Exchange Pricing Models and Optimal Venue Selection

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US Liquidity Landscape

- The US equity market has more than 13 venues with varying pricing structures and market share:

  - NYSE 12.7%
  - TRF 19.5%
  - CS Crossfinder 2.7%
  - GS Sigma X 1.6%
  - Knight Link, 1.2%
  - GES, 1.1%
  - Other Dark Pools 5.6%
  - NASDAQ 18.3%
  - NYSE Arca 12.7%
  - EDGX 5.4%
  - EDGA, 3.7%
  - BATS BZX 8.4%
  - Other Dark Pools 5.6%

- The US market is also organized by tape, based on the primary exchange listing of the security:

  **Tape A (NYSE/Amex Listed)**
  - TRF 31%
  - NYSE 23%
  - BATS BZX 6%
  - NASDAQ 14%
  - NYSE Arca 10%

  **Tape B (Arca Listed)**
  - TRF 28%
  - NYSE Arca 22%
  - BATS BZX 13%
  - EDGX 6%
  - NASDAQ 18%

  **Tape C (NASDAQ Listed)**
  - TRF 35%
  - NYSE Arca 12%
  - BATS BZX 9%
  - EDGX 6%
  - NASDAQ 28%

Sources: BATS, Rosenblatt
## Pricing Models

<table>
<thead>
<tr>
<th>Lit Venue</th>
<th>Pricing Model</th>
<th>Provider (Mils)</th>
<th>Taker (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYSE</td>
<td>Maker-taker</td>
<td>15</td>
<td>-23</td>
</tr>
<tr>
<td>ARCA</td>
<td>Maker-taker</td>
<td>29</td>
<td>-30</td>
</tr>
<tr>
<td>Nasdaq PSX</td>
<td>Maker-taker</td>
<td>24</td>
<td>-25</td>
</tr>
<tr>
<td>Direct Edge X</td>
<td>Maker-taker</td>
<td>26</td>
<td>-30</td>
</tr>
<tr>
<td>BATS</td>
<td>Maker-taker</td>
<td>27</td>
<td>-28</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>Maker-taker</td>
<td>29</td>
<td>-30</td>
</tr>
<tr>
<td>Boston</td>
<td>Inverse Maker-taker</td>
<td>-18</td>
<td>14</td>
</tr>
<tr>
<td>BATS-Y</td>
<td>Inverse Maker-taker</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Direct Edge A</td>
<td>Inverse Maker-taker</td>
<td>-2.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- **Within lit venues**, there are two primary pricing models:
  - **Maker-Taker**: Liquidity **providers** get **rebates**, liquidity **takers** are charged a **fee**
  - **Inverse Maker-Taker**: Liquidity **takers** get **rebates**, liquidity **providers** are charged a **fee**

- **Within dark venues**, pricing structures vary by the type of dark pool:
  - **Broker/Dealer Pools**: Negotiated through reciprocity, both sides pay a fee
  - **Enhanced Liquidity Provider (ELP) Pools**: Option for price Improvement or rebate
  - **Block Pools**: Tariff structure, usually much higher cost

*Positive entries represent a rebate. Negative entries represent a cost.*
Inverse Pricing – Narrowing Spread

- Reg NMS prevents sub-penny spreads for dollar stocks; inverse pricing models effectively reduce this
  - For an aggressive Sell order for 800 shares of a security with liquidity present at NYSE, NASDAQ and BX, each at the NBB

\[
\begin{align*}
\text{NBB: } & 50.00 \\
\text{NBO: } & 50.01 \\
\text{BX Bid: } & 50.0014 \\
\text{NYSE Bid: } & 49.9977 \\
\text{NASDAQ Bid: } & 49.9970
\end{align*}
\]

- Due to inverse pricing structure, \textbf{BX} is the \textit{cheapest} venue, hence top priority for SOR
- Due to liquidity taker fees, \textbf{NASDAQ} is the most \textit{expensive} venue, hence lowest priority for SOR
- Original penny spread is narrowed due to varying pricing models
Smart Order Router Considerations

