

THE FLASH CRASH

Events of May 6th, 2010



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Abstract

May 6th, 2010 changed the way many around the world viewed the stability and volatility of global financial markets. On that day at 2:45pm, many U.S.-based equity products crashed and then recovered over the span of just minutes. How can the price of a future fluctuate so quickly? Why did so many traders pull out of the market all at once? How did the actions of one high frequency trader cause such a catastrophe?

Introduction

Throughout the following report, we will examine the events leading up to this crash, the exact cause of the crash, and the aftermath of such events. This will be done mainly by summarizing the SEC's report on their findings regarding the crash, as well as explaining the various mechanisms that combined to produce such devastating events.

May 6th started out as a turbulent day on the markets. Due to the European debt crisis, the euro had began to drop in value against the US dollar and Yen. As well, the volatility of the prices of many individual securities was increasing at such a rate that liquidity replenishment points (LRP) were triggered. If electronic trading results in a rapid price change over a short time period, the LRP system will halt and briefly switch to auction market trading. This system is used to help regulate the market, and was triggered multiple times throughout the morning before the crash. The S&P 500 volatility index had increased by 22.5% by 2:30pm, and the Dow Jones was down 2.5%. After this, at an unusually volatile time in the market, a large fundamental trader initiated an automated sell program to sell 75000 E-mini contracts. The fact that this individual trader chose an automated algorithm program without regard to price or time is key in understanding the reactions of the market. The massive sell order took only 20 minutes to execute, and was absorbed by high frequency traders, fundamental buyers, and cross-market arbitrageurs. As the algorithm's orders were fed into the market, two separate liquidity concerns formed. One of these issues surrounded the E-mini, and the other was throughout individual stocks traded on the market that day. This will be explained in greater detail throughout this paper. The actions of this singular trader caused a massive ripple effect throughout the entire market, creating a flash crash unlike anything experienced previously on the market.

May 6th, 2010 in detail

To explain the actions and reactions of the crash, one can separate the day into five separate phases:

Phase one (start of day to 2:32pm):

Prices were declining across the markets, and stock market index products had losses of around 3%.

Phase two (2:32pm to 2:41pm):

The broad markets lost more ground and declined another 1-2%.

Phase three (2:41pm to 2:45:28pm):

Volume spiked and the board markets dropped another 5-6%.

Phase four (2:45 pm to 3pm):

Broad market indices recovered while at the same time, any individual securities experienced extreme price fluctuations and traded in a disorderly fashion at extreme prices.

Phase five (3pm onwards):

Prices of most individual securities recovered and trading resumed to a normal fashion.

To understand the actions of the market, it is important to understand the nature of the key indicators of the crash, the E-mini and the SPY. As well, we have defined those involved in the market on May 6th 2010.

E-Mini and SPY

These are two of the most active stock index instruments traded in the electronic futures and equity markets. They track the S&P 500 (the 500 largest companies that have common stock listed on the NYSE or NASDAQ) which represents 75% of the market cap of US listed equities. Many traders use these to hedge against large swings in the financial markets. The E-mini individually is a futures contract that was introduced in 1997 by CME (an American futures company which is one of the largest options and futures exchanges). The E-mini trades only on the CME global electronic platform, and one E-Mini contract is equivalent to approximately 500 SPY shares. The amount of outstanding E-mini contracts is not fixed and therefore has no limit. Limit orders can be placed only with prices that are within 12 index points of the last transaction price. The SPY is a registered investment company started in 1993, which trades on all large equity trading venues. The number of shares outstanding of SPY is therefore fixed, and there are no cut offs on the price of limit orders. Both of these track the same S&P 500 stocks, which is why they are comparable.

Market players

Those who participated on May 6th throughout the entire market can be split into 6 categories. Their actions in the market throughout the day is explain in detail in Appendix A. The following defines their characteristics as traders:

1- Intermediaries:

These are market makers who follow the strategy of buying and selling large amounts of securities, but maintain a low inventory.

2- High frequency traders (HFT):

These are also market makers with very large daily trading volumes.

3-4- Fundamental buyers and sellers:

Either buy or sell in one direction during a trading day and hold a significant net position by the end of it.

5-Noise traders:

Traders who traded less than 10 contracts on May 6th 2010.

6-Opportunistic traders:

Traders who do not fall into any of the other categories.

The market prior to the crash

This phase runs from the opening of the market on May 6th until 2:32pm. As previously mentioned, the market opened up to news of the European debt crisis, mainly the resulting riots in Greece. This was an increasing issue, as the debt crisis had been an issue since the end of 2009. As many riots were held in Greece and shown on television, the market dropped little by little throughout the morning. This drop was due to the increase of risk. As during any international catastrophe, those who trade demand higher premiums due to the potential instability of the market. Premiums on credit default swaps increased for many European sovereign debt securities, and the value of the euro faced downward pressure in global currency markets. As this event increased in severity, the S&P 500 volatility index (VIX) increased. The VIX measures the potential expected volatility in the S&P 500 index. Throughout the morning, the VIX increased by 31.7%, being the 4th largest single day increase in VIX history. Also as a result of the news, many investors engaged in a "flight to quality" strategy, which is very common in volatile markets. Those involved will move away from risky investments and towards the safest investments they can find due to their increased uncertainty in the market. On May 6th, the markets saw an increase in prices of gold futures and a decrease in yields of ten-year Treasuries.

By 1pm, the increase in risk affected the price volatility of individual equities. This resulted in an above average amount of LRPs triggered for individual equities listed on the NYSE.

By 2:30pm, the selling pressure that came as a result of the increased risk pushed the Dow Jones Industrial average (average using price of 30 significant stocks traded on the NYSE and NASDAQ) down by 2.5% from the start of day average. The buy side liquidity of both the E-mini and SPY suffered serious declines. It was at 2:32pm, under this volatile market, that a large fundamental trader executed an automatic sell program to sell 75000 E-mini contracts.

Liquidity crisis in the E-mini

It should be expected that the E-mini and SPY move in tandem during their decline in price. What is found, however, is that the E-mini experienced a large loss of liquidity where the buy-side market depth was not able to keep up with the sell-side market depth on May 6th. Market depth is the amount of resting orders that those participating in the market place, which show what they are willing to buy or sell. Appendix B shows that the E-mini divergences between buy and sell side-resting orders began early in the day and hit a low by 2pm. Appendix C shows the difference in the movement of the SPY, which did not see this divergence until 1:30. This proved that the issue of the crash must have had something to do with the trading behavior of the E-mini. More specifically, this is what led investigators to believe the crash was a result of a single trader's large automated E-mini sell order.

