

## Louvain School of Management

### High Frequency Trading

« What do we know and where do we need to go ? »

Mémoire recherche réalisé par  
**Jeremy Verbist**

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**Mikael Petitjean**

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*“While high frequency trading might  
bring some benefits, we need to make  
sure that it doesn’t cause instability, and isn’t a source of market abuse.”*

*Michel Barnier*

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## **General introduction**

### **Abstract**

On May 6, 2010, a trader called Navinder Singh Sarao was arrested because of his contribution to the Mini Flash Crash (or Flash Equity Failures) that took place on that date on the U.S. financial market. It was one of the biggest flash crashes ever to be recorded in history and caused nearly 1 trillion dollars of value being evaporated from the U.S. stock market in just a few minutes. After this event, High Frequency Trading (HFT) gained a massive public attention and a lot of interest from different market participants.

The evolution of HFT started approximately in year 2000 when electronic mechanisms were used on stock exchanges. Nowadays, technology is changing the business world dramatically and is reshaping the whole financial environment. It is therefore of utmost importance to maintain the integrity upon which stock exchanges and marketplace were founded.

### **Research Question and significance**

This thesis is the result of many months of thinking, questioning, networking, and interviewing different parties involved in the HFT market. This includes definitions, drivers, strategies, academic research and current regulatory discussions. I was drawn to HFT by my personal discovery that the financial markets were not playing with the same old rules of trading. In this way, this thesis project is aimed at answering the following question “What do we know about High Frequency Trading and where do we go?” In order to get a clear idea, the case of Sarao from 2010 will be the starting point to our analysis.

In the Financial Times (2016), U.S. prosecutors claim that Mr. Sarao was engaged in the manipulation of the market in the U.S. and used the method of “spoofing” when some studies argue that he may not have been responsible for the Flash Crash.

According to a Wall Street Journal (2011) article, “high-speed trading hurts small investor” but many researches has proven that HFT in fact brings a lot of benefits by making prices less

volatile and trading costs lower. In opposite, skeptics are scared of HFT because of the idea that the market can be manipulated.

## **General Literature Review and Background**

Stock market crashes have been taking place perpetually since a long time and more precisely since the time of the great depression in 1929. Unlike today, crashes had economic reasons and were taking more time to recover. Nowadays, technology evolve very quickly which has inevitably changed the way we trade. Some people would say that it is a great revolution when others would say that they have created their own destruction mechanism thanks to trades which are driven by complex algorithms that carry unforeseen risks.

Algorithms are becoming more complex and therefore more efficient and smarter. Originally, humans were behind this technology, but it seems that the algorithms are becoming more performing and have developed an accurate perspective of what happens in the market and how to efficiently trade to maximize profit without human consent. The evolution of buying and selling financial instruments is outlined in Appendix I, II, III, IV, V. Moreover, you can see how a typical trade on a stock exchanged is executed in Appendix VI.

There was a time when investors all over the world were believing in the utopia that stocks were on a path of ever-increasing prices, making bubbles and then crisis or not. Many investors believe that economic crash was coming every seven-year cycle. Nowadays digitals are taking more important space in the financial sphere. Should we consider that crises will be more frequent where every microsecond counts?

In his latest book “Flash Boys”, Michael Lewis describes the U.S. stock market, as “the most iconic market in global capitalism which is rigged” (Lewis, M. (2014)). In order to establish an unbiased, fair system, it is important that immoral activity is avoided by documentation and punishment. Many reports and researches have been published since the Flash Crash of May 6 which purpose was to discern if HFT is positive or negative for our society.

## **Structure of the thesis**

In order to answer to the core question, the thesis has been structured broadly across six different chapters. Chapter one focuses on the general concept of HFT and its emergence. Chapter two presents and analyzes different HFT strategies. Then, chapter three concentrates on such event as a Flash Crash that took place on May 6<sup>th</sup>, 2010 which raised serious questions about ethics, regulations and whether stock exchanges are fully equipped to handle such kind of situation. We based our research on papers that were published by different researchers, in particular “High Frequency Trading and Price Discovery” by The European Bank, “Equity Market Structure Literature Review” by the United States Securities and Exchange Commission (SEC). Chapter four focuses on the impact of HFT on market efficiency. After that, chapter five exposes different regulations that have been adopted on the subject of HFT all over the world. The last chapter exposes the results of a qualitative survey based on interviews which aim was to try to evaluate the relevance of HFT and different regulatory measures that have a potential to limit negative effects of HFT. Finally, in the conclusion I will give an interpretation of obtained results and my personal opinion on different concepts.

This thesis primarily draws from approximately fifteen academic reports on the subject of High Frequency Trading events, strategies, and policy.

# Chapter 1: Literature review and background

## 1. Definition of High Frequency Trading

High Frequency Trading (HFT) is a term that has grown to enclose a diverse number of strategies. Many definitions can be found in the literature on this topic. First, there are some common terms among various HFT strategies such as “execution speed” and thus “latency” that are determinant factors in definition of HFT. Secondly, whereas a few years ago seconds were considered as HFT, today it is about milliseconds and microseconds<sup>1</sup> that are considered as a minimum speed of execution. Finally, computers play an important role in replacing humans in the trading decisions.

Another important factor is the turnover. Since the profit per transactions is small, High Frequency Traders (HFTs) need to compensate their investment in infrastructure by entering hundreds of thousands of transactions. Moreover, as soon as they enter into a position, they try to profit from it and just as quickly get out.

To define what is HFT, it is also important to understand that there is a difference between trading and HFT. Kirilenko and Lo (2014) describe HFT on the most fundamental level as “a form of automated trading that takes advantage of innovations in computing and telecommunication to consummate millions upon millions of trades per day”.

## 2. Other Definitions

There are other definitions that need to be understood which will be discussed throughout this thesis. NASDAQ defines the following terms:

1. **Program trading:** “Trades based on signals from computer programs, usually entered directly from the trader’s computer into the market’s computer system and executed automatically [...]”

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<sup>1</sup> Millisecond: one thousandth of a second; microsecond: one millionth of a second

Three factors help to explain the explosion in program trading. First, technological advances such as the electronic communication networks (ECNs). Such electronic exchanges, as Instinet (later absorbed by Nasdaq OMX) and Archipelago (later absorbed by NYSE Euronext) allow thousands to buy and sell orders that are matched very rapidly without human intervention. Second, in 2001, the SEC put the stock prices in dollars and cents instead of fractions. Previously 81/8 is now listed at \$ 8.13, making it easier for buyers and sellers to match. Finally, we could observe a proliferation of hedge funds.

2. **Quantitative trading**: trading that refers to strategies based on quantitative analyses, which is “a mathematical analysis of the measurable figures of a company, such as the value of assets or projected sales [...]”.

Quantitative trading techniques are used by a panel of investors: HFTs, institutional or individual. The most familiar quantitative tools are “moving average” and “oscillators”.

3. **Algorithmic trading**<sup>2</sup> “refers to computerized trading using proprietary algorithms (algo). There are two types algo trading. Algo execution trading is when an order (often a large order) is executed via an algo trade. The algo program is designed to get the best possible price”.
4. **Statistical arbitrage**, in the context of hedge funds, is “a style of management that employs complex statistical models that try to capture small abnormalities in a security's intraday return”.

Statistical arbitrage is a strategy; it is a heavily quantitative approach to equity trading. It describes a variety of automated trading systems that commonly make use of data mining, statistical methods and artificial intelligence techniques.

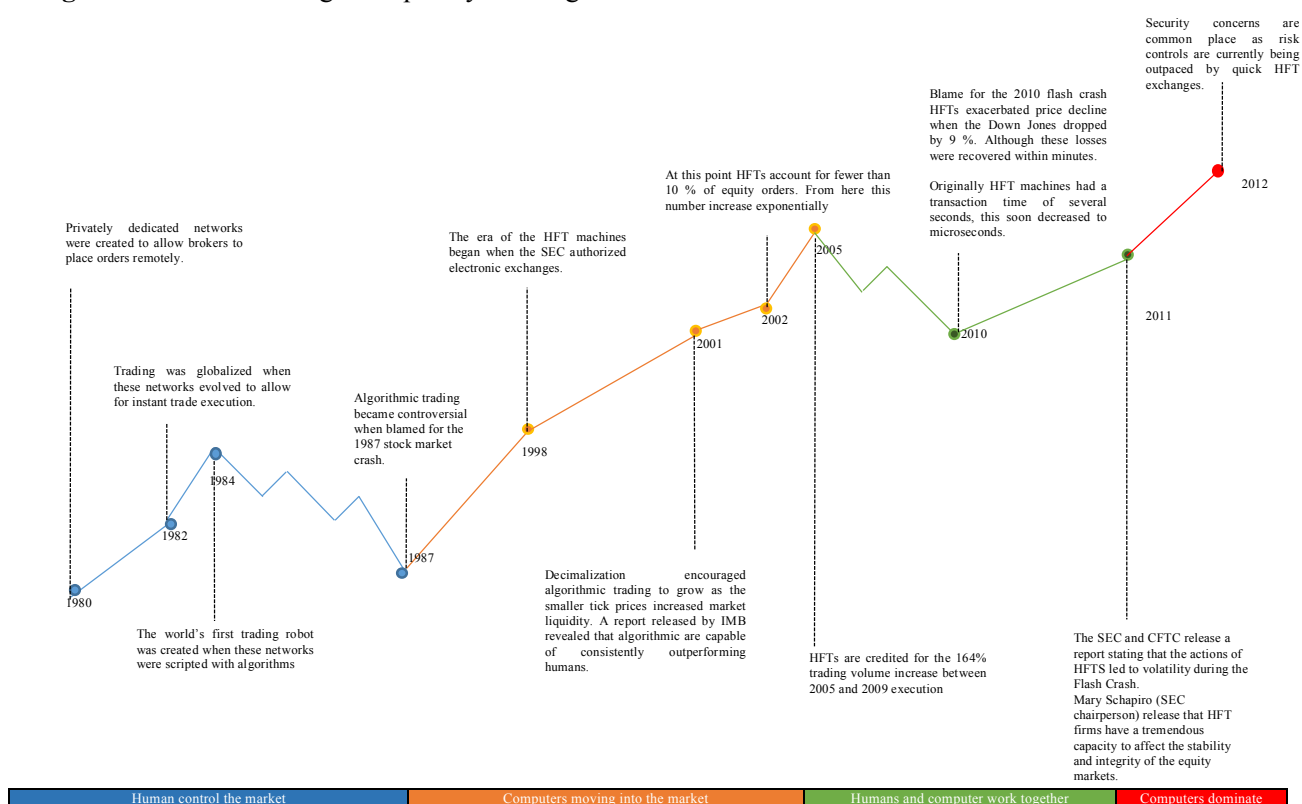
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<sup>2</sup> Appendix VII: An example of **Algorithmic trading**

### 3. The rise of High Frequency Trading

Prior to the computer age, securities were traded through physical venues where buyers and sellers met and negotiated the exchange of ownership of securities. It was made by a carrier pigeon first, then it was followed by telegraph cables (1840), telephone (1875), the radio (1915), computers (1970s), internet (2000s). Nowadays, there has been a shift in how securities are traded in the capital markets. The usage of super computers and complex algorithms seems to become the new practice. A summary of the rise of HFT is shown in Figure 1.

**Figure 1:** The rise of High Frequency Trading



Source: Marketfy, n.d.

Today HFT practice has considerably increased around the world and currently accounts for 40% to 60% of all trading activity across the universe of financial markets, including stocks, derivatives, and liquid foreign currencies (Kirilenko and Lo, 2014).

According to Tabb Group (2016) HFT represents over 50% of trading volume in the U.S., with estimates for Asia and Europe markets ranging between 20% and 30%.

**Figure 2:** High frequency trading as a % of all US Equity Trading

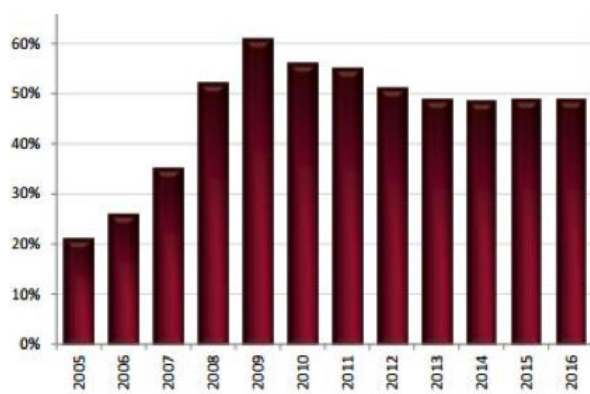


Figure 2 shows that U.S. HFT accounted for a little less than half of all equity traded in 2016. A rate that was stable within the previous three years. This is more than double of the market in 2006 but started to go down from a 2009 peak when it topped 60%.

Source: Tabb Group

#### 4. The emergence of High Frequency Trading

Since the early 18th century, securities trading methods and techniques have come a long way to perform in a commodities market on Wall Street. Traditionally, financial markets were physical locations where standing on crowded trading floors, brokers acting as buyers and sellers were seeking to find the right counterparty in order to match a trade. Until recently, information spread slowly, typically through ticker tapes.

Everything started on February 24, 1969, when the Institutional Networks Corps filed a patent application called “Instinet communication system for effectuating the sale or exchange of fungible properties between subscribers”. It brought computer services and communications network for the automated buying and selling of securities on an unidentified, confidential basis.

The 1970s saw the markets embrace more modern technology. February 8, 1971 was the first trading day at the National Association of Securities Dealers Automated Quotation (NASDAQ). It opened with 2,500 over-the-counter (OTC) stocks. It became the world’s first electronic stock

market which introduced an electronic quotation system. On May 1, 1975, the Securities and Exchange Commission (SEC) banned fixed minimum commission rates.

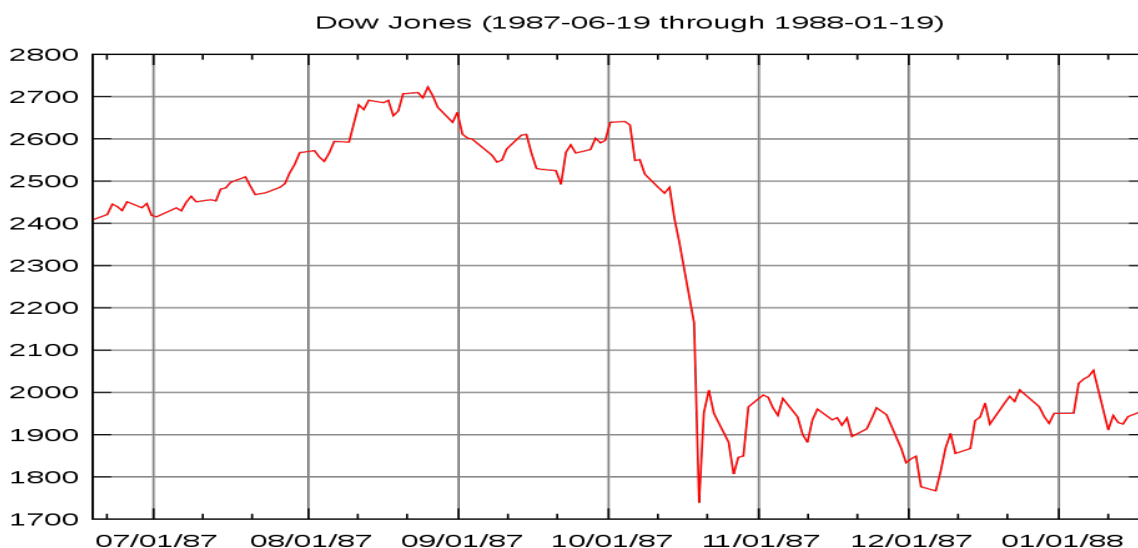
On March 1, 1976, the Designated Order Turnaround (DOT) system was introduced by the New York Stock Exchange (NYSE). DOT is an electronic system which enabled investors to submit orders that were logged into the server for exchange. It went directly to a specialist on the trading floor, instead of passing through a broker. It was considered as real time transfer because investors could benefit from having orders execute immediately instead of 15 minutes or more. The 1980s saw the advent of program trading (see definition above). On July 5, 1984, was introduced the Super-DOT by NYSE. Obviously, it was an advancement of the previous version of DOT. The system guaranteed that any market order of less than 2,100 shares of a stock would be completed within three minutes.

On October 19, 1987, the Dow Jones Industrial Average (DIJA) lost 22%. It started in the U.S. and it was going to affect the rest of the world. Floor traders were dominant while computers were still infancy. At that time, HFT was science fiction.

#### 4.1 1987 Market Crash: the emergence of programs tied to Market crash

There were many voices blaming that the market collapse on electronic trading was the “Flash Crash” of 2010 but it already happened 23 years ago on Monday, October 19, 1987, called “Black Monday”. Even back then it was already the electronic trading race between start-ups, banks and insurance companies. The impact resulted in a decline in the financial markets. The DIJA fell by a record 22.61% as depicted in Figure 3.

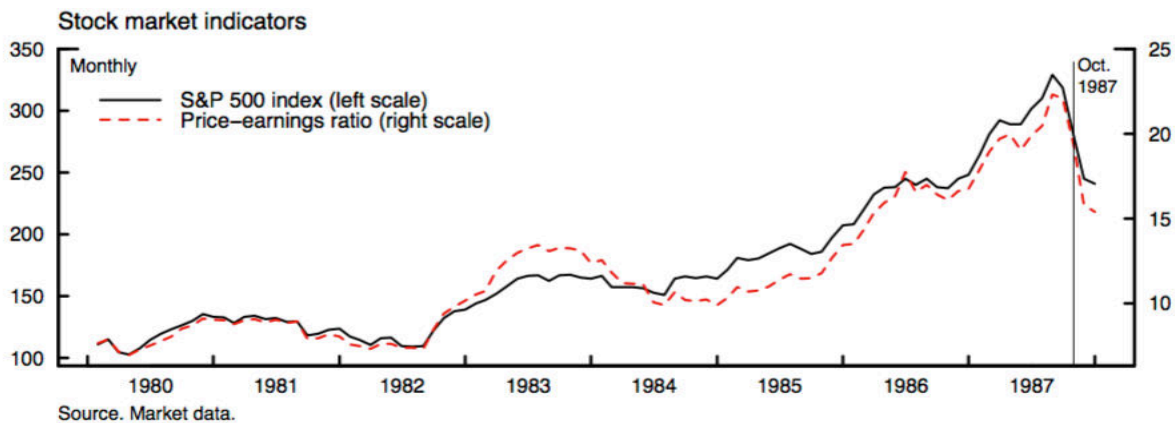
**Figure 3:** Impact of the Black Monday crash on the Dow Jones Industrial Average index



Source: Wikipedia, n.d.

