High Frequency Trading and the Flash Crash

"The Flash Crash: The Impact of High Frequency Trading on an Electronic Market" (Kirilenko, Kyle, Samadi, Tüzün)

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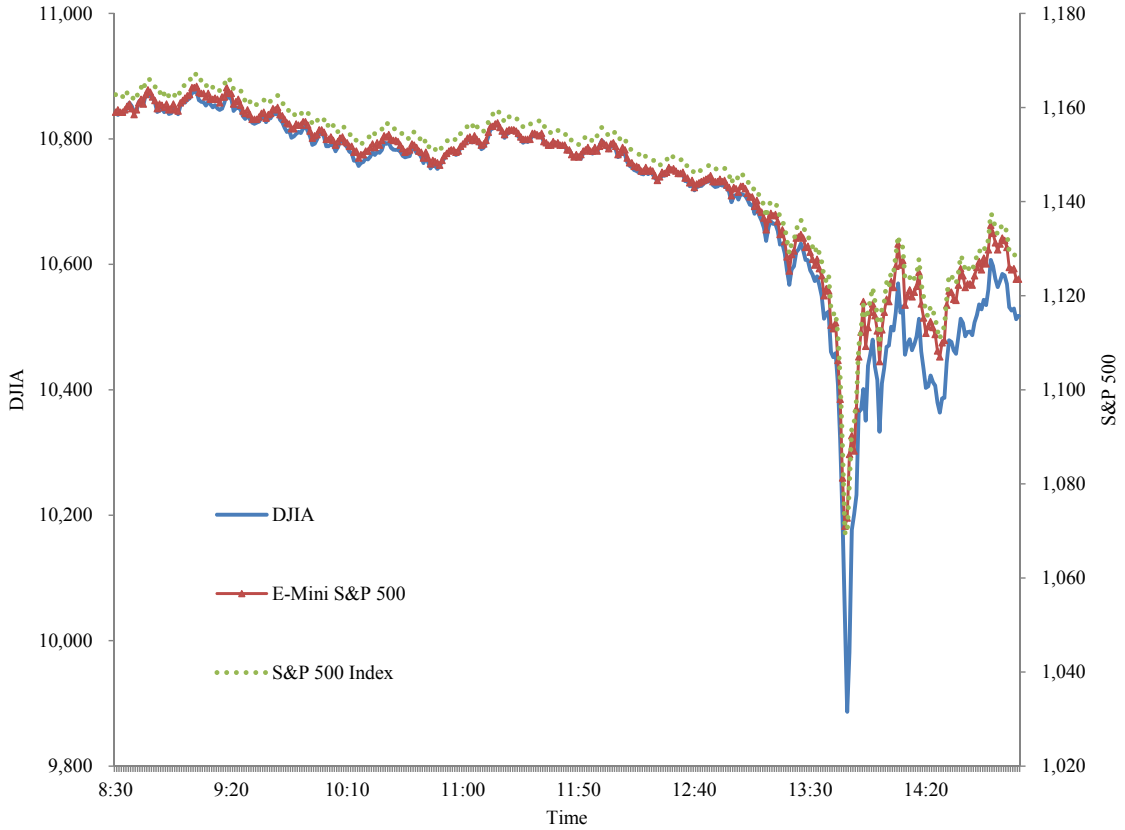
"The research presented in this paper was co-authored by Andrei Kirilenko, a former full-time CFTC employee, Albert Kyle, a former CFTC contractor who performed work under CFTC OCE contract (CFCE-09-CO-0147), Mehrdad Samadi, a former full-time CFTC employee and former CFTC contractor who performed work under CFTC OCE contracts (CFCE-11-CO-0122 and CFOCE-13-CO-0061), and Tugkan Tuzun, a former CFTC contractor who performed work under CFTC OCE contract (CFCE-10-CO-0175). The Office of the Chief Economist and CFTC economists produce original research on a broad range of topics relevant to the CFTCs mandate to regulate commodity futures markets, commodity options markets, and the expanded mandate to regulate the swaps markets pursuant to the Dodd-Frank Wall Street Reform and Consumer Protection Act. These papers are often presented at conferences and many of these papers are later published by peer-review and other scholarly outlets. The analyses and conclusions expressed in this paper are those of the authors and do not reflect the views of other members of the Office of the Chief Economist, other Commission staff, or the Commission itself."

The Flash Crash - May 6, 2010



- Major equity indices experienced an extraordinarily rapid decline and recovery.
- Futures and stock markets moved down and up together.

Investors' Opinion

According to a survey conducted by Market Strategies International in June 2010, 80% of U.S. retail advisors believe:

"Over reliance on computer systems and high frequency trading" were primary contributors to the volatility observed on May 6. High Frequency Trading is defined by low latency.

What Is High Frequency Trading?

- **Electronic Trading:** All E-mini trades are by definition electronic, since E-minis traded exclusively on Globex.
- **Algorithmic Trading:** Electronic trading which uses computer algorithms to process market information, manage inventory, manage order execution, optimize trading strategies.
- **High Frequency Trading:** Algorithmic trading which takes advantage of profit opportunities at the shortest time intervals (several milliseconds).
- **Our Empirical Proxy for High Frequency Trading:** Trading in accounts which have high volume and low inventories relative to volume.

Research Questions

- How did High Frequency Traders and other traders act on May 6, in comparison with previous days?
- What may have triggered the Flash Crash?
- What role did High Frequency Traders play in the Flash Crash?
- How do High Frequency Traders in electronic futures markets differ from the human market makers of the past?
- How do High Frequency Traders in electronic futures markets differ from high frequency traders in the stock market?

Answer: How Did HFTs Trade?

- High Frequency Traders participate in about 30% of trades, have inventories with a half-life of about two minutes, and rarely hold aggregate net positions exceeding 0.2% of average daily volume.
- High frequency traders tend to initiate trades with resting ("non-aggressive") limit orders but often liquidate positions with executable ("aggressive") orders which move prices.
- High frequency traders do not appear to have changed their trading strategy on May 6 in comparison with May 3-5.
- High Frequency traders have strategies similar to human market makers from previous decades, but with dramatically faster latency.

Answer: Why Did the Flash Crash Occur?

- One account sold 75,000 contracts ($4 billlion, or about 1.5% of May 6 volume).
- This was the largest sale by one account from January 1 to May 6, 2010.
- This sale occurred precisely during the 20 minute period corresponding to the flash crash and V-shaped rebound.
- The buy side of the limit order book was greatly depleted when the sale occurred, due to large price declines previously during the day.
- This sale was executed rapidly compared to other sales of similar size.

Answer: Did HFTs Cause the Flash Crash?

- The inventories of High Frequency Traders are too small either to have caused the Flash Crash or to have prevented it.
- After buying during the initial minutes of the flash crash (thus dampening price declines), high frequency traders liquidated long positions (thus exacerbating price declines resulting from other continued selling).
- Because the execution strategy of the 75,000 contract sale was to participate in 9% of trading volume, an explosion in trading volume due to the "hot potato" effect amplified the speed with which the 75,000 contract was executed, probably increasing its transitory price impact.

Answer: HFTs versus Human Market Makers? Similarities

- Both intermediate a significant fraction of all trades.
- Both hold positions for a short period of time.
- Both try to buy and bid and sell at offer.
- Both try to "lean" on "resting" limit orders (conjecture).
- Both take liquidity to get out of bad positions, "scratching trades" to avoid losses: "Take your losses, let your profits run."
- Both use relatively lower latency to gain advantage in trading process.

Answer: HFTs versus Human Market Makers: Differences (1)

- HFTs have dramatically faster latency: milliseconds or microseconds, not seconds. Co-location helps.
- Humans gain faster latency with proximity to pit. Physical structure of pit important.
- Since HFTs trade algorithmically, scientific methods can be applied to develop trading strategies.

Answer: HFTs versus Human Market Makers: Differences (2)

- Human pit trading did not enforce time priority like Globex does, making it more straightforward for humans scalpers to get in front of paper.
- Human market makers observe more about whom they are trading with, avoid trading with each other. HFTs trade in anonymous market, therefore frequently trade with one another by accident (conjecture).
- Personal trust (or lack of trust) affects whom a human trades with (friends and enemies, pit crony-ism, "bag-men").
- Human trading is error prone; avoiding and fixing errors influences whom one trades with.

Answer: HFTs in Futures Market versus HFTs in Stock Market

- Futures Markets have centralized order flow coming into one integrated market (Globex). Centralized market can strictly enforce both time and price priority. Futures market HFTs make money by racing to the front of the queue at the same price level, with other traders behind in the queue.
- Stock markets are fragmented. HFT strategies help increase fragmentation. Rebates make fragmentation worse. Stock market HFTs make money by inducing orders to move from one venue to another.

Fragmented National Market System for Stocks

- **1990's:** Blume and Goldstein (JF, 1997): NYSE usually had best bid and offer and got volume, but smaller exchanges got volume when posting better prices, and also for payment for order flow.
- **2000's:** Latency dramatically declined. NYSE share of its own stocks dramatically declined. Rebates and fragmentation. Low latency helps trading venues compete for orders flow. Arms race. Blume (2000) and Blume (2002): Unintended consequences of Regulation NMS, such as trading going overseas.

HFT Strategies in Futures and Cash Markets are Different

- **Futures:** HFTs use speed to be first in a central order book which preserves time and price priority.
  Given high liquidity of futures, futures tick size is very large. Tick size in futures is 2.5 basis points. Tick size in less liquid stock is similar, e.g. 2.5 basis points for $40 stock with penny tick size.
- **Cash:** HFTs arbitrage fragmented markets against one another, game system of rebates. In effect, they undermine both time and price priority. "Flash trading" involved here.

The S&P 500 E-mini Futures Contract:

- One contract = 50 x S&P Index
  = $50,000 at S&P level of 1,000.
- One tick = 0.25 index points = $12.50 = about 2.5 basis points.
- Traded exclusively on the CME Globex electronic trading platform.
- CME Globex trading rules respect price and time priority.
- E-mini has the most dollar trading volume among U.S. equity index products.
- Hasbrouck (2003) finds that the E-mini is the largest contributor to price discovery of the S&P 500 index.
- Price discovery typically occurs in the "front-month" contract.

