Algorithmic and High Frequency Trading: Issues and Evidence

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DEFINING ALGO TRADING AND HIGH FREQUENCY TRADING

Definitions 1/2

- ▶ **Algorithmic trading:** using computers' program to implement investment and trading strategies.

  1. **Not a new phenomenon:** consider for instance "portfolio insurance" strategies (replication of index put options to hedge a large basket of stocks) or "stat arbs" strategies by hedge funds.

  2. **What is new is:**

     2.1 The adoption of automated trading strategies by the buy-side or their brokers to minimize execution costs.
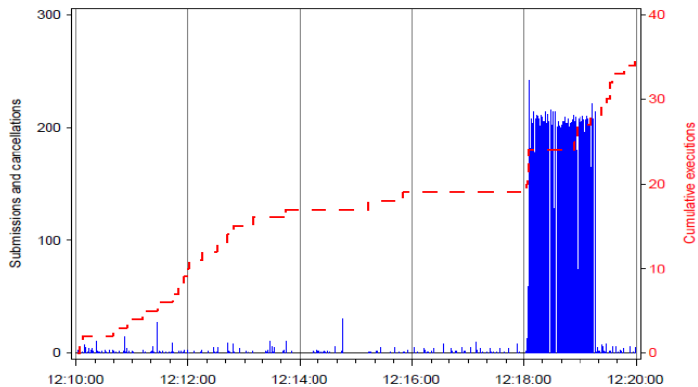
     2.2 The development High Frequency Trading (HFT)

Algorithmic and High Frequency Trading: Issues and Evidence
└─What is algorithmic trading
  └─Definitions and Typology

Definitions 2/2

- **High Frequency Trading:** Proprietary trading strategies based on ultra fast reaction to market events (news, changes in the state of the market, etc...) and very short lived holding positions

  1. Ultra fast: reaction times inferior to the millisecond (of the order of 100 to 200 microseconds for some high frequency traders).

  2. High Frequency Traders (HFTs) are algorithmic traders but not all algorithmic traders are HFTs.

Algorithmic and High Frequency Trading: Issues and Evidence
└─What is algorithmic trading
   └─Definitions and Typology

Panel C: GNTX on June 12, 2008, 12:10pm to 12:20pm (14,925 Messages)

Typology

- **Agency Algorithms:**
  1. Programs used by brokers or sold by brokers to institutional investors to optimally execute (i.e., at lowest price impacts) large buy or sell orders programs.
  2. Smart Routing Technologies.

- **Proprietary Algorithms: used by banks' prop trading desks, hedge funds, or prop trading firms for**
  1. Market-Making
  2. Statistical Arbitrage
  3. Order Flow Anticipation
  4. News Trading
  5. **These strategies are not new.** What is new is the use of speed to implement these strategies.

Players (High Frequency Trading Firms)

Classification & Characteristics of HFF			
Item	Prop Firms		HF (Stat Arb)
	Majors	Small & Mid	
Financial	Equity		Fund
Investor	Trader		HNW, Pension, etc.
Main Players	Getco, ATD, Tradebot, IMC, Optiver, Sun Leading IB Props	Eastwest, Trading Machine	Citadel, Renaissance, D.E. Shaw, SAC
Number of Firms	About 15	300~400	200~400
Assets Managed	Over $500M	$5~500M	Over $1B
Position	Almost none (a few seconds)		Yes (a few days)
Broker Registration	Yes		None
Broker Usage	None	2 Firms	3~10 Firms
Investment Strategy	Latency arbitrage (multi-market arb, momentum also taken by majors)		Multi-market arb, momentum
Investing Asset	Single asset (majors cover multi-assets)		Multi-assets

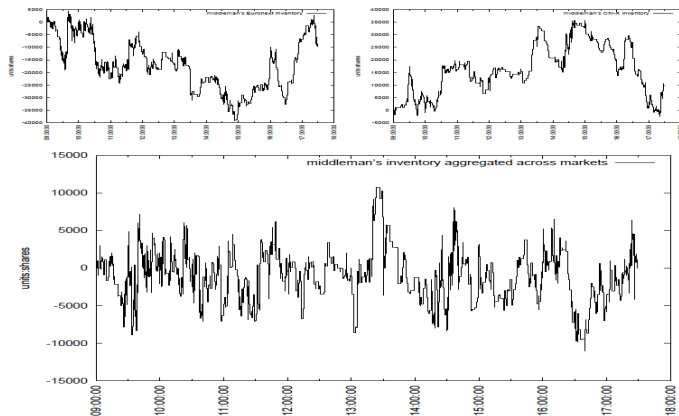Algorithmic and High Frequency Trading: Issues and Evidence
└─ What is algorithmic trading
  └─ Definitions and Typology

High Frequency Market-Making

► **Many HFTs are market-makers. They need speed to:**

1. React quickly to change in asset value
2. Get time priority in limit order books (being at the top of the queue has value)
3. Turn around their positions very quickly, often jockeying between markets

Cross-market market-making

Source: Jovanovic and Menkveld (2010)

Algorithmic and High Frequency Trading: Issues and Evidence
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High Frequency "Arbitrage"

► **High frequency arbitrageurs ("stat arbs"). They need speed to:**

   1. Exploit fleeting arbitrage opportunities before other arbitrageurs do (e.g., crossed markets, triangular arbitrage in FX markets etc...).
   2. Pick off stale limit orders when news arrive before other traders (possibly HFTs) cancel their limit orders
   3. Exploit systematic price patterns (e.g., contrarian strategies) before other traders complete their trades.