The crash marked the end of an era of 5 years “bull market” (see Figure 4). According to Carlson (2007) “prices increases outpaced annual earnings growth and lifted price-earnings ratios; some commentators warned that the market had become overvalued”.

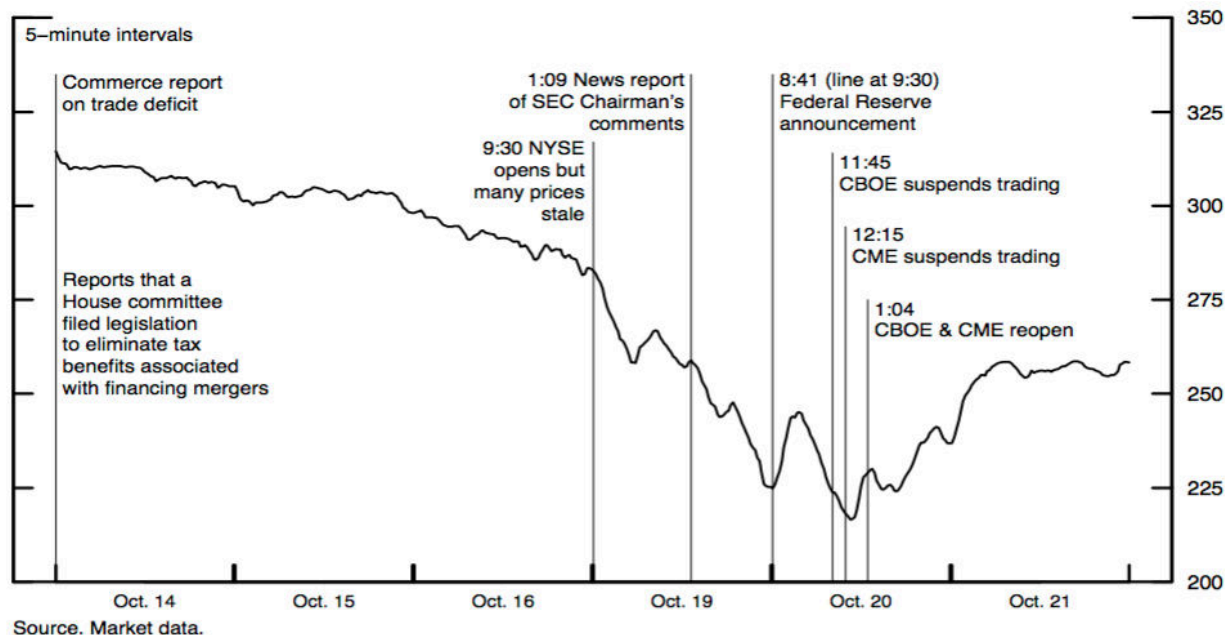
**Figure 4:** The evolution of S&P500 before the Black Monday crash



Source: Carlson, 2007

The Standard & Poor's 500 (S&P 500), along with futures and options markets also crashed to similar degrees. The following days, they recorded significant losses of nine percent (Carlson, 2007). The Figure 5 summarizes the events leading to the crash.

**Figure 5:** S&P 500 index around the time of the crash



Source: Carlson, 2007

Prior to crash, two events have been pointed as crucial in the drop of the market. First, the new legislation that aimed to eliminate tax benefits associated with financial mergers (Carlson, 2007). Second, the announcement of the trade deficit which was above expectations. This accelerated the losing value of dollar and increased the interest rate which put pressure on equity prices. Also, abnormally high selling volumes were recorded due to the anxiety of investors on the last half hour of Thursday, October 15.

On October 16, anxiety did not vanish but it took more importance in the stock market that carried on to plunge amidst market fear, forcing investors to hedge. By the end of the day, the fall was considerable. On October 19, the situation did not change, the event combined with the unexplainable glitches and behavior created disastrous results.

According to many analysts, the cause of the crash can be explained by 4 main reasons such as computer trading and derivative securities, illiquidity, trade and budget deficit, and overvaluation.

Many blame the use of computer trading (also known as program trading), especially portfolio insurance which is theorized to have also led to the crash (Carlson, 2007). The Chicago Mercantile Exchange (CME) report pointed out that “portfolio insurance did contribute significantly to selling in the futures markets. However, this strategy was only one of many sources of selling, and does not by itself explain the magnitude of the crash.” (CME, committee of Inquiry, 1987, p.56). Some blame the practices of futures or derivatives securities that has increased the variability, risk and uncertainty of the U.S. stock markets.

The U.S. Government’s reaction to the crash via the Federal Reserve (FED) provided liquidity and restored investors’ confidence in the financial system. Some changes have been taken after the 1987. In response, the NYSE and CME instituted a “Circuit Breaker<sup>3</sup>” which stops temporarily when there are large price movements. Moreover, they introduced uniform margin requirement which aims is to reduce volatility of securities (stocks, index, futures and stock options). After the 1987 crash, exchanges had changed their computer system to better one in order to improve the effectiveness, efficiency and increase accuracy.

#### 4.2 After the Black Monday

In 1990, electronic trading improved with the introduction of ECNs. It supported trading of financial securities outside of the regular stock exchanges. Since the 1990s, trading firms have made investments into ECNs. In 1994 for example, Banque National de Paris (BNP) purchased Cooper Neff, a trading firm. The acquisition brought to BNP all Cooper Neff’s technology and research capabilities. Then in 1999, Goldman Sachs acquired the Hull Group with a similar result.

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<sup>3</sup> Circuit breaker are “measures instituted by exchanges to stop trading temporarily when the market has fallen by a certain percentage in a specified period. They are intended to prevent a market free fall by permitting buy and sell orders to rebalance.” (NASDAQ, n.d.)

On November 28, 1997, Deutsche Börse, based in Frankfurt, Germany, launched its electronic trading system. It was originally created for the use only of the Frankfurt Stock Exchange, but it will be expanded to other stock exchanges in Europe.

On April 21, 1999, in order to restrict the monopoly retained by NYSE and NASDAQ, the SEC passed the regulation of Alternative Trading Systems (ATS). There were three new elements to the new framework. First, there was a new clarification of key terms in the statutory definition of exchange. Second, Congress's immune systems from exchange registration was installed, which gave ATSS the option of registering as exchanges or as broker-dealers while adhering to various conditions. Finally, the Securities Exchange Act of 1934 (SEA 1934) which was created to govern securities transaction on the secondary market was interpreted so that it accommodated the registration of for-profit entities as exchanges (Domowitz and Ruben, 2001).

On April 9, 2001, algorithmic trading gained immense popularity. Therefore, the SEC required all U.S. stock markets to convert to the decimal system for prices instead of traditional fractions, bringing down the minimum spread between the bid and ask prices. Previously stocks prices had been measured in sixteenths of a dollar, or 6.25 cents. It was a clear turning point for electronic trading.

On June 9, 2005, the SEC passed the regulation National Market System (NMS), which updated the trade-through Rule<sup>4</sup> and looked to improve the U.S. exchanges through greater fairness, in price execution, promoting transparency and competition between markets and improving display of quotes. Its aim was to ensure that investors received the best price when their orders were executed.

Giving acceleration to the new approach to trading, these developments, along with improving the speed, have acted as an incentive to HFT.

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<sup>4</sup> The trade-through rule is a rule that was instituted by the NYSE that requires of fostering competition and transparency in the markets and therefore ensuring that investors receive the best prices at the least execution costs when trading shares.

## 5. The speed advantage

Is the speed of HFT new in the history of trading? The following analysis will show that a century ago, men were already considering how to spread information faster. Information speed has always played a major role.

### 5.1 Munehisa Homma

Homma-san was without doubt, the most successful market trader in history. He is considered as the father of the candlestick chart<sup>5</sup>. He was a rice merchant from Japan who traded in the Dojima Rice market in 600 km during the Tokugaza Shogunate. In 1710, futures market emerged in form of coupons, promising delivery of rice at a future time. After that a secondary market of coupon trading emerged. In his book “The fountain of Gold”, he describes how market psychology can help predict prices.

Instead of using faster horses or pigeons, to accelerate the speed of information, it is said “he established a personal network of men at about every 6km” (Petitjean & Laly, 2016). Homma used this information to predict the evolution of the rice price and hence buying all rice from growers. His edge was in the rice paper parchments. They were symbols that recorded the previous days and weeks of rice prices called “Candlesticks” that would give him the probability of the likely future direction of rice price. Although his methodology would never work if he did not get the news before the competition.

### 5.2 Nathan Mayer Rothschild

The story of Nathan Mayer Rothschild in Waterloo is legendary. In fact, acting on his early knowledge of the victory, he started to buy into the market in the certain knowledge that stocks would rise once victory confirmed.

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<sup>5</sup> “A candlestick is a chart that displays the high, low, opening and closing prices of a security for a specific period. The wide part of the candlestick is called the "real body" and tells investors whether the closing price was higher or lower than the opening price. Black/red indicates that the stock closed lower and white/green indicates that the stock closed higher.” (Investopedia, n.d.)

The speed and effectiveness of communication were the keys of success. During this time, postal system was just developing and was not efficient enough and had to be relied on a network of trusted couriers. They found a genius solution that consisted in the use of pigeons to carry short and important messages between them. They got a farm in Kent where carrier pigeons could station.

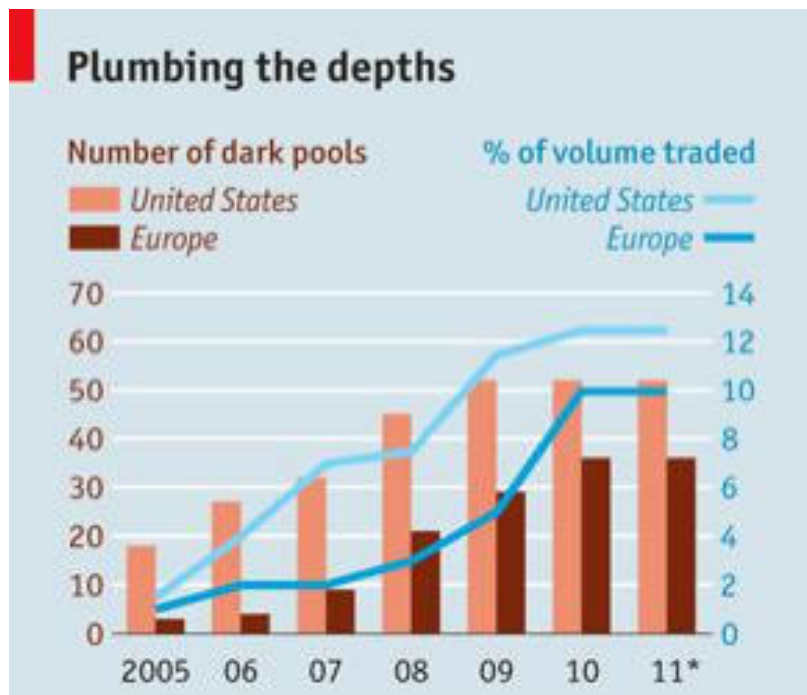
A letter written in August 1846 by Nathaniel de Rothschild from Paris (Nathaniel was Nathan's son) says: "I hope our feathered messengers will have brought you in due time our good prices". Elsewhere in the letter he reveals, "A B in our pigeon dispatches means: buy stock, the news is good; C D...means sell stock, the news is bad". (RAL XI/109/57).

One more time, the speed race was determinant. The speed has always been a matter for men. Thereafter, "it became technological with the invention of the telegraph (1840), the telephone (1875), the radio (1915), computers (1970s), until the invention and the use of the internet (2000s)" (Petitjean & Laly, 2016).

## **6. Dark Pools**

The term "dark pool" has been bandied around in the past few years in the financial world. The term gets different names: these include ATS or dark liquidity trading pools which are simply places where stocks are traded "off exchange". It originated from investors that wanted anonymity when they were trading large orders.

In response to the new regulations (NMS) dark pools have been created. It is one of the murkiest trading platforms which resulted in much debate and controversy encircling HFT (Tuttle, 2013). Access to dark pools are not easy and it is prohibited for the general public. Most commonly, dark pools are owned by Stock Exchanges, brokers and independent companies (owners of automated trading systems). According to Arnuk and Saluzzi (2012) and Lewis (2014), HFTs receive access to dark pool to use them in their trading activity and therefore owners of dark pools earn more money by charging fees. The emergence of dark pools in the United States and Europe from 2005 to 2011 is shown in Figure 6.

**Figure 6:** Dark Pools evolution

Source: TABB Group, 2011

The number of dark pools and the percentage of volume traded in the U.S. and EU have increased substantially between 2005 and 2009, then stabilized. The volume traded in 2008 through 2010 showed an increase by approximately 7% in trade volume in dark pools. By 2011, just over 10% of volume was traded in dark pools in the EU, while that number was about 12% for the U.S.

## 7. Mini Flash Crash

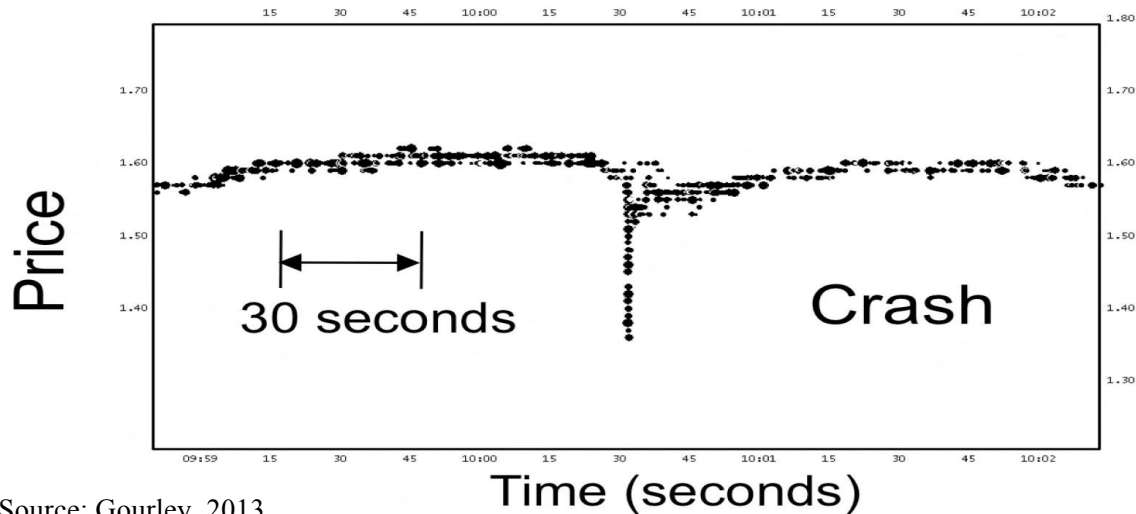
In the course of my research many papers and industry professionals have defined what is a “Mini-Flash-Crash” (MFC). This term became known to the general public when Nanex took the initiative to perform a thorough analysis of these kinds of events that regularly happen on the financial markets. MFC can be defined as a result of abrupt and severe price changes that occur in an extremely short period.

### 7.1 Characteristics of MFC

In November, 2010, Nanex Llc., a data analytics company, was the first to identify MFC. To qualify as a down crash, the stock price change has to satisfy the following conditions:

“For a large price drop to qualify as an extreme event the stock price had to tick down at least ten times before ticking up, it must occur within 1.5 seconds and the price change had to exceed 0.8%” (Nanex Llc., 2010) as show in Figure 7.

**Figure 7:** Characteristics of down crash

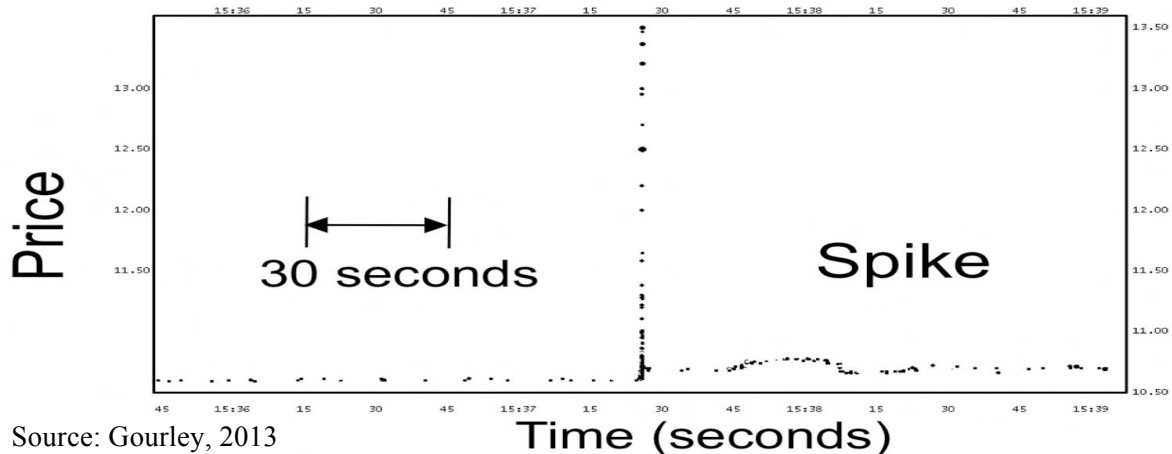


Source: Gourley, 2013

The second type is up crashes. Again, to be considered as a candidate, the stock price change must satisfy three conditions:

“For a large price rise to qualify as an extreme event, the stock had to tick up at least ten times before ticking down, occur within 1.5 seconds and the price change had to exceed 0.8%” (Nanex Llc., 2010) as show in Figure 8.

