FIN11 Term Paper 2016

High Frequency Trading and Front Running

Henning Boganes s145153

Richard Friis s164349

Erik Tveiti s144908

Word count: 5543

Table of Contents

Introduction……3

Trading Theory……....4

Why People Trade.……....4

Participators in the Market ……...4

Types of Orders ……....5

High Frequency Trading ……..6

HFT Strategy ……6

Latency ……7

Flash Trading ……....……7

Front Running ……..8

HFT and Flash Trading in Today's Market.……9

Capital gains ……9

Using HFT to Front-Run……..……9

Rebate ……..11

IEX……...11

Criminalization ……...12

Illegal use of HFT……....12

Virtue Financial and Hudson River Trading.....13

Skimming …….....13

Flash Crash, The Perfect Example ……..…14

Conclusion …….14

High Frequency Trading ……..…14

Front Running ……15

Our Opinion ……15

Reference List ……....17

Introduction

This is the third and final paper in the course FIN11 – Trading and Market Microstructure. We were able to choose a topic of our choice within the subject of trading. After some reflecting on the course, we chose to look deeper into the topic of modern trading, more specifically high frequency trading. To narrow it down to a manageable topic we choose to focus on front running within the high frequency trading (HFT) sector. Here we will look into the use and capital gains from using HFT and front running. We will also examine the market and the world's general opinion on it, and especially different governments view on the subject.

In the early days' people had to meet up on squares or similar, to trade. In the 1990s the market became more and more available for the public as well as affordable, because of the internet. The market became increasingly available for everyone, but today trading is starting to favor the professionals again. Computers and algorithms are analysing and trading in large quantities that is not possible for a human. Ordinary people have no access or cannot afford these systems. Computer and algorithms give the professionals advantages due to the amount of information they are able to gain, as well as time. It is HFT and front running that is making this possible.

HFT and front running has been related in various discussion, and there is a term called electronic front running, which is front running done in high frequency trading. Since it gives you an advantage regarding process time, it can in some way be used to front run the regular traders in the market. We will later return to elaborating on these terms.

Trading Theory

Why People Trade

There are various reasons why people trade, but the common goal for everyone participating in trading is capital gains. Trading can be use in different ways, for example to invest, hedge, borrow and so forth. Trading is essential to the capital market and the society in general. Finance and trading is often criticized for being useless professions, and is not contributing to the society like engineering and research. There is no doubt that some people use the markets for the single reason to make money, but these people are an important part as well. They provide liquidity, which makes the markets more efficient, as well as more valuable for short-term financial arrangements, through easy turnover (Harris, 2003).

Someone have to provide cash and liquidity to the average person for him to be able to buy a house, and trading contribute to this. Consumers buying a house or another product is again contributing to the general market. Trading helps companies grow, for instance through fresh capital and ownership. Fewer people would wish to own a company if it was hard to sell and realize profits, and as mentioned, trading makes the market more liquid (Harris, 2003)

Participators in the Market

Trading consist of different participators. The most "famous" one, is probably the broker. Almost everyone must go through a broker to execute a trade through an exchange. The definition of an exchange is a marketplace where financial instruments are traded. The exchange is there to make sure the trades are fair and orderly executed, as well as ensuring efficiency. Brokers charge a commission for executing an order (buy or sell) submitted by an investor. Before the internet, most people couldn't afford a broker, and the stock market was therefore only for rich people. The internet changed this, and today, most people can afford to submit an order through a broker. A financial broker is very similar to a real estate broker, where they handle the paperwork and arrange the sale. An investor has to specify what type of order (price) and amount, and the broker does the rest (Harris, 2003)

While brokers execute orders for their clients, dealers execute orders for their own account. Dealers execute trades both through a broker as well as without one. It is very common that a dealer is also a broker (broker-dealer). Dealers is a person (or a company) that is buying and

selling securities on a business basis. That dealers trade on a business basis is what separate them from other traders or investors. Dealers provide liquidity to the market, and is very useful for the rest of the participators. They also create immediacy which brings buyers and sellers together as a side effect (Harris, 2003)

A trader is very much like an investor. Everyone knows what an investor is, but very few (who is a non-business major) knows the difference between a trader and an investor. The difference is the holding time of securities. Investors have a long-term view, while a trader try to capitalize on the short-term. Investor do most of their investing decisions based on fundamentals of a security, while traders look at short-term trends in the market (Harris, 2003).