Literature

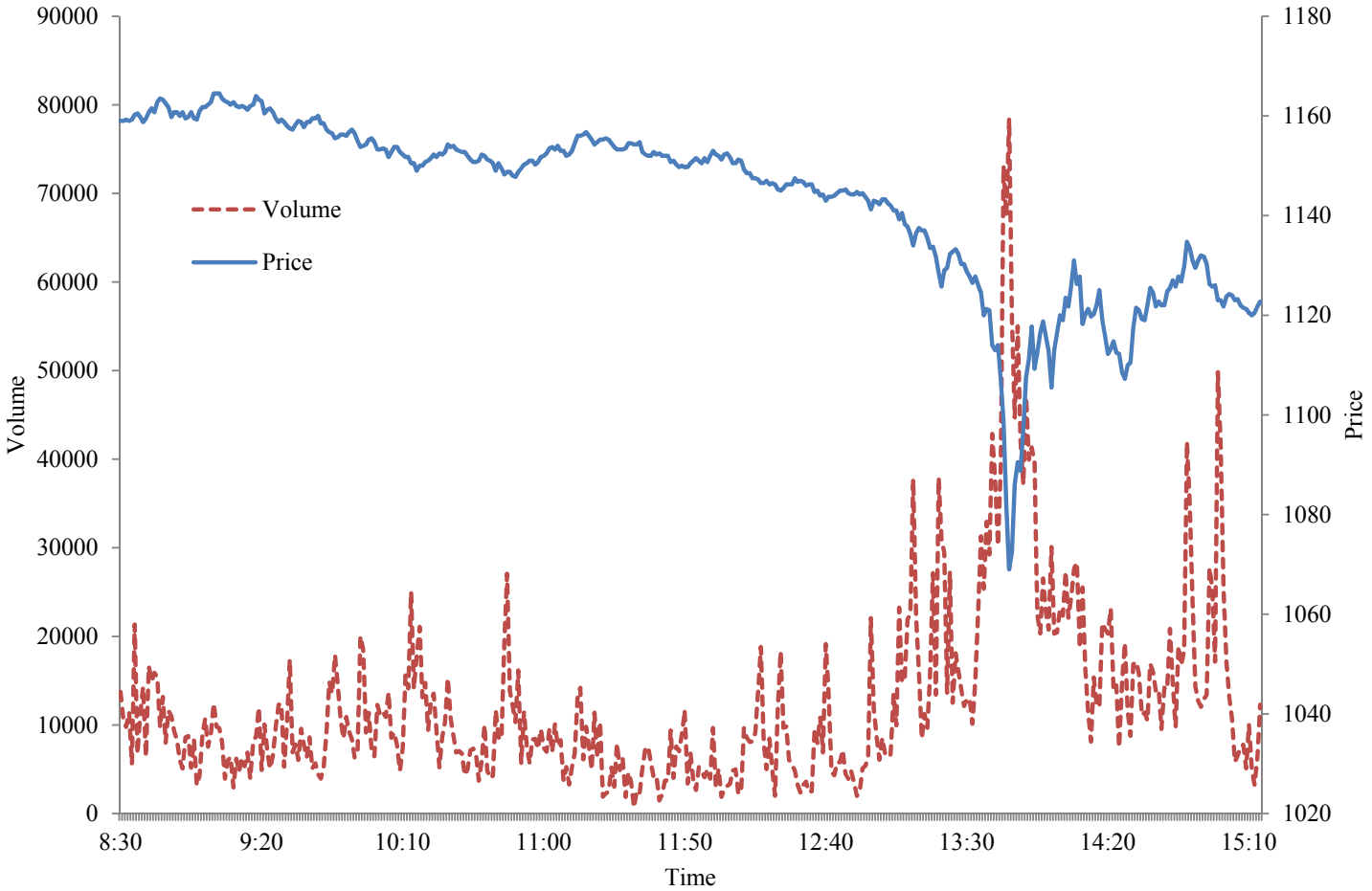
- **Brogaard** (2010): Argues HFTs increase efficiency.
- **Chaboud, Chiquoine, Hjalmarsson, and Vega (2009)**: Analyze FX with second-by-second data.
- **Hendershott, Jones and Menkveld (2010)**: Liquidity improves as technology speeds up.
- **Hasbrouck and Saar (2010)**: Flickering quotes from interactions of HFTs.
- **Easley, Prado, and O'Hara (2010)**: VPIN high during flash crash.

Summary Statistics

Table: Market Descriptive Statistics

	May 3-5	May 6th
Contract Volume	**2,397,639**	**5,094,703**
Number of Trades	446,340	1,030,204
Number of Traders	11,875	15,422
Trade Size	5.41	4.99
Order Size	10.83	9.76
Limit Orders Volume	95.45%	92.44%
Limit Orders Trades	94.36%	91.75%
Volatility	**1.549%**	**9.82%**
Return	-0.02%	-3.05%

June 2010 E-mini Contract: Trading Volume and Price



Arbitrage between Futures and Stock Markets

- **Index Arbitrage**: S&P cash and futures moved very closely together during flash crash.
- **ETF Arbitrage**: Liquid ETFs moved very closely with futures during flash crash, but some illiquid ones traded at one cent.
- **Stock Arbitrage**: Dow and S&P moved differently during flash crash.
- **Blume, MacKinlay, and Terker (JF, 1989)**: S&P stocks declined more than non-S&P stocks on the day of the 1987 stock market crash. Rebounded next day.

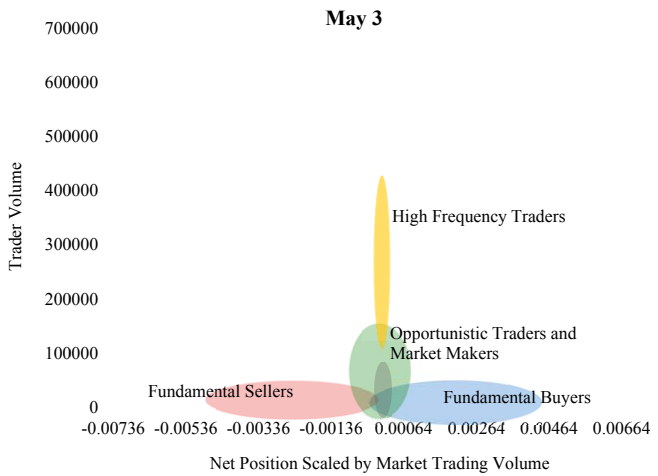
CFTC Audit Trail Data

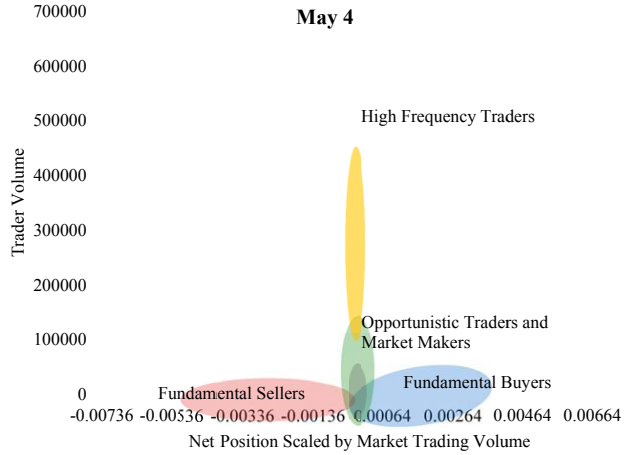
- **Quantity, Price, Trade Direction**: Buys and Sells matched consistently.
- **Date and Time**: up to one second.
- **Match ID**: Matches buyer and seller uniquely. Sequences trades within one second (reasonably accurately).
- **Account Number, Broker ID, Clearing Firm**: Identifies accounts, but firms may control multiple accounts.
- **Order Type**: Limit orders versus market orders.
- **Aggressiveness Flag**: Non-aggressive (resting limit order) versus aggressive (executable limit order or market order).
- **CTI Category**: Captures agency versus non-agency trading (not used in paper).

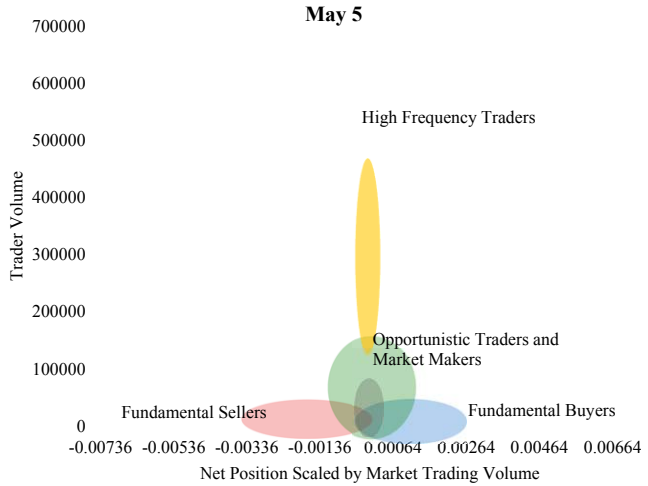
Trader Categories

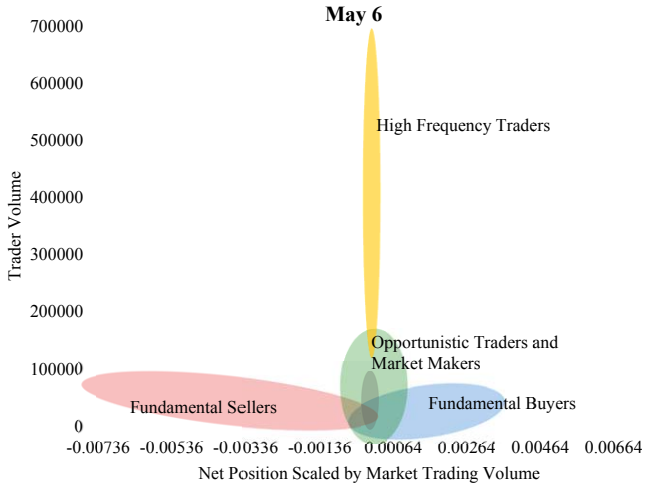
- **High Frequency Traders (16)**: High volume, low inventory relative to volume.
- **Intermediaries (179)**: Lower volume, low inventory relative to volume (market makers).
- **Fundamental Buyers (1263)**: Consistent buyers during day (but not necessarily 100% buyers).
- **Fundamental Sellers (1276)**: Consistent sellers during day (but not necessarily 100% sellers).
- **Small (Noise) Traders (6880)**: Trade a few contracts per day.
- **Opportunistic Traders (5808)**: Everybody else, including index arbitrage, day traders, miscellaneous speculators (mixed bag).