**Figure 8:** Characteristics of up crash

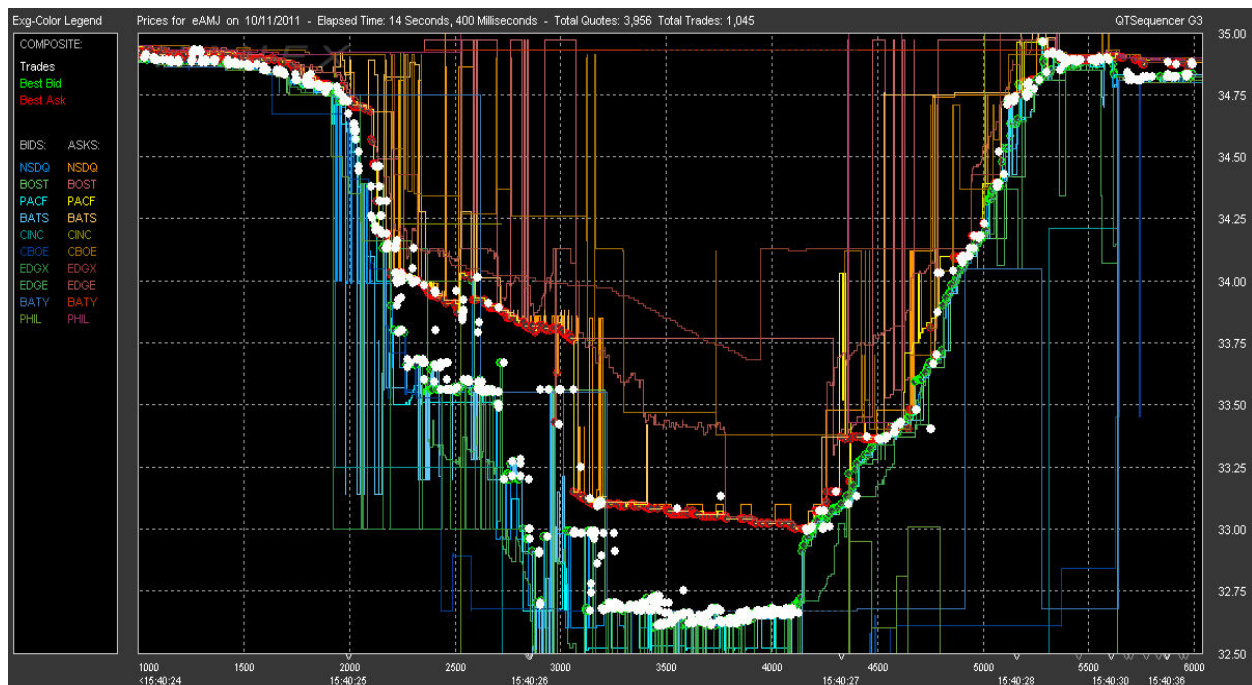


Source: Gourley, 2013

## 7.2 Examples

An example of a down flash crash with a decrease in the stock price can be the October 11, 2011, when the stock JPMorgan Alerian MLP ETN (NYSEarca ticker: AMJ) plummeted from \$ 34.90 to \$ 32.61 corresponding to a 6.5 % loss in 4 second and then recovered. This crash is shown in Figure 9.

**Figure 9:** Mini flash crash of JPMorgan Alerian



Source: Nanex, 2011

Flash Crashes can also have positive direction with a sudden increase in the stock price. It can be illustrated by the day of August 18, 2011, when the stock price of Hewlett- Packard (NYSE ticker: HPE) went up to a 14 % raise in less than 400 milliseconds in the aftermath of Bloomberg publication that “HP said to plan spinoff of PC business”. As we can see from Figure 10 after the spike, the stock quickly recovered.

**Figure 10:** Mini Flash Crash of Hewlett- Packard



Source: Gourley, 2013

These two examples are not the only one having experienced a quick drop or jump and later recovery in a short period of time. There were other cases of mini crashes involving such company as Goldman Sachs (October 7th 2008, 1.6% drop occurred in less than 400 milliseconds and then returned), BATS Index and others.

We called this quick change a MFC because this event was not caused by a “fat-finger error”, in fact no human was involved. Today, algorithms in HFT have gotten much stronger and it has the ability to read more than one news articles and determine the gravity of an event that occurred and plug variables into a mathematical model.

In Johnson et al. (2012) paper, the authors suggest that the crashes may be a result of interaction between several trading algorithms or a positive news induced by market environment.

## 8. Impact of HFT on Market efficiency

Much criticism has been focused against HFTs with specific concerns including the fact that it amplifies the potential for market volatility (such as during the Flash Crash). The academic literature has largely spotlighted the impact of HFT on such elements of market efficiency as spreads, volatility, liquidity, etc.

While all these elements are fundamental to the operation of efficient markets, the mandate of national regulatory agencies and exchanges alike is to promote market efficiency. This chapter demonstrates the impact of HFT participation on market efficiency. Empirical evidences have shown that increasing HFT participation has resulted in increased efficiency. In opposition, there are many criticisms raised by other market participants against HFT on the impact of HFT on the fairness and transparency.

### 8.1 Market efficiency

Market efficiency is defined as “the degree to which stock prices and other securities prices reflect all available, relevant information” (Investopedia, n.d.). It was developed in 1970 by economist Eugene Fama, whose theory of the Efficient Market Hypothesis (EMH) stated that it is not possible for an investor to outperform the market because all available information is already built into all stock prices. According to EMH, there are three different types of market hypothesis.

**Strong Form:** all available information (public and private) is quickly and accurately reflected in the market price in the sense that no individual trader can outperform the market and achieve higher trading profits (Fama, 1970).

**Semi-Strong Form:** all relevant publicly available information is quickly reflected in the market price (Fama, 1970). Public information is not only past prices, but also a company’s financial statement and data. The statement behind semi- strong market efficiency is that no one should be able to profit using something everybody else knows (Clark et al., 2001).

**Weak form:** is a subset of public information about the historical price (Fama, 1970). Weak form efficiency supporters assert that technical analysis cannot be used to outperform the market because there is no correlation between successive prices; hence excess returns cannot consistently be achieved through the study of past price movements. Instead, fundamental analysis can identify if stocks are over or undervalued (Jensen, 1978).

The theoretical findings of Jovanovic and Menkveld (2011) hint that HFT participants may generate welfare gains, by increasing efficiency through the reduction of bid-ask spread<sup>6</sup>. According to Brogaard et al. (2012), HFT contributes to market efficiency. HFTs take actions against price inconsistency and arbitrage any inconsistency away. The authors argue that because HFTs are able to update their information set faster than a traditional market maker, they are able to increase their ability to avoid adverse selection, and thereby reduce the cost of liquidity provision. On the other hand, Jovanovic and Menkveld (2011) remind that the ability of HFT participants to update their information set faster than human traders may reduce the eagerness of human participants to enter the market because they fear of trading with a better informed HFT participants.

Jovanovic and Menkveld (2011), present evidence that HFT is beneficial for market efficiency, and their findings are consistent with studies that of Brogaard et al. (2012), Jarnećić and Snape (2010), and Hendershott, Jones, and Menkveld (2011).

However, a large body of literature suggests significant adverse effects associated with HFT. Kirilenko and Lo (2014) show that “in contrast to a number of public claims, high frequency traders do not, as a rule, engage in the provision of liquidity like traditional market makers.” McNish and Upson (2012) suggest that “the ability of fast liquidity suppliers to use their speed advantage to the detriment of slow liquidity demander [...] unambiguously lowers market quality.”

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<sup>6</sup> Bid-ask spread: “A bid-ask spread is the amount by which the ask price exceeds the bid price for an asset in the market. The bid-ask spread is essentially the difference between the highest price that a buyer is willing to pay for an asset and the lowest price that a seller is willing to accept to sell it.” (Investopedia, n.d.)

## Chapter 2: Algorithmic Trading Strategies

HFT involves the concept of electronic marketplace and order, which are the basic tools that use HFTs to implement strategies.

### **The electronic marketplace**

An electronic financial marketplace is a virtual or online environment for electronic exchange of assets, (e.g. stocks, bonds, contracts), where buyer and seller find each other. It performs the same function as a traditional marketplace.

### **Order Book**

Every asset at an exchange has an order book, sometimes more than one. This is the place where all the orders to trade the asset are contained and matched, even non-active orders. Orders that are not immediately matched upon insertion will remain in the order book until they can be executed or are canceled by the trader or the trading system. The difference between the current best bid prices and best ask order price in the order book is called the spread.

### **1. Orders and order types**

An order is either a buy or a sell order entered by a market participant at an exchange.

Traders have access to a number of different order types available that can be use in various combinations to make trades, each with its own characteristics. The order types allow putting in place different strategies. Here are the main order types:

- Market orders

A market order is the simplest order type. It is an order with the instruction to trade at the price available in the marketplace, no matter how good or bad it might be. For example, if a participant entering a market order does not specify a price that he is willing to trade at, he will get whatever price is available from those willing to sell or buy from him.

Market orders are advantageous because it gets the highest priority and are the first to be executed. When the price is moving quickly, it is a good tool to use to get into or out of a trade quickly. In the opposite, the participant does not know what the exact price he will end up buying or selling at.

- Limit orders

Unlike market orders (orders filled at the best available price), a limit order is filled only if it can be filled at your limit price. So a limit order is an order that establishes a maximum or minimum price that participants are willing to buy or sell at. The limit order will remain in the order book until being matched or canceled.

- Stop orders

A stop order is an order to buy or sell a stock when a certain price is reached. Stop orders are used to set a risk limit by closing a position once it reached a certain level of loss, also referred to as a stop-loss order or it can be used to take advantage of market movements by opening a position when market drops to a certain price.

These are the main types of orders used in the financial markets, other types exist that allow participants to put a large number of strategies in place.

## **2. Algorithmic Techniques**

HFT strategies are very important to HFT firms. In fact, they are very secretive about their way of operating. They operate through multiple strategies. There are several participants at an exchange, each with different roles.

First, there are market makers, they are broker-dealers firms that maintain bid and ask price in a given security by standing ready, willing, and able to buy or sell a stated security on its own account at any time at publicly quoted price (called making a market). They often receive rebates and privileges by the Exchange for providing liquidity in an order book. Second, brokers,

individuals or brokerage firms, intervene into the market by taking care of transactions between a buyer and a seller and by charging a fee or a commission for this service. The last participant is the customer, retail and institutional customer who trade an asset either for purpose of investment or speculation.

HFTs employ a diverse range of trading strategies that may also be used in connection with each other. Some analysis generally categorizes these strategies into passive and aggressive trading strategies. An example of passive strategy would be market-making and an aggressive would be a momentum ignition trading for example. Aldridge (2009) mentions four HFT strategies as being the most popular. They are presented in Table 1.

**Table 1:** High Frequency Trading Strategies

<b>STRATEGY</b>	<b>DESCRIPTION</b>	<b>HOLDING PERIOD</b>
<b>Automated Liquidity Provision</b>	Market-making positions with optimal pricing and execution through quantitative algorithms	Less than 1 minute
<b>Market Microstructure Trading</b>	Identifying Order Flow through reversed engineering of observed quotes	Less than 10 minutes
<b>Event Trading</b>	Short-Term on macroeconomic events	Less than 1 hour
<b>Statistical Arbitrage</b>	Statistical arbitrage of deviations from equilibrium	Less than 1day

Source: Aldridge, 2010, p.4

Another type of strategies that is not considered as legal is called manipulative strategies. They are generally illegal violations of the anti-fraud provisions of the SEA of 1934.

Further, I highlight and explain the intentions with the most commonly used HFT strategies that might be used to manipulate and abuse the market.

## 2. Manipulative strategies

Manipulative strategies are the exploitations of certain vulnerabilities of markets and participants and are often called predatory strategies (Gourley, 2013). Quote stuffing, Spoofing and Momentum Ignition strategies are often mentioned in the literature. Other strategies are listed as potential abusive types of strategies (latency arbitrage, order anticipation, etc.).

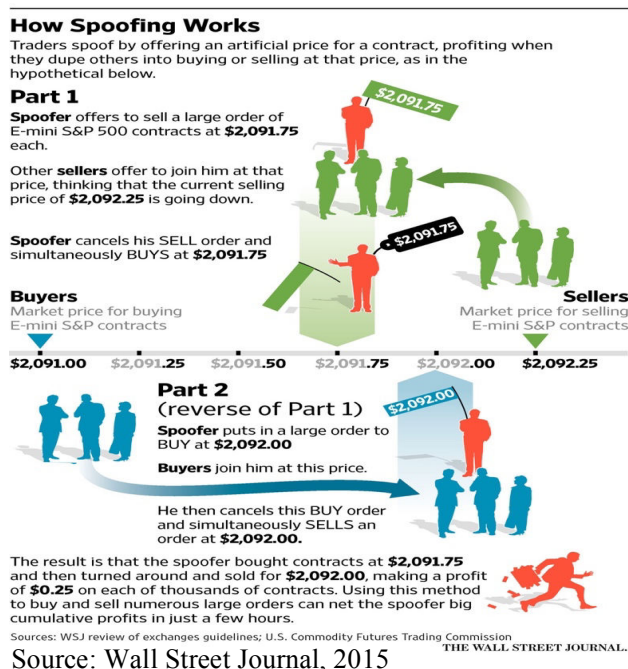
### 2.1 Quote stuffing

Quote stuffing can be classified as illegal depending on the trader's intent. It is a tactic of entering and withdrawing a large amount quickly, that will "stuff" false quotes into the market. After filling the market with false quotes, competitors with other algorithm will process, causing them to lose the competitive advantage in HFT because this process of interpretation adds significant time. The result is that the time, despite the fact that it consists in microseconds, will be significant.

### 2.2 Spoofing

During the 2010 Flash Crash, Navinder Sing Sarao was accused to have used the spoofing technique. Wall Street Journal describes a fundamental spoofing operation as shown in Figure 11.

**Figure 11:** How spoofing works



Traders can be either sellers or buyers. There are two mechanisms: first, where the spoofer is a buyer, then the algorithm floods the markets with false quotes and deceives other buyers. Second, the spoofer is a seller, then other sellers are injured. Spoofers fake the market in one of two ways:

Way I: The spoofer lowers the price of a contract to make other seller believe that the market price is falling. Way II: The spoofers submit a fake

order to buy a large contract with the intention of cancelling the order

In the end, the profit by contract is very low and is considered to be \$0.25 by contract, however the strategy consists in selling thousands of contracts, which results in large profits. This shows clearly a manipulative strategy against traditional investors.

### 2.3 Momentum Ignition

Momentum ignition strategies involve a proprietary trading firm initiating a series of orders aimed to ignite a rapid price movement in one direction by a series of orders or trades. While other traders follow the price movement, HFTs would take the opposite position on the market and they would attempt to profit from the artificially high or low prices. This kind of market manipulation would harm market quality by increasing market inefficiency (IIROC, 2012).

## 3. Ethical decision factors

After reviewing the HFT manipulation strategies, we can say that there is a lack of ethics in the process of decision. Therefore, firms have to take into consideration different elements such as fairness, equality and responsible investment criteria in order to make an ethical decision. Equality and fairness are significant to accurately analyze the difference between the ethical decision-making ability of humans and computers (Boatright, 2010).

### 3.1 Fairness and Equality

As Boatright (2010) observed, “fairness is a notoriously complex moral concept that has a wide range of application and standards.” In our case, fairness will mean to be treated similarly to others with respect to a rule, agreement, or recognized expectation. Therefore, the actions of individuals, trading rules and trading practices, regulations and public policies may all be evaluated in relation to fairness. They may also be addressed in terms of equality and liberty as well as their impact on welfare.

### 3.2 Responsible investment

Responsible investment (RI) is commonly referred to as Socially Responsible Investing (SRI) or ethical investing. It has become a mainstream investment strategy of the major capital markets. They promote human rights, diversity, and environmental awareness called ESG (Environment, Social, Governance). One of the key features of RI is to encourage long-term perspective investments. RI has performed equally or, in some cases, even better than conventional mutual funds (Boatright, 2010; Guay et al., 2004; Bauer et al., 2005)

### 3.3 National Governments and Stock exchanges

Governments and national stock exchange around the world have taken steps to promote corporate social responsibility (CSR), along with the development of SRI indexes through private parties (Boatright, 2010). The implementation of SRI in the equity market is not efficient, due to the lack of data on the CSR record of publicly traded companies. To promote SRI, firms have created indexes and listed companies they believe fit several criteria for RI.

### 3.4 Competitive Advantage

In today's highly competitive environment the goal of each organization is to defeat competition. According to Perkins et al. (2009), the sources of competitive advantage in automated trading are:

1. **“Strategic creativity or differentiation”**: from an empirical aspect, it is the ability to detect opportunities in a market that is overlooked by human traders or other firms;
2. **“Quantitative improvement”**: the ability to acquire profitable opportunities through more exhaustive forecasting models, order management techniques, and valuation;
3. **“Optimization and Data Cleaning”**: the capacity to expose profitable strategies by repairing and manipulating financial optimizing signal and data;
4. **“Order Execution Speed”**: the capability to react faster to real-time market movements than market competitors;

5. “**Cost minimization**”: the ability to execute strategic decisions at low cost, compared to competitors;
6. “**Rapid Model Deployment**”: the capacity to audit trading-system research and the progress of the projects conducting to the quickly deployment systems on technological platform;
7. “**Trading System**”: the capacity to revise capital allocations across a group of working trading systems and to carry on the research and advancements of new systems;
8. “**Defect Minimization or Quality**”: software bugs or holes in trading are defects that reduce market return, moreover it reduces the investors’ confidence in the organization ability to succeed.