Algorithmic and High Frequency Trading: Issues and Evidence
└─ What is algorithmic trading
  └─ Definitions and Typology

HFT is growing

- **Broogard (2011):** 120 Nasdaq stocks, randomly picked across various market caps; Direct information on trades by 26 HFTs on Nasdaq and 25 on BATS.

NASDAQ

Panel A - HFT %

Size	Minimum	25%	Mean	Median	75%	Maximum	Std Dev
Small	23.93	32.16	35.07	34.83	37.98	52.26	4.5
Medium	37.91	46.42	50.02	49.83	53.62	62.27	4.96
Large	61.31	67.38	69.36	69.19	71.33	76.51	2.73
All	60.44	66.49	68.49	68.27	70.48	75.85	2.77

Source: Brogaard (2011a)-Table 3

Algorithmic and High Frequency Trading: Issues and Evidence
└─What is algorithmic trading
  └─Definitions and Typology

HFT is growing

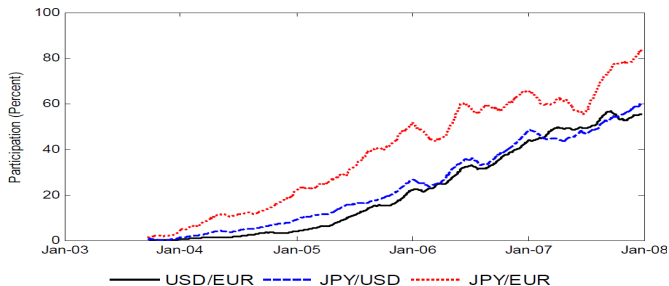Figure 1: 50-day moving averages of participation rates of algorithmic traders

Source: Chaboud et al. (2009)-Figure 1

Algorithmic and High Frequency Trading: Issues and Evidence
└─What is algorithmic trading
  └─Definitions and Typology

ISSUES

High Frequency Trading is highly controversial 1/2

► **"Rewarding Bad Actors," (Paul Krugman, New-York Times, Aug 2-09)**

"High-frequency trading probably degrades the stock market's function, because it's a kind of tax on investors who lack access to those superfast computers — which means that the money Goldman spends on those computers has a negative effect on national wealth."

► **"Rise of the (Market) Machines" (Wall Street Journal, Jun-19-09)**

"...the stock market is more prone than ever to large intraday moves with little or no fundamental catalyst."
"locusts ... feeding off the equity market."

High Frequency Trading is very controversial 2/2

▶ **"High Frequency Trading is a natural part of trading evolution" (B. Malkiel, FT, Dec 14-10).**

"In their quest to find trading profits, competition among high-frequency traders also serves to tighten bid-offer spreads, reducing transactions costs for all market participants, both institutional and retail. Rather than harming long-term investors, high-frequency trading reduces spreads, provides price discovery, increases liquidity and makes the market a fairer place to do business."

▶ On regulatory debates, see SEC:
http://www.sec.gov/rules/concept/2010/34-61358fr.pdf or
European "SEC" (ESMA):
http://www.esma.europa.eu/data/document/10_142.pdf

Issues 1/2

- ▶ **Effects of High Frequency Traders on**
  1. *Market liquidity:* do HFTs increase or decrease (implicit) trading costs for institutional and retail investors
  2. *Volatility:* do HFTs cause more volatility or do they trade in volatile markets?
  3. *Price discovery:* do HFTs accelerate the speed at which prices reflect new information?
  4. *Systemic risk/market stability:* do HFTs make markets more unstable? Is speed dangerous?
  5. *Fairness:* do HFTs have unfair advantages?

  "does co–location provide proprietary firms an unfair advantage because they generally will have greater resources and sophistication to take advantage of co–location services than other market participants, including long term investors? Is it fair for some market participants to pay to obtain better access to the markets than is available to those not in a

Issues 2/2

▶ **Answering these questions is difficult:**

1. **Lack of data:** Very few independent studies on these questions using data on trades by HFTs. We know very little on the effects of HFTs.

2. **HFTs' strategies are heterogeneous:** various strategies may have different effects on market quality⟹ **A strategy based-approach rather than a category-based** (HFTs vs non HFTs) is likely to be more fruitful to assess HFTs' impact on market quality.

Variety of strategies: do HFTs make or take liquidity?