Trader Categories







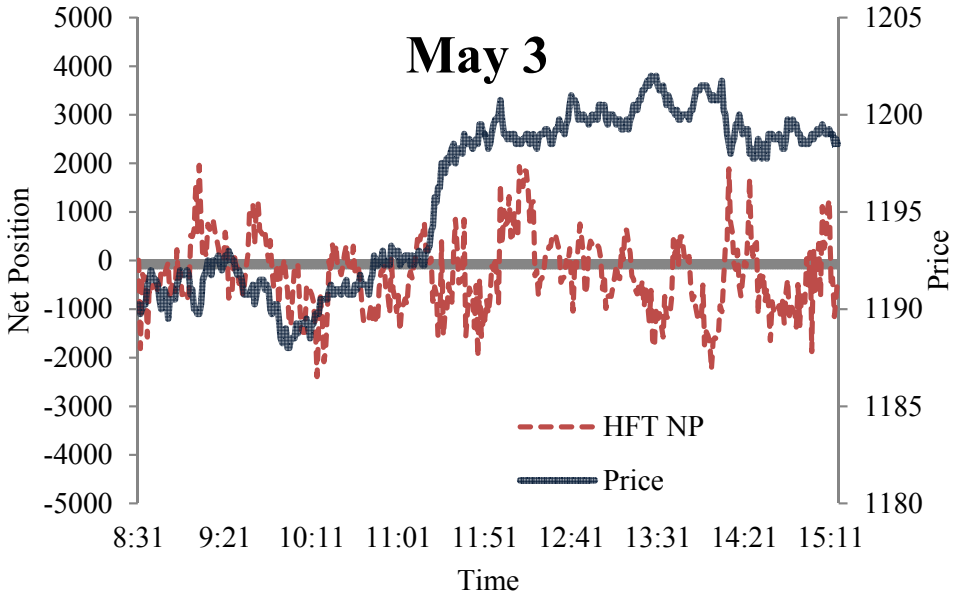


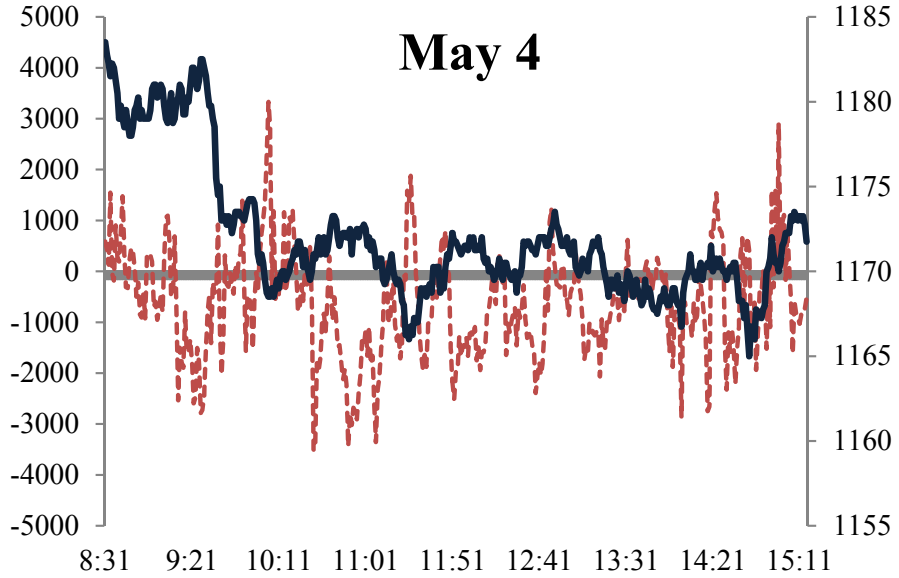
Trader Category Summary Stats

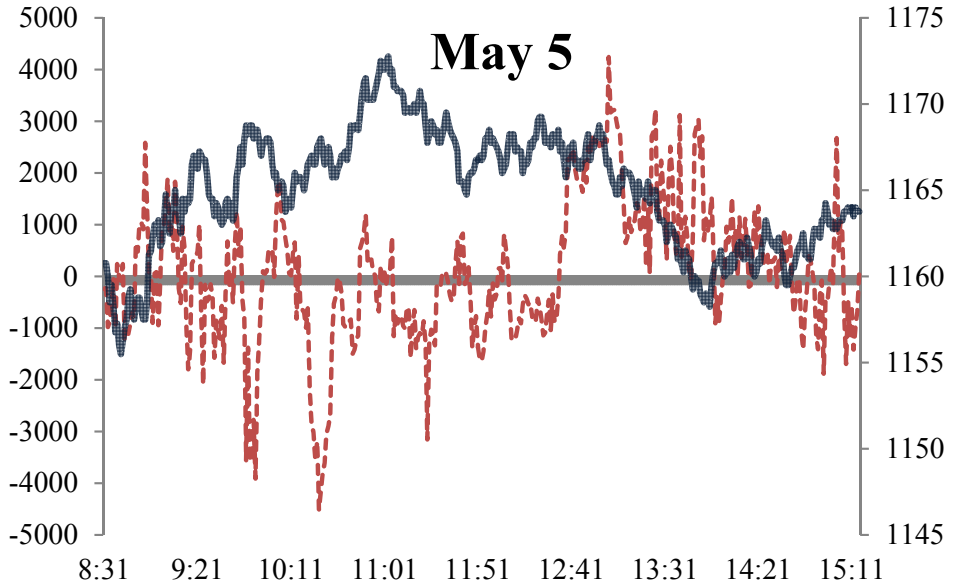
Trader Type	May 3-5 % Volume	May 3-5 % of Trades	May 6 % Volume	May 6 % of Trades
High Frequency Trader	**34.22%**	32.56%	**28.57%**	29.35%
Intermediary	10.49%	11.63%	9.00%	11.48%
Fundamental Buyer	**11.89%**	10.15%	**12.01%**	11.54%
Fundamental Seller	**12.11%**	10.10%	**10.04%**	6.95%
Opportunistic Trader	30.79%	33.34%	40.13%	39.64%
Noise Trader	0.50%	2.22%	0.25%	1.04%
	Volume	# of Trades	Volume	# of Trades
All	2,397,639	446,340	5,094,703	1,030,204

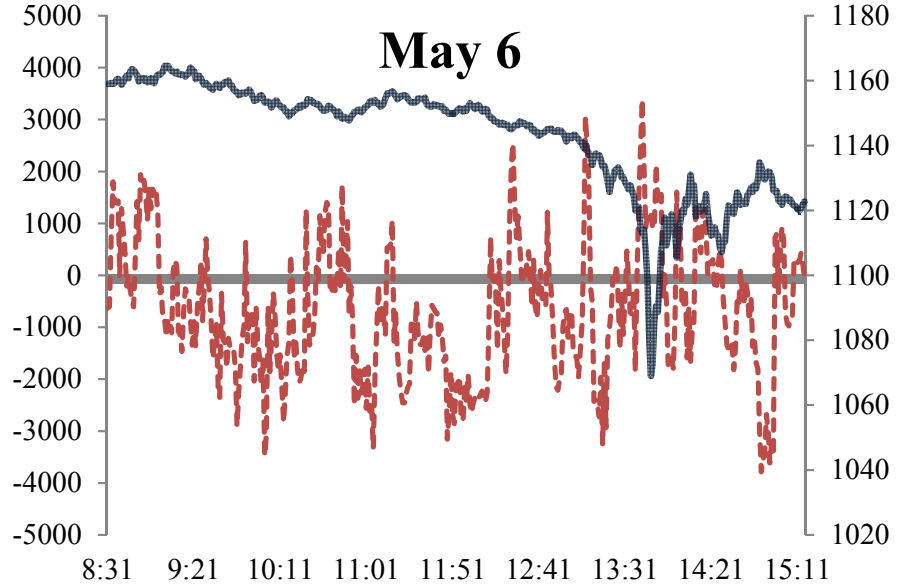
16 HFTs are responsible for approximately a third of trading volume...

