Competing on Speed

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1. Speed Choices

Some Examples

<table>
<thead>
<tr>
<th>Market</th>
<th>Slow Venues</th>
<th>Fast Venues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equities</td>
<td>Crossing Network</td>
<td>Direct access to exchange, co-location</td>
</tr>
<tr>
<td>FX</td>
<td>OTC dealer/bank</td>
<td>Currenex, EBS, Reuters, Futures</td>
</tr>
<tr>
<td>Bonds</td>
<td>OTC dealer/bank</td>
<td>Aladdin, eSpeed</td>
</tr>
<tr>
<td>Swaps</td>
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<td>Bloomberg, MarketAxxes</td>
</tr>
<tr>
<td>Funds</td>
<td>Mutual Funds</td>
<td>ETF, Index futures</td>
</tr>
<tr>
<td>Inter-City</td>
<td>Internet</td>
<td>Microwaves</td>
</tr>
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2. Fragmentation

[Diagram showing 1-Herfindahl–Hirschman Index for various stock exchanges from 2004 to 2012, with a color legend indicating different years.]
Issue & Analytical Approach

**Financial Markets Organization**

- Why do venues compete on speed?
- Both speed and fragmentation ↗. Is there a relationship?

**Normative**:  
- Social value of speed investments?  
- Is fragmentation socially desirable?  
- Optimal regulation?

**Approach**:  
- Key: all investors value speed, but not equally ⇒ Speed acts as (vertical) differentiation factor  
- Emphasizes liquidity and gains from trade (no asymmetric info)

\[ t = 0 \text{ to } \infty \]
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 Venues: Market Structure
 Investors: Pre-trade choices
 Trading \((t = 0 \text{ to } \infty)\)

'Long-run' 'Short-run' 'day' time
Main Findings

- **Speed-Enhancing Investments**
  - Accelerate fragmentation
  - Equilibrium speeds are inefficient

- **Fragmentation:**
  - Incentivizes trading speeds
  - Enhances “market quality” (evidence in O’Hara Ye 2011) and investor participation, but not necessarily higher welfare

- **Regulations** that protect executions (*SEC’s trade-through*) distort competition, increase fragmentation, and may have *negative welfare effects*
1. Trading in one market (time 0 to ∞)

Micro foundations of Speed Demand

• Two assets: cash (yields \( r \)). Illiquid asset yields \( \mu \) per unit of time, holdings \( a \) in \([0, 1]\).

• Mass one continuum of investors. Endowment \( \bar{a} \) (also total supply). Flow utility:

\[
u_{\sigma, \epsilon_t}(a_t) = (\mu + \sigma \epsilon_t) a_t\]

• time-varying type \( \epsilon \) in \({+,-}\), times \( \sim \exp(\gamma) \), \( \Pr\{\epsilon=+\} = 1/2 \)

• fixed type \( \sigma \in [0, \bar{\sigma}] \) CDF \( G \) (can see as brokers’ “clienteles”)

• Trading:

  • Contact rate (speed) is \( \rho \) (i.e. “latency” \( \rho^{-1} \))
  • “Normalized” speed \( s \equiv \frac{\rho}{r+\gamma+\rho} \)
  • Conditional on contact, market is Walrasian
1. Trading in one market (time 0 to $\infty$)

Micro foundations of Speed Demand

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  - “Normalized” speed $s \equiv \frac{\rho}{r + \gamma + \rho}$
  - Conditional on contact, market is Walrasian
• **Value function** \((\sigma, \varepsilon(t))\) holding \(a\): 
\[ V_{\sigma,\varepsilon(t)}(a, t) = \]
\[ \mathbb{E}_t \left[ \int_t^T e^{-r(s-t)} u_{\sigma,\varepsilon(s)}(a) ds + e^{-r(T-t)} \left( V_{\sigma,\varepsilon(T)}(a^*_T, T) - p_T (a^*_T - a) \right) \right] \]

Flows until contact  
Cont. value at time-T contact

• Optimal holding problem recursive (Lagos Rocheteau EMA 2009)

• **Supply**: \(\bar{a} \leq 1/2\) (supply is short, \(1/2\) investors have \(\varepsilon = +1\))

• **Demand**: Let \(\hat{\sigma}\) type indifferent on buying when \(\varepsilon = +1\).
  