Panel B - HFT Demand %

Size	Minimum	25%	Mean	Median	75%	Maximum	Std Dev
Small	11.44	20.93	24.41	24.16	27.55	46.27	5
Medium	21.06	32.77	36.43	36.76	40.29	49.35	5.1
Large	33.86	40.43	43.09	43.08	45.94	52.04	3.68
All	33.66	40.14	42.74	42.69	45.42	51.72	3.65

Panel C - HFT Supply %

Size	Minimum	25%	Mean	Median	75%	Maximum	Std Dev
Small	6.84	11.07	13.53	12.45	14.94	31.7	3.84
Medium	11.74	16.3	19.83	18.68	23	32.14	4.38
Large	33.29	40.41	42.06	41.99	43.83	51.7	2.4
All	32.37	39.49	41.12	41.07	42.86	50.75	2.4

Source: Brogaard (2011a)-Table 3

Empirical studies

- ▶ **Direct data on HFTs**

  1. Chaboud et al.(2010, unpublished): FX market-Sample period 2003-2007 (focus on 2006-2007)
  2. Brogaard (2011a, unpublished): 120 Nasdaq stocks-26 HFTs-Sample period 2010.
  3. Brogaard (2011b, unpublished): 120 Nasdaq stocks-26 HFTs-Sample period 2010
  4. Hendershott and Riordan (2011, unpublished): 120 Nasdaq stocks-26 HFTs.
 5. Hendershott and Riordan (2009, unpublished): Dax Stocks-2008.

Empirical studies

- **Indirect inference:**
  1. Jovanovic and Menkveld (2010, unpublished)-1HFT-14 stocks constituents of the AEX index-2008
  2. Menkveld (2011, unpublished)-1HFT-14 stocks constituents of the AEX index-2007-2008
  3. Kirilenko et al. (2010, unpublished): E.mini futures on the SP500 index-May 3 to 6, 2010.
  4. Hasbrouck and Saar (2010, unpublished): Nasdaq stocks-Sample period: 2006-2007
  5. Hendershott et al.(2011, Journal of Finance): NYSE Tocks-Sample period: 2001-2005-algos or HFT?

CHANGES IN MARKET STRUCTURES AND HFTs: A TWO WAY RELATIONSHIPS.

Structural causes of algorithmic trading and high frequency trading

- **Development of electronic trading platforms**

- **Market Fragmentation $\implies$**
  1. Needs for smart routing technologies
  2. New market-making opportunities across markets
  3. New arbitrage opportunities

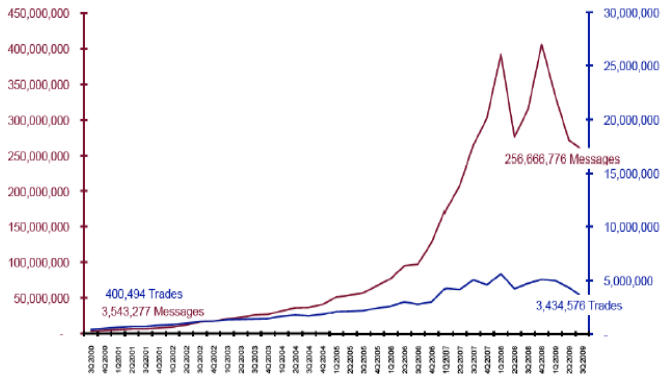- Amount of tape information and improvement in the speed of dissemination of this information

Structural effects
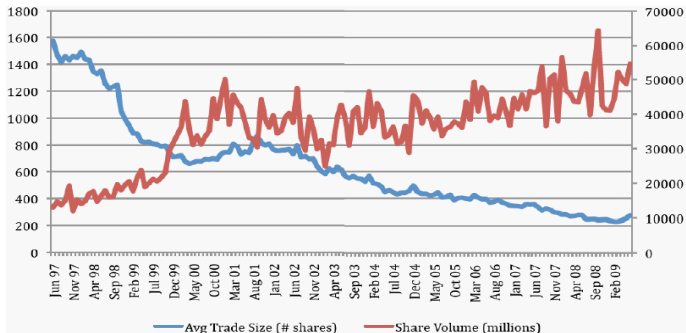
Source: Angel, Harris and Spatt (2010)

▶ **Trades sizes decline but trading volume increases.**

Number of messages/orders per second explodes

- **Blue line:** NYSE nber of trades (2000-2009); **Red Line:** NYSE nber of "messages" (2000-2009).

News business models for trading platforms

- **Being fast is important**: technological race for decreasing "latencies" (see http://www.latencystats.com/)
- **Providing fast access to market data is important**: "co-location"
- **Getting high frequency market-makers on board is important**: make/take fees
- **End-users want to be "in-control:"** Development of "Direct Market Access" or "Sponsored Market Access" Services.

