

Louvain School of Management

High-Frequency Traders: a blessing in disguise? (IEX Group Case)

Mémoire recherche réalisé par

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en vue de l'obtention du titre de

Master 120 crédits en sciences de gestion, à finalité spécialisée

Promoteur

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Année académique 2016-2017

UNIVERSITE CATHOLIQUE DE LOUVAIN

Abstract

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Master in Business Management

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In 2014, Michael Lewis published the book *Flash Boys* exposing the U.S. equity market as rigged because of the uncontrolled technological innovation on financial markets. New forms of very aggressive and often ethically-questionable practices of trading have appeared: one above all, high-frequency trading. This paper aims at analyzing this new form of trading and discussing its impacts on the market quality going through the past and current regulatory frameworks, through the operational strategies created and implemented in HFT and through the quality factors essential to reach a real market excellence. The analysis also covers the story of Bradley Katsuyama, the man who is considered today as the first *whistle-blower* of the debate around high-frequency traders and is today the actual founder of IEX Group which turns out to be an exchange protecting the investors against high-frequency traders.

Keywords: rigged financial market, innovation, ethics, high-frequency trading, market quality, Bradley Katsuyama, IEX Group, investors protection.

Preface and acknowledgements

Before anything else, I would like to thank my family and my girlfriend. They supported me all through this work and suggested many improvements. They also fully understood my paper: this is my first victory.

I would also like to show gratitude and appreciation to one of my close friends, Luca Billi, for sending me the Canal+ documentary. Without that documentary, I would never have chosen this subject. Without him, this paper would not exist.

Finally, I would like to acknowledge my promotor, Leonardo Iania and his assistant, Jonas Striaukas, for their constant availability and supervision. In addition, I would like to thank my internship supervisor, Pierpaolo Squillante, and the direct person in charge, Alessandro Sperti, for their help in the writing of this paper.

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Abbreviations

AT	Algorithmic Trading
ATS	Alternative Trading System
CFTC	Commodity Futures Trading Commission
ECN	Electronic Communication Network
EMH	Efficient Market Hypothesis
FINRA	Financial Institution Advisory & Financial Regulatory
HFT	High-Frequency Trading
IPO	Initial Public Offering
ITS	Intermarket Trading System
MIDAS	Market Information Data Analytics System
NBBO	National Best Bid Offer
NMS	National Market System
OTC	Over-The-Counter
RBC	Royal Bank of Canada
SEC	Securities And Exchange Commission
SIP	Securities Information Processor
SL	Stop Losses
TOB	<i>Taxe sur les Opérations Boursières</i>
TP	Take Profit

General Introduction

"In a poker game, there is always a *patsy*. If after playing half an hour, you still do not know who the *patsy* is, you certainly are." This quote belongs to one of the most successful investors of all time. His name is Warren Buffett. Next to his passion for poker, Buffett became known worldwide for his incredible performance as a family-portfolio manager and as the CEO of Berkshire Hathaway Inc., one the biggest American multinational conglomerate companies. Some people also know him simply because he is the third richest person on the planet.

In some senses, Buffett's quote also reflects the view of many experts about the current situation of the financial markets: complex, opaque and where the patsies might be all the people holding securities in the stock market.

In 2014, the famous financial best-seller writer, Michael Lewis, published his book *Flash Boys* exposing the U.S. equity market as rigged, triggering a fierce and still ongoing debate about the impact of technological innovation on financial markets. The writer exposed the negative impacts of the digitalization of the markets, their disconnection from markets' reality and identified one specific trading practice as uniquely guilty: *high-frequency trading*.

However, innovation is not something new in the financial market. It has always been present in some form. Since the creation of the first stock exchanges, traders have always tried to improve their speed in placing orders: from flying pigeons to the telephone, the main objective was to increase the automation, speed and efficiency of the stock markets. In the early 80's, the computer finally made its appearance and quickly became a fundamental tool for traders. The more time passed, the more complicated and computerized the trading framework became.

According to Michael Lewis, these new traders were born thanks to the synergy between the complex technological advancements and a convenient regulatory framework. These new traders negatively impacted the U.S. stock market: the market became *rigged* (Lewis, *The Wolf Hunters of Wall Street*, 2014). Because of computers, the markets became too fast for traditional investor to even understand what was happening inside.

After the financial crisis and the several crashes the markets have undergone in the last few years, investors' confidence in the markets declined more than ever. Traders should have behaved themselves, calm the troubled waters to regain their confidence back (Lewis, *The Wolf Hunters of Wall Street*, 2014). As the reader might guess, they did not. The uncontrolled innovation led to new forms of trading to appear and be free to operate.

I read Michael Lewis' book and I did appreciate the reading. However, after finishing it, I started asking myself a series of questions about the real impact of those technological developments on the quality of the financial markets and about how those innovations, which I consider as a positive phenomenon, could be so negative for them. Furthermore, if that innovation was so bad for the markets, what was the reaction of the regulators?

This is where I started my analysis of high-frequency trading. I wanted to understand more about this new trading practice and about its impact on market quality (on the level of liquidity or on the volatility). My analysis consists of five parts. The first one will be a historical scenario giving an introduction on the theme and on the actors in it. It will go through the main events that put the light on high-frequency trading and the unconventional practices they use.

