MEMORANDUM

TO: File No. S7-31-22

FROM: Jill S. Henderson, Senior Counsel
Division of Economic and Risk Analysis

RE: Conference on Financial Market Regulation

DATE: June 28, 2023

On May 5, 2023, staff from the Division of Economic and Risk Analysis (DERA) hosted the 10th Annual Conference on Financial Market Regulation that included presentations by Andriy Shkilko (Wildrid Laurier University), Joshua Mollner (Northwestern University), Chester Spatt (Carnegie Mellon University), and Eric Budish (University of Chicago) which included discussion of the Commission's Order Competition Rule proposal. Attendees included members of the Commission staff and members of the public.

Attachments:

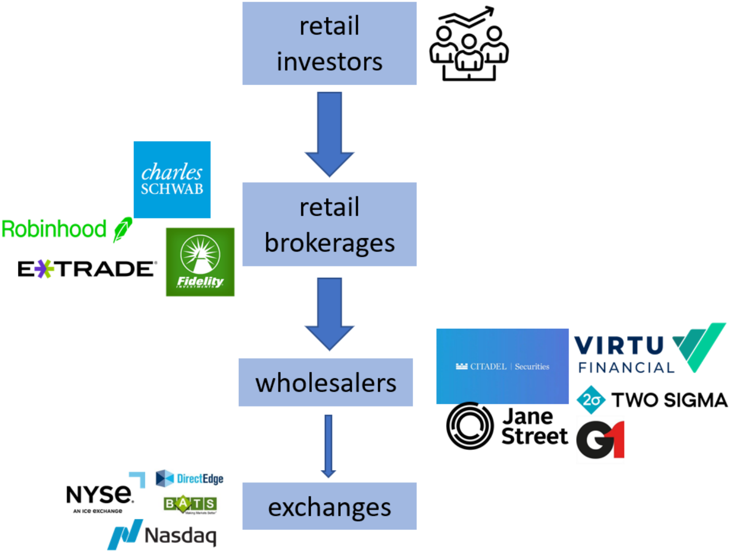
- Andriy Shkilko Presentation
- Joshua Mollner Presentation
- Chester Spatt Presentation
- Eric Budish Presentation

The Retail Execution Quality Landscape

Anne Dyhrberg   Andriy Shkilko   Ingrid M. Werner

10th Annual Conference on Financial Market Regulation
(CFMR 2023)

The landscape



What we find

1. Would retail investors be better off on exchanges?
    - Likely, no. Their trading costs would increase by 14%
2. Do wholesalers abuse market power?
    - Likely, no. Retail brokerages are the ones wielding the power
    - The wholesale environment appears to be a contestable market characterized by economies of scale
3. Would retail investors benefit from order-by-order auctions?
    - In large stocks – possibly; in small stocks – unlikely

What has been done by others

- Wholesalers do retail investors good
  - Kothari, So, and Johnson (2021), Battalio and Jennings (2023a)

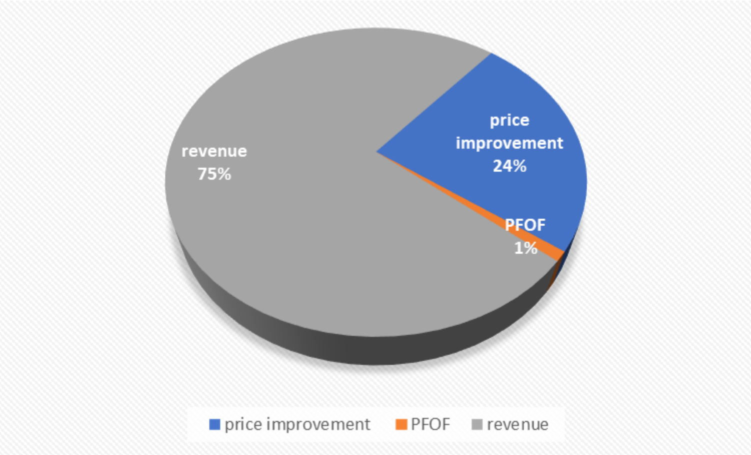
- The status quo has its downsides
  - Equities: Hu and Murphy (2023), Schwartz, Barber, Huang, Jorion, and Odean (2023)
  - Options: Bryzgalova, Pavlova, and Sikorskaya (2023), Ernst and Spatt (2023), Hendershott, Khan, and Riordan (2023)

- Order-by-order auctions may face challenges
  - Battalio and Jennings (2023b), Ernst, Spatt, and Sun (2023)

Data & sample

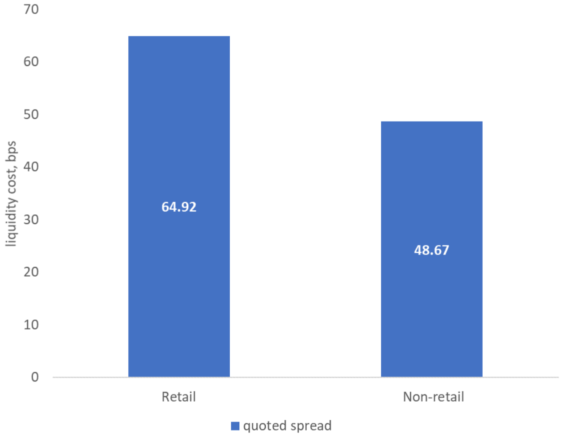
- Sample period: 2019-2022Q1
- Close to 11,500 equities traded in the U.S.; about 3.5 trillion traded shares
  - Focus on over 8,000 non-ETFs (ETFs in the Appendix)
- Data sources:
  - Rule 605/606 execution quality reports
  - CRSP, 13F institutional holdings, short interest
- We see all orders that do not come with special conditions (about 40% of all orders)
  - These include all retail orders and some institutional orders

How wholesalers split earnings



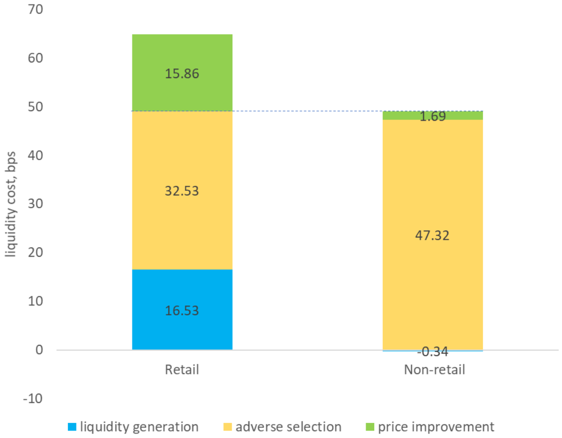
Trade timing

- Retail investors demand liquidity when spreads are wide, while non-retail investors do so when spreads are narrow



Liquidity costs

- Wholesalers provide substantial price improvement, while exchanges generate liquidity at a notably lower cost



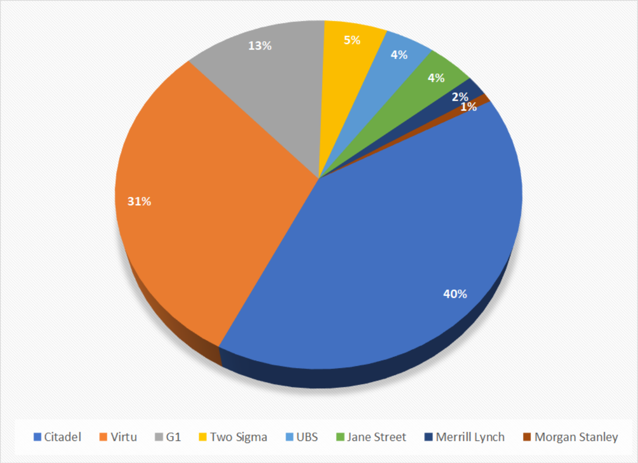
Moving retail to exchanges

- Retail spreads widen
- Institutions face lower spreads

	Δ effective spread, in %	
realiz. spr.	RET LDs	EXCH LDs
-0.64	13.97	-10.77
-0.54	14.23	-10.57
-0.44	14.49	-10.37
-0.34	**14.75**	**-10.17**
-0.24	15.00	-9.96
-0.14	15.26	-9.76
-0.04	15.52	-9.56

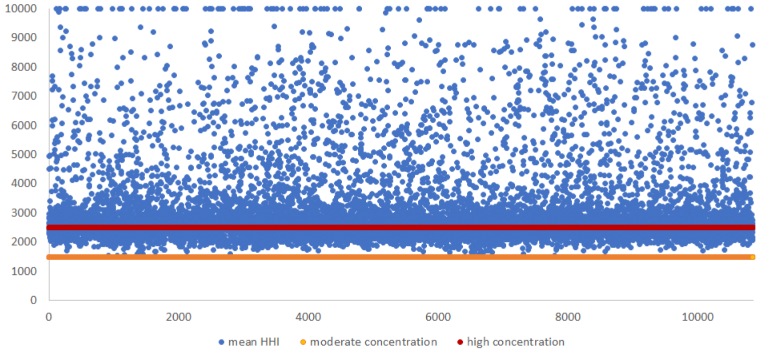
The wholesale competitive landscape

- A total of 8 wholesalers, with Citadel and Virtu capturing 71% of all retail flow



Marketplace competitiveness: HHI

- The wholesale marketplace in most assets would be characterized by the U.S. Department of Justice as non-competitive



