The Flash Crash: The Impact of High Frequency Trading on an Electronic Market

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Commodity Futures Trading Commission

joint with

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This presentation and the views presented here represent only our views and do not necessarily represent the views of the Commission, Commissioners or staff of the Commodity Futures Trading Commission.
The Flash Crash - May 6, 2010
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
<table>
<thead>
<tr>
<th></th>
<th>May 3-5</th>
<th>May 6th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>2,397,639</td>
<td>5,094,703</td>
</tr>
<tr>
<td># of Trades</td>
<td>446,340</td>
<td>1,030,204</td>
</tr>
<tr>
<td># of Traders</td>
<td>11,875</td>
<td>15,422</td>
</tr>
<tr>
<td>Trade Size</td>
<td>5.41</td>
<td>4.99</td>
</tr>
<tr>
<td>Order Size</td>
<td>10.83</td>
<td>9.76</td>
</tr>
<tr>
<td>Limit Orders % Volume</td>
<td>95.45%</td>
<td>92.44%</td>
</tr>
<tr>
<td>Limit Orders % Trades</td>
<td>94.36%</td>
<td>91.75%</td>
</tr>
<tr>
<td>Volatility</td>
<td>1.54%</td>
<td>9.82%</td>
</tr>
<tr>
<td>Return</td>
<td>-0.02%</td>
<td>-3.05%</td>
</tr>
</tbody>
</table>
Trader Categories

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

- HFT
- Opp
- Int
- Fundamental
- Noise

% of Trades vs Rank

% of Volume vs Rank
## Trader Category Summary Statistics

### Panel A: May 3-5

<table>
<thead>
<tr>
<th>Trader Type</th>
<th>% Volume</th>
<th>% of Trades</th>
<th># Traders</th>
<th>Trade Size (Avg.)</th>
<th>Order Size (Avg.)</th>
<th>Limit Orders % Volume</th>
<th>Limit Orders % Trades</th>
<th>Agg Ratio Trade-Weighted</th>
<th>Agg Ratio Vol-Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Frequency Traders</td>
<td>34.22%</td>
<td>32.56%</td>
<td>15</td>
<td>5.69</td>
<td>14.75</td>
<td>100.000%</td>
<td>100.000%</td>
<td>49.91%</td>
<td>45.68%</td>
</tr>
<tr>
<td>Intermediaries</td>
<td>10.49%</td>
<td>11.63%</td>
<td>189</td>
<td>4.88</td>
<td>7.92</td>
<td>99.014%</td>
<td>98.939%</td>
<td>43.10%</td>
<td>41.62%</td>
</tr>
<tr>
<td>Fundamental Buyers</td>
<td>11.89%</td>
<td>10.15%</td>
<td>1,013</td>
<td>6.34</td>
<td>14.09</td>
<td>91.258%</td>
<td>91.273%</td>
<td>66.04%</td>
<td>64.09%</td>
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<tr>
<td>Fundamental Sellers</td>
<td>12.11%</td>
<td>10.10%</td>
<td>1,088</td>
<td>6.50</td>
<td>14.20</td>
<td>92.176%</td>
<td>91.360%</td>
<td>62.87%</td>
<td>61.13%</td>
</tr>
<tr>
<td>Opportunistic Traders</td>
<td>30.79%</td>
<td>33.34%</td>
<td>3,504</td>
<td>4.98</td>
<td>8.80</td>
<td>92.137%</td>
<td>90.549%</td>
<td>55.98%</td>
<td>54.71%</td>
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<tr>
<td>Small Traders</td>
<td>0.50%</td>
<td>2.22%</td>
<td>6,065</td>
<td>1.22</td>
<td>1.25</td>
<td>70.092%</td>
<td>71.205%</td>
<td>59.04%</td>
<td>59.06%</td>
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</table>

<table>
<thead>
<tr>
<th>Volume</th>
<th># of Trades</th>
<th># Traders</th>
<th>Trade Size (Avg.)</th>
<th>Order Size (Avg.)</th>
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<th>Limit Orders % Trades</th>
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<tr>
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<td>95.45%</td>
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<td>1.54%</td>
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</tbody>
</table>

### Panel B: May 6th

<table>
<thead>
<tr>
<th>Trader Type</th>
<th>% Volume</th>
<th>% of Trades</th>
<th># Traders</th>
<th>Trade Size (Avg.)</th>
<th>Order Size (Avg.)</th>
<th>Limit Orders % Volume</th>
<th>Limit Orders % Trades</th>
<th>Agg Ratio Trade-Weighted</th>
<th>Agg Ratio Vol-Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Frequency Traders</td>
<td>28.57%</td>
<td>29.35%</td>
<td>16</td>
<td>4.85</td>
<td>9.86</td>
<td>99.997%</td>
<td>99.997%</td>
<td>50.38%</td>
<td>45.53%</td>
</tr>
<tr>
<td>Intermediaries</td>
<td>9.00%</td>
<td>11.48%</td>
<td>179</td>
<td>3.89</td>
<td>5.88</td>
<td>99.639%</td>
<td>99.237%</td>
<td>45.18%</td>
<td>43.55%</td>
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<tr>
<td>Fundamental Buyers</td>
<td>12.01%</td>
<td>11.54%</td>
<td>1,263</td>
<td>5.15</td>
<td>10.43</td>
<td>88.841%</td>
<td>89.589%</td>
<td>64.39%</td>
<td>61.08%</td>
</tr>
<tr>
<td>Fundamental Sellers</td>
<td>10.04%</td>
<td>6.95%</td>
<td>1,276</td>
<td>7.19</td>
<td>21.29</td>
<td>89.985%</td>
<td>88.966%</td>
<td>68.42%</td>
<td>65.68%</td>
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<tr>
<td>Opportunistic Traders</td>
<td>40.13%</td>
<td>39.64%</td>
<td>5,508</td>
<td>5.05</td>
<td>10.06</td>
<td>87.385%</td>
<td>85.352%</td>
<td>61.92%</td>
<td>60.28%</td>
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<tr>
<td>Small Traders</td>
<td>0.23%</td>
<td>1.04%</td>
<td>6,880</td>
<td>1.20</td>
<td>1.21</td>
<td>63.690%</td>
<td>64.879%</td>
<td>63.49%</td>
<td>63.53%</td>
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</tbody>
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<td>15,422</td>
<td>4.99</td>
<td>9.76</td>
<td>92.443%</td>
<td>91.750%</td>
<td>9.82%</td>
</tr>
</tbody>
</table>