Then, I will devote the second chapter to a literature review. I will introduce and deeply explain all the concepts which the reader might not know and which are fundamental to the full understanding of this paper.

The third and fourth chapters will focus respectively on the regulatory and operational side of high-frequency trading. After a quick explanation about the structural context in which they both apply, the third chapter will depict the past and current regulatory frameworks and the structural contexts in which they apply. My focus will be on the regulations that have had and still have a major direct impact on high-frequency trading rather than on the general rules of the financial markets which indirectly and only slightly shaped high-frequency trading.

Regarding the fourth chapter, it will consist of a description and an analysis of the trading strategies that came into view with the technological developments. I will go through both the technical characteristics and the operational strategies. The analysis will dwell on the positive and negative consequences of these practices on market quality and soundness. Combined with the literature review, this analysis will help me to build my own opinion on the subject and to answer some of the questions mentioned above.

Finally, the fifth chapter will focus on some of the most famous propositions financial markets' participants made in attempts to limit, block or even eliminate high-frequency trading from the markets. Depending on my answers and conclusions from the previous chapters, I will give my personal view on the validity of those propositions.

CHAPTER I - Historic Scenario

Before I get to the main subject of the thesis, I would like to start with an introductive ride-along regarding the beginning of this whole debate around high-frequency traders. This historic scenario will enable me to deeply understand the origin of these new actors of the financial markets who made their appearance over the last few years and how they have been discovered. This will give me some fundamental elements in order to form my opinion on the matter. I will also go through a succinct presentation of the main characters of this story. I think doing so will be important for the complete understanding of the whole paper.

The first man who noticed the presence of a *bug* in the financial markets' system is **Bradley Katsuyama**. He appeared in Michael Lewis' best-seller called *Flash Boys* and is considered today to be the first *whistle-blower* of the debate around high-frequency traders. That book has been one of the major triggers of this debate.



Cover artwork by
Zachary Walsh
(Bloomberg.com)

Bradley Katsuyama is a Canadian trader who arrived on Wall Street from Toronto in 2001. At the age of 24, Bradley was already managing a thirty-broker team at the Royal Bank of Canada and managed several types of trading teams: electronic sales and trading, algorithmic construction and product management. He was considered the *young prodigy* of RBC. He would then become the first trader in the bank to notice that something was not working as it should:

(Macaux, 2015) *"I was a trader my entire career and until 2007, whatever I was seeing on my screen whether a bid or an offer, I could trust it 100%. I could always rely on what I saw on my screen. I was seeing ten thousand shares available, I would have made an offer for these ten thousand shares. However, in 2007 something happened: when I saw ten thousand shares on*

my screen, the time to write the offer, send it on my PC, the order came back saying: “You only bought seven thousand shares.” And in 2008, six thousand. And by 2009, only five thousand. The more time passed, the more the fraction of what I saw on my screen decreased.”

To better understand what was happening in the markets at the time, we must go back in time, to when the actual problems began. In 2006, just like many other big Wall Street banks, the Royal Bank of Canada decided to invest in an electronic-trading system. They thus acquired this firm called *Carlin Financial Group* and paid more than \$100 million for it. This new-generation-software firm acquisition was part of a big collective shift of the whole industry towards new technologies.

In Bradley’s opinion and before even noticing any flaws in the systems, this move was done with undue haste. The problem was that RBC acquired this electronic-trading firm without knowing anything about the company or even about electronic trading. Moreover, Carlin’s CEO, Jeremy Frommer, was a classic Wall Street *snake*. During an interview with Michael Lewis, Bradley remembered him like this:

(Lewis, The Wolf Hunters of Wall Street, 2014, pp. 2-3) “On the first day after the merger, I got a call from a worried female employee, who whispered, ‘There is a guy with suspenders walking around with a baseball bat in his hands. He was, whatever else he was, not RBC nice’.

[...] One day, he made a presentation about the state-of-the-financial-markets and told us: ‘The markets are now all about speed and I’m going to show you how fast our system is.’ He entered an order on the screen, pressed Enter and the order appeared on the screen. He repeated it 5 times and was like “Oh my God, it’s happening in real time!’. I couldn’t believe it: it was 5 in the afternoon; the market wasn’t open and nothing was happening. That guy who just sold us our new electronic-trading system either doesn’t know that his display of technical virtuosity is absurd or, worse, he thinks we don’t know.”

Jeremy Frommer got fired a few years after the acquisition. Unfortunately for Bradley, this new electronic system made it impossible for him to properly do his job. He could

not **play his role of middleman between buy- and sell-investors** because whenever he pushed the *Enter* button to complete a trade, the offers would vanish at that exact same moment (Lewis, *Flash Boys: A Wall Street Revolt*, 2014). Bradley simply could know neither the demand nor the prices of the shares he wanted to buy.

To answer the questions of Bradley about this *bug*, the RBC's IT department and tech support mentioned the increasing presence of investors in the markets and the coincidence of simultaneous orders. Even though, they told him that there was a lot of news making the market data slow, he started to investigate the issue for himself. He wanted to prove to his colleagues that this could not justify the fact that his specific orders only vanished when he was trying to trade them. He therefore tried to buy some shares but sent the order **a few seconds later** (Lewis, *The Wolf Hunters of Wall Street*, 2014).

