What Does Best Execution Look Like?

Thomas Ernst,1, Andrey Malenko2, Chester Spatt3, and Jian Sun4

1University of Maryland, Robert H. Smith School of Business
2Boston College, Carroll School of Management
3Carnegie Mellon University, Tepper School of Business
4Singapore Management University, Lee Kong Chian School of Business
Retail trades can be more desirable than anonymous order flow:

Wholesalers offer combination of PFOF and price improvement to obtain retail orders.
Brokers set a uniform PFOF rate across all wholesalers. Level playing field.
Broker’s Routing: Competition

- Brokers route more to wholesalers who offer better average prices.
- Wholesalers compete for order flow based on average prices.
Findings

• **Brokers Measure and Respond to Wholesaler Performance**
  • Evaluate based on effective-over-quoted spreads
  • Better wholesalers obtain more order flow

• **Wholesalers Respond to Broker Measures**
  • When a broker changes focus, wholesalers respond immediately
  • Wholesalers offer more price improvement in volatile markets
  • Wholesalers change behavior around month-end

• **Broker Choices Impact Competitive Landscape**
  • Large vs. Small stocks - wholesaler competition looks quite different
  • Choices a broker makes can impact competition
Related Literature

- Topbas and Ye (2023): FINRA ATS Data
- Battalio and Jennings (2023): Price improvement from wholesaler data
- Dhyrberg, Shkilko, Werner (2023): SEC 605 data - market centers offering better prices obtain more order flow - aggregate, no small trades
- Huang, Jorion, Lee, Schwarz (2023): Own trades - six brokers, small trades

Our contributions:

- Proprietary data from three brokers: observe exact broker-wholesaler relationship
- Document how each of our brokers obtains best-execution:
  - What do they measure, how do they adjust flow, etc
Plan

1 Brokers Respond to Wholesalers
   - Broker Focus Points
   - Routing-Performance Relationship
   - Market Conditions and Wholesaler Performance

2 Wholesaler Respond to Brokers

3 Competitive Landscape
## Data Overview

Three Retail Brokers. Collectively > 50% of retail equity market:

<table>
<thead>
<tr>
<th></th>
<th>Broker A</th>
<th>Broker B</th>
<th>Broker C</th>
</tr>
</thead>
<tbody>
<tr>
<td>History:</td>
<td>30 Days</td>
<td>90 Days</td>
<td>90 Days</td>
</tr>
<tr>
<td>Symbol:</td>
<td>Each Symbol</td>
<td>Four Security Bins</td>
<td>One Bin</td>
</tr>
<tr>
<td>(Size):</td>
<td>5 Size Categories</td>
<td>3 Size Categories</td>
<td></td>
</tr>
<tr>
<td>Decisions:</td>
<td>Daily (Rolling)</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
</tbody>
</table>
Performance Variables

- **Effective Over Quoted Spread (EFQ)**
  - EFQ is effective over quoted spread
  - Effective spread: how much the market maker charges on orders
  - Quoted spread: benchmark of how much the exchange would charge on orders
  - EFQ of 100% - charging the exchange bid-ask spread
  - EFQ of 0% - filling every order at the mid-quote

- **Order Share:**
  - Brokers allocate some portion of orders to each market maker
  - Use about 5 wholesalers
  - Unequal distribution — two firms at 30 - 40%, two firms at 5-10%
### Broker B - Nasdaq 100 Orders

#### Market Center
- Firm_A
- Firm_B
- Firm_C
- Firm_D
- Firm_E

#### Punish: (Less Flow)
- 10
- 20
- 30
- 40
- 50

#### Reward: (More Flow)
- 10
- 20
- 30
- 40
- 50

#### Effective Over Quoted (90 Day Average)

**Date**
- 2019
- 2020
- 2021
- 2022
- 2023

---

**Ernst, Malenko, Spatt, Sun**

**What Does Best Execution Look Like?**
Performance Regression

- How does a wholesaler’s EFQ impact their monthly order share?