- In general, SOR routing logic relies on four major factors:
  - **Liquidity**: Includes available published liquidity, hidden liquidity as well as venue latency
  - **Costs/Rebates**: Pricing structures across lit and dark venues affect aggressive and passive orders differently
  - **Latency**:
    - Significant variation among venues when measured
    - Quantitative measures of venue latency include quote lifetimes and quote update frequencies
  - **Performance/Toxicity**:
    - Passive orders: Venue toxicity/adverse selection is measured as price reversion post-execution
Smart Order Routing: Aggressive Orders

OBJECTIVE: Maximize fill rate, minimize cost

- **Liquidity**: Displayed liquidity is adjusted for venue latency and hidden liquidity estimation

- **Exchange Costs**: For liquidity available on multiple venues, costs/rebates decide routing logic

![Diagram showing liquidity and exchange costs](image)
Smart Order Routing: Passive Orders

**OBJECTIVE:** Maximize fill rate, minimize cost

- **Liquidity:** Displayed queues are adjusted by multipliers, which are a function of:
  - **Queue Length:** Shorter queue lengths are preferable
  - **Trading Rate:** Higher trade rates are preferable
  - **Exchange Costs:** Maker-taker venues are preferable

\[
\text{Multiplier} = \text{Queue length} \times \frac{\text{Cost}}{\text{Trading rate}}
\]

For a 700 share passive order:

<table>
<thead>
<tr>
<th>Venue</th>
<th>Queue Length</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>BX</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>NYSE</td>
<td>300</td>
<td>1.5</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>300</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Multipliers: 1, 1.5, 0.5

<table>
<thead>
<tr>
<th>Venue</th>
<th>NBO: 50.01</th>
<th>200</th>
<th>450</th>
</tr>
</thead>
<tbody>
<tr>
<td>BX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NYSE</td>
<td></td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>NASDAQ</td>
<td></td>
<td>200</td>
<td>350</td>
</tr>
</tbody>
</table>

Allocation policy:

- BX: 300
- NYSE: 450
- NASDAQ: 350
Characteristics of Venue Liquidity

<table>
<thead>
<tr>
<th>Venue</th>
<th>Avg. % of NBBO</th>
<th>Max. % of NBBO</th>
<th>% Time Outside NBBO</th>
<th>% Market Share</th>
<th>Pricing Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYSE</td>
<td>28%</td>
<td>100%</td>
<td>13%</td>
<td>28%</td>
<td>Normal</td>
</tr>
<tr>
<td>ARCA</td>
<td>19%</td>
<td>77%</td>
<td>18%</td>
<td>17%</td>
<td>Normal</td>
</tr>
<tr>
<td>Nasdaq PSX</td>
<td>2%</td>
<td>16%</td>
<td>60%</td>
<td>2%</td>
<td>Normal (price-size)</td>
</tr>
<tr>
<td>Direct Edge X</td>
<td>6%</td>
<td>44%</td>
<td>40%</td>
<td>8%</td>
<td>Normal</td>
</tr>
<tr>
<td>BATS</td>
<td>12%</td>
<td>50%</td>
<td>25%</td>
<td>13%</td>
<td>Normal</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>24%</td>
<td>89%</td>
<td>13%</td>
<td>21%</td>
<td>Normal</td>
</tr>
<tr>
<td>Boston</td>
<td>1%</td>
<td>8%</td>
<td>63%</td>
<td>2%</td>
<td>Inverse</td>
</tr>
<tr>
<td>BATS-Y</td>
<td>1%</td>
<td>7%</td>
<td>72%</td>
<td>2%</td>
<td>Inverse</td>
</tr>
<tr>
<td>Direct Edge A</td>
<td>4%</td>
<td>25%</td>
<td>49%</td>
<td>5%</td>
<td>Inverse</td>
</tr>
</tbody>
</table>

- **Proportion of the NBBO Size:**
  - Inverse maker-taker exchanges typically represent a small portion of the total NBBO volume

- **Probability of Being Outside NBBO:**
  - Inverse maker-taker exchanges have a higher probability of being outside the NBBO

- **Provision of Unique Liquidity**
  - Maximum contribution to total NBBO liquidity per venue
  - For example, the max. contribution of BATS-Y to total NBBO liquidity in the Feb. 2011 in any S&P 500 symbol was only 7.13%
  - Inverse maker-taker exchanges rarely provide unique liquidity to the market

Venue analytics are generated for the month of February 2011 for members of the S&P 500 index
### Venue Quote Dynamics

