High-frequency trading strategies

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Is HFT beneficial to market quality?

"The U.S. stock market was now a class system, rooted in speed, of haves and have-nots. The haves paid for nanoseconds; the have-nots had no idea that nanoseconds had value. The haves enjoyed a perfect view of the market; the have-nots never saw the market at all." (Michael Lewis, Flash Boys)



- * "there are also HFT firms who believe that 350 microseconds is critical to what they do, as they look to pick up trading signals so that they can race ahead and pick off trades from regular investors." (Brad Katsuyama, CEO of IEX)
- The Senate Banking Committee has "expressed concerns about increased market speed, complexity, and potential market fragility as a result of increased automated trading." (Congressional Research Service Report, 2016)



Is HFT beneficial to market quality?

- > Earlier academic evidence is almost always supportive:
 - "AT improves liquidity and enhances the informativeness of quotes." (Hendershott, Jones and Menkveld, 2011)
 - "greater AT intensity improves liquidity and informational efficiency" (Boehmer, Fong and Wu, 2012)
 - "increased low-latency activity improves traditional market quality measures decreasing spreads, increasing displayed depth in the limit order book, and lowering short-term volatility" (Hasbrouck and Saar, 2013)
 - "Overall HFTs facilitate price efficiency" (Brogaard, Hendershott and Riordan, 2014)
 - "Increasing the speed of market-making participants benefits market liquidity" (Brogaard, Hagstromer, Norden and Riordan, 2015)



Is HFT beneficial to market quality?

- > But then...
 - "I find evidence consistent with HFTs being able to anticipate order flow from other investors." (Hirschey, 2013)
 - "Because speed is a source of market power, it enables fast traders to extract rents from other market participants and triggers a costly arms race that reduces social welfare" (Hoffmann, 2014)
 - "trades are followed by limit order cancellations on competing venues" (van Kervel, 2015)
 - "Reductions in latency exacerbate quote-fade and latency arbitrage" (Malinova and Park, 2016)
 - Van Kervel and Menkveld (2016) and Korajczyk and Murphy (2016) find that HFTs initially trade 'against the wind' but eventually trade 'with the wind' as the large trade progresses.



Objectives and motivations

- Much is known about the effects of HFT, the literature is unclear on how HFTs trade to influence financial markets.
 - i.e., what are the information channels that drive HFT behavior?
- Most of the existing evidence is based on executed trades. The order submission behaviour and strategies of HFTs is not well understood.
- We examine HFT trading strategies directly by reconstructing the shape of the limit order book at the time of order submissions, cancellations and amendments.
- Related studies:
 - Malinova and Park (2016): Study HFT order submission behaviour in a multimarket setting
 - Subrahmanyam and Zheng (2016): examine HFT limit order placements on Nasdaq and find that HFT have a stabilizing influence on markets.



- 1. All traders trade with the order book imbalance but HFT do it better.
- 2. HFT supply liquidity to the thick side of the order book (where it is not required) and demand liquidity from the thin side of the order book (where it is most needed).
 - Consistent with order anticipation strategies
- **3**. HFT cancel limit orders that are at high risk of being picked off.
- 4. After the introduction of ITCH (a faster data feed) on the ASX, HFT become even more strategic.
- 5. By competing with non-HFT, HFT crowd out non-HFT limit orders from the order book.



Data and sample

- Full order book and trade data for stocks in the S&P/ASX 100 index from AusEquities (provided by SIRCA)
 - Data contains stock symbol, date and time of order entry, order size and price, identifier for submitting broker (proprietary HFT firms, institutions, retail)
 - Each order has a unique identifier such that subsequent amendments/executions/cancellation can be traced to the original submitted order
- We examine the period January 1, 2012 to December 31, 2012
 - ITCH introduced on April 2, 2012 (more later)



Data and sample

Panel A: Stock characteristics								
	Mean	Std.dev.	Q1	Median	Q3			
Market capitalization (AUD billions)	13.52	22.77	2.844	10.00	114.8			
Dollar volume (AUD millions)	25.54	43.67	5.179	10.51	23.44			
Number of trades	2,176	1,718	1,088	1,633	2,614			
Price (AUD)	11.67	13.18	3.052	6.431	15.05			
Volatility (%)	2.026	1.215	1.280	1.756	2.443			
Spread (cents)	1.037	0.369	0.956	1.014	1.119			

