} \right) \right] \), price volatility
\( S_t = | \log \left( \frac{P_t}{M_t} \right) | \), effective half-spread
Drivers of Liquidity

**Structural VAR models**

- Generalized impulse response functions (IRFs)
- Forecast error variance decompositions (FEVDs)
Figure: Unadjusted (top) and adjusted (bottom) effective spread (blue), realized spread (red) and price impact (green)
Liquidity Measurement of 1MA NBP Forward Market

Figure: Effective spread (top), realized spread (left) and price impact (right) monthly medians
**Table: Descriptive statistics**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Q^{25}</th>
<th>Median</th>
<th>Q^{75}</th>
<th>(\rho_1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective spread</td>
<td>0.311</td>
<td>0.222</td>
<td>0.173</td>
<td>0.262</td>
<td>0.393</td>
<td>0.397***</td>
</tr>
<tr>
<td>Realized spread</td>
<td>0.171</td>
<td>0.185</td>
<td>0.078</td>
<td>0.145</td>
<td>0.237</td>
<td>0.156***</td>
</tr>
<tr>
<td>Price impact</td>
<td>0.140</td>
<td>0.146</td>
<td>0.059</td>
<td>0.112</td>
<td>0.196</td>
<td>0.189***</td>
</tr>
</tbody>
</table>

**Table: Spearman’s rank correlation coefficients**

<table>
<thead>
<tr>
<th></th>
<th>Effective spread</th>
<th>Realized spread</th>
<th>Price impact</th>
<th># of trades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realized spread</td>
<td>0.533***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price impact</td>
<td>0.421***</td>
<td>-0.394***</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of trades</td>
<td>-0.003</td>
<td>0.107***</td>
<td>-0.113***</td>
<td></td>
</tr>
<tr>
<td>Trading volume</td>
<td>0.031</td>
<td>0.135***</td>
<td>-0.114***</td>
<td>0.729***</td>
</tr>
</tbody>
</table>
Relative Contributions of Transaction Costs to 1MA NBP Liquidity

Table: Three way-decomposition of transaction costs

<table>
<thead>
<tr>
<th></th>
<th>Coeff</th>
<th>SE</th>
<th>t-Stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>0.237***</td>
<td>0.007</td>
<td>34.06</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.147*</td>
<td>0.086</td>
<td>1.703</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.505***</td>
<td>0.087</td>
<td>5.820</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>0.269***</td>
<td>0.037</td>
<td>7.248</td>
</tr>
</tbody>
</table>

Adjusted $R^2$ 0.132
Impact of Trading Activity on Prices

Figure: Price pressure $\lambda_n \pm 2\ SE$ (top) and order flow (bottom)
Drivers of 1MA NBP Liquidity: IRFs

**Figure:** Impulse response functions: Trading activity, returns, their volatility and liquidity
Drivers of 1MA NBP Liquidity: IRFs

**Figure:** Impulse response functions: Trading activity, returns, their volatility and liquidity
### Table: Percent of k-Step Ahead FEVD of Spread

<table>
<thead>
<tr>
<th>$k$</th>
<th>Volume</th>
<th>Returns</th>
<th>Volatility</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.115</td>
<td>0.052</td>
<td>8.141</td>
<td>91.69</td>
</tr>
<tr>
<td>2</td>
<td>0.150</td>
<td>0.054</td>
<td>8.324</td>
<td>91.47</td>
</tr>
<tr>
<td>8</td>
<td>0.177</td>
<td>0.098</td>
<td>8.411</td>
<td>91.31</td>
</tr>
<tr>
<td>16</td>
<td>0.200</td>
<td>0.098</td>
<td>8.532</td>
<td>91.17</td>
</tr>
<tr>
<td>24</td>
<td>0.200</td>
<td>0.140</td>
<td>8.780</td>
<td>90.88</td>
</tr>
<tr>
<td>$\infty$</td>
<td>0.200</td>
<td>0.154</td>
<td>8.875</td>
<td>90.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$k$</th>
<th># of trades</th>
<th>Returns</th>
<th>Volatility</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.452</td>
<td>0.053</td>
<td>8.085</td>
<td>91.41</td>
</tr>
<tr>
<td>2</td>
<td>0.478</td>
<td>0.054</td>
<td>8.263</td>
<td>91.21</td>
</tr>
<tr>
<td>8</td>
<td>0.536</td>
<td>0.099</td>
<td>8.337</td>
<td>91.03</td>
</tr>
<tr>
<td>16</td>
<td>0.544</td>
<td>0.099</td>
<td>8.449</td>
<td>90.91</td>
</tr>
<tr>
<td>24</td>
<td>0.532</td>
<td>0.141</td>
<td>8.689</td>
<td>90.64</td>
</tr>
<tr>
<td>$\infty$</td>
<td>0.527</td>
<td>0.155</td>
<td>8.774</td>
<td>90.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$k$</th>
<th>Order flow</th>
<th>Returns</th>
<th>Volatility</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.129</td>
<td>0.055</td>
<td>8.095</td>
<td>91.72</td>
</tr>
<tr>
<td>2</td>
<td>0.125</td>
<td>0.057</td>
<td>8.275</td>
<td>91.54</td>
</tr>
<tr>
<td>8</td>
<td>0.135</td>
<td>0.101</td>
<td>8.362</td>
<td>91.40</td>
</tr>
<tr>
<td>16</td>
<td>0.133</td>
<td>0.101</td>
<td>8.485</td>
<td>91.28</td>
</tr>
<tr>
<td>24</td>
<td>0.137</td>
<td>0.144</td>
<td>8.732</td>
<td>90.99</td>
</tr>
<tr>
<td>$\infty$</td>
<td>0.139</td>
<td>0.160</td>
<td>8.830</td>
<td>90.87</td>
</tr>
</tbody>
</table>
Drivers of 1MA NBP Liquidity: FEVDs