The aftermath of the large automated sell order

In general, a customer of the stock market has a few alternatives of how to execute whatever trade they are attempting. They can pay intermediaries to execute their trade, manually enter the order

themselves, or choose an automated execution algorithm to complete their trade. These choices surround how much human judgment and error the customer prefers. What is important to understand is that not only did the large fundamental trader use an automated execution algorithm, but this algorithm was programmed to execute at a rate of 9% of the trading volume without taking into account price or time. The result of this, was the largest net change in the daily position of the E-mini made by a single trader since the beginning of the year. High frequency traders and intermediaries were likely the buyers of the first batch of the orders placed by this sell algorithm, which means it was high frequency traders who initially provided liquidity to the market and were therefore in a long position. However, during phase 3 of the day, HFTs sold large amounts of these E-mini contracts that they had just bought in order to reduce their long position. By ceasing to provide liquidity to the market, they began to take liquidity and therefore increased the liquidity crisis in the E-mini. As HFTs continued their strategy of having high trading volumes without high inventories, the sell algorithm responded by increasing the rate it was feeding orders into the market. This shows the danger of using an algorithm without any human judgment, as the sell algorithm could not tell that the orders it had already sent into the market were not fully absorbed, as HFTs were continuing to buy and sell at rapid rates. Due to these factors, the E-mini dropped 3% in price from 2:41pm to 2:44 pm. Although during this time opportunistic buyers were still purchasing the E-mini, it was not enough to keep up with the selling pressure from the algorithm. As liquidity vanished, the price of the E-mini had dropped over 5% by 2:45:27pm. Prices were moving so fast that many in the market were not willing to supply enough buy-side liquidity as an investment in the E-mini had become very risky, which deepened the issue. By 2:45:28 pm, the CME stop logic function was triggered, which paused the E-mini for 5 seconds to regulate the trading and prevent future losses. This short break decreased the sell pressure of the E-mini and the prices stabilized shortly after trading was resumed. By 3:08 pm, the E-mini prices were back to their pre-crash level.

Liquidity crisis in individual stocks

After the first liquidity crises observed in the E-mini, many automated trading systems used by large market participants were temporarily paused. These were used in order to prevent trading when the prices moved far beyond the average market price. Many individual traders had to assess the risk of trading in the market on that day. These traders took into consideration the validity of the information they were receiving, the potential for the trades they were making to be broken, and the idea that the trends in the market signaled a devastating unknown event that their strategies could not handle. Due to these factors, many individual traders reduced their trading or left the market entirely. This is also when many “stub quote” trades were made, which is when market makers quote very far from the market. The drop-in market depth extended out to other securities in the S&P 500, as shown in Appendix D. The reason why the liquidity shock stretched across the market can be traced to the cross-market strategies of many firms participating in the market. Cross-market strategies, which many firms execute, focus on trading products in the futures and securities markets. The goal is to capture any price differences between two related products without the risk of taking on only one. With this, separate firms focus on providing liquidity to either one or multiple products in order to hedge against risk. Due to this, if the E-mini dropped in value in comparison with SPY, many firms would respond by lowering their bids in SPY. With this, many firms noticed that the E-mini was trading at lower prices than the SPY and many other baskets of individual securities, and therefore changed their strategy to sell many SPY baskets in order to purchase E-Mini baskets at their low price.

Between 2:40 pm and 3 pm, over 20000 trades were executed at prices 60% or more away from their prices at 2:40 pm. After 2:45 pm when the prices of the E-mini and Spy were back on track, many other individual securities still found reduced buying interest. Most of these securities returned to normal by 3 pm.

Market Participants and Withdrawal of Liquidity

Overview

Looking at Appendix E, it shows the extent of which large capitalization stocks lost liquidity. As shown at the time stamp between 2:35 and 2:46, the buy side depth fell around 25% of its mid-day value and the sell side fell roughly 15%.

Market Participants

To understand the reduction in liquidity, extensive interviews were conducted across a wide range of firms that regularly provide market liquidity including:

- Traditional Equity Market Makers
- High-Frequency Traders
- Internalizers
- Options Market Makers

The interview conducted was split into two segments. The first part, required firms to outline their trading strategies & business model. In the second part, focused on the reason why the individual firms acted the way they did in relation to the events on May 6th.

The collected data showed that many (but not all) firms significantly curtailed or halted their trading during the afternoon of May 6th. Since these firms were major players in the market, their change in normally trading activity deeply impacted the rest of the market. It is noted that each firm, had their own unique way of trading in the market, however many common problems were evident that explain the results of the flash crash.

General Withdrawal of Liquidity

Data collected after interviews show that firms use a combination of automated algorithms and human traders to oversee operations. This sometimes can be a problem and can result in doubts of the integrity of the data. To avoid this, firms implemented automated stops to pause trading when questionable data is received.

One way of identifying inaccurate data is screening. This means looking for large, rapid price movements, whether it is a rapid incline or decline in individual securities that will trigger trading pauses. Another way to avoid erroneous data, is firms use multiple sources as inputs and when it does not agree, a pause can be triggered.

As a safety concern, any potential for data integrity, firms will temporarily pause trading. This also means that trading is paused, any provided liquidity into the market becomes unavailable and the other respective firms must absorb the continued order flow. This leads to price pressure, and rapid price moves will trigger yet another data-integrity pause.

Firms were asked about three specific external factors in regards to the May 6th event.

(i) Delays in consolidated market data for NYSE-traded stocks

(ii) Declarations of self-help by Nasdaq and BATS on NYSE Arca

(iii) Use of LRPs

Most firms were concerned with the data latency in relation to the live feed offered by the exchange. Firms do not generally rely on consolidated market data to make decisions, so their trading has not been affected by the delay of data. However, the few firms that do use this data are were greatly impacted on May 6th. Firms that were not concerned with the data latency, simply stopped trading as the volatility increased and reasoned that the delays and price-discrepancies on the market data feeds were a contributing factor to their decision.

On May 6th, Nasdaq and BATS declared self-help against the NYSE Arca meaning they did not have to route orders to NYSE Arce. Many market participants were unaffected by this because they normally route their orders directly to the exchange using their own algorithms. Firms also commented that even with the declared self-help, their trading continued directly with the NYSE Arca and traded based off of their quotes and trade prices.

The use of LRPS by the NYSE received many mix reactions from market participants. Firms mentioned that since they route their orders and were able to make their own real-time decisions they were not directly impacted by the LRPs. Rather, firms raised concerns about the market volatility and integrity of prices. However, some firms were concerned with the use of LRPs and lead to a sense of unease and potentially influenced their trading decisions.

Trading Equity and ETF Market Makers

While equity and ETF traders differ, they are classified as “traditional” market makers as firms with business models that primarily aim to profit from passively trading on resting limit orders and capturing the bid-ask spread. These types of traders are non-directional and very neutral in trading. In relation to the flash crash, they reported the rapid price movements and market volatility which caused their internal risk limited to crash. This triggered their automated systems that widened the bid-ask spread for quotes. Most market makers reported that due to several breaches, price-driven integrity pauses, as well as feed-driven integrity pauses were triggered. Market makers were experiencing severe internal system problems having trouble dealing with overwhelming external information being let into the system and were even incapable of manually overriding the systems to continue providing liquidity in a timely fashion. The systems required human intervention after the automatic pauses were triggered, but the time to reenter the market ranged from several seconds to several hours.

To combat this severe problem and having to maintain quotations, market makers utilized the use of stub quotes as these were automatically generated and were available for immediate withdrawal upon request. The way it worked was that when there was available liquidity for an ETF or stock, market orders would be executed against the stub quotes and the executions represented a proportion of trades.

ETFs and May 6

Equity-based ETFs experienced the most severe price dislocations. They treated ETFs as corporate stocks and did not track the prices of the individual securities underlying the ETFs. Some market makers based their decisions on immediate buy and sell interest, subject to market indicators that may affect the bias of bids and offers, while some used algorithmic modeling, and others would trade individual securities at the same time they traded ETFs. It could be said that the latter two types of trades had correlation between securities prices and ETFs.

