Market Microstructure: Confronting Many Viewpoints #3
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Tick Size: Theory and Evidence

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• Research questions
  – Motivation
  – Relevance of Tick Size Change
• Theory:
  – Model of Limit Order Book
  – Empirical Predictions
• Empirics:
  – Europe: LSE
  – U.S. : Nasdaq & NYSE
• Conclusions
  – SEC: Recent Proposal for a new Pilot
Tick Size: Minimum Price Improvement

$\tau = \text{inside spread}$
Tick Size Affects Supply and Demand of Liquidity

The seller’s choice is between:

- posting at \( A_1 \) a LIMIT SELL ORDER
- hitting \( B_1 \) with a MARKET SELL ORDER

depends on the tick size

= price improvement
Decimalization

Current scheme in U.S. (post decimalization):
- $0.01 for stocks priced $1 and above
- $0.0001 for stocks priced below $1.00

Source: Public Rule 605 Reports from Thomson, Market orders 100-9,999 shares
Does One Tick-Size Fit All?

• The 2012 JOBS Act puts the focus squarely on the role of the tick size for U.S. capital formation and secondary market liquidity.

• Is the current tick size “too small” for Emerging Growth Companies (EGCs)?
  ↑ Tick Size
  ↑ Limit Orders (LO) => ↑ Market Making
  ↑ Liquidity (depth?) and analyst coverage
  ↑ Attract investors to the market => ↑ volume => ↑ IPOs

• The SEC has been charged with evaluating this hypothesis by the U.S. Congress and therefore recently published the proposed tick size pilot for public comment: http://www.sec.gov/rules/sro/nms/2014/34-73511.pdf
**Research Questions**

**Large vs Small Tick Size change**

**Market Orders vs Limit Orders?**
- Quoted and Relative Spread?
- BBO Depth and Aggregate Depth?
- Volume?
- Welfare of market participants?

**Relative Tick Size matters?**

\[ \tau \downarrow \quad \tau \downarrow \]

**Stock Characteristics affect outcome?**

\[ \tau \downarrow \quad \downarrow \tau \quad \tau \uparrow \quad \uparrow \tau \]

- High vs Low-price stocks?
- Liquid vs Less Liquid books?

**Equivalence holds?**
Our Answers

Theory:

Model of Limit Order Book (LOB) to draw empirical predictions on:

- Large vs small absolute tick size $\Delta$
- Equivalence: absolute tick size $\Delta$ vs asset price $\Delta$
- Liquid vs less liquid books
- High-priced vs low-priced stocks

Empirics:

- LSE stocks
- Nasdaq stocks

Large Absolute tick size $\rightarrow$ RDD

- Nasdaq & NYSE stocks: relative tick size $\Delta$ $\rightarrow$ Fama-MacBeth
Most Related Theoretical Literature

- Seppi (RFS, 1997) $\rightarrow$ Specialist market

- Cordella and Foucault (JFI, 1999) $\rightarrow$ Dealers market
- Kadan (JFI, 2006)

- Foucault, Kadan and Kandel (RFS, 2005) $\rightarrow$ LOB with limit orders being price improving

- Goettler, Parlour and Rajan (JF, 2005) $\rightarrow$ LOB consider a reduction in tick size from 1/8 to 1/16 and adjust the grid as well as the position of the trading crowd (TC) in such a way that market orders (MO) are encouraged
## Evidence on Tick Size Reduction

<table>
<thead>
<tr>
<th>Related Work</th>
<th>Market</th>
<th>Stock</th>
<th>Spread</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahn et al. (JFI, 1996)</td>
<td>AMEX</td>
<td>low-priced &amp; liquid</td>
<td>↓</td>
<td>--</td>
</tr>
<tr>
<td>Ronen &amp; Weaver (JFM, 2001)</td>
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<tr>
<td>Bacidore (JFI, 1997)</td>
<td>TSE</td>
<td>liquid</td>
<td>↓</td>
<td>↓</td>
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<tr>
<td>Griffiths et al (JFI, 1998)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Glostein &amp; Kavajecz (JFE, 2000)</td>
<td>NYSE/NASDAQ</td>
<td>liquid</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Bessembinder (JFQA, 2003)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Jones &amp; Lipson (JFE, 2001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O’Hara, Saar, Zhong (2014)</td>
<td>NYSE</td>
<td>All stocks</td>
<td>SQuoted SRelative ≈</td>
<td>↓</td>
</tr>
</tbody>
</table>
Model Setup

- One asset with value $v$ is exchanged over four trading periods: $t = t_1, t_2, t_3, t_4$
- Market opens with an empty book at $t_1$
- Trade size is normalized to one unit
- A trading crowd absorbs any amount of liquidity demanded at $A_2$ and $B_2$
- Time and price priority are enforced
- At each trading round Nature draws one risk neutral trader with a personal valuation of the asset
  - Buy/Sell/No Trade
  - Market/Limit Order

