Price Dispersion in OTC Markets: A New Measure of Liquidity

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Outline

Research problem
Theoretical model
Data description
Results
Microstructure of OTC markets

• Importance of over-the-counter (OTC) markets: Real estate, bond (Treasury and corporate), most new derivative markets etc.

• Microstructure of OTC markets is different from exchange-traded (ET) markets.

• Lack of a centralized trading platform: Trades are result of bilateral negotiations → Trades can take place at different prices at the same time.

• Search costs for investors and inventory costs for broker-dealers (and information asymmetry).

• Challenges of assembling market-wide data.

• Important issues of illiquidity, in crises such as the present credit crisis.
Research Questions

• In the presence of search costs for traders and inventory costs for dealers: how are prices determined in an OTC market?

• What determines price dispersion effects, i.e., deviations between the transaction prices and their relevant market-wide valuation?

• How does price dispersion capture illiquidity in such markets?

• How is the “hit rate” – the proportion of transactions within the average quoted bid-ask spread – related to illiquidity?
Literature Review

• Price quote determination in a inventory cost setting:

• Price determination in an asymmetric information setting:

• OTC markets:

• Liquidity effects in Corporate Bond Markets
  – Edwards et al. (2007), Chen et al. (2007), Mahanti et al. (2008)
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Market Microstructure Model

• There are $i$ assets, $i = 1,2\ldots I$, and a continuum of dealers of measure $J$. $j$ indexes the type of the agent.

• Competitive dealers face inventory costs and quote bid and ask prices depending on their desired inventory levels.

• Several investors, who have exogenously given buying and selling needs, trade with the dealers.

• Investors have to directly contact dealers to observe their price quotes (“telephone market”).

• Investors face search costs every time they contact a dealer, before they can trade.
The Dealer’s Decision

- Denote by $s_{i,j}$ the inventory of asset $i$ with dealer of type $j$.
- Each dealer faces inventory holding costs $H$ that are convex in the absolute quantity held, given by $H = H(s)$. Independent across assets.
- The marginal holding cost of adding a unit is approximated by $h = H'(s)$.
- Each trade incurs a marginal transaction cost function $f^a$ and $f^b$.
- Since the dealership market is competitive:
  \begin{align*}
  \text{ask: } p^a_{i,j} &= m_{i,j} + f^a(h(s_{i,j})) \\
  \text{bid: } p^b_{i,j} &= m_{i,j} - f^b(h(s_{i,j}))
  \end{align*}
- The market’s expectation of the price of asset $i$ is defined by $m_i = E(m_{i,j})$. 
The Investor’s Decision

- An investor wishes to execute a buy-trade of one (infinitesimal) unit.
- The investor has contact with one dealer and is offered an ask price $p_{a,0}$.
- The investor faces search cost $c$ for contacting an additional dealer; thus, she evaluates the marginal cost and benefit of doing so.
- Garbade and Silber (1976) show that the investor will buy the asset at $p_{a,0}$ if this price is lower than his reservation price $p^a$.
- The reservation price solves:

$$
c = \int_{0}^{p^a} (p^a - x) g^a (x) dx
$$

where $g^a(.)$ is the density function for the ask price when contacting an arbitrary dealer.
Price Dispersion and “Hit Rate”

• Assumption for inventory holding distribution:
  – Uniformly distributed with mean zero (zero net supply)
  – Support from $-S$ to $+S$, independent across assets

• Assumption for cost functions:
  \[ f^a = \gamma - h(s) \quad \text{and} \quad f^b = \gamma + h(s) \]

• Assumption for the holding costs:
  \[ H = \alpha s^2/4 \quad \rightarrow \quad h = \alpha s/2 \]

• Assumption for the fixed trading cost:
  \[ \gamma = \alpha S/2 \]

• Solving for the reservation prices for a trader gives:
  \[ p^a^* = m + (2c\alpha S)^{0.5} \quad \text{and} \quad p^b^* = m - (2c\alpha S)^{0.5} \]

• Ask and bid prices, when contacting a dealer are uniformly distributed with supports $[m; m+\alpha S]$ and $[m; m-\alpha S]$
Graphical depiction of solution – zero net inventory