**Table:** Percent of $k$-Step Ahead FEVD of *Volatility*

<table>
<thead>
<tr>
<th>$k$</th>
<th>Volume</th>
<th>Returns</th>
<th>Spread</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.647</td>
<td>0.143</td>
<td>8.137</td>
<td>89.07</td>
</tr>
<tr>
<td>2</td>
<td>2.625</td>
<td>0.209</td>
<td>8.464</td>
<td>88.70</td>
</tr>
<tr>
<td>8</td>
<td>2.611</td>
<td>0.239</td>
<td>8.560</td>
<td>88.59</td>
</tr>
<tr>
<td>16</td>
<td>2.582</td>
<td>0.304</td>
<td>8.878</td>
<td>88.24</td>
</tr>
<tr>
<td>24</td>
<td>2.557</td>
<td>0.299</td>
<td>9.010</td>
<td>88.13</td>
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<tr>
<td>$\infty$</td>
<td>2.553</td>
<td>0.307</td>
<td>9.086</td>
<td>88.05</td>
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</table>

<table>
<thead>
<tr>
<th>$k$</th>
<th># of trades</th>
<th>Returns</th>
<th>Spread</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.556</td>
<td>0.139</td>
<td>7.881</td>
<td>86.42</td>
</tr>
<tr>
<td>2</td>
<td>5.500</td>
<td>0.204</td>
<td>8.201</td>
<td>86.09</td>
</tr>
<tr>
<td>8</td>
<td>5.471</td>
<td>0.235</td>
<td>8.297</td>
<td>86.00</td>
</tr>
<tr>
<td>16</td>
<td>5.420</td>
<td>0.297</td>
<td>8.606</td>
<td>85.68</td>
</tr>
<tr>
<td>24</td>
<td>5.340</td>
<td>0.293</td>
<td>8.733</td>
<td>85.63</td>
</tr>
<tr>
<td>$\infty$</td>
<td>5.332</td>
<td>0.300</td>
<td>8.809</td>
<td>85.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$k$</th>
<th>Order flow</th>
<th>Returns</th>
<th>Spread</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.031</td>
<td>0.145</td>
<td>8.318</td>
<td>91.51</td>
</tr>
<tr>
<td>2</td>
<td>0.036</td>
<td>0.209</td>
<td>8.649</td>
<td>91.11</td>
</tr>
<tr>
<td>8</td>
<td>0.036</td>
<td>0.241</td>
<td>8.746</td>
<td>90.98</td>
</tr>
<tr>
<td>16</td>
<td>0.035</td>
<td>0.307</td>
<td>9.068</td>
<td>90.59</td>
</tr>
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<td>24</td>
<td>0.035</td>
<td>0.302</td>
<td>9.201</td>
<td>90.46</td>
</tr>
<tr>
<td>$\infty$</td>
<td>0.037</td>
<td>0.312</td>
<td>9.277</td>
<td>90.37</td>
</tr>
</tbody>
</table>
Main Findings and Implications

- Transaction costs led by inventory costs
  - Flexibility in hedging and portfolios’ re-balancing
  - Equity option markets “ [...] *We do not add inventory cost risk because this is a much smaller component of the bid and ask spread than asymmetric-information costs*” (Engle and Neri, 2010)
  - Principally affecting smaller players

- Time-varying price pressure
  - Market conditions
  - Changing hedging demand and storage evaluation (Felix et al., 2013)
  - Efficiency and transparency

- Vicious liquidity/volatility cycle
  - Liquidity is endogenous, i.e. asset/market determined
  - Price risk exposure and risk premia (ACER, 2015; Martínez and Torró, 2016)
  - Market quality
Contributions

- Costs of liquidity $\Rightarrow$ Unrecoverable from churn ratio and bid-ask spread

- $\lambda_n$ $\Rightarrow$ Measure of depth and efficiency in physical markets

- Relevance for understanding the impact of liberalization and hubs development (GTM metrics)
"Overall traded volumes saw double-digit growth at most EU gas hubs in 2016[...]. Interestingly, increased hub liquidity in 2016 was also influenced by an upward trend in price volatility”.

(ACER/CEER Annual Report on the Results on Monitoring the Internal Natural Gas Markets in 2016 - Assessment of the functioning of EU gas hubs: AGTM market participants’ needs benchmarks, p.24-25) ⁶

Figure 8: Day-ahead gas prices and price volatility evolution in selected EU hubs – 2013 – 2016

Source: ACER based on Platt's and ICIS Heren.

What are the implications of different levels of hubs liquidity for EU gas markets integration?

- Is the efficiency of illiquid hubs questionable?
- Can illiquidity further foster market frictions?
Price Convergence at European Gas Hubs: 1MA

Figure: State-space models\textsuperscript{7}

\textsuperscript{7}Russo, M. European Natural Gas Markets Integration and the Relationship between Natural Gas and Crude Oil Markets, \textit{Working Paper}. 
Price Convergence at European Gas Hubs: DA

Figure: State-space models\(^7\)

\(^7\)Russo, M. European Natural Gas Markets Integration and the Relationship between Natural Gas and Crude Oil Markets, *Working Paper*. 
THANK YOU