Market Makers, as the name suggest, makes the market, through offering to sell and buy when needed. The bid-ask spread is often maintained by the market maker, and he profits from the spread. He might buy a security for $10.00, and the best sell order is $10.05, he makes his shares available to purchase for $10.04. This makes him a profit of $0.04 per share, and he most likely makes a quick buy and sell trade. If there are few transactions in a security and someone wants to sell, the market maker, makes the market work, by buying the shares outstanding. Dealers do often work as a market maker as well as trading for his own account (Harris, 2003).

Types of Orders

Orders can be avoided by traders who directly negotiate, or the participators who makes the market (market makers and dealer, as mentioned). Aside from these scenarios, most traders use orders. The definition of an order is an instruction to sell or buy a security, with instruction regarding what security, quantity and side of order (buy or sell side). Orders may specify more than these specifications, but do not have to (Harris, 2003).

Market order is an order that instruct the brokers to buy a specific security at the best price available at the time of the order. This type of order gives immediacy, which can prevent "chasing" the security. If the trader wants to specify the price he is interested in buying at, limit order has to be used. Limit order is less risky, but you can end up "chasing" the security which the market order prevents. Limit orders is not executed before someone is willing to sell or buy at a specific price or better. This provides liquidity to the market, and is very easy

to keep track of through the order book. The order book is an electronic list of all the orders regarding the security. It provides both price and amount. Market order and limit order are the most common types of orders, but there are other types of orders like ISO (intermarket sweep orders), PEG orders and discretionary orders. Another commonly used order type is stop order, which instructs the broker to sell a security at a certain price. Stop orders take liquidity and destabilize the market, which is both opposite of what the limit order does (Harris, 2003).

High Frequency Trading

High Frequency Trading (HFT) is trading done by computers at a very high speed. These computer trades are regulated by an algorithm. An algorithm is a program or a "recipe" made by someone that the computer follows. The algorithm usually decides timing, price and quantity of the relevant security. The algorithms analyse the markets and the computer acts according to the results of the algorithm. Usually the algorithms or computers who execute order fastest, are the most profitable. Both the computers and the algorithms are very expensive to purchase, and is therefore more common in large firms. This is one of the problems with HFT. It became more common when exchanges started to pay a fee or give rebate for providing liquidity to the market. Since they provide orders or execute trades at a very high speed they are very useful to provide liquidity compared to conventional market makers. Another advantage occurred from HFT is decreased bid-ask spread. HFT is also criticized, mostly for removing the human factor away from the investment/trading decisions. The trades are done in milliseconds which can move the market significantly in no time (Harris, 2003).

HFT Strategy

HFT is quantitative trading with short holding periods. The models/algorithms are quantitative models. The more information the system is able to process in a period of time, the more efficient the system is. The amount of information a HFT-system process cannot be compared to a human's capacity to process information. The algorithms are closely guarded by the employees of the company owning the system (Harris, 2003).

Latency

Definition of latency is the time that elapses from the moment a signal is sent to its recipient. Latency is crucial to trading in general, and especially HFT. This is due to the fact that with

gradually more latency brings a larger disadvantage. There are many ways to shorten this, a HFT-firm can locate their servers closer to an exchange, use better cables and use the latest computer software. Every second counts in the trading world, and when these seconds add up, it becomes increasingly important to lower this latency. Estimates tells us that each mile distance away from the main exchange servers adds up eight milliseconds for the information to reach its destination (Wired, 2012)

This has led to a competitive environment where the most influential companies elect to spend several thousand dollars each month to secure their position where they are able to trade with as little latency as possible. It has reached a point where some computers close to the exchange with fiber optic cables actually receive information about an upcoming transaction before the order itself has gone through. Other competitors such as speculators and uninformed traders comes short in situations like this, as their information might be outdated even before information of an order actually is executed. More about this is explained at a later point.

An example of how expensive an investment in trading infrastructure can be when battling latency is the "Tradeworx" technology issued in the winter of 2012. This technology was able to send microwave beams through the air with a round-trip time for the transmitted data of only 8.5 milliseconds. However, even if price may vary, the baseline price was set at $250 000 a year (Wired, 2012)

Flash Trading

Flash trading is a computerized trading practice like high frequency trading. Flash trading allows traders to see orders fraction of a second before others traders. It uses high-speed computer technology like HFT to receive the orders before the ones without flash trading opportunities. Flash trading is considered unfair and controversial. This because it gives an advantage to some people who have the right equipment for the job. Flash trading is not possible on all exchanges, which prevents it from an even bigger problem than it is. Flash trading is closely related to front running which is a very unethical practice among brokers and other professionals (Harris, 2003).