$\beta \sim U[0,2]$
Traders’ Asset Valuation

\[ \beta = 0 \quad \beta = 1 \quad \beta = 2 \]

- \( \beta = 0 \):
  - Impatient sellers
  - Market order

- \( \beta = 1 \):
  - Patient sellers
  - Limit order

- \( \beta = 2 \):
  - Patient buyers
  - Limit order
  - Impatient buyers
  - Market order

\[ \beta = \frac{1}{2} \]
## Traders’ Strategy Space

<table>
<thead>
<tr>
<th>Strategy</th>
<th>$H_t$</th>
<th>$U(\cdot)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Sell Order</td>
<td>$-1^{B_k'}$</td>
<td>$B_k' - \beta v$</td>
</tr>
<tr>
<td>Limit Sell Order</td>
<td>$1^{A_k}$</td>
<td>$p_t(A_k</td>
</tr>
<tr>
<td>No Trade</td>
<td>$0$</td>
<td>$0$</td>
</tr>
<tr>
<td>Limit Buy Order</td>
<td>$1^{B_k}$</td>
<td>$p_t(B_k</td>
</tr>
<tr>
<td>Market Buy Order</td>
<td>$-1^{A_k'}$</td>
<td>$\beta v - A_k'$</td>
</tr>
</tbody>
</table>
At $t_2$ a seller come to the markets and can choose between a market/limit order to sell, or no trade: $H_t = -1^B_{t_2}, +1^A_{t_2}, 0$

The trader can choose between:
- a market sell order at $B_{t_2}$
- a limit sell order at $A_{t_2}$

This trade-off depends on:
- Current state of the book
- Future states of the book that affect the order’s execution probability, e.g., $\text{Pr}(A_{t_2} | S_{t_2})$
Solved by backward induction
- Start by period $t_4$:

\[
\max_{H_{t_4}()} \pi^e\left[-1^{A_{K'}}, -1^{B_{K'}}, 0|S_{t_3}, \beta\right]
\]

- The outcome of this are the equilibrium strategies $H_{t_4}^n$ which depend on $\beta \sim U[0,2]$.

- We solve for the $\beta$-thresholds which make agents indifferent between two consecutive strategies by equating expected profits from these strategies:

\[
\beta_{H_{t_4}^{n-1},H_{t_4}^n}^{H_{t_4}^{n-1},H_{t_4}^n} : \pi^e_{t_4}(H_{t_4}^{n-1}|S_{t_3}) - \pi^e_{t_4}(H_{t_4}^n|S_{t_3}) = 0
\]
This way we can solve for the ex-ante probability that a trader at $t_4$ chooses the $n^{th}$ strategy $H_{t4}^n$ as this is equal to the probability that $\beta$ lies between the two thresholds which delimit this strategy:

$$
\Pr(H_{t4}^n|S_{t3}) = F(\beta_{t4}^{H_{t4}^n, H_{t4}^{n+1}}|S_{t3}) - F(\beta_{t4}^{H_{t4}^{n-1}, H_{t4}^n}|S_{t3})
$$

At $t_3$ these probabilities are used to compute the execution probabilities of limit orders, and the procedure is repeated up to $t_1$. 
Large Tick Reduction: \( \tau \rightarrow \frac{\tau}{3} \)

- Consider
  - LM: with a large tick all periods, and
  - SM: with the tick size reduced from \( t_2 \) onwards

Pl = 0.3
t1: empty book $\rightarrow$ t2: 3 states of book

- **MOS**
  - $H_i = -1^{a_2}$

- **LOS at $A_1$**
  - $H_i = +1^{a_1}$

- **LOS at $A_2$**
  - $H_i = +1^{a_2}$

- **No Trade**
  - $H_i = 0$

- **LOB at $B_2$**
  - $H_i = +1^{b_2}$

- **LOB at $B_1$**
  - $H_i = +1^{b_1}$

- **MOB**
  - $H_i = -1^{b_1}$

- **t = t1**

- **t = t2**

- **Empty** [Less liquid]

- **1 share on $A_1$** [Liquid]

- **1 share on $A_2$**

- **LM**
  - A2 0 a5
  - A1 0 a2
  - B1 0 b2
  - B2 0 b5

- **SM**
  - v=1

- **LM**
  - A2 1 a5
  - A1 1 a2
  - B1 0 b2
  - B2 0 b5

- **SM**
  - v=1

- **Compute indicators of market quality and welfare from t2 onward for LM**
- **Compare measures of market quality and welfare across equilibria at t2**
## Tick Size: Large Absolute Reduction