Finally, there are several sources of competitive advantage tied to the use of HFT. The most significant is the “Order Execution Speed” because it gives a major advantage to HFTs over ordinary investors. The flash crash of May 6 has shown the importance of implementing ethics in the sector of HFT and authorities need to fully evaluate to what extend these advantages can be used to manipulate and abuse the market.

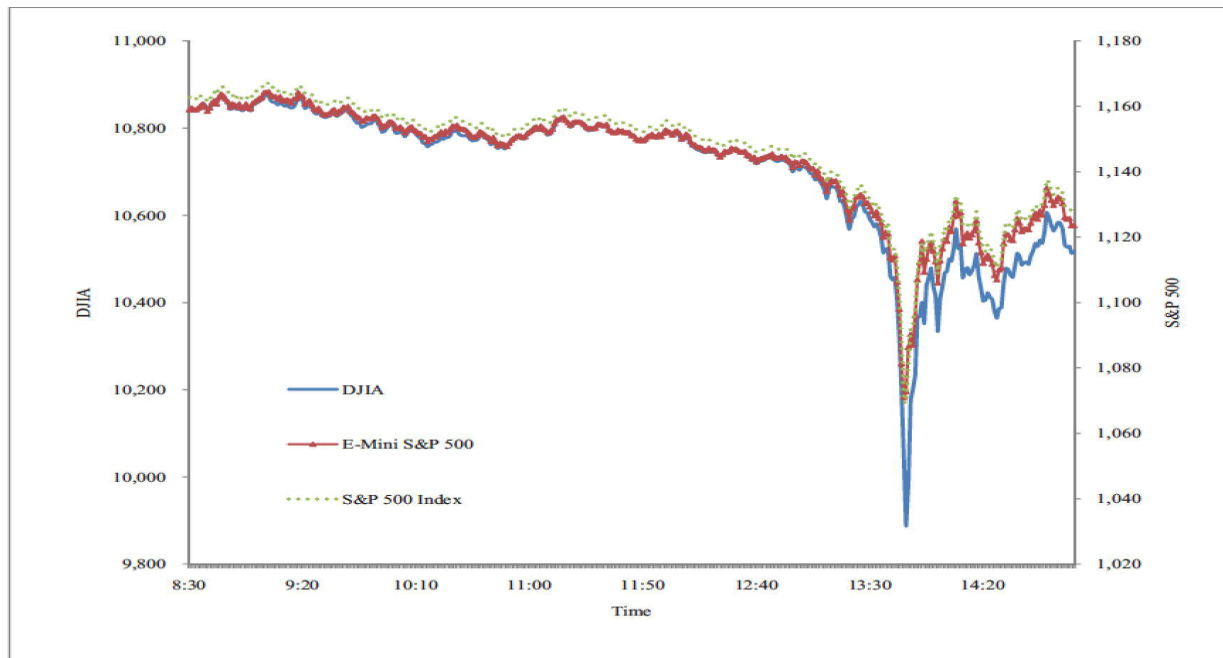
## Chapter 3: Analysis of Sarao's Case

### 1. Flash Crash

The Flash Crash of May 6, 2010, was atypical in the history of American equity markets. From 2:41 p.m. to 2:45:28 p.m. the market plummeted from 5% to reach intraday lows of 10%. The market would recover shortly after as it is shown in Figure 12. Such a large and rapid drop and recovery has raised many concerns about the stability of capital markets. The event of May 6, 2010 has become known as the “Flash Crash”.

Broad stock market indices as the S&P 500, the E-mini S and the 2000 collapsed and rebounded with extraordinary velocity. The DJIA experienced the biggest intraday point decline in its entire history.

**Figure 12:** U.S. Equity Indices on May 6, 2010



Source: Kirilenko et al. (2011)

A joint investigation led by SEC and the Commodity Futures Trading Commission (CFTC) attributed this event to “an automated execution algorithm on autopilot, a game of “hot potato”

among HFTs, cross-market trading and a practice by market makers to keep placeholder bid-offer stub-quotes” (Kirilenko & Lo, 2014).

Kirilenko and Lo (2014) disclose that a later investigation seemed to connect the event to a “rapid automated sale of 75,000 E-mini S&P 500 June 2010 stock index futures contracts (worth about \$4.1 billion) over an extremely short time period which created a large order imbalance that overwhelmed the small risk-bearing capacity of financial intermediaries that is, the high frequency traders and market makers.”

The CFTC-SEC report led to the following statement (2010):

“At 2:32 p.m., against a backdrop of unusually high volatility and thinning liquidity, a large fundamental trader (a mutual fund complex) initiated a sell program to sell a total of 75,000 E-Mini [S&P 500 futures] contracts (valued at approximately \$4.1 billion) as a hedge to an existing equity position. [...] This large fundamental trader chose to execute this sell program via an automated execution algorithm (“Sell Algorithm”) that was programmed to feed orders into the June 2010 E-Mini market to target an execution rate set to 9% of the trading volume calculated over the previous minute, but without regard to price or time. The execution of this sell program resulted in the largest net change in daily position of any trader in the E-Mini since the beginning of the year (from January 1, 2010 through May 6, 2010). [...] This sell pressure was initially absorbed by: high frequency traders (“HFTs”) and other intermediaries in the futures market; fundamental buyers in the futures market; and cross-market arbitrageurs who transferred this sell pressure to the equities markets by opportunistically buying E-Mini contracts and simultaneously selling products like SPY [(S&P 500 exchange-traded fund (“ETF”))], or selling individual equities in the S&P 500 Index. [...] Between 2:32 p.m. and 2:45 p.m., as prices of the E-Mini rapidly declined, the Sell Algorithm sold about 35,000 E-Mini contracts (valued at approximately \$1.9 billion) of the 75,000 intended. [...] By 2:45:28 there were less than 1,050 contracts of buy-side resting orders in the E-Mini, representing less than 1% of buy-side market depth observed at the beginning of the day. [...] At 2:45:28 p.m., trading on the E-Mini was paused for five seconds when the Chicago Mercantile Exchange (“CME”) Stop Logic Functionality was triggered in order to prevent a cascade of further price declines. [...] When trading resumed at 2:45:33 p.m., prices stabilized and shortly thereafter, the E-Mini began to recover, followed by the SPY. [...] Even though after 2:45 p.m. prices in the E-Mini and SPY were recovering from their severe declines, sell orders placed for some individual securities and ETFs (including many retail stop-loss orders, triggered by declines in prices of those securities) found reduced buying interest, which led to further price declines in those securities. [...] Between 2:40 p.m. and 3:00 p.m., over 20,000 trades (many based on retail-customer orders) across more than 300 separate securities, including many ETFs, were executed at prices 60% or more away from their 2:40 p.m. prices. [...] By 3:08 p.m., [...] the E-Mini prices were back to nearly their pre-drop level [...] and most securities had reverted back to trading at prices reflecting true consensus values” (CFTC & SEC, 2010).

HFT gained prominence in the media after the most severe price drop in history. On Tuesday, April 21, 2015, British authorities arrested a person on charges of fraud manipulation and spoofing, among a lengthy list of other charges. There was a name behind the story of May 6, 2010 to blame. This name is Navinder Singh Sarao.

### 1.1 Navinder Singh Sarao

Navinder Singh Sarao is a 36-year-old trader from Hounslow. He was born and raised in the UK and graduated from Brunel University in West London. He worked in the banking sector before becoming a day trader. He was the man accused of causing the U.S. market crash in 2010. He was charged with 22 of criminal activities by the U.S. department of Justice, including wire fraud, commodities fraud, commodities manipulation and spoofing. Justice Department investigators assumed that Sarao caused the 2010 down crash and played a significant role in creating market imbalance. Sarao's illegal algorithmic trading strategies were recorded in the derivatives markets and the stock markets. He made about \$ 200 million worth of orders betting that the market would fall (Viswanatha and Hope, 2015). At that time, that amount represented 20-29% of all market orders. He is accredited with making \$ 40 million in profits between 2010 and 2014.

### 1.2 Lawsuit

Unlike previous rogue traders who caused billions of dollars in losses, such as Nick Leeson from Barings Bank, and Jérôme Kerviel from Société Générale, Sarao did not have the balance sheet of a big financial institution behind him. Though Sarao claims that "he has not done anything wrong apart from being good at his job" (WSJ, 2015), the U.S. court asked his extradition. According to FBI's investigators, "Sarao did not only place fake orders to manipulate the market but he is also accused of causing the flash crash" (BBC, 2016). The strategy that he used and that was supposed to provoke the crash, was the spoofing (which is explained above).

According to Mr Sarao's barrister James Lewis, "Sarao could not, as the FBI allege, have materially contributed to the flash crash of 2010 and therefore he attacked those claims, pointing the growing body in the City and in academia". Thereafter, Sarao said that "he had canceled large

volumes of orders manually, without the help of an automated trading program” but prosecutors allege him that he created an automated trading algorithm that allowed him to quickly place, modify and cancel orders. Moreover, prosecutors alleged Mr. Sarao of setting up an offshore entity in Anguilla to avoid taxes (BBC, 2016).

In parts of London’s financial community, Sarao’s arrest and indictment were greeted with incredulity. They were pretty surprised when they read about the arrest of a London based futures trader for allegedly causing the flash crash of 2010. How could a small-time trader with limited means help to almost bring down one of the world’s biggest and most liquid financial markets? After asking experts in the fields of HFT “if they believe that Sarao cause the flash crash” we obtained following answers. We have to take into account that these opinions are not scientific proofs but are simply based on professionals HFTs knowledge and opinion.

According to Adrian Ip (HFTs), layering is an extremely common activity in the market. According to him, the fact that Sarao’s manipulative activity contributed to the flash crash is very surprising due to the fact that authorities are looking to pin the flash crash on one person. From his experience, there are other participants as market makers, HFTs, algorithm traders who took benefit from volatility of the market and other companies that made a lot of money on that day.

Another person who does not believe in the determinant role of Sarao strategy in the flash crash, is his ex-former employer, Paolo Rossi (chairman and Founder of Futex), who said that “a million thing were a contributing factor to the crash but Sarao did not cause it” (Bloomberg, 2015).

Not only the financial community is sceptic about the fact that only one person could cause the flash crash. On April 22, 2015, the Financial Times posed in his editorial: “Why was it that the market so closely resembled a powder keg?”

The flash crash shocked investors, traders and regulators. For a moment, shares in some companies such as Accenture PLC, traded for one cent. Nearly one trillion of dollars of value was temporarily erased before being restored. HFTs believe that authorities are looking for a

scapegoat instead on focusing on real matters as creating a better system. Finally, they do not believe that one person could have intentionally caused the flash crash.

Last year, Sarao had been extradited and he pleaded guilty to spoofing. He admitted: “using an automated trading program to manipulate the market for S&P 500 futures contracts.”

### 1.3 A recap of an Expert Analysis from Kirilenko et al. (2011)

In a 2010 study of the Flash Crash, the SEC and the CFTC found that HFTs substantially increased volatility during the event and accelerated the crash. Kirilenko et al. (2011) studied the 2010 Flash Crash and found the same, concluding that high frequency traders "can amplify a directional price move and significantly add to volatility." Menkveld and Yueshen (2015) confirmed the U.S. government's and Kirilenko's narratives about the flash crash.

After the results (SEC & CFTC) were released in 2010, Kirilenko et al. (2011) later published a report further investigating the structure of the flash crash. They attempted to answer three questions:

- “How did HFTs trade on May 6?”
- “What may have triggered the Flash Crash?”
- “What role did HFTs play in the Flash Crash?”

The origin was the analysis of the U.S. Equity Indices on May 6, 2010. As shown in the Figure 12 (above), we noticed that the E-mini S&P 500 has the same trend as the DJIA and the S&P 500. Table 2 presents the Equity indices drop on May 6, 2010.

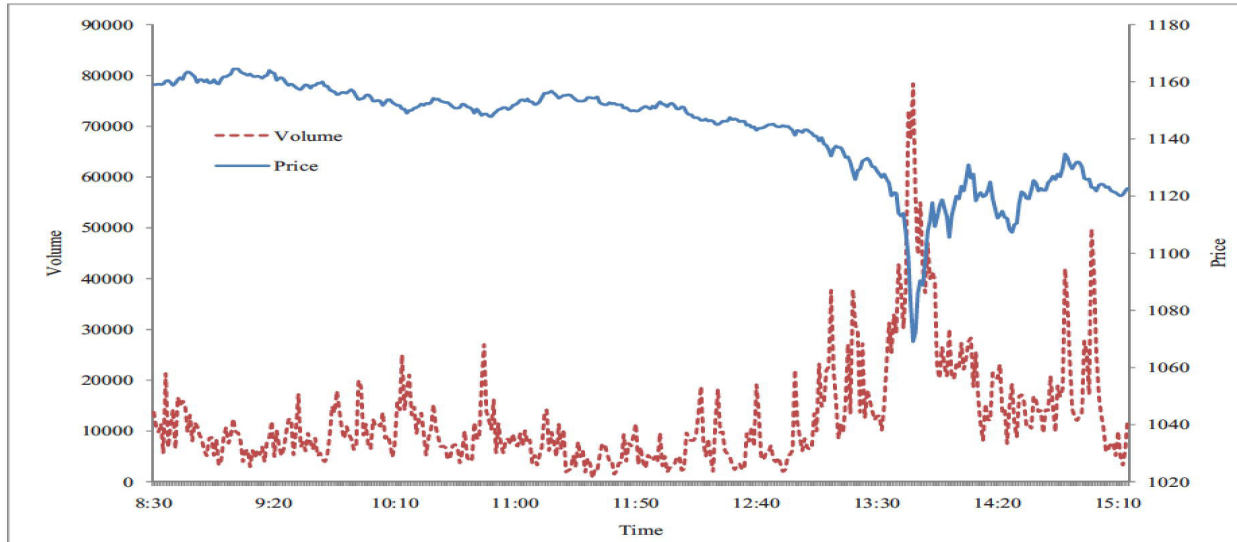
**Table 2:** U.S. Equity Indices on May 6, 2010

Indices	Dropped to
<b>DJIA</b>	9,872.57
<b>S&amp;P 500</b>	1,065.79
<b>E-mini S&amp;P 500</b>	1,056.00

Source: Kirilenko et al. (2011)

In the course of 13 minutes, the E-mini S&P 500 declined by 5.1%. Then it dropped another 1.3 % again a second later (13:45:27), due to cascading orders. The next transaction (13:45:28), triggered the CME Globex Stop Logic Functionality<sup>7</sup> (SLF), because the market would be operating out of its predefined bounds and would experience a drop in price of 6.5 index points, if the SLF safety function failed to turn on. The SLF stopped all transactions for five seconds (called “Reserve State”) and allowed additional bids/offers to enter as the market remained open. After the Reserve State time, the E-mini S&P 500 quickly rebounded. The price reached 1,123.75 at 14:06, which was close to the previous price at 13:32:00, as shown in Figure 13.

**Figure 13:** Prices and Trading Volume of the E-Mini S&P 500 Stock Index Futures Contract



Source: Kirilenko et al. (2011)

Furthermore, the study analyzed the day of the Flash Crash and the day prior to that, May 5-6, 2010. It first examined the “audit trail” transaction-level data from all regular transactions in the June 2010 E-mini S&P futures contract. The dataset for this study was retrieved from the Trade Capture Report (TCR). The results have been summarized in Table 3

<sup>7</sup> Stop Logic Functionality: “A provision applicable to futures traded on the CME’s Globex electronic trading system designed to prevent excessive price movements caused by cascading stop orders. Stop Logic Functionality introduces a momentary pause in matching (Reserved State) when triggered stops would cause the market to trade outside predefined values. The momentary pause provides an opportunity for additional bids or offers to be posted.”

**Table 3:** Trading Volume During the Flash Crash

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

	Panel B: May 6th			
	DOWN		UP	
	Sell	Buy	Sell	Buy
High Frequency Traders	152,436	153,804	191,490	189,013
Intermediaries	32,489	33,694	47,348	45,782
Fundamental Buyers	28,694	78,359	55,243	165,612
Fundamental Sellers	94,101	10,502	145,396	35,219
Opportunistic Traders	189,790	221,236	302,417	306,326
Small Traders	1,032	947	1,531	1,473

Source: Kirilenko et al. 2011

Panel A (May 3-5) and B (May 6) results indicate the average number of contracts sold or bought by the 6 categories of traders, during the down and up periods (Kirilenko et al. (2011).

- The Down period started at 13:32:00 and stopped at 13:45:33 CT.

- The Up period started at 13:45:33 and stopped at 14:08:00

Both panels experienced different volumes changes. We immediately saw a huge increase in the number of contracts that were bought and sold on May 6. During the down phase, HFTs made gross sales of 152,436 contracts. This quantity was six times the gross sales of HFTs during the same period (May 3-5).

There are six categories of traders because holding horizons and trading strategies vary from trader to trader. Some traders take intra-day positions while others hold positions overnight. Some trade thousands of contracts every day, while others trade few.