An example would be, market makers look at the securities that are underlying components to ETFs and will track the prices. These types of trades are more likely to be paused due to price-driven or feed-driven integrity questions. Many ETF market makers that value underlying stocks stated that it was a part of their normal trading activities and halted their market making for long periods of time on May 6th. It is believed that the main reason was the extreme price volatility of that afternoon. However, many traders in ETFs stated they trade from individual securities to increase liquidity in exchange order books. ETFs consider it a "professionals market" where depth of a book is more limited than individual stocks.

In Appendix F and G, it shows the comparison between the liquidity books for 100 ETFs and 100 individual stocks (represented as F – 2.A and G – 3.A). As shown the 100 individual stocks are well distributed from 10 to 500 basis points, while the 100 ETFs are highly concentrated with a spread of only 30 basis points. Focusing on the peak of the decline, It is evident that the buy-side liquidity for ETFs suffers more falling to 10% of their value, while only at 20% for the stocks.

Equity-Based High Frequency Traders

HFTs are trading firms that use quantitative and algorithmic methodologies to maximize quick access to markets and trading strategies to submit large quantity orders. HFT firms have different strategies when approaching the market such as either ending the day at a flat position or taking net long and net short positions.

According to the HFTs interviewed, some stated they exited the market due to internal risk parameters that triggered an automated pause due to the rapid price movements, while others continued to actively trade. Those who continued to trade had made the decision based on the performance of their algorithms and whether or not that were operating profitability under the given market conditions.

Based on the FINRA data analysis, 6 of 12 HFTs pulled back trading after indices hit their lows around 2:45 pm. Two HFTs halted trading around 2:47pm. and remained inactive. The last for HFTs curtailed their trading for short periods of time ranging from 1 minute to 21 minutes. (as shown below). Appendix H, I, J is comprised of 3 charts showing the trading activity for the 12 HFTs after 2:30 pm. as well as the rapid decline from the indices. It also shows the recovery of the market and how the HFTs

reacted to the market change. In the NYSE market HFT activity slightly declined, in the NYSE Arca market the activity drastically fell and in the Nasdaq market HFT activity returned to previous operating levels (all pre 2:43 and after 2:46).

Appendix K, L, M have data sets for the participation rates of the 12 HFTs with and without broken trades taking place between 2:00 pm. and 2:40 pm in each respective market. It is evident that the average participation rate is slightly higher in the NYSE Arca compared to the NYSE and Nasdaq. This data suggests that HFTs were more active in ETFs than in corporate stocks.

The FINRA analysis provided a data set for HFT buying and selling which helped track if the trades were one sided during the decline of the market indices. The data concluded that HFTs were primarily on the sell side. Appendix N, shows the buy vs sell activity over the course of the day throughout all three listed markets. It shows that prior to 2:00 pm, HFT sells roughly 52.4% of total activity and after 2:00pm the totally activity increases to 53.5%. However, after 2:46pm the selling activity decreased down to 52%. The selling of securities in this manner could show signs of cross market strategy meaning HFTs may buy futures products and sell ETFs or stocks or vice versa.

Internalizers

Internalizers are comprised of both OTC market makers and block positioners and only take orders from their own customers or customers of other brokers. Customers would benefit as they receive better prices, as the internalizers would match and provide better prices compared to NBBO. In order to do this, they preferred trading centers with no access fee (dark pools/alternative trading systems) but if orders were not filled in a specific time period they would be directly routed to an exchange with the next best available price.

Considering the events that perspired on May 6th the behavior of internalizers varied. For block positioners (institutional customers) stated that they were indirectly affected by the volatility and many clients backed away from the market to think whether or not to invest. While OTC market makers stated the market behavior directly affected their market events and even paused trades for extended periods of time. Some OTC internalizers reduced sell orders but continued with buy orders, while others stopped internalization altogether. Therefore, during the market crash, instead of providing liquidity in dark pools, internalizers routed orders to the exchange putting an even greater pressure on the remaining liquidity in those markets. Appendix O shows the trades as a percentage of overall volume as it rapidly declines after the price began to drop at around 2:30pm. The ADF/TRF show a significant decline around 2:30pm and orders part of this were subject to be executed and the lowest extreme prices.

Options Market Makers (OMMs)

Option market makers are represented by members of an exchange that submit particular buy or sell options on the options exchange. The market for listed options often depends on the amount of liquidity available from parties such as market makers. The option exchange allows members to register as an OMM and within each exchange there must be at least one OMM for trading to occur. Based of the events of May 6th, OMMs and options exchanges stated that by their trading in options did not

exhibit the same behaviors as in the underlying securities market. The OMMs however tend to trade in the underlying securities market, so their quotes ended up being widened or some decided to exit. However, the OMMs that traded in the options market do so by getting a valuation on underlying securities then would either set a higher and lower price to capture a higher bid-ask spread. OMMs faced high risk as the data feed was unreliable because the securities were extremely volatile. Therefore, they had to mitigate risk by widening quotes and decreasing order sizes along with withdrawing from the market for a short period of time. They believed that by widening the quote fewer orders would be executed, however the number of orders executed remained the same. Although the OMMs had internal system problems, they were able to remove themselves from the market for a brief moment and then were able to reenter the market in a reasonable time.

Analysis of Broken Trades – Stub Quotes and Broken Trades

Stub Quotes

As discussed above, stub quotes were used to execute orders after market makers had either exhausted liquidity or liquidity was being withheld. A stub quote is "an offer to buy or sell a given stock at a price far away from the prevailing market that it is not intended to be executed". In some cases, exchange automatically provide stub quotes and are implemented to ensure market makers meet the standards of a continuous two-sided quote even when disconnected from the market. Normally, market makers stated that the use of stub quotes is rare but registered in the system and are only activated when real-time quotes are exhausted resulting in quotes being generated at the stub level. In relation to the events of May 6th, some participants had to route orders to the stub quote levels to fill client orders. Others based their decision on the assumption that the quote would be broken and therefore sent orders to hit stub quote levels to avoid an internal system crash. In addition, other firms had automated algorithms that repeatedly routed orders as the system isn't capable of knowing whether or not orders are being filled at the stub quote level as it was still within the parameters set by the firm.

Broken Trades

It was noted many securities that had experienced severe price movements regained normal levels relatively quickly. This meant that the available liquidity was unable to meet the high demand to sell and prices therefore rebounded back to the original state. As discussed above the spreads in securities had widened as liquidity was being held back causing market makers to pauses quotes and instead would rely on exchange generated bids to their own obligations. Executions against stub quotes represented a large portion of broken trades that occurred on May 6th.

Market and limit orders were also traded against stub quotes on May 6th. Marker orders are submitted with the hopes of finding the best available liquidity. This means that the order will be execute whether price is high or low if it is the best liquidity option. Limit orders on the other hand are just orders with a set limit, if the liquidity price exceeds the set limit the order will not be filled. Sine stub quotes are automatically generated as soon as orders are filled, new quotes will be generated to meet the next order.

An in-depth analysis of the trade and order data was conducted and it shows that internalizers (sell) and a single market makers (buy) were responsible for over 50% of broken trades. Per the data, internalizers represented over half of broken trade volume meaning that this one market maker was one of the few remaining providers of liquidity as others had either pulled back or completely halted live quotes.

The analysis of broken trades concluded that there were concerns with a few market participants. A large majority of trades broken occurred from the sell side mainly from retail consumers who sent orders to internalizers for execution at the current market price. Internalizers routed these orders to public exchanges but the problem that occurred was that liquidity had been withdrawn and there was a lack of buy interest, which resulted in those trade orders to be executed at very low prices instead of the current prices shown.