Make/Take Fees

	Make Fee	Take Fee	Exchange Fee
NYSEArca	-21	30	9
BATS	-27	28	1
EDGX	-29	30	1
Nasdaq	-20	30	10
Nasdaq OMX PSX	-13	18	5
Nasdaq OMX BX	14	-18	-4

March 2010 (in cents/1000 shares)-Tape A

Source: "The price of liquidity", Traders' Magazine, 2010. (fees are in cents per round lot)

▶ SEC (2010) expressed the concern that HFTs supply liquidity to earn the rebate.

Make/Take Fees and HFT

Panel A: HFT Revenue per stock day

	Large	Medium	Small	All
HFT^{Init}	$7,464.64	$428.88	$59.91	$2,681.16
(t-stat)	(6.89)	(5.38)	(3.77)	(7.30)
HFT^{Pass}	$-1,911.30	$-46.43	$-0.04	$-660.12-
(t-stat)	(-2.19)	(-0.92)	(0.00)	(-2.22)
HFT^{All}	$5,553.33	$382.45	$59.95	$2,021.04
(t-stat)	(4.03)	(5.01)	(2.94)	(4.32)

Panel B: HFT Revenue per stock day after fees

|	Large	Medium	Small	All
HFT^{Init}	$2,433.43	$144.52	$16.18	$874.54
(t-stat)	(2.27)	(1.83)	(1.02)	(2.41)
HFT^{Pass}	$4,209.15	$148.91	$21.62	$1,476.56
(t-stat)	(4.76)	(2.93)	(1.43)	(4.90)
HFT^{All}	$6,642.58	$293.44	$37.81	$2,351.11
(t-stat)	(4.70)	(3.88)	(1.85)	(4.99)

Source: Hendershott and Riordan (2011), Table 8

▶ Rebates are indeed important for HFTs but not necessarily a bad thing: they should translate in smaller bid-ask spreads (Colliard and Foucault (2010)).

EFFECTS OF ALGO (HFT??) TRADING ON MARKET QUALITY: ACADEMIC EVIDENCE.
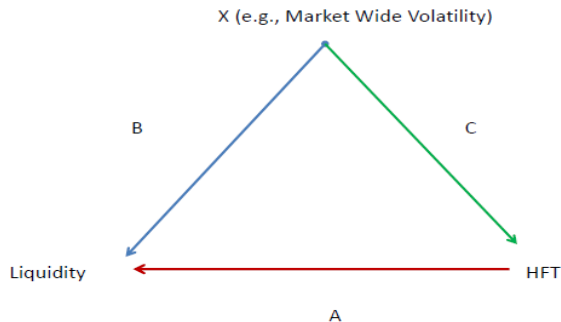
Causation vs. Correlation

THE FAMILY CIRCUS
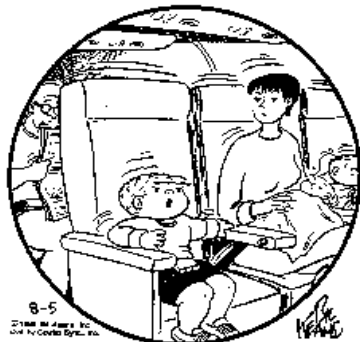
"I wish they didn't turn on that seatbelt sign so much! Every time they do, it gets bumpy."
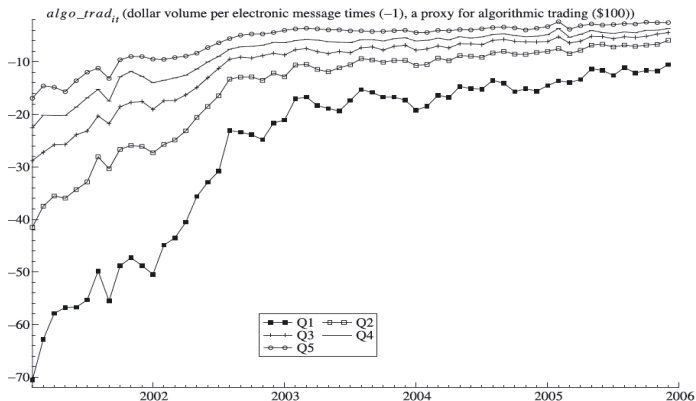
A methodological problem

- We want to measure "A", but how do we know that we are not measuring "B" instead?

Preliminary academic evidence

▶ **The jury is still out regarding the effects of HFTs on market quality.** As usual in economics, it is very difficult to establish whether HFTs **cause** market instability, illiquidity or excess volatility or the opposite or is just correlated.

▶ **Preliminary evidence however find that:**

1. Algorithmic trading has a positive effect on market liquidity (see Hendershott et al.(2011)).
2. HFTs is positively correlated with volatility but do not seem to cause of volatility (Hasbrouck and Saar (2010), Brogaard (2011b) or Chaboud et al.(2009)).
3. HFTs contribute to price discovery but maybe a cause of adverse selection (Hendershott and Riordan (2011), Jovanovic and Menkveld (2010)).

