

# The Flash Crash:

## The Impact of High Frequency Trading on an Electronic Market

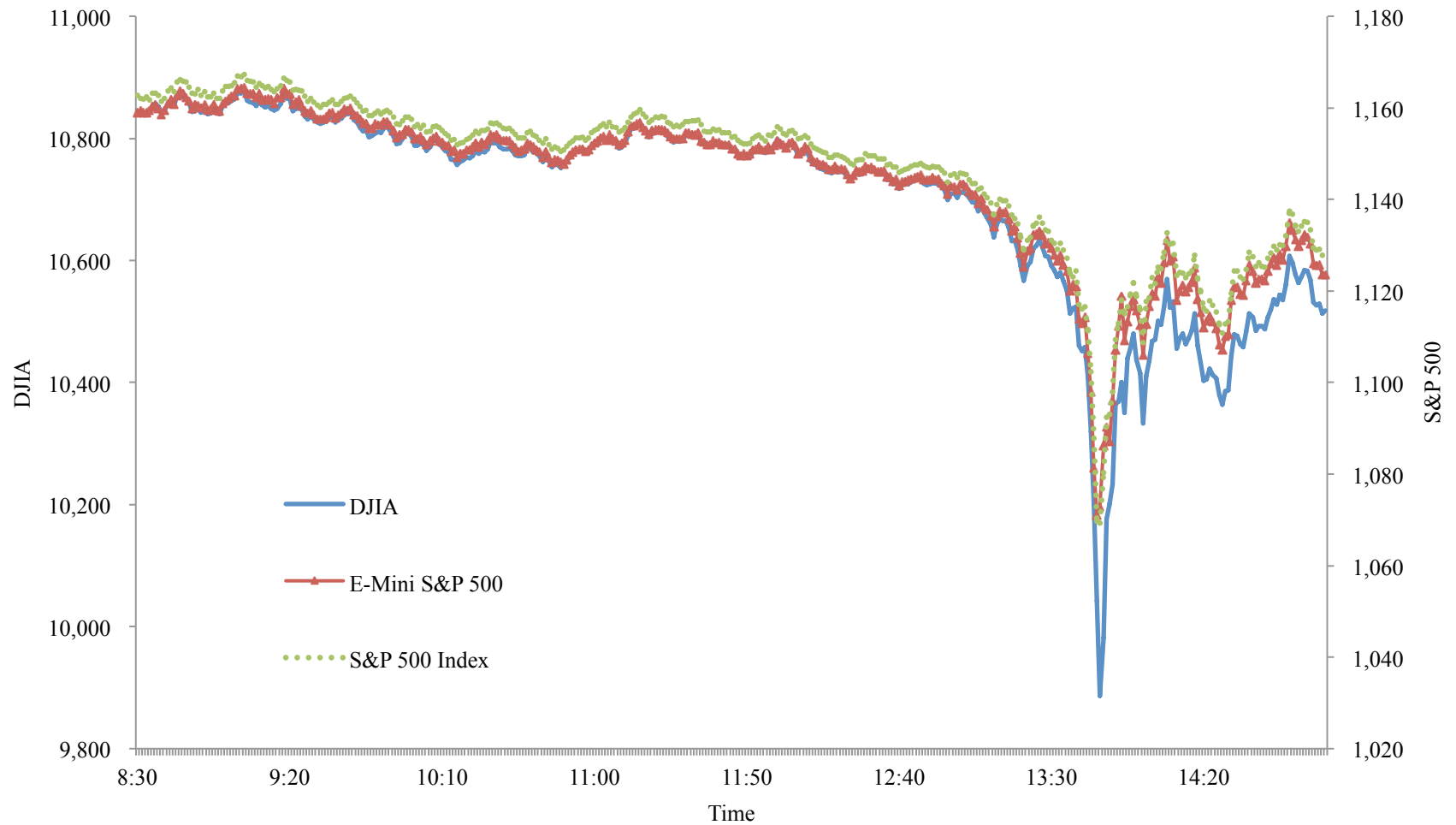
**Andrei Kirilenko**  
**Commodity Futures Trading Commission**

**joint with**

**Pete Kyle (Maryland), Mehrdad Samadi (CFTC) and  
Tugkan Tuzun (Maryland and CFTC)**

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# The Flash Crash - May 6, 2010



The background of the slide features a faint, light blue financial chart with a grid. The chart includes a candlestick pattern in the upper right and a line graph with multiple peaks and valleys across the lower half. The overall color scheme is a mix of dark teal at the top and light blue at the bottom.

## What did people think?

A survey conducted by Market Strategies International in June 2010 reports that over 80 percent of U.S. retail advisors believe that

“overreliance on computer systems and **high-frequency trading**”  
were the primary contributors to the volatility observed on May 6.



## This paper

We use audit-trail data for the E-mini S&P 500 stock index futures contract to answer three questions:

How did High Frequency Traders and others traded on May 6?

What may have triggered the Flash Crash?

What role did High Frequency Traders play in the Flash Crash?



## Findings

High Frequency Traders did not cause the Flash Crash.

On May 6, HFTs traded the same way as they did on May 3-5:  
Small inventory, high trading volume, take more liquidity than provide.

A large, but short lived imbalance between Fundamental Sellers and Fundamental Buyers appeared.

Opportunistic Traders held it, but for a massive price concession.

Fundamental Buyers eventually stepped in and pushed prices up.





## E-mini S&P 500 futures contract

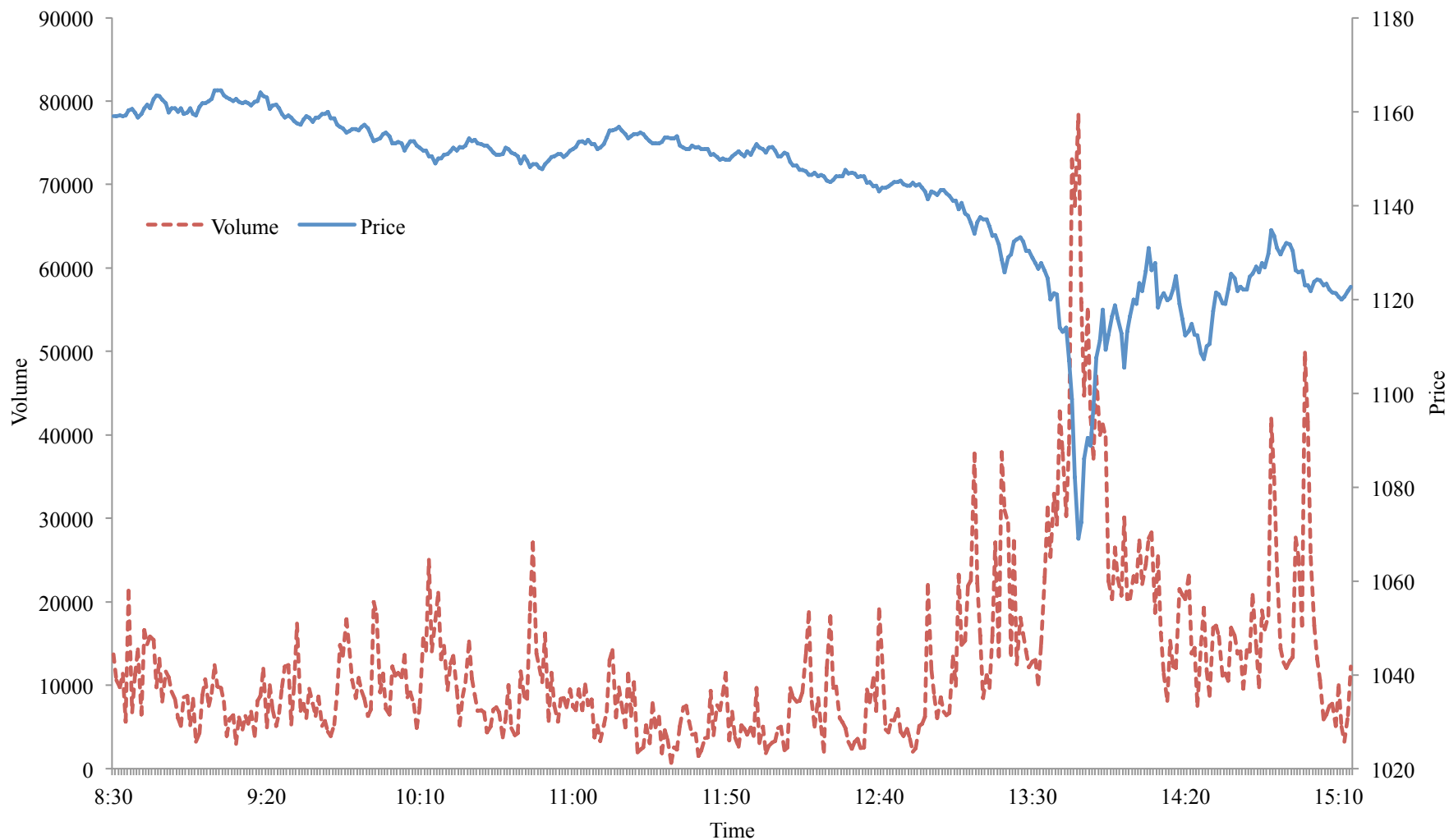
Trades exclusively on the CME Globex electronic trading platform.

Highest dollar trading volume among U.S. equity index products.