The reasoning was actually very ingenious. If after those few seconds, the shares had disappeared, that would have meant that someone else was in fact buying the shares and that the coincidence hypothesis was valid. However, it did not happen: after counting to five, Bradley pushed the *Enter* button on his keyboard and right after the click, the order changed. The offerings all disappeared and the stock popped at a higher price. By doing so, he proved to himself and to the other members of the bank that he was the only trigger of the *bug* and that the *bug* was a reality. The only reason why the prices were going up was that he was willing to buy, Bradley then thought to himself that someone was way faster than him (Macaux, 2015). To that RBC and Carlin's IT had no response. Bradley assumed that the real problem was with Carlin's technology.

However, by discussing with some of his friends from other banks and hedge funds, he realized how many people were getting fooled by this *bug* and how much money that *bug* was losing his bank and others each year.

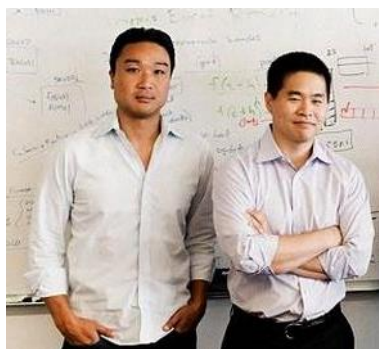
That discovery made Bradley thinking about quitting Wall Street, his position and his cushy \$1.5-million-a-year salary to become engaged and start a new business away from all of this. He had been slightly disgusted by the Wall Street environment and especially by the people in Wall Street. His trading machines were not working as they should. He started accumulating doubts and questions about whether someone had a real clue of what was happening on the markets, about the transparency of the markets and about the cause of the enormous *money hemorrhage* his bank suffered during these last years. He felt like the only thing people were caring about was money.

This was probably true but, in the end, he did not quit and promised himself to answer this existential question: *why was the display of the market on all trading screens just an illusion?*

In February 2009, Bradley's bosses in Toronto called him and asked him to seriously investigate this *bug*: how did it work, who was faster and why were they losing so much money? After the dismissal of Jeremy Frommer, RBC needed someone to run the operations in the electronic-trading business. Because of his discovery and the large knowledge he acquired during his professional carrier, the RBC's golden boy was the perfect candidate for this investigation. Bradley persuaded his superiors in RBC to let him recruit a team with which he would start doing some experiments on several stock exchanges. They did let him conduct these experiments in order to test his theories and try to answer his questions while losing up to \$10.000 a day to figure this out.

Bradley was not a computer wizard. He barely knew how to program and write codes (Lewis, *The Wolf Hunters of Wall Street*, 2014). To understand what was happening inside all these black boxes of public stock exchanges, he would need some tech-lovers

and computer people who actually knew what they were talking about and who could translate information from computer language to *finance and human terms*.



Picture representing Bradley Katsuyama and Rob Park. The picture was taken from pophistorydig.com

The first one to join the team was **Rob Park**. He was the algorithm expert, the *quant* of the team. Before joining RBC, he previously co-founded a small high-frequency-trading firm that specialized in statistical and machine learning algorithms (Macaux, 2015).

On joining RBC, he became the head of global algorithmic trading. Rob and his team created specialized algorithms and smart order routing¹ strategies for RBC's clients.

Rob's professional career path and knowledge about the strategies and techniques of order routing made him the perfect candidate for this investigation.

Rob Park had the first intuition about orders vanishing Bradley had experienced for few years. After discussing with him, Rob immediately thought that people on the market **were cancelling orders**: what Bradley saw on his screen were *phantom orders* to bait him.

Based on this assumption, Bradley, Rob and a group of young programmers started testing their theories on the public markets, on all 13 equity stock exchanges (run by NYSE, NASDAQ, BATS or Direct Edge). They quickly noticed something that made no sense to Bradley: as they increased the number of exchanges, the percentage of the order that was filled decreased, except for one. BATS was the only exchange where the orders were always 100% filled, no matter how many exchanges they sent their order to and no

¹ *Order Routing* is, according to the definitions from IG.com and invest-faq.com, the process by which an order goes from the end user to an exchange. *Smart Order Routing* attempts to achieve best execution of trades while minimizing market impact.

matter the combination of exchanges. Why would all the orders get totally filled if you sent your order to BATS only, but would not when including other exchanges? Neither Rob nor Bradley had an immediate explanation to this phenomenon.

A few months later, Rob Park arrived at the office with an idea. His new theory was linked to a bar chart he had seen during his research. It showed the time an order took to travel from their RBC trading desk in the World Financial Center to the several exchanges. They discovered that a time-increment (even absurdly small) could make a lot of difference. Indeed, with this chart, they finally understood why their orders sent to BATS were always 100% filled: it was the fastest to reach.