**Empirical Predictions**

<table>
<thead>
<tr>
<th>Tick Size</th>
<th>Book</th>
<th>Spread Quoted &amp; Relative</th>
<th>BBO Depth</th>
<th>Total Depth</th>
<th>Volume</th>
<th>Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large reduction</td>
<td>Liquid</td>
<td>DOWN</td>
<td>DOWN</td>
<td>UP</td>
<td>DOWN</td>
<td>DOWN</td>
</tr>
<tr>
<td></td>
<td>Less Liquid</td>
<td>UP</td>
<td>DOWN</td>
<td>DOWN</td>
<td>UP</td>
<td>UP</td>
</tr>
</tbody>
</table>

**Market Quality Deteriorates**

- Market Quality Improves
- Volume Improves
- Volume Deteriorates
Large Absolute Tick Size Reduction Liquid Books

\[ \tau \quad \frac{\tau}{3} \quad \text{Traders undercut } A_1 \text{ by posting orders at } a_1 \]

1/. \downarrow \text{ price improvement from LO} \quad \downarrow \text{ incentive to post LO}

2/. \uparrow \text{ execution probability of LO} \quad \uparrow \text{ incentive to post LO}

2/. > 1/. - Liquid Books MOs>LOs - Traders switch MO to LO:
\[ \uparrow \text{ LO (supply ask side)} \quad \downarrow \text{ MO (demand ask side)} \]

MARKET QUALITY & WELFARE?

- Spread \downarrow
- Total Depth \uparrow
- Volume \downarrow
- Welfare \uparrow

BBO Depth \downarrow
MARKET QUALITY & WELFARE?

- Spread
- Total Depth and BBO
- Volume
- Welfare

NO ORDERS posted at A₁
NOTHING TO UNDERCUT but FEAR OF BEING UNDERCUT!

incentive to post LO

Traders switch from LO to MO:

↓ LO (liquidity supply) and ↑ MO (liquidity demand)
Magnitude of Tick Size Change Matters

Large Tick Reduction

\[ \begin{align*}
A1 & \rightarrow a2 \\
A2 & \rightarrow a5 \\
A1 & \rightarrow a2 \\
B1 & \rightarrow b1 \\
B2 & \rightarrow b5
\end{align*} \]

Small Tick Reduction

\[ \begin{align*}
A1 & \rightarrow a1 \\
B1 & \rightarrow b2 \\
B2 & \rightarrow b5
\end{align*} \]

\[ \begin{align*}
A1 & \rightarrow a1 \\
B1 & \rightarrow b1 \\
B2 & \rightarrow b2
\end{align*} \]

Price Improvement

\[ \begin{align*}
\text{PI} & = 0.3 \\
\tau & = 0.1 \\
\text{PI} & = 0.3
\end{align*} \]
Small Absolute Tick Size Reduction

Small Tick Reduction  \( \tau \iff \tau (1-5\%) \)

| A2 | A'2 | \( \downarrow \) price improvement from LO  \( \downarrow \) incentive to post LO \\
| A1 | A'1 | 1./  \( \uparrow \) execution probability of LO  \( \uparrow \) incentive to post LO \\
| v=1 | B'1 | 2./  \( \downarrow \) LO (supply ask side) and \( \uparrow \) MO (demand ask side) 2./ < 1./ - Traders switch from LO to MO: \\
| B1 | B'2 | 

No Undercutting!

MARKET QUALITY & WELFARE?
- Inside spread  \( \downarrow \)
- Total Depth  \( \downarrow \)
- BBO Depth  \( \downarrow \)
- Volume  \( \uparrow \)
- Welfare  \( \uparrow \)
# Tick Size: Small Absolute Reduction

## Empirical Predictions

<table>
<thead>
<tr>
<th>Tick Size</th>
<th>Spread Quoted &amp; Relative</th>
<th>BBO Depth</th>
<th>Total Depth</th>
<th>Volume</th>
<th>Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Reduction</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>
Relative Tick Size Change \( \frac{\tau}{\nu} \)

\[ \downarrow \frac{\tau}{\nu} \quad \downarrow \tau \quad \uparrow \nu \]

EQUIVALENCE HOLDS?

YES!

- Large absolute tick size
- Small absolute tick size
- Large asset price
- Small asset price

but...

Quoted Spread \( \uparrow \) proportional to asset value

= effects on

- Relative Spread
- BBO Depth
- Total Depth
- Volume
- Welfare
Relative Tick Size Change $\frac{\tau}{v}$: Large $\Delta$