Wholesaler cross-section: Regression

- The top two wholesalers receive more toxic order flow
- Yet they offer lower liquidity costs

$$DepVar_{ijt} = \alpha + \beta_1 top2_j + \beta_2 top2 \times T1_{ij} + \beta_3 top2 \times T2_{ij}$$
$$+\beta_4 top2 \times T3_{ij} + \beta_5 price_{it} + \beta_6 volatility_{it} + \beta_7 volume_{it} + \varepsilon_{ijt}$$

	eff/quot	price impact	realized spr.
*top*2	0.055***	0.999***	-0.552**
*top*2 × *T*1	-0.028***	0.086	-0.261**
*top*2 × *T*2	-0.066***	1.510***	-2.130***
*top*2 × *T*3	-0.077***	6.285***	-8.809***

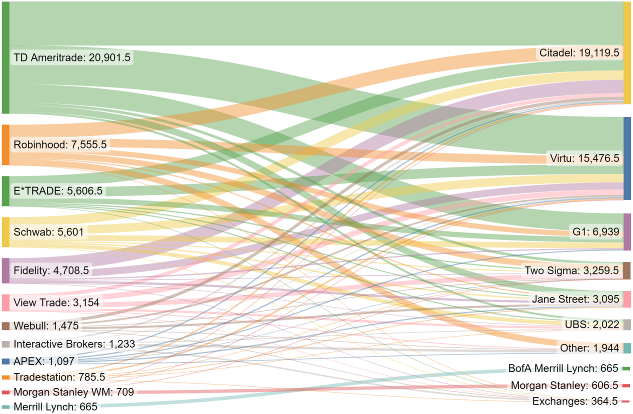
Wholesaler liquidity generation: Regression

- The top two charge less due to economies of scale
- A cross-subsidy between the large and small stocks

$$
\begin{aligned}
rlzd.spr._{ijt} \quad = \quad & \alpha + \beta_1 top2_j + \beta_2 top2 \times T1_{ij} + \beta_3 top2 \times T2_{ij} \\
& + \beta_4 top2 \times T3_{ij} + \beta_5 price_{it} + \beta_6 volat_{it} + \beta_7 vol_{it} \\
& + \beta_8 retvol_{ijt} + \varepsilon_{ijt}
\end{aligned}
$$

top2	-0.552**	0.866	3.111***
$top2 \times T1$	-0.261**		0.156
$top2 \times T2$	-2.130***		-1.761***
$top2 \times T3$	-8.809***		-8.133***
retvol	No	Yes	Yes

Retail broker routing



- Retail brokers charge the same PFOF to all wholesalers
- How do they decide where to send the flow?

Retail broker routing: Regressions

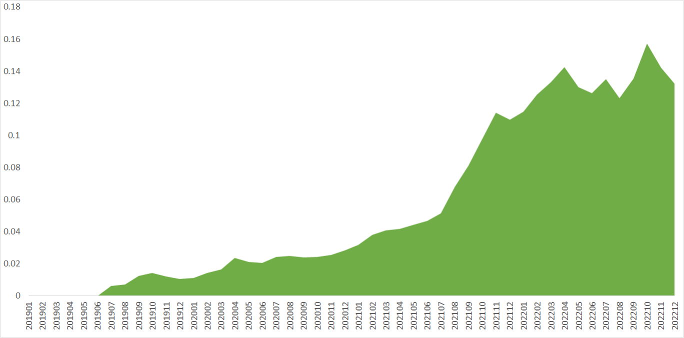
- Retail brokers send more flow to the wholesalers that offered relatively low liquidity costs in the prior month

$$\begin{aligned} \textit{mkt. share}_{ijt} &= \alpha + \beta_1 \textit{abn realiz spr}_{ijt-1} + \beta_2 \textit{abn realiz spr}_{jt-1} \\ &\quad + \beta_3 \textit{price}_{it} + \beta_4 \textit{volatility}_{it} + \beta_5 \textit{volume}_{it} + \varepsilon_{ijt} \end{aligned}$$

	S&P 500	Tercile 1	Tercile 2	Tercile 3
abn realiz spr_{ij}	-0.000	-0.000	-0.000***	-0.000***
abn realiz spr_{j}	-0.023***	-0.025***	-0.024***	-0.020***

Competitor entry: Jane Street

- Jane Street starts at zero and reaches ∼15% market share by the end of our sample period



Competitive entry: Regressions

- Jane Street entry does not lead to lower liquidity costs
- For Terciles 2 and 3, the costs actually increase

$$
\begin{aligned}
realiz.spr._{ijt} = \alpha + \beta_1 WHOL_j + \beta_2 WHOL \times POST_{jt} \\
+\beta_3 price_{it} + \beta_4 volatility_{it} + \beta_5 volume_{it} + \varepsilon_{ijt}
\end{aligned}
$$

	S&P 500	Tercile 1	Tercile 2	Tercile 3
WHOL	1.174***	5.218***	11.228***	20.167***
WHOL× *POST*	0.375	1.535	5.578**	14.003***

The cross-section

- Divide sample into S&P 500 and mcap terciles
- Retail plays an out-sized role in less liquid stocks

	S&P 500	Tercile 1	Tercile 2	Tercile 3
WHOL	31.87	34.30	51.02	63.79
EXCH	68.13	65.70	48.98	36.21
No. of Stocks	514	2,550	2,550	2,551

Inventory costs

- Liquidity costs in less liquid stocks are relatively low after controlling for inventory costs

	[1]	[2]
Tercile 1	3.514***	-18.203***
Tercile 2	13.035***	-32.457***
Tercile 3	41.307***	-20.374***
volatility		-8.843***
price		0.197***
volume		-9.928***
intercept	0.798	169.756***

Institutional interest

- Institutional interest in many stocks favored by retail investors is limited

	mean	**median**	*p25*	*p75*
S&P 500	0.620	**0.198**	0.128	0.394
Tercile 1	1.215	**0.218**	0.112	0.681
Tercile 2	2.316	**0.571**	0.155	2.364
Tercile 3	7.399	**4.209**	0.802	13.795

The table reports average retail volume divided by institutional volume (changes in 13F holdings plus changes in short interest)

To conclude

- The status quo benefits retail investors compared to the alternative of sending their orders to exchanges
- There appears to be no evidence of wholesaler abuse of market power
  - Power appears to lie with retail brokerages
  - Wholesale is a contestable market characterized by economies of scale
  - Liquidity in small stocks is cross-subsidized via the bundling mechanism

The Retail Execution Quality Landscape

by Anne Haubo Dyhrberg, Andriy Shkilko, Ingrid M. Werner

Discussion by
Joshua Mollner
Kellogg School of Management, Northwestern University

CFMR 2023

May 5, 2023

Toy Model

A single **investor** will arrive

- R-type w.p. w, I-type w.p. $1 - w$
- for $k \in \{R, I\}$, a k-type investor is...
  - informed w.p. α_k: privately knows the common-value component ± 1
  - uninformed w.p. $1 - \alpha_k$: private-value component ± 1

  (assume $\alpha_R < \alpha_I$)

On-exchange and off-exchange **market makers** set half-spreads s_{on} and s_{off}

- for $j \in \{on, off\}$, market makers demand a realized spread of r_j
  - compensation for other costs
  - profit

  (assume $r_{on} < r_{off}$)

A **broker** routes R-orders off-exchange iff $s_{off} < s_{on}$

Regime #1: internalization

Step 1: conjecture an equilibrium with $s_{off} < s_{on}$

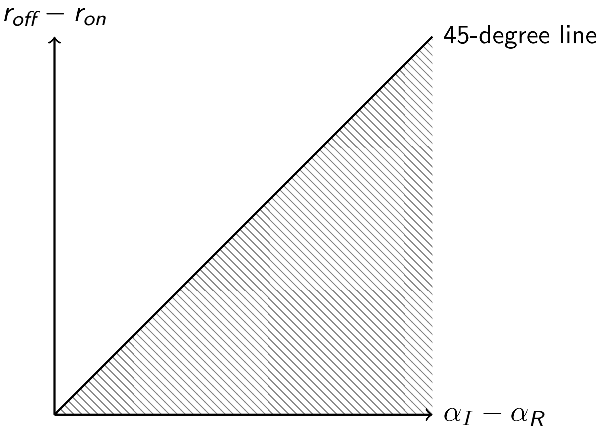
Step 2: solve for equilibrium half spreads:

$$(1-\alpha_I)s_{on} + \alpha_I\left(s_{on}-1\right) = r_{on}$$
$$\implies s_{on} = \alpha_I + r_{on}$$

$$(1-\alpha_R)s_{off} + \alpha_R\left(s_{off}-1\right) = r_{off}$$
$$\implies s_{off} = \alpha_R + r_{off}$$

Step 3: verify: $s_{off} < s_{on} \iff r_{off} - r_{on} < \alpha_I - \alpha_R$

Relevant parameter values



Would R-types be better off without internalization?

- If the on-exchange spread would not change, then no
  - they are getting price improvement
- But the on-exchange spread would change!
  - order flow becomes less informed (my toy model; Battalio and Holden, 2001)
  - order flow becomes less directional (Baldauf, Mollner and Yueshen, WP)

Regime #2: no internalization

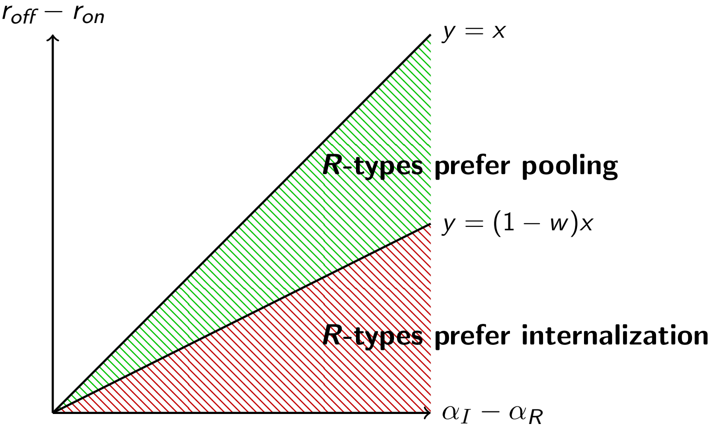
Solve for the equilibrium half spread:

$$[w(1-\alpha_R)+(1-w)(1-\alpha_I)]\, s_{pool} + [w\alpha_R + (1-w)\alpha_I]\,(s_{pool}-1) = r_{on}$$
$$\implies s_{pool} = w\alpha_R + (1-w)\alpha_I + r_{on}$$

Cui bono?