Theoretically, it took 2 milliseconds for an order to travel from Bradley's desk in Manhattan to the BATS exchange in New Jersey. The slowest to reach was the NASDAQ, where it took around 4 milliseconds. They still could not believe that such a small fraction of a blink of an eye could have any real impact on the financial markets until one of the young programmers in their team, Allen Zhang, showed them a program he had written and been testing for a few weeks. That program was building a time delay into the orders that were sent to the faster exchanges. By doing so, Allen succeeded in making them arrive exactly at the same time to all exchanges, BATS and NASDAQ. When Rob and Bradley tried to run the program with a real order on all exchanges, the screens lit up green, which meant that they got everything they asked for:

(Lewis, The Wolf Hunters of Wall Street, 2014, p. 7) "Rob said: 'It was counterintuitive. Because everyone was telling us it was all about faster. We had to go faster, and we were slowing it down.'

[...] Katsuyama said: 'It's 2009. This had been happening to me for almost two years. There is no way I'm the first guy to have figured this out. What happened to everyone else?' The question seemed to answer itself: anyone who understood the problem was making money off it.

The investigation lasted an entire year. They finally fixed the problem of the RBC electronic-trading business and had a product to sell to investors: the program that Allen wrote to build delays into the orders and enabling traders and other middlemen like Bradley to do the job they were meant to do. The program was then named *THOR*.

Bradley and Rob truly understood the potential THOR had during some sales' visits to some of the world's biggest money managers. One meeting showed them that the *bug* was not only caused by speed differences but that the framework was way wider than they imagined.

That visit was to Mike Gitlin, Head of Capital Fixed Income of T. Rowe Price, which was at that time managing billions of dollars in assets in global trading. From that discussion, the RBC duo learned just how much power the brokerage firms had. In theory, brokerage firms were supposed to represent and act **in the best interest of their customers**. They should be sending the orders to the stock exchange showing the best price for that specific stock.

However, in practice, the story was very different. The brokerage firms had the power to decide how and where to submit the orders they receive from the banks and the money-management firms like T. Rowe Price. Mike Gitlin told them that many of these firms were even paid hundreds of millions of dollars each year to send their orders to hedge funds or stock exchanges. He mentioned the example of TD Ameritrade (an online broker) being paid to send the orders to Citadel (a hedge fund) so they (Citadel) execute the orders on the behalf of TD Ameritrade. This practice was called *Payment for Order Flow*.

By testing their tool, or in other words by removing the ability of other traders to **front-run** them thanks to their speed, Bradley and Rob noticed some positive results: they were saving a lot of money. This front-running process was like an *invisible tax* to them, so small and so fast that it was impossible for traditional investors to be able to even notice it. From the reading of Michael Lewis book *Flash Boys*, I remember this explicit sentence showing Brad's point of view about this:

*(Lewis, Flash Boys: A Wall Street Revolt, 2014, p. 52) "The profit of 0,1% sounds so small until you realized that the average daily volume in the US stock market was \$225 billion. [...] People are getting s*****d because they cannot imagine a microsecond."*

After that meeting, Bradley and Rob decided to further test THOR and try to improve it. However, from a logarithmic and financial point of view, the tool could not be improved exponentially. Brad also needed someone from the high-frequency trading industry to add credibility to his THOR presentations. This is where **Ronan Ryan** comes in our story line.



Picture representing Bradley Kastuyama and Ronan Ryan at the creation of IEX Group in 2013. Picture taken from thetradenews.com

To better understand the character, quickly going back in time would be necessary. Born and raised in Dublin, Ronan Ryan was the typical teenager wanting to chase his American dream of working on Wall Street. Even though he sent applications to many investment banks, his Wall Street career started in a big telecom company. There, he learned how information circuits work, how hardware companies make computers faster. Moreover, he learned how information travelled from one place to another. He oversaw helping the big banks like Goldman Sachs or Lehman Brothers to find the best routes for their fiber cables and the best machines to execute their stock-market trades.

In 2005, he was hired by BT Radianz as a product-salesman. His job was to go and meet big investment banks and trading firms to convince them to locate their computers and trading machines in Radianz's data center in New Jersey. The purpose behind this change of location was to be closer to the stock exchanges in order to be faster than the others. That specific process is called **co-location**. Around the end of 2012 and the start of 2013, nearly every stock exchange was selling to interested companies the right to place their trading computers in the same data rooms as the exchange's computer servers themselves. By being present in those centers, the computers were almost guaranteed to be the first on any order.

This data centers were so important for HFT firms seeking the lowest levels of **latency** possible that, by the end of 2007, Ronan Ryan was making hundreds of thousands of dollars a year building and selling milliseconds systems. His clients were HFT companies, normal hedge funds and big investment banks. He was paid to make the markets faster. This was exactly the profile Bradley Katsuyama needed to complete his investigation team. His career, his knowledge and his recognition in the world of high-frequency trading were the biggest assets Ronan had to offer and were warmly welcomed by Bradley. Ronan Ryan joined the team in the autumn of 2009 after a short interview where Ronan explained to Bradley all he knew and witnessed during its career: from the tens of millions spent by high-frequency traders to the tremendous competition for tiny increments of speed.