Net Holdings of High Frequency Traders

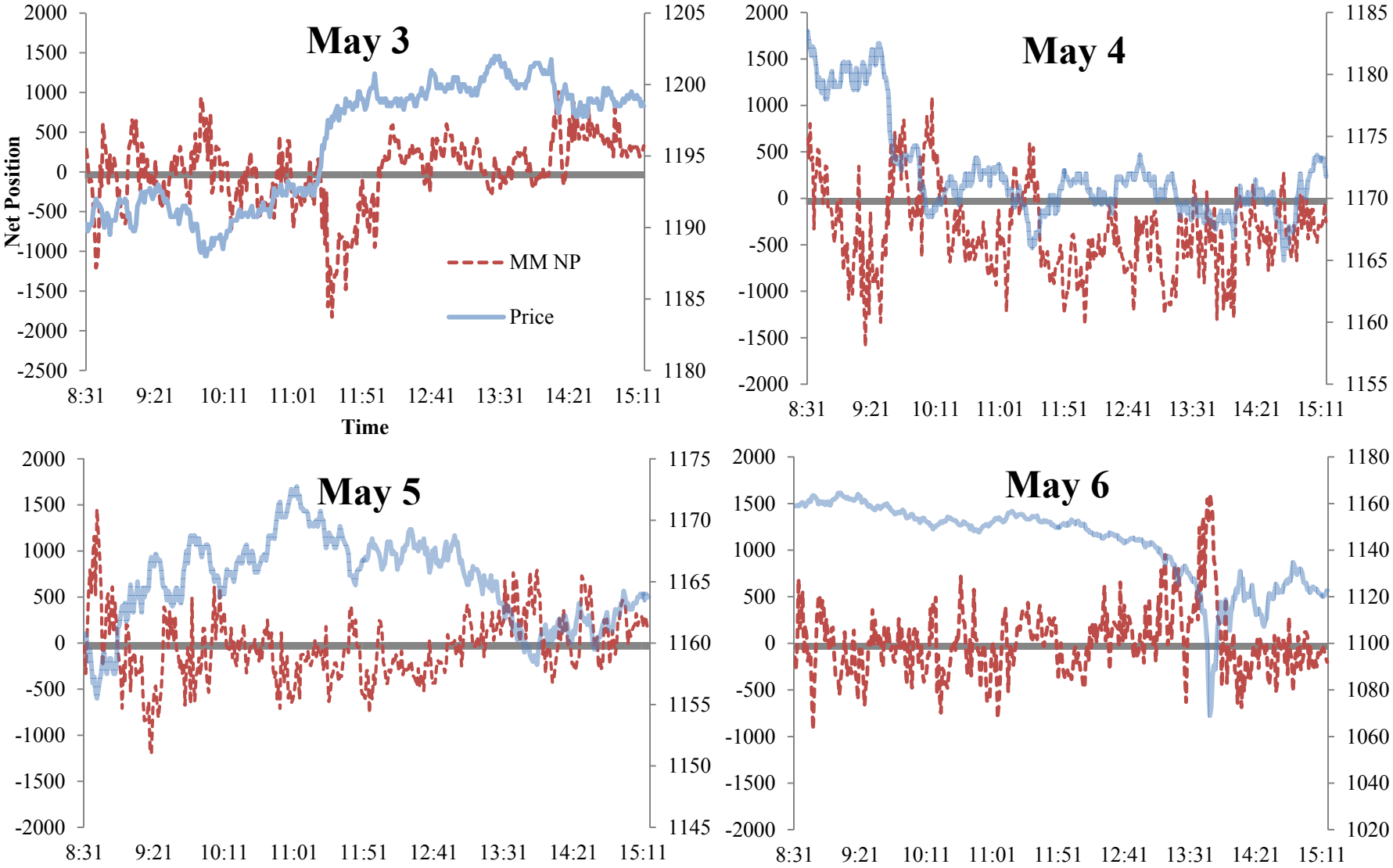




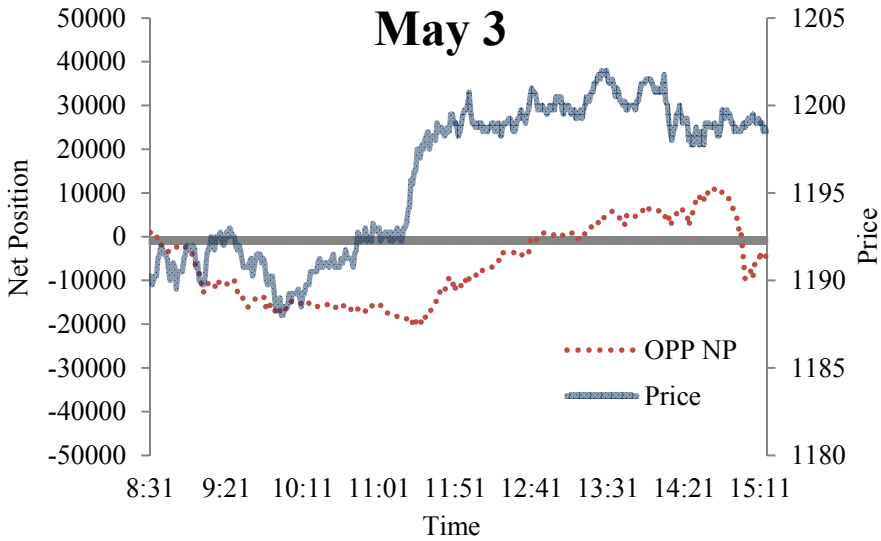


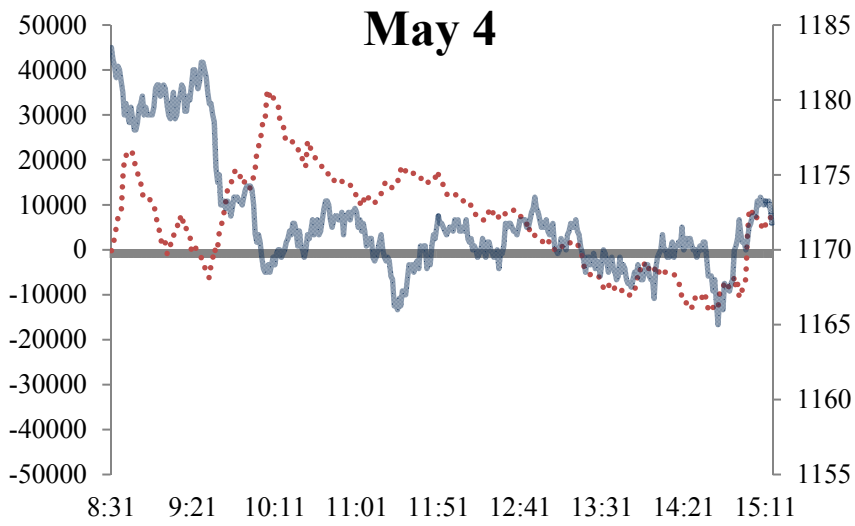


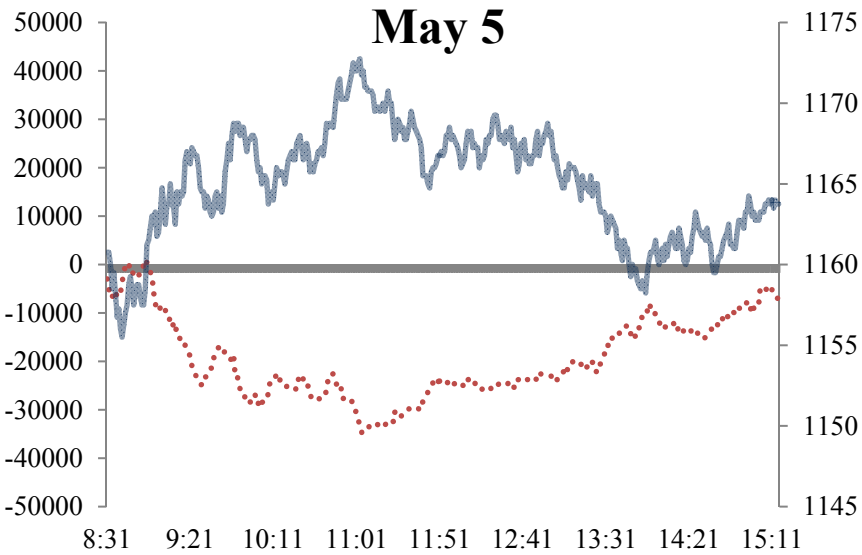
Net Holdings of Intermediaries

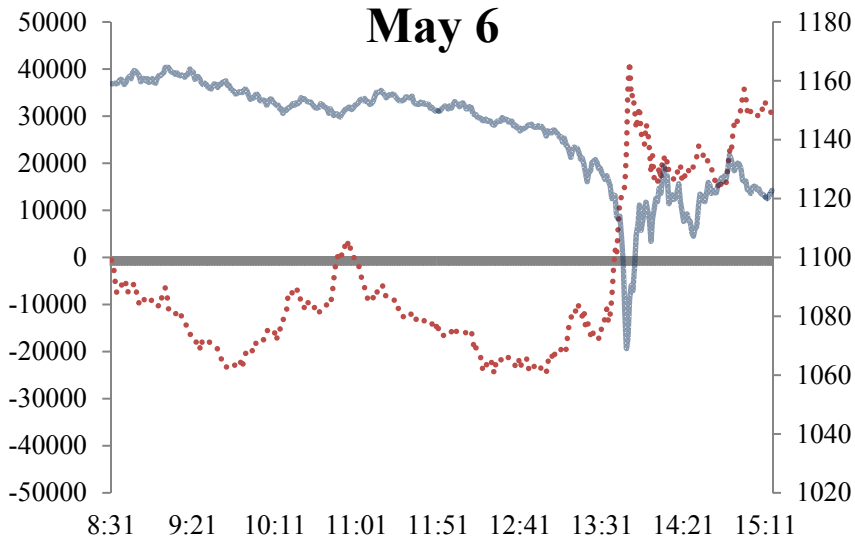


Net Holdings of Opportunistic Traders

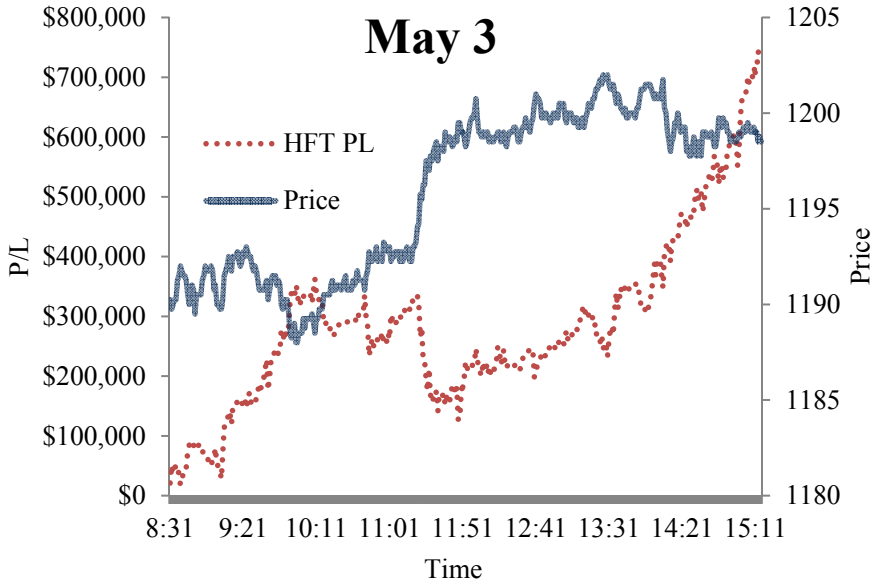


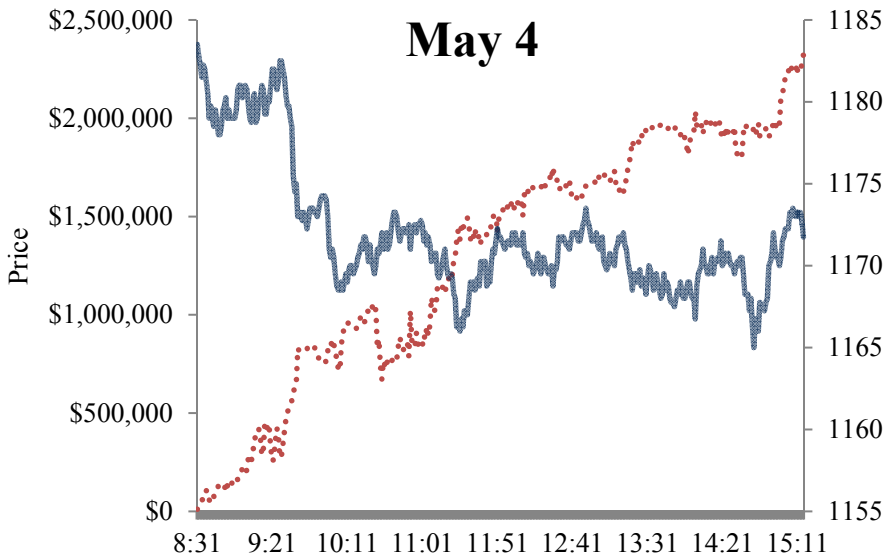


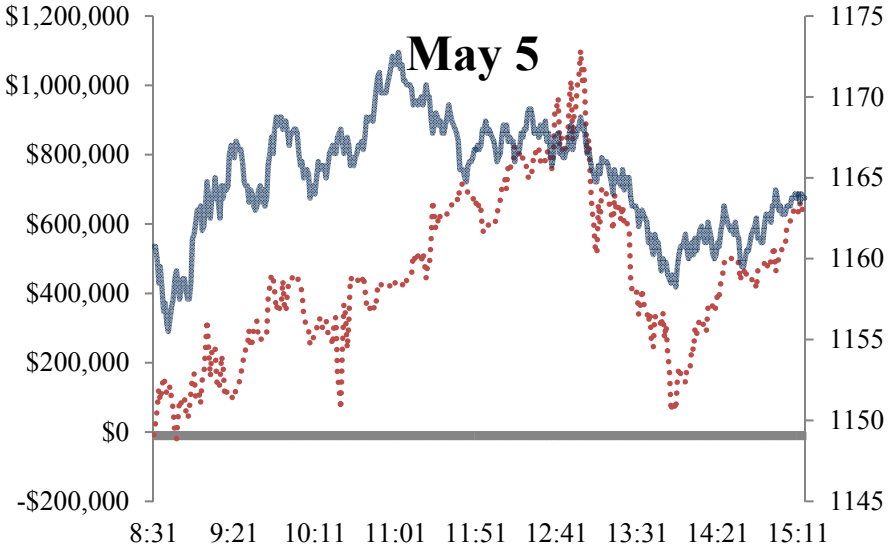


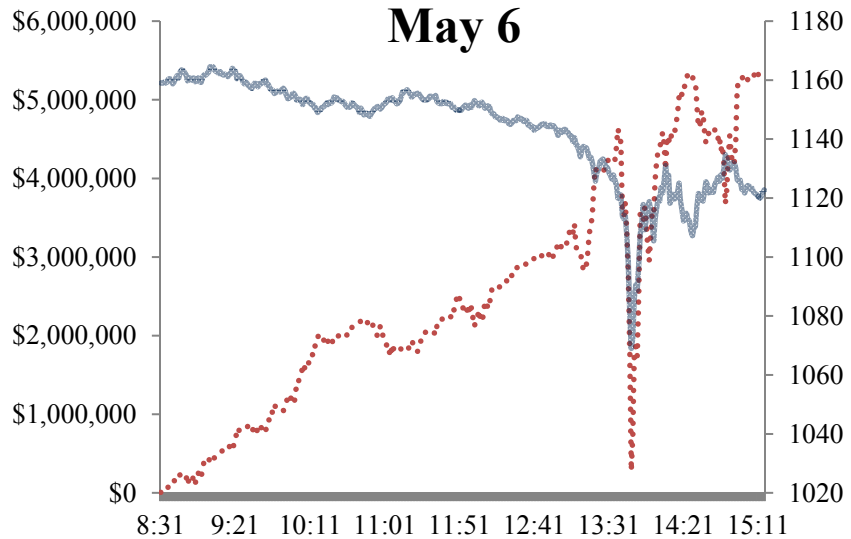


Profits and Losses of High Frequency Traders

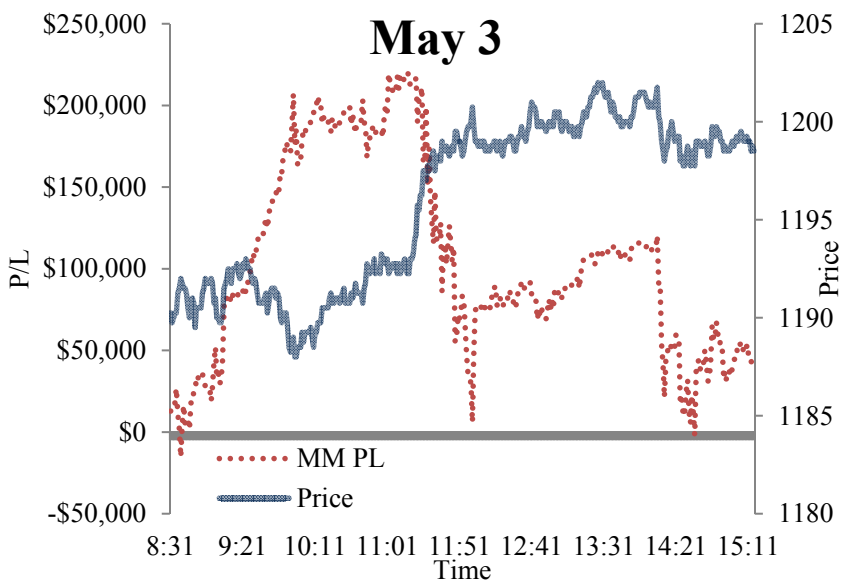


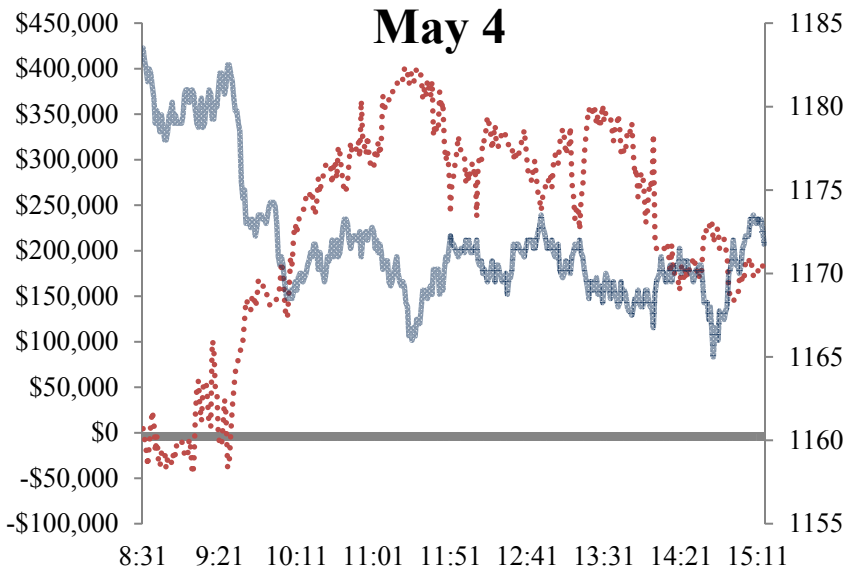


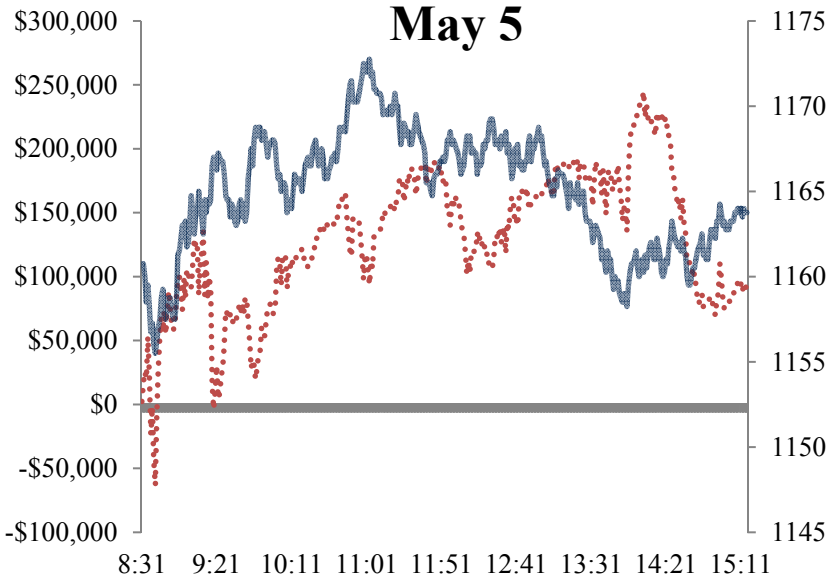


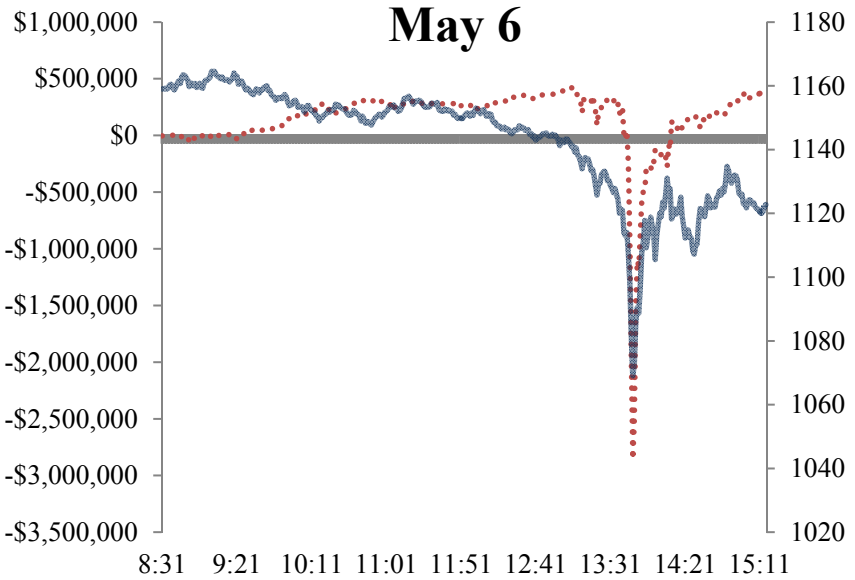


Profits and Losses of Intermediaries









Price Increase and Decrease Events, May 3-5, 2010

Panel A: Aggressive Buy Trades, Price Increase Events, May 3-5, 2010

	Last 100 Contracts		First 100 Contracts		All Aggressive Buys	
	Passive	Aggressive	Passive	Aggressive	Passive	Aggressive
HFT	28.72%	57.70%	37.93%	14.84%	34.33%	34.04%
MM	15.80%	8.78%	19.58%	7.04%	13.48%	7.27%
BUYER	6.70%	11.61%	4.38%	26.17%	4.57%	21.53%
SELLER	16.00%	2.65%	11.82%	7.09%	16.29%	5.50%
OPP	32.27%	19.21%	25.95%	43.39%	30.90%	31.08%
SMALL	0.51%	0.04%	0.34%	1.46%	0.44%	0.58%

Panel B: Aggressive Sell Trades, Price Decrease Events, May 3-5, 2010

	Last 100 Contracts		First 100 Contracts		All Aggressive Sells	
	Passive	Aggressive	Passive	Aggressive	Passive	Aggressive
HFT	27.41%	55.20%	38.31%	15.04%	34.45%	34.17%
MM	15.49%	8.57%	20.64%	6.58%	13.79%	7.45%
SELLER	5.88%	11.96%	3.83%	24.87%	5.67%	20.91%
BUYER	17.98%	3.22%	12.71%	8.78%	15.40%	6.00%
OPP	32.77%	20.99%	24.18%	43.41%	30.30%	30.89%
SMALL	0.47%	0.06%	0.34%	1.32%	0.39%	0.58%

Price Increase and Decrease Events, May 6, 2010

Panel C: Aggressive Buy Trades, Price Increase Events, May 6, 2010

	Last 100 Contracts		First 100 Contracts		All Aggressive Buys	
