A Tale of One Exchange and Two Order Books: Effects of Fragmentation in the Absence of 'Exchange' Competition

Alejandro Bernales[1] Nicolas Garrido[1] Satchit Sagade[2, 4]
Marcela Valenzuela[1] Christian Westheide[3, 4]

[1]University of Chile [2]Goethe University, Frankfurt
[3]University of Mannheim [4]Research Center SAFE

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Outline

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Contribution and Main Findings

Model

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Does fragmentation affect market performance?

What is fragmentation?

- **Fragmentation:** It is when an asset is traded in multiple markets
- Equity markets have moved from a monopolist single-market setup to a fragmented multi-market environment

Does fragmentation affect market performance?

There is a problem to evaluate the effect of fragmentation on market performance

- **'Exchange' competition:** In a fragmented market there is also 'exchange' competition
- Exchanges may compete through distinct features: lower fees, speed, execution of large blocks, etc.
- 'Exchange' competition may also affect market performance
  - E.g. 'Exchange' competition may reduce trading cost $\Rightarrow$ reduction of the bid-ask spread

We do not know whether changes in market performance are due to 'pure' fragmentation or due to 'exchange' competition

We attempt to separate fragmentation from 'exchange' competition. Why. . . ?

Market Consolidation

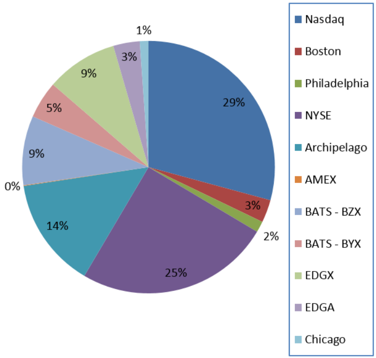
A wave of mergers among exchanges in the US. . .

. . . and the EU

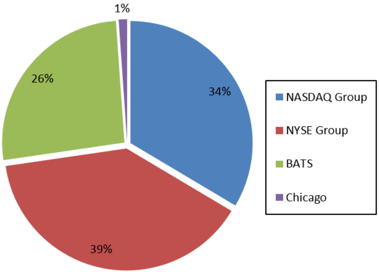
Wrong Appearance of 'Exchange' Competition

Only a small number of operators, each running several exchanges, now compete with one another

Individual Markets



Market Operators



Market Shares for S&P 500 stocks: Week Ending 17 July 2015

Source: Fidessa

Why do operators want to have (artificially) fragmented markets?

Earnings conference transcript from Intercontinental Exchange (ICE)

- *"When you split these liquidity pools, and entrants may do that and regulators may cause that, what happens is that overall volumes tend to go up because the market starts to arbitrage and tries to put the market back together, the value of data goes up. And the whole thing for us turns out to be very good business. We fight that because we don't think it's in the best interest of the market. We have ways of growing otherwise, but we have positioned ourselves for more fragmentation which ultimately I think leads to higher revenues and earnings for ICE."*

Jeffrey Craig Sprecher, 03-May-2017
(Chairman and Chief Executive Officer, ICE Inc)

Objective: Central Questions

Is such artificially fragmented structure optimal?

1. How do liquidity and price efficiency compare in consolidated versus fragmented markets?
2. How is welfare (trading gains) distributed between traders (i.e. between intermediaries and agents with intrinsic reasons to trade)?
3. How does welfare (trading gains) compare in consolidated versus fragmented markets?

Outline

Intuitions

Two intertwined elements affects market performance under fragmentation

1. **'Trader' competition:** There are several traders who compete each other through limit orders and through market orders
   - It is different from 'exchange' competition
2. **Picking-off risk (adverse selection):** Limit orders submitted by agents can be picked-off, when agents cannot quickly modify their limit orders, which are in unfavorable positions after changes in the fundamental value of the asset
   - This is because the fundamental value of the asset is stochastic
   - Limit orders are picked-off through market orders submitted by other agents

Why are these two elements important?