1. HFTs are generally defined as “market makers with very large daily trading frequency. For classification purposes, the top 3% of the market makers sorted by the number of trades were designated as HFTs” (Kirilenko et al. (2011).
2. Intermediaries or Markets makers are defined as “short horizon investors who follow a strategy of buying and selling a large number of contracts to stay around a relatively low target level of inventory” (Kirilenko et al. (2011).
3. Fundamental traders which can be buyers or sellers. They are defined as “trading accounts which mostly bought or sold in the same direction during May 6” (Kirilenko, Kyle,

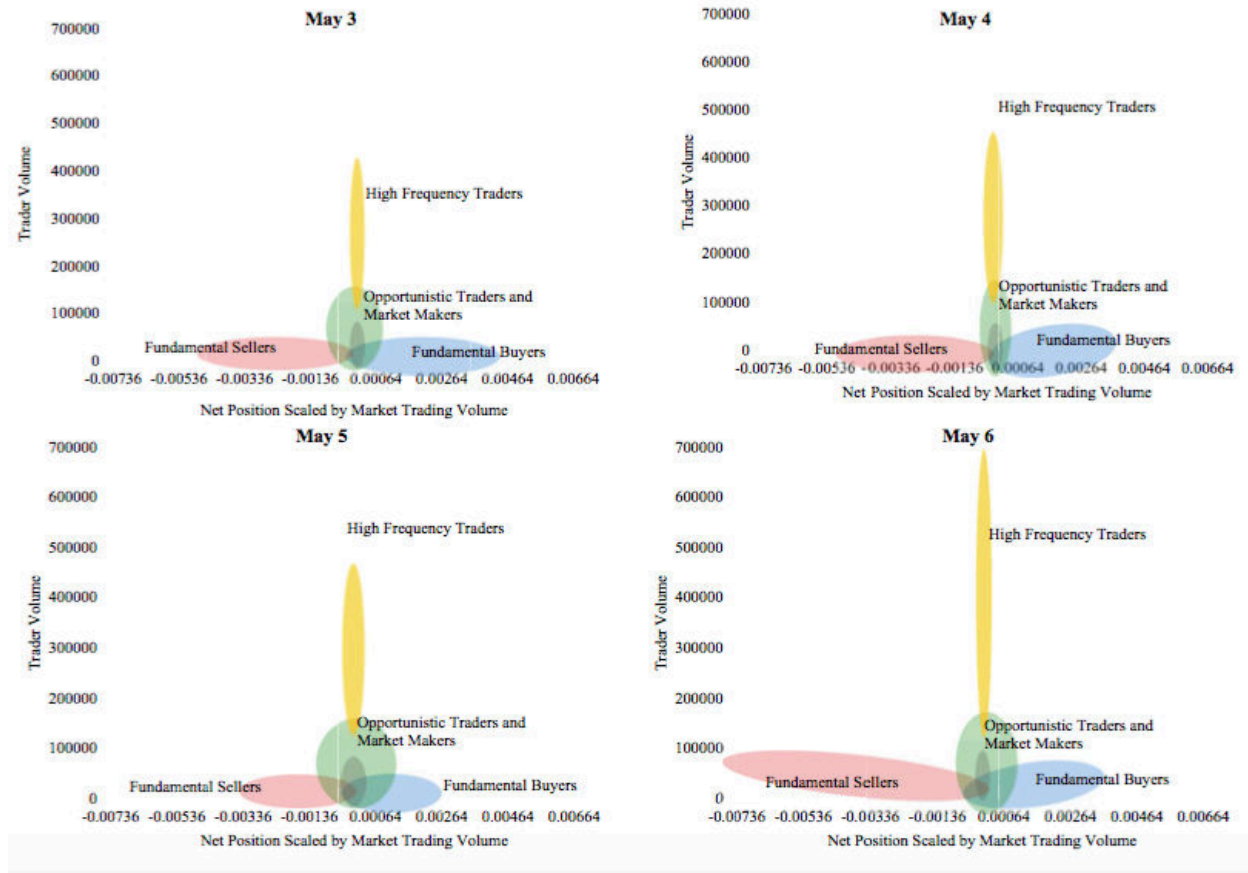
Samadi & Tuzun, 2011). The criteria that will decide whether they are buyers or sellers is their net position at the end of the day. If it is positive, they are buyers, in the other case they are sellers.

4. Opportunistic Traders “may behave like market makers (both buying and selling around a target net position) and at other times may behave like Fundamental Traders (accumulating a directional long and short position)” (Kirilenko et al. (2011).
5. Small Traders are defined as a “trading account which traded no greater than 9 contracts on May 6.” (Kirilenko et al. (2011).

In the report (Kirilenko et al. (2011) it was found that these six categories of traders have a quite distinct goal but have some overlap positions in a liquid market “ecosystem” as shown in Figure 14.

**Figure 14:** Trading accounts trading Volume and Net Position Scaled by Market Trading

Volume



Source: Kirilenko et al. 2011

Table 4 presents market descriptive statistics for these categories of traders for the June 2010 E-Mini S&P 500 futures contracts during May 3-5 and on May 6, 2010.

**Table 4:** Market Descriptive Statistics

	May 3-5	May 6th
Daily Trading 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%
Log High-Low Range	1.54%	9.82%
Return	-0.02%	-3.05%

The first column reports average statistics for the three days prior to the Flash Crash, May 3-5 and the second column gives statistics for the day of the Flash Crash. We again see the difference between both periods. We can see a massive influx of traders participating in the market on May 6.

Source: Kirilenko et al. 2011

According to Table 4, on May 6, the daily trading volume was significantly higher (5,094,703) corresponding approximately to twice the average volume of 2,397,639 contracts during the previous three days. If we take a look at the other market descriptive statistics (size, order, limit order % volume, and limit orders % trades), they do not fluctuate excessively. We can conclude that the behavior of an individual trader did not necessarily change, however the strategy has maybe changed.

Table 5 presents orders properties for each trader category. The authors created two columns “Agg Ratio Trade-Weighted” and “Agg Ratio Vol-Weighted” which measure aggressiveness in orders<sup>8</sup>. Aggressive orders take market liquidity while passive orders provide market liquidity. According to Table 5, the findings show interesting solutions. We observe that HFTs and Intermediaries add market liquidity while Fundamental Traders consume more market liquidity.

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<sup>8</sup> An aggressive order is when it is executed against a “passive” order that was resting in the limit order book.

Table 5: Order Properties

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	Return
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		
All	2,397,639	446,340	11,875	5.41	10.83	95.45%	94.36%	1.54%		-0.02%

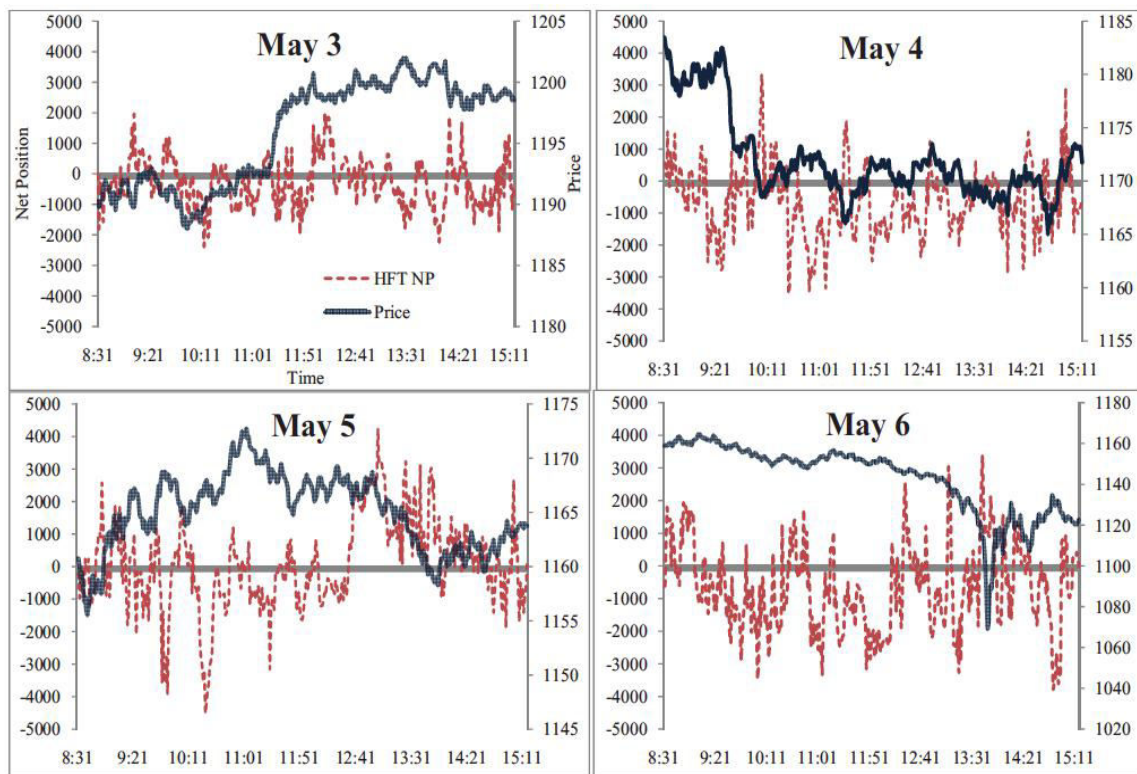
Panel B: May 6th										
Trader Type	% Volume	% of Trades	# Traders	Trade Size (Avg.)	Order Size (Avg.)	Limit Orders % Volume	Limit Orders % Trades	Agg Ratio Trade-Weighted	Agg Ratio Vol-Weighted	Return
High Frequency Traders	28.57%	29.35%	16	4.85	9.86	99.997%	99.997%	50.38%	45.53%	
Intermediaries	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		
All	5,094,703	1,030,204	15,422	4.99	9.76	92.413%	91.750%	9.82%		-3.05%

Source: Kirilenko et al. 2011

In the report, the severe drop in market prices was explained by two factors. The first is the fact that HFTs continue to compete for market liquidity with Fundamental Sellers. The second is explained by the “hot potato” effect which consists in positions being moved back and forth between HFTs and other market makers.

In order to get an idea of the net positions of HFTs and Intermediaries, authors analyzed the change in net positions of these traders. Figure 15 shows that from May 3-6, the net positions of HFTs fluctuated by approximately 3,000 contracts and had a mean close to 0.

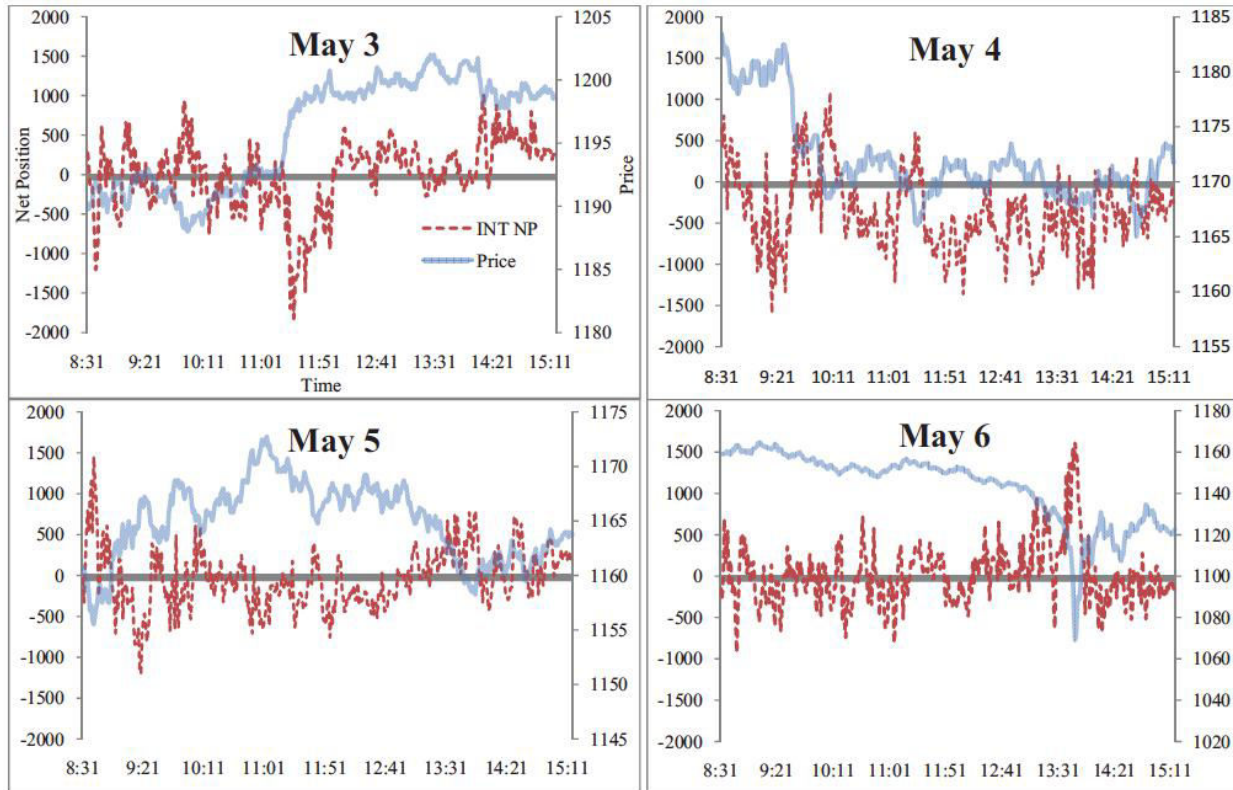
**Figure 15:** Net Positions of High Frequency Traders



Source: Kirilenko et al. 2011

Figure 16 shows that from May 3-6, the net positions of intermediaries are quite similar to the HFTs. They behave like HFTs during the same day interval with a mean that is close to 0.

**Figure 16:** Net Positions of intermediaries



Source: Kirilenko et al. 2011

From Figures 15 and 16, we can conclude that HFTs had the same behavior as intermediaries over the four-day period but during May 6, 2010 HFTs accumulated a net long position and were able to sell their long inventory before prices fell at a faster rate. In contrary, the Intermediaries held their net long position longer than HFTs.

This report has shown that the Flash Crash of May 6, 2010 was one of the most important events regarding the role of HFTs. It also displayed that HFTs increase price volatility when they start selling (looking for liquidity) in the market. Finally, it proves the fragility of the financial ecosystem.

#### 1.4 A recap of an Expert Analysis from Boulton, et al. (2014)

This chapter investigates the impact of the Flash Crash on May 6, 2010 on market participants. Much of the current academic literature has focused on developing metrics that indicate the probability of flash crash occurrence before the event takes place.

The research paper called “The Flash Crash: Effect on Shareholders Wealth and Market Quality” from Boulton, Braga-Alves and Kulchania (2014) demonstrates that “the flash crash was not just a 20-minute glitch as it has been described in the popular press. Overall, the flash crash was a significant event that affected shareholder wealth, trading costs, and volatility of stock.”

To arrive to this conclusion, they realized an event study. They decided to pick the May 6 flash crash as an event and observed the following trading days. They collected 29 U.S. stocks from the NYSE and they divided them into two groups: base sample (stocks which consist of executed trades on May 06, 2010 and respectively cancelled by either Nasdaq or NYSE Arca) and matched sample (stocks which were matched with the base sample based on the price, turnover measure, the volume of daily traded shares, market capitalization and volatility). The control period enclosed 255 trading days that ended 46 days before the flash crash and the studied sample represented 29 NYSE-listed firms. The analysis of the abnormal returns was based on the Fama-French (1993) three-factor model and Cahart’s (1997) momentum factor.

In this way, the paper gives us a broad perspective of the change in shareholders’ wealth due to the flash crash. Indeed, the flash crash occurred on May 06, 2010 and recovered in a span of few minutes but it managed to have a great impact on the financial market and erode the shareholders’ wealth substantially.

#### 1.5 The role of the media

The Flash Crash episode raised such a controversy because articles were depicting HFTs as certain privileged traders trying to front-run orders from innocent retail investors. The press certainly led everyone to believe that huge banks such as Goldman Sachs and big hedge funds such as Renaissance are big players in HFT, but this is not necessarily the case.

The emergence of HFT in the market received a lot of attention and people could see that the U.S. equity markets had been captured by HFT. It raises some questions for people who do not deal with financial subjects.

Such a quick change in prices scared people. The May 6 flash crash was a good example of how pervasively HFT had entered the market because it shows what happens when HFTs are in action. We can suggest that the fear of HFT derives from ignorance. This is probably the biggest challenge to overcome right now in terms of public opinion about this practice. HFT is not a monolith; it does not consist of one type of firms, it can be led by different types of institutions such as banks, proprietary trading firms, and hedge funds. They have different time horizons and different strategies. The only characteristic that makes them similar is an intensive use of new computer technologies.

## **2. AFTER THE FLASH CRASH**

After May 6, 2010, an abundance of unanswered questions remained as the entire financial world sought to find a reasonable explanation for the events that had befallen the market. What needed to be done to prevent this type of event from happening again? Who was guilty? Why did market keep going out of control so rapidly? What needed to be done?

All the questions arise from around to world. The SEC and the CFTC said they were examining the cause of the unusual trading activity. After the Flash Crash, they decided to implement rules that will help to avoid this kind of events.

### **2.1 Stub quotes**

On May 24, 2010, the SEC and the CFTC hosted their first meeting. As a result, they decided to eliminate traders' use of stub quotes. By a stub quote, the SEC meant: "an offer to buy or sell a stock at a price so far away from the prevailing market that it is not intended to be executed, such as an order to buy at a penny or an offer to sell at \$ 100,000." (U.S. SEC, 2010d)

Stub quotes were used by companies when they did not want to trade. When a company wanted to pull away and ensure that no trades occurred, it offered quotes that were wildly out of bounds. In a normal context, such trades would not get executed, but investigators of the flash crash believed that some traders were suddenly executed unintentionally at stub-quote prices during the afternoon of May 6.

The aim of removing these orders from the markets was to prevent trades from being carried out at an irrational price. Under the new system, orders sent to the market must be within a price range not exceeding a certain limit above or below the last available price for that security. This limit may vary between 8% and 30%, depending on the market.

## 2.2 Circuit breakers

As explained in the Black Monday section, circuit breakers appeared for the first time in October 19, 1987, but there was no use of them during May 6, 2010 (Koba, 2011).

There are two types of circuit breakers (single-stock circuit breakers and market wide circuit breakers) that are used by regulators around the world. The settings can vary significantly from one to another, depending on the national policy of the country. For practical questions, we will focus mainly on U.S. and EU financial markets.