Contributes the most to price discovery of the S&P 500 index:  
Hasbrouck (2003).

Price discovery typically occurs in the front-month contract.

## June 2010 E-mini S&P 500: Trading Volume and Price





## Summary Statistics

	May 3-5	May 6th
Volume	2,397,639	5,094,703
# of Trades	446,340	1,030,204
# 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	1.54%	9.82%
Return	-0.02%	-3.05%

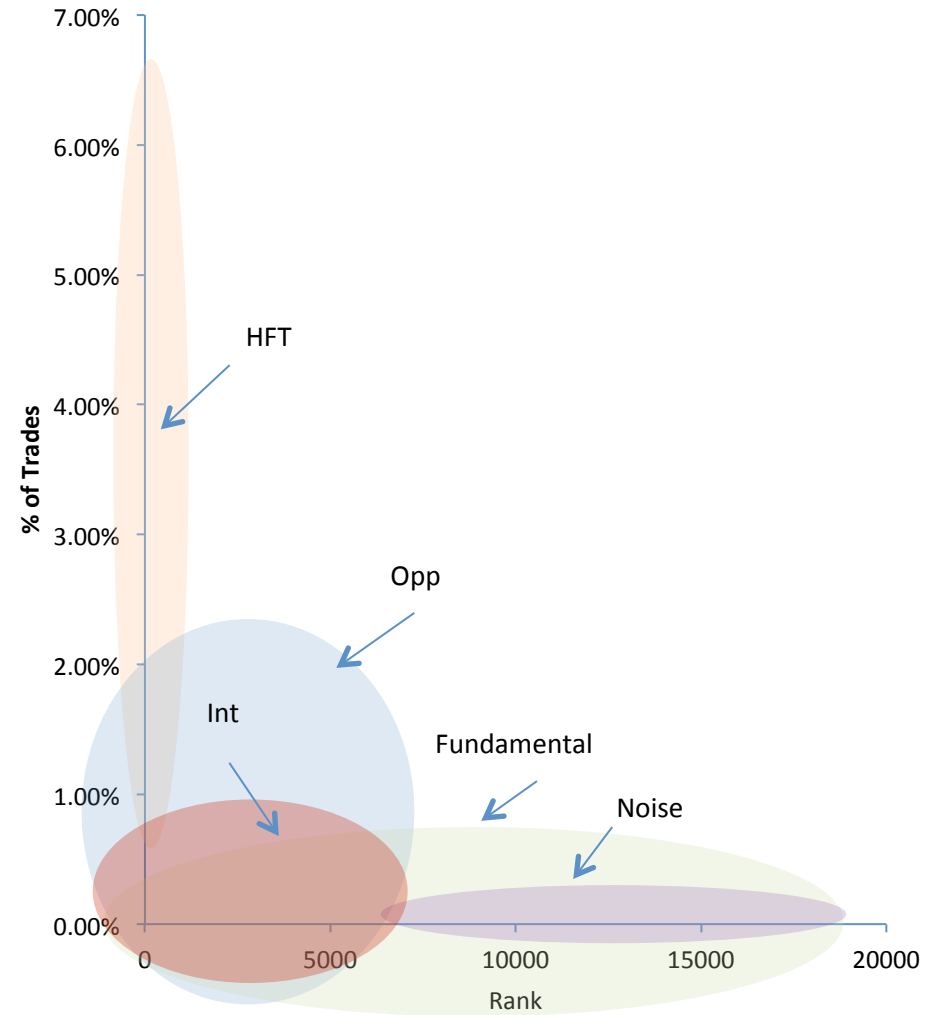
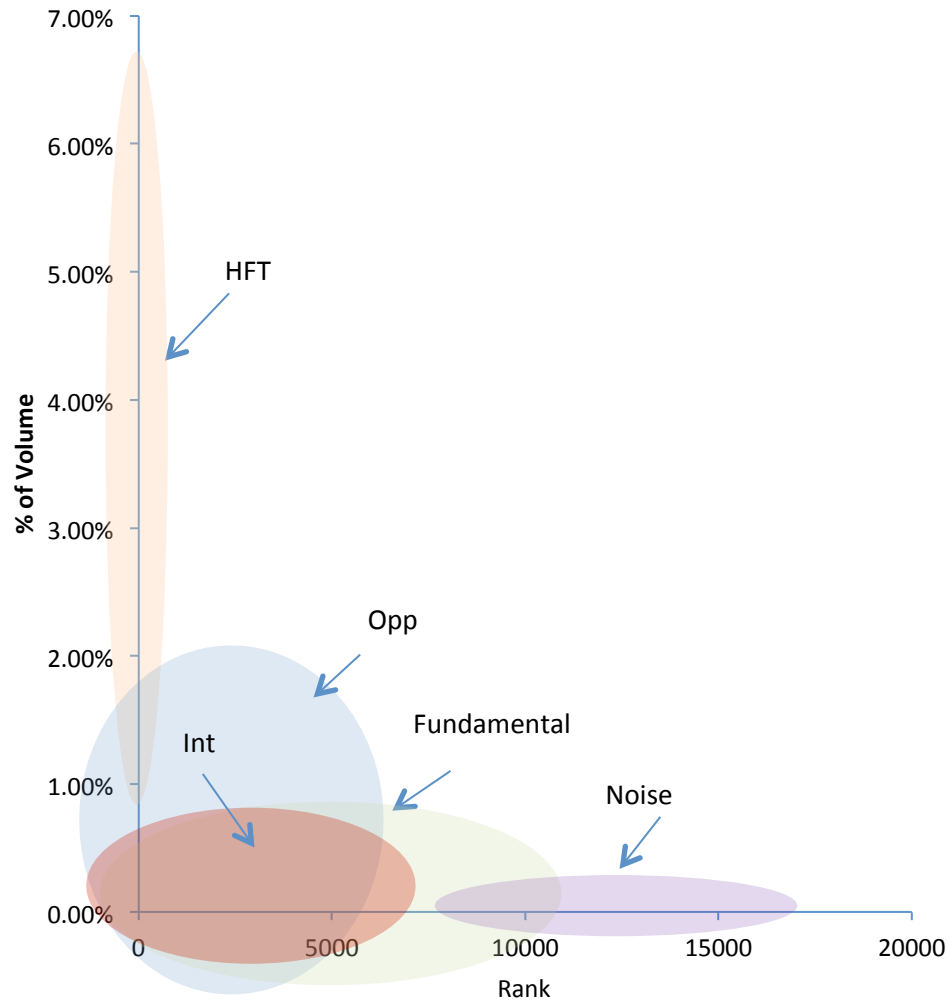


The background of the slide features a dark teal header and a light blue footer. The central white area contains a faint, stylized financial chart with a grid. The chart includes a candlestick pattern at the top right and a line graph with multiple peaks and valleys across the middle and bottom sections.

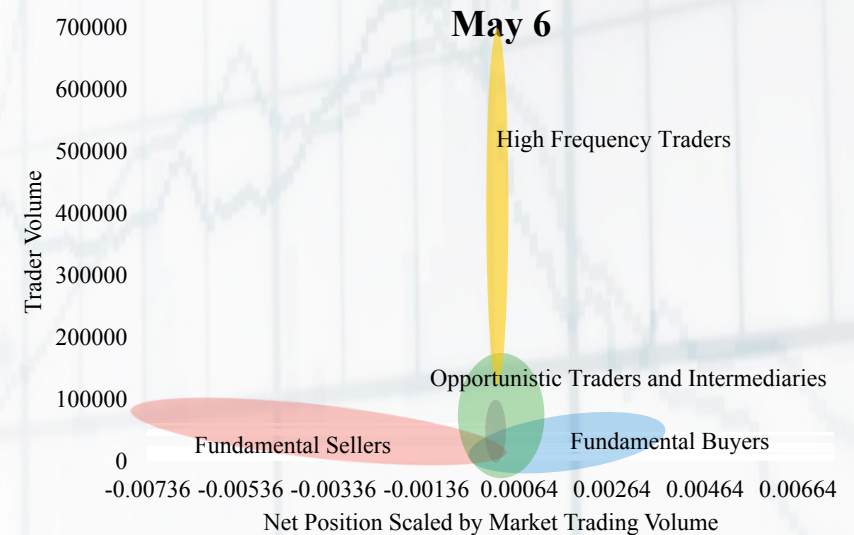
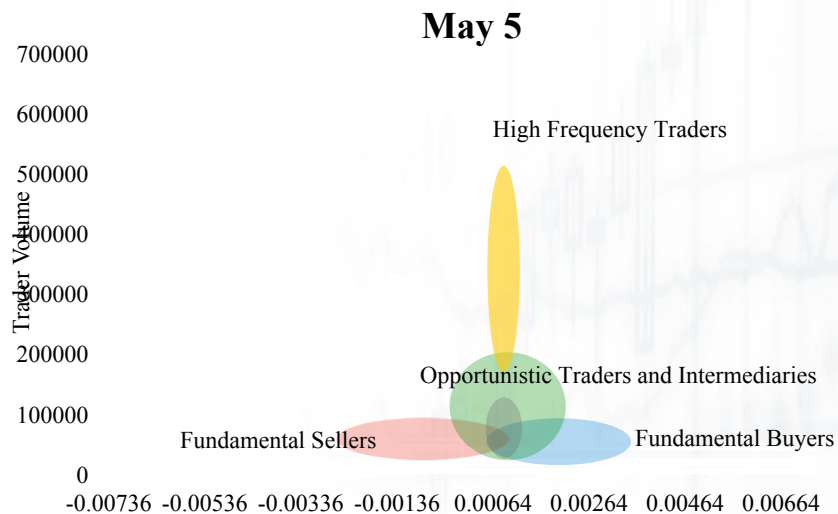
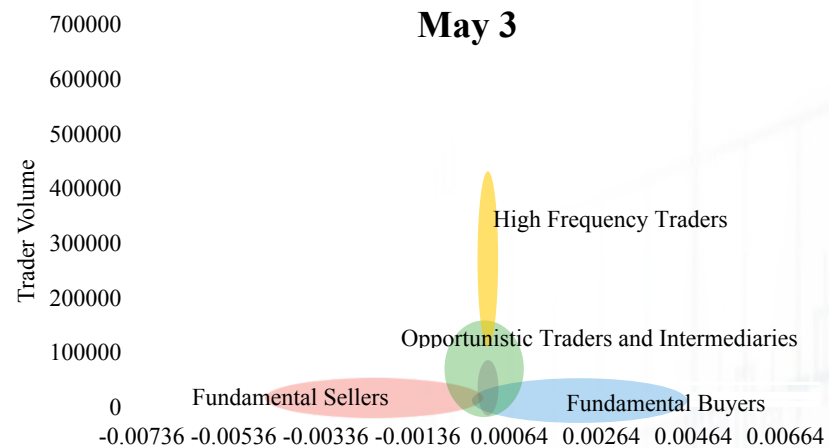
## Trader Categories