- *I-types:* $s_{pool} < s_{on}$ (unambiguously)
- *R-types:* $s_{pool} < s_{off} \iff r_{off} - r_{on} > (1-w)(\alpha_I - \alpha_R)$

What do R-types prefer?



But it's not this simple!

Market timing

Observation: retail traders tend to submit their orders when on-exchange quoted spreads are wide

In my toy model: w and α_I are positively-correlated random variables

- $\tilde{w}$ and $\tilde{\alpha}_I$ henceforth

Updated expressions

$$s_{off} = \alpha_R + r_{off}$$

$$\mathbb{E}[s_{on}] = \mathbb{E}[\tilde{\alpha}_I] + r_{on}$$

$$\begin{aligned}\mathbb{E}[s_{on}|R] &= \mathbb{E}[\tilde{\alpha}_I|R] + r_{on} \\ &= \mathbb{E}[s_{on}] + \frac{\mathrm{Cov}(\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]}\end{aligned}$$

details

$$\begin{aligned}\mathbb{E}[s_{pool}] &= \mathbb{E}[\tilde{w}]\alpha_R + \mathbb{E}\big[(1-\tilde{w})\tilde{\alpha}_I\big] + r_{on} \\ &= \mathbb{E}[\tilde{w}]\alpha_R + \big(1-\mathbb{E}[\tilde{w}]\big)\mathbb{E}[\tilde{\alpha}_I] - \mathrm{Cov}(\tilde{\alpha}_I, \tilde{w}) + r_{on}\end{aligned}$$

$$\begin{aligned}\mathbb{E}[s_{pool}|R] &= \mathbb{E}[\tilde{w}|R]\alpha_R + \mathbb{E}\big[(1-\tilde{w})\tilde{\alpha}_I|R\big] + r_{on} \\ &= \mathbb{E}[s_{pool}] + \frac{\mathrm{Var}(\tilde{w})\alpha_R + \mathrm{Cov}((1-\tilde{w})\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]}\end{aligned}$$

What do R-types prefer now?

We need to compare: s_{off} vs. $\mathbb{E}[s_{pool}|R]$

Problem: the expression for $\mathbb{E}[s_{pool}|R]$ is complicated (involves higher moments)

The paper implicitly uses two approximations:

1. $\dfrac{\mathbb{E}[s_{pool}|R]}{\mathbb{E}[s_{pool}]} \approx \dfrac{\mathbb{E}[s_{on}|R]}{\mathbb{E}[s_{on}]}$
2. $\mathbb{E}[s_{pool}] \approx \mathbb{E}[\tilde{w}]\alpha_R + \big(1 - \mathbb{E}[\tilde{w}]\big)\mathbb{E}[\tilde{\alpha}_I] - \xcancel{\text{Cov}(\tilde{\alpha}_I, \tilde{w})} + r_{on}$

$$\implies \mathbb{E}[s_{pool}|R] \approx \frac{\mathbb{E}[s_{on}|R]}{\mathbb{E}[s_{on}]}\Big(\mathbb{E}[\tilde{w}]\alpha_R + \big(1 - \mathbb{E}[\tilde{w}]\big)\mathbb{E}[\tilde{\alpha}_I] + r_{on}\Big)$$

- *comment:* make this explicit!

How good is this approximation? Let's do an example.

- Assume $r_{on} = 0$, $\alpha_R = 10$, the following joint distribution for $(\tilde{w}, \tilde{\alpha}_I)$:

		w	
		0.05	0.25
α_I	10	.45	.05
	40	.05	.45

- $\mathbb{E}[\tilde{w}] = 0.15$
- $\mathbb{E}[s_{on}] = \mathbb{E}[\tilde{\alpha}_I] = 25$
- $\mathbb{E}[s_{on}|R] = \mathbb{E}[s_{on}] + \frac{\text{Cov}(\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]} = 33$
- $\mathbb{E}[s_{pool}|R] = \mathbb{E}[\tilde{w}]\alpha_R + (1 - \mathbb{E}[\tilde{w}])\mathbb{E}[\tilde{\alpha}_I] - \text{Cov}(\tilde{\alpha}_I, \tilde{w}) + \frac{\text{Var}(\tilde{w})\alpha_R + \text{Cov}((1-\tilde{w})\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]} = 27.35$

$$27.35 \approx \underbrace{\frac{33}{25} \cdot (0.15 \cdot 10 + 0.85 \cdot 25)}_{= 30.03}$$

$\therefore$ the approximation may understate the benefits of pooling

- *comment:* maybe you can bound the approximation error?

Comment: can volume proxy for inventory costs?

Two effects

1. more volume $\implies$ more netting (lower per-unit inventory costs)
2. more volume $\implies$ potential for larger deviations (higher per-unit inventory costs)

Simple model

- a market maker handles Q orders, each equally likely to be a buy/sell
- total inventory costs quadratic in net inventory $\sum_{q=1}^{Q}(-1)^{B_i}$,
  - where $B_i \sim_{\text{iid}} \text{Bernoulli}(\frac{1}{2})$
- per-unit expected inventory cost

$$\frac{1}{Q}\mathbb{E}\left[\underbrace{\sum_{q=1}^{Q}(-1)^{2B_i}}_{=Q} + \underbrace{2\sum_{i<j} Q(-1)^{B_i+B_j}}_{=0}\right] = 1$$

$\therefore$ the two effects cancel out!

- not true that more volume implies lower inventory costs (in this simple model)

Summary

Main contribution: assesses implications of moving retail order flow on-exchange

- estimates change in on-exchange order flow toxicity
- deals carefully with order-timing issues, heterogeneous liquidity-generation costs

Other contributions: (that I didn't even talk about!)

- cross-sectional analysis
- assessment of wholesaler market power (e.g., analysis of Jane Street's entry)
- discussion of proposed order-by-order auctions

Wishlist for the next version:

- clarify the underlying theoretical framework, close some logical gaps
- smaller comments

Back-Up Slides

Smaller comments

- I wouldn't emphasize computing price improvement as one of your contributions
  - this has already been done, e.g., by Bloomberg [https://bloom.bg/3KQt35u]
  - your other contributions are much deeper!
- I wasn't sure about the meaning of "liquidity-generation costs"
  - costs borne by the liquidity supplier or the liquidity demander?
  - is this a synonym for "realized spread"?
- Retail traders tend to submit their orders when on-exchange quoted spreads are wide...
  - presumably, also when on-exchange effective spreads would be wide...
  - is that due to the adverse selection component or the realized spread component?
  - my toy model effectively assumes it's all through the adverse selection component

Math details

back

$$
\begin{aligned}
\mathbb{E}[s_{on}|R] &= \mathbb{E}[\tilde{\alpha}_I|R] + r_{on} \\
&= \left[\sum_{\alpha,w} \alpha \mathbb{P}(\tilde{\alpha}_I = \alpha, \tilde{w} = w|R)\right] + r_{on} \\
&= \left[\sum_{\alpha,w} \alpha \frac{\mathbb{P}(R|\tilde{\alpha}_I = \alpha, \tilde{w} = w)\mathbb{P}(\tilde{\alpha}_I = \alpha, \tilde{w} = w)}{\mathbb{P}(R)}\right] + r_{on} \\
&= \frac{1}{\mathbb{P}(R)} \left[\sum_{\alpha,w} \alpha w \mathbb{P}(\tilde{\alpha}_I = \alpha, \tilde{w} = w)\right] + r_{on} \\
&= \frac{\mathbb{E}[\tilde{\alpha}_I \tilde{w}]}{\mathbb{E}[\tilde{w}]} + r_{on} \\
&= \frac{\mathbb{E}[\tilde{\alpha}_I]\mathbb{E}[\tilde{w}] + \text{Cov}(\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]} + r_{on} \\
&= \underbrace{\mathbb{E}[\tilde{\alpha}_I] + r_{on}}_{=\mathbb{E}[s_{on}]} + \frac{\text{Cov}(\tilde{\alpha}_I, \tilde{w})}{\mathbb{E}[\tilde{w}]}
\end{aligned}
$$

References

Baldauf, Markus, Joshua Mollner, and Bart Zhou Yueshen, "Siphoned Apart: A Portfolio Perspective on Order Flow Segmentation," *Available at SSRN 4173362*, WP.

Battalio, Robert and Craig W. Holden, "A simple model of payment for order flow, internalization, and total trading cost," *Journal of Financial Markets*, 2001, *4* (1), 33–71.

Would Order-by-Order Auctions Be Competitive?