- Consider EFQ and EFQ Rank
  - EFQ - lower is better
  - EFQ rank - ordinal ranking of wholesalers
## Performance Regression

**Dependent variable:** OrderShare

<table>
<thead>
<tr>
<th></th>
<th>Broker A Data</th>
<th>Broker B Data</th>
<th>Broker C Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Prior EFQ</td>
<td>−1.230***</td>
<td>−0.958***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td>(0.286)</td>
<td></td>
</tr>
<tr>
<td>Prior EFQ Rank</td>
<td></td>
<td>−8.882***</td>
<td>−5.553***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.754)</td>
<td>(1.898)</td>
</tr>
<tr>
<td>Prior Score</td>
<td></td>
<td></td>
<td>−3.015***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.646)</td>
</tr>
<tr>
<td>Prior Score Rank</td>
<td></td>
<td></td>
<td>−7.294***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.653)</td>
</tr>
<tr>
<td>Observations</td>
<td>129,526</td>
<td>129,526</td>
<td>786</td>
</tr>
<tr>
<td></td>
<td>786</td>
<td>786</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>170</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.316</td>
<td>0.339</td>
<td>0.248</td>
</tr>
<tr>
<td></td>
<td>0.253</td>
<td>0.613</td>
<td>0.766</td>
</tr>
</tbody>
</table>

**Note:**
*\(p<0.1\); **\(p<0.05\); ***\(p<0.01\)
Importance of Broker Focus

- Broker A routes based on 30 days of history and specific size categories:

- How sensitive are broker’s routing decisions?
  - Consider multiple time horizons
  - Consider multiple order size histories
### Broker Focus - Time Horizon

<table>
<thead>
<tr>
<th></th>
<th>OrderShare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Prior 5 Days EFQ</td>
<td>-0.469***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Prior 10 Days EFQ</td>
<td>-0.635***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Prior 30 Days EFQ</td>
<td>-0.835***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
<tr>
<td>Prior 45 Days EFQ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>129,526</td>
</tr>
<tr>
<td><em>R</em>^2^</td>
<td>0.051</td>
</tr>
</tbody>
</table>

*Note:* *p<0.1; **p<0.05; ***p<0.01

- Broker A routes based on 30 days of prior history.
- *R*^2^ peaks at 30 days history, the history window length that Broker A uses in practice.
## Broker Focus - Order Size

<table>
<thead>
<tr>
<th>Dependent variable: OrderShare For Trades Size 3</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior EFQ - Size 1</td>
<td>-0.518***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior EFQ - Size 3</td>
<td></td>
<td>-0.975***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.024)</td>
<td></td>
</tr>
<tr>
<td>Prior EFQ - Size 5</td>
<td></td>
<td></td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>Observations</td>
<td>11,420</td>
<td>11,420</td>
<td>11,420</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.024</td>
<td><strong>0.125</strong></td>
<td>0.0002</td>
</tr>
</tbody>
</table>

- Consider 3 Sizes:
  - Size 1 - < 100 shares
  - Size 3 - 500 to 2,000 shares
  - Size 5 - Over 5,000 shares

- \(R^2\) for Size 3 order routing is highest for size 3 EFQ
Suppose one had an incomplete view of a broker’s history:

- Could an average retail customer understand their broker’s decisions? (No)
- SEC Rule 605 updates - Brokers will start providing much more data to customers
• Distribution of all Odd-Lot Trades in JP Morgan on March 13, 2023

• How large of a sample of trades would be needed to distinguish wholesaler performance?

• Experiment: draw a random sample of trades, calculate wholesaler rankings
Individual Orders: Broker A Data

- Very easy to tell the top two wholesalers from the rest.
- Very hard to distinguish some individuals:
  - First-vs-Second, Fourth-vs-Fifth no better than chance
Days in the Month: Broker B Data

- Broker B routes based on 90-day average
- Plot individual day-level wholesaler performance
- How many days of data does one need to accurately guess 90-day average?
**Days in the Month: Broker B Data**

- Easy to distinguish first-vs-second
- Extremely hard to distinguish third-vs-fourth
Plan

1. Brokers Respond to Wholesaler Performance
   - Broker Focus Points
   - Observability of wholesaler performance

2. Wholesalers Respond to Broker Objectives
   - What happens when a broker changes focus?
   - End of month evaluation?
   - Different market conditions?