(Lewis, The Wolf Hunters of Wall Street, 2014, pp. 11-12) "The US stock market was now a class system of haves and have-nots, only what was had was not money but speed. The haves paid for nanoseconds; the have-nots had no idea that a nanosecond had value. The haves enjoyed a perfect view of the market; the have-nots never saw the market at all. [...] Bradley recalled: 'The second I met him, I wanted to hire him. I learned more from talking to him for one hour than I learned from six months of reading about HFT'."

When he joined the team, Ronan Ryan quickly noticed the many technical problems THOR had. Specifically, the group had no control over the path the signals took to get to their destination. According to Ronan, the product Bradley and Rob had been trying to sell for more than a year was completely inconsistent because they could not guarantee a constant travel time for the orders. Sometimes the orders took four milliseconds to get to the New York Stock Exchange and sometimes they took seven milliseconds. The inconsistent and unpredictable path of the orders had to be optimized.

One day, Ronan Ryan came in the office with an oversized map of the states of New York and New Jersey focusing on the fiber-optic networks linking Lower Manhattan to New Jersey City. This map was the solution to their problems with THOR and the answer to all Bradley's questions: it showed the fiber-optic routes that telecom companies had built to make the trading signals travel from anywhere in Lower Manhattan (in this case, where RBC offices were located) to the several exchanges.

They finally understood the results of their investigative experiments some years before. The market on BATS was so accurate because it was the first stock exchange to be reached and to receive the orders. The map showed them that the route to access the BATS exchange was a simple straight line from Wall Street to the New Jersey centers but from BATS, it became way more complicated. Ronan Ryan justified the time losses by explaining that each turn or deviation in a fiber-optic network sacrifices a few milliseconds. A long but straight line will always be faster than a smaller but complex line with few deviations: *"to get from a building to another building across the street, the rope could be 15 miles long"* (Lewis, *The Wolf Hunters of Wall Street*, 2014, p. 13).

However, the rapidity of reaching the BATS implied something else very important: because the BATS was always the first exchange to receive the orders, the news of their

willingness to buy or sell a stock had no time to spread to the other marketplaces. Once the orders arrived there and got fulfilled, the market knew their intention. This meant that just after receiving the orders, it was very easy for the high-frequency firms present in the exchange center (and paying for the colocation) to front-run them. Traders just had to wait the appearance of some news in the market (like market orders for example), to trade on other exchanges. They could do this little trick simply because they were faster to get to those other exchanges. Ronan was not really surprised when Bradley told him that the BATS exchange had been created by high-frequency traders themselves, allowing no counter strategies to normal (and slower) investors.

This map was Ronan's *golden goose*. It came to be a valuable argument when Ronan and Bradley started to sell THOR again. The RBC sales' team met more than 500 professionals controlling fortunes of many trillions in assets: big mutual funds, big money-management firms or sophisticated hedge funds. **None of these investors had a clue of what was going on in their own market.** A salesman for RBC responsible for the THOR presentation to the several investors recalls one big investor phoning him:

(Lewis, The Wolf Hunters of Wall Street, 2014, p. 13) "You know, I thought I knew what I did for a living, but apparently not, because I had no idea this was going on!"

Most of the professionals were astonished after Bradley and Ronan's explanations: they knew something was not working as it should be, but they did not know what until Bradley's story.

These meetings helped the little RBC investigative team a lot. By exposing the situation to these big investors, Bradley and Ronan gained their total trust. Investors started to themselves investigate their brokers' activities and shared the information with the

RBC's duo. They started to collect a large amount of data around these brokers' strategies: what percentage of the trades were executed, the execution percentage inside brokers' dark pools² and to what extent investors were encouraged to choose to pass from these dark pools to trade. Because it was a very opaque tool and there were no clear rules on the subject, Ronan and Bradley discovered the fundamental role played by these **dark pools** in the strategies of the big banks running them. This problem of *moral inertia* could be underlined with a little paragraph of Michael Lewis' article in the New York Times:

(Lewis, The Wolf Hunters of Wall Street, 2014, p. 14) "Even giant investors simply had to take it on faith that Goldman Sachs or Merrill Lynch acted in their interest, despite the obvious financial incentives not to do so. As Mike Gitlin of T. Rowe Price says: 'It's just very hard to prove that any broker dealer is routing the trades to someplace other than the place that is best for you. You couldn't see what any given broker was doing.' If an investor as large as T. Rowe Price, which acted on behalf of millions of investors, had trouble obtaining the information it needed to determine if its brokers had acted in their interest, what chance did the little guy have?"

The external rules were clear. Those about dark pools, however, were not, and were not even published. It is then easy to imagine the possibility that these brokers' own traders were trading against the customers in their dark pools.

In May 2011, after discussing the several meetings they had had, the small RBC team sat around a table to plan the future strategy of the sales team. They wanted to sell and to license THOR to a stock exchange as a way to attract orders. THOR could indeed become an asset (thanks to its investors' protection). This was in Rob's mind a possible new strategy: if just one exchange accepted the proposition to convert itself into an

² This concept will be defined in the second chapter of this thesis.

investor-protecting exchange, the small (and slower) brokers might be willing to choose to use it and focus their trading routes on that single exchange:

(Lewis, The Wolf Hunters of Wall Street, 2014, p. 15) “[...] and it might become the mother of all exchanges. ‘Forget that’, Katsuyama said, ‘Let’s just create our own stock exchange’.”