### a. Single-stock circuit breakers

On June 10, 2010 the SEC approved rules that required the exchanges and the Financial Industry Regulatory Authority (FINRA) to pause trading in certain individual stocks.

Under the rules, trading in a concrete stock would pause across U.S. equity markets for a five-minute period in the case when the stock experienced a 10% change in price over the preceding five minutes. The pause, which would apply to stocks in the S&P 500 and would give the markets the opportunity to attract new trading interests in an affected stock, establish a reasonable market

price, and resume trading in a fair and traditional way. This rule will be applied to all financial securities exchanged on the NMS Securities starting from June 2011 (U.S. SEC, 2010c).

Circuit breakers exist in EU as well and have the same functions as in the U.S. Their functioning will depend on such factors as volatility, volume exchange, etc. and the threshold of application will be lower. In particular, the pause will be applied if prices experience at least 3% change in the last 5 minutes (Grant, 2010).

#### b. Market-wide circuit breakers

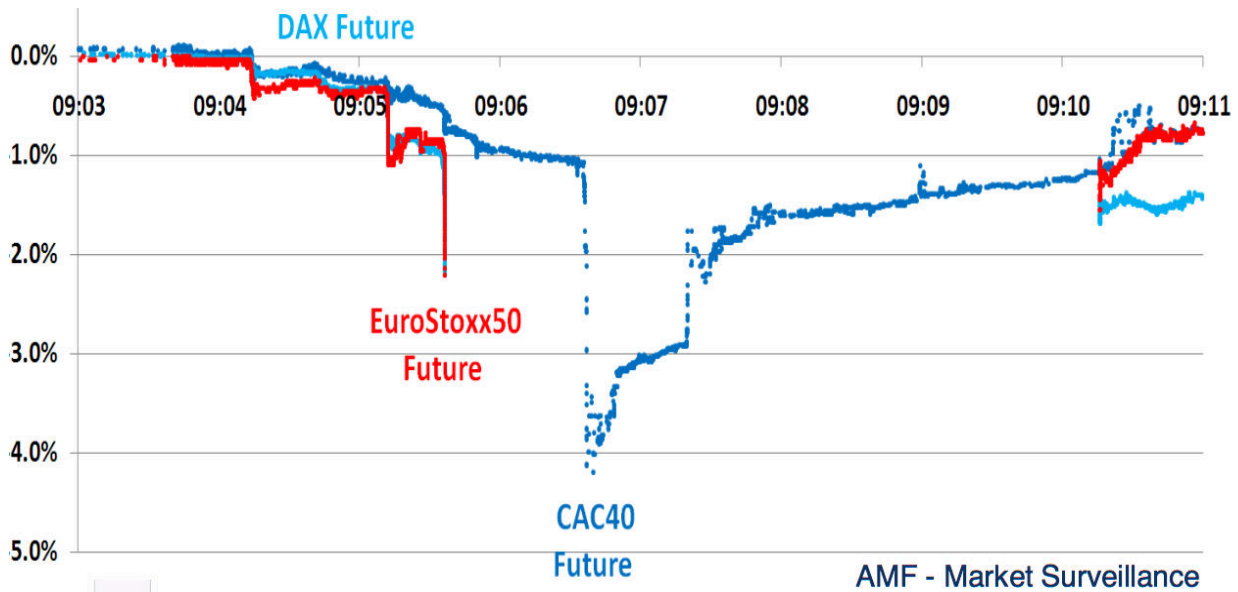
Additionally, there are other kinds of circuit breakers. They are called market-wide circuit breakers. These can stop the listing of all the securities traded on the U.S. stock exchanges.

In order to avoid a chain reaction on the various stock markets during a crash, the SEC decided to make a circuit breaker on the S&P 500 index that has the capability of temporarily closing all the NMS Securities. The step of closing of all stock markets for the rest of the day automatically applies when prices vary by more than 20%. The price changes of the index are calculated at each moment in relation to the price of the index at the last closing trading session (U.S. SEC, 2010c).

In the context of EU, there are no market-wide circuit breakers because each market has its own circuit breaker. Which means that the activation of the circuit breaker on the Euro Stoxx 50 market would not stop the French index CAC40.

Moreover, there is some criticism surrounding circuit breakers. Instead of curbing the fear, it elevates it. However, the following figure (Figure 17) demonstrates the efficiency of circuit breakers.

**Figure 17:** European indices during the mini crash of 27 December 2010



Source: Grillet-Auert, 2011

The result from the pause was that DAX Future and EuroStoxx50 Future had a drop of around 2% due to the circuit breaker that suspended the quotation for 5 minutes. The CAC40 Future, which did not activate the circuit breaker, suffered a drop of 4%.

### 2.3 Limit Up-Limit Down

In May 2012, the SEC approved a new NMS regulation plan in order to address extreme market volatility by creating a market wide Limit Up – Limit Down (LULD) that replaced the single-stock circuit breaker rules. This regulation occurs due to the highly frequent activation of circuit breakers placed on certain market securities. Exchanges were sometimes suspending unnecessarily the quotation of a security for several minutes due to erroneous pricing. This new LULD system is, therefore, designed with more specificities to avoid unnecessary activation of certain circuit breakers. LULD allows the market to recover independently. In the event of price movements exceeding the authorized limit 5%, 10 %, 20 % or 75% and depending on the security concerned and its usual volatility rate, the system will allow 15 seconds for the movement to stabilize and return to a reasonable price level within the allowed price range (U.S. SEC, 2010c).

## 2.4 Rule 48

The primary purpose of circuit breakers is to calm the possible panic that can spread among investors, in order to avoid an unjustified fall or increase in the price of a financial security. Table 6 shows that circuit breakers are divided into three levels.

**Table 6:** Downtime when circuit breaker is activated

	<b>Trigger</b>	<b>Between 9:30 am and 3:25 pm</b>	<b>After 3:25</b>
<b>LEVEL I</b>	7%	15 min	0 min
<b>LEVEL II</b>	13%	15 min	0 min
<b>LEVEL III</b>	20%	All day	All day

However, on December 2007, the SEC approved a new rule, called Rule 48 which consists in making easier and faster to open the stock markets when there are fears that the market could open with a lot of volatility that would disrupt trading.

To appeal to Rule 48, the Exchange would have to determine that certain conditions occur and so would cause market disruptions. Those conditions include:

1. Volatility during the previous day's trading session;
2. Trading in foreign markets before the open;
3. Substantial activity in the futures market before the open;
4. The volume of pre-opening indications of interest.

## Chapter 4: Regulation of High Frequency Trading

As it was noticed by Menkveld (2014), the HFT quickly caught the attention of the general public because of a few extreme and dramatic momentary price drops or spikes during the past few years of which the Flash Crash in May 2010 is the most notorious one.

According to the U.S. Securities and Exchange Commission “the mission of the SEC is to protect investors; maintain fair, orderly, and efficient markets; and facilitate capital formation”. The SEC strives to promote a market environment that is worthy of the public’s trust. In this way, new regulation was adopted in order to control HFT activities in the U.S. as well as in EU markets.

### 1. U.S. market

To prevent the evolution of IT in financial market, the regulation of ATS first appeared on April 21, 1999. It comprised systems called proprietary trading systems, broker-dealer trading systems and ECN. The SEC wanted to introduce more transparency in the markets. According to Arnuk and Saluzzi (2012), Regulation ATS “required alternative trading systems that trade five percent or more of the volume in NMS securities to be tied with a registered market in order to advertise the best priced orders in those national market system securities advertised in their systems (including institutional orders) into the public quote stream” (Arnuk and Saluzzi, 2012, p.69).

As of April 9, 2001, the SEC requires all the U.S. exchanges to convert to decimals. Previously, stocks prices had to be measured to the sixteenths of a dollar, or 6.25 cents. Now price increases can be measured to the penny, leading to smaller fluctuations in price and smaller commission possible.

On June 9, 2005, the NMS was established by the SEC. It improved the U.S. exchange by enabling greater fairness in terms of price execution, boosting the display of quotes, and promoting more connections to market data. This regulation consisted of the order protection rule that aimed to ensure that the investors received the best price when their orders were executed. This was implemented by eliminating the ability to have orders traded (executed at the worst

price) through the access rule, by requiring greater linking and lower access fees; and the sub-penny rule, which sets quotation increments of all stocks over \$ 1.00 per share to at least \$ 0.01. In addition, Regulation NMS included market data rules that allotted revenue to Self-Regulatory Organizations (SRO) that advocated and upgraded market data. As a result, traders were able to leverage and profit from any small price differences between exchanges if they were fast enough. (Agarwal, 2012)

In January, 2010, the SEC solicited comments on the impact of HFT strategies on the quality and integrity of markets. After the Flash Crash, the SEC and CFTC formed a joint committee to present instructions on emerging regulatory concerns in May 2010. In February 2011, they delivered a report with regulatory response recommendations to the Flash Crash. The following years, the SEC has implemented several regulations and systems intended at restricting the adverse behavior of HFTs. These include Market Information Data Analytics System (MIDAS), the Consolidated Audit Trail (CAT), Regulation System Compliance and Integrity (Reg SCI), Large Trader Reporting Rule, rule 15c3-5 to prohibit HFT firms from receiving raw access and introduction of new circuit breakers (Shorter & Miller, 2014).

One of the most important initiatives from the SEC is MIDAS<sup>9</sup> which was initiated in 2012. Its purpose was to gather trading information data from markets in the U.S. It authorizes the SEC to review in details the incident which was not possible several years ago. This system allowed to collect publicly available information. Additionally, a new regulation called CAT was voted in 2012 which involved that all registered stock exchanges and Self-Regulatory Organizations keep an audit trail of trading activity. This system allowed to collect private information.

On March 7, 2013, the Chairman of the SEC, Elisse Walter announced “a new regulation targeting technological challenges facing US markets.” Regulation SCI has been created as a direct consequence of recent and historical events related to technological breakdowns in the market. This regulation is not specifically targeting HFT as such. Indeed, HFT is not mentioned once in the 104 pages long proposed regulation but takes a wide approach to address all software related problems in the U.S. market. Although HFT might be the origin of the entire technology

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debate in the U.S., it has been fueled during recent years by incidents with technology breakdowns. We can give such examples as Black Monday, Knight Capital and BATS which have made the general public very aware of the consequences of software errors in trading systems.

## **2. EU market**

The Markets in Financial Instruments Directive (MiFID) 1 was implemented in 2007 (Bréhier, 2013), Its purpose was to strengthen and modernize the international financial system, including promoting competition between Stock Exchange. But in 2012 it was already starting to be revised due to the financial crisis that exposed weaknesses in the transparency of financial markets. MiFID 1 was European Markets' Regulation ATS. (Gregoriou, 2015).

On December 2010, The European Commission's MiFID Review Consultation document (European Commission, 2010) put forth several regulatory proposals on automated trading and HFT. MiFID II, which applies to all Member States within the EU, was passed in 2014. Regulations from MiFID II deal with the growth of HFT as well as algorithmic trading (AT). The European Securities and Market Authority (ESMA) are making a clear distinction between AT and HFT to make the regulation more appropriate and to help the market participants to apply the rules. MiFID II states that any person who is dealing with HFT falls under the rules and regulations set forth by MiFID II (Gregoriou, 2015). It also states that all HFT firms have to register, have to keep records about all orders placed, cancelled and executed, and that all records need to be available for the authorities upon request to make sure that the proper regulations are followed (Gregoriou, 2015).

MiFID II ambition was to establish a transparent financial system. It included the first EU-based regulatory curbs on HFT activities, including the requirement to install circuit breakers, requirement to get authorization by regulators on trading algorithms and the obligations to store all trade orders. (Shorter & Miller, 2014)

### **3. Other markets**

The authorities in other countries have also taken the initiative to regulate the activity of HFTs by creating regulation bodies and adopting different measures.

In this way, in April 2011, the Canadian Securities Administrators (CSA) published a rule for comment focused on the risks associated with automated trading.

As for the Asia-Pacific market, regulators have also been investigating the effect of HFT on the health of financial markets. In March 2010, the Securities and Exchange Board of India (SEBI) set up a Technology Advisory Committee to advise on matters pertaining to HFT co-location services, and security issues related to internet-based trading.

In November, 2010, the Australian Securities and Investment Commission issued a consultation package on updating the equity markets regulation which also looked at the benefits and challenges arising from HFT.

## Chapter 5: Qualitative analysis

Many voices ask today for new policies to regulate HFT activities. The goal of this section is to outline what experts in different financial fields think about HFT and to understand the following question regarding HFT: “Is HFT good for the financial market?”

A number of scientific studies have been carried out on the subject (Kirilenko *et. al.* (2011) ; Brogaard *et. al.* (2011); ...). They mostly focus on the question whether HFT has a positive or negative impact on the financial market in terms of such criteria as liquidity, volatility, efficiency and bid-ask spread, resulting in an nearly unanimous conclusion that HFT is in fact beneficial for the market. Consequently, these conclusions lead to an interesting paradox. While questioning people with no or little knowledge in the field of finance, HFT gets a bad score due to the overheated debate produced by the media, which resulted in a risk of undermining the trust of the financial market. Another possibility is the deficiency in the data used by academic researchers, which did not scientifically examine all the vital aspects of the issue, as they did not approach it from all perspectives.

### 1. Research Method

A big part of previous studies (Golub *et. al.* (2012); Brogaard *et. al.* (2012); ...) on the subject had a quantitative nature, they were analyzing the functioning of HFT using intraday data from foreign exchange and equity markets. This thesis will complete the existing literature in one major way: it will address the subjective opinions and concerns of people from the industry.

As the first step, to investigate and understand the potential consequences of HFT, I used a survey to obtain general public opinions regarding the issues of fairness, ethics and effectiveness levels, but the obtained result was not significant and nor appropriate for interpretation due to the misunderstandings of the respondents (public opinion) of what HFT is and its role in the financial market. A gap was identified between the media debate and the scientific research. My last result from this survey has shown that public opinion is that HFT is bad for the society which was highly correlated to the Flash Crash coverage by the media.

The result from this survey was the regulation “slow down the market” which according to the respondents was the most appropriate because it would have eliminated the discriminating speed advantage of HFT. Figure 18 shows the scores that this type of regulation obtained according to such criteria as effectiveness, efficiency, equity, manageability and political feasibility.

Figure 18: Criteria appreciation of “slow down the market” option



Source: mokey.com

In order to deepen the analysis and obtain more relevant opinions compared to the simple general public appreciation, an additional survey has been carried out this time in form of personal interviews with professionals of the field. It was also made because HFT is a phenomenon where improvement is made extremely fast and consequently, opinions change rapidly.

The advantages of performing open interviews come from the fact of direct interaction with the interviewees which is opposed to a closed survey where the interviewee answers to predefined questions limited by concrete options. Open interviews have been chosen for this study because they give respondents more flexibility in their answers which give them the possibility to raise

subjects that they consider as important. It enables to obtain deeper insights on the studied subject.

Therefore, I decided to get two views from two lobbies which have different goals as well as from external professionals. This survey was built around different hypothesis that emerged from my previous study. In this way, I arrived at a total of 5 hypotheses that I will explain below and for each hypothesis I associated a neutral question to ask to my interlocutors. The assumptions expressed in the hypotheses are a little biased and it is for this reason that I preferred to keep a neutral question so as to have no influence on my interlocutors. Each question may lead to other sub-questions related to the main hypothesis, but this will be detailed in the next section “methodology”.

**Hypothesis 1:** *HFT is bad for the financial market.*

According to the public opinion, the positive effects of HFT are hardly detectable, very ambiguous and far from unanimous, while the negative effects have already been shown and can be much more devastating. Consequently, the general opinion was that HFT is bad for the financial market. The question associated with this hypothesis is the following: “Do you think HFT is good or bad for the financial market?”

**Hypothesis 2:** *Thanks to the high technology and their algorithms, HFTs took advantage from an unfair competition.*

The survey has shown that the technology enjoyed by HFTs is very expensive and therefore accessible to very few people which makes impossible any competition with a traditional trader. The question will be “Do you think that HFTs got an unfair advantage in comparison to traditional investors?”

**Hypothesis 3** *The Flash Crash was caused by Sarao who used HFT strategies to manipulate the market.*

The fact that Sarao used high speed frequency trading has marked him as a very potential suspect without any concern from the survey and that is why I asked “Do you think Sarao was guilty for the 2010 Flash Crash?”

**Hypothesis 4** *Slow Down the market is the best regulation.*

As I proposed different regulation options, this one was judged to be the most appropriate one according to the different criteria and so I wanted to know the positions of professionals on this subject and therefore my question was “Do you think that HFT needs regulations to be implemented?”

**Hypothesis 5** *HFT will be the reason of the next crisis.*

Here, I was a surprise to discover that many respondents believed that HFT will be the cause of the next crisis. I decided to ask to my interviewees “Do you think that HFT can be the cause of a crisis?”

This thesis addresses HFT from a qualitative research method through a questionnaire with open questions and interviews by phone were applied in order to give the participators an opportunity to freely discuss on the subject of proposed questions. In this way, the empirical content of this study will be represented by opinions of different kinds of respondents and capture the concerns regarding HFT.

## **2. Methodology**

To facilitate the conversation and to be able to the respondents in the right direction an interview guide has been created (See Appendix VIII). All questions in the guide have not necessarily been asked but have rather been used as suggestions of subjects to keep the conversation flowing. This

guide is built up around issues discussed in previous research (survey on general public opinion) and the interviews have revolved around these. This guide has only been used to the extent to give a similar structure to the interviews as our main objective was to encourage respondents to speak freely.

Interviews also allow an understanding of the problem and not only looking at the frequency of an answer. Compared to quantitative questionnaires which aim is to obtain general statistics that reflect the opinion of the sample, open interviews enable the researcher to go more in depth of the respondent opinion. By performing interviews, the source of the difference can be identified and not only how often this difference might occur

Attention has been paid to the fact that respondents are subjective in their affirmations and that their answers may not be taken for facts. It is interesting to see how the answers in the interviews correlate with already published and known research. Even more interesting is if the interviews were to point out some new points that the academic research not yet has.