Potential impact of additional factors

There are 3 additional factors whose effects on the events that day we will examine. These factors are:

- NYSE Liquidity Replenishment Points
- Declarations of Self-Help Against NYSE Arca
- Market Data Issues

NYSE Liquidity Replenishment Points

Within their hybrid floor/electronic trading model, which differs from the mostly fully electronic markets today, NYSE implemented what are known as liquidity replenishment points (LRPS). These are price bands intended to decrease volatility in stocks by changing the market from automated to manual when a certain price movement is achieved. At this point, automatic executions will halt, which lets the designated market makers (DMM) to add or subtract liquidity. This does not completely cease trading on the exchange, but merely slows it down. Most LRPs are resolved within one second, as buys and sells bring the price back within the limits, or the DMM sets a new price. On May 6th, 75% of the LRPs were resolved in one second, but one quarter lasted at least multiple seconds. In fact, over 1000 securities experiences multiple second LRPs in just half an hour, which is significantly higher than the normal day average of 20-30. For many participants, this increase in LRP triggers caused them to increase their liquidation or withdraw entirely, as the market conditions looked to have worsened. There was not a substantial amount of “trapped liquidity” in the LRPs as for over half of them, there were either no reported executions on other exchanges during the LRP event or the available bid depth was 0. The data also shows that significant liquidity was not being attracted to the NYSE during the LRP events, as the average increase in liquidity was only 133 shares.

Considering the continued ability of market participants to trade and cancel orders, the fact that many securities with broken trades did not experience extended LRPs, and that very few securities had sufficient liquidity to absorb some of the sell pressures from different exchanges, we can conclude that the LRP events at the NYSE did not cause the liquidity crisis on May 6th. However, the significant increase in LRPs caused many participants to alter their behaviour, and reduce liquidity or leave the market entirely.

Declarations of Self-Help Against NYSE Arca

Self-help is an exception to Regulation NMS Rule 611 that allows a trading center to bypass quotes given by an exchange that is undergoing system issues. It is intended to ensure that participants are not forced to the send orders meant to execute against quotes that are inaccessible. This occurred on May 6th when Nasdaq and Nasdaq OMX BX declared self-help on NYSE Arca. Nasdaq publicly disclosed this on their website, meaning most market participants knew of the use of the exception very soon after it was made. Most of these participants continued to route their orders through the NYSE despite the declaration. Furthermore, they did reprogram their trading systems to account for the declaration as a risk measure, which indicates that most participants route their trades directly.

A concern about the declaration was that it might have caused inaccessible liquidity at the NYSE. This would happen if a significant amount of liquidity demand bypassed the NYSE, and it would make the imbalance between the liquidity supply and demand worse. For this to happen, a significant amount of the order flow would have to have bypassed the NYSE and be sent to the Nasdaq, who would execute it themselves.

By analyzing the comparable volume of trading around the declaration, it is clear to see that the NYSE liquidity continued to be accessible after the declaration. Additionally, Nasdaq routed away only 13.6% of the orders away from the NYSE. This leads us to conclude that the self-help declarations did not directly cause the significant imbalance between supply and demand. However, as with the LRPs, the declaration likely added to participants concerns, and thus could have affected behaviour.

Market Data Issues

Consolidated information on quotations and transactions is disseminated through securities processers. Many exchanges also offer proprietary data feeds directly to customers. These proprietary feeds are not consolidated, and thus can reach the end user faster than those that are.

On May 6th, the NYSE set traffic records and had several significant delays in the dissemination of certain information. The NYSE was part way through upgrading its systems at the time, and the high volume of information delayed the dissemination of information in 1665 listed symbols that were on the NYSE servers that dad yet to be upgraded. The average delay for the 1665 symbols was over 5 seconds, with some delays reaching as long as 35 seconds. These delays affected the consolidated feeds and at least one of the proprietary feeds. SEC rules dictate that exchanges provide timely and accurate data, which was clearly not being accomplished. Concerns about data integrity led to pauses and halts in some automated trading systems, which caused a decrease in market liquidity. Many firms reported that the delays were a significant part of their decision to decrease or halt trading that day.

Lessons Learned

From the flash crash, there were several key lessons to be learned by all of those who participate in the market. First, under a stressed market, large automated algorithmic sell orders can trigger massive price movements. These automatic execution programs without regard to price or time can deeply affect strategies throughout those participating in the market, and demolish liquidity. The crash also taught

those studying it that our securities markets are very interconnected. The effect of many index products prices as a result of the crash shows how many cross-market strategies are used, and therefore the importance of cross-market security measures. Another lesson learned was the fact that many market participants have their own versions or a trading pause. These can cause a liquidity crisis when too many do so at once. IN relation to this, pausing a market can be an effective way of providing time for market participants to reassess their strategies. Due to this and the aftermath of the flash crash, the SEC created a circuit breaker pilot program for individually traded securities. Lastly, a key lesson to be learned from the crash is that automated systems need more data, and cannot be relied on to do all of the trading when markets are volatile. Human judgement is imperative, as this entire crash could have been avoided had more human action had been involved in the large automatic sell order placed. Contrary to what many believe, the actions of a single, reckless trader can cause catastrophic consequences throughout the entire market.

How to Avoid This in the Future

The SEC has already taken an essential step in avoiding a similar issue in the future by creating the circuit breaker pilot program for individual traded securities. A significant improvement would also be ensuring that all systems are up to date and able to run at the needed speeds, and not causing information delays. Deeper analysis of their own algorithms by traders would be beneficial to ensure that they do not make large orders when it is not appropriate to do so.

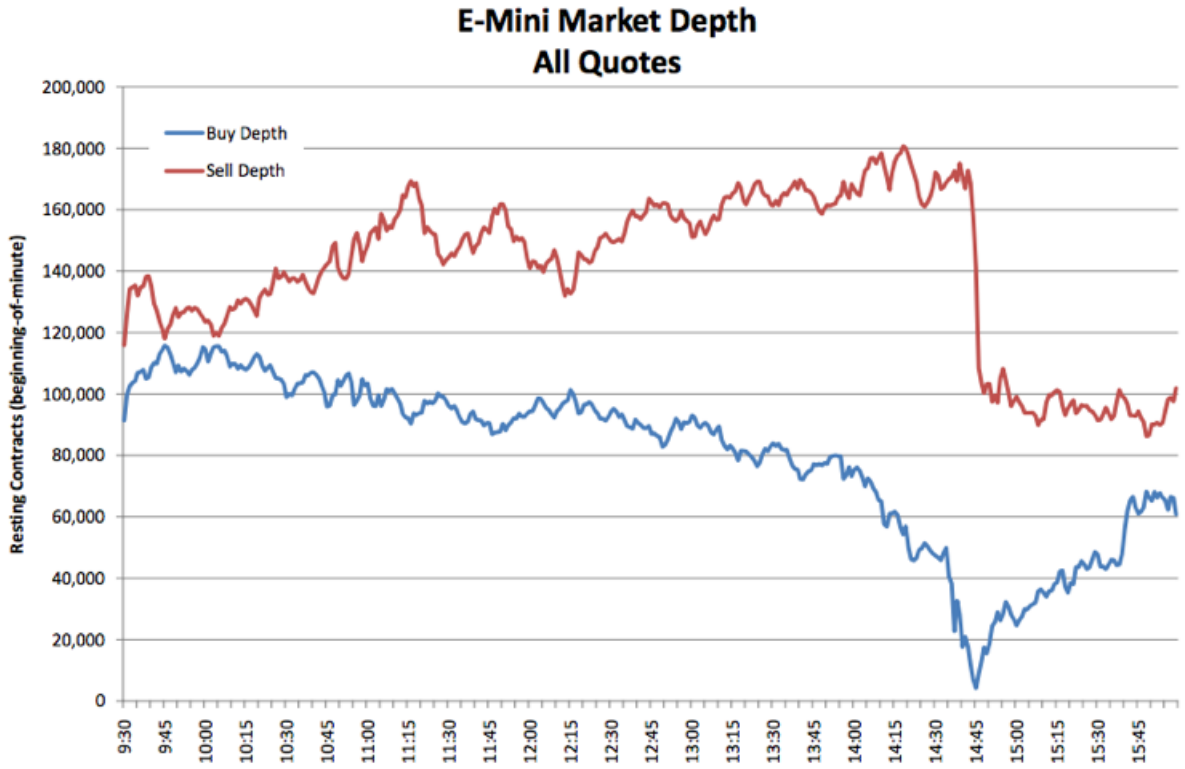
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https://www.youtube.com/watch?v=YS1k5hz0cfE&t=292s
http://financial-dictionary.thefreedictionary.com/CME