3. Competitive Landscape
Focus Change

- If brokers changes focus, how do wholesalers respond?

- Broker B: implemented a focus change on January 1, 2020.
  - Consider all aspects of performance.
  - 2019: special focus on orders from 100-1,999 shares
  - 2020: special focus on orders from 1-1,999 shares

- Wholesalers immediately respond.
  - Consistent with competitive, monitored performance
Orders 1-99 Shares

What Does Best Execution Look Like?
Very Large Orders (2000+ shares)

What Does Best Execution Look Like?
Focus Change Regression

<table>
<thead>
<tr>
<th></th>
<th>Odd Lot</th>
<th>Large Orders</th>
<th>Odd Lot</th>
<th>Large Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>OddLot</td>
<td></td>
<td>44.685**</td>
<td></td>
<td>66.695***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.731)</td>
<td></td>
<td>(4.483)</td>
</tr>
<tr>
<td>LargeOrder</td>
<td></td>
<td></td>
<td></td>
<td>85.549***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(10.749)</td>
</tr>
<tr>
<td>FocusChange</td>
<td>−61.821***</td>
<td>−17.085***</td>
<td>68.992***</td>
<td>−16.847***</td>
</tr>
<tr>
<td></td>
<td>(8.034)</td>
<td>(1.641)</td>
<td>(11.205)</td>
<td>(1.591)</td>
</tr>
<tr>
<td>OddLot*FocusChange</td>
<td>−44.790***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.642)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LargeOrder*FocusChange</td>
<td></td>
<td></td>
<td></td>
<td>85.549***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(10.749)</td>
</tr>
<tr>
<td>Observations</td>
<td>820</td>
<td>1,650</td>
<td>820</td>
<td>1,650</td>
</tr>
<tr>
<td>R²</td>
<td>0.841</td>
<td>0.809</td>
<td>0.544</td>
<td>0.886</td>
</tr>
</tbody>
</table>

*Note:* \( p < 0.1; \) \( **p < 0.05; \) \( ***p < 0.01 \)
Market Conditions

- Wholesaler are evaluated on long-run historical averages
  - Do they care about market volatility?
    $$EFQ = \alpha_0 + \alpha_1 \text{IntradayVolatility} + \epsilon$$

- How does wholesaler performance change with market conditions?
  - Competitive pressure - increase performance when they can

Ernst, Malenko, Spatt, Sun
What Does Best Execution Look Like?

26
<table>
<thead>
<tr>
<th></th>
<th>Dependent variable:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EFQ (%)</td>
</tr>
<tr>
<td></td>
<td>Effective Spread (BPS)</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Trade Volume</td>
<td>1.449**</td>
</tr>
<tr>
<td></td>
<td>(0.722)</td>
</tr>
<tr>
<td>Variance Ratio</td>
<td>-4.001***</td>
</tr>
<tr>
<td></td>
<td>(0.673)</td>
</tr>
<tr>
<td>1 Minute</td>
<td></td>
</tr>
<tr>
<td>Intraday Vol</td>
<td>-0.581***</td>
</tr>
<tr>
<td></td>
<td>(0.152)</td>
</tr>
<tr>
<td>Depth</td>
<td>-0.820**</td>
</tr>
<tr>
<td></td>
<td>(0.325)</td>
</tr>
<tr>
<td>Log Return</td>
<td>-0.882</td>
</tr>
<tr>
<td></td>
<td>(1.435)</td>
</tr>
<tr>
<td>Observations</td>
<td>64,906</td>
</tr>
<tr>
<td>R²</td>
<td>0.126</td>
</tr>
</tbody>
</table>

- In volatile markets:
  - Effective spreads increase
  - Quoted spreads increase more
  - EFQ ratios decrease