	Passive	Aggressive	Passive	Aggressive	Passive	Aggressive
HFT	28.46%	38.86%	30.55%	14.84%	30.94%	26.98%
MM	12.95%	5.50%	13.88%	5.45%	12.26%	5.82%
BUYER	6.31%	17.49%	5.19%	21.76%	5.45%	20.12%
SELLER	13.84%	3.84%	14.30%	5.71%	14.34%	4.40%
OPP	38.26%	34.26%	35.94%	51.87%	36.86%	42.37%
SMALL	0.19%	0.06%	0.16%	0.37%	0.16%	0.31%

Panel D: Aggressive Sell Trades, Price Decrease Events, May 6, 2010

	Last 100 Contracts		First 100 Contracts		All Aggressive Sells	
	Passive	Aggressive	Passive	Aggressive	Passive	Aggressive
HFT	28.38%	38.67%	30.13%	14.59%	30.09%	26.29%
MM	12.27%	5.04%	14.85%	5.64%	12.05%	5.88%
SELLER	4.19%	16.46%	3.77%	21.21%	3.82%	17.55%
BUYER	15.83%	5.90%	13.89%	6.97%	15.27%	7.26%
OPP	39.12%	33.86%	37.15%	51.10%	38.56%	42.68%
SMALL	0.21%	0.08%	0.21%	0.48%	0.21%	0.34%

How High Frequency Traders Trade

- Prices move in direction of HFT trades. Movement is greater after aggressive trades (which liquidate inventories).
- HFTs use Aggressive trades to reduce inventories.
- HFTs frequent "scratch" trades, even within one second.
- "Re-pricing" trades to one second later eliminates all profits.

HFT Trading When Prices are About to Change

- Sort trades into "Aggressive buys" and "Aggressive sells"
- Shift to higher prices for Aggressive buys indicates last offers taken out at lower price.
- Examine last 100 contracts at old price and first 100 contracts at new price.
- Sort by trader category, Aggressive/Passive, buy/sell, first/last/all, May 3-5/May 6.

Immediately Scratched Trades

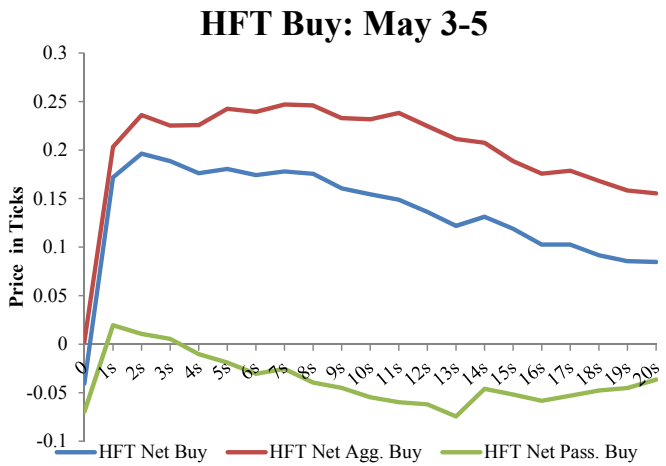
Panel A: May 3-5

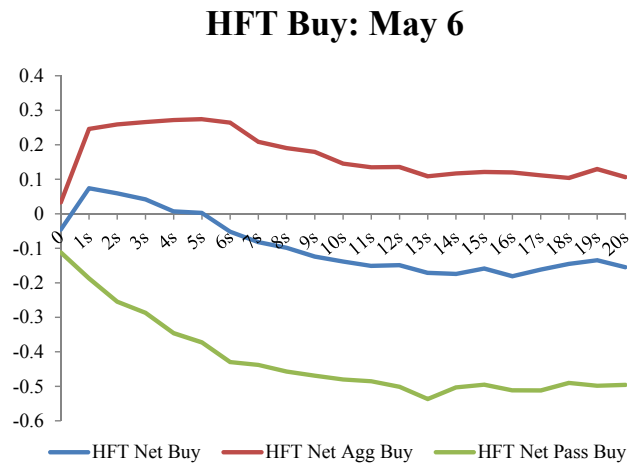
	All Trades	Scratched	% Scratched	Mean	Std	Median
HFT	871,177	24,781	2.84	540.56	768.32	218.50
Market Maker	314,780	7,847	2.49	13.35	54.44	0.00
Buyer	268,808	977	0.38	0.30	6.22	0.00
Seller	257,637	816	0.32	0.25	4.92	0.00
Opportunistic	893,262	15,980	1.79	1.45	39.97	0.00