- $\tau = \frac{\tau}{3}$ & $v=1$
- $\tau = \frac{\tau}{3}$ & $v=3$

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(A)</th>
<th>(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a5)</td>
<td>1+9/2 x 0.1/3</td>
<td>1.15</td>
<td>3+9/2 x 0.1</td>
<td>3.45</td>
</tr>
<tr>
<td>(a4)</td>
<td>1+7/2 x 0.1/3</td>
<td>1.12</td>
<td>3+7/2 x 0.1</td>
<td>3.35</td>
</tr>
<tr>
<td>(a3)</td>
<td>1+5/2 x 0.1/3</td>
<td>1.08</td>
<td>3+5/2 x 0.1</td>
<td>3.25</td>
</tr>
<tr>
<td>(a2)</td>
<td>1+3/2 x 0.1/3</td>
<td>1.05</td>
<td>3+3/2 x 0.1</td>
<td>3.15</td>
</tr>
<tr>
<td>(a1)</td>
<td>1+1/2 x 0.1/3</td>
<td>1.02</td>
<td>3+1/2 x 0.1</td>
<td>3.05</td>
</tr>
<tr>
<td>(b1)</td>
<td>1-1/2 x 0.1/3</td>
<td>0.98</td>
<td>3-1/2 x 0.1</td>
<td>2.95</td>
</tr>
<tr>
<td>(b2)</td>
<td>1-3/2 x 0.1/3</td>
<td>0.95</td>
<td>3-3/2 x 0.1</td>
<td>2.85</td>
</tr>
<tr>
<td>(b3)</td>
<td>1-5/2 x 0.1/3</td>
<td>0.92</td>
<td>3-5/2 x 0.1</td>
<td>2.75</td>
</tr>
<tr>
<td>(b4)</td>
<td>1-7/2 x 0.1/3</td>
<td>0.88</td>
<td>3-7/2 x 0.1</td>
<td>2.65</td>
</tr>
<tr>
<td>(b5)</td>
<td>1-9/2 x 0.1/3</td>
<td>0.85</td>
<td>3-9/2 x 0.1</td>
<td>2.55</td>
</tr>
</tbody>
</table>

- 3 ticks = 0.3 = PI
- 9 ticks = 0.9 = PI

Tick = 0.1 & $v=1$

$\tau = \frac{\tau}{3}$ & $v=1$

$\tau = \frac{\tau}{3}$ & $v=3$
Relative Tick Size Change \[ \frac{\tau}{v} \rightarrow \text{Small } \Delta \]

\[\begin{align*}
\tau &= 0.1 \\
\tau &= 0.095
\end{align*}\]

\[\begin{align*}
v &= 1 \\
v &= 0.1/0.095
\end{align*}\]

\[\begin{align*}
A'2 &\quad 1+3/2 \times 0.1 \\
A'1 &\quad 1+1/2 \times 0.1 \\
B'1 &\quad 1-1/2 \times 0.1 \\
B'2 &\quad 1-3/2 \times 0.1
\end{align*}\]

\[\begin{align*}
A2 &\quad 1+3/2 \times 0.1 \\
A1 &\quad 1+1/2 \times 0.1 \\
B1 &\quad 1-1/2 \times 0.1 \\
B2 &\quad 1-3/2 \times 0.1
\end{align*}\]

\[\begin{align*}
A'2 &\quad 1+3/2 \times 0.095 \\
A'1 &\quad 1+1/2 \times 0.095 \\
B'1 &\quad 1-1/2 \times 0.095 \\
B'2 &\quad 1-3/2 \times 0.095
\end{align*}\]

\[\begin{align*}
A2 &\quad 1+3/2 \times 0.1 \\
A1 &\quad 1+1/2 \times 0.1 \\
B1 &\quad 1-1/2 \times 0.1 \\
B2 &\quad 1-3/2 \times 0.1
\end{align*}\]

\[\begin{align*}
\tau = 0.1 &\rightarrow \quad \text{Small } \Delta \\
\tau = 0.095 &\rightarrow \quad \text{Small } \Delta
\end{align*}\]

\[\begin{align*}
\text{Grid Pressure} &\quad 1.15 - 1.143 = 0.007 \\
\text{Grid Pressure} &\quad 1.211 - 1.203 = 0.007
\end{align*}\]
<table>
<thead>
<tr>
<th>Tick Size/Asset Value</th>
<th>Book Quality</th>
<th>Quoted Spread</th>
<th>Relative Spread</th>
<th>BBO Depth</th>
<th>Total Depth</th>
<th>Volume</th>
<th>Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Tick Size Increase</td>
<td>Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Price Reduction</td>
<td>Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less Liquid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Empirical Predictions:

- Stronger for High-Priced Stocks

- Small TS Increase
- Small Price Reduction

Price Reduction = Relative Tick Size Increase
Test the effects of an **LARGE absolute tick size** ↑
1 to 1 conformity with model’s predictions for large tick size change for liquid books

- BBODepth ↑  Quoted & Relative Spread ↑  Volume ↑

- **European Sample** – LSE Stocks
  – Includes stocks getting across the thresholds of LSE tick size grid

- **US Sample** – Nasdaq Stocks
  – Includes stocks getting across the USD1 threshold

Test the effects of a **relative tick size** ↑ (↓ stock price)
Exploit the fact that absolute tick size is constant (0.01) for stocks priced above USD1
No control for price change so can only test predictions for:

- BBODepth ↑  Quoted Spread ↓ : *do not change with state book and magnitude* \( \Delta p \)

- **US Sample** – Nasdaq and NYSE Stocks \( \rightarrow \) Fama MacBeth
  – Includes randomly-picked stocks (all above $1) from a sample of 180 stocks stratified by market cap and price
European Market Sample #1

- Sample: LSE stocks during January 2013 – December 2013
  - LSE Tick size Grid: as stock price crosses the threshold, the absolute tick size increases

LSE Tick Size Grid

<table>
<thead>
<tr>
<th>Stock Price</th>
<th>Tick Size</th>
<th>Relative Tick Size: Tick Size / Stock Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBP</td>
<td>GBX</td>
<td>GBX</td>
</tr>
<tr>
<td>100</td>
<td>10000</td>
<td>10 1000</td>
</tr>
<tr>
<td></td>
<td>x 2</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>5000</td>
<td>5 1000</td>
</tr>
<tr>
<td></td>
<td>x 5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1000</td>
<td>1 1000</td>
</tr>
<tr>
<td></td>
<td>x 2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>0.5 1000</td>
</tr>
<tr>
<td></td>
<td>x 5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>0.1 1000</td>
</tr>
<tr>
<td></td>
<td>x 2</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>50</td>
<td>0.05 1000</td>
</tr>
<tr>
<td></td>
<td>x 5</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>10</td>
<td>0.01 1000</td>
</tr>
</tbody>
</table>

- Selection criteria:
  - Stocks with price crossing one of the existing thresholds at least once
  - Stocks falling in a segment price group that has at least 10 stocks

- Final sample:
  - 142 stocks
  - 4 groups
Quasi-experimental design $\rightarrow$ the probability of receiving a treatment (tick size) changes discontinuously as a function of an underlying variable (stock price)

Sharp design $\rightarrow$ treatment known and depends in a deterministic way on price
# LSE Summary Stats

<table>
<thead>
<tr>
<th>Price (GBX)</th>
<th>Number of stocks</th>
<th>Tick Size TS (GBX)</th>
<th>Bid Depth # of shares</th>
<th>Quoted Spread (GBX)</th>
<th>Relative Spread (%)</th>
<th>Volume # of shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>41</td>
<td>TS above 1</td>
<td>2667</td>
<td>4.62</td>
<td>0.45</td>
<td>18248</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TS below 0.5</td>
<td>1755</td>
<td>3.97</td>
<td>0.40</td>
<td>18003</td>
</tr>
<tr>
<td>500</td>
<td>60</td>
<td>TS above 0.5</td>
<td>2975</td>
<td>2.53</td>
<td>0.50</td>
<td>18126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TS below 0.1</td>
<td><strong>1750</strong></td>
<td>2.39</td>
<td><strong>0.48</strong></td>
<td><strong>21046</strong></td>
</tr>
<tr>
<td>100</td>
<td>21</td>
<td>TS above 0.1</td>
<td>12327</td>
<td>0.36</td>
<td>0.35</td>
<td>93660</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TS below 0.05</td>
<td>9047</td>
<td>0.35</td>
<td>0.35</td>
<td>87435</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>TS above 0.05</td>
<td>50084</td>
<td>0.52</td>
<td>3.71</td>
<td>136636</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TS below 0.01</td>
<td>32728</td>
<td>0.38</td>
<td>4.56</td>
<td>142080</td>
</tr>
</tbody>
</table>
LSE – Regression Discontinuity Design (RDD): 500 GBX

- Local linear regression as suggested by Gelman and Imbens (NBER 2014)

\[
y_{i,t} = b_i + b_1 D_{i,t} + b_2 (price_{i,t} - c) + b_3 (price_{i,t} - c)D_{i,t} + \varepsilon_{i,t}
\]

where

\[
D_{i,t} = \begin{cases} 
1 & \text{if } price_{i,t} \geq c \\
0 & \text{otherwise}
\end{cases}
\]

- \( D_{i,t} \): as the price crosses the threshold, the absolute tick size increases
- \( price_{i,t} \) is reduced by \( c \) to have the threshold at zero. \( c \) is GBX500.
- \( y_{i,t} \) can be bid depth, quoted or relative spread, or volume. Estimation is done using a panel regression with standard errors clustered by stock.