Intuitions: 'Trader' competition

Example: Suppose there is 'trader' competition for execution of their limit orders with 'impatient' agents (there is 'impatience' costs), but there is NO picking-off risk (the fundamental value of the asset is constant)

- **'Trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$**
  - Under this environment, fragmentation reduces 'trader' competition. Why?
  - Traders submit more aggressive limit orders in a single market than in a fragmented market
  - In a single market, traders can only jump ahead of the queue of limit orders through more aggressive orders (since there is time priority for executions)
  - In a fragmented market, traders can circumvent time priority in one order book by submitting an limit order to a second order book

Fragment. $\uparrow \Rightarrow$ 'Trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$

Intuitions: Picking-off risk (adverse selection)

Example: Suppose there is picking-off risk of limit orders (there is a stochastic fundamental value) but there is NO 'trader' competition for the execution of limit orders (there is no an 'impatience' costs)

- **Picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$**
  - Under this environment, fragmentation reduces picking-off risk in limit orders. Why?
  - Suppose that there are n limit orders queuing at the bid price (B).
  - In a single market, if the probability of picking-off risk a limit order in the first priority at price B is: ϕ_B
  - Then, in a fragmented market with TWO limit order books, the probability of picking-off risk a limit order in the first priority at price B is: $\phi_B/2$
    - The n limit orders are divided in the two books

Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$

Intuitions: 'Trader' competition / Picking-off risk

Fragment. $\uparrow \Rightarrow$ 'trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$
Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$

- Which one of these two effects is stronger?
- Is fragmentation always reducing or increasing liquidity?

Problem

Previous theoretical models in fragmentation do not simultaneously include 'trader' competition and picking-off risk

- Fragment. $\uparrow \Rightarrow$ 'trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$
- Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$

Why?

- Very difficult: it is required a complex model
- Thus, previous literature only has a partial view of the effect of fragmentation on market performance

Problem

Previous theoretical models on fragmentation do not simultaneously include 'trader' competition and picking-off risk

- Fragment. $\uparrow \Rightarrow$ 'Trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$
- Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$

Previous theoretical literature in limit order markets:

- Parlour and Seppi (2003, RFS), Foucault and Menkveld (2008, JF):
  - 'Trader' competition: YES (several traders) / Picking-off risk: NO (asset value is fixed)
- Colliard and Foucault (2012, RFS):
  - 'Trader' competition: NO (only one trader) / Picking-off risk: YES (asset value is stochastic)

Outline

Contribution I

We present a dynamic equilibrium model for a multi-market environment WITHOUT 'exchange' competition (i.e. 'pure' fragmentation), which directly includes:

- Several (and heterogeneous) traders: There is 'trader' competition
- Asset value is stochastic: Picking-off risk for limit orders

Contribution II

The model also includes make-take decisions:

- Traders can endogenously decide to compete through limit orders or market orders
- This feature is important. For example:
  - We will show that fragmentation induces intermediaries to prefer more limit orders (Liquidity $\uparrow$)
  - Intermediaries are traders without intrinsic reasons to trade (they can wait with limit to find a trading opportunity)
  - Ideally, intermediaries should submit limit orders, while traders with intrinsic motives to trade should submit market orders (they want to trade immediately)

Contribution III

We provide an explanation of the mixed empirical results about the effect of fragmentation on market liquidity

- Positive association between fragmentation and liquidity:
  - Branch and Freed (1977, JF); Hamilton (1979, JF); Neal (1987, JF); Battalio (1997, JF); Foucault and Menkveld (2008, JF); O'Hara and Ye (2011, JFE)
- Negative association between fragmentation and liquidity:
  - Bessembinder and Kaufman (1997, JFE); Arnold et al. (1999, JF); Amihud et al. (2003, JFQA); Hendershott and Jones (2005, RFS); Nielsson (2009, JFM)
- Mixed association between fragmentation and liquidity:
  - Degryse et al. (2015, RoF); Haslag and Ringgenberg (2016)

We show that fragmentation increases (decreases) liquidity, depending on the market conditions

Main Findings

- Fragmentation increases (decreases) liquidity, depending on the market conditions
- Fragmentation reduces market depth
- Fragmentation increases preferences of intermediaries for limit orders
- Fragmentation shifts welfare from traders with intrinsic reasons to trade to intermediaries

Outline

Model Setup

Dynamic equilibrium model in continuous-time with a single asset

- The fundamental value of the asset, v, is random and follows a Poisson process with parameter λ_v
- $\Delta v = \pm d$ with equal probability