That moment, Bradley Katsuyama understood the potential of such an idea. He felt the necessity to quit everything and that the markets needed to be revolutionized. That program with those people was the starting point of their new life dedicated to change the financial markets as they knew it.

When I first heard Bradley Katsuyama’s story, it was in February 2015 thanks to a Canal+ report: *Les Nouveaux Loups de Wall Street* (Macaux, 2015). That documentary triggered in my head a series of questions I wanted to explore. I wanted to try to give my own view on them and maybe even formulate an answer to those questions: *What are high-frequency traders doing that is so bad for market quality? But first, what are they doing exactly? If they are so negative for the markets, why do the authorities not react to that new phenomenon?*

I am not an expert on financial markets and I do not claim to be one. However, I have been following Brad Katsuyama and his team for around two years and a half in their adventure to create a stock exchange protecting the investors. In those two years, I have collected a lot of information, and this continues to grow since their IEX Group’s project is still ongoing. The results of my research will be presented throughout in this paper.

CHAPTER II - Literature Review

The first chapter allowed me to introduce the storyline and the characters that will help me illustrate my theory with concrete examples in this thesis. The following chapter will be more theoretical and dedicated to a review of literature about this subject. Some important terms and concepts that will be used in this thesis will also be explained.

Thanks to experts' comments and academic papers, I will further develop the definition of high-frequency trading practice and the identification of the traders involved. This second part will be based on an economic report written by the European Securities and Market Authority (ESMA, 2014) about high-frequency trading activities. I will go through their given dataset and try to provide an insight of who these high-frequency firms are.

This second section of my analysis will be crucial for the following chapters. By completing the analysis with the current regulations (see Chapter 3), I will be in a better position to study high-frequency traders' activities, behavior and impacts.

1 Theoretical definitions

Before going too much into technical detail, I would like to take a step back to explain the practice of *trading* and the several types and derivatives that were created over the passage of time.

Over the last few years, the financial markets' scene has significantly changed. With technological advancements, the development of current and new regulations and with growing competition, the trading infrastructures and techniques had to be adapted. This

trend started and developed on the US equity market and it only took a few years before it started spreading and expanding to a more global scale.

1.1 The trading scene

From all these developments interacting with each other, the increase in competition between trading venues and the increasing dispersion of venues, the first consequences were to be seen on the **market structure and on trading techniques**.

1.1.1 Trading & Stock Exchanges

Trading is a basic economic concept. According to the Cambridge Dictionary, it is the activity of buying, selling, or exchanging goods and services between two parties, a buyer paying compensation to a seller³. These trades usually take place on the market, which can take different forms. Whereas the **primary market** is dedicated to the first issuance of new securities on an exchange to raise funds and financing for companies or other groups (with IPO's), the trading we are going to focus on happens on the **secondary market**. This is typically the place most people think of when discussing about the stock market: the place where investors buy, sell or exchange the securities issued.

When trading a stock, a bond or any other security, investors usually go and look at the prices on the secondary market. Through the agency of a broker (the person receiving the order and in charge of passing them to the market), they make the trade on the exchange where the security is listed.

There is, however, no obligation for a security to be issued or traded on a stock exchange. The investor willing to avoid the broker's intermediary would then trade *over-the-counter* (OTC). In those kinds of transactions, traders are taking a major risk because

³ Definition can be found in the Cambridge Dictionary, available on dictionary.cambridge.org

the operation will not be supervised by an exchange. The OTC trade is executed directly between the two parties on the third (for institutional trades) and fourth (for direct institution-to-institution trades) markets. These two terms have become less prevalent in the era of electronic trading. They will then not be used in our analysis.

Originally, stock exchanges were created as mutual organizations with the only purposes of enabling buyers and sellers meet and to supervise the trades. They differed from each other only in terms of commissions, fees, transaction costs and the *bid-ask* spread⁴ offered. However, in 1975, the Congress of the United States gave the Securities and Exchange Commission (SEC) the authority to propose a series of rules with the aim of creating a *national market system* (NMS) **to ultimately suppress intermediation in a trade**. I will be going deeper into these new regulations in the next chapter.

After the adoption of the rules from this Securities Acts Amendments (*Alternative Trading System* and *National Market System* regulations), at the end of the twentieth century and the beginning of the twenty first, stock exchanges started to *demutualize* (the exchange creators began to sell their shares) making the exchanges become effective corporations. It is then easy to understand that this transformation changed the purpose of stock exchanges.

The exchanges became **private businesses** and just like any other business, they started looking after their own interests and competing with one another for order flow. They also had to start to differentiate themselves from their new competitors and start attracting investors to their exchange rather than to others. Some trading venues began

⁴ The *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.com)

to specialize themselves in specific sectors. For example, the NASDAQ is today the stock exchange for the whole technological sector (Apple, Adobe, Google, PayPal...). In London, investors will find a SME-specialized venue called *AIM*.

It became also much easier to create a stock exchange. After the European equivalent regulation, the number of exchange platforms in Europe (physical stock exchanges and through online services) has been multiplied by more than six times: from 40 to 267 exchange platforms (Macaux, 2015).