Thomas Ernst,[1], Chester Spatt[2], and Jian Sun[3]

[1]University of Maryland, Robert H. Smith School of Business
[2]Carnegie Mellon University, Tepper School of Business
[3]Lee Kong Chian School of Business, Singapore Management University

Motivation

- Retail Orders are segmented:
  - Battalio and Holden (2001): lower adverse selection, can offer them better prices

- *How* should they be segmented?
  1. **Broker's routing**: current system
  2. **Order-by-Order Auctions**: SEC proposal

Overview

- **Broker's routing**: Brokers route to wholesalers.
    - Competition among wholesalers is based on aggregate performance
    - No communication on individual trades
- **Order-by-Order Auctions**: SEC proposal to auction off each retail order
    - Allocatively efficient: highest bidder gets the order
    - Winner's curse problem makes bidding less competitive

- **Model results:**
    - Tradeoff between allocative efficiency and competition
    - Smaller or more illiquid stocks will especially suffer
- **Exchange Retail Liquidity Programs** (RLP) empirical analysis:
    - RLPs function very similarly to the proposal for order-by-order auctions
    - Offer less liquidity in small stocks, mid-quote trading rare

Place in Literature

- Segmentation: Battalio and Holden (2001); Baldauf, Mollner, and Yueshen (2022); Parlour and Rajan (2003); Battalio and Jennings (2022)
- Payment for Order Flow: Hu and Murphy (2022), Jain, Mishra, O'Donoghue, and Zhao (2022); Schwarz, Barber, Huang, Jorion, and Odean (2022)
- Cross-Subsidizing Liquidity: Foley, Liu, Malinova, Park, and Shkilko (2020)
- RLPs: Jain, Linna and McInish (2021)
- Option Auctions: Ernst and Spatt (2022); Bryzgalova, Pavlova, and Sikorskaya (2022), and Hendershott, Khan, and Rioridan (2022)
- Trading, Mechanisms: Bernhardt and Hughson (1997); Biais, Matrimort and Rochet (2000); Klemperer (1999); Menezes and Montiero (2004)

Here:

- Theoretical model of *how* retail flow should be segmented
- What do RLPs suggest about order-by-order auctions?

1. Theoretical Model:

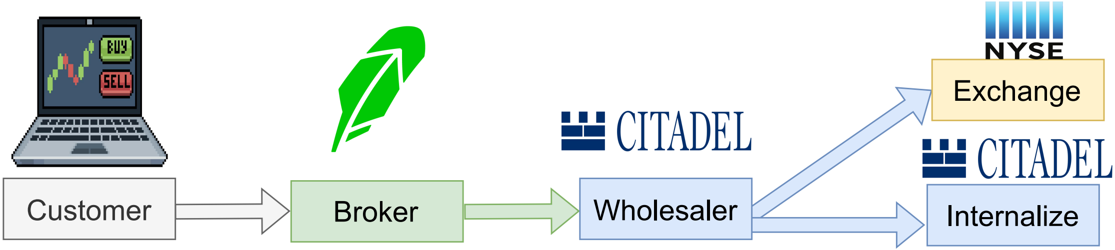
1.1 Background Market Structure Information

1.2 Model Assumptions

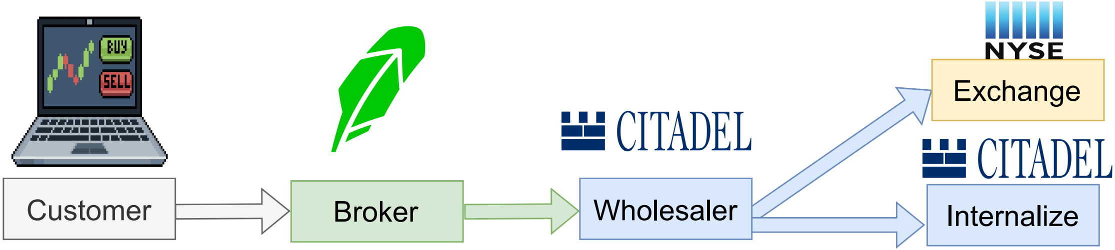
1.3 Equilibria and Welfare

2. Empirics: Retail Liquidity Programs

Broker's Routing

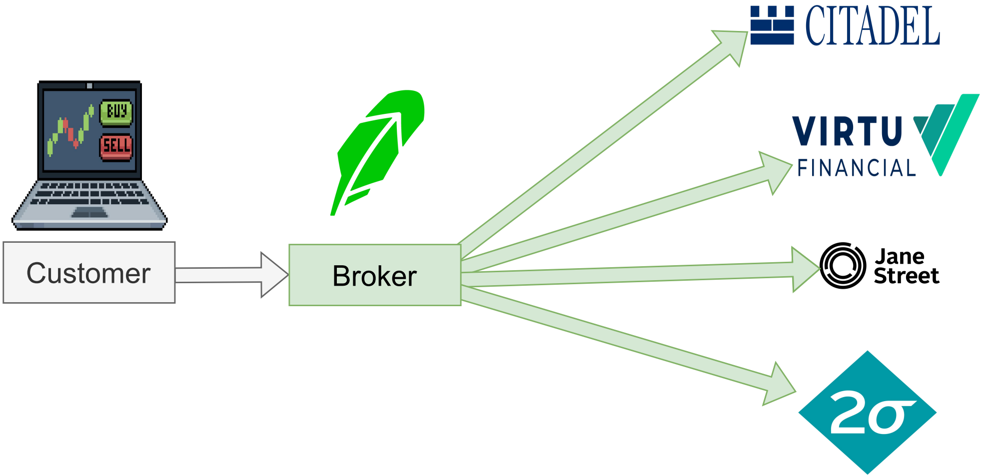


Broker's Routing



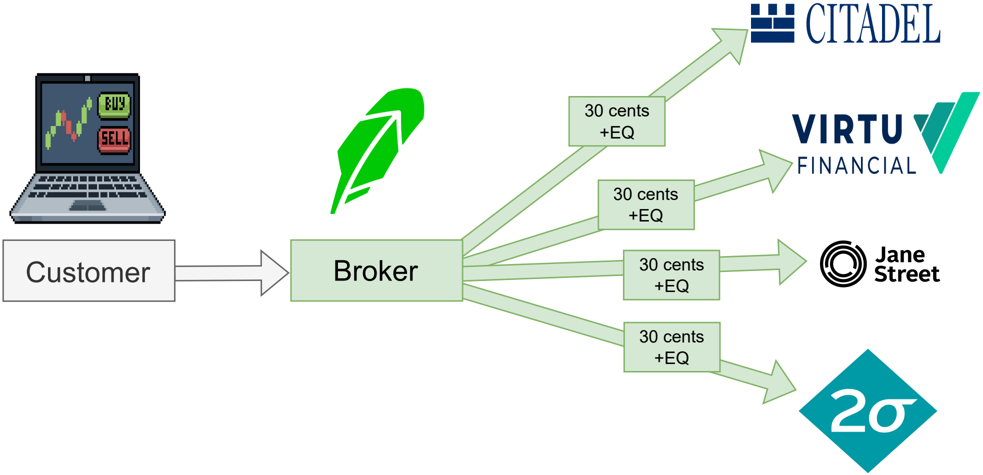
- Brokers only route to wholesalers
  - Wholesalers offer price improvement, qualify for exchange volume tiers, invest in routing technology, low-latency feeds, regulatory compliance, etc.
- When Citadel decides where to route each order Citadel receives from Robinhood:
  - Is this competitive?

Broker's Routing: Competition



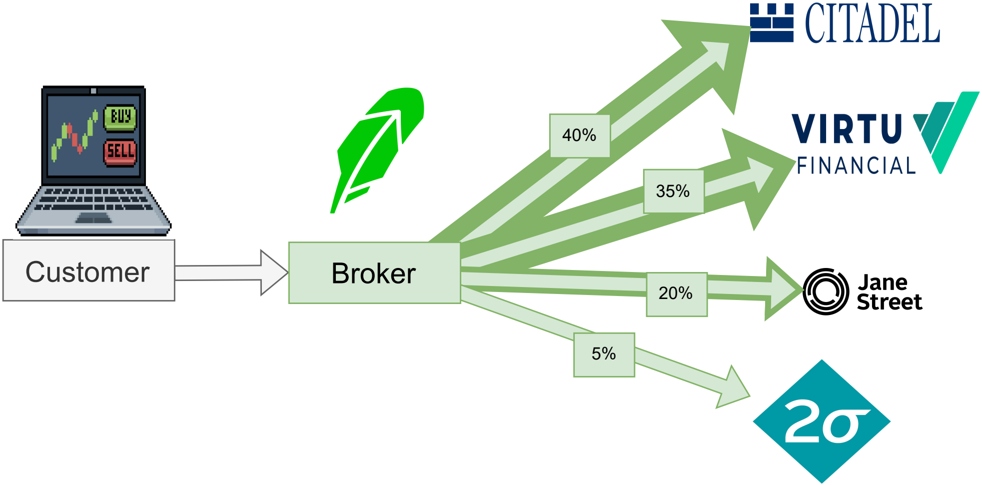
- Brokers route to multiple wholesalers, based on wholesaler execution quality

Broker's Routing: PFOF



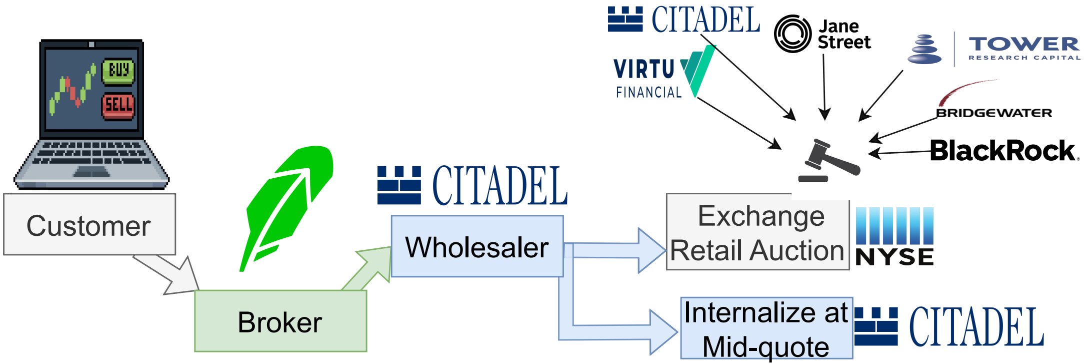
- PFOF is always the same rate across all market makers
- Competition is on execution quality