- High Frequency Traders (16)
- Intermediaries (179)
- Fundamental Buyers (1263)
- Fundamental Sellers (1276)
- Opportunistic Traders (5808)
- Small Traders (Noise) (6880)

# Trader Categories



# Trader Categories



## Trader Category Summary Statistics

**Panel A: May 3-5**

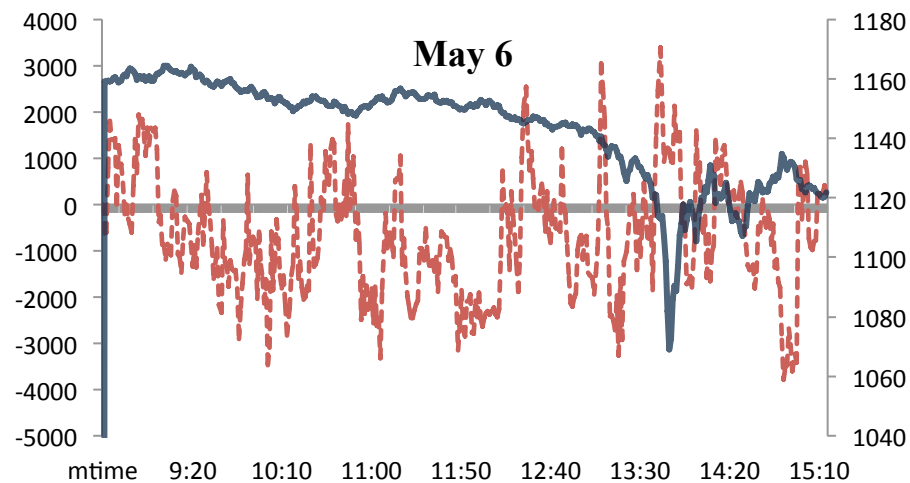
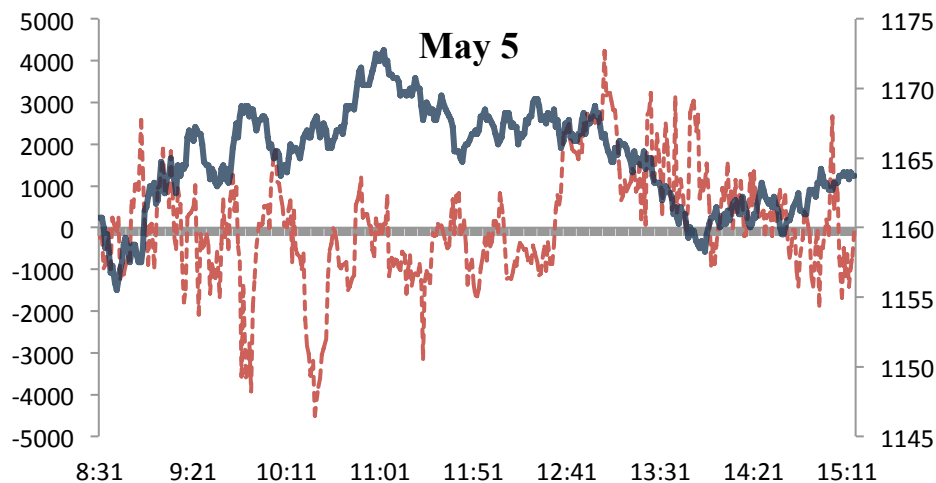
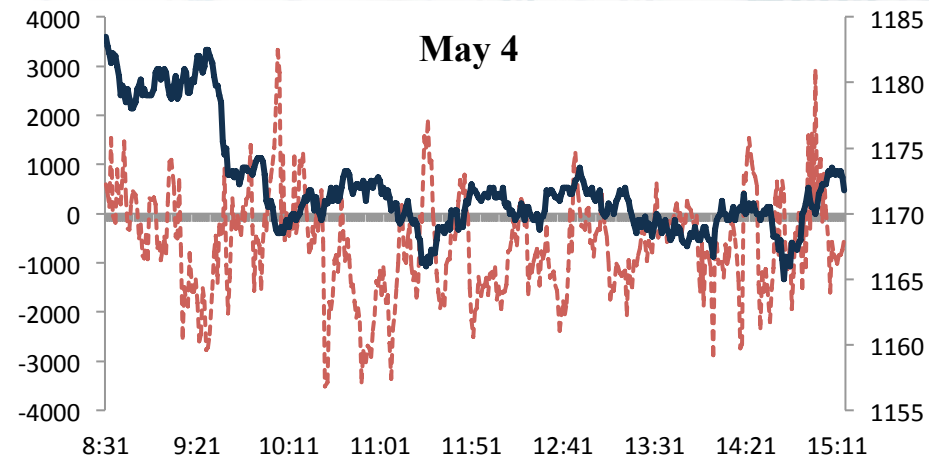
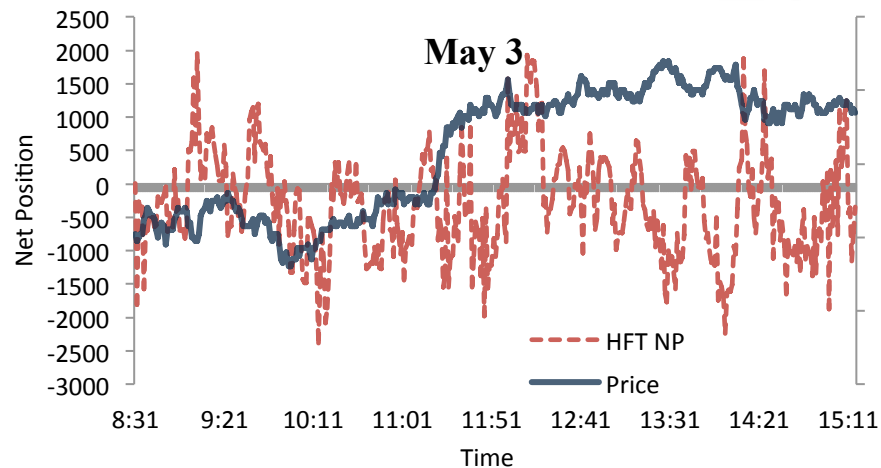
Trader Type	% Volume	% of Trades	# Traders	Trade Size (Avg.)	Order Size (Avg.)	Limit Orders % Volume	Limit Orders % Trades	Agg Ratio Trade-Weighted	Agg Ratio Vol-Weighted
High Frequency Traders	34.22%	32.56%	15	5.69	14.75	100.000%	100.000%	49.91%	45.68%
Intermediaries	10.49%	11.63%	189	4.88	7.92	99.614%	98.939%	43.10%	41.62%
Fundamental Buyers	11.89%	10.15%	1,013	6.34	14.09	91.258%	91.273%	66.04%	64.09%
Fundamental Sellers	12.11%	10.10%	1,088	6.50	14.20	92.176%	91.360%	62.87%	61.13%
Opportunistic Traders	30.79%	33.34%	3,504	4.98	8.80	92.137%	90.549%	55.98%	54.71%
Small Traders	0.50%	2.22%	6,065	1.22	1.25	70.092%	71.205%	59.04%	59.06%
	Volume	# of Trades	# Traders	Trade Size (Avg.)	Order Size (Avg.)	Limit Orders % Volume	Limit Orders % Trades	Volatility	Return
All	2,397,639	446,340	11,875	5.41	10.83	95.45%	94.36%	1.54%	-0.02%