- Wholesalers improve EFQ on volatile days

- Suggests competitive pressure to improve when they can improve
Wholesaler Dynamics

• Two of our brokers evaluate wholesalers right around the end of the month

• Next month’s allocation depends on the 90-day-average right at the end of the month

• End-of-race effect: wholesalers may try to
  • catch a competitor
  • decide to give up
End-Of-Month Race

Lead of 1st-Best over 2nd-Best

End of Month
## End-Of-Month Race

**Graph:**
- Y-axis: Execution Score Difference: First – Second
- X-axis: Dates (2021, 2022, 2023)
- Legend:
  - Market_Center
    - MM1
    - MM2
    - MM3
    - MM6

**What Does Best Execution Look Like?**
Plan

1. Brokers Evaluate Wholesalers

2. Wholesaler Respond to Broker Focuses

3. Competitive Landscape
   - Different Races in Large vs Small Differences
   - Wholesaler Entry
Order Type Distribution

• Broker A routes selectively:
  • Each symbol is on its own. AAPL is routed based on AAPL history, not MSFT history
  • Five independent order size categories
  • Routing a 50 share AAPL order? Look at 1-99 share AAPL performance
  • Routing a 3,000 share AAPL order? Look at 2-5,000 share AAPL performance

• Are certain types of orders more or less competitive?
  • Consider distribution of wholesaler performance across stocks and across order sizes
Stock Liquidity

Illiquid Symbols

Mean Improvement Across Wholesalers

0.00
0.25
0.50
0.75
1.00

De-meaned Price Improvement

Density

anonvenue
Venue1
Venue2
Venue3
Venue4
Venue5

Daily PI Distribution Size 1

Liquid Symbols

Mean Improvement Across Wholesalers

0.00
0.25
0.50
0.75
1.00

De-meaned Price Improvement

Density

anonvenue
Venue1
Venue2
Venue3
Venue4
Venue5

Daily PI Distribution Size 9

Ernst, Malenko, Spatt, Sun

What Does Best Execution Look Like?
Order Size

Small Orders

Daily PI Distribution Size 1

Mean Improvement Across Wholesalers

0.00

0.25

0.50

0.75

1.00

−50 −25 0 25 50

De-meaned Price Improvement

Venue1

Venue2

Venue3

Venue4

Venue5

Large Orders

Daily PI Distribution Size 5

Mean Improvement Across Wholesalers

0.00

0.25

0.50

0.75

1.00

−50 −25 0 25 50

De-meaned Price Improvement

Venue1

Venue2

Venue3

Venue4

Venue5

Ernst, Malenko, Spatt, Sun

What Does Best Execution Look Like?
Race Example

Bundling is a complicated choice:

- Simple problem: transfers from one stock to another
- Hard problem: some stocks have a close race, others do not
- Bundling changes the respective lead of competitors
Wholesaler Entry

• Large market maker begins working as a wholesaler with Broker A in December 2021

\[ \text{Outcome} = \alpha_0 + \alpha_1 \text{Post} + \epsilon \]

• Where does wholesaler A5 enter?
  • Endogenous choice - each symbol and order size category is independent.

• How does entry change outcomes:
  • EFQ? Increased competition? Displacement?
## Wholesaler Entry: Endogenous Entry