Broker's Routing: Competition



- Brokers route more to wholesalers who provide better execution quality

SEC Proposal



- Wholesalers could internalize at midquote
- Otherwise: has to go to an auction

Theoretical Model: Agents

Capture the trade-offs in inventory management and competition:

- Retail Investor places an order to buy asset
- $N \geq 2$ identical market makers
- If market maker i fulfills the order at price s_i, they bear inventory cost ζ_i
- Market maker profit:

$$s_i - \zeta_i$$

- Retail Investor welfare:

$$-s_i$$

Theoretical Model: Cost Structure

- Each market maker has private signal

$$\tilde{y}_i \sim U[-1/2, 1/2]$$

- Market maker inventory cost:

$$\tilde{\zeta}_i = c_0 + c_1 \frac{1}{N} \sum_{j=1}^{N} \tilde{y}_j + c_2 \tilde{y}_i$$

Theoretical Model: Cost Structure

- Each market maker has private signal

$$\tilde{y}_i \sim U[-1/2, 1/2]$$

- Market maker inventory cost:

$$\tilde{\zeta}_i = c_0 + c_1 \frac{1}{N} \sum_{j=1}^{N} \tilde{y}_j + c_2 \tilde{y}_i$$

Individual Cost Component. Motivation:
-private signal (e.g. inventory)
-firm-wide capital position

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Aggregate Cost Component:
-aggregate signal / inventory
-unobservable
-adds common value element

Individual Cost Component. Motivation:
-private signal (e.g. inventory)
-firm-wide capital position

Broker's Routing

- Market Makers bid before observing private signals
  - Bid can only depend on expected cost
  - Real world: no negotiation on individual orders
- Equilibrium: each market maker bids expected cost:

$$\mathbb{E}[\zeta] = \mathbb{E}\left[c_0 + c_1 \frac{1}{N} \sum_{j=1}^{N} y_j + c_2 y_i\right] = c_0$$

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- Broker choses market maker at random
  - Highly 'competitive': market makers earn zero profit
  - Market makers will earn money on some trades, lose money on others
  - Allocatively inefficient: trade won't always go to market maker with lowest cost

Order-by-Order Auction

- Market maker bids after observing private signal
  - First-price sealed bid auction (similar to SEC Rule 615 proposal)
  - Market maker i observes y_i but does not observe $y_{j \neq i}$
- Equilibrium: market maker bids s_i, a function of the signal y_i:

$$\boldsymbol{s_i = k_0 + k_1 y_i}$$

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- Allocative efficiency: market maker with lowest signal always wins the auction
- Market Makers earn positive expected profits
  - Intuition: once market makers observe their signals, they are heterogenous
  - Bertrand competition no longer obtains

Welfare Analysis

Tradeoff between allocative efficiency and competition

Retail investor welfare under order-by-order auctions is worse whenever:

$$\frac{c_1}{c_2} > \frac{N(N-3)}{2}$$

- Few market makers: auction is uncompetitive
- High c_1: market makers concern with aggregate inventory is high
- Low c_2: importance of allocative efficiency is low

Model Results

- Order-by-Order Auctions struggle for illiquid stocks
- Extension 1: Institutional Traders amplify adverse selection in auctions
  - Institutional traders trade directionally. They have information about asset quality
  - Strong winner's curse: incumbent market makers bid cautiously
  - Retail welfare decline
- Extension 2: Broker's routing allows cross-subsidizing liquidity
  - Market makers offer better execution quality on illiquid stocks, funded from profits trading liquid stocks
  - Order-by-Order auctions have each order on its own

1. Theoretical Model
    1.1 Background Market Structure Information
    1.2 Model Assumptions
    1.3 Equilibria and Welfare

2. Empirics: Retail Liquidity Programs (RLPs)
    2.1 Discuss similarities between OBO auction and RLPs
    2.2 What does RLP data suggest about OBO auctions?

Exchange Retail Liquidity Programs

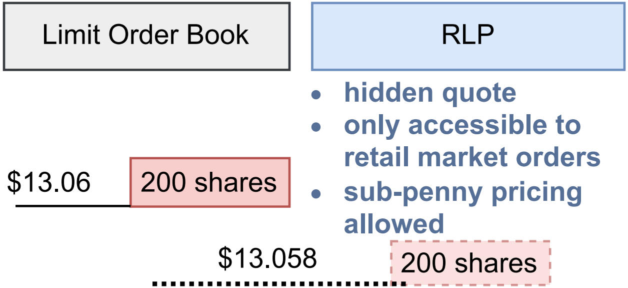
- Allison Bishop (Proof Trading): “Exchanges already have ways for retail orders to be identified and treated specially by market makers, called retail liquidity programs (RLPs)”
- Five RLP programs proposed by SROs were approved by SEC over the last ten years
- RLPs share many features with the OBO proposal:
  - order-by-order competition
  - segmentation
  - institutional traders directly trading with retail

Exchange Retail Liquidity Programs

RLP

- **hidden quote**
- **only accessible to retail market orders**
- **sub-penny pricing allowed**

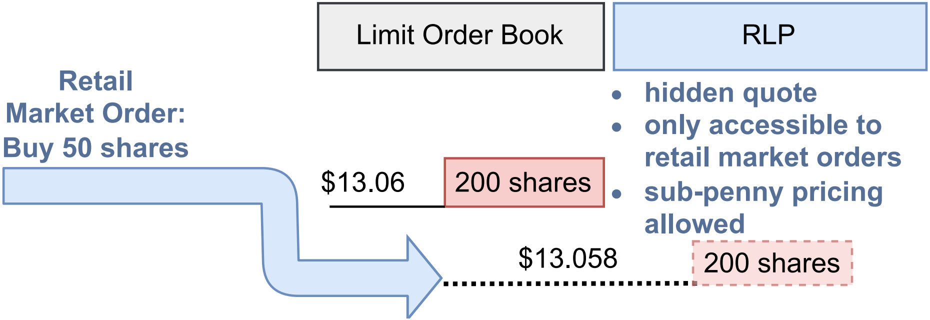
Exchange Retail Liquidity Programs



Example:

- **Public best ask: $13.06**
- **Hidden RLP ask at $13.058**
- **RLP only accessible to retail market orders**

Exchange Retail Liquidity Programs



- Segmentation: can give retail better quote
- Competitive: anyone can post in RLP and any retail market order goes to best bid/ask

RLP Technical Details

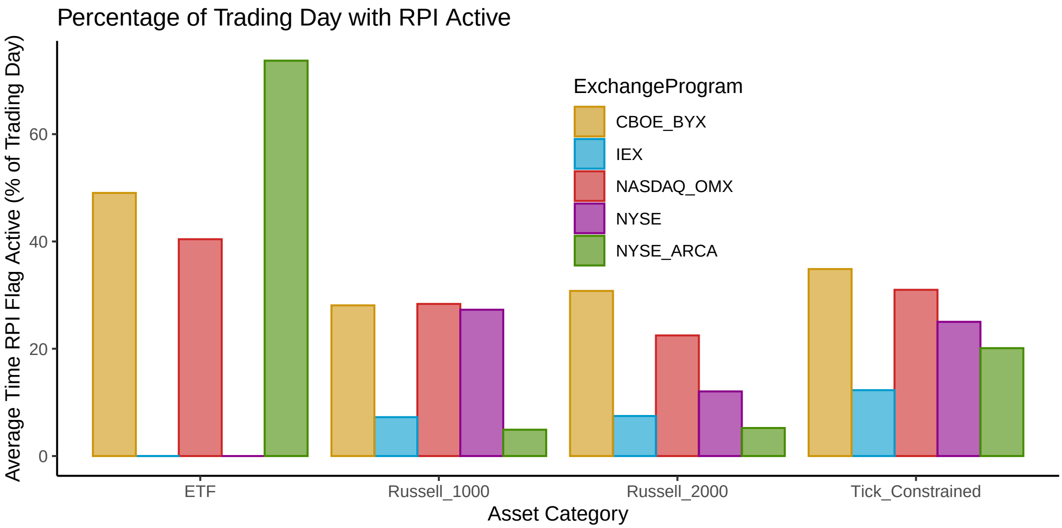
Five programs: NYSE, ARCA, NASDAQ, CBOE, IEX

- Competition: Anyone can post quote. Traditional market makers, as well as institutional investors and hedge funds
- Segmentation: only retail market orders can access quote.
- Hidden: price and size of RLP quote unobserved
- Very similar to proposed auctions

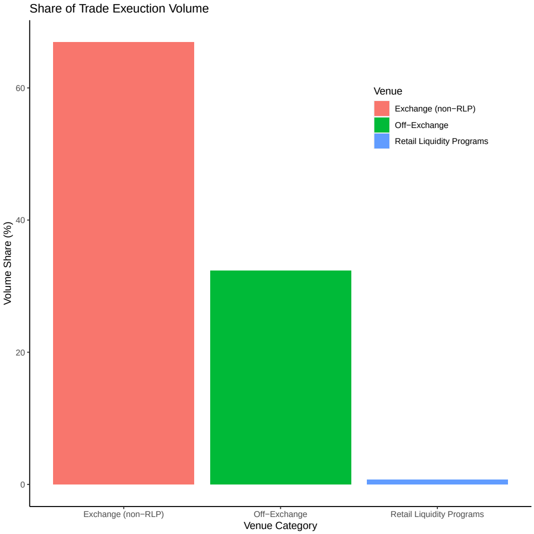
Liquidity is hidden, but exchanges announce if are at least 100 hidden RLP shares:

- Know side (>100 hidden shares to buy, >100 hidden shares to sell, both, or neither)
- No indication of price.