**Bandwidth: 1%**

**Note:**

*BBODepth*  
↑ 1311/1750 =75%

*Quoted Spread*

↑ 0.4861  
(TS below 500GBX=0.1)

*Relative Spread*

↑ 10bp  
(Rel Spread Below =48bp)

*Volume*

↓ 10632  
(Average volume below =21046)

**Fragmentation?**

**Predictions for Liquid Books confirmed**

<table>
<thead>
<tr>
<th></th>
<th>Bid Depth</th>
<th>Quoted Spread</th>
<th>Relative Spread</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>106.9633***</td>
<td>-0.1072**</td>
<td>-0.0002**</td>
<td>1013.9381</td>
</tr>
<tr>
<td></td>
<td>(3.00)</td>
<td>(-2.16)</td>
<td>(-2.23)</td>
<td>(1.54)</td>
</tr>
<tr>
<td>Price*Dummy</td>
<td>-713.225</td>
<td>0.0498</td>
<td>0.0001</td>
<td>1385.0356</td>
</tr>
<tr>
<td></td>
<td>(-1.00)</td>
<td>(1.02)</td>
<td>(1.08)</td>
<td>(1.20)</td>
</tr>
<tr>
<td>Observations</td>
<td>33736</td>
<td>33736</td>
<td>33736</td>
<td>25815</td>
</tr>
<tr>
<td>FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.2008</td>
<td>0.7049</td>
<td>0.7062</td>
<td>0.0182</td>
</tr>
</tbody>
</table>

\( t \) statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01
\[ y_{i,t} = b_i + b_1 D_{i,t} + b_2 (price_{i,t} - c) + b_3 (price_{i,t} - c) D_{i,t} + \varepsilon_{i,t} \]

where

\[ D_{i,t} = \begin{cases} 
1 & \text{if } price_{i,t} \geq c \\
0 & \text{otherwise}
\end{cases} \]

- \( c \): threshold \( \rightarrow \) GBX 10, 100, 500 or 1000 depending on the group.
- \( y_{i,t} \) can be bid depth, quoted spread, relative spread or volume.
- The bandwidths considered are of 1%, 2% and 3% respectively: 3/3 means that the coefficient is significance for all the three bandwidths.
- Optimal bandwidths: 1000GBX: 2.33%; 500GBX: 2.05%; 100GBX: 2.65%; 10GBX: 2.6%
- Estimation is done using a fixed effect panel regression with standard errors clustered by stock.
Conclusions (I): SEC Pilot?

What can we say about the **proposed SEC tick size increase**?

AIM of the proposed tick size ↑:

- ↑ Tick Size
- ↑ LO => ↑ Market Making
- ↑ Liquidity (depth?) and analyst coverage
- ↑ Attract investors to the market => ↑ volume => ↑ IPOs

- Our model does not focus on analysts' coverage but only on liquidity.

- Our results show that the connections above are not so straightforward.

- Clearly aiming at ↑ both market quality and volume is not an easy task, given the trade-off between liquidity supply and liquidity demand.

- Hence it can be achieved ONLY by attracting new trading from other markets in such a way that overall: ΔLO↑ >ΔMO↑
# Tick Size Increase

## From Theory to Empirics

<table>
<thead>
<tr>
<th>Tick Size</th>
<th>Book</th>
<th>Liquidity Supply</th>
<th>Liquidity Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Tick Size Increase</td>
<td>Liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSE</td>
<td>Less Liquid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Quoted Spread**
- **Relative Spread**
- **BBO Depth**
- **Total Depth**
- **Volume**

### Effects from Inter-market Competition

<table>
<thead>
<tr>
<th>Endogenous entry HFTs and other Investors</th>
<th>Market Makers HFTs</th>
<th>O’Hara, Saar and Zhung (2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Takers SORs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions (II)

Effects of \( \uparrow \) tick size (PILOT)

LIQUID BOOKS
1. Model: not supportive of Pilot in terms of total depth
2. Empirics: not supportive of Pilot in terms of volume
3. With endogenous entry of HFTs and other investors, one may assume that market quality would improve but volume would further decrease.

LESS LIQUID BOOKS
1. Model: not supportive of Pilot in terms of volume
2. Empirics: supportive of Pilot in terms of depth but no evidence on volume

So: increasing the tick size would probably foster market making by HFT firms but NOT volume and therefore not necessarily more IPOs.

More analysts’ coverage? OSZ (2014) rightly note that HFT firms are not generally in the business to provide equity research! and anyway a 1 year pilot is not long enough to test whether the tick size change will \( \uparrow \) IPOs!
Thank you!
Effects of a tick size reduction from $1/8 to $1/16:

MO Increase
LO Decrease
U.S – RDD (I)

Our Paper:
• Select all Nasdaq listed stocks with price between $0.8 and $1.2 on September 30, 2010.
• Keep the stocks whose price crosses the $1 threshold at least once during the sample period (Oct-Nov, 2010).

Bartlett and McCrary (2014):
• Find similar results
\[ y_{i,t} = b_i + b_1 D_{i,t} + b_2 (price_{i,t} - 1) + b_3 (price_{i,t} - 1)D_{i,t} + \varepsilon_{i,t} \]

where \( D_{i,t} = \begin{cases} 1 & \text{if } price_{i,t} \geq 1 \\ 0 & \text{otherwise} \end{cases} \)

- \( price_{i,t} \) is the price rounded down to the closest cent and is reduced by one to have the threshold at zero.
- \( Y_{i,t} \) is the logarithm of the bid depth and of quoted and relative spread respectively.
- Estimation is done using a panel regression with standard errors clustered by stock.
- Estimation is carried out for three different bandwidths (10%, 15% and 7.5% of $1).