Front running

Front running is a term used in a situation where a trader obtains information about trades that other traders arrange, followed by trading on this information anterior to the transaction in order to capitalize on the trade (Harris, 2003). This information can be obtained in various ways, for instance through brokers, public sources, or even the traders themselves. The term "front-runners" derive from the way the trades are being done, that being to "run" to trade before other traders are able to go through with their transaction.

There are several ways of practicing front running, however some are more in the "grey" area when it comes down to an ethical point of view than others. Some are even downright illegal. For instance, if a broker elects to front run based on a client's pending transaction, that is an illegal trade and counts as inside trading. If this information is based on public information it is technically not illegal, however this type of trading could be seen upon as controversial in terms of an ethical point of view (Harris, 2003).

Front runners are able to manipulate the direction of the market, and they can affect the degree of efficiency and liquidity in certain markets. When it comes down to market efficiency, the impact of a front runner is dependent on whether they front run an informed or uninformed trader. In a scenario where a front runner front-run an uninformed trader, it often leads to the price being less informative compared to beforehand. When an uninformed trader trades a security at a price equal to the fundamental value, it always makes prices less informative. On a similar note, when the prices differ from the fundamental value, an uninformed trader is at best able to drive the prices closer to the fundamental value by chance. Therefore, when a front runner front-run an uninformed trader, the chances of making the market more inefficient is high. The opposite happens if front running of an informed trader occurs. In that case the price is pushed towards its fundamental value at a faster pace. Front runners will therefore strive to front-run traders with reliable information. Regarding liquidity in markets and front running, it generally makes the markets less liquid (Harris, 2003).

HFT and Flash Trading in Today's Market

As we defined in the introduction of this paper, we want to take a better look at how HFTs act in the market, present different opinions by users of the market and discuss various measures done to prevent the possible ripple effects of HFT.

Capital Gains

Traders trade to gain more capital. In trading you are paid to take on risk, the general rule in the industry is that more risk equals bigger (potential) return. Everyone tries to minimize the risk and maximize the return, and one way to make the odds better is to practice front running or use HFT. In other words, the trading industry is all about money, not more, not less. The industry is constantly developing new systems to maximize their profit. They are always trying to push the limits of what is legal when developing a new trading system. There will always be discussions about whether it is fair or not.

Generally, a high frequency trader makes his money in quite a different manner from traditional investors. They want to execute trades with a very small margin and benefit from the fact that the trade is very quick. Where a traditional investor would want long-term returns on few trades, the HFT wants the accumulated return of millions of small trades to be as big as possible. HFTs can get as little as one twentieth of a pence from the dollar, but the speed and volume over time contributes to huge returns in total.

Trading is all about information and when you receive information. The person sitting on the most relevant and true information will make the most. HFT systems search for information that is relevant for a security and buys or sells according to the information. As mentioned, latency is the term used in the industry for the time it takes to receive information from the source, and HFT is all about minimizing this time and act on the information in time. Front running is, as mentioned, illegal most of the time, but it does not mean that nobody does it. Trader make money by front running by using their "inside information". For example, a broker who knows about large order on the way. Electronic front running is related to HFT and is using the low latency to achieve profits.

Using HFT to Front-Run

High Frequency Trading is widely discussed whether it contributes to front running or not. As mentioned earlier HFT use powerful computer to trade in no time compared to humans. The question is; is it possible to front run using HFT? HFT systems have direct connection to the market, and will react faster than human traders, but all the information the algorithms process is public information. In one way, it can be called front-running, and there are university publications which consider it front-running, but if you think about it, it may be impossible. Even though it might not be precisely like front-running, there is a reason why investment banks and similar spend billions of dollars on these systems. Without doubt, HFT gives a huge advantage, and is relatively unfair to the rest of the market, but is there reason to consider it unethical and in worst case; make it illegal? (Karang, 2014)

Universally front running has been morally dubious because traders would use information not generally available to the public for personal financial gains. Although it is remarkably similar to an insider trade, front running is yet to be defined as an illegal act.