	HFT	Institutions	Retail				
Panel B: Trader characteristics							
Average daily submissions	839.5	12,781	525.6				
Average daily cancelations	375.9	4,309	58.79				
Average daily trades (active)	241.9	1,463	98.90				
Average daily trades (passive)	279.4	3,529	167.7				
Median trade size	1,681	926.5	2,187				
Median submission to cancel time	128.7	246.8	3,034				



Strategic trading





Depth Imbalance and volume imbalance

We capture the shape of the order book using depth imbalance (DI) at the time of each order book event (i.e., submission, trade, amendment or cancelation):

$$DI_{t} = \frac{\sum_{i=1}^{n} VolBid_{i,t} - \sum_{i=1}^{n} VolAsk_{i,t}}{\sum_{i=1}^{n} VolBid_{i,t} + \sum_{i=1}^{n} VolAsk_{i,t}}$$

- We expect:
 - 1. A positive relationship between *DI* and future stock returns.
 - 2. A strategic trader to buy when *DI* is high and sell when *DI* is low.



Depth imbalance, returns and trading volumes







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Depth imbalance and volume imbalances

 $Volume \ imbalance_k\% = \frac{Buy \ volume_k \ - Sell \ volume_k}{Buy \ volume_k \ + Sell \ volume_k}$





Depth imbalance and volume imbalances

Depth imbalance decile	Depth imbalance	HFT	Institutions	Retail	HFT vs. Institutions	HFT vs. Retail
0 (most negative)	-0.375	-61.8	-16.8	-6.2	-44.9 ***	-55.6 ***
1	-0.219	-46.8	-12.8	-7.4	-34.0 ***	-39.5 ***
2	-0.141	-34.2	-8.6	-5.6	-25.6 ***	-28.6 ***
3	-0.080	-21.3	-4.6	-4.1	-16.7 ***	-17.2 ***
4	-0.025	-6.9	-1.0	-1.8	-5.9 ***	-5.0 ***
5	0.028	6.4	2.8	0.0	3.5 ***	6.3 ***
6	0.084	20.2	6.0	1.3	14.3 ***	18.9 ***
7	0.146	33.3	9.8	3.7	23.5 ***	29.6 ***
8	0.225	47.1	14.2	4.4	32.9 ***	42.7 ***
9 (most positive)	0.380	62.6	17.1	6.1	45.5 ***	56.5 ***



Depth imbalance and volume imbalances

Dependent variable: *Volume imbalance*_k% = $\frac{Buy \ volume_k - Sell \ volume_k}{Buy \ volume_k + Sell \ volume_k}$

		Volume imbalance%		Trade imbalance%			
	(1)	(2)	(3)	(4)	(5)	(6)	
	All trading days	Low volatility	High volatility	All trading days	Low volatility	High volatility	
	8,-	days	days		days	days	
I(HFT) × DI	1.017***	0.980***	1.084***	0.921***	0.895***	0.962***	
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	
I(Institutions) × DI	-0.021	0.006	-0.036*	0.080***	0.081***	0.088***	
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	
I(HFT)	0.015	0.024*	0.009	0.022*	0.028**	0.014	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
I(Institutions)	0.018*	0.024*	0.016	0.043***	0.047***	0.036***	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
DI	-0.204***	-0.183***	-0.242***	-0.138***	-0.140***	-0.129***	
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	
Volume	0.011***	0.007**	0.008**	0.010***	0.006	0.009**	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
Constant	-0.288***	-0.209***	-0.242***	-0.288***	-0.292***	-0.216***	
	(0.03)	(0.04)	(0.05)	(0.03)	(0.05)	(0.05)	
Obs.	503,990	150,376	166,644	503,990	150,376	166,644	
Adj. R-square	0.183	0.175	0.198	0.254	0.242	0.283	



Order placement strategies

$$Adjusted DI = q \times \frac{\sum_{i=1}^{n} VolBid_{t} - \sum_{i=1}^{n} VolAsk_{t}}{\sum_{i=1}^{n} VolBid_{t} + \sum_{i=1}^{n} VolAsk_{t}}$$

	HFT	Institutions	Retail
	Panel C: Adjusted depth	imbalance	
Trades (active)	0.148	0.024	0.024
Trades (passive)	0.083	-0.030	-0.012
Submissions	0.059	-0.005	0.030
Amendments	0.043	-0.003	0.014
Cancelations	0.017	0.003	0.027