#### Quote Turnover

<table>
<thead>
<tr>
<th>Price Band</th>
<th>NYSE</th>
<th>ARCA</th>
<th>PSX</th>
<th>Edge X</th>
<th>BATS</th>
<th>NASDAQ</th>
<th>Boston</th>
<th>BATS-Y</th>
<th>Edge A</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; $10</td>
<td>3.9</td>
<td>0.7</td>
<td>5.0</td>
<td>1.5</td>
<td>0.5</td>
<td>1.0</td>
<td>16.7</td>
<td>5.8</td>
<td>8.8</td>
</tr>
<tr>
<td>$10 - $40</td>
<td>1.4</td>
<td>0.9</td>
<td>5.5</td>
<td>1.1</td>
<td>0.8</td>
<td>1.0</td>
<td>2.2</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>&gt; $40</td>
<td>1.5</td>
<td>1.0</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
<td>1.0</td>
<td>0.3</td>
<td>0.4</td>
<td>0.9</td>
</tr>
</tbody>
</table>

#### Market Share

<table>
<thead>
<tr>
<th>Price Band</th>
<th>NYSE</th>
<th>ARCA</th>
<th>PSX</th>
<th>Edge X</th>
<th>BATS</th>
<th>NASDAQ</th>
<th>Boston</th>
<th>BATS-Y</th>
<th>Edge A</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; $10</td>
<td>25.7%</td>
<td>18.7%</td>
<td>1.4%</td>
<td>12.9%</td>
<td>16.6%</td>
<td>34.5%</td>
<td>3.9%</td>
<td>4.2%</td>
<td>9.0%</td>
</tr>
<tr>
<td>$10 - $40</td>
<td>17.3%</td>
<td>11.5%</td>
<td>0.7%</td>
<td>4.4%</td>
<td>8.0%</td>
<td>21.1%</td>
<td>1.5%</td>
<td>1.8%</td>
<td>3.7%</td>
</tr>
<tr>
<td>&gt; $40</td>
<td>16.3%</td>
<td>16.2%</td>
<td>0.6%</td>
<td>5.1%</td>
<td>9.7%</td>
<td>20.6%</td>
<td>0.9%</td>
<td>1.1%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

#### % of Time Spent at NBBO

<table>
<thead>
<tr>
<th>Price Band</th>
<th>NYSE</th>
<th>ARCA</th>
<th>PSX</th>
<th>Edge X</th>
<th>BATS</th>
<th>NASDAQ</th>
<th>Boston</th>
<th>BATS-Y</th>
<th>Edge A</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; $10</td>
<td>25.7%</td>
<td>18.7%</td>
<td>1.4%</td>
<td>12.9%</td>
<td>16.6%</td>
<td>34.5%</td>
<td>3.9%</td>
<td>4.2%</td>
<td>9.0%</td>
</tr>
<tr>
<td>$10 - $40</td>
<td>17.3%</td>
<td>11.5%</td>
<td>0.7%</td>
<td>4.4%</td>
<td>8.0%</td>
<td>21.1%</td>
<td>1.5%</td>
<td>1.8%</td>
<td>3.7%</td>
</tr>
<tr>
<td>&gt; $40</td>
<td>16.3%</td>
<td>16.2%</td>
<td>0.6%</td>
<td>5.1%</td>
<td>9.7%</td>
<td>20.6%</td>
<td>0.9%</td>
<td>1.1%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

- Quote turnover: Number of times a quote is fully filled, canceled (Base: NASDAQ)
- Lower-priced stocks have larger turnover, more pronounced in the inverse maker-taker venues
- Inverse maker-taker exchanges are less likely to be at the NBBO
- Inverse maker-taker venues have a higher market share in low priced stocks
- Profitability of taking rebates (in basis points) on low-price stocks is far greater than in higher priced stocks which may explain the bias towards low priced stocks in inverse price exchanges

Venue analytics are generated on February 2011 for members of the S&P 500 index.
Measuring Adverse Selection

Passive limit order

“Positive spread capture”