RLPs: Quoting Reach



RLPs: Volume Share



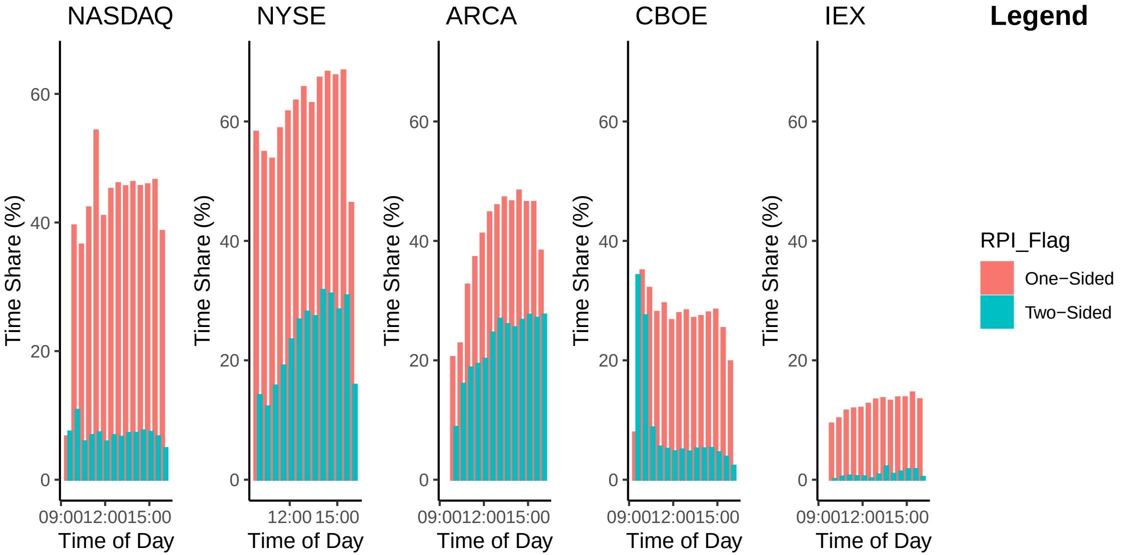
- Around 0.5% of all trading volume occurs in RLPs
- If retail is ∼10% of all trading, then 5% of retail trades go through RLPs
- Volume is very small compared to quote interest

IEX RLP: Midquote only

What insight do RLPs have for auctions?

- IEX RLP: only allows mid-quote liquidity
- Quite different from other programs:
  - If IEX RLP Flag is active, you know the specific price available (mid-quote)
  - Offers insight into the interest of market participants in trading with retail at mid-quote

RLPs: Intraday Quoting



IEX Interest: Low

SEC analysis (based on CAT data):

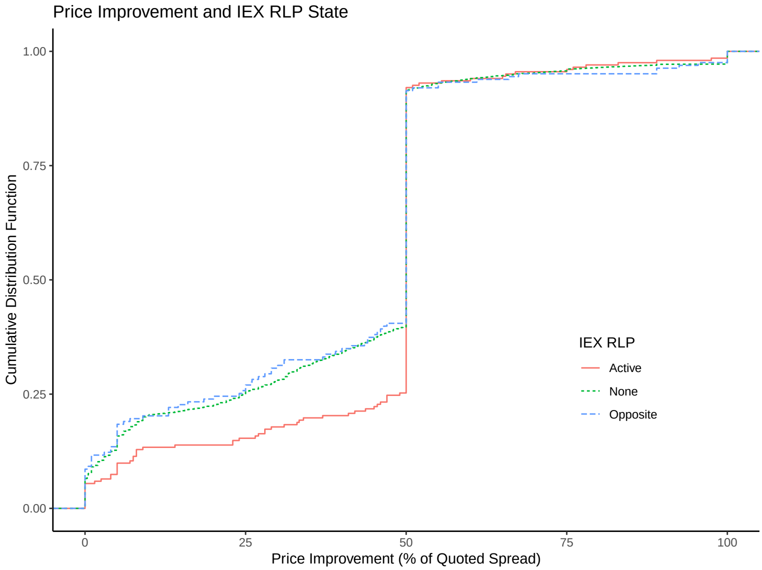
- Retail traders obtain mid-quote 49% of the time
- When retail does not obtain mid-quote:
  - 68% of the time there is hidden mid-quote liquidity available
  - Would this hidden liquidity like to trade with retail? Would auctions help facilitate this?
  - Number of bidders is fundamental to auction outcomes

Hidden liquidity may not want to trade with retail:

- IEX RLP already offers a method to trade with retail at mid-quote?
  - IEX RLP two-sided liquidity less than 6% of the day
  - IEX RLP one-sided liquidity less than 20% of the day

Do wholesalers access or ignore IEX RLP liquidity?

RLPs: Price Improvement Graph



RLPs: Price Improvement Graph

- Retail traders obtain midquote more when IEX RLP is active
  - Do not obtain mid-quote 100% of the time. Surprising
- Retail traders obtain less price improvement when the IEX RLP is opposite-side compared to no RLP at all
  - Consistent with adverse selection

Conclusion

- **Broker's routing**: Brokers route to wholesalers.
  - Competition among wholesalers is based on aggregate performance
  - No communication on individual trades
- **Order-by-Order Auctions**: SEC proposal to auction off each retail order
  - Allocatively efficient: highest bidder gets the order
  - Winner's curse problem makes bidding less competitive

- **Model results:**
  - Tradeoff between allocative efficiency and competition
  - Smaller or more illiquid stocks will especially suffer
- **Exchange Retail Liquidity Programs** (RLP) empirical analysis:
  - RLPs function very similarly to the proposal for order-by-order auctions
  - Offer less liquidity in small stocks, and volatile market conditions

Discussion of "Would Order-By-Order Auctions Be Competitive?" by Thomas Ernst, Chester Spatt and Jian Sun

Eric Budish
University of Chicago, Booth School of Business

May 5th, 2023
SEC, 10th Annual Conference on Financial Market Regulation

Model of Order-by-Order Competition

- Very nice simple model of order-by-order competition.

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- $N > 3$ ex-ante identical market makers. Each market maker i has private signal $y_i \sim U[-\frac{1}{2}, +\frac{1}{2}]$, which determines "inventory cost" given by:

$$\zeta_i = c_0 + c_1 \frac{1}{N} \sum_{j=1}^{N} y_j + c_2 y_i$$

- Parameter interpretation
  - c_0: cost shifter.
  - c_1 : common-value weight.
  - c_2 : private-value weight.
  - For understanding equilibrium, I will set $c_0 = 0$ and $c_1 + c_2 = 1$

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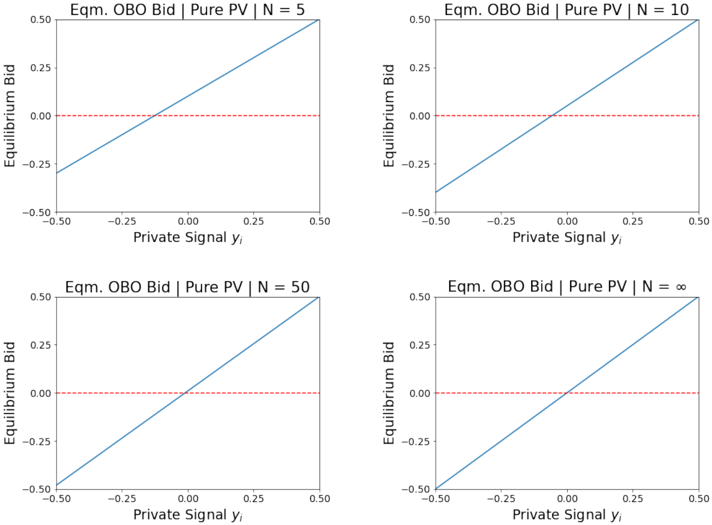
  - c_2 : private-value weight.
  - For understanding equilibrium, I will set $c_0 = 0$ and $c_1 + c_2 = 1$
- Auction game
  - Retail investor arrives wanting to trade one unit. Uninformed.
  - Each market maker bids s_i, the "half bid-ask spread."
  - First-price auction, lowest s_i wins, receives payoff $s_i - \zeta_i$
  - Important note: s_i can be *negative* in equilibrium. Possible interpretation is that the retail investor receives a price better than the midpoint.

Equilibrium: Pure Private Values Case

$(c_0 = 0, c_1 = 0, c_2 = 1)$



Equilibrium: Pure Common Values Case

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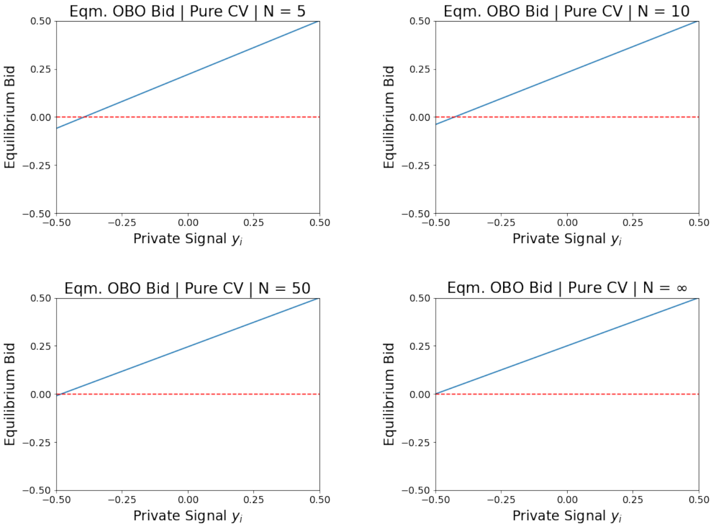
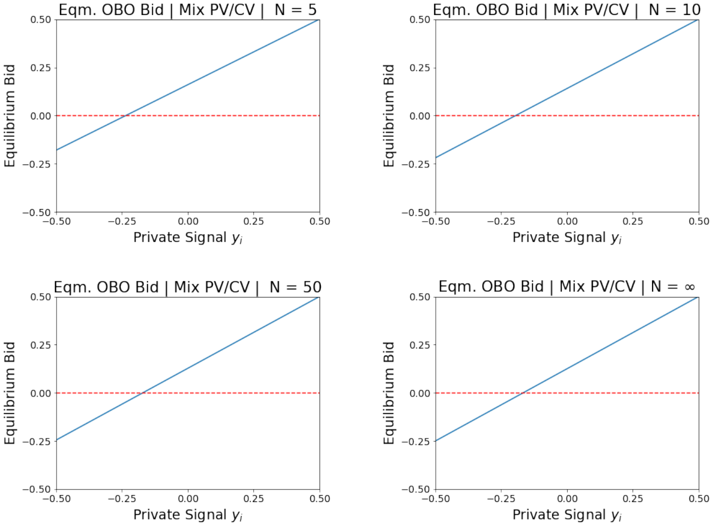
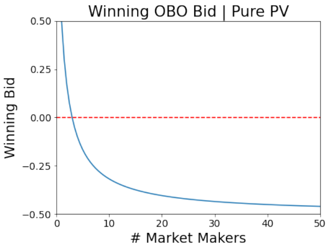