Order placement strategies

	Adjusted depth imbalance (5 levels)			Adjus	Adjusted depth imbalance (1 level)			
	(1)	(2)	(3)	(4)	(5)	(6)		
	HFT	Institutional	Retail	HFT	Institutional	Retail		
I(Aggressive trade)	0.087***	0.029***	-0.006***	0.330***	0.221***	0.059***		
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)		
I(Passive trade)	0.024***	-0.026***	-0.041***	0.002	-0.095***	-0.077***		
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)		
I(Amend)	-0.014***	0.001**	-0.015***	-0.026**	-0.061***	-0.030***		
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)		
I(Cancel)	-0.043***	0.008***	-0.003	-0.278***	-0.035***	-0.018***		
	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)		
Volatility	0.380***	0.105**	0.206**	0.101	0.070	0.046		
	(0.10)	(0.04)	(0.08)	(0.08)	(0.04)	(0.07)		
Volume	-0.001	0.004***	-0.000	0.001	0.002*	0.001		
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)		
Price	-0.007	-0.006**	0.001	0.025	-0.003	-0.005		
	(0.01)	(0.00)	(0.01)	(0.02)	(0.00)	(0.01)		
Qspread	3.871***	0.545**	-0.496	1.753*	-1.009***	-0.483		
	(0.64)	(0.26)	(0.71)	(0.99)	(0.27)	(0.58)		
Constant	-0.004	-0.071***	0.040	-0.025	-0.025	0.033		
	(0.04)	(0.02)	(0.03)	(0.05)	(0.02)	(0.03)		
Obs.	109,351	111,417	110,409	109,351	111,417	110,409		
Adj. R-square	0.265	0.132	0.042	0.531	0.712	0.091		



Volatility and trading volumes by broker





Volatility and trading volumes by broker

	А	ggressive Volume %		I	Aggressive Trade %	
_	(1)	(2)	(3)	(4)	(5)	(6)
	All stocks	Large stocks	Small stocks	All stocks	Large stocks	Small stocks
I(HFT) × I(Low volatility)	-4.056***	-3.877***	-4.335**	-2.707***	-4.520***	-3.260*
	(0.89)	(1.38)	(1.81)	(0.96)	(1.21)	(1.84)
I(HFT) × I(High volatility)	7.432***	6.520***	7.746***	7.378***	6.614***	7.790***
	(0.62)	(0.91)	(1.59)	(0.87)	(1.19)	(1.95)
I(Institutional) × I(Low volatility)	3.319***	-0.733	9.903***	4.910***	1.177	8.316***
	(0.80)	(0.82)	(1.53)	(0.77)	(0.96)	(1.36)
I(Institutional) × I(High volatility)	4.481***	6.952***	1.859	2.222***	5.019***	-1.705*
	(0.52)	(0.51)	(1.20)	(0.55)	(0.59)	(0.88)
I(High volatility)	-3.527***	-7.910***	4.874**	-0.801	-5.890***	5.871***
	(0.99)	(0.99)	(1.86)	(1.05)	(1.13)	(1.27)
I(HFT)	13.676***	10.160***	14.835***	16.523***	13.366***	16.783***
	(1.39)	(1.75)	(3.00)	(2.01)	(2.65)	(3.90)
I(Institutional)	-10.871***	-12.168***	-9.679***	2.625**	-5.141***	10.629***
	(0.72)	(1.04)	(1.66)	(1.16)	(1.52)	(1.51)
Volatility	86.826***	108.259*	14.548	125.915***	160.321**	73.512**
	(24.55)	(59.77)	(19.76)	(24.72)	(62.06)	(27.85)
Volume	-0.697***	-0.849***	-0.631***	-0.617***	-0.786***	-0.352*
	(0.08)	(0.12)	(0.14)	(0.11)	(0.17)	(0.19)
Constant	59.934***	67.513***	53.625***	42.688***	55.252***	33.113***
	(1.44)	(2.55)	(2.58)	(2.04)	(3.07)	(2.46)
Obs.	449,556	175,152	118,303	449,556	175,152	118,303
Adj. R-square	0.241	0.239	0.207	0.200	0.245	0.162