The asset can be traded in two limit order books L_m, $m \in \{1, 2\}$

- It is allowed to submit market orders or limit orders
- Limit order books are described by a discrete set of prices: $\{p_m^i\}_{i=(N,-N)}$
- d is the tick size
- In each book, there is a backlog of unexecuted limit orders to buy or sell, $l_{m,t}^i$, which are associated to each price p_m^i (i.e. $l_{m,t}^i$ is the depth at each price p_m^i).
- Each LOB independently respects *price and time priority*

Model Setup

The model is a stochastic asynchronous game with diverse agents

- Agents arrives randomly over time:
  - Arrival Poisson Process λ
  - Agents can re-enter to modify unexecuted limit orders: Poisson Process λ_r
- Agents are risk-neutral, but they are heterogeneous in their intrinsic (exogenous) reasons to trade:
  - Intrinsic reasons to trade: private values α
  - α is drawn from a discrete vector $\Psi = \{\alpha_1, \alpha_2, \ldots, \alpha_g\}$
  - Using distribution F_α
  - α reflects exogenous reasons to trade such as liquidity need to implement investments projects, hedging needs, etc.
- Agents face a delaying cost ρ with $0 < \rho < 1$ (cost of not executing immediately)
- There is non-cooperation among the agents

Agents' Decisions Are Endogenous and Depend on Market Conditions (States)

Each agent makes four trading decisions after arriving:

1. submit an order to $L_{1,t}$ or $L_{2,t}$
2. choose the direction of the order (buy or sell)
3. choose a market order or a limit order
4. choose the limit price

Upon reentry the agent makes additional trading decisions:

1. keep her unexecuted limit order unchanged (preserve its time priority)
2. cancel and submit a new order (new opportunities or limit orders in wrong positions)
   - submit the new order to $L_{1,t}$ or $L_{2,t}$
   - choose the direction of the new order (buy or sell)
   - choose a market order or a limit order
   - choose the price of the new order

Agents can trade one share and exit forever after trading this share

Agents' Order Submission Strategies

Differences in private values and delay costs drive trading strategies

Agents with high $|\alpha|$:

- Less patient: they prefer to immediately realize their intrinsic values
- (More likely to) prefer market orders / consume liquidity
- Pay an immediacy cost because they cross the bid-ask spread

Conversely, agents with low $|\alpha|$:

- More patient
- (More likely to) prefer limit orders / supply liquidity
- Picking-off risks (i.e. limit orders in wrong positions)

Agents' Dynamic Maximization Problem I

Let $s \in \{1, 2, \dots, S\}$ be the population of observable states.
Each state s described by:

– Contemporaneous LOBs, v, agent's private value and status of unexecuted limit orders

Expected value of *initial decision* $\tilde{a} \in \Theta(s)$, if order is executed prior to the agent's reentry at time h_r, is:

$$\pi(h_r, \tilde{a}, s) = \int_0^{h_r} \int_{-\infty}^{\infty} e^{-\rho h} \underbrace{[(\alpha + v_h - \tilde{p})\tilde{x}]}_{\text{Instantaneous Payoff}} \cdot \gamma(v_h|h) \cdot \eta(h|\tilde{a},\ s) dv_h dh$$

- where $\tilde{p}$ is the optimal submission price and $\tilde{x}$ the optimal order direction (+1 in case of a buy, -1 in case of a sell)
- $\gamma(v|h)$ is the density function of v at time h
- $\eta(h|\tilde{a},\ s)$ is the probability that an optimally submitted order is executed at time h

Agents' Dynamic Maximization Problem II

$\psi(s_{h_r}|h_r, \tilde{a},\ s)$ is the probability that agent observes state s_{h_r} at re-entry time h_r, given her initial decision $\tilde{a}\ \in \Theta(s)$

– it depends on potential states and optimal decisions made by other agents up to time h_r