Bid Depth: ↑ 1.5-1.6 log(share), i.e. 4.5-5 shares: small compared to 821 average below

Quoted Spread: ↑ 1.3%-1.4% USD economically significant compared to ave below 0.99%

Relative Spread: ↑ 1.2%-1.3% USD economically significant compared to ave below 1.19%
Test the effects of a relative tick size $\uparrow$, i.e., $\downarrow$ price

No control for price change: hence only 2 sharp predictions:
BBODepth $\uparrow$ Quoted Spread$\downarrow$;
$\Delta$Relative Spread and $\Delta$volume depend on state book.

Sample Stocks: 180 common stocks listed on NYSE or Nasdaq

Sample Period: Oct 1st – Nov 30th, 2010
Sort all NYSE stocks into tertiles by size and price as of the end of year 2009 $\Rightarrow$ 3-by-3: 9 bins of 10 stocks randomly from each size-price bin - Repeat for Nasdaq, using NYSE cutoffs

Daily Fama-MacBeth regressions with controls for characteristics that affect market quality (volume, volatility, order imbalance, etc.)
Consider a \( \downarrow \) in price by 10USD from 35 to 25

DBBODepth \( \uparrow \) .33% economically significant compared to sample mean 6.73

\( \uparrow \) 235 shares=837-602

---

Table 11 Nasdaq and NYSE sample. BBO Depth. This table reports the results of regressions of the log of BBO depth on contemporaneous market characteristics based on daily cross-sectional Fama-MacBeth regressions. We take the log of market capitalization and volume. The intraday price range is defined as (high-low)/high. NYSE is a dummy variable which takes the value of 1 for stocks whose primary listing exchange is NYSE. We report the average daily coefficients on top and p-values below, computed accordingly Newey-West with 5 lags.

<table>
<thead>
<tr>
<th></th>
<th>(1) Full sample</th>
<th>(2) Small Mkt Cap</th>
<th>(3) Medium Mkt Cap</th>
<th>(4) Large Mkt Cap</th>
<th>(5) Low Price</th>
<th>(6) Medium Price</th>
<th>(7) High Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYSE</td>
<td>0.0078</td>
<td>-0.20***</td>
<td>0.20***</td>
<td>0.10***</td>
<td>-0.10***</td>
<td>-0.023</td>
<td>0.20***</td>
</tr>
<tr>
<td></td>
<td>(0.620)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.102)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>share volume (TAQ)</td>
<td>0.70***</td>
<td>0.58***</td>
<td>0.71***</td>
<td>0.98***</td>
<td>0.78***</td>
<td>0.63***</td>
<td>0.33***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>closing price (CSRIP)</td>
<td>-0.033***</td>
<td>-0.040***</td>
<td>-0.038***</td>
<td>-0.033***</td>
<td>-0.17***</td>
<td>-0.050***</td>
<td>-0.0090***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>quoted spread cents (TAQ)</td>
<td>0.075***</td>
<td>0.066***</td>
<td>0.15***</td>
<td>0.34***</td>
<td>0.22***</td>
<td>0.15***</td>
<td>0.019***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>relative order imb. in % (TAQ)</td>
<td>-0.73***</td>
<td>-0.37*</td>
<td>-1.17***</td>
<td>-1.62***</td>
<td>-0.026</td>
<td>-0.43***</td>
<td>-0.52***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.031)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.891)</td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>(high-low)/high (TAQ)</td>
<td>-6.67***</td>
<td>-4.70***</td>
<td>-10.2***</td>
<td>-25.9***</td>
<td>-17.2***</td>
<td>-15.4***</td>
<td>-3.37***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Constant</td>
<td>-4.92***</td>
<td>-2.58***</td>
<td>-5.20***</td>
<td>-10.0***</td>
<td>-4.66***</td>
<td>-4.45***</td>
<td>-0.43**</td>
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<tr>
<td></td>
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<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Observations</td>
<td>7560</td>
<td>2520</td>
<td>2520</td>
<td>2520</td>
<td>2478</td>
<td>2604</td>
<td>2478</td>
</tr>
</tbody>
</table>

\( p \)-values in parentheses

\( * < 0.05, \quad ** < 0.01, \quad *** < 0.001 \)
Consider a \( \downarrow \) in price by 10USD from 35 to 25

Quoted Spread \( \downarrow \) 1.9 cents: economically significant compared to sample mean of 3.96 cents

### Table 12 Nasdaq and NYSE sample

Quoted spread. This table reports the results of regressions of quoted spread on contemporaneous market characteristics based on daily cross-sectional Fama-MacBeth regressions. We take the log of market capitalization, volume and BBO depth. The relative order imbalance is the absolute value of (buys-sells)/share volume. The intraday price range is defined as (high-low)/high. NYSE is a dummy variable which takes the value of 1 for stocks whose primary listing exchange is NYSE. We report the average daily coefficients on top and p-values below, computed accordingly Newey-West with 5 lags.