**Panel B: May 6th**

Trader Type	% Volume	% of Trades	# Traders	Trade Size (Avg.)	Order Size (Avg.)	Limit Orders % Volume	Limit Orders % Trades	Agg Ratio Trade-Weighted	Agg Ratio Vol-Weighted
High Frequency Traders	28.57%	29.35%	16	4.85	9.86	99.997%	99.997%	50.38%	45.53%
Intermediaries	9.00%	11.48%	179	3.89	5.88	99.639%	99.237%	45.18%	43.55%
Fundamental Buyers	12.01%	11.54%	1,263	5.15	10.43	88.841%	89.589%	64.39%	61.08%
Fundamental Sellers	10.04%	6.95%	1,276	7.19	21.29	89.985%	88.966%	68.42%	65.68%
Opportunistic Traders	40.13%	39.64%	5,808	5.05	10.06	87.385%	85.352%	61.92%	60.28%
Small Traders	0.25%	1.04%	6,880	1.20	1.24	63.609%	64.879%	63.49%	63.53%
	Volume	# of Trades	# Traders	Trade Size (Avg.)	Order Size (Avg.)	Limit Orders % Volume	Limit Orders % Trades	Volatility	Return
All	5,094,703	1,030,204	15,422	4.99	9.76	92.443%	91.750%	9.82%	-3.05%

**16 HFT accounts are responsible for almost a third of trading volume...**

## Net Holdings of High Frequency Traders

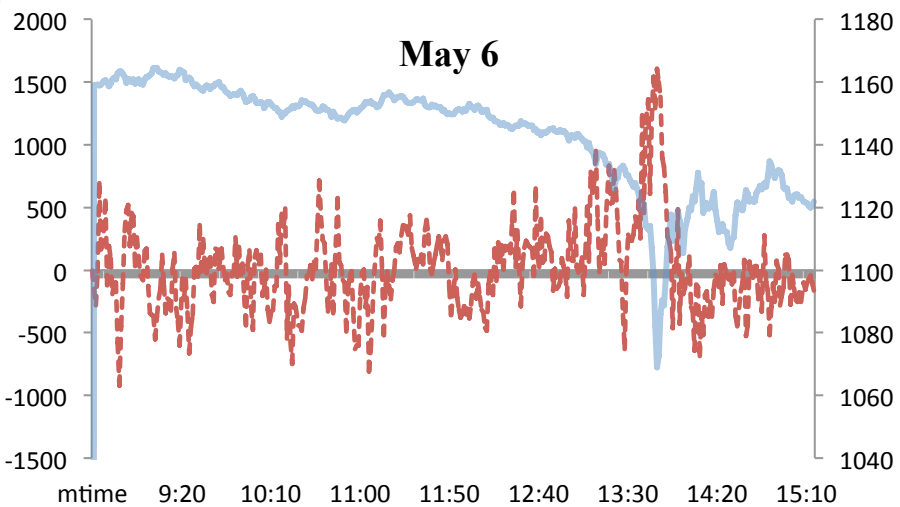
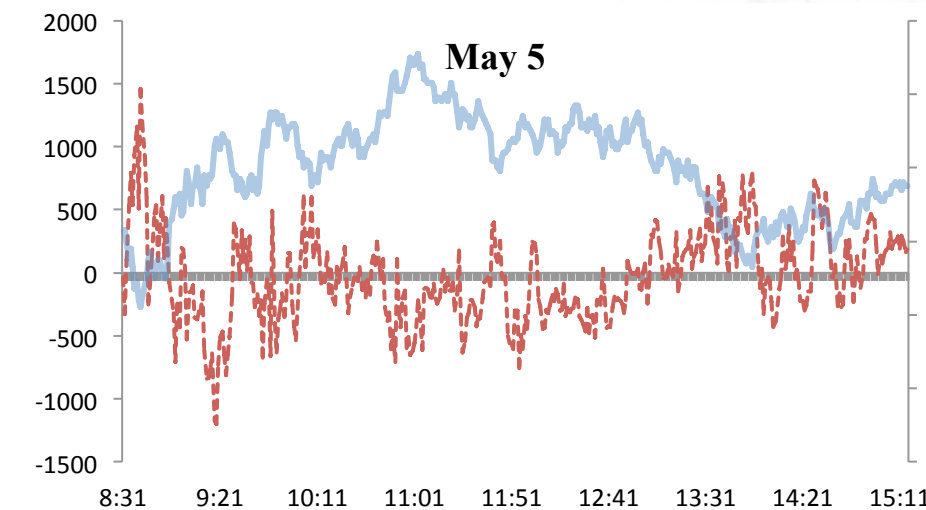
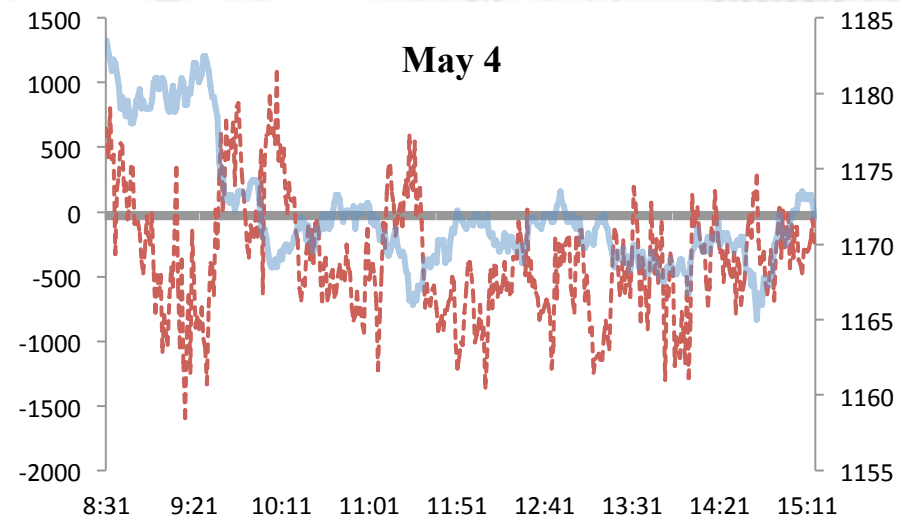
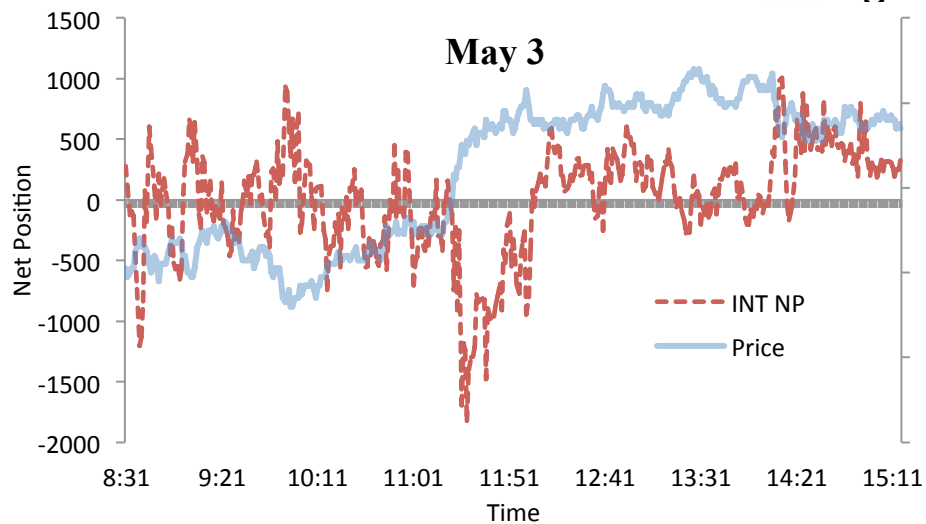


**Yet they do not accumulate of position larger than 4500 contracts!**





## Net Holdings of Intermediaries



## HFTs: Net Holdings and Prices

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

May 3-5

HFTs reduce 0.6 percent of their net holdings in 1 second.

HFTs trade in the direction of the price movement for the first 5 seconds.

Trade in the direction opposite the price movement after 10 seconds.

Interpretation: Speed or predictive ability enables HFTs to buy right when prices are about to increase and sell after the prices rose.