One of the biggest critics of HFTs and front running is author Michael Lewis. In his book "Flash Boys" he highlights what he defines as "the most dangerous affliction on Wall Street: the scammy-sounding practice of high-frequency trading". The front running done by HFTs is visualized as "a family of four deciding to buy four tickets to a theatre show for $10 each. But after hitting the buy button, only two tickets are bought, and the other two now cost $15". Lewis argues that this "skim" is actually high-frequency traders' way of cutting the line to steal profits from hard working investors (Michael Lewis, 2014).

The book "Flash Boys" speaks highly of the IEX exchange, a new exchange that removes the HTF advantage by creating a "speed bump" in the system. This "speed bump" is set to neutralize the possibility of front running and thus creating a more just system. We will discuss the IEX exchange further later in this paper.

Lewis' book has obviously been criticised by firms and traders who live off high frequency trading. They argue that the possible ethical problems are nothing compared to the good HFTs do to the market. Mark Buchanan, writer for Bloomberg, says that high frequency

trades keep the market in tune because of the quick trading speed. It takes a shorter time from an event of significance to the market's reaction and synchronization. Furthermore, HFTs high volume contributes to liquidity in the market and also lowers the market spread. The general opinion from the "pro-HFT community" is that the "skim" the traditional investors "pay" to HFTs are a lot less than what they save through the extra liquidity and lower spread (Levenson & Bennett, 2014).

Rebate

As mentioned earlier, market makers can receive a liquidity rebate in exchange for providing liquidity. The "takers" of liquidity are charged a very small fee for "taking" liquidity, but again this is given to those who provide liquidity to the market. The fee/rebate is barely noticeable, but when you trade millions of shares, it adds up to decent amounts. High frequency traders have taken advantage of this through their massive trading. Through providing what Michael Lewis call "unreliable liquidity" they earn a lot of money by seeking this rebate (Investopedia.com, 2014).

HFT makes this earning liquidity rebate much more efficient, because of their high-speed compared to ordinary market makers, and we can question whether they deserve this "reward" or not. Unreliable liquidity or not, liquidity is liquidity, and HFT is an efficient way of providing it, and a lot of people will gain from this liquidity whether they know about or not. It is of course a treat to the profession Market Maker, but most of them are working in firms with HFT-systems so they will still gain from it.

IEX

IEX is a relatively new stock exchange based in the USA. It was started by Brad Katsuyama and was opened for trading in October 2013. What separates IEX from most exchanges and why we mention it, is that they use a delay to reduce the advantage of high frequency trading. By using a 38 mile coil of optical fiber in front of their trading machine they delay the information and remove the speed advantages. This delay ensures that the flow of data arrives simultaneously at two different points in New Jersey. It was created as a response to increasing criticism of HFT and to keep the game "fair".

In addition to the optical fiber coil, the exchange has employed different strategies to achieve these goals. Strategies include offering a limited number of simple and familiar order types,

refusing to pay order flow, charging fixed fees on most orders and others.

The IEX exchange has also rearranged the traditional price-time priority in the order book to prevent high frequency traders of front running normal investors. Their priority is called broker-priority and prioritizes orders by price, followed by broker trades and then time. IEX argues that by doing so they increase the transparency and fairness of the markets by letting investors trade at the prices observed in the markets. (Wikipedia, 2016)

Criminalization

There are people suggesting that HFT have a positive impact on the market. The Investment Industry Regulatory Organization of Canada said: "The results of the study did not reveal any concerns that warranted a regulatory response beyond measures already implemented by IIROC and indicate that the presence of HFT has different, mostly positive impacts on Canadian equity markets and those who invest on those markets," (this was said one year ago). They suggest that HFT provide liquidity to the market, while Michael Lewis says the liquidity HFT provide is not reliable. Some Canadian trading platforms agree with Michael Lewis. They have issued concern about the practice. TMX Group (Toronto Stock Exchange) has announced that they plan to slow down high frequency traders. In other words, there is no plans to criminalize the practice, but to restrict it. This is another argument against HFT being a form of front running, since most front running is illegal. Front running is considered way more unethical in the market, than HFT. (Brian Louis, 2015)

In the United States, however, the FBI launched an investigation in 2013 to probe whether or not the high frequency traders were taking advantage of market information at such a high speed that it makes the information unavailable to the public. The investigations have led to a few HFTs and other companies being targeted and some has even been taken to trial in a court. These individual cases have not contributed to any change of law, however they showed us that there are definitively ways of illegally exploiting the advantages that comes with high frequency trading.