<table>
<thead>
<tr>
<th></th>
<th>(1) Full sample</th>
<th>(2) Small Mkt Cap</th>
<th>(3) Medium Mkt Cap</th>
<th>(4) Large Mkt Cap</th>
<th>(5) Low Price</th>
<th>(6) Medium Price</th>
<th>(7) High Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYSE</td>
<td>0.18***</td>
<td>1.49***</td>
<td>-0.43***</td>
<td>-0.14***</td>
<td>0.14***</td>
<td>-0.15***</td>
<td>-1.36***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>share volume (TAQ)</td>
<td>-2.66***</td>
<td>-2.96***</td>
<td>-1.60***</td>
<td>-0.40***</td>
<td>-0.52***</td>
<td>-1.62***</td>
<td>-4.85***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>closing price (CSRP)</td>
<td>0.19***</td>
<td>0.37***</td>
<td>0.20***</td>
<td>0.025***</td>
<td>0.13***</td>
<td>0.16***</td>
<td>0.22***</td>
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<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>time-weighted BBO depth (TAQ)</td>
<td>2.52***</td>
<td>2.71***</td>
<td>2.03***</td>
<td>0.24***</td>
<td>0.30***</td>
<td>1.20***</td>
<td>5.83***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>relative order imb. in % (TAQ)</td>
<td>0.43</td>
<td>0.93</td>
<td>0.97***</td>
<td>0.84***</td>
<td>0.41*</td>
<td>1.43***</td>
<td>2.64</td>
</tr>
<tr>
<td></td>
<td>(0.350)</td>
<td>(0.163)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.333)</td>
<td>(0.065)</td>
<td>(0.065)</td>
</tr>
<tr>
<td>(high-low)/high (TAQ)</td>
<td>75.7***</td>
<td>84.1***</td>
<td>46.3***</td>
<td>18.4***</td>
<td>13.1***</td>
<td>50.3***</td>
<td>159.4***</td>
</tr>
<tr>
<td></td>
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<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
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</tr>
<tr>
<td>Constant</td>
<td>26.6***</td>
<td>25.3***</td>
<td>11.8***</td>
<td>6.03***</td>
<td>7.17***</td>
<td>18.5***</td>
<td>41.9***</td>
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<tr>
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<td>(0.000)</td>
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<tr>
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<td>7560</td>
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<td>2520</td>
<td>2520</td>
<td>2478</td>
<td>2604</td>
<td>2478</td>
</tr>
</tbody>
</table>

\( p \)-values in parentheses

\( ^* p<0.05, ^{**} p<0.01, ^{***} p<0.001 \)
Consider a ↓ in price by 10USD from 35 to 25

Relative Spread ↓ 0.33bp for a 10USD price; economically not significant compared to sample mean of 15bp
Large Tick Reduction $\tau = 0.1 \implies \frac{\tau}{3}$

Large Tick Size Reduction makes undercutting possible

Market Quality?
- Spread
- Depth
Volume?
Welfare?
Small Tick Reduction $\Rightarrow$ No Undercutting

Small Tick Reduction

\[
\begin{align*}
A2 & \rightarrow A'2 \\
A1 & \rightarrow A'1 \\
B1 & \rightarrow B'1 \\
B2 & \rightarrow B'2
\end{align*}
\]

Small Tick Size Reduction does not generate new price levels so: no undercutting

Market Quality?
- Spread
- Depth
Volume?
Welfare?

\[PI = 0.3\]
The pilot program will take place over one year and will include four test scenarios:

- **A control segment** in which all rules will remain constant;
- **Pilot 1**, a target group of securities that will **quote at nickels but can execute at any increment**;
- **Pilot 2**, a target group of securities that will **quote and trade only at nickels**, with **the ability to improve price by half-tick increments** (Minimum Price Variation – $0.025) through internalization, dark pools and on displayed markets (exchanges and ECNs);
- **Pilot 3**, a target group of securities that will **quote and trade only at nickels**, with the added kicker of a **Trade-At provision** that will mandate that **order flow can only trade off-exchange** (internalized or in dark pools) if the trade improves the quoted price by at least 1MPV or, in a 1MPV market, at the midpoint. Brokers and dark pools will no longer be able to match the bid or offer away from a quote displayed on an exchange or ECN.
- There also are limited exceptions for bona fide retail trades and other limited negotiated trades.
Exhibit 1: Full implementation of the rules would see 66% of stocks quoted in 5-cent increments (green).

Source: KCG Data