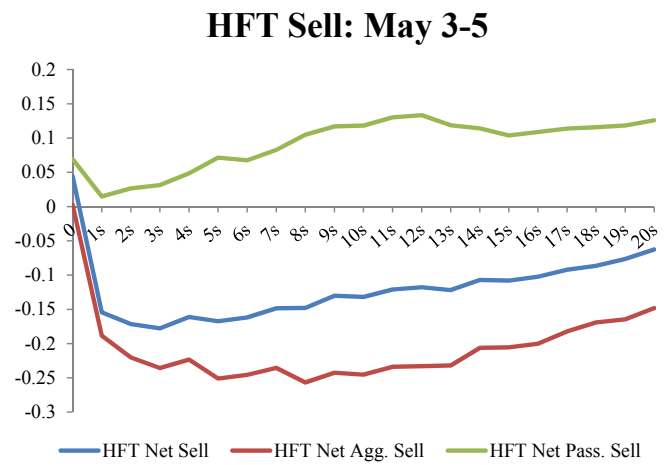
Panel B: May 6

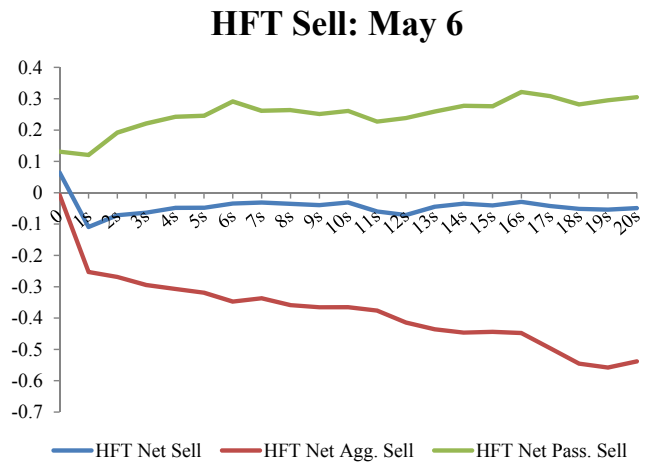
	All Trades	Scratched	% Scratched	Mean	Std	Median
HFT	604,659	25,772	4.26	1610.75	2218.86	553.00
Market Maker	236,434	13,064	5.53	72.98	422.19	0.00
Buyer	236,501	2,715	1.15	2.15	30.86	0.00
Seller	141,853	295	0.21	0.23	7.18	0.00
Opportunistic	810,901	11,571	1.43	1.99	71.94	0.00

HFT Trading and Prices









High Frequency Traders: Net Holdings and Prices

$$\Delta y_t = \alpha + \phi \Delta y_{t-1} + \delta y_{t-1} + \sum_{i=0}^{20} [\beta_{t-i} \times \Delta p_{t-i}/0.25] + \epsilon_t \quad (1)$$

Where:

- y_t denotes the net holdings of HFTs or Intermediaries at the end of second t.
- $t = 0$ corresponds to 8:30:00 CT.
- Δp_{t-i}, $i = 0, ..., 20$ are price changes measured in ticks (0.25 index points).

Inventory Dynamics

	Panel A: May 3-5			Panel B: May 6	
	Δ NP HFT	**Δ NP INT**		**Δ NP HFT**	**Δ NP INT**
Intercept	**-1.637**	**-0.529**	**Intercept**	**-3.222**	0.038
ϕ **HFT**	-0.006		ϕ **HFT**	0.011	
δ **HFT**	**-0.005**		δ **HFT**	**-0.005**	
ϕ **INT**		-0.006	ϕ **INT**		**-0.035**
δ **INT**		**-0.004**	δ **INT**		**-0.008**
ΔP_t	**32.089**	**-13.540**	ΔP_t	**10.808**	**-8.164**
ΔP_{t-1}	**17.178**	**-1.218**	ΔP_{t-1}	**4.625**	**6.635**
ΔP_{t-2}	**8.357**	**2.160**	ΔP_{t-2}	-1.520	**2.734**
ΔP_{t-3}	**5.086**	**2.525**	ΔP_{t-3}	-1.360	**1.138**
ΔP_{t-4}	**3.909**	**2.654**	ΔP_{t-4}	-1.815	0.487
ΔP_{t-5}	1.807	**2.499**	ΔP_{t-5}	-0.228	-0.768
ΔP_{t-6}	-0.078	**2.163**	ΔP_{t-6}	-0.312	-0.312
ΔP_{t-7}	-1.002	**1.842**	ΔP_{t-7}	**-5.037**	-0.617
ΔP_{t-8}	-1.756	**1.466**	ΔP_{t-8}	-1.775	-0.359
ΔP_{t-9}	-1.811	0.453	ΔP_{t-9}	-1.678	**-1.105**
ΔP_{t-10}	**-3.899**	0.525	ΔP_{t-10}	-1.654	-0.387
# obs	72837	72837	**#obs**	24275	24275
$Adj - R^2$	0.0194	0.0263	$Adj - R^2$	0.0101	0.0390

Aggressive and Passive Inventory Dynamics

	Panel A: May 3-5				Panel B: May 6			
	HFT		INT		HFT		INT	
	Δ A	Δ P	Δ A	Δ P	Δ A	Δ P	Δ A	Δ P
Intercept	**-1.285**	-0.352	**-0.344**	-0.185	**-2.863**	-0.359	-0.246	0.284
ϕ **HFT**	**-0.042**	**0.036**			-0.003	0.014		
δ **HFT**	**-0.005**	**-0.001**			**-0.004**	**-0.001**		
ϕ **INT**			0.007	-0.013			-0.003	**-0.032**
δ **INT**			**-0.002**	**-0.002**			**-0.003**	**-0.004**
ΔP_t	**57.778**	**-25.689**	**6.377**	**-19.917**	**23.703**	**-12.895**	**4.939**	**-13.103**
ΔP_{t-1}	**22.549**	**-5.371**	**5.791**	**-7.009**	-1.118	**5.744**	**3.909**	**2.726**
ΔP_{t-2}	**9.614**	-1.258	**4.752**	**-2.592**	**-2.661**	1.141	**1.659**	**1.075**
ΔP_{t-3}	**5.442**	-0.356	**3.642**	**-1.117**	-1.151	-0.209	**0.536**	0.602
ΔP_{t-4}	**3.290**	0.619	**3.114**	-0.460	**-2.814**	0.999	0.229	0.258
ΔP_{t-5}	1.926	-0.119	**2.591**	-0.092	-0.690	0.461	0.161	-0.929
ΔP_{t-6}	-0.987	0.909	**2.038**	0.125	-1.824	1.512	0.053	-0.365
ΔP_{t-7}	-0.291	-0.711	**2.101**	-0.258	**-2.688**	-2.350	**-0.516**	-0.102
ΔP_{t-8}	-0.977	-0.779	**1.740**	-0.274	-2.216	0.441	**-0.625**	0.267
ΔP_{t-9}	-0.732	-1.078	**1.158**	**-0.705**	-0.801	-0.877	-0.099	**-1.007**
ΔP_{t-10}	**-2.543**	**-1.356**	**1.007**	-0.483	**-2.958**	1.304	-0.513	0.125
#obs	72837	72837	72837	72837	24275	24275	24275	24275
$Adj - R^2$	0.0427	0.0260	0.0202	0.0631	0.0252	0.0270	0.0457	0.0698

The Flash Crash

	Panel A: DOWN				Panel B: UP			
	HFT		INT		HFT		INT	
	Δ A	Δ P	Δ A	Δ P	Δ A	Δ P	Δ A	Δ P
Intercept	-0.614	**7.792**	-1.320	**9.992**	2.111	-1.880	1.484	-1.477
ϕ **HFT**	-0.023	-0.014			0.025	-0.026		
δ **HFT**	**-0.008**	0.0010			**-0.005**	-0.001		
ϕ **INT**			-0.043	-0.005			**0.053**	0.008
δ **INT**			-0.0003	**-0.012**			**-0.004**	-0.0009
ΔP_t	**24.226**	8.533	**8.251**	**-9.603**	-0.251	**-9.107**	**2.912**	**-4.105**
ΔP_{t-1}	2.397	9.540	**8.821**	2.075	-0.993	**6.350**	**2.150**	**2.934**
ΔP_{t-2}	-4.273	3.669	**4.257**	0.298	**-3.043**	-0.445	0.402	0.457
ΔP_{t-3}	-2.891	1.747	0.759	-0.138	0.814	-1.763	-0.099	0.283
ΔP_{t-4}	-2.040	**-5.780**	**-2.175**	0.009	-2.391	**3.192**	0.109	0.128
ΔP_{t-5}	-4.990	-5.326	0.070	-1.314	0.586	1.898	0.007	-0.657
ΔP_{t-6}	-7.924	**6.621**	-1.187	0.266	-0.426	2.800	0.282	-0.749
ΔP_{t-7}	6.843	**-11.357**	0.597	-1.384	**-4.091**	-3.299	**-0.708**	-0.753
ΔP_{t-8}	-6.903	6.837	**-2.720**	1.184	-0.049	-0.676	-0.401	0.183
ΔP_{t-9}	0.624	-7.531	-1.732	-0.761	0.219	-0.115	-0.444	-0.709
ΔP_{t-10}	2.024	-3.278	-2.189	-0.300	-1.380	0.609	-0.299	-0.302
#obs	808	808	808	808	1347	1347	1347	1347
$Adj - R^2$	0.0423	0.0593	0.1779	0.0739	0.0084	0.0583	0.0655	0.0816

Price Impact

$$\frac{\Delta P_t}{P_{t-1} \times \sigma_{t-1}} = \alpha + \sum_{i=1}^{5} [\lambda_i \times \frac{AGG_{i,t}}{Shr_{i,t-1} \times 100,000}] + \epsilon_t \quad (2)$$

Where:

- returns are calculated over one minute intervals.
- σ is $\ln(range_t)$.
- i denotes the trader category.
- $AGG_{i,t}$ is the aggressiveness imbalance (aggressive buys - aggressive sells) during interval t.
- $Shr_{i,t-1}$ denotes market share of volume during the previous interval.