Nowadays, in the United States, there are exactly twenty registered securities exchanges (online platforms not considered). Only thirteen of them trade common stocks and related products. Some of them are parts of a bigger group and are owned by a single parent company (for example the 4 NYSE exchanges or the 4 BATS). Some of them are even entirely automated: the three NASDAQ exchanges, the second most prominent group of exchanges in the US for example, has been entirely converted into an automated and electronic exchange. The old days where traders had to scream and shout louder than the others and in their own dialect are gone: at the height of the day, the NYSE in Wall Street would look like a municipal library (Macaux, 2015).

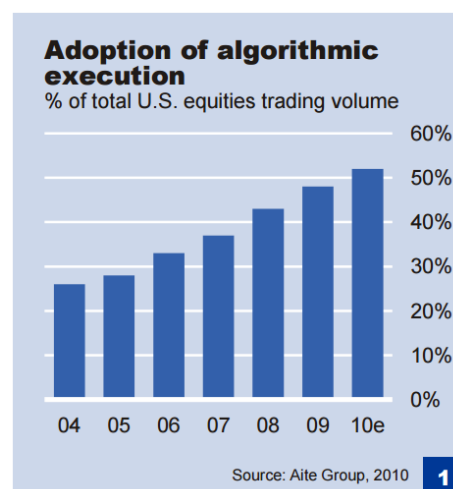
This change in the stock exchange structure re-shaped the markets and pushed the **dispersion and the competition** between them further upwards. Furthermore, these two effects boosted each other and encouraged the use of more computer-assisted trading techniques: *algorithmic trading* at first and *high-frequency trading* later.

1.1.2 Algorithmic trading

Thanks to the new information and telecommunication technologies, in the late 1990s, banks, brokers and all the other market participants had the possibility to remotely access the order books with their computer rather than with their telephone or in person.

This was the first form of electronic trading. Some years later and following this development trend, algorithmic trading appeared.

This new form of **computer-assisted trading** was an immediate success. The cost saving and the possibility of anonymity offered by the algorithms, combined with the computer's speed and consistency, became trump cards that every trader or investor needed to be competitive. The use of this new trading technique nearly doubled in a few years.



The first complete and relevant definition that did not simplistically define algorithmic trading as *a more complex form of electronic trading*, was the one by Hendershott et al.:

(T. Hendershott, 2011) “AT [Algorithmic trading] may be defined as electronic trading whose parameters are determined by strict adherence to a pre-determined set of rules aimed at delivering specific execution outcomes.”

Terrence Hendershott, professor at the University of California, further explains in his article that algorithmic trading allows traders to suppress the behavioral and emotional component in their decision-making process. This is actually possible because every aspect of the trade is **automated**: the timing, the price, the quantity, even the routing orders⁵. With that system, the algorithm will continuously monitor market conditions across all the different trading venues, track the benchmarks chosen for the executions and try to reduce the market impact of the orders (breaking them into smaller ones). To further underline the importance of the concept of automation in the definition, I would also mention the definition of Andrei A. Kirilenko and a brief survey he made about

⁵ As explained in the first chapter, the orders' routing is the practice where the investor decides by which stock exchanges your orders will pass. This technique will be further explained in the following chapters.

algorithmic trading in one of his publication. He described algorithmic trading as a system making trading decision **without human intervention** but thanks to mathematical models, computer, and telecommunications networks, in order to automate the buying and selling of financial securities (Kirilenko and Lo, 2013). Andrei A. Kirilenko justified the rise of algorithmic trading over these last two decades with a brief survey⁶. In that paper, the director of the center for Global Finance and Technology of the Imperial College of London exposed the three main developments that have assisted this growing power.

The first factor is complexity. The whole system of financial markets is becoming more complex instead of the opposite and this growing complexity is due to the general economic growth and globalization. These two phenomena bring a lot of new market participants, new risks, new and varied financial transactions, and a rising sum of money involved. The idea behind this is the presence of a vicious circle between new technologies and being greedy for benefits: “as the financial system becomes more complex, the benefits of more highly developed financial technology become greater and greater, and ultimately, indispensable” (Lo, 2013).

Secondly, the many breakthroughs in quantitative finance have played a role in this development. According to Hendershott, the many authors and math giants (Markowitz, Modigliani, Samuelson, Scholes, Sharpe and many other pioneers) have contributed to assert quantitative analysis in the financial markets (Lo, 2013). Algorithmic trading is just a direct consequence of this: financial analysis cannot be done anymore without mathematic models, and technology makes computations faster and with less (hardly any) error margins.

⁶ See page 53 of Kirilenko and Lo (2013).

Following the exact same reasoning, the third factor is linked to technological breakthroughs. This phenomenon has perfectly followed Moore's Law⁷. Hardware, software, data collection or other telecommunication technologies have all exponentially grown in the last decades.

(Lo, 2013) "The exponential growth in computing power per dollar and the consequences for data storage, data availability, and electronic interconnectivity have irrevocably changed the way financial markets operate."

By having a deeper look at all the developments explained in Kirilenko's survey, it is easier to understand the success of algorithmic trading. In a financial structure more competitive and fragmented than ever, every market participant who receives the opportunity to work and make money faster, more efficiently, with quantitative models and at lower transaction costs, would take advantage of it if the risks are justified. It is according to me, a perverse but realistic argument.