Range of quotes

Range of transacted prices

Average Bid-ask spread

$P_b^l = m - \alpha S$

$P_b^* = m - \sqrt{2\alpha}cS$

$E(P_b)$

$m$

$E(P_a)$

$P_a^h = m + \alpha S$

$P_a^* = m + \sqrt{2\alpha}cS$
Price Dispersion and “Hit Rate”

• Based on this setup, the dispersion of transacted prices $p_k$ from the market’s valuation, $m$, have a mean zero and variance equal to:

$$E(p_k - m)^2 = \begin{cases} 
(2/3) c\alpha S \text{ if } c \leq \alpha S/2 \\
(1/3) \alpha^2 S^2 \text{ if } c > \alpha S/2
\end{cases}$$

• Percentage of trades that fall within the median quote (hit-rate) can be derived:

$$HR = \begin{cases} 
50\% \text{ if } c > \alpha S/2 \\
\frac{\sqrt{\alpha S}}{2\sqrt{2c}} \text{ if } \alpha S/8 \leq c \leq \alpha S/2 \\
100\% \text{ if } c < \alpha S/8
\end{cases}$$
Liquidity Measure

• Based on the model we propose the following new liquidity measure for bond $i$ on day $t$:

$$d_{i,t} = \sqrt{\frac{1}{\sum_{j=1}^{N_{i,t}} V_{i,j,t}} \cdot \sum_{j=1}^{N_{i,t}} (p_{i,j,t} - m_{i,t})^2 \cdot V_{i,j,t}}$$

where

- $N_{i,t}$ … number of transactions, for bond $i$ on day $t$
- $p_{i,j,t}$ … transaction price for $j = 1$ to $N_{i,t}$, for bond $i$ on day $t$
- $V_{i,j,t}$ … trade volume $j = 1$ to $N_{i,t}$, for bond $i$, trade $j$, on day $t$
- $m_{i,t}$ … market-wide valuation, for bond $i$ on day $t$

• Intuition behind the measure: Sample estimate of the price dispersion using all trades within a day.
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Data for the Present Study

- Time period: October 2004 to October 2006

US bond market data from three sources:
- TRACE: all transaction prices and volumes
- Markit: average market-wide valuation each trading day
- Bloomberg: closing bid/ask quotes at the end of each trading day
- Bloomberg: bond characteristics

→ 1,800 bonds with 3,889,017 transactions:
  - Dollar denominated
  - Fixed coupon or floating rate
  - Bullet or callable repayment structure
  - Issue rating from Standard & Poor’s, Moody’s or Fitch
  - Traded on at least 20 days in the selected time period
Data for the Present Study

• Selected bonds represent:
  – 7.98% of all US corporate bonds
  – 25.31% (i.e., $1.308 trillion) of the total amount outstanding
  – 37.12% of the total trading volume

• Available bond characteristics:
  – Coupon, maturity, age, amount issued, issue rating, and industry

• Available trading activity variables:
  – trade volume, number of trades, bid-ask spread and depth (i.e., number of major dealers providing information to Markit)
Data for the Present Study

• Trading frequencies:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 200</td>
<td>411</td>
<td>392</td>
</tr>
<tr>
<td>151 – 200</td>
<td>309</td>
<td>369</td>
</tr>
<tr>
<td>101 – 150</td>
<td>236</td>
<td>322</td>
</tr>
<tr>
<td>51 – 100</td>
<td>221</td>
<td>222</td>
</tr>
<tr>
<td>≤ 50</td>
<td>444</td>
<td>459</td>
</tr>
<tr>
<td>Total # bonds</td>
<td>1621</td>
<td>1704</td>
</tr>
</tbody>
</table>
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Empirical Results – Market Level Analysis

• Volume-weighted average difference between TRACE prices and respective Markit quotations is 4.88 bp with a standard deviation of 71.85 bp → no economically significant bias.

• Price dispersion measure (i.e. root mean squared difference) is 49.94 bp with a standard deviation of 63.36 bp.

• Market-wide average bid-ask spread is only 35.90 bp with a standard deviation of 23.73 bp.