Results

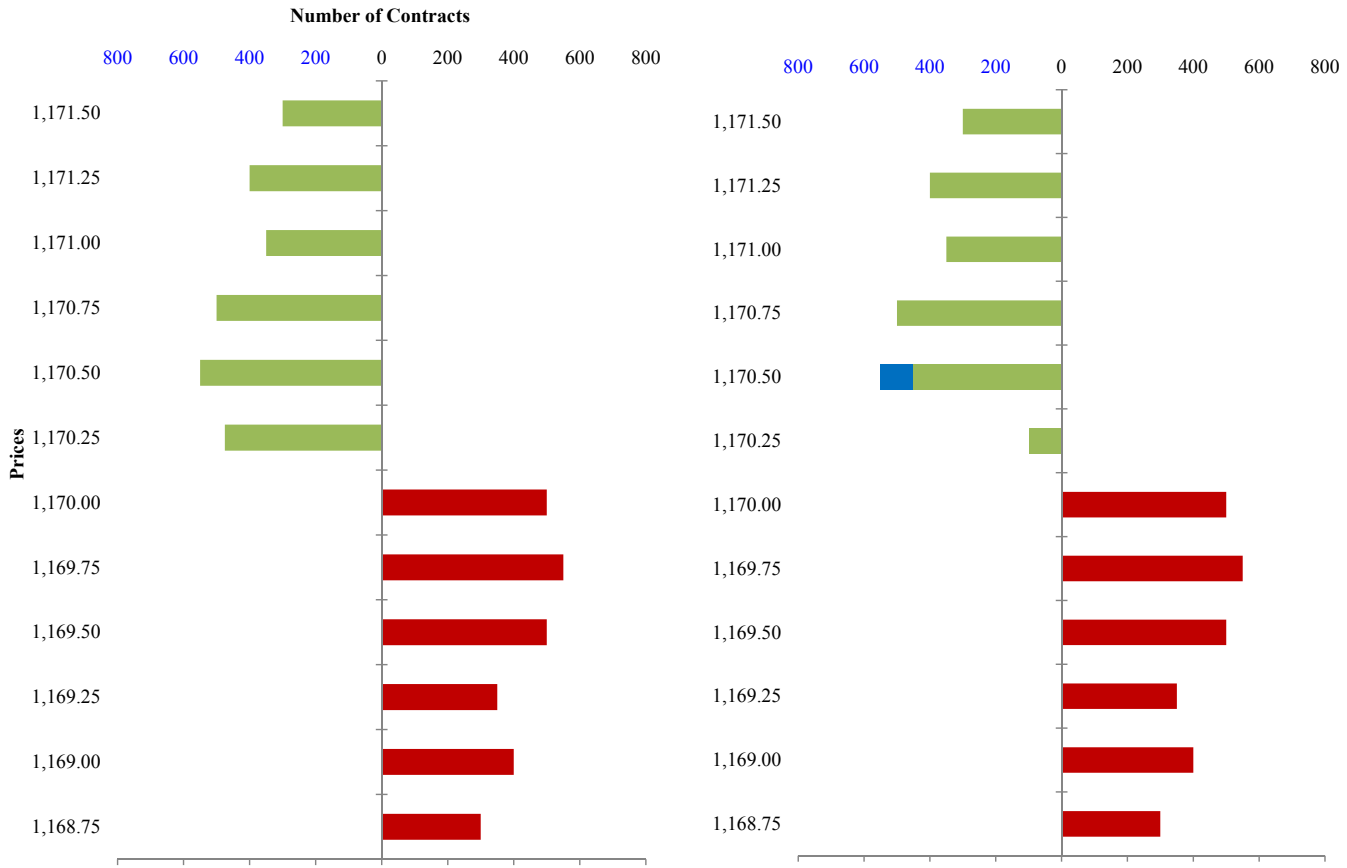
	May 3-5	May 6
Intercept	-0.01	0.01
	(-0.19)	(0.31)
HFT	5.37	3.23
	(6.43)	(3.37)
INT	0.83	5.99
	(1.08)	(5.08)
Fundamental Buyers	1.31	0.53
	(4.32)	(2.20)
Fundamental Sellers	1.36	0.92
	(5.81)	(6.40)
Opportunistic	7.60	7.49
	(9.74)	(10.61)
# of Obs	1210	404
Adj-R2	0.36	0.59

According to the CFTC-SEC May 6 Staff Report

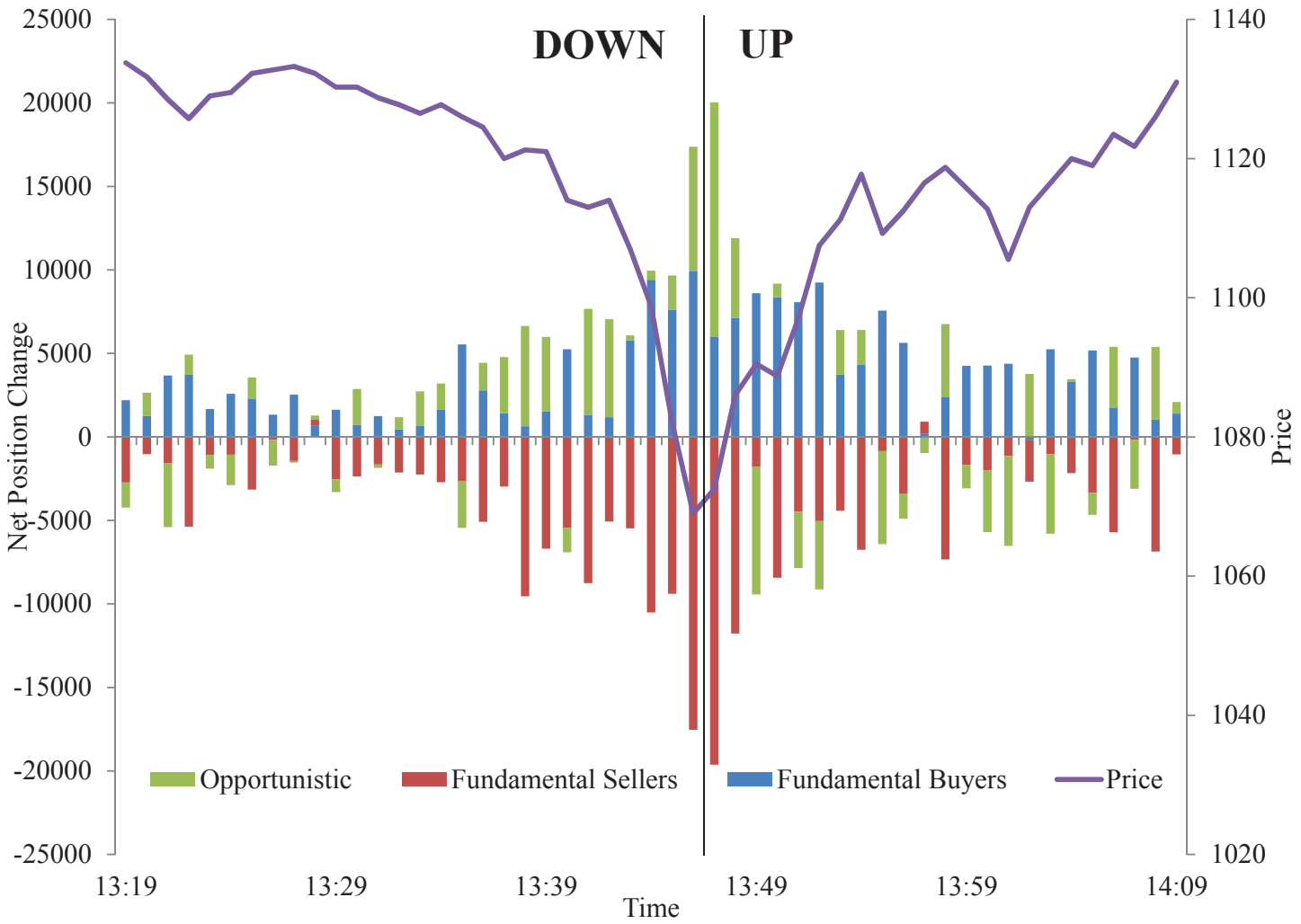
- A trader started executing a sell program of 75,000 contracts ($4.1 Billion) in the E-mini S&P June 2010 futures contract at 13:32 CT.
- This program was executed by an algorithm which was set to target 9% of trading volume.
- This program was the largest net position change in the E-mini of the year.
- Orders of this size are usually executed over the course of a day. However, this order was executed over approximately 20 minutes.

June 2010 E-mini Contract: Order Book Depth

Source: SEC-CFTC Joint Staff Report to the Advisory Committee, October 2010

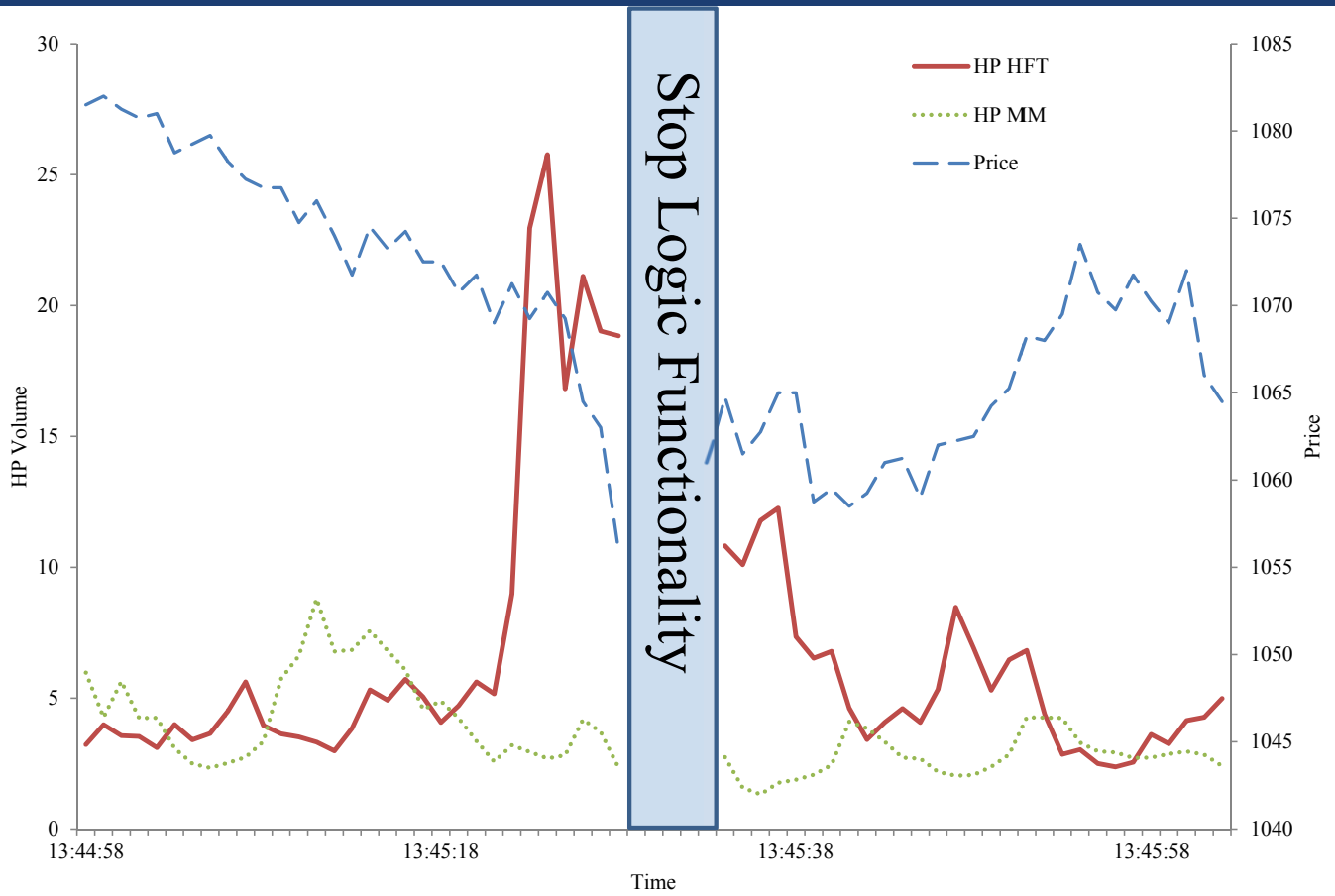


Opportunistic Traders and Price Concession



Opportunistic Traders take the other side of the sell pressure. They are likely to be cross-market arbitraguers who buy E-Mini S&P 500 Future contracts and sell in equity markets, resulting in contagion.

The Hot Potato Effect



Fundamental Buyers are delayed. High Frequency Traders pass the contracts among themselves until they find a longer horizon investor.