## HFTs: Net Holdings and Prices

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

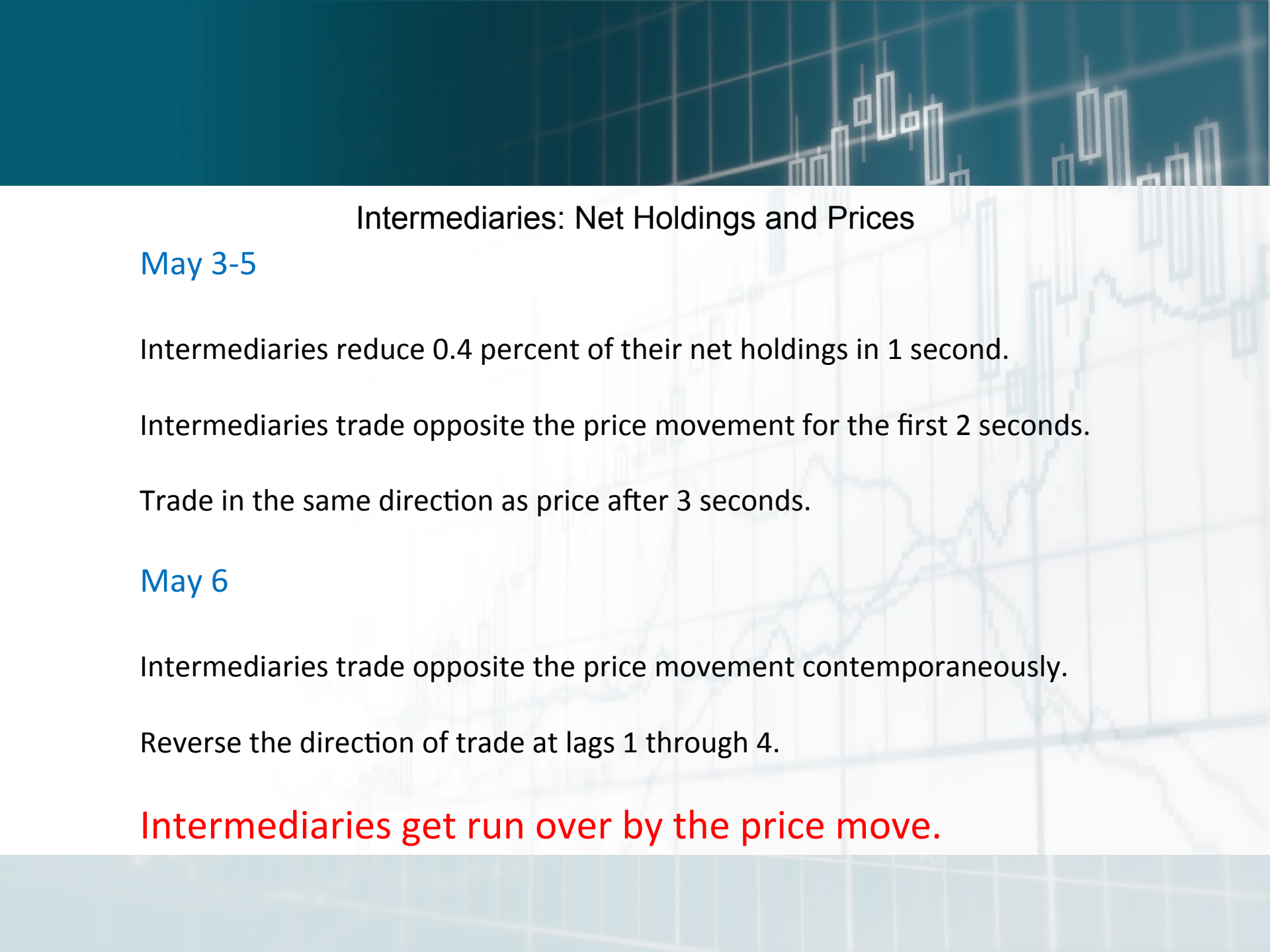
May 6

HFTs trade in the direction of the price movement for the first 2 seconds.

Trade in the direction opposite the price movement after 4 seconds.

On May 6, HFTs reverse the direction of their trading a lot faster

**Follow the same strategy, but do it faster**

The background of the slide features a dark teal header and a light blue footer, both with a faint grid pattern. The central white area contains text. In the background, there is a faint, light blue line chart and a candlestick chart, suggesting a financial or market context.

## Intermediaries: Net Holdings and Prices

### May 3-5

Intermediaries reduce 0.4 percent of their net holdings in 1 second.

Intermediaries trade opposite the price movement for the first 2 seconds.

Trade in the same direction as price after 3 seconds.

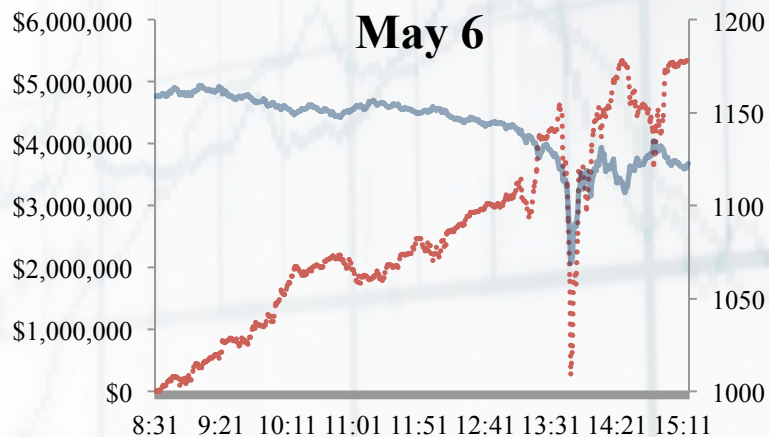
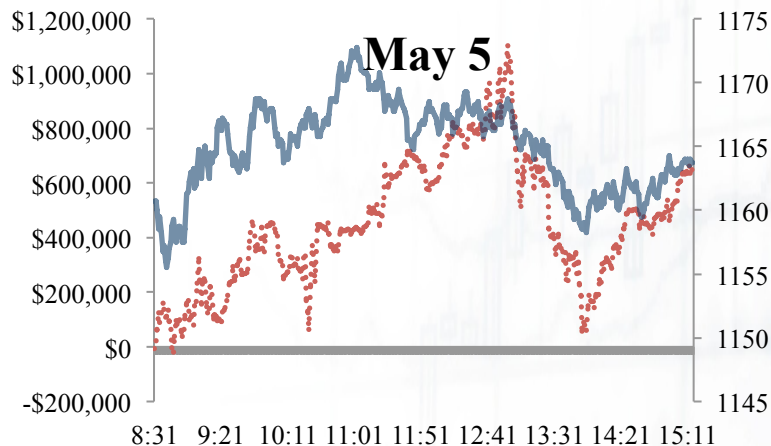
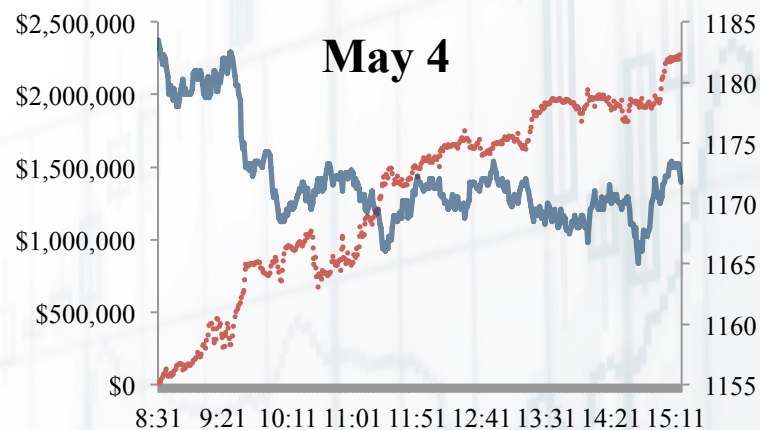
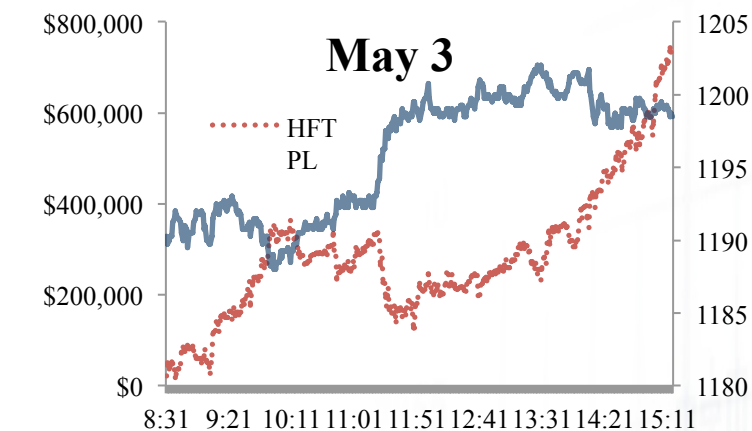
### May 6

Intermediaries trade opposite the price movement contemporaneously.

Reverse the direction of trade at lags 1 through 4.