LIQUIDITY/TRADING COSTS (Hendershott, Jones, and Menkveld (2011))

Algorithmic and High Frequency Trading: Issues and Evidence
└─ Effects on market quality
  └─ Liquidity

Proxy for Algorithmic Trading

$algo\_trad_{it}$ (dollar volume per electronic message times (−1), a proxy for algorithmic trading ($100))

▶ "Algo Trading" = $Volume/Number of Messages × − 1
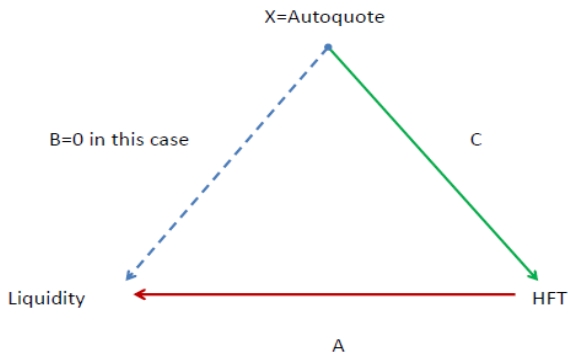
Algorithmic Trading and Effective Bid-Ask Spreads
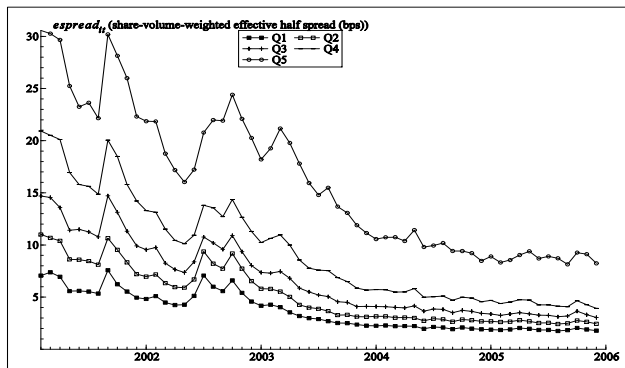
Source: Hendershott et al. (2011)

- ▶ Effective spread = Price Impact
- ▶ Hence, the growth of algo trading seems to be positively correlated with the evolution of liquidity on NYSE.
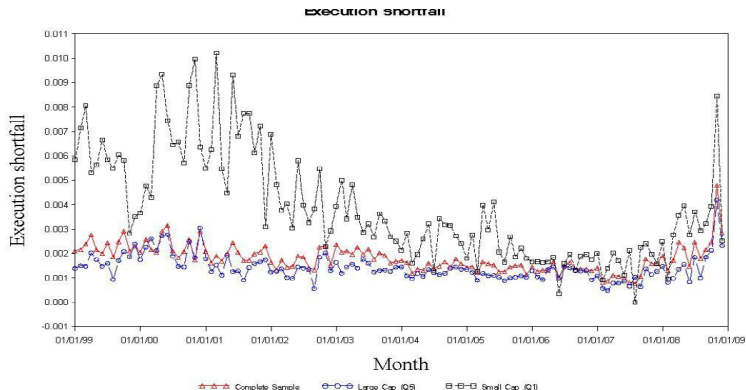
Algorithmic and High Frequency Trading: Issues and Evidence
└─Effects on market quality
 └─Liquidity

Causality

▶ To measure the causal effect of algo trading on liquidity, Hendershott et al.(2011) exploits a change in NYSE market structure ("Autoquote") that facilitates algorithmic trading **without directly** affecting liquidity.

Findings

- ▶ **Algorithmic trading has a positive effect on liquidity for large caps and no effect on small caps:**

    1. Effective bid-ask spreads decline after the implementation of Autoquote for stocks in the two largest quintiles of capitalization.
    2. Effective bid-ask spreads increase for the smallest quintile but the effect is statistically not significant.

- ▶ **Finer analysis reveals that improvement in liquidity is mainly due to a reduction in the exposure to adverse selection ("toxic orders") for liquidity providers.**

- ▶ **Limitations:** (i) no direct observation of trades by algo traders and (ii) the autoquote changes seem to affect mainly automated liquidity provision (only one form of algorithmic trading).

Institutional Investors

Source: Anand et al.(2009)

Algorithmic and High Frequency Trading: Issues and Evidence
  └─ Effects on market quality
     └─ Liquidity

PRICE DISCOVERY

Measuring HFTs effect on price discovery 1/2

▶ **Idea (not new):**

Change in Prices

$=$ Permanent Change in Prices $+$ Transient Change in Prices

(1)

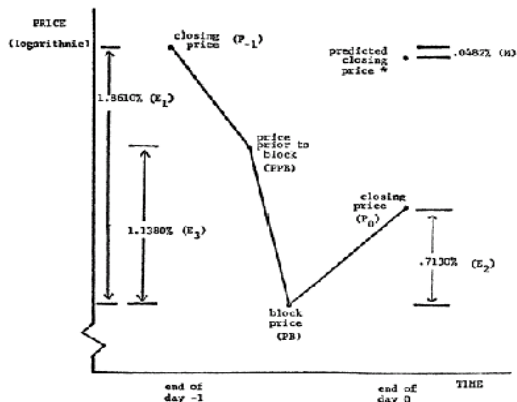▶ **Standard Interpretation**

1. Permanent change in prices: reflect adjustment of prices to "fundamental" values.
2. Transient change in prices $=$ "pricing errors" (due to illiquidity, irrationality, manipulation etc...)