Illegal use of HFT

High frequency trading can be used to manipulate the market. For example in October 2014, Athena Capital Research LCC was fined $1 million for manipulating the market. They rig prices of thousands of stocks (included eBay Inc.). The SEC said that Athena used: "high-

powered computers, complex algorithms and rapid-fire trades," to manipulate the market. This was one of the first actions against HFT-firms done by the SEC. (High frequency trading-Wikipedia, 2016)

Virtue Financial and Hudson River Trading

Both Virtue Financial and Hudson River Trading are HFT-firms. We have looked at their culture to try to find anything about their own view on HFT. They both state that they are committed to keep the market fair for everyone, while at least Hudson River Trading states that it does millions of trades every day around the globe. One thing to notice is that both firms lack organizational charts and titles, and are promoting to be non-Wall Street firm in case of doing business. They present themselves more like a technology-firm than a Wall Street firm. This may be a good thing, since Wall Street has a kind of bad reputation among people outside the financial business. The firms themselves do not seem to "advertise" their advantage at all, just the opposite. They claim they provide a fair market, as well as they claim their ethics are way better than the normal standard on Wall Street. (Virtue.com and hudson-trading.com)

One fun fact we can include is that Donald Trump, the next president of USA, has elected Vincent Viola as his minister of the army, who is cofounder and owner of Virtue Financial. He is not the only one from Wall Street going in to congress, Donald has elected a lot of billionaires from finance to be his ministers, as well as former presidents have. This shows the kind of impact they have on the politicians and the government, and is one of the reasons Wall Street firms are making as much money as they are.

Skimming

Some people refers to HFT as skimming instead of trading. Skimming is "slang" for an illegal way to take cash "off the top" of a business. In other words, those against high frequency trading refers to it as "stealing" from other investors. Trading is a zero game, where someone have to lose money, for other to gain. There is an example of a HFT-firm (Tradebot) who did not lose money one single day in four years in a row. This should be statistically impossible, and the most shocking fact was that the average holding-period of a security was 11 seconds. To process this kind of information would take a lot more than the holding period for a regular trader. There is no doubt that HFT has a huge advantage, and is a form of front running (electronic front running). This kind of information processing would

require a huge server senter, and will only be available for the very rich. (Skimming-Wikipedia, 2015)

Flash Crash, The Perfect Example

On 6 May 2010, there was a crash in the stock market most likely due to high frequency trading. Dow Jones had its largest intraday point drop in history. Even though it was a huge drop, it recovered in minutes. This is the perfect example for the HFT debate. Most people thought it was due to HFT, but studies done by different several organizations argued that HFT was not to blame. Some even argued that HFT had a stabilizing effect on the market. After five months after the crash SEC and CFTC issued a joint report, where they identified a large sale of future contract ($4,1 billion), which the algorithms reacted to and created volatility in the market. In other words, the supercomputers was to blame to a certain extent. (Flash Crash-Wikipedia, 2015)

Conclusion

High Frequency Trading

There are a lot of arguments both for and against high frequency trading and front running, depending on who you ask. The standard argument for HFT is it provides liquidity, narrows bid-offer spread, lower volatility and makes trading cheaper for other participators in the market. Those who are against HFT argue the exact opposite, the liquidity is unreliable, takes bid-offer spread and makes trading more expensive, like an extra taxation for trading.

If we look at the market share of HFT-firms, we see that HFT-firms represents 2% of the about 20 000 trading firms operating in USA today. Even though the HFT-firms are relatively few, do they account for 73% of all equity orders volume. This indicates there is no doubt that HFT provide liquidity, but how useful is this liquidity compared to normal market maker's contribution? (Kenett et al., 2013)

HFT-firms is becoming more and more common. They started appearing already in 1999 and has been an industry in growth since. This is not just a positive effect for the industry, the profit has decreased the latest years at HFT-firm as a result. This shows us that the market is not fair when some use HFT while other do not. It is logical, but it proves the point anyway,

the more common HFT is, the more equal the market is. The more equal the market is, the more do HFT-firms profits decrease.