**Intermediaries get run over by the price move.**

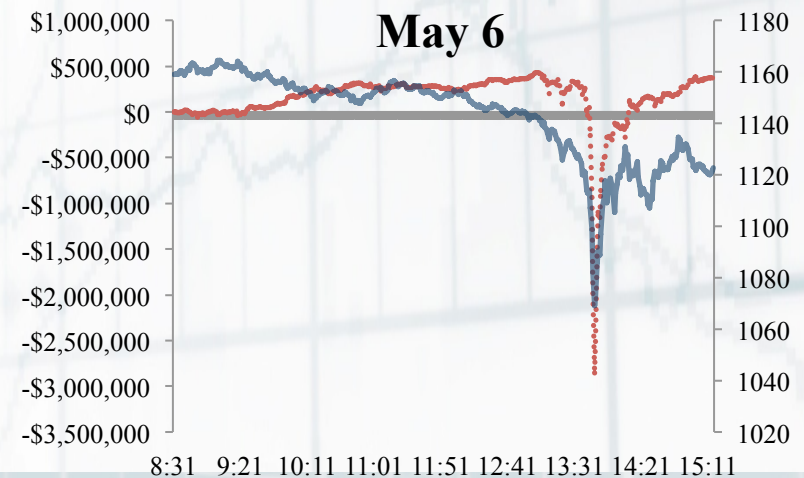
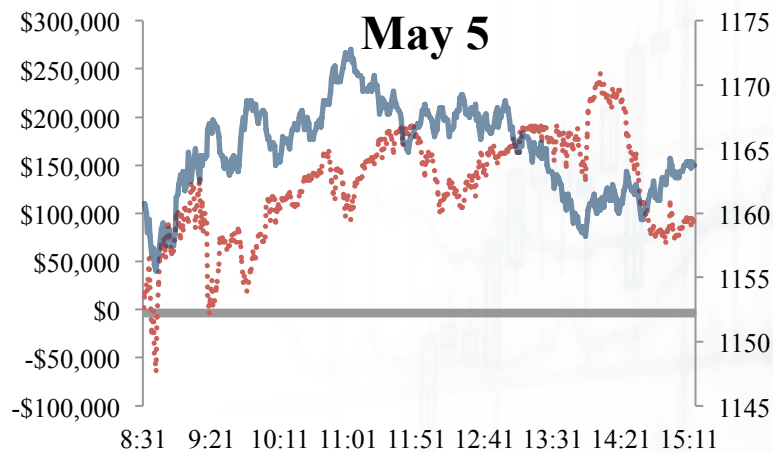
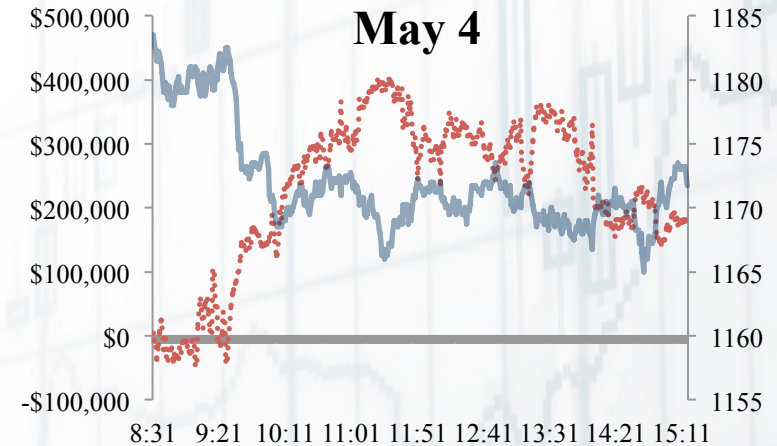
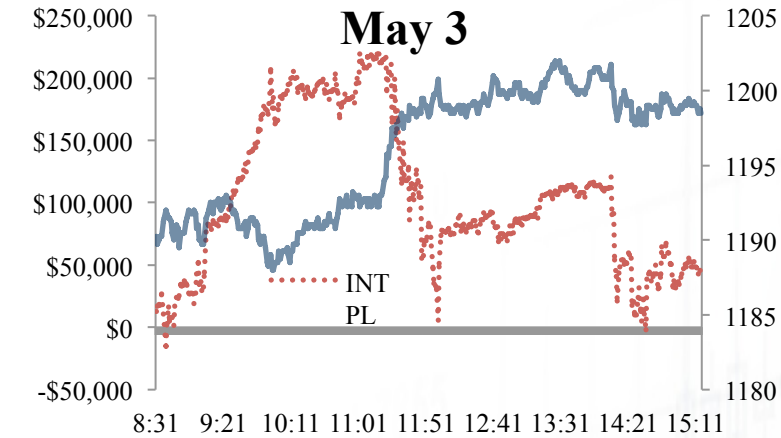
## Profits and Losses of High Frequency Traders



**Never negative.**



## Profits and Losses of Intermediaries





## HFTs: Liquidity Provision (Passive) or Removal (Aggressive)

### May 3-5

Aggressively reduce 0.5 percent of their net holdings in 1 second.

Aggressively trade in the direction of the price movement for the first 6 seconds.

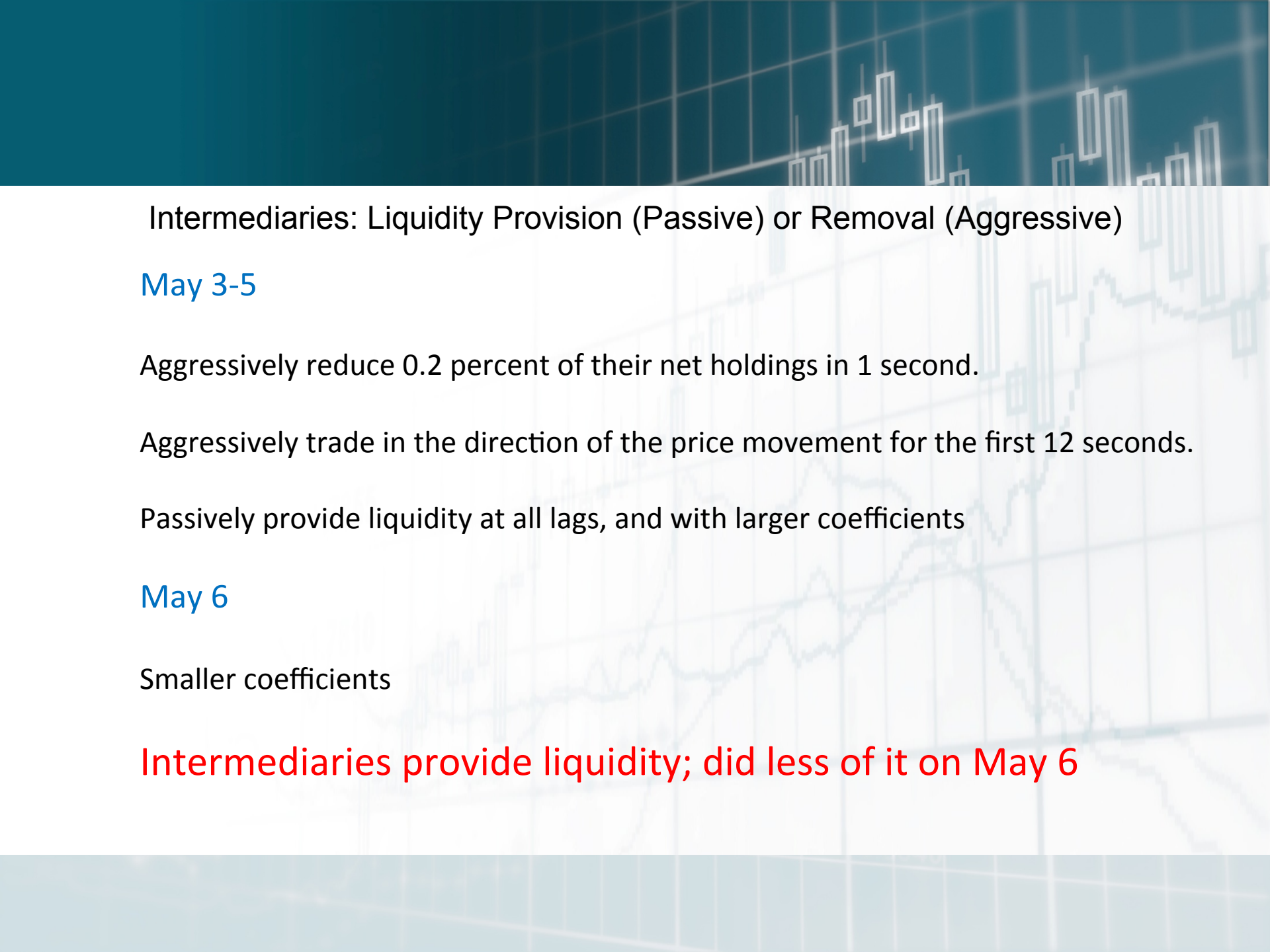
Aggressively trade in the direction opposite the price movement after 10 seconds.

Passively provide liquidity at all lags, but with smaller coefficients

### May 6

Same strategy, but faster

**HFTs more aggressively remove liquidity, then passively supply it**

The background of the slide features a dark teal header and a light blue grid. Overlaid on the grid is a white line chart with candlestick-style bars, representing price movement over time. The chart shows an upward trend followed by a sharp drop and then a recovery.

Intermediaries: Liquidity Provision (Passive) or Removal (Aggressive)

May 3-5

Aggressively reduce 0.2 percent of their net holdings in 1 second.

Aggressively trade in the direction of the price movement for the first 12 seconds.

Passively provide liquidity at all lags, and with larger coefficients

May 6

Smaller coefficients

**Intermediaries provide liquidity; did less of it on May 6**



## HFTs and Intermediaries: The Flash Crash

DOWN (13:32:00-13:45:28 CT)

HFTs follow the same strategy

Intermediaries get caught on the wrong side

UP (13:45:33-14:08:00 CT)

HFTs are less aggressive (fundamental and opportunistic buyers are)

Intermediaries close positions and about half of them withdraw



## Fundamental Traders

Panel A: May 3-5

		DOWN		UP	
		Sell	Buy	Sell	Buy
HFT		23,746	23,791	40,524	40,021
Intermediaries		6,484	6,328	11,469	11,468
Buyers		3,064	7,958	6,127	14,910
Sellers		8,428	3,118	15,855	5,282
Opportunistic Traders		20,049	20,552	37,317	39,535
Noise Traders		232	256	428	504