▶ **New question**

1. How do trades by HFTs affect each component? $\rightarrow$ Hendershott and Riordan (2011)
2. Data: 120 Nasdaq stocks-Direct data on HFTs passive and aggressive orders.

Algorithmic and High Frequency Trading: Issues and Evidence
└ Effects on market quality
  └ Price Discovery

Permanent vs. transient changes in prices-Example

Measuring HFTs effect on price discovery 2/2

▶ **Methodology:**

1. Compute the net HFTs' order imbalance over 10-second interval (passive, aggressive and all)
2. Distinguish HFTs' aggressive trades (market orders) from HFTs' passive trades (limit orders)
3. Use a state space model estimation to decompose change in prices into (i) the permanent change component and (ii) the transient change component over 10 second intervals
4. Regress these components over measures of HFTs' order imbalances.
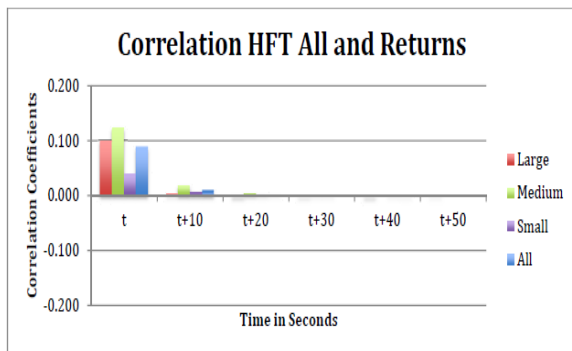
Findings

- **HFTs' aggressive trades:**

  1. **Positively associated with permanent price changes**
  2. **Negatively associated with pricing errors**
  3. **HFTs' aggressive trades do contribute to price discovery: their orders contain information and countervail "transient mispricings."**

- **HFTs' passive trades:**

  1. **Negatively associated with permanent price changes: passive orders by HFTs are adversely selected.**
  2. **Positively associated with pricing errors. Why?**

Algorithmic and High Frequency Trading: Issues and Evidence
└─ Effects on market quality
  └─ Price Discovery

Issues

- ▶ **HFTs' aggressive trades contain information but this information is short-lived (their trades have no forecasting power beyond 10 seconds):**
  1. These trades could be a source of adverse selection (see Biais, Foucault, Moinas): not good for liquidity.
  2. Is this useful for real investment decisions? Is it useful to have information incorporated very fast into prices or is some delay acceptable?
  3. No well-articulated answer to this key question in economics.

Algorithmic and High Frequency Trading: Issues and Evidence
└─Effects on market quality
  └─Price Discovery

Source: Hendershott and Riordan (2011)

VOLATILITY

HFT and Volatility are inter-related

- **Brogaard (2011b)**
    1. Same sample as Hendershott and Riordan (2011)
    2. There are positive lead-lag relationships between volatility and HFT trading activity at short horizons and in large caps (less than 1 minute).
    3. Relationship is bi-directional
    4. This does not prove that HFTs cause volatility: they may simply be more active in more volatile securities or more volatile periods.

Algorithmic and High Frequency Trading: Issues and Evidence
└─ Effects on market quality
   └─ Volatility

Causality again

- ▶ **Chaboud et al.(2009):**
    1. Direct data on algo and human trades on EBS in the euro-dollar, yen-dollar and euro-yen.
    2. They do find a positive correlation between volatility and the amount of algo trading in these currencies.
    3. They use the number of trading desks equipped for algo trading on EBS as an "exogenous" measure of the daily capacity of algo trading.
    4. **Result:** algo trading has a weak negative effect on realized daily volatility.

Algorithmic and High Frequency Trading: Issues and Evidence
└Effects on market quality
    └Volatility

Volatility and HFT
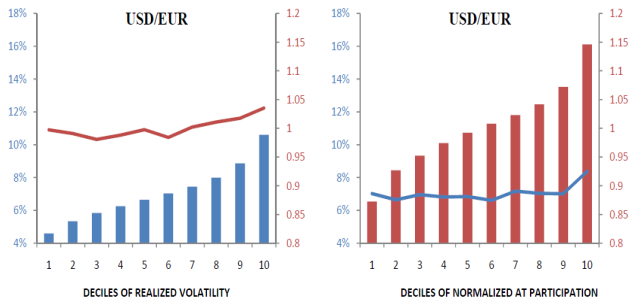
Source: Chaboud et al.(2009)-Figure 5

MARKET INSTABILITY/SYSTEMIC RISK

Flash Crash: May 6, 2010

- ▶ See CFTC-SEC (2010)

In the stock market

- **The Chronology:**
  1. From market opening to 2:32 p.m: a declining market; Stock indexes down 3% (Greece, Euros...).
  2. 2:32 p.m. to 2:41 p.m: acceleration of the decrease (stock returns down 2% on average
  3. 2:41 p.m. to 2:45:28 p.m: THE CRISIS: stock indexes down by 5 to 6% with some stocks trading as low as a penny.
  4. 2:45 to 3:00 p.m : Reversal: Market is up and back almost to level before 2:30 p.m.