16 HFT accounts are responsible for almost a third of trading volume...
Yet they do not accumulate of position larger than 4500 contracts!
HFTs: Net Holdings and Prices

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

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
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

May 3

May 4

May 5

May 6

Never negative.
Profits and Losses of Intermediaries

**May 3**

---|---|---|---|---|---|---|---|---
$-50,000$ | $0$ | $50,000$ | $100,000$ | $150,000$ | $200,000$ | $250,000$ | $300,000$ | $350,000$

**May 4**

---|---|---|---|---|---|---|---|---
$-50,000$ | $0$ | $50,000$ | $100,000$ | $150,000$ | $200,000$ | $250,000$ | $300,000$ | $350,000$

**May 5**

---|---|---|---|---|---|---|---|---
$-50,000$ | $0$ | $50,000$ | $100,000$ | $150,000$ | $200,000$ | $250,000$ | $300,000$ | $350,000$

**May 6**

---|---|---|---|---|---|---|---|---
$-100,000$ | $0$ | $100,000$ | $200,000$ | $300,000$ | $400,000$ | $500,000$ | $600,000$ | $700,000$
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
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
### Panel A: May 3-5

<table>
<thead>
<tr>
<th></th>
<th>DOWN</th>
<th></th>
<th></th>
<th>UP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sell</td>
<td>Buy</td>
<td>Sell</td>
<td>Buy</td>
<td></td>
</tr>
<tr>
<td>HFT</td>
<td>23,746</td>
<td>23,791</td>
<td>40,524</td>
<td>40,021</td>
<td></td>
</tr>
<tr>
<td>Intermediaries</td>
<td>6,484</td>
<td>6,328</td>
<td>11,469</td>
<td>11,468</td>
<td></td>
</tr>
<tr>
<td>Buyers</td>
<td>3,064</td>
<td>7,958</td>
<td>6,127</td>
<td>14,910</td>
<td></td>
</tr>
<tr>
<td>Sellers</td>
<td>8,428</td>
<td>3,118</td>
<td>15,855</td>
<td>5,282</td>
<td></td>
</tr>
<tr>
<td>Opportunistic Traders</td>
<td>20,049</td>
<td>20,552</td>
<td>37,317</td>
<td>39,535</td>
<td></td>
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<tr>
<td>Noise Traders</td>
<td>232</td>
<td>256</td>
<td>428</td>
<td>504</td>
<td></td>
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</table>
### Panel B: May 6th

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

![Chart showing the cumulative aggressiveness imbalance over time, with two lines representing different measures, and the x-axis showing time from 8:30 to 15:10.]
Aggressiveness Imbalance: HFTs

[Diagram showing HFT Buy Imbalance, HFT Sell Imbalance, and Price over time from 8:31 to 15:11.]
Aggressiveness Imbalance: Intermediaries

INT Buy Imbalance
INT Sell Imbalance
Price

Imbalance

Price

Price Impact Regressions

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

<table>
<thead>
<tr>
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<th>May 3-5</th>
<th>May 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(-0.19)</td>
<td>(0.31)</td>
</tr>
<tr>
<td>HFT</td>
<td>5.37</td>
<td>3.23</td>
</tr>
<tr>
<td></td>
<td>(6.43)</td>
<td>(3.37)</td>
</tr>
<tr>
<td>INT</td>
<td>0.83</td>
<td>5.99</td>
</tr>
<tr>
<td></td>
<td>(1.08)</td>
<td>(5.08)</td>
</tr>
<tr>
<td>Buyers</td>
<td>1.31</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>(4.32)</td>
<td>(2.20)</td>
</tr>
<tr>
<td>Sellers</td>
<td>1.36</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>(5.81)</td>
<td>(6.40)</td>
</tr>
<tr>
<td>Opportunistic</td>
<td>7.60</td>
<td>7.49</td>
</tr>
<tr>
<td></td>
<td>(9.74)</td>
<td>(10.61)</td>
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<tr>
<td># of Obs</td>
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<td>404</td>
</tr>
<tr>
<td>Adj-R2</td>
<td>0.36</td>
<td>0.59</td>
</tr>
</tbody>
</table>
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? Did it re-start the trading clocks?

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