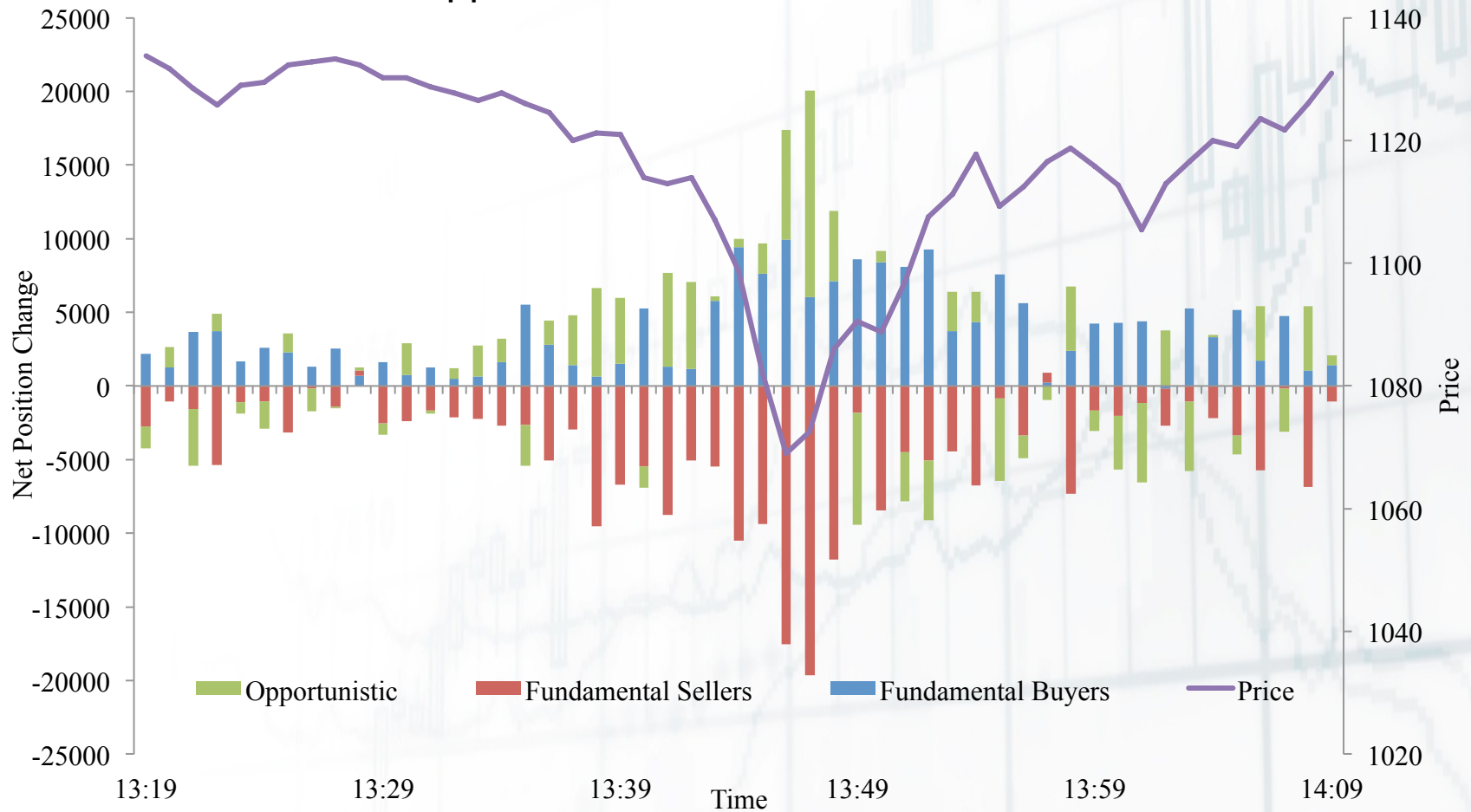
A candlestick chart with a grid background, showing price movement over time. The chart is positioned in the upper right corner of the slide.

## Fundamental Traders: Flash Crash

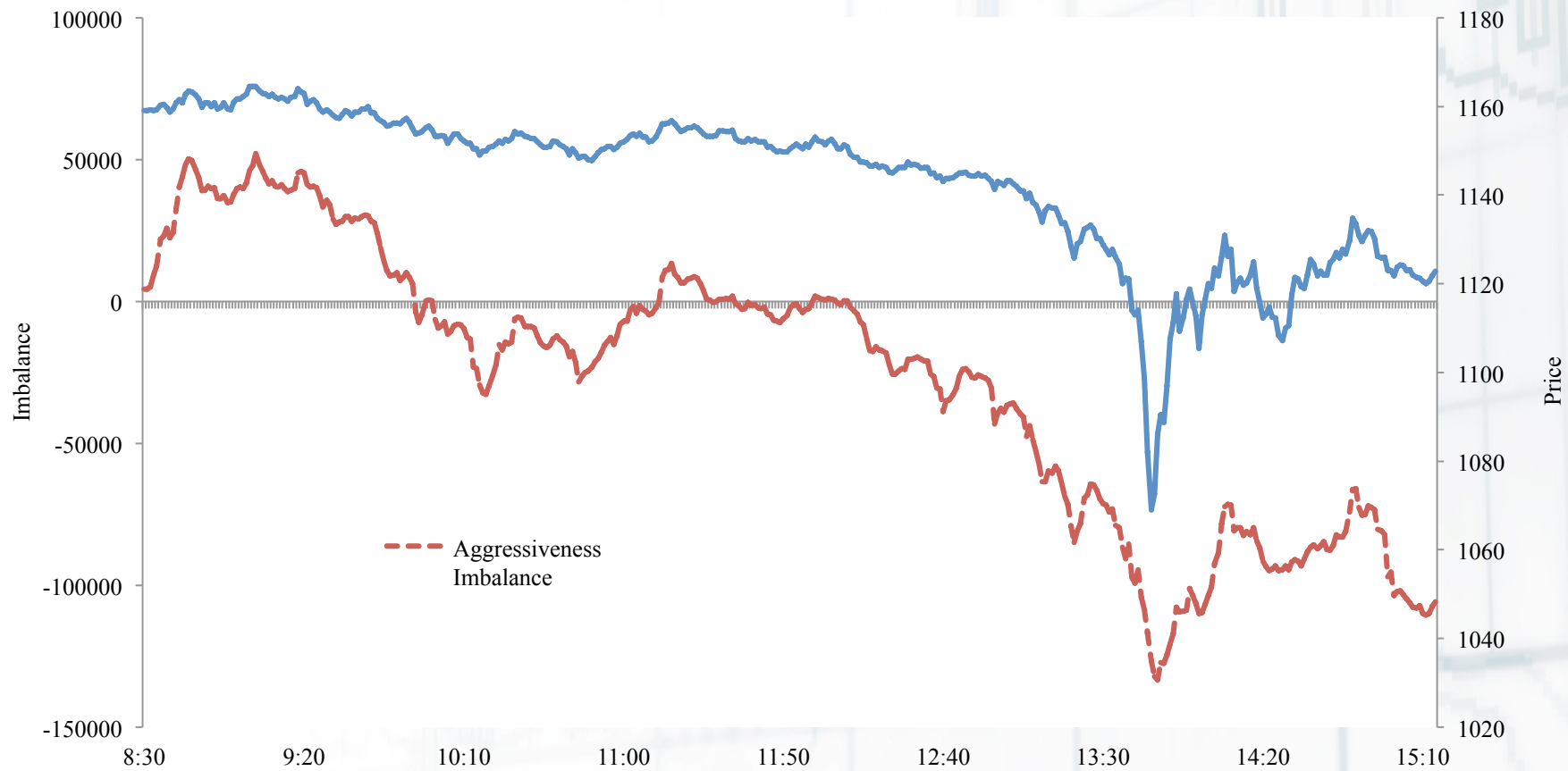
### Panel B: May 6th

		DOWN		UP	
		Sell	Buy	Sell	Buy
	HFT	152,436	153,804	191,490	189,013
	Intermediaries	32,489	33,694	47,348	45,782
	Buyers	28,694	78,359	55,243	165,612
	Sellers	94,101	10,502	145,396	35,219
Opportunistic Traders		189,790	221,236	302,417	306,326
Noise Traders		1,032	947	1,531	1,473