## 2.1 Identifying suitable contacts

In order to identify a relevant study sample that matches my selection criteria and get relevant opinions on the subject, I needed to contact people who have more profound knowledge of HFT subject. As a result, I managed to take contact with representatives of the academic world and professionals in the field of finance. This research has been made via the personal network of the first and second degree. In the end, four professionals agreed to give an interview.

## 2.2 Questionnaire design and structure

When structuring my questionnaire, I needed to be clear in questions proposed and explain precisely what kind of information I wanted to collect. Semi-structured interviews type was selected as it allows the respondents to express and develop thoughts by their own wishes. Here the objective was to approach HFT from a different perspective compared to previous research, the ambition is to detect the roots causing the media debate.

To start the conversation and obtain information about the interviewees and their background, some introductory questions were first asked. This is aimed to explain why the respondents are relevant to this study. Together with previous knowledge this information is presented in the section "Profile of interviewees".

Then, questions about the concept of HFT were asked. Partly because it was found necessary to make sure the interviewees had an understating of HFT, secondly to get their general appreciation of the subject.

The questions about HFT were mainly taken from the media debate. Investors, for example, claimed through the media that HFTs do not play fair whereas professionals HFTs claims that HFT brings more liquidity, less volatility and smaller bid-ask spread. To get as broad picture as possible, an additional number of possible concerns were also written down in the interview guide. Several of these have previously been highlighted in the media debate and served as finishing questions to sum up the interviews.

### 2.3 Profile of interviewees

The issue of HFT is of high relevance to the society because there is a chance of hollowing the trust of the financial market when concerns of human market participants are not highlighted in scientific research. To conduct this study, it was important for me to get different opinions and not only one opinion. Since the aim is to capture as many different opinions of the issue as possible, with the help of Mikael Petitjean, I decided to confront the analysis of the "Sarao case" coming from the lobby "Finance Watch", a critic of the HFT, and those of the HFT industry itself by contacting the IMC Financial Markets and / or the FIA European Principal Traders Association or HFTs.

A total of four interviews have been performed which has been judged sufficient as many different opinions ranging from very positive to very negative have been captured. Neutral actor has also been found.

Due to one anonymity request from a respondent, he will now on be referred to as Individual 1. To still be able to argue why the respondents are relevant to this study the following descriptions of the interviewees have been made:

**Respondent n1:** Benoit Lallemand (Finance Watch)

Benoit Lallemand is the Secretary General of Finance Watch. He is an expert in market infrastructure, asset servicing and data reporting. He has ten years' experience in the clearing and settlement industry, most recently as senior internal consultant at Euroclear. He has also roots in the NGO world.

**Lobby n1:** Finance Watch is a non-profit public interest association which dedication is “to making finance work for society”. This association represents the opinions of trade unions, housing associations, think tanks, financial experts, foundations and millions of EU citizens.

The central principles of Finance Watch are i) that markets have to be fair and transparent, ii) that capital has to be brought to productive use, iii) that credit risk transfer to general society is unacceptable, and finally iv) that finance should serve the economy.

Its secretariat of this association is staffed by former finance professionals.

**Respondent n2:** Luc Henrad (BNP Paribas)

Luc Henrad has held several Board and Executive roles for Financial Institutions in Europe and in Asia. Since march 2010, Luc is the Chief Risk Officer (CRO) for all the operations of BNP Paribas in Luxembourg and a Member of the Executive Board of BGL BNP Paribas. He also holds several Board positions for the BNP Paribas Group. Mr Henrad is also a Professor at the Louvain School of Management of the Catholic University of Louvain and an Adjunct Professor at the School of Business and Management of the Hong Kong University of Science and Technology. His areas of teaching are Banking, Insurance, Risk Management, Financial Regulation, Financial Strategy and Corporate Governance.

**Respondent n3:** Ahn Nguyen (Nagelmackers Bank)

Anh Nguyen is a Senior Asset Manager at Nagelmackers Bank. There, he is member of the Bond Investment Committee and is also a Fund Analyst with a focus on the Fixed Income markets and the Alternative Investments. He is also one of the Co-Fund Manager of the Nagelmackers funds. He is also an Adjunct Professor at ICHEC Management School and the Catholic University of Louvain.

**Respondent n4:** Individual 1

The individual 1 is an asset manager for a relatively large fund management company where he is in charge of optimizing algorithmic order routing strategies. He has worked in different financial services before becoming HFTs.

**Lobby n2:** The FIA European Principal Traders Association (FIA EPTA) is an organization that represents more than 25 trading firms (clearing firms, exchanges, commodities specialists, etc.) in Europe that trade their own capital in options, futures, and equities markets worldwide. FIA EPTA declared mission is to supports transparent and safe markets, protect the integrity of financial systems and promote high standards of professional conduct. FIA EPTA members believe principal traders contribute significantly to markets by providing liquidity and enabling immediate risk transfer by others.

### 3. Results

This part consists in summarizing the different answers of my interlocutors which will serve to the future analysis in order to confirm or invalidate the basic hypotheses. Each question will be taken individually and corresponding answers will be exposed.

1. Do you believe that HFT is good or bad for the financial market?

**Benoit Lallemand** thinks that HFT is detrimental for several reasons. His main argument is that it does not contribute to the real economy. He points the usefulness of buying and selling thousands of orders in a few seconds, especially when we know that most of these orders were canceled.

According to him, HFT had nothing to do with the reduction of trading costs, quite the opposite. While automation of trading (or anything else) obviously brings costs down, strategies designed primarily to take advantage of technological or speed advantages actually push costs up for the entire trading community.

Recently he has written a note where he analyzes the costs, risks and benefits of HFT. He applied his analysis to each market intermediary and his main question was “Are the additional risks and costs that HFT brings to the trading environment were compensated by benefits to end-users, i.e. investors and issuers?”

The result that he obtained was that the outcome of additional costs and risks overwhelmingly outweigh the not-so-clear benefits put forward by exchanges and HFT firms. He analyzed different points such as infrastructures costs, trading costs, risks, abusive strategies and investor confidence.

Furthermore, according to his view, the sort of liquidity brought by HFTs is at best useless for traditional investors and often constitutes unnecessary intermediation. HFTs are essentially

liquidity takers, even in their activity of “passive” quoting, if it makes sense to call “passive” an order that is modified and potentially cancelled every other millisecond.

Finally, lower trading costs and more liquid markets are not absolute values and could in fact incentivize speculative behaviors, without proper safeguards.

In addition, he considers that HFT absorbs too many human resources (mathematicians, computer scientists, etc.) that would be more useful in other sectors. He also thinks that the risk of market infrastructure disruption is enormous as the order stuffing in a very short period of time represents a challenge for these infrastructures. Finally, the multiplication of flash crashes could have disastrous consequences on the economy.

**Luc Henrad** thinks that technology is never inherently good or bad. According to him, the basic principle was good because it was aimed to simply automate arbitration principles that took place at all times. According to his memory, in the trading room in the early 80s, there were arbitrageurs who were trading the US dollar side against the Deutsche Mark. The dollar was quoted in New York at one price and in Frankfurt at another price, which was giving the possibility to arbitrage. Today the usage of HFT helps to make the price more efficient by doing arbitrages. Then markets became more advanced and saw the derivatives that also led to arbitrages with the launch of future contracts, whether in the short-term interest rate or in the middle term. They resulted in more efficient rates that better reflected the perception of offer and real market demand and allowed a form of arbitrage in different products such as balance sheet or off-balance sheet products.

The concept of arbitrage is healthy because it allows market efficiency. According to his opinion, the efficiency exists when at any time when a market actor wants to make a transaction, the price is the same everywhere. The buyer and the seller face the net present value of this product that is equal to zero and if it is not equal to zero, it means that there is no market efficiency.

In this aspect, HFT contributes to the arbitrage but today technological development has gone too far. We no longer speak of arbitrage technique in terms of the cash flow decomposition, we are

more in the situation where one has a technological advantage in terms of an ultra-fast technology, such as for example a cable near the decision center and this actor will have an advantage of some micro seconds that will allow him to place his orders before others. At this time, we are not operating with a real definition of arbitrage because there is no longer symmetrical access to information, but with a term of competitive advantage. In addition, today we can notice that trading activities and financial products are generally highly controlled by the authorities, but there is no regulation at all at the HFT level, which is paradoxical.

**Ahn Nguyen** states that a priori, HFT is good for the market, mainly for the matter of market efficiency. In fact, it enables faster price recovery and exclusion of behavioral bias that can influence trading decision and in this way, it enables the price to be the closest to the real value.

**Individual 1** has a much more nuanced opinion on the issue. He used the question "Is Uber good for the economy?" You will always find pros and cons. About HFT, he thinks that a technology is never intrinsically good or bad, it is the use that is made by the man who will determine the positive or harmful nature of it. According to him, the use of HFT narrows spreads. For example: If you bought stock that was \$10.15 you might actually be able to buy 1,000 shares at \$10.25 or sell at \$10.05 (a spread of \$0.20), whereas today it's more like \$10.15 or \$10.16. So traditional investors can buy immediately for a clear price but it is true that this may change in extreme market conditions but in terms of normal day-to-day market operations, HFT reduced spreads.

HFT has other advantages such as reducing retail brokerage fees, he remembered that cost was around \$25-50 when today is actually around \$7. But it also do arbitrage or in other words keep the price in line because today there are numbers of ETFs, ETNs, derivatives contracts and the existence of lots of disparate exchanges where there is not enough humans beings able to line up the price correctly unlike HFTs. His conclusion is that HFTs played a vital role in the stock market.

2. Do you think that HFTs have an unfair advantage in comparison to traditional investors?

**Benoit Lallemand** thinks it is obvious that HFT firms have an advantage over traditional investors, moreover they pay additional fees to stock exchange to get exclusivity. According to him, the biggest cost that HFT brings to markets is undoubtedly its damage to investors' confidence. An interview on the subject was realized in Germany by MNI between Remco Lenterman, head of the HFT lobby and professional investors. Many professional investors "rejected the case that HFT has slashed the costs of trading for the end-user and so provided massive benefits for savers, pensioners and for the wider economy". This anecdote illustrates the widespread negative experience of traditional investors with HFT. In addition to that, the Government Office for Science released a report called "End-user Perspectives on Computerized Trading" where their goal was to gather the views of buy-side participants on the usage, impact, and policy options for computer generated trading, in particular algorithmic and high frequency trading. It shows that buy-side traders have lost trust in the fairness and integrity of regulated markets.

As it was already mentioned in the first question, **Luc Henrad** thinks that HFTs definitely have advantage over traditional investors not only for possessing high-speed technologies but also thanks to colocation. In fact, HFTs spend millions each year to place their trading models near or right on exchange servers. Even though there are no legal barrier to such a practice, not everyone has the financial resources to do it.

According to professor **Nguyen**, traditional investors do not have the reason to suffer from inequality or disadvantage compared to HFTs. The reason is that each investor has its own investment horizon: traditional investors generally have a larger investment horizon compared to a high frequency trader who makes hundreds of millions transactions per day. Consequently, the competition with HFTs would be "unfair" for short-term investors, and for those who practice low-frequency trades and plans far-going investments it would not a problem.

**Individual 1** thinks that HFTs do not have a competitive advantage due to the fact that HFTs do not compete with traditional investors as they are not trading day-to-day their stock portfolio unlike market-makers and arbitrageurs and because HFTs do better than other participants by making the price in line, it makes the market more efficient. His conclusion was that the only way that traditional investors may be impacted will depend on their investment horizon.

3. Do you think Sarao was guilty for the 2010 Flash Crash?

**Benoit Lallemand** thinks it was not Sarao who manipulated the market but according to him, it would probably be a fat finger error or an error in the activation of the algo. However, it is definitely the HFT which was the cause of the extent and gravity of the crash, according to him there is not the debate on that.

In addition, according to the interlocutor, if HFT mechanism had not existed, the Flash Crash would have not occurred. HFTs have followed the trend that has exacerbated the situation and created more volatility. So in conclusion, this type of trading was not the origin of this event but contributed to it though an increased volatility.

As for **Luc Henrad's** point of view, for him it is not clear. His impression is that we are probably entering into a much more systemic form of risk that is tied to the payment systems, and it is difficult to classify the flash crash into a mere human error. He thinks that the problem is much more complex and that there was a sequence of events that led to such a devastating result. He concludes that he does not have a specific opinion, but his intuition puts him strongly in doubt that it would be a simple human error.

**Ahn Nguyen** holds to the official opinion of SEC and CFTC, according to which HFTs as Sarao significantly increased market volatility and accelerated the crash but were not however judged to be the primary source of the initial drop in itself.

**Individual 1** thinks that the judgement that Sarao was guilty for causing the Flash Crash is not convincing. He saw in him just a 'straw man,' put in place by dignitaries where the priority was to

find someone to blame. HFT is not the result of crazy events. Markets has already done crazy things without HFT (1927, 1987, etc.).

He concluded that before the existence of HFT, there were already price moves in all sorts of stocks every single day but no specific attention was paid to these changes unlike HFT. The reason may be that it was not easy to find a single scapegoat in such a diversity of market actors.

4. Do you think that HFT needs regulations to be implemented?

**Benoit Lallemand** thinks that the actual regulations are not enough and that there is a need to find measures that will significantly reduce the potential of market abuse. He proposed three measures that should be implemented:

1. Implement a small fee on each modification or cancellation of an order.

This measure will help to avoid potential price manipulation or other forms of abuse generated by quoting activity.

2. Define harmonized minimum obligations for market makers

This method is also indispensable to close a considerable loophole that would immune “market makers” from the first measure.

3. Implement a new tick size regime taking liquidity into account (on top of price)

**Luc Henrad** thinks that the solution, which has already been suggested in the scientific literature, would be to impose a minimum threshold in terms of time that placing an order has to take, for example an interval of minimum half a second. In this way, it will enable to slow down the speed of trading if only one order can be placed by second and it will restrain technological development. But more importantly, it will allow models to gain primacy compared to the technological advance. You will have enough actors in the market who can take positions and provide then a more efficient market without extreme volatility.

**Ahn Nguyen** is of the opinion that no regulation has to be implemented, according to him slowing down the market would not be a good solution. He admits that putting a shock-absorber or some kinds of limits when the market goes down sharply, may in fact be efficient to fix market liquidity. On the other hand, if the market wants to go down by 20%, it will happen whatever absorber is put in place. This interlocutor is profoundly convinced in market efficiency and for him, HFT trading contributes absolutely to this efficiency.

**Individual 1** does not think that there should be specific regulations that will target HFTs because they are often market maker or arbitrageur and therefore it would penalize all sorts of trading activity. He thinks that specific strategies employed by some HFTs could be regulated because they are cause for concerns. He concluded by the fact that there is no point to over-regulating and preventing the correct use of a technology.

5. Do you think that HFT can be the cause of a future crisis?

**Benoit Lallemand** does not know if the HFT could be the cause. According to him, there are enough rotten fundamentals that could be the cause of a future crisis, but HFT will definitely play an important role because it will accentuate the potential crash. We just need to see the order volume passed by HFTs to understand it.

According to **Luc Henrad** the question is very simple: the human being cannot make projections, one tends to make conclusions on the future from the present situation on the market, which is a simple linear projection.

The world experienced the crisis of 2008 which was a liquidity crisis while the markets had the impression that liquidity was a problem of 70's and that since the 80's it was no longer a problem. Many banks that disappeared had very high BAL solvency ratios but they burnt out at the level of liquidity, that is why Basel 2.5 and Basel 3 were put in place.

According to him, it is sure that the next crisis will not be a liquidity crisis and that by definition the it will be a crisis of unknown origin. It is unknown whether the next crisis will be caused by HFT, but for him, it is clear that it will be related to payment systems. We are living in a very interconnected world, so in case of a crash on the internet, a cyber attack, a problem with payment system, indirectly a super flash crash, HFT can be related to all these potential causes.

**Ahn Nguyen** does not have a clear opinion regarding this question. It could be possible that HFT participates in the future crisis but It is very difficult to predict the future as there are hundreds of other factors that could be the cause.

**Individual 1** thinks that it is impossible to predict if HFT will be the cause of the next crisis. There are so many events that could cause the crisis such as cybersecurity incident, low interest rates, Eurozones breakup and others.

His opinion is that today he does not see HFT as the cause of the next financial crisis because according to him the systemic risk from HFT is lower than from banking sector.

## 4. Interpretation

**H1:** *HFT is bad for the financial market.*

It is very difficult to make a univocal conclusion from respondents' opinions because it was noticed that the answers to this question were diverse. I have the feeling that people with concrete interests or goals in the financial industry and consequently with a subjective position, have a sharper and more categorical views. Academic representatives who know the subject in more depth have a more neutral opinion. That is why, the hypothesis that HFT is detrimental for the market cannot be confirmed or refuted as there are still too many different opinions on this subject.

**H2:** *Thanks to the high technology and their algorithms, HFTs took advantage from an unfair competition.*

The opinions are diverse. Whereas Ahn Nguyen and individual 1 do not see any unfair advantage, Benoit Lallemand and Luc Henrad think the opposite. To definitely decide on this question, we must first prove the fact that investors are affected and then prove a causality between these lesions and HFT. Thus the results of the study cannot confirm or refute the hypothesis that HFTs benefit from unfair advantage and have a negative effect on other market participants.

**H3:** *The Flash Crash was caused by Sarao who used HFT strategies to manipulate the market.*

In this case, the opinions are unanimous. According to all the respondents, Sarao was not the cause of the Flash Crash and could not play a crucial role in this event. Consequently, we can refute the hypothesis of Sarao guilt which is contrary to the opinion that acquired general public through the media cover.