  • \(a^* = 1\) when \(\varepsilon = +1\) and \(\sigma \geq \hat{\sigma}\) (’active’ investor)
  
  • \(a^* = 0\) when \(\varepsilon = -1\) or when \(\sigma < \hat{\sigma}\) (’small’ investor)

• **Equilibrium**: \((p, \hat{\sigma})\) solving demand system and market clearing.

• **Walrasian Case**: \(\rho \to \infty\) (+ free access)

\[ p_W = \frac{1}{r} (\mu + \hat{\sigma}_W), \quad \hat{\sigma}_W = G^{-1} (1 - 2\bar{a}) \]
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Participation value in venue with speed $s$:

$$W(\sigma, \hat{\sigma}, s) \equiv \frac{1}{2} \sum_{\varepsilon} V_{\sigma,\varepsilon}(\hat{a}; s); \quad \text{Autarchy: } W_{out} = \bar{a} \frac{H}{r}$$

Result: Net Participation Value with Speed $s$

- Ex ante net participation value is the sum of the value of transient ownership and trading repeatedly:

$$W(\sigma, \hat{\sigma}, s) - W_{out} = \frac{s\bar{a}\hat{\sigma}}{r} + \frac{s}{2r} \max(0; \sigma - \hat{\sigma})$$

- The value of trading is super-modular in $(s, \sigma)$

Participation Decision $[0, \bar{\sigma}] \rightarrow \{in, out\}$

- $q$: market access fee (membership, co-location, data feed...)
- If $\sigma$ joins, enjoys $W(\sigma, \hat{\sigma}, s) - q$
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\[ p = \frac{\mu}{r} + \hat{\sigma} \left( \frac{r + \gamma s}{r + \gamma} \right) \]

- \( p \) constant a.s. given stationarity of \( \varepsilon \)
- Fraction of traders with mis-allocated assets = \( \frac{\gamma (1-s)}{4 \gamma + rs} \)
- With limited participation \( \hat{\sigma} > \hat{\sigma}_W = G^{-1}(1 - 2\bar{a}) \)
- Mass active traders = \( 1 - G(\hat{\sigma}) \)

- Key difference wrto literature: \( (\hat{\sigma}, s) \) endogenous
- How do investor characteristics, technology, competitive structure, and regulation shape market prices? (see Pagnotta 2013)
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2. Consolidated Market

\[ \max_{q,s} \left\{ q \times \left[ 1 - G(\hat{\sigma}(q,s)) \right] - C(s) \right\} \]

- Assumption 1: \( G(\sigma) \sim 1 - \exp\left(-\frac{\sigma}{\nu}\right), \quad \nu > 0 \)
- Assumption 2: Speed cost is \( c \times \max\{0, \rho - \rho_0\} \), where \( c > 0, \rho_0 > 0 \) “default” speed
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Solution

\[ \hat{\sigma}_{con} = \nu, \quad s_{con} = 1 - \sqrt{2rc \left( \gamma + r \right) \left( \frac{e}{\nu} \right)} \]

Replacing in equilibrium price:

\[ p_{con} = p_{W} + \frac{\nu}{r} \left[ 1 + \log \left( 2a \right) \right] - \frac{\nu}{r} \left( \gamma \sqrt{\frac{2rc}{(r + \gamma) \nu}} e \right) \]

Limited participation distortion \( \equiv \lim_{\rho \to \infty} [p - p_{W}] \)

Illiquidity discount \( \equiv \lim_{q \to 0} [p - p_{W}] \)

Remarks:

- Participation depends only on distribution of types
- Optimal speed level \( (\rho) \) is decreasing in \( c \), increasing in \( \nu \), concave in \( \gamma \)
3. Fragmented Trading

\[ s_1 = s_2 \]

J. Bertrand

\[ s_1 \neq s_2 \]

E. Chamberlin
**Segmentation**  
(multiple asset prices)

- Decision Maker
  - Slow Venue
    - Asset Market 1
  - Fast Venue
    - Asset Market 2

**Protection**  
(single asset price)

- Decision Maker
  - Slow Venue
  - Fast Venue
    - Asset Market
Regulation on Price Protection (Reg NMS’s trade-through)

- **YES**: USA, Canada. **NO**: Europe, Japan, Australia,…
  - Example: *Buy C @ NYSE. If* \( \text{ask}_{\text{NYSE}} > \text{ask}_{\text{NASDAQ}} \), *then unless* \( \text{ask}_{\text{NYSE}} \neq \text{ask}_{\text{NASDAQ}} \), *buy order @ NYSE is routed to NASDAQ.*
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Vertically-differentiated Competition (e.g., Shaked Sutton, EMA 1983)

- **First Stage**: Venue 1 owns \( s_2 = \bar{s} \). Venue 2 selects optimal \( s_2 \)
- **Second stage**: Given speeds, venues compete in fees
Regulation and Competition

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**Proposition: Price protection and competition**

Price protection *increases the profits of the slow venue and decreases total active participation*

- All temporary traders will join slow market $\Rightarrow$ demand less elastic for slow venue
- Ex-Post venue competition less intense $\Rightarrow$ total investor participation $\downarrow$ $(\hat{\sigma}^{prot} > \hat{\sigma}^{seg})$
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Entry: Endogenous Fragmentation

- Two potential entrants, simultaneous entry game (see paper)
- Entry cost $\kappa$

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## Proposition

- Fragmented market: Participation fast venue alone is higher than monopolist case ($\hat{\sigma}_{12} < \hat{\sigma}_{con}$)
- The fast venue chooses higher speed than monopolist

### Intuition: Profits vs. differentiation $s_2 > s_{con}$

- Two-way feedback: trading technologies $\leftrightarrow$ fragmentation
- Measurable Market Quality (Liquidity, Participation, Volumes) higher under fragmentation (as reported in O’Hara Ye (2011) for U.S., Degryse et al. (2011) for Europe)
Fragmentation and Market Quality

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Regulation of...

1. **Speed investments?**
2. **Entry?**
3. **Price Protection?**

Welfare (pre-trading). $i$ indexes venues

\[
\mathcal{W} = \sum_i \int_\sigma (W(\sigma, \hat{s}_i, s_i) - W_{out})dG(\sigma) - \sum_i (\kappa + C(s_i))
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Partic. gains & Allocation efficiency  Entry+Speed Investment
Regulation of...

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Regulation of Speed

- **Regulator**: take number of venues and equilibrium pricing as given.

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- Dodd Frank’s mandate to execute OTC assets in exchanges
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Avg. Execution Speed NYSE in seconds (Source: SEC Rule 605)
Should Fragmentation be encouraged?

- **Regulator**: Takes post-entry strategies as given
- **Classic**: No liquidity externalities or entry costs $\Rightarrow$ fragmentation is best

**Entry**

- The free-entry equilibrium can lead to excessive fragmentation
- Unlikely with only two venues
- More likely with price protection

- Intuition: business stealing and excessive differentiation
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Does Price Protection add Value?
U.S. Reg NMS (2007)

- Model: Affects participation, speed choices, and importantly, entry.