“Adverse selection”
Adverse Selection for Passive Orders

<table>
<thead>
<tr>
<th>Venue</th>
<th>Avg. Price</th>
<th>5 Minute VWAP Slippage (bps)</th>
<th>Provider (Mils)</th>
<th>Taker (Mils)</th>
<th>Provider (Rebate + Price Reversion) (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYSE</td>
<td>32.7</td>
<td>-1.28</td>
<td>15</td>
<td>-23</td>
<td>-0.82</td>
</tr>
<tr>
<td>ARCA</td>
<td>36.5</td>
<td>-1.08</td>
<td>29</td>
<td>-30</td>
<td>-0.29</td>
</tr>
<tr>
<td>Edge X</td>
<td>36.7</td>
<td>-1.73</td>
<td>26</td>
<td>-30</td>
<td>-1.02</td>
</tr>
<tr>
<td>BATS</td>
<td>35.6</td>
<td>-1.17</td>
<td>27</td>
<td>-28</td>
<td>-0.41</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>39.2</td>
<td>-1.47</td>
<td>29</td>
<td>-30</td>
<td>-0.73</td>
</tr>
<tr>
<td>Boston</td>
<td>32.9</td>
<td>0.25</td>
<td>-18</td>
<td>14</td>
<td>-0.30</td>
</tr>
<tr>
<td>BATS-Y</td>
<td>24.2</td>
<td>-0.15</td>
<td>0</td>
<td>3</td>
<td>-0.15</td>
</tr>
<tr>
<td>Edge A</td>
<td>26.1</td>
<td>-0.37</td>
<td>-2.5</td>
<td>1.5</td>
<td>-0.47</td>
</tr>
</tbody>
</table>

- Exchanges differ in terms of explicit as well as implicit costs
- Implicit adverse selection costs for passive fills are measured as the price reversion or slippage against the 5-minute VWAP following the trade
- Cheaper-to-take venues (Boston, Edge A, BATS-Y) have smaller adverse selection for passive fills
- Expensive-to-take venues (NASDAQ, ARCA, Edge X) have larger adverse selection for passive fills
- Adjusting for rebate/fee for providing liquidity, the difference between venues is much smaller

Venue analytics are generated for the month of February 2011 for members of the S&P 500 index
Adverse Selection: Time to Reversal

The higher the time to price reversion, the less the adverse.

- Liquidity taking strategies trade in cheap venues first, expensive venue last.
- Whenever a trade happens on a cheap venue, the price is less likely to move because the liquidity in more expensive venue provides support.
- By the time a trade happens on an expensive venue, liquidity at the cheaper venues is already exhausted, and the price is likely to move adversely.
- Based on the overall objective, a provider may post in cheap-to-take venues to maximize their fill rate, or post in expensive-to-take venue to capture more rebates.

Venue analytics are generated for the month of February 2011 for members of the S&P 500 index.
Trade-offs

- **Inverse pricing venues:**
  - Expensive to provide liquidity, cheap to take → “paying a premium for queue priority”
  - High degree of competition for aggressive flow → high quote turnover
  - Low degree of competition for passive flow → “need conviction that price is right”
  - High degree of provider interest in low price “wide spread” stocks
  - First in the queue, gets first look but very little time to get out the way

- **Regular pricing venues:**
  - Expensive to take liquidity, cheap to provide → “paid a premium to compensate for adverse selection”
  - High degree of competition for passive flow → high quote update frequency
  - Lower degree of competition for aggressive flow → “need conviction to cross the spread”
  - Low latency platform is essential for managing queue priority and adverse selection
  - Last in the queue, can observe activity in queue ahead but has opportunity cost of not being filled

Venue analytics are generated for the month of February 2011 for members of the S&P 500 index
Implications for Optimal Venue Selection

- **Passive Orders:**
  - **Utilize alpha signals:** High-frequency alpha signals can be utilized to identify opportune times to provide liquidity, i.e. cash flow, order-book pressure
  - **Maximization of fill rate:** Allocate and dynamically rebalance limit orders based on ratio of queue size to trading rate
  - **Adverse Selection:** Monitor adverse selection of venues can preference according to objectives
  - **Explicit Costs:** Utilize explicit costs as a factor in the limit order placement strategy

- **Aggressive Orders:**
  - **Utilize alpha signals:** Venue selection conditional on “aggressiveness” and size of the order
  - **Estimation of Dark Pool Liquidity:** Maximize hit rate, reduce inadvertent signaling and minimize latency
  - **Pinging:** Simultaneous access to all available liquidity in lit and dark pools
  - **Explicit Costs:** Utilize explicit costs as a factor in venue selection
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