**H4:** *Slow Down the market is the best regulation.*

As in the case of the first and the second questions, here again the opinions are diverse depending on the general positive or negative attitude of respondents to HFT. Interviewees supporting this activity claim that no regulation is needed, respondents who expressed some critics, suggest such measures as time minimum threshold for order passing or taxation or fees system on quickly changed positions. The strategy of slowing down the market was noticed only by one of the

respondents. Consequently, we cannot confirm or refute the hypothesis that HFT needs specific regulations.

**H5:** *HFT will be the reason of the next crisis.*

For this question, the opinions are unanimous. According to all the interviewees, there is no evidence that HFT will be the cause of a future crisis but it can play an important role in its escalation. Besides HFT, there can be many other potential causes as cyber attacks, internet crashes or problems related to payment systems. So, we cannot confirm the hypothesis that HFT will be the reason of the next crisis.

To conclude, we can see that there is a big difference between the judgements of the public opinion, which is more negative, and professionals who have better knowledge of technical aspects of the subject and consequently possess a better insight.

## Conclusion

Through the thesis, we have addressed many aspects of market finance. In particular, we have been able to reach the heart of a new phenomenon called HFT, which is based on technological progress and was implemented by complex speculative strategies based essentially on the speed of detection of opportunities in gains and execution of operations.

After introducing the concept of HFT, carefully explaining the various factors that led to its development, and defining some technical specificities related to it, we focused on the different trading strategies used by HFTs. We were able to quickly categorize these strategies according to the type of externality they provide to financial markets. While market making strategies are seen as beneficial to market efficiency, order-based or information-based strategies are much more controversial. Although moderated by regulators, due to their compliance with the various regulations, these strategies develop an adverse selection phenomenon that they impose on other slower investors present in the markets.

Then we analyzed the most important event, which occurred on May 6, 2010, and served as the baptism by fire for the HFT industry. HFTs started that year in the U.S. on an auspicious note; however, the people threatened to take down the most developed financial market in the world, and there was an increasing scrutiny from regulators and legislators, until the Flash Crash on May 6. As the report (Kirilenko et al, 2011) clearly showed, “the conflict is that HFTs believe they are providing liquidity, but just buying and selling assets can artificially manipulate market prices and not necessarily provide liquidity.” Despite the positive associations linked to HFT (bringing more liquidity), a large body of literature suggests significant adverse effects associated with this activity. Kirilenko et al. (2011) have shown that HFT participants played a big part in causing the May 6, 2010 Flash Crash in E-mini futures.

Regarding this issue, I personally believe that in order to ensure an ethical market for all investors, it would be necessary implement certain regulations. An idea would be, for example, to Implement a small fee on each modification or cancellation of an order. This measure will help to avoid potential price manipulation or other forms of abuse generated by quoting activity.

Moreover, we analyze the Sarao case, who was a guilty party during the Flash Crash. We have seen that the media played a key role in the process. The fact that only one man can destabilize the entire financial market in minutes makes you think.

Finally, I used qualitative research through a questionnaire which is the most appropriate method for investigating the views of professionals about HFT. The respondents, however, have had different knowledge related to my specific research targeting HFT. The different factors and the complexity regarding HFT are extensive, therefore, it's of importance that my respondents could in an adequate way give reliable answers.

With the help of the qualitative analysis I could show that opinions on HFT were uncertain. Indeed, in order to analyze the impact of this practice, many experts and scientists have researched and written many articles. If we currently know that for a market to be efficient it must be liquid, stable and have prices that correspond to the reality of known information, we do not know the concrete effects of HFT on these parameters. Many studies have come to different or even opposite conclusions. The general public, through the mainstream media, is very suspicious of it unlike professionals who are very enthusiastic and positive about this issue.

The realization of this thesis was personally extremely rewarding because it enabled me to highlight a world that is not always known to the public, and to realize how completely the financial market had been revolutionized in just a few years was fascinating.

I met some challenges during the realization of this thesis. First of all, although, I chose a specialization in finance, some articles I faced seemed to me complicated. The jargon was sometimes unknown to me and some logical links were incomprehensible. So I had to take a period of adaptation to upgrade myself.

To conclude, there is a need to pay close attention to the danger that HFT may represent and, therefore, the HFT industry will face significant challenges on its way if it wants to prosper in the long run.

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## List of Abbreviations

ATS: Alternative Trading Systems	/	S&P 500: Standard & Poor's 500
BNP: Banque National de Paris		
CAT: Consolidated Audit Trail		
CFTC: Commodity Futures Trading Commission		
CME: Chicago Mercantile Exchange		
CSA: Canadian Securities Administrators		
CSR: Corporate Social Responsibility		
DIJA: Dow Jones Industrial Average		
DOT: Designated Order Turnaround		
ECNs: Electronic Communication Networks		
EMH: Efficient Market Hypothesis		
ESG: Environment, Social, Governance		
ESMA: European Securities and Market Authority		
FINRA: Financial Industry Regulatory Authority		
HFT: High Frequency Trading		
HFTs: High Frequency Traders		
LULD: Limit Up – Limit Down		
MIDAS: Market Information Data Analytics System		
NASDAQ: National Association of Securities Dealers Automated Quotation		
NMS: National Market System		
NYSE: New York Stock Exchange		
OTC: Over The Counter		
Reg SCI: Regulation System Compliance and Integrity		
RI: Responsible Investment		
SEA 1934: Securities Exchange Act of 1934		
SEBI: Securities and Exchange Board of India		
SEC: Securities and Exchange Commission		
SLF: Stop Logic Functionality		
SRI: Socially Responsible Investing		
SRO: Self-Regulatory Organizations		

## References

- Agarwal, A. (2012), *High Frequency Trading: Evolution and the Future*. Capgemini. Retrieved from [https://www.capgemini.com/resource-file-access/resource/pdf/High\\_Frequency\\_Trading\\_\\_Evolution\\_and\\_the\\_Future.pdf](https://www.capgemini.com/resource-file-access/resource/pdf/High_Frequency_Trading__Evolution_and_the_Future.pdf)
- Aldridge, I. (2009). *High frequency trading: A practical guide to algorithmic strategies and trading systems*. Wiley Trading: Ed. John Wiley & Sons.
- Arnuk, S., & Saluzzi, J. (2012). *Broken markets: How high frequency trading and predatory practices on Wall Street are destroying investor confidence and your portfolio*. Upper Saddle River, NJ: FT Press.
- Balch, T. (2012). *The high frequency trading arms race is a problem but taxing isn't the solution*. Retrieved from <http://augmentedtrader.com/2012/08/11/discrete-time-markets-one-way-to-derail-the-high-frequency-trading-arms-race/>
- Bauer, R. Koedijk, K., & Otten, R. (2005). International evidence on ethical mutual fund performance and investment style, *Journal of Banking & Finance*, 29(7), 1751-1767.
- Bloomberg. (April 24, 2015). *Alleged Flash Crash Trader's Former Employer Speaks*. Retrieved from <https://www.bloomberg.com/news/videos/2015-04-24/alleged-flash-crash-trader-s-former-employer-speaks?cmpid=yhoo>
- Boatright, J.R. (2010). *Finance Ethics: Critical issues in theory and practice (Robert W. Kold Series)*, Wiley, pp. 592.
- Bréhier, B. (2013). *High frequency trading: should technological developments be considered a potential threat to financial markets and be subject to specific regulation?*. ERA Forum, 14(1), 69. doi:10.1007/s12027-013-0293-0
- Brogaard, J. (2011). *High-frequency trading and volatility*. Washington University.
- Brogaard, J. A. (2010). *High frequency trading and its impact on the market quality*. Kellogg School of Management, Northwestern University School of Law.
- Brogaard, J. Hendershott, T. & Riordan, R. (2012). *High frequency trading and price discovery*. Retrieved from: <http://ssrn.com/abstract>
- Brogaard, Hendershott, R. (2015), *High Frequency Trading and the 2008 Short Sale Ban*. Retrieved from: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2600240&rec=1&srcabs=2514334&alg=1&pos=8](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2600240&rec=1&srcabs=2514334&alg=1&pos=8)

- Brush, S., Schoenberg, T., & Ring, S. (2015, April 21). *How a mystery trader with an algorithm may have caused the flash crash?* Bloomberg. Retrieved from <http://www.bloomberg.com/news/articles/2015-04-22/mystery-trader-armed-with-algorithms-rewrites-flash-crash-story>
- Bunge, J. (2011, October 10). Does High-Speed Trading Hurt the Small Investor. Retrieved from Wall Street Journal: <https://www.wsj.com/articles/SB10001424052970204226204576600980170960802>
- Carlson, M. (2006, November). A brief history of the 1987 stock market crash. *Journal of Economic Literature*.
- Chicago Mercantile Exchange, Committee of Inquiry (1987). Preliminary Report of the Committee of Inquiry. Merton Miller (Chairman), Chicago: Chicago Mercantile Exchange.
- Clarke, J., Jandik, T. & Mandelker, G. (2001). *The efficient Markets Hypothesis. In Expert Financial Planning: Advice from Industry Leaders*, ed. R. Arffa, 126-141. New York: Wiley & Sons.
- Croft, J. & Stafford, P. (2016, February 4). *Trader Navinder sarao starts fight against US extradition*. Retrieved from Financial Times: <https://www.ft.com/content/a0f736e8-cb27-11e5-be0b-b7ece4e953a0>
- Croft, J. & Stafford, P. (2016, February 5). *Prosecutors say most of trader Sarao's victims are in the US*. Retrieved from Financial Times: <https://www.ft.com/content/a0f736e8-cb27-11e5-be0b-b7ece4e953a0>
- Croft, J. & Stafford, P. (2016, March 23). *Sarao loses first round of US extradition fight*. Retrieved from Financial Times: <https://www.ft.com/content/a0f736e8-cb27-11e5-be0b-b7ece4e953a0>
- Curtis, G. (2006). MiFID: Unintended consequences – the markets in financial instruments directive may lead to increased fragmentation and, in turn, drive the demand for algorithmic trading. *Wall Street & Technology*, 18.
- Domowitz, I. & Ruben, L. (2001). *On the road of Reg ATS: a Critical History of the regulation of Automated Trading Systems*, International Finance, Blackwell Publishing, 2001
- Fama, E. (1970). Efficient Capital Markets: A review of theory and Empirical Work. *Journal of Finance*, Vol. 25, No. 2, Papers and Proceedings of the Twenty-Eighth Annual Meeting of the American Finance Association New York, N.Y. December, 28-30, 1969 (May, 1970), pp. 383-417
- FINRA. (2012, May 31). *Limit Up/Limit Down (LULD) Plan*. Retrieved from <http://www.finra.org/industry/trf/limit-uplimit-down-luld-plan>

- Garnaud, L. (2011). Pourquoi faut-il réguler le trading à haute fréquence? *Funds*, 42, 26–29.
- Golub, A., Keane, J., Poon, S.-H. (2012). *High frequency trading and mini flash crashes*. University of Manchester.
- Gourley, S. (2013, June 7). *High frequency trading and the new algorithmic ecosystem*. TEDx Talks. Retrieved from <http://tedxnewwallstreet.org/sean-gourley>
- Grant, J. (2010). *Quick View: US looks at European-style circuit breakers*. Retrieved from <http://www.ft.com/intl/cms/s/0/139ddd44-6325-11df-99a5-00144feab49a.html#axzz3gRJnT1y>
- Gregoriou, G. N. (2015). *The handbook of high frequency trading*. Elsevier.
- Grillet-Aubert, L. (2011). *Stratégies de Trading Haute Fréquence (HFT): Quels impacts pour le marché*. Retrieved from <http://www.eifr.eu/files/file9435613.pdf>
- Guay, T., Doh, J.P & Sinclair, G. (2004). Non-governmental organizations, shareholder activism, and socially responsible investments: ethical, strategic, and governance implications, *Journal of business ethics*, 52(1), 125-139.
- Harris, L. (2013). *What to do about high-frequency trading*. CFA Institute.
- Hasbrouck, J. & Saar, G. (2012). *Low-latency trading*. New-York University.
- IIROC. (2012). Proposed guidance on certain manipulative and deceptive trading practices. 12-0221.
- Hendershott, J. & Menkveld, A. (2011). Does algorithmic trading improve liquidity? *The Journal of Finance*, Volumes 66, Issue 1, pages 1-33.
- Jarnecic, E. & Snape, M. (2014). The Provision of Liquidity by High-Frequency Participants. *Financial Review*, 49(2), pp.371-394.
- Jensen, N. (1978). Some Anomalous Evidence Regarding Market Efficiency. *Journal of Financial Economics*, Vol. 6, Nos. 2/3 (1978) 95-101
- Johnson, N., et al. (2012). *Financial Black Swans Driven by Ultrafast Machine Ecology*. Retrieved from: <http://arxiv.org/abs/120z.1448>

- Jovanovic, B. & Menkveld, A. (2011). *Middlemen in limit order markets*. VU University Amsterdam.
- Kirilenko, A. & Lo, A. (2014, October 22). Moore's Law versus Murphy's Law: Algorithmic Trading and Its Discontents. *The Journal Of Economic Perspectives*
- Kirilenko, A., Kyle, A., Samadi, M., & Tuzun, T. (2011, January 12). The flash crash: The impact of high frequency trading on an electronic market. *Journal of Economic Literature*.
- Lewis, M. (2014). *Flash boys: A Wall Street revolt* (1st ed.). New York, NY: Norton & Company
- McInish, T.H. & Upson, J. (2013). The quote exception rule: Giving high frequency traders an unintended advantage. *Financial Management*, 42(3), pp.481-501.
- Menkveld, A. J. (2014). High-Frequency Traders and Market Structure. *Financial Review*, 49(2), 333-344. doi:10.1111/fire.12038
- Menkveld, A. & Yueshen, B. (2013). *Anatomy of the Flash Crash*. Retrieved from <http://ssrn.com/abstract=2243520>
- Nanex. (2011). Definition of a Mini-Flash-Crash. Retrieved from <http://www.nanex.net/Research/MiniFlashCrashDef/MiniFlashCrashDef.html>
- Nasdaq. (n.d.). *Program Trading Definition*. Retrieved from <http://www.nasdaq.com/investing/glossary/p/program-trading>
- Nasdaq. (n.d.). *Quantitative Trading Definition*. Retrieved from <http://www.nasdaq.com/investing/glossary/q/quantitative-easing>
- Nasdaq. (n.d.). *Algorithmic Trading*. Retrieved from <http://www.nasdaq.com/investing/glossary/a/algo-trading>
- Nasdaq. (n.d.). *Statistical Arbitrage*. Retrieved from <http://www.nasdaq.com/investing/glossary/s/statistical-arbitrage>
- Norman, L., & Froymovich, R. (2012, September 26). *EU Lawmakers Call for Enforced Delay on High-Frequency Trades*. Retrieved from Wall Street Journal: <http://www.wsj.com/articles/SB10000872396390443916104578020470662664506>
- Perkins, P., Van Vliet, B. & Kumiega, A. (2009) The five drivers of profitability. *Automated trader*, 12, Q1

- PetitJean, M., & Floris L. (2017). *Mini Flash Crashes: Taxonomy and Policy responses*. Louvain School of Management, Belgium
- PetitJean, M., & Floris L. (2016). *Flash Crashes: What do we know and where do we need to go?* Louvain School of Management, Belgium
- PetitJean, M., & (2017). *Que sat-on du Trading Haute Fréquence*. Louvain School of Management, Belgium
- Securities Exchange Commission. (2010). *Findings Regarding the Market Events of May 6, 2010: Report to the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues*. Retrieved from <https://www.sec.gov/news/studies/2010/marketevents-report.pdf>
- Shorter, G. & Miller, R.S. (2014). High-frequency trading: background, concerns, and regulatory developments. CRS Report, 43608.
- Tuttle, L. (2013, October). Alternative Trading Systems: Description of ATS Trading in National Market System Stocks. *Journal of Economic Literature*.
- THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. (2014, May 15). *EUR-lex.europa.eu*. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0065>
- U.S. Securities and Exchange Commission. (n.d.). *Comments on Investors' Exchange LLC; Notice of Filing of Application, as Amended, for Registration as a National Securities Exchange under Section 6 of the Securities Exchange Act of 1934*. Retrieved from <https://www.sec.gov/comments/10-222/10-222.shtml>
- U.S. Securities and Exchange Commission. (n.d.). Retrieved from <http://www.sec.gov>
- U.S. Securities and Exchange Commission, (2010a). *Concept Release on Equity Market Structure*. Retrieved from <https://www.sec.gov/rules/concept/2010/34-61358.pdf>
- U.S. Securities and Exchange Commission & U.S. Commodity Futures Trading Commission (2010b). Findings regarding the market event of may 6, 2010.
- U.S. Securities and Exchange Commission. (2010c). *Investor Bulletin: New Measures to Address Market Volatility*. Retrieved from <http://www.sec.gov/investor/alerts/circuitbreakersbulletin.htm>
- U.S. Securities and Exchange Commission. (2010d). *SEC Approves New Rules Prohibiting Market. Maker Stub Quotes*. Retrieved from <https://www.sec.gov/news/press/2010/2010-216.htm>

- Viswanatha, A. & Hope, B. (2015, April 21). '*Flash Crash*' Charges Filed. Retrieved from Wall Street Journal: <http://www.wsj.com/articles/u-k-man-arrested-on-charges-tied-to-may-2010-flash-crash-1429636758>
- Verity, A. (2016, March 23). Navinder Sarao: The man accused of causing the US market to crash. Retrieved from <http://www.bbc.com/news/business-35863848>
- Viswanatha, A., Albanese, C. & Hope, B. (2015, May 6). Navinder Sarao's 'Flash Crash' Case Highlights Problem of 'Spoofing' in Complex Markets. Retrieved from Wall Street Journal: <https://www.wsj.com/articles/navinder-saraos-flash-crash-case-highlights-problem-of-spoofing-in-complex-markets-1430943635>