Volatility and depth imbalance by broker





Volatility and depth imbalance

Dependent variable: Adjusted depth imbalance

		Active trades		Passive trades			
	(1)	(2)	(3)	(4)	(5)	(6)	
	All stocks	Large stocks	Small stocks	All stocks	Large stocks	Small stocks	
I(HFT) × I(Low volatility)	-0.048***	-0.034***	-0.054***	-0.055***	-0.039***	-0.064***	
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	
I(HFT) × I(High volatility)	0.065***	0.064***	0.074***	0.080***	0.068***	0.092***	
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	
I(Institutional) × I(Low volatility)	-0.013***	-0.007*	-0.009	-0.008**	-0.008**	-0.004	
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	
I(Institutional) × I(High volatility)	0.010***	0.007**	0.009**	0.007***	0.003	0.005*	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
I(High volatility)	-0.004	-0.013**	0.007	-0.040***	-0.034***	-0.038***	
	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	
I(HFT)	0.115***	0.098***	0.120***	0.101***	0.082***	0.110***	
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
I(Institutional)	0.002	0.007**	0.003	-0.022***	-0.026***	-0.019***	
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	
Volatility	1.414***	1.677***	1.463***	-0.139	-0.132	-0.083	
	(0.23)	(0.47)	(0.32)	(0.15)	(0.22)	(0.16)	
Volume	-0.006***	-0.004***	-0.008***	-0.002***	-0.000	-0.003**	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
Constant	0.076***	0.052***	0.082***	0.023***	0.008	0.058***	
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	
Obs.	519,904	189,054	168,110	519,670	191,623	174,017	
Adj. R-square	0.157	0.185	0.155	0.148	0.189	0.149	



- ASX ITCH: designed to meet the requirements of speed sensitive traders and increased market information access speeds by up to 7 times existing connections.
 - Implemented on April 2, 2012
 - Pre period: March 2, 2012 to April 1, 2012
 - Post-period: April 9, 2012 to May 9, 2012
 - This event creates benefits for HFT participants, who are the most speed sensitive.



HFT strategies and trading speeds

	(1)		(2)	(3)	(4)		(5)	(6)
-	Volume	imbalance (9	%)		Tra	%)		
	Pre-ITCH		Post-ITCH	F-Test	Pre-ITCH		Post-ITCH	F-Test
I(HFT) × Depth imbalance	0.942***		1.064***	5.350**	0.938***		1.066***	7.71***
	(0.05)		(0.06)	(0.023)	(0.05)		(0.05)	(0.007)
I(Institutional) × Depth imbalance	-0.030		-0.038	0.040	0.017		0.128***	5.27**
	(0.04)		(0.04)	(0.850)	(0.04)		(0.04)	(0.024)
Depth imbalance	-0.095**		-0.118**	0.480	-0.028		-0.121***	6.36**
-	(0.05)		(0.05)	(0.490)	(0.04)		(0.04)	(0.014)
I(HFT)		0.025	. ,	. ,	. ,	0.026		
		(0.02)				(0.02)		
I(Institutional)		0.033**				0.040**		
		(0.02)				(0.02)		
Volume		0.016 ^{***}				0.019 ^{***}		
		(0.00)				(0.01)		
Constant		-0.373***				-0.561***		
		(0.06)				(0.07)		
Obs.		80,666				80,666		
Adj. R-square		0.186				0.278		



- As HFTs become faster, we expect the probability of fill for non-HFT limit orders to decrease.
 - i.e., it becomes more difficult for non-HFT traders to receive executions for their limit orders.
- > Examine only limit orders submitted to the best bid or ask:

 $P(fill) = \frac{\sum TradeVolume}{\sum SubmitVolume}$



Probability of fill and trading speeds

	(1)	(2)
I(Non-HFT) × I(Post-ITCH)	-0.037***	
	(0.01)	
I(Non-HFT)		
I(Institutional) × I(Post-ITCH)		-0.021**
()		(0.01)
I(Institutional)		-0.069***
		(0.02)
I(Retail) × I(Post-ITCH)		-0.057***
		(0.02)
I(Retail)		0.301***
ID . ITOIN	0.020*	(0.02)
I(Post-ITCH)	0.028*	0.029*
37-1-4114	(0.02)	(0.02)
volatinty	(0.17)	(0.17)
Volume	0.071***	0.060***
voidille	(0.00)	(0.00)
Price	0.031	0.033
	(0.04)	(0.04)
Qspread	-1.359	-1.328
	(2.37)	(2.38)
Constant	-0.564***	-0.534***
	(0.08)	(0.08)
Obs.	10,646	10,646
Adj. K-square	0.190	0.586



- HFT trade on information contained in the limit order book. Our findings provide an explanation for how HFT:
 - i. Predict future order flow
 - ii. Increases stock volatility
- > HFT supply liquidity to the thick side of the order book (where it is not required) and demand liquidity from the thin side of the order book (where it is most needed). This trading behaviour exacerbates future order book imbalances.
- > HFT become more strategic with faster trading speeds. However, HFT strategies come at the cost of crowding out non-HFT limit orders from the order book.