People in the industry will always favour positive arguments, while the rest will try to stop it, or limit it through for example technology as mentioned. HFT is positive in some ways and negative in others.

Front Running (Electronic Front Running)

Front running is a problem within the trading industry, and has become an even bigger discussion after it has been related to high frequency trading. Some argue that it is not possible at all to front run using HFT, while other argue that HFT is a form of front running at its basic. As explained in the paper, HFT is all about time and information, and front running is all about the same. HFT gives you a time advantage, as well as front running. Normal front running involves a broker or another informed person, using his or her knowledge gained from her job to front run a customer or similar. As HFT are increasing its market share, the less front running it is.

Our Opinion

We think for sure that general front running is highly unethical, and should be illegal (which it is in most cases). Regarding HFT and front running we do agree that it is similar, but in theory we tend towards the claim that it is impossible to actually front run using HFT and algorithms. Algorithms are a set of instructions and respond to information that is available. Unless the HFT-firm has special algorithm they feed with non-public information, should front running be impossible in HFT. We do not agree with the HFT-industry regarding HFT having positive effects on the market. It is highly unfair, and since trading is a zero game, it may be considered a crime in our opinion. We think HFT should be illegal, or give equal latency to everyone who wish to participate in the market. The stock market and futures market and so on, should be a fair trading market where everyone has the same information available at the same time. Some differences it has to be, but make it as equal as possible.

The industry will always try to maximize its profits and will always develop new technology to achieve this. If the stock market is going to be a fair place, it needs to be heavily regulated, and controlled at all times. However, the stock market is also a place where Darwin's law of survival applies just as well as in all other competitive businesses. The trader who has done

the best possible research deserves to be awarded for that, and it is dangerous to regulate the skill factor away from the market. Furthermore, the factor of market levelling that HFT provides is a positive effect to everyone participating in the market. The price a normal investor has to pay because they are slower than the HFTs might actually be lower than the possible risk they'd have with a slow market that reacted more slowly to important events.

Ultimately we can wrap up this paper by establishing the fact that HFT and front running is definitively a subject that has brought a lot of attention and discussion into the trading world. It is indeed ethically dubious and there has been taken some measures both within the community, as well as by governments to reduce the advantages that are defined as being on the edge of what is morally acceptable. Some companies have focused on their code of ethics, and there has even been created a new and more fair market exchange, the IEX, where normal investors can trade on more equal terms. These measures are made to ensure that the world of trading is just, to keep having skills as an important factor and to avoid creating hollow bubbles based on HFTs predatory trading techniques.

References:

Jerry Adler, "Raging Bulls: How Wall Street got addicted to light-speed trading", 8 mar 2012, downloaded 15.12.16 at
https://www.wired.com/2012/08/ff_wallstreet_trading/2/

Levenson & Bennett, "Is High Frequency Trading as bad as Michael Lewin wants you to think?", 1 apr 2014, downloaded 16.12.16 at
http://www.theatlantic.com/business/archive/2014/04/is-high-frequency-trading-as-bad-as-michael-lewis-wants-you-to-think/359903/

Wikipedia, "IEX", 3 nov 16, downloaded 16.12.16 at
https://en.wikipedia.org/wiki/IEX

Rishi N. Karang, “High-frequency traders can’t front-run anyone”, 3 apr 2014, downloaded 14.12.16 at http://www.cnbc.com/2014/04/03/high-frequency-traders-cant-front-run-anyonecommentary.html

Brian Louis, “High-frequency trading helps Canadian markets, regulator says”, 9 dec 2015, downloaded 15.12.16 at http://www.theglobeandmail.com/globe-investor/high-frequency-trading-helps-canadian-markets-regulator-says/article27661164/

Elvis Picardo, “You’d better know your High-frequency trading terminology”, 5 aug 2016, downloaded 15.12.16 at http://www.investopedia.com/articles/active-trading/042414/youd-better-know-your-highfrequency-trading-terminology.asp

Dror Y. Kenett, Eshel Ben-Jacob, H. Eugene Stanley & Gitit gur-Gershgoren, “How High Frequency Trading Affects a Market Index”, 27 mar 2013.

Larry Harris, Trading and Exchanges: Market Microstructure for Practioners, Oxford University Press, 2003

Michael Lewis, Flash Boys: A Wall Street Revolt, W.W Norton & Company, 2014