The crash in the E.mini futures market

FIGURE 1.1: E-Mini Volume and Price
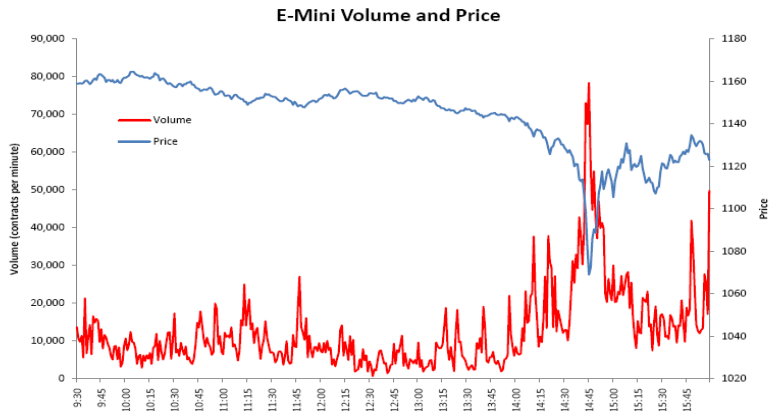
Trigger event: a large trade in the E-Mini futures contract (?)

- 2:32 p.m.: one fund (based in Kansas City) decides to sell 75,000 E-mini contracts on the SP500 index as an hedge to an existing position.
- Largest change in a trader's position in this market since January 2010.
- Liquidity????

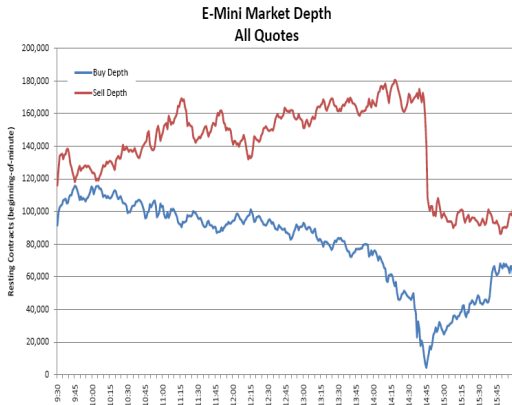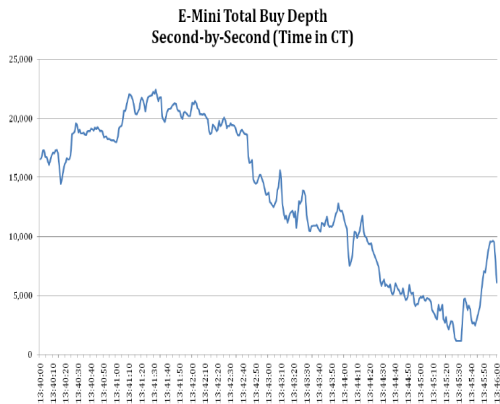FIGURE 1.3: E-Mini Buy-Side and Sell-Side Market Depth (all quotes)

FIGURE 1.6: E-Mini Buy-Side Market Depth, Second-by-Second (note time is in CT)

E-Mini Total Buy Depth
Second-by-Second (Time in CT)

- 2:45 p.m.: the buy side depth is less than 1% of its level in the morning (about $58 million).

Propagation

- **Why did the crash in the E.mini futures market propagate to the cash market?**
  1. **Unclear**
  2. **Cross-market arbitrage: buy the futures; sell the index constituents?**
  3. **Learning from prices: Uncertainty on exact cause of the decline in the E.mini futures liquidity: liquidity shock or unknown cataclysmic event?**
  4. ....

What has been the role of HFTs in the flash crash? 1/2

- **Kirilenko et al.(2010):** use audit-trail data on trades and orders in the E-mini futures on the SP500 to analyze the role of HFTs (inferred from the data) in the E.mini futures during the flash crash.

- **Main conclusion:**
  "*We conclude that the inventories of High Frequency Traders were too small to have caused or prevented the Flash Crash.*" (Kirilenko et al., p1)

What has been the role of HFTs in the flash crash? 2/2

- **Kirilenko et al.(2010)-Main Findings: HFTs:**
    1. Have small inventories (about 3,000 contracts) for very short amount of time.
    2. Use mainly passive orders and trade in the direction of price movements (rather than being contrarian).
    3. Appear to anticipate very-short term price movements.
    4. Their willingness to absorb risk was too small to absorb the large sell order and other intermediaries took time to react to the drop in price in the E.mini futures SP500.