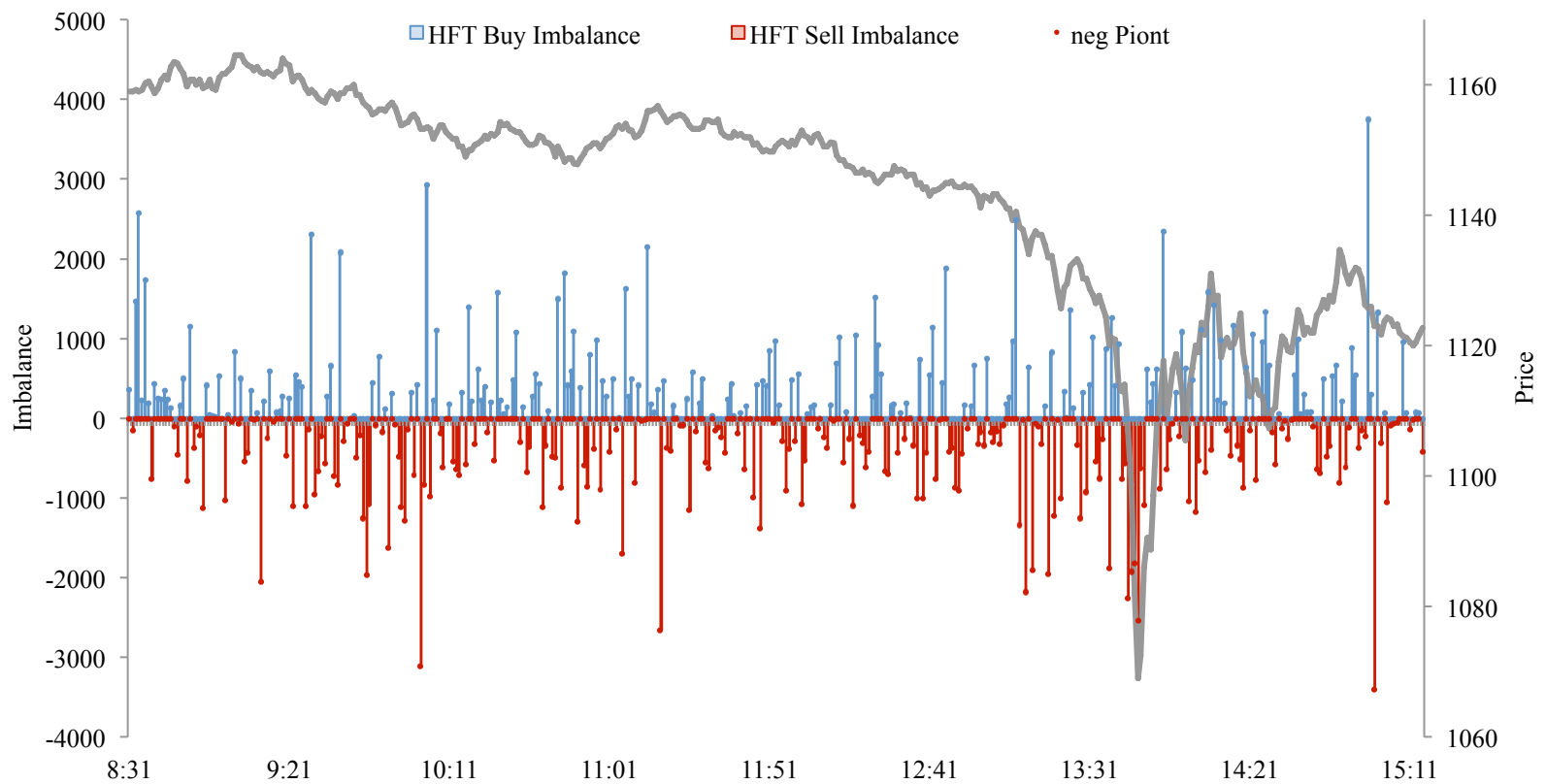
## Opportunistic Traders: Flash Crash



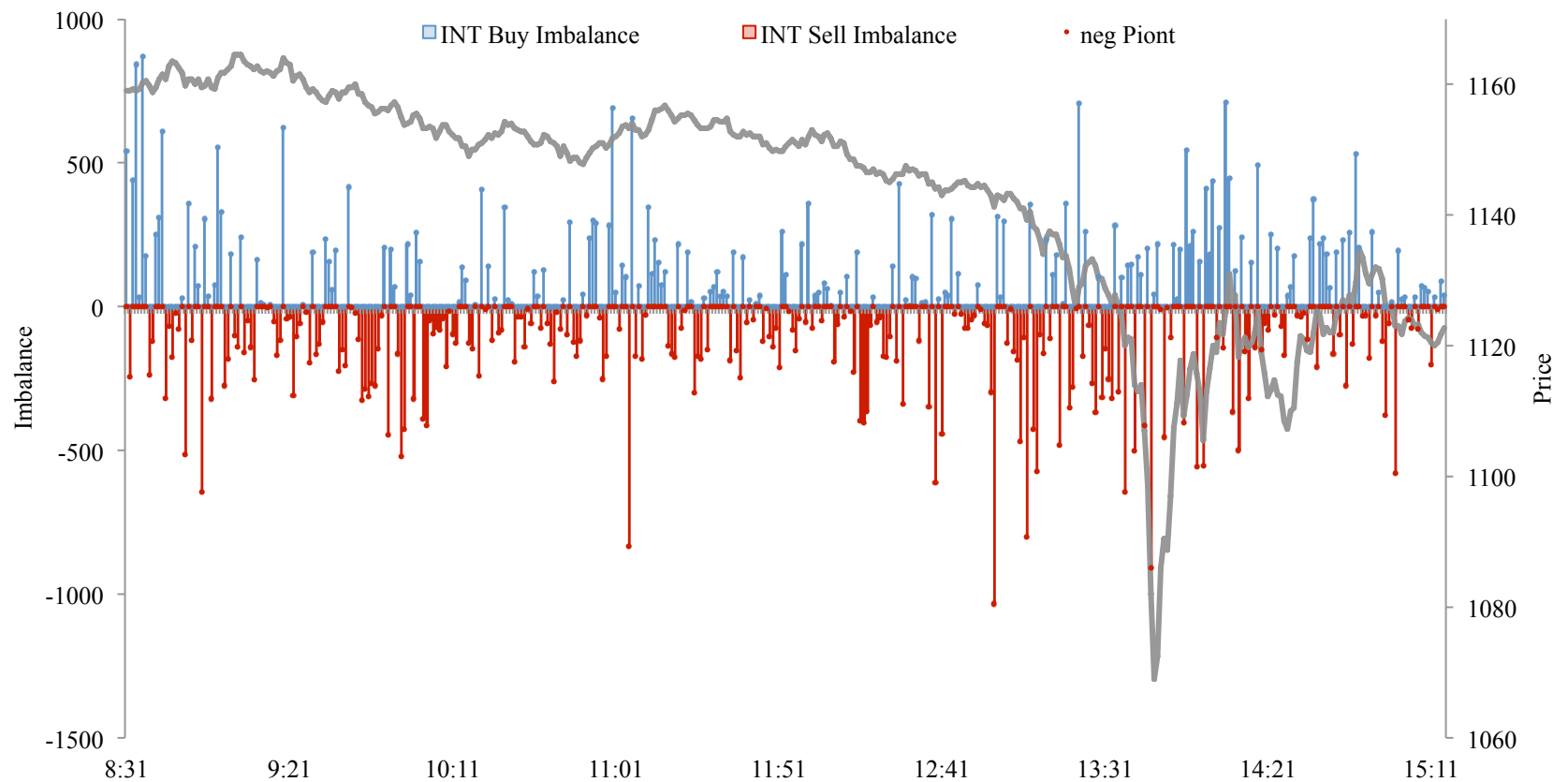
## Cumulative Aggressiveness Imbalance



## Aggressiveness Imbalance: HFTs



## Aggressiveness Imbalance: Intermediaries





## Prices and Aggressiveness Imbalance

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



## Prices and Aggressiveness Imbalance: Regressions

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



## The Flash Crash

13:32 A large fundamental seller initiates a sell program

13:42 HFTs reverse the direction of their trading (start selling)

13:45 “Hot Potato”: Lack of Fundamental and Opportunistic Buyers

13:45:28 - 13:45:33 5 second trading pause

13:45:33 – 13:45:58 Prices stabilize

13:46 Fundamental Buyers lift prices up

14:08 Prices are at the 13:32 level



## The Flash Crash: CFTC-SEC Report

Large Fundamental Seller – hedges exposure in equities

Sell Algorithm – sell 75,000 E-mini's with 9% volume participation target

Size – Largest net position of the year executed in about 20 minutes

Price Decline – sells 35,000 (\$1.9 billion) contracts in 13 minutes

Cross-Market Arbitrage – buy E-mini/sell SPY or basket of equities

Across the Board Price Declines – trigger automated pauses

Lack of Liquidity in Individual Equities – systems reset to reflect higher risk

Broken Trades – retail stop loss orders executed against stub quotes



## Conclusions

A large trade will always have an impact and may trigger a cascade

Volume is really not the same as liquidity

HFTs did not cause the Flash Crash, HFTS are not liquidity providers

## Questions

Fundamental Buyers – why did it take so long?

How did the 5-second pause work?

More safeguards needed to prevent cascades. How dumb/smart?



The background of the slide features a faint, stylized financial chart with a grid. The chart includes a line graph showing an upward trend and several candlestick-like bars, suggesting market data. The overall color scheme is a mix of light blue and white, with the chart elements in a slightly darker shade of blue.

## The CFTC-SEC Joint Advisory Committee on Emerging Regulatory Issues

Recommendations Regarding Regulatory Responses to the Market Events of May 6, 2011  
Summary Report presented at the public meeting on February 18, 2011

- I. Dealing with volatility in individual instruments:
  - single stock pauses/circuit breakers;
  - minimum quoting requirements for securities;
  - limit up/limit down for securities;
  - enhancements to pre-trade risk safeguards/pauses for the futures.
- II. Dealing with market-wide volatility: market-wide circuit breakers:
  - use S&P 500;
  - start at 10 percent;
  - pause for as low as 10 minutes;
  - go as late as 3:30 p.m.

The background of the slide features a dark teal header and a light blue footer. The central area has a white background with a faint, light blue grid. Overlaid on this grid is a financial chart. The top portion of the chart is a candlestick chart with white bars and black outlines, showing an upward trend. The bottom portion is a line chart with a jagged, fluctuating line in a light blue color. The overall aesthetic is professional and financial.

## The CFTC-SEC Joint Advisory Committee (continued)

III. Restrictions on co-location/access/disruptive trading practices:  
support the SEC's "naked access" rulemaking;  
support the CFTC's disruptive trading rulemaking;  
look into restrictions on the executions of large orders.

IV. Liquidity Enhancements:  
"peak load" pricing;  
"reasonably related" market making quotes ;  
"trade at" rule for routers/internalizers;  
order cancellation fees;  
reporting new measures of liquidity.

V. Regulators' Access to Information:  
consolidated audit trail for the SEC;  
order book and ownership data for the CFTC.