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<td>• No: Small negative effect (total participation ↘)</td>
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- Policy: Price protection effect on welfare is ambiguous (likely positive in US, likely negative in Europe in light of MiFID II)
- Remark: Rationalizes experience of U.S. markets after Reg NMS: many more markets, faster speeds.
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Table II: Parameter values in Calibration

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<th>Parameter</th>
<th>Notation</th>
<th>Baseline Value*</th>
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<tbody>
<tr>
<td>Interest rate</td>
<td>$r$</td>
<td>2.5%</td>
</tr>
<tr>
<td>Holding cash flow</td>
<td>$\mu$</td>
<td>2.44</td>
</tr>
<tr>
<td>Default contact rate</td>
<td>$\rho$</td>
<td>$2.95 \times 10^5$</td>
</tr>
<tr>
<td>Short-run contact rate market 2</td>
<td>$\rho_2$</td>
<td>$1.18 \times 10^6$</td>
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<tr>
<td>Long-run contact rate consolidated market</td>
<td>$\rho_{con}$</td>
<td>$5.90 \times 10^6$</td>
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<td>Switching intensity temporary types</td>
<td>$\gamma$</td>
<td>73,710</td>
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<tr>
<td>Marginal cost of speed investments</td>
<td>$c$</td>
<td>$7.6 \times 10^{-9}$</td>
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<td>Asset supply</td>
<td>$\bar{a}$</td>
<td>0.47</td>
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<td>Average investor type (baseline value)</td>
<td>$\nu$</td>
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- Notes
  - Annualized rates
  - For the baseline value $\nu = 1/2$ the annual utility flow lies in $\{2.14, 2.78\}$. (private value $\sim$ 20% of dividend)
Calibration results: Participation
(Walrasian outcome=100)

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<th>Long-run (2007) (s variable)</th>
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<td>Slow Venue</td>
<td>36.26</td>
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<td>33.35</td>
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<td>61.87</td>
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<td>Slow + fast</td>
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Remarks:
- In the long-run speed differentiation reduces participation
- Protection reduces competition thus access fees are higher in slow venue
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- **Policy Remarks:**
  - Rational to foster fragmentation (SEC’s Reg ATS 1998)
  - Protection is suboptimal (SEC’s Reg NMS 2007)
Calibration results: Speed and Welfare
(Walrasian outcome=100)

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<th>Short-run (s fixed)</th>
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- **Policy Remarks:**
  - Rational to foster fragmentation (SEC’s Reg ATS 1998)
  - Protection is suboptimal (SEC’s Reg NMS 2007)
Asset prices are bad proxy for welfare

**Market Structure and Asset Prices**

1. \( p_{con} \leq p_{frag} \). For small frictions asset classes: \( p_{con} > p_{frag} \)
2. \( p_{con} > p_{nb} \)
3. \( p_{frag} \leq p_{nb} \). If differentiation is not too small: \( p_{frag} > p_{nb} \)

**Some Empirical Implications**

- When stock markets open to competition: liquidity increases but asset price level may decrease (Brazil, South Korea, Australia?)
- Do prices decrease with protection in fragmented markets? Testing: Canada 2011
- International: Fix asset features \( \Rightarrow p^{CHINA} > p^{EU} > p^{US} \)
- OTC Derivatives: liquidity effects more likely to be important (and investors typically high \( \sigma \))
A Few Related Papers

• **Search Frictions.** and asset prices: Duffie Garleanu Pedersen (2005, 2007), Weill (2007, 2008), Lagos Rocheteau (2009), Vayanos Tang (2008), ...

• **Theory of Fragmentation.** Mendelson (1987), Pagano (1989), Madhavan (1995), ...


• **Competition between exchanges.** Santos Scheinkman (2001, margins), Foucault Parlour (2000, listing fees)

• **Vertically differentiated oligopolies.** Gabsewisz and Thisse (1979), Shaked and Sutton (1982, 1983), ...
Final Remarks

- We provide a positive and normative analysis of trading speed and fragmentation in financial markets
  - Positive. Accounts for US and European experiences after Reg. NMS & MifID.
  - Testable implications for market organization, volumes, prices...
  - Normative. Several regulation insights. First normative analysis of investor protection

- Stresses poor mapping between price levels and welfare: tensions PRIMARY-SECONDARY markets
- Tractable model for regulation/policy analysis
THANKS !