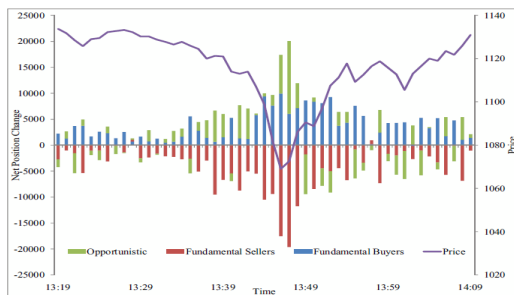# Net inventory positions HFTs (Kirilenko et al.(2010)
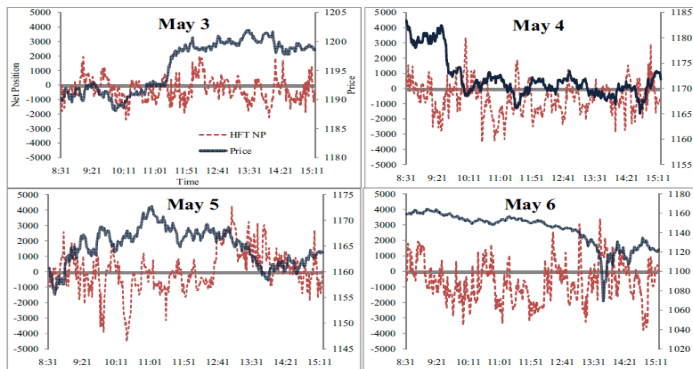
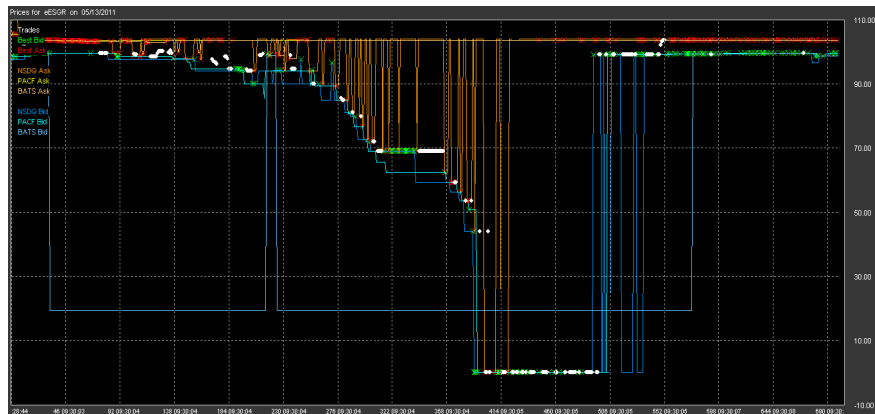# Profits and Losses of HFTs (Kirilenko et al.(2010))
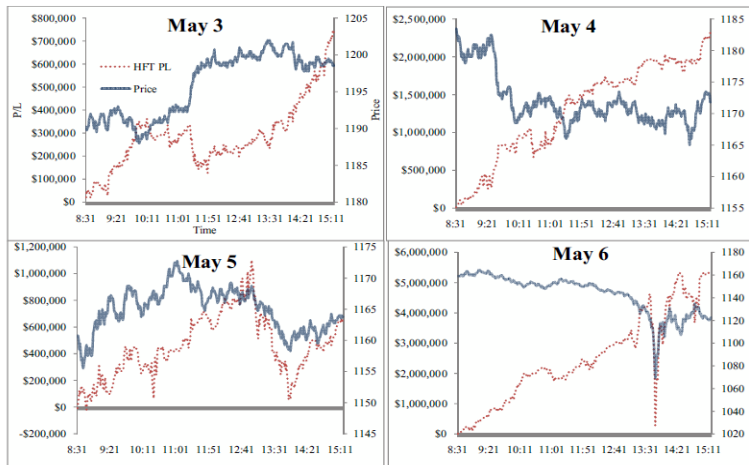
Reversal

- ▶ Eventually prices revert when "opportunistic traders" enter the market and absorb the large sell order imbalance. Why did it take so long? What was the information available on the state of the limit order book?

Source: Kirilenko et al.(2010)

Are mini flash-crashes more frequent? Why?

▶ ESGR-ENSTAR: from $102 to 1 penny in 1 one second

Final thoughts

- **Not clear that HFTs have impaired market quality BUT:**
  1. They may be a source of adverse selection for slow participants $\implies$ transfers from slow to fast traders. Does the benefit of faster price discovery justify this transfer?
  2. They may have crowded out more traditional liquidity suppliers $\implies$ Markets may lack robustness (risk bearing capacity) in stress time even if HFTs are still active during turbulent periods.
  3. HFTs require massive investments in technology, human capital etc... Is this efficient? (see Biais, Foucault, Moinas (2011)).

'Well in our country' said Alice, still panting a little, 'you'd generally get to somewhere else – if you ran very fast for a long time, as we have been doing.'

'A slow sort of country!' said the Queen. 'Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to go somewhere else, you must run at least twice as fast as that!'

Lewis Carroll, Through the Looking Glass

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