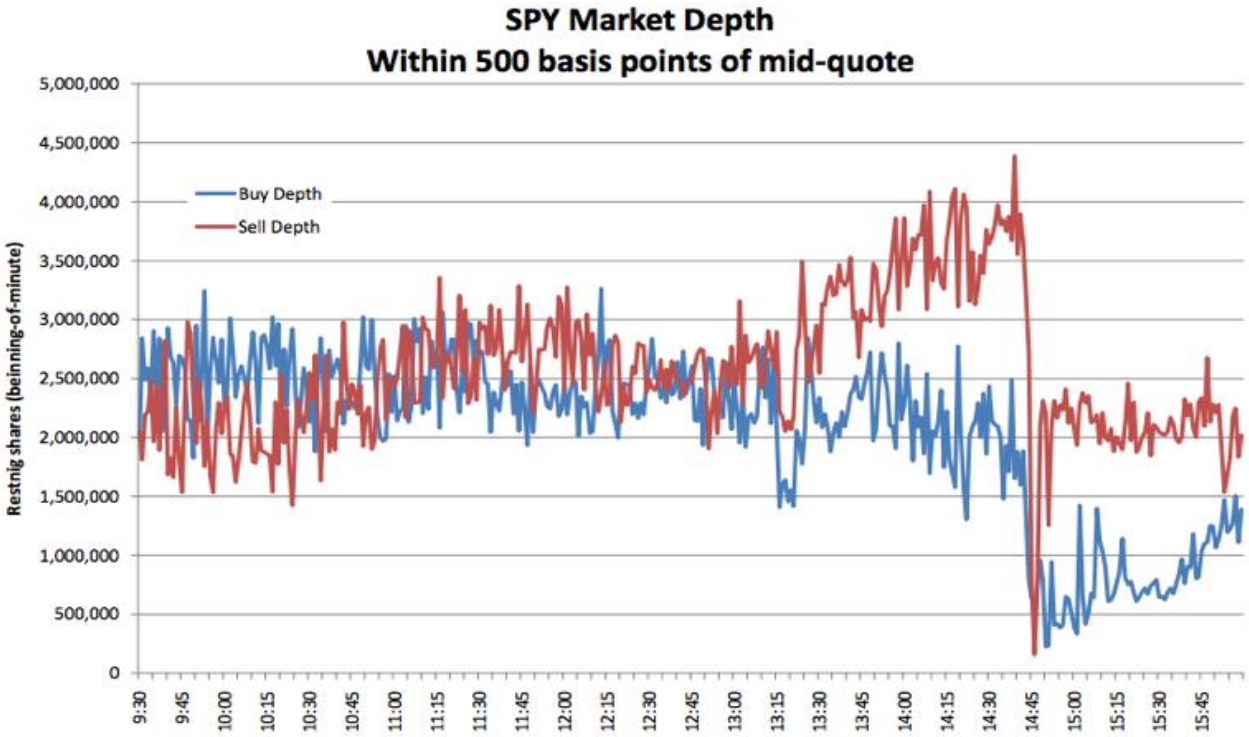
Appendix A:

Trader Type	% Volume	% of Trades	# Traders	Avg Trade Size	Limit Orders % Volume	Limit Orders % Trades
High Frequency Trader	28.57%	29.35%	16	4.85	99.997%	99.997%
Intermediary	9.00%	11.48%	179	3.89	99.639%	99.237%
Buyer	12.01%	11.54%	1,263	5.15	88.841%	89.589%
Seller	10.04%	6.95%	1,276	7.19	89.985%	88.966%
Opportunistic Trader	40.13%	39.64%	5,808	5.05	87.385%	85.352%
Noise Trader	0.25%	1.04%	6,880	1.20	63.609%	64.879%
All	5,094,703	1,030,204	15,422	4.99	92.443%	91.750%

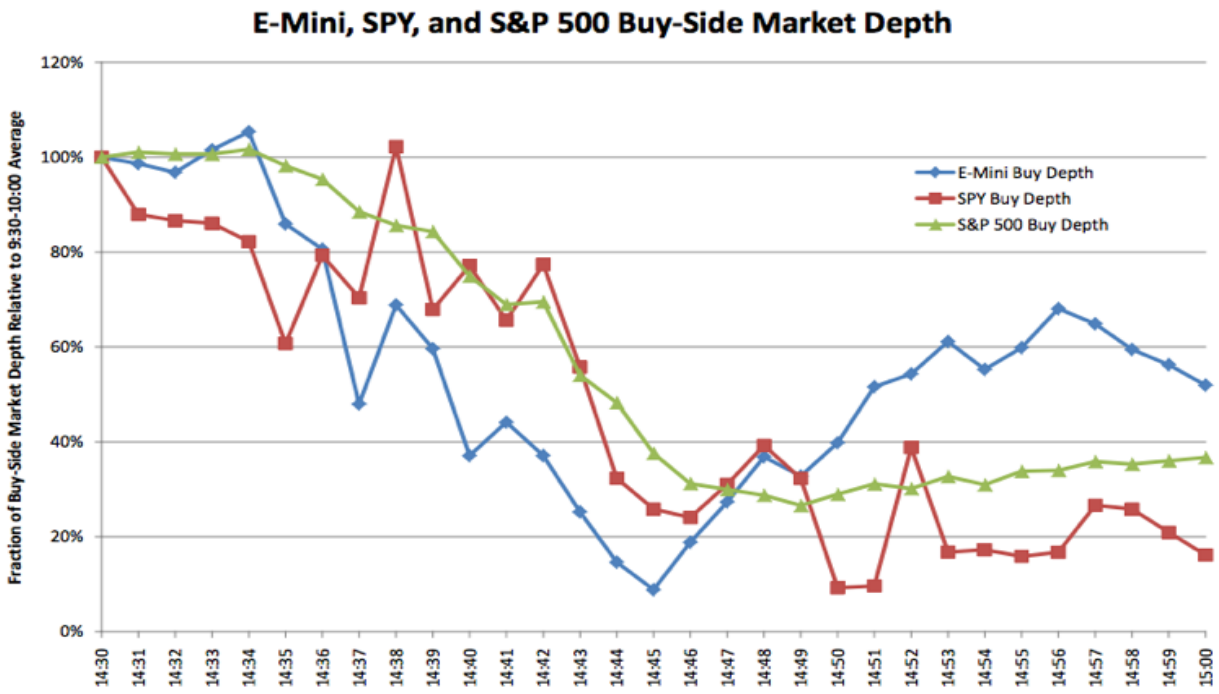
Appendix B:



Appendix C:



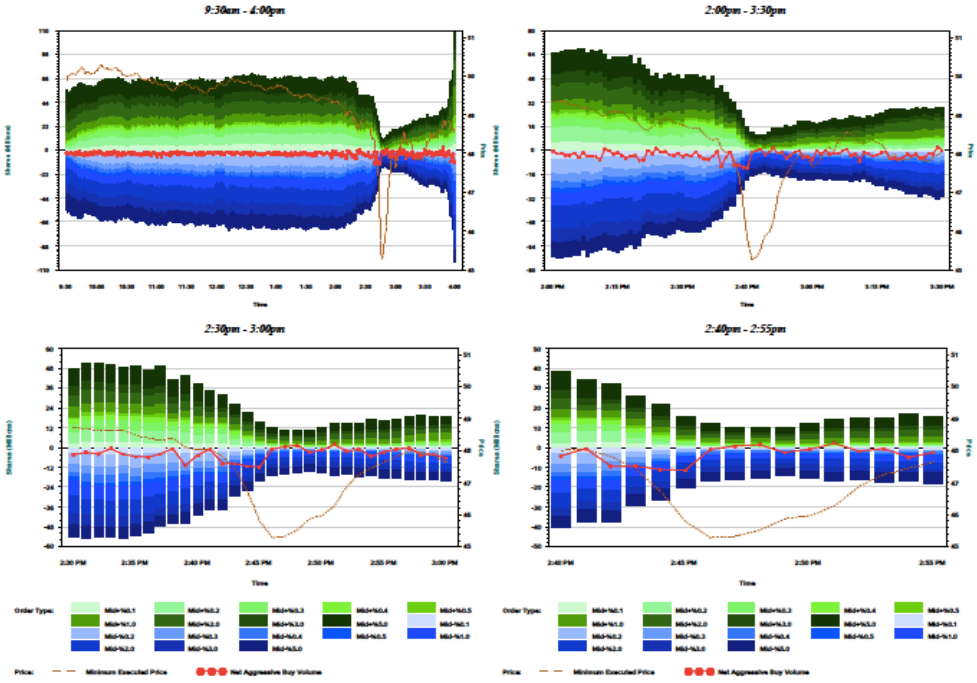
Appendix D:



Appendix E:

Chart 1.A: S&P 500

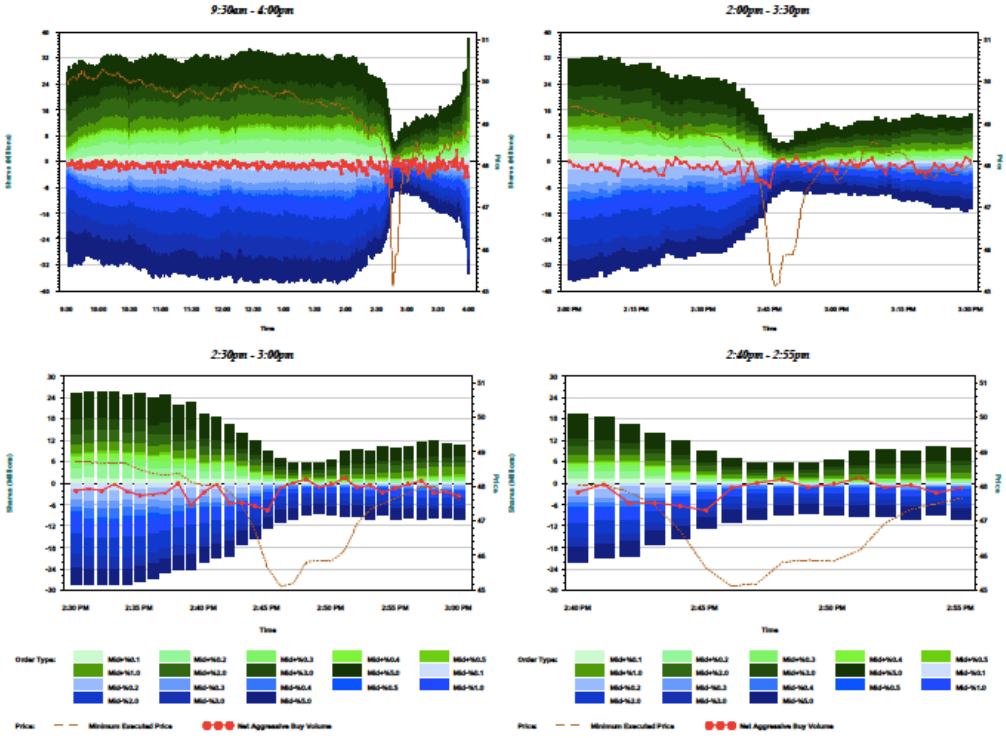
Market Depth (within 500 basis points) and Net Aggressive Buy Volume



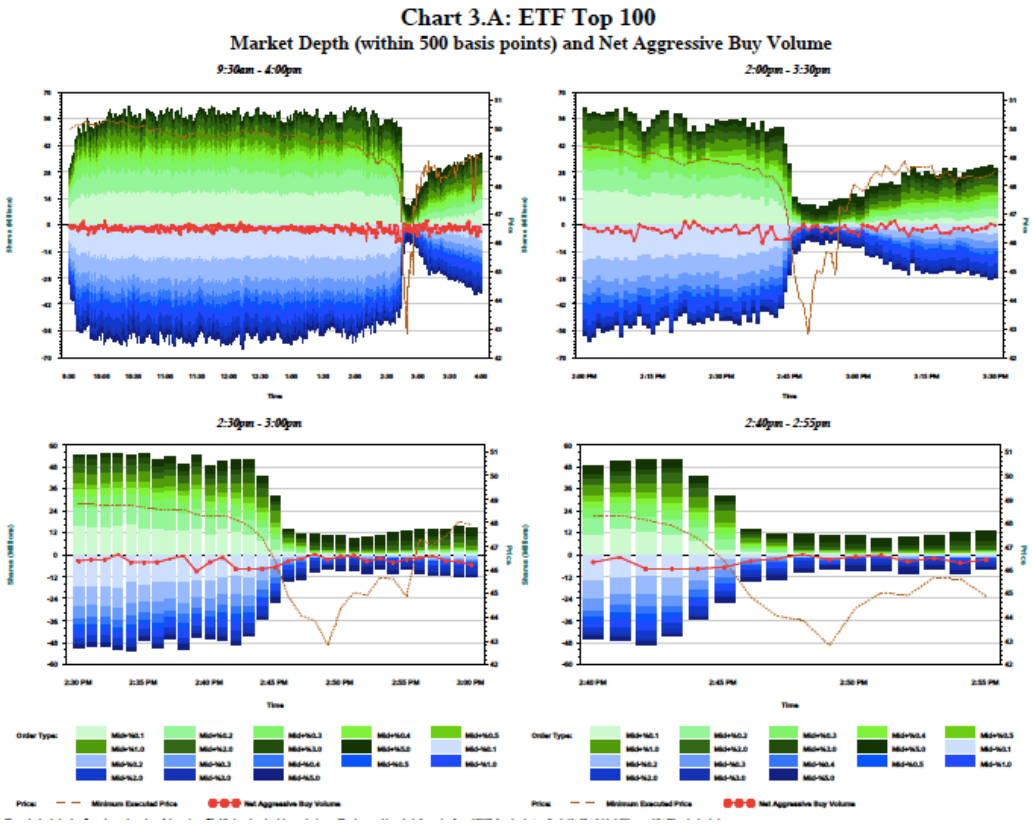
Appendix F:

Chart 2.A: Non-ETF Top 100

Market Depth (within 500 basis points) and Net Aggressive Buy Volume

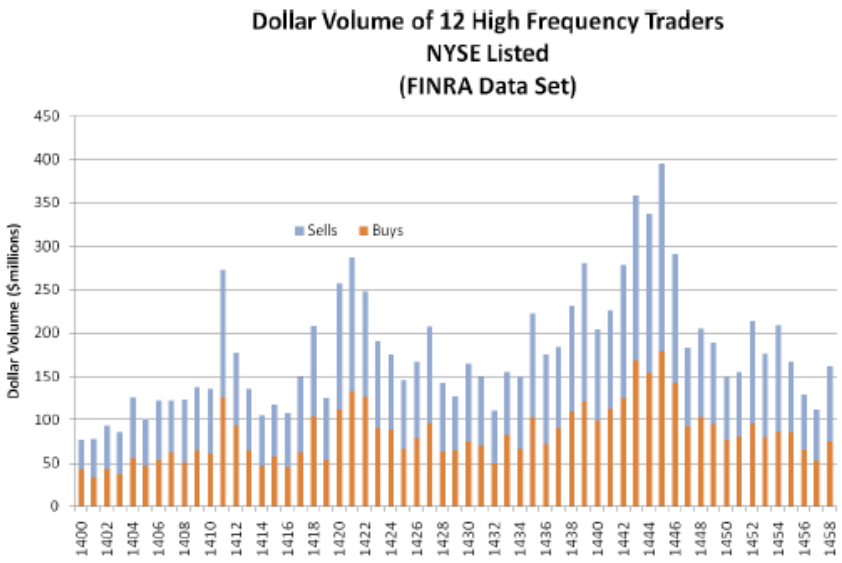


Appendix G:


Chart 3.A: ETF Top 100
Market Depth (within 500 basis points) and Net Aggressive Buy Volume
9:30am - 4:00pm
2:00pm - 3:30pm
2:30pm - 3:00pm
2:40pm - 2:55pm

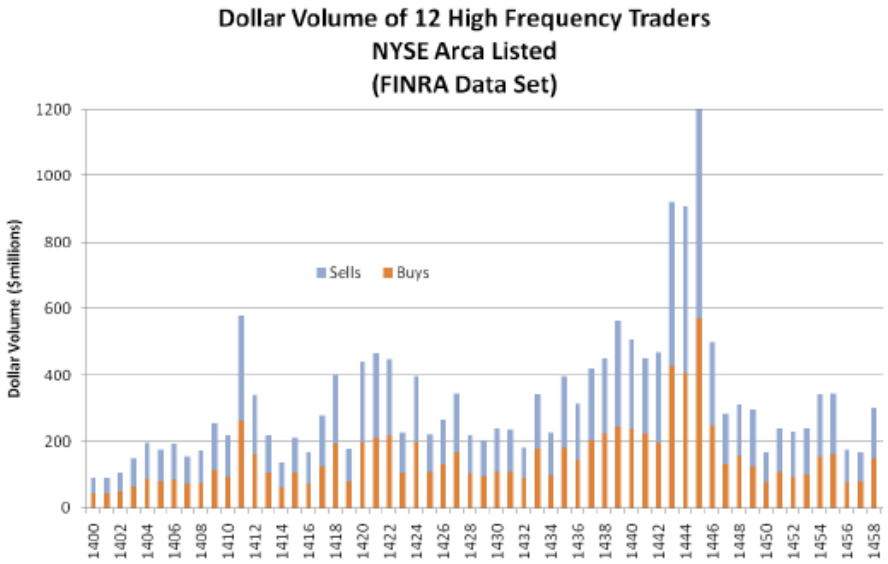
Appendix: H

Figure 2.1: Dollar Volume of High Frequency Traders for NYSE-Listed Securities



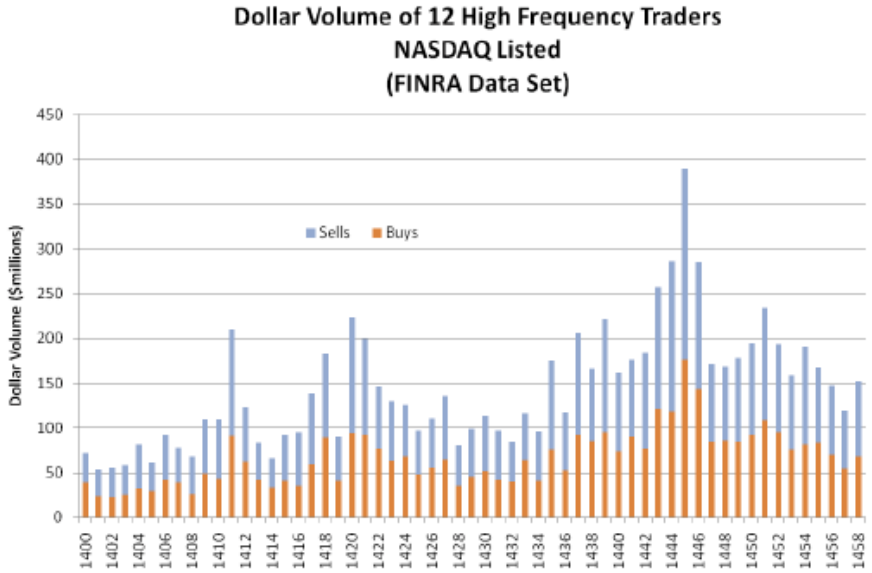
Appendix I:

Figure 2.2: Dollar Volume of High Frequency Traders for NYSE Arca-Listed Securities



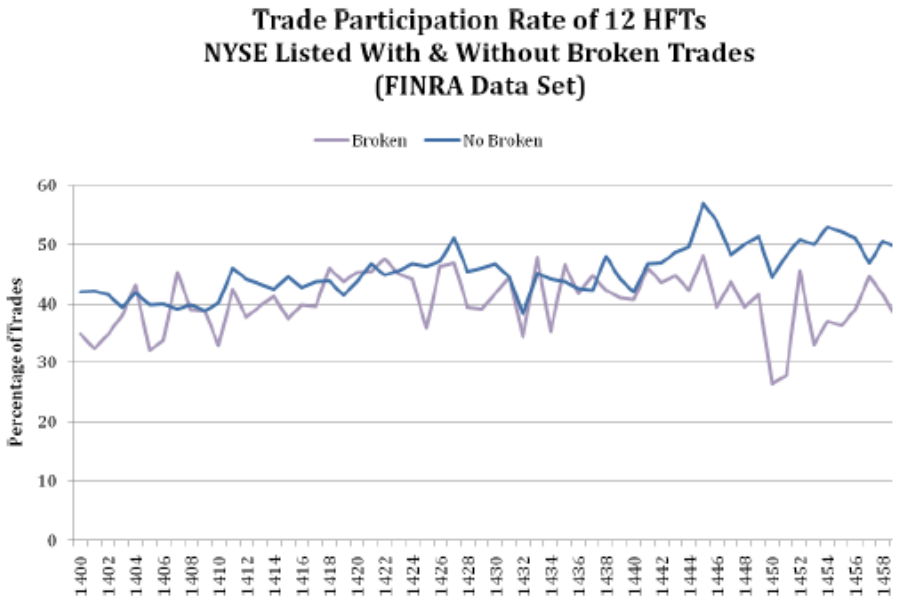
Appendix J:

Figure 2.3: Dollar Volume of High Frequency Traders for Nasdaq-Listed Securities



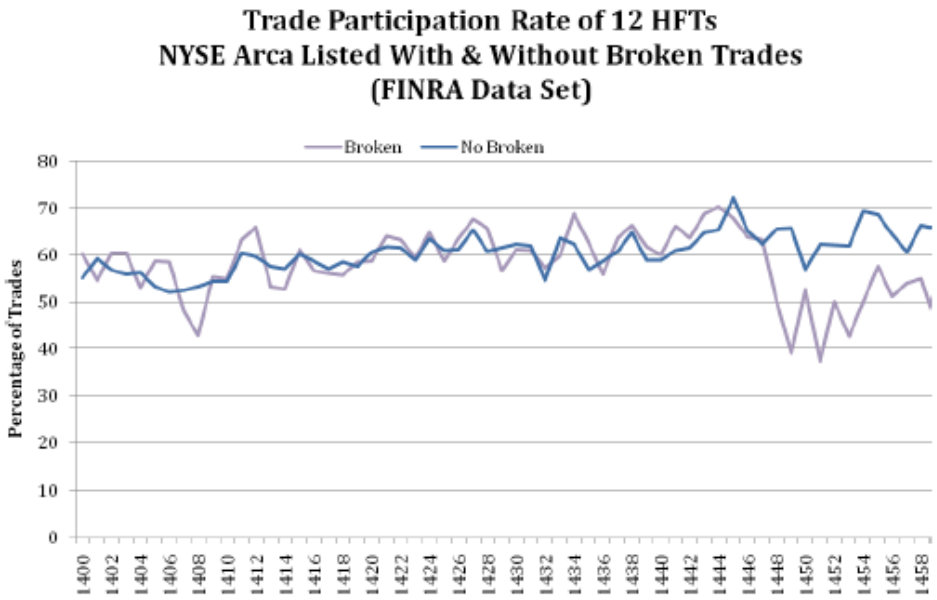
Appendix K:

Figure 2.4: HFT Participation Rates for NYSE-Listed Securities



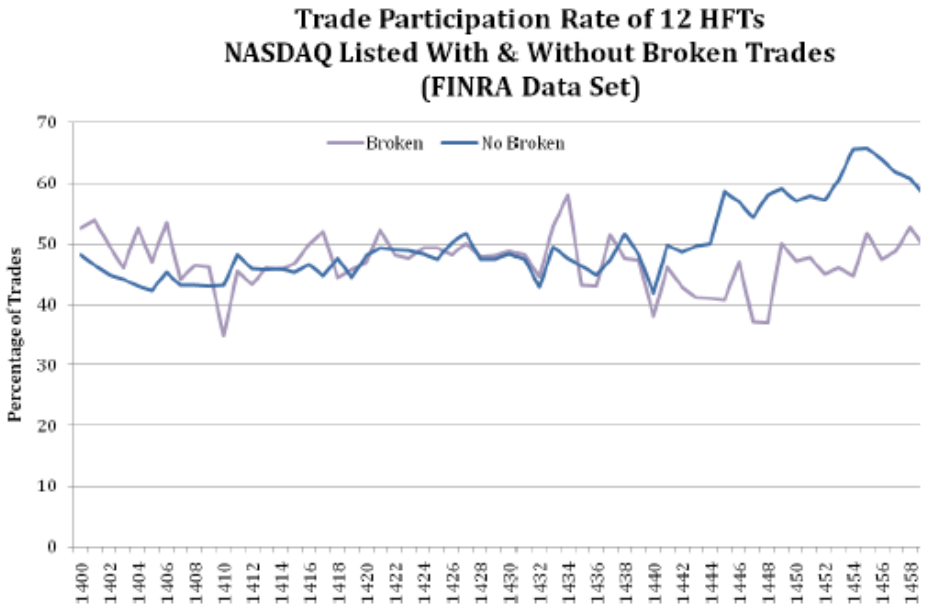
Appendix L:

Figure 2.5: HFT Participation Rates for NYSE Arca-Listed Securities



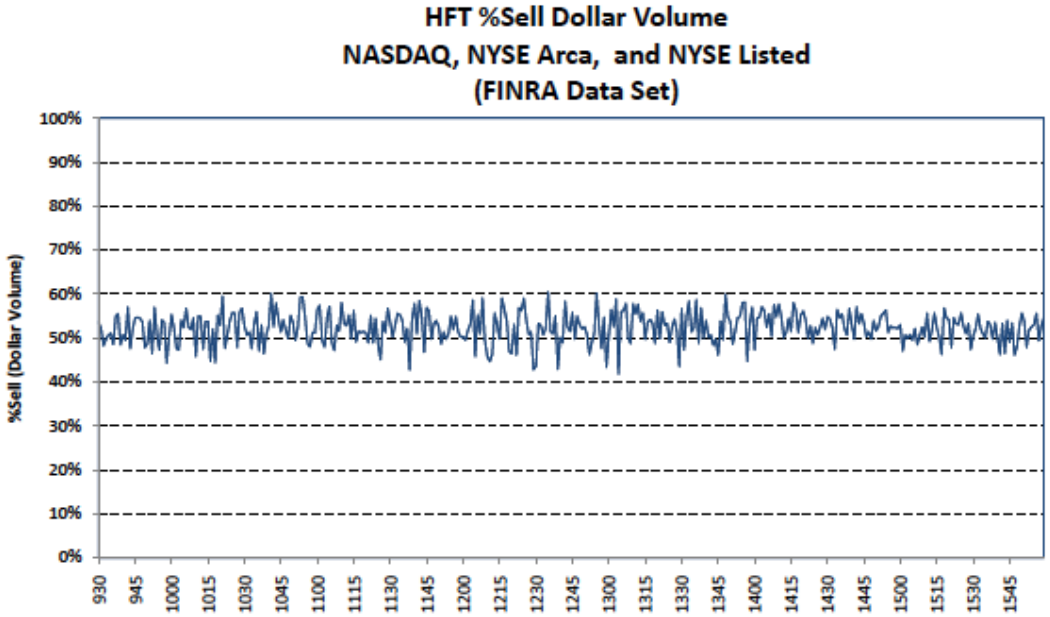
Appendix M:

Figure 2.6: HFT Participation Rates for Nasdaq-Listed Securities



Appendix N:

Figure 2.7: HFT Buying and Selling Ratios for Securities Listed on Nasdaq, NYSE Arca, and NYSE



Appendix O:

Figure 2.9: Volume across each large market venue