The Flash Crash: Events

- 13:32 - A large fundamental seller initiates a sell program.
- 13:42 - HFTs reverse the direction of their trading (start aggressively selling).
- 13:45 - Lack of Fundamental Buyers: "HFT Hot Potato Effect"
- 13:45:28 - 13:45:33: 5 second pause in trading.
- 13:45:33 - 13:45:58: Price stabilize.
- 13:46 - Fundamental Buyers lift prices up.
- 14:08 - Prices return to their 13:32 level.

Trading Volume During the Flash Crash

Panel A: May 3-5

	DOWN			UP		
	Sell	Buy	Net	Sell	Buy	Net
High Frequency Traders	23,746	23,791	45	40,524	40,021	-503
Market Makers	6,484	6,328	-156	11,469	11,468	-1
Fundamental Buyers	3,064	7,958	4,894	6,127	14,910	8,783
Fundamental Sellers	8,428	3,118	-5,310	15,855	5,282	-10,573
Opportunistic Traders	20,049	20,552	503	37,317	39,535	2,218
Small Traders	232	256	24	428	504	76
Total	62,003	62,003	0	111,720	111,720	0

Panel B: May 6th

	DOWN			UP		
	Sell	Buy	Net	Sell	Buy	Net
High Frequency Traders	152,436	153,804	1,368	191,490	189,013	-2,477
Market Makers	32,489	33,694	1,205	47,348	45,782	-1,566
Fundamental Buyers	28,694	78,359	49,665	55,243	165,612	110,369
Fundamental Sellers	94,101	10,502	-83,599	145,396	35,219	-110,177
Opportunistic Traders	189,790	221,236	31,446	302,417	306,326	3,909
Small Traders	1,032	947	-85	1,531	1,473	-58
Total	498,542	498,542	0	743,425	743,425	0

Policy Questions

- **Are Circuit Breakers Needed?**
- **Do High Frequency Traders Play a Useful Role?**
- **How Can Playing Field between HFTs and Other Traders Be Leveled?**
- **Is Market Depth an Entitlement?**
- **How Can Stock Markets be Made Less Fragmented?**

Circuit Breakers: Co-ordination

- Shutting down entire market versus speed bumps for a specific venue.
- If market-wide shutdown is needed, futures market should lead other markets.
- Market-wide circuit breakers in fragmented stock market require co-ordination across markets.
- Many flash-crash problems were venue specific. Could have been addressed with venue-specific speed bumps, such as brief pauses before prices are allowed to rise or fall to new levels. Would one cent per second have been slow enough to fix problems in stock market? Too slow?
- Five-second Globex "stop logic" pause corresponded to bottom of flash crash. Would flash crash have ended sooner if Globex had paused sooner?

Circuit Breakers: Time Frames

- Computer time = 5 seconds = current Globex policy.
- Human time = 1-5 minutes.
- Clearing and margin call time = 15-60 minutes.
- Lawyer time (weeks and months).
- 5 second pause recognizes primacy of computerized algorithmic trading.

Do High Frequency Traders Play a Useful Role? Futures Market versus Stock Market

- Disintermediation strategy of HFTs in fragmented stock market undermines time and price priority.
- HFTs in centralized futures market intermediate trades without undermining time or price priority.
- HFTs more harmful in fragmented stock market than centralized futures market.
- HFTs in futures markets do not currently dis-intermediate E-mini, but might do so in future if CME facts significant competition from other exchanges.

Do High Frequency Traders Play a Useful Role?

- HFTs play a useful role to the extent that otherwise wider spreads would discourage other traders from traders.
- This potential benefit must be weighed against costs of HFTs picking off orders when price level is about to change.
- Is "demand for immediacy" great enough to justify HFTs? Probably not, since demand for immediacy is a derived demand, existing because slow trading systems may conceal bad execution performance from customers.
- Inventory models do not justify demand for immediacy because HFTs do not hold inventories for a long enough time period to provide a valuable service to large institutions.

Do High Frequency Traders Play a Useful Role?

- If you think HFTs are like a tax on other traders, it may not be practical to order HFTs to disappear. It might be more practical to encourage competition among HFTs to minimize the "tax." This strategy allows HFTs to play useful role of smoothing out provision of liquidity across time and price levels.
- Revenue model of exchanges would justify higher fees if HFT profitability is reduced.
- Is it revenue-maximizing for CME to have lower fees for HFTs and higher fees for other traders? Or same fees for all traders?

Level Playing Field: Order Cancellation Fees

- Levels playing field, assuming HFTs cancel larger percentage of orders than other traders.
- But discourages provisions of liquidity, so might increase trading costs.

Level Playing Field: Minimum Order Resting Time

- HFTs may cancel a larger percentage of orders than other traders.
- Therefore minimum resting time levels playing field between HFTs and other traders.
- Long resting time may effectively discourage competition among HFTs.
- Perhaps optimal minimum resting time is about 50 ms, long enough for computers to respond (but not humans).
- Would cut down on message counts. Especially useful for stock market, which are choking on vast quantities of message data.

Level Playing Field: Batch Matching

- Batch matching at regular intervals (e.g. each second): HFTs wait until last millisecond to place orders.
- Advantage especially reduced if orders cannot be canceled until after next batch match period.

Level Playing Field: Random Time Delay

- Adding random time delay to each arriving message (say uniform delay distributed across 1 second or 100 ms) negates speed advantage of high frequency traders over market makers and other traders.
- Require centralized trading, like Globex, so feasible in stock index futures market.

Level Playing Field: Tick Size

- If HFTs scalp a tick by being faster than other traders, then reduction in tick size would undermine HFT profitability per trade.
- Reduced tick size might lead to dramatic increase in number of messages (by a factor equal to square of tick size reduction?)

Is Market Depth an Entitlement?

- Even if legally mandated, HFTs or other market makers will not step in front of a moving freight train.
- Black (1971): We should not expect "efficient" markets to offer huge depth. We should expect tight spreads and price continuity for small trades, big jumps on large blocks.

Additional Questions (Time Permitting)

- **How Common Are Flash Crashes?**: They are not rare occurrences.
- **What Causes Flash Crashes?**: They are often associated with large quantities dumped aggressively into a weakened market.
- **How Much Impact Should Large Orders in S&P E-minis Have?**: Kyle and Obizhaeva (2010): Trading Game Invariance.

Past Flash Crashes

- **Monday, October 19, 1987 Stock Market Crash**: Large Portfolio Insurance orders. Market recovered after about six months. But two "flash crashes," one on Tuesday, October 20, and the other on Thursday, October 22. Thursday associated with George Soros?
- **October 1989**: Reports by SEC and CFTC did not identify why price dropped at end of day and recovered the next day.
- **July 1997**: A flash crash that has been forgotten.
- **Societe General, January 2009**: Rapid liquidation of stock futures positions corresponded to worldwide stock declines, dramatic interest rate cuts by Fed.

Kyle and Obizhaeva (2010): Market Microstructure Invariance

- **Trading Game Invariance**: Faster "game clock" changes speed of game but not game itself. Speeding up clock speeds up order arrival rate and returns variance proportionally.
- **"Trading Activity"**: Measure "trading activity" as product of dollar volume and returns standard deviation.
- **Implication for Order Size:** If trading activity increases by one percent, then number of orders increases by two-thirds of one percent, and size of orders (dollar volume times returns standard deviation) increases by one-third of one percent.
- **Implication for Market Impact**: Holding order size as fraction of average daily volume constant (say, 1% or 5%), a one percent increase in trading activity leads to a one-third of one percent increase in price impact.

Kyle and Obizhaeva (2010): Extrapolation to May 6 Flash Crash

- **Benchmark Stock Trading Activity**: $40 million average daily volume, 2% daily volatility.
- **Benchmark Stock Market Impact**: A trade of one percent of average daily volume has price impact of about 3 basis points.
- **Trading Activity Assumptions for May 6 Flash Crash:** Use volume and volatility "between" May 3-5 and May 6. Assume volume of $160 billion per day and volatility of 2% per day.
- **Implication:** Trading activity of E-mini is 4,000 times larger than benchmark stock. Impact greater by factor of $4000^{1/3} = 16$. Impact of trading one percent of average daily volume is about 100 basis points. Impact of $4 billion trade (2.5% of ADV) is about 250 basis points.
- **Caveat:** Flash Crash program was executed very fast, amplifying impact.

Conclusion: Answers to Research Questions

- High Frequency Traders did not trade differently on May 6 than other days.
- Flash Crash triggered by the arrival of an unusually large 75,000 contract sell order, executed unusually aggressively in a unusually weakened market.
- HFTs did not hold large enough inventories either to cause or prevent the Flash Crash.

Future Directions for Market Microstructure Research

Research is driven by institutional changes, data availability, computation power, breakthroughs in other fields.

- MiFid and Reg NMS resulted in fragmented equity markets, implying equity data is bad.
- Futures markets more centralized.
- Dodd-Frank Act mandates better data for U.S.: Audit trail, swap reporting, data repositories, legal entity identifiers (LEIs).
- Microstructure research has mostly been data intensive (disk space, disk read times, data compression) but not computationally intensive.
- Increasing computational power will make text processing and important part of microstructure research. Both computationally and data intensive.

Data with Trader IDs—LEIs

Prices are formed by interaction of large buyers and sellers, not HFTs.

- Sweden a good laboratory because less concern with protection confidentiality of data than in U.S. and perhaps other countries.
- How big are largest traders? What is distribution of "bet" sizes?
- How to separate "directional traders" from "intermediaries"? Holding period? Past behavior?
- How fast or slowly do large traders accumulate positions? Given kurtosis, how much do large traders slow down their trades?
- What is role of "market resiliency" in governing the speed with which traders trade?

Trading Liquidity and Funding Liquidity

- Propagation mechanisms based on LEIs. Example: Index arbitrage during flash crash could not be studied empirically due to lack of data.
- Repo markets: role of liquidity of collateral.
- Banks: Speed of capital raising.
- Might get interesting microstructure fireworks if Euro regulators use aggressive restrictions on short sales to prevent bank failures from being recognized or to prevent collapse of Euro.

Optimal Execution Strategies

Studies based on LEIs:

- Do less informed firms hit bids and lift orders, or try to buy at bid, sell at offer? PK thinks "aggressiveness" of strategy (in the sense of speed of adjustment) not necessarily related to "Aggressiveness" of trading (in the sense of hitting bids and offers).
- Who provides liquidity if high frequency traders do not do so?
- Use of accurate time stamps to separate traders based on latency.
- Do big unsophisticated traders randomize enough?

Text Processing and Factor Models

- What does "entity resolution" mean? Does "Apple" mean a fruit, a company, a computer, or a cell phone?
- Do small changes in covariance structure reveal how markets absorb information?
- Is complexity of information associated with size of market?
- Connecting factor structure of returns with text information: industry classification, classification based on other features like governance quality.

Some Contrarian Vies on Research

- Human versus electronic markets: HFTs do the same thing humans used to do, only faster. Put humans out of business.
- Network Models: Is this a computer science agenda looking for an application that does not work in finance?
- Need for speed and fragmentation: Delays are so short that speed may not matter much in long run. Focus on equal access and protection of price and time priority across markets.
- In what sense do "market makers" really provide liquidity? Perhaps only in shortest time scales. Idea that market makers buffer against significant order imbalances for a long time is a fiction (propagated by market makers to justify preferential access to trading).

My Own Specific Agenda Relates to Invariance.

- Liquidity is provided over time, not instantaneously.
- Modeling and measuring liquidity factors.
- Practical ways to look for systemic risk. (Wait until Friday.)
- Can macroeconomics be better understood based on invariance concepts? For example, quantities adjust more slowly than prices, especially in illiquid markets.
- Can we understand point at which "dealer" markets break down and are replaced by "broker" markets.