I would like to illustrate the logic of AT with the following example. The strategy presented is called *arbitrage trading*⁸. It is one of the first strategies that appeared with the rise of algorithmic trading. It consists of **exploiting inefficiencies in the market and monetizing these inefficiencies**: when two securities on two different market places and offer identical cash flow trade at different prices, there is the opportunity for an arbitrage⁹. Since the algorithm makes the trader faster, it is a risk-free profit.

⁷ Moore's Law refers to Intel co-founder Gordon Moore's suggestion made in 1965 predicting the exponential growth of the number of transistors per square inch. He predicted that, every two years until the foreseeable future, the number of these transistors would double. (Investopedia.com)

⁸ See chapter 4 for further explanation.

⁹ An *arbitrage opportunity* is the opportunity of realizing a sure profit monetizing market inefficiencies without any risks. It's the fact of not losing any money with a probability of winning something.

Another professor from the Polytechnic University Pierre Marie Curie (Paris), Mathieu Rosenbaum, defined the trading algorithms like this:

(Macaux, 2015) “A trading algorithm is an IT program that will try at its best to complete the transactions according to a client’s needs. The algorithm will do exactly the same job as a human but faster and with an integration capability of the market’s context, of the information from the data collected, way more important than a human.”

Professor Rosenbaum underlined during his interview one of the major consequences of this new practice: **investors lose contact with the real economy**. Those new electronic programs will treat aeronautical companies and small food retailers in the exact same way. Traders may not know what the algorithm is actually doing and what securities he is buying or selling at a specific moment. Algorithms just rely on the statistical and mathematical instructions they have been built on.

Furthermore, in this algorithm battle, big banks and other investment companies have invested a lot in developing their own solutions. Each algorithm has some specific characteristics of its own. For example, most of the algorithms today have a self-learning process making them even more efficient in a continuously changing environment. Some are however totally illegal. In his interview, Professor Rosenbaum added:

(Macaux, 2015) “Some students may start working in high-frequency companies that have a form of bad practices. [In our university] we have some courses of regulation to make students become aware of the illegality of some practices. But you know, when we give a chemistry class, we are not going to say to the student: ‘Watch out! You may create a nuclear bomb...’.”

Back in the early 2000s, the number of algorithms and of high-frequency players on the financial markets (no matter the legality) had become uncountable. Market participants did not control the financial markets anymore. This is actually the automation of the markets that caused on the 6th of May 2010 a very unexpected event: a *flash crash*.

1.1.3 Flash Crash

Before going into the details of the 2010 crash, a theoretical definition of what a flash crash is, might be helpful. Alfonso Puorro, analyst of Banca d'Italia, defined the flash crash in a very detailed research paper on high-frequency trading. According to him, it is a phenomenon characterized by a sudden, rapid and often baseless fall in prices of one or more financial instruments, and it is usually immediately followed by a vigorous bounce-back in the following minutes (Puorro, 2013). The flash crash can affect isolated shares but, in the most serious cases, it can also influence the course of the most capitalized indexes in the world (Puorro, 2013).

The first time the world heard the words *Flash Crash* was on the news, on the 7th May 2010, the day after the largest and fastest financial crash the world had ever known. One day before, at 2:42 pm more precisely, the Dow Jones lost within a few minutes 10% of its value (nearly 998.5 points):



Graph showing the movement of the Dow Jones on the 6th of May 2010 from Bloomberg

Every single stock went red only to recover 2:47pm. A very solid stock like *P&G* lost more than 27% of its value in just a few seconds (Macaux, 2015). Thomas Peterffy, a

Hungarian-born American financial engineer and programmer who played a crucial role in the development of electronic trading¹⁰, narrated his experience of that flash crash in an interview for the Canal+ documentary:

(Macaux, 2015) “I immediately called my traders asking what was going on! And they were literally petrified and told me: ‘We don’t know!’. [...] At this point, we were starting to feel that the entire system would collapse.”

The collective fear increased, making the effect snowball. Trading firms and investment banks started to leave the market, shut down their software and phone calls because they were losing too much money. To stop the market collapsing, the Chicago stock exchange decided to stop every transaction: they used the building’s electrical circuit breaker. “Suddenly, everything was gone. The market disappeared” (Macaux, 2015). For just five seconds, the US market was offline and fortunately, those five seconds allowed the algorithms to start working again properly on newer and fresher data.

This was the biggest crash the global stock market had ever known. Investors in all parts of the world lost more than a trillion dollars. Many people (mainly newspapers) speculated about the cause of such a crash and came up with improbable theories like the theory of the *fat-finger*¹¹. The two responsible regulators, the SEC (U.S. Securities and Exchange Commission) and the CFTC (Commodity Futures Trading Commission), published the results of their investigations a few months later, in September 2010.

¹⁰ Thomas Peterffy has been the first trader to create an automatized trading machine. He created a little box (looking like a very big, heavy and less technological-looking tablet) with a chip inside calculating the live quotations of the stock market and showing them on its screen. By tapping the screen, he could select the buy or sell option directly from that little machine. In 1997, he