Equation describing the agent's problem of maximizing her expected value, $V(s)$, after arriving in state s, is given by:

$$V(s) = \max_{\tilde{a}\ \in \Theta(s)} \int_0^\infty [\pi(h_r, \tilde{a}, s) + \underbrace{e^{-\rho h_r} \int_{s_{h_r} \in S} V(s_{h_r}) \cdot \psi(s_{h_r}|h_r, \tilde{a},\ s) ds_{h_r}}_{\text{Payoff from Reentries}}] dR(h_r)$$

$R\left(h_r\right)$ is the distribution of agent's re-entry time

Numerical solution: Pakes and McGuire (2001) algorithm

Model Parametrization

Standard parametrization based on Goettler et al. (2009)

Both LOBs set up with exactly the same features (i.e. there is no 'exchange' competition)

Parameters:

- $\lambda = 1$; $\lambda_r = 0.25$; $\lambda_v = 0.125$;
- $d = 1$; $N_1 = N_2 = 31$; $\rho = 0.05$
- $\Psi = \{-8, -4, 0, 4, 8\}$
- Baseline: $F_\alpha = \{0.15, 0.35, 0.65, 0.85, 1.0\}$

Outline

We analyze TWO main setups to observe the effect of fragmentation

We already explained that:

- Frag. $\uparrow \Rightarrow$ 'trader' compet. $\downarrow$ (without picking-off risk)
- Frag. $\uparrow \Rightarrow$ picking-off risk $\downarrow$ (without 'trader' compet.)

Therefore, we analyze TWO setups:

1. Under LOW volatility (i.e. LOW levels of picking-off risk):
   - Mainly the 'trader' competition effect should be observed
2. Under HIGH volatility (i.e. HIGH levels of picking-off risk):
   - Mainly the picking-off risk effect should be observed

Results: Fragmentation increases (decreases) spread, depending on the market conditions

Fragment. $\uparrow \Rightarrow$ 'trader' competition $\downarrow \Rightarrow$ bid-ask spread $\uparrow$
Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ bid-ask spread $\downarrow$

- Under LOW volatility (i.e. LOW levels of picking-off risk):
  - Mainly the 'trader' competition effect should be observed
- Under HIGH volatility (i.e. HIGH levels of picking-off risk):
  - Mainly the picking-off risk effect should be observed

	Spread after fragmentation under high (low) picking-off risk					
	Low volatility: $\lambda_v = 0.125$ (Low levels of picking-off risk)			High volatility: $\lambda_v = 0.025$ (High levels of picking-off risk)		
	Single Market (1)	Frag Market (2)	Difference (2)-(1)	Single Market (1)	Frag Market (2)	Difference (2)-(1)
Picking-off risk	21.80%	20.81%	-0.99%	59.29%	42.29%	-17.00%
Quoted Spread: Local	1.50	2.56	1.06	5.13	4.93	-0.20
Quoted Spread: Inside	1.50	1.86	0.36	5.13	3.66	-1.47
Effective Spread: Local	1.34	1.89	0.55	3.58	3.53	-0.06
Effective Spread: Inside	1.34	1.57	0.23	3.58	2.89	-0.70

Results: Fragmentation reduces market depth

Under LOW and HIGH volatility levels (i.e. LOW and HIGH levels of picking-off risk):

Frag. $\uparrow \Rightarrow$ 'trader' comp. $\downarrow \Rightarrow$ cancel. $\downarrow \Rightarrow$ exec. time LO $\downarrow \Rightarrow$ depth $\downarrow$

- Frag. decreases 'trader' comp. $\Rightarrow$ Reduction of: LO cancel., new LO submiss., and exec. time of traders with LO $\Rightarrow$ depth decreases

Frag. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ cancel. $\downarrow \Rightarrow$ exec. time LO $\downarrow \Rightarrow$ depth $\downarrow$

- Frag. decreases of picking-off risk. $\Rightarrow$ Reduction of: LO cancel., new LO submiss., and exec. time of traders with LO $\Rightarrow$ depth decreases