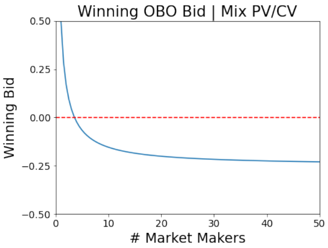
Equilibrium: Mix of Private Values + Common Values

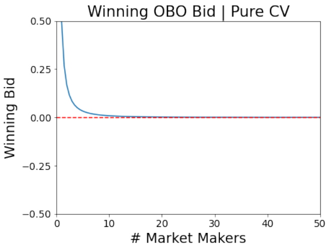
$(c_0 = 0, c_1 = \frac{1}{2}, c_2 = \frac{1}{2})$



Equilibrium Winning Bids







Features of the OBO Equilibrium

- Allocates to the most efficient participant
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- If the private-value weight c_2 is sufficiently large and the number of bidders N is sufficiently large, can get a *negative* winning bid in equilibrium
  - Interpretation: retail investor gets a price better than the midpoint (or, better than the average inventory cost c_0 if we don't normalize that to 0)
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$$\mathbb{E}[s_i(y_i^*)] < 0 \iff \frac{c_2}{c_1} > \frac{2}{N(N-3)}$$

- Bidders rationally account for a winner's curse if there is a common value component. In the pure CV case, we get the famous Milgrom-Wilson intuition that the price aggregates information.

Model of Broker Routing

- I want to take two issues with the way Broker Routing is modeled: a substantive issue and a technical quibble
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  - Example: all retail order flow from a broker in a month

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  - So that's about 130M per month
- So for any one order ... we should treat $p_0 \approx 0$.

Model of Broker Routing

- As a reminder of the technical details of the model of BR: exactly the same as OBO competition but for one key difference. Instead of observing their signal y_i for the particular order:
  - With probability p_0: the market maker sees y_i
  - With probability $1 - p_0$: the market maker sees an uninformative draw from the same distribution, $U[-\frac{1}{2}, +\frac{1}{2}]$
  - (Interpretation: "market-maker performance is evaluated in the aggregate but not order-by-order, and market makers do not have a choice in when they want to accept order flow from the broker")

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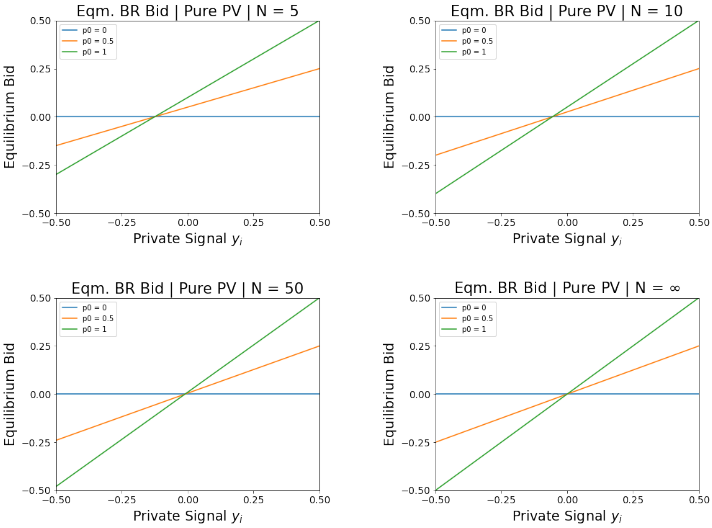
- And what happens in the limit as $p_0 \to 0$?
  - That is, when competition is in the aggregate, as opposed to the individual order?

- Bertrand competition on <u>average costs</u>.
  - Nobody has any information.
  - We all bid our expected costs, which are equal because we are all ex-ante identical.
  - So we all bid <u>exactly zero</u>.

Equilibrium of Broker Routing ($p_0 = 1, 0.5, 0$)

(Pure PV: $c_0 = 0, c_1 = 0, c_2 = 1$)



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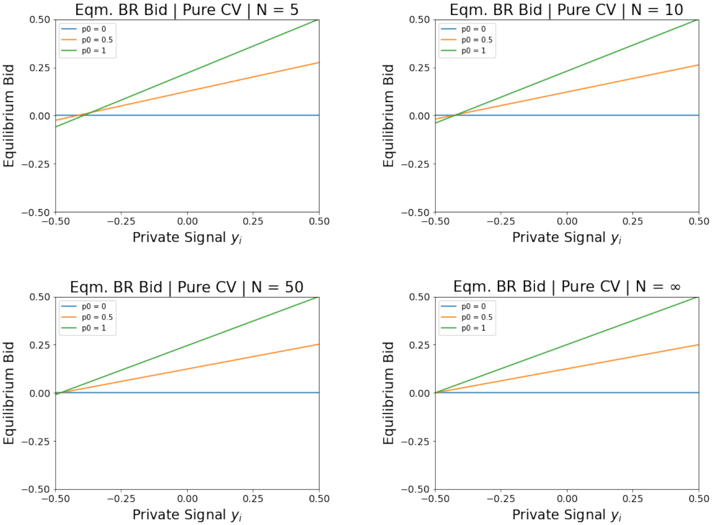
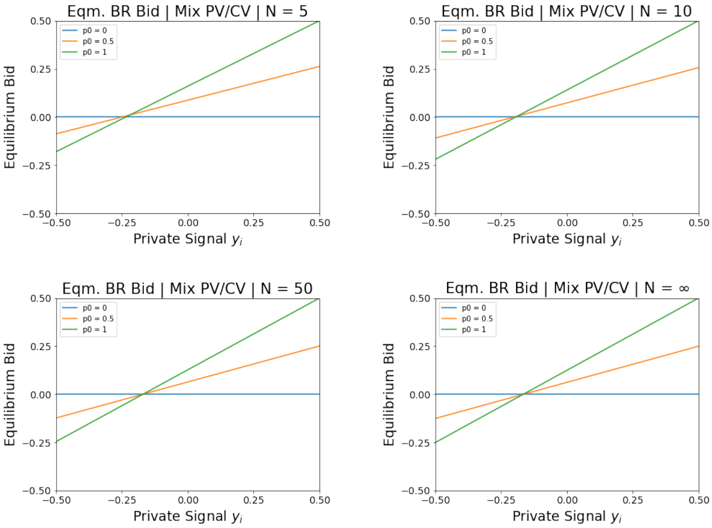


Equilibrium of Broker Routing ($p_0 = 1, 0.5, 0$)

(Mix PV + CV: $c_0 = 0, c_1 = \frac{1}{2}, c_2 = \frac{1}{2}$)



Equilibrium of Broker Routing

- So, if we take the model reasonably seriously, and think about how it applies in practice, it implies that all bids are 0 because of law-of-large-numbers
  - Which we can think of as bidding the midpoint
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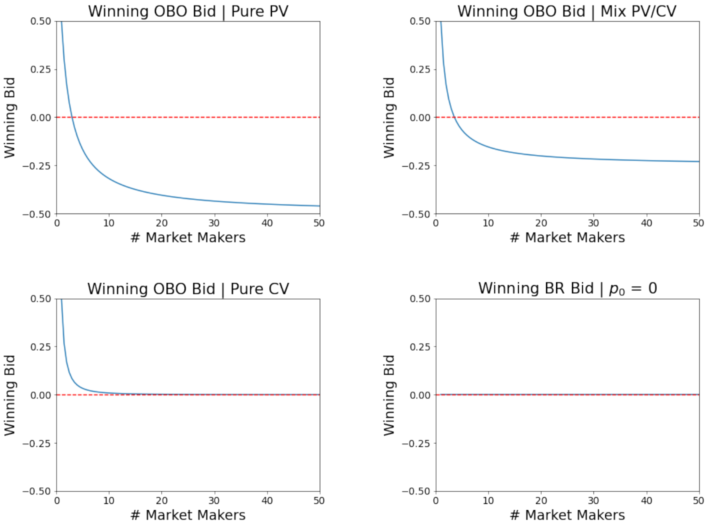
  - Which we can think of as bidding the midpoint
  - Or a small positive amount if the average inventory cost c_0 is positive.
- Importantly: this is worse than the equilibrium price in order-by-order competition for reasonable cases where entry N is decent and there is some weight on private values c_2
  - Need N very low and private-value weight c_2 very low to get BR better than OBO