We estimate Regression 3, which measures the impact of a new wholesaler entering the market. Our outcome variable is A5 PostShare, which measures the share of wholesaler A5 obtained in each category in the March 3 to April 3, 2022 data. Categories are the unique symbol and order size bins for each stock. Within each category, we measure First-To-Second (the difference between the effective-over-quoted spread of the first vs. second wholesaler), First-To-Average (the difference between the effective-over-quoted spread of the first wholesaler vs. volume-weighted average), and First Firm Order Share (the share of orders obtained by the top firm in that category). These variables are measured between November 15 to December 15, 2021 and March 3 to April 3, 2022, and we fit a fixed effect for each stock, order size bin, and each top wholesaler.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable:</strong></td>
<td>A5 PostShare</td>
<td>A5 PostShare</td>
<td>A5 PostShare</td>
<td>A5 PostShare</td>
<td>A5 PostShare</td>
<td>A5 PostShare</td>
</tr>
<tr>
<td>First-To-Second</td>
<td>0.073**</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.057)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-To-Avg</td>
<td>0.054</td>
<td>0.060</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.073)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Firm Order Share</td>
<td></td>
<td>0.147***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.030)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td></td>
<td>17.102***</td>
<td>9.990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.809)</td>
<td>(13.297)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective-Over-Quoted Spread</td>
<td></td>
<td>0.053</td>
<td>0.148**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.036)</td>
<td>(0.062)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1,461</td>
<td>1,461</td>
<td>1,586</td>
<td>1,586</td>
<td>1,586</td>
<td>1,461</td>
</tr>
<tr>
<td>R²</td>
<td>0.444</td>
<td>0.442</td>
<td>0.396</td>
<td>0.403</td>
<td>0.384</td>
<td>0.447</td>
</tr>
</tbody>
</table>

*Note:*
*p<0.1; **p<0.05; ***p<0.01

Ernst, Malenko, Spatt, Sun
What Does Best Execution Look Like?
**Wholesaler Entry: Outcomes Including Entrant**

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>First-To-Second</th>
<th>First-To-Avg</th>
<th>First Firm Order Share</th>
<th>HHI</th>
<th>Effective Over Quoted Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Post</td>
<td>0.674</td>
<td>-2.977***</td>
<td>9.617***</td>
<td>-0.070***</td>
<td>-7.109***</td>
</tr>
<tr>
<td></td>
<td>(0.586)</td>
<td>(0.432)</td>
<td>(1.188)</td>
<td>(0.006)</td>
<td>(0.478)</td>
</tr>
<tr>
<td>Observations</td>
<td>3,157</td>
<td>3,157</td>
<td>2,106</td>
<td>3,467</td>
<td>3,467</td>
</tr>
<tr>
<td>R²</td>
<td>0.293</td>
<td>0.205</td>
<td>0.441</td>
<td>0.421</td>
<td>0.560</td>
</tr>
</tbody>
</table>

- EFQ, HHI, First-to-Average decrease - increased competition
- Current system was not perfectly competitive if wholesaler could enter?
### Wholesaler Entry: Outcomes Excluding Entrant

**Dependent variable:**

<table>
<thead>
<tr>
<th></th>
<th>First-To-Second</th>
<th>First-To-Avg</th>
<th>First Firm Order Share</th>
<th>HHI</th>
<th>Effective Over Quoted Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post</td>
<td>$-1.367^{**}$</td>
<td>$-2.021^{***}$</td>
<td>0.159</td>
<td>0.112$^{***}$</td>
<td>$-6.020^{***}$</td>
</tr>
<tr>
<td>(0.589)</td>
<td>(0.405)</td>
<td>(0.599)</td>
<td>(0.013)</td>
<td>(0.499)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>3,133</td>
<td>3,133</td>
<td>3,467</td>
<td>2,100</td>
<td>3,467</td>
</tr>
<tr>
<td>R$^2$</td>
<td>0.262</td>
<td>0.233</td>
<td>0.384</td>
<td>0.470</td>
<td>0.555</td>
</tr>
</tbody>
</table>

- Table - results without Wholesaler A5
- Changes are smaller - wholesaler A5 might be subsidizing liquidity
- HHI goes up - suggests displacement
Findings

• Brokers Respond to Wholesalers
  • Evaluate based on effective-over-quoted spreads
  • Better wholesalers obtain more order flow

• Wholesalers Respond to Brokers
  • When a broker changes focus, wholesalers respond immediately
  • Wholesalers offer more price improvement in volatile markets
  • Wholesalers change behavior around month-end

• Broker Choices Impact Competitive Landscape
  • Large vs. Small stocks - wholesaler competition looks quite different
  • Choices a broker makes can impact competition