	Depth after fragmentation under high (low) picking-off risk					
	Low volatility: $\lambda_v = 0.125$ (Low levels of picking-off risk)			High volatility: $\lambda_v = 0.025$ (High levels of picking-off risk)		
	Single Market (1)	Frag Market (2)	Difference (2)-(1)	Single Market (1)	Frag Market (2)	Difference (2)-(1)
Picking-off risk	21.80%	20.81%	-0.99%	59.29%	42.29%	-17.00%
Cancellations per trader	1.20	1.01	-0.19	1.74	1.10	-0.64
Submissions per trader	1.70	1.51	-0.19	2.24	1.60	-0.64
Exec. time of traders with LO	8.61	7.14	-1.47	7.15	4.60	-2.55
Quoted Depth (Total): Local	3.51	1.60	-1.91	4.17	1.62	-2.55
Quoted Depth (Total): Inside	3.51	2.67	-0.84	4.17	2.65	-1.52

Results: Fragmentation increases preferences of intermediaries for limit orders

- Intermediaries: agents without intrinsic reasons to trade

Under LOW and HIGH volatility levels (i.e. LOW and HIGH levels of picking-off risk):

Frag. $\uparrow \Rightarrow$ 'trader' compet. $\downarrow \Rightarrow$ intermediaries limit orders $\uparrow$

- Frag decreases of 'trader' compet.: Intermediaries prefer more LO

Frag. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ intermediaries limit orders $\uparrow$

- Frag. decreases picking-off risk: Intermediaries prefer more LO

Order type preferences after fragmentation under high (low) picking-off risk

		Low volatility: $\lambda_v = 0.125$ (Low levels of picking-off risk)				High volatility: $\lambda_v = 0.025$ (High levels of picking-off risk)			
	Order Type	Picking-off risk	Private value $\|\alpha\|$ 0	4	8	Picking-off Risk	Private value $\|\alpha\|$ 0	4	8
Single Market	Limit	21.80%	77.12%	52.51%	19.51%	59.29%	21.39%	65.35%	58.15%
	Market		22.88%	47.49%	80.49%		78.61%	34.65%	41.85%
Frag Market	Limit	20.81%	78.42%	50.67%	20.67%	42.29%	51.27%	57.51%	38.71%
	Market		21.58%	49.33%	79.33%		48.73%	42.49%	61.29%

Results: Fragmentation shifts welfare from traders with intrinsic reasons to trade to intermediaries

Fragment. $\uparrow \Rightarrow$ 'trader' compet. $\downarrow \Rightarrow$ intermediaries payoffs $\uparrow$

Fragment. $\uparrow \Rightarrow$ picking-off risk $\downarrow \Rightarrow$ intermediaries payoffs $\uparrow$

- Intermediaries: agents without intrinsic reasons to trade
- Under LOW and HIGH volatility levels (i.e. LOW and HIGH levels of picking-off risk):
  - Fragmentation decreases of 'trader' compet.: Intermediaries increase their payoffs
  - Fragmentation decreases picking-off risk: Intermediaries increase their payoffs

Average payoffs after fragmentation under high (low) picking-off risk

	Low volatility: $\lambda_v = 0.125$ (Low levels of picking-off risk)					High volatility: $\lambda_v = 0.025$ (High levels of picking-off risk)				
	Picking-off Risk	Private value $\lvert\alpha\rvert$				Picking-off Risk	Private value $\lvert\alpha\rvert$			
		0	4	8	Total		0	4	8	Total
Single Market	21.80%	0.543	3.510	7.265	3.745	59.29%	0.606	3.398	7.039	3.652
Frag Market	20.81%	0.626	3.479	7.202	3.740	42.29%	0.817	3.389	6.871	3.662

Outline

Conclusion I

-We examine the impact of market fragmentation (*in the absence of 'exchange' competition*) on market quality and investor welfare

- Relevance in light of *exchange mergers*

-We present a dynamic equilibrium model for a multi-market, which includes:

- 'Trader' competition
- Picking-off risk
- Make-take decisions

Conclusion II

-Fragmentation increases (decreases) liquidity, depending on the market conditions

– We provide an explanation of the mixed empirical results about the effect of fragmentation on market liquidity

-Fragmentation reduces market depth

-Fragmentation increases preferences of intermediaries for limit orders

-Fragmentation shifts welfare from traders with intrinsic reasons to trade to intermediaries

- Market fragmentation may induce that exogenous project may not be implemented
- Market fragmentation may induce an excessive investment capacity from intermediaries

-Policy Implications: Should regulators prevent artificial fragmentation?

Thank You!