Equilibrium Winning Bids: Comparison of OBO and BR



Equilibrium of Broker Routing

- My substantive concern is right there in the setup of the model:
  - "... we abstract away from agency problems between the investor and the broker, and assume that the broker's objective is to maximize the investor's welfare, which in our model is equivalent to minimizing the spread." (pg. 8)

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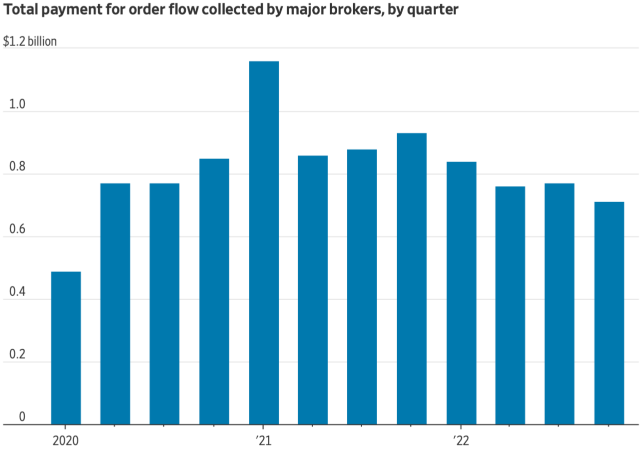
  - (Is the assumption even plausible as a legal matter? Don't publicly traded brokers have a duty to their shareholders to maximize profits, which is in tension with maximizing investor welfare?)
- So my substantive concern is:
  - While the broker-routing model has a lot of moving pieces
  - If you take the most natural limiting case ($p_0 = 0$), where law-of-large-numbers kicks in, the model of BR implies zero economic rents.
  - And if you just look in the world, there is economic rent.

Payment for Order Flow: Magnitudes



Note: Brokers included in total are Ally Invest, Apex, Charles Schwab, E*Trade, Fidelity, Interactive Brokers, Robinhood, TD Ameritrade, TD Ameritrade Clearing, Tastyworks, Tradestation and Webull.

Source: "Robinhood Hits Back at SEC, Warns of Threat to Zero-Commission Trading," Wall Street Journal, Feb 7th 2023.

Broker Routing Realized Spreads: Magnitudes

Table 7: Wholesaler CAT Analysis of Exchange Individual Investor Order Execution Quality for Marketable Orders in NMS Common Stocks and ETFs by Type of Stock

Panel A: Wholesaler and Exchange Execution Quality

Variable	All	SP500	NonSP500	ETF
Average Price	\$29.87	\$110.31	\$10.52	\$53.14
WH Principal Execution Rate	90.44%	93.07%	87.66%	88.12%
WH Share Volume (billion shares)	87.11	11.63	63.17	12.31
EX Share Volume (billion shares)	281.90	66.98	140.82	74.10
WH Dollar Volume (billion \$)	\$2,601.44	\$1,282.62	\$664.41	\$654.41
EX Dollar Volume (billion \$)	\$16,194.84	\$6,479.89	\$3,246.09	\$6,468.85
WH Effective Spread (bps)	2.11	0.67	6.23	0.76
EX Effective Spread (bps)	3.18	1.52	8.11	1.42
WH Realized Spread (bps)	0.85	0.42	2.00	0.51
EX Realized Spread (bps)	-1.22	-0.28	-3.90	-0.34
WH Realized Spread Adj PFOF (bps)	0.49	0.29	0.99	0.36
EX Realized Spread Adj Rebate (bps)	-0.40	-0.06	-1.54	0.08
WH Price Impact (bps)	1.26	0.25	4.22	0.25
EX Price Impact (bps)	4.40	1.80	12.00	1.75
WH E/Q Ratio	0.39	0.32	0.50	0.41
EX E/Q Ratio	1.04	1.01	0.98	1.17

Source: SEC Order Competition Rule Proposal, Page 224.

Broker Routing Realized Spreads: Magnitudes

Table 18: Competitive Shortfall Rates Estimates

Data Source	Stock Type	All	S&P 500	Non-S&P 500	ETF
Rule 605	WH Realized Spread (bps)	0.72	0.30	1.55	0.64
Rule 605	EX Realized Spread (bps)	-0.67	-0.30	-1.97	-0.12
Rule 605	EX Realized Spread Adj Rebate Base (bps)	-0.001	-0.05	-0.24	0.28
Rule 605	EX Realized Spread Adj Rebate High (bps)	0.19	0.02	0.25	0.41
Rule 605	EX Realized Spread Adj Rebate Low (bps)	-0.20	-0.12	-0.73	0.15
CAT	WH Realized Spread (bps)	0.85	0.42	2.00	0.51
CAT	EX Realized Spread (bps)	-1.22	-0.28	-3.90	-0.34
CAT	EX Realized Spread Adj Rebate Base (bps)	-0.40	-0.06	-1.54	0.08
CAT	EX Realized Spread Adj Rebate High (bps)	-0.18	0.00	-0.90	0.20
CAT	EX Realized Spread Adj Rebate Low (bps)	-0.63	-0.12	-2.19	-0.05
Rule 605	Competitive Shortfall Rebate Base (bps)	0.58	0.30	1.42	0.26
Rule 605	Competitive Shortfall Rebate High (bps)	0.38	0.23	0.93	0.13
Rule 605	Competitive Shortfall Rebate Low (bps)	0.77	0.37	1.91	0.38
CAT	Competitive Shortfall Rebate Base (bps)	1.08	0.44	3.07	0.34
CAT	Competitive Shortfall Rebate High (bps)	0.86	0.38	2.42	0.22
CAT	Competitive Shortfall Rebate Low (bps)	1.31	0.50	3.71	0.46

Source: SEC Order Competition Rule Proposal, Page 268.

Broker Routing Realized Spreads: Magnitudes

Table 19: Total Annual Competitive Shortfall Dollar Values under Different Volume Scenarios				
		Segmented Order Volume Scenario		
Data Source	**Competitive Shortfall Scenario**	Base (7.80% of Total Executed Dollar Volume)	Low (7.34% of Total Executed Dollar Volume)	High (10.08% of Total Executed Dollar Volume)
Rule 605	Competitive Shortfall Rebate Base (0.58 bps)	$800 million	$753 million	$1.03 billion
Rule 605	Competitive Shortfall Rebate High (0.38 bps)	$530 million	$499 million	$684 million
Rule 605	Competitive Shortfall Rebate Low (0.77 bps)	$1.07 billion	$1.01 billion	$1.38 billion
CAT	Competitive Shortfall Rebate Base (1.08 bps)	$1.50 billion	$1.41 billion	$1.94 billion
CAT	Competitive Shortfall Rebate High (0.86 bps)	$1.20 billion	$1.12 billion	$1.54 billion
CAT	Competitive Shortfall Rebate Low (1.31 bps)	$1.82 billion	$1.71 billion	$2.35 billion

Source: SEC Order Competition Rule Proposal, Page 272.

Summary Comparison of OBO and BR

- Pure common values model ($c_1 = 1$, $c_2 = 0$)
  - As N grows large, winning bid converges to 0 in both OBO and BR
  - This is the Milgrom and Wilson intuition from their seminal work in the late 1970s

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    - OBO converges to a negative spread – interpretable as a price better than the midpoint.

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  - Similar message as private values case: BR converges to 0, OBO converges to a negative spread

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- So – even assuming that BR has zero rent, OBO looks better in the most natural cases
- **And if broker-routing has economic rents that auctions eliminate (as auctions do!), then that only amplifies the case for OBO $>$ BR for investors.**

Adding Institutional Investors

- It's great that the model separately considers entry by institutional investors. A case to have in mind might be
  - Number of market makers N might be somewhat small: 5?
  - Number of institutional investors N_0 should be pretty large: 20? 50? 100?

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- Proposition 6: $W_I^{OBO} > W_I^{BR}$ if and only if $\frac{c_2}{c_1} > \frac{\frac{1}{(N+N_0)(1+N+N_0)} - \frac{p_0(2-p_0)}{N(N+1)}}{\frac{N+N_0-3}{2(N+N_0+1)} - \frac{p_0(N-3)}{2(N+1)}}$.
- Let $p_0 = 0$ and this threshold becomes $\frac{c_2}{c_1} > \frac{2}{(N+N_0)(N+N_0-3)}$. If...
  - $N = 5, N_0 = 20$, this is $\frac{c_2}{c_1} > .004$.
  - $N = 5, N_0 = 50$, this is $\frac{c_2}{c_1} > .0007$.
  - $N = 5, N_0 = 100$, this is $\frac{c_2}{c_1} > .0002$.

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  - $N = 5, N_0 = 100$, this is $\frac{c_2}{c_1} > .0002$.
- So even a tiny amount of private-values is enough to tip the scales in favor of OBO. And again, that's without any rent in broker routing!

Magnitudes, Political Economy of

- It's worth remembering, since this analysis assumes away any economic rent in the status quo — for the brokers or the market makers — what the rent is
  - PFOF is a few $bn per year
  - Wholesaler rents are $<$1bps on volume (SEC filing analysis)

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- So ... we are fighting about on the order of a basis point.
- This is a classic concentrated vs. dispersed interests problem, in the spirit of Mancur Olson ("The Logic of Collective Action", 1971)
  - If you are one of the parties sharing a piece of the pie, that's a great business
  - Whereas the beneficiaries of improving the market are very dispersed

Magnitudes, Political Economy of

- You can see this concentrated-dispersed dynamic play out in the diversity of comment letters on the Order Competition Rule

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  - And then another surprisingly large set of comment letters that says PFOF is a vast conspiracy — perhaps because it's kind of hard to get worked up over a basis point otherwise
- But the fact is, basis points add up to real money, and the regulator's job is to work on behalf of dispersed interests not the concentrated ones.
- So I commend the SEC for its proposal, and that's why I wrote in support of it.