• Overall, we find significant differences between TRACE prices and Markit composite that cannot be simply explained by bid-ask spreads or trade time effects.
Empirical Results – Bond Level Analysis

• At the individual bond level, we relate our liquidity measure to bond characteristics and trading activity variables to show its relation to liquidity.

• We employ cross-sectional linear regressions using time-weighted averages of all variables.

• We present results based on the whole time period, as well as based on each available quarter (2004 Q4 to 2006 Q3).

• To further validate the results, we analyze the explanatory power of our liquidity measure in predicting established estimators of liquidity → Amihud ILLIQ measure.
Empirical Results – Bond Level Analysis

- Cross-sectional regressions with the new price dispersion measure as dependent variable:

<table>
<thead>
<tr>
<th></th>
<th>2004 Q4</th>
<th>2006 Q3</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>231.732***</td>
<td>167.760***</td>
<td>187.648***</td>
</tr>
<tr>
<td>Maturity</td>
<td>2.576***</td>
<td>1.453***</td>
<td>1.840***</td>
</tr>
<tr>
<td>Amount Issued</td>
<td>-5.597***</td>
<td>-3.710***</td>
<td>-3.060***</td>
</tr>
<tr>
<td>Age</td>
<td>3.849***</td>
<td>1.242***</td>
<td>2.064***</td>
</tr>
<tr>
<td>Rating</td>
<td>2.090***</td>
<td>1.096***</td>
<td>1.254***</td>
</tr>
<tr>
<td>Bid-Ask</td>
<td>0.237***</td>
<td>0.544***</td>
<td>0.568***</td>
</tr>
<tr>
<td>Trade Volume</td>
<td>-7.963***</td>
<td>-6.023***</td>
<td>-8.458***</td>
</tr>
<tr>
<td>$R^2$</td>
<td>44.9%</td>
<td>49.3%</td>
<td>61.5%</td>
</tr>
<tr>
<td>Observations</td>
<td>1270</td>
<td>1513</td>
<td>1800</td>
</tr>
</tbody>
</table>
Empirical Results – Bond Level Analysis

• To validate these results, we compare the new measure to established estimators of liquidity in the literature.

• One important approach to measure liquidity is through the price impact of trading. A popular (and intuitive) measure was introduced by Amihud quantifying the effect of trading on price changes.

• Cross-sectional univariate regressions with the Amihud measure as dependent variable:

<table>
<thead>
<tr>
<th></th>
<th>2004 Q4</th>
<th>2006 Q3</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>-18.192***</td>
<td>-18.377***</td>
<td>-17.932***</td>
</tr>
<tr>
<td><strong>Price Dispersion</strong></td>
<td>0.021***</td>
<td>0.027***</td>
<td>0.025***</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>22.0%</td>
<td>27.3%</td>
<td>31.3%</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>1169</td>
<td>1426</td>
<td>1800</td>
</tr>
</tbody>
</table>
Empirical Results – Hit Rate Analysis

- Many studies use bid-ask quotations (or mid quotes) as proxies for traded prices. Our data set allows us to validate this assumption.

- The hit-rate for the TRACE price is 51.37% (i.e., in these cases, the traded price lies within the bid and ask quotation).

- Deviations are symmetric → 50.12% are lower than the bid and 49.88% are higher than the ask.

- Even the hit rate of the Markit quotation (58.59%) is quite low.

- Overall, we find that deviations of traded prices from bid-ask quotations are far more frequent than assumed by most studies.
Conclusions

• A new liquidity measure based on price dispersion effects is derived from a market microstructure model.
• The proposed measure is quantified in the context of the US corporate bond market.
• It is larger and more volatile than bid-ask spreads and shows a strong relation to bond characteristics and trading activity variables, as well as established liquidity proxies.
• A “hit-rate” analysis shows that bid-ask spreads can only be seen as a rough approximation of liquidity costs.
• The proposed measure can potentially explain and quantify the liquidity premia.
• These findings foster a better understanding of OTC markets and are relevant for many practical applications, e.g. bond pricing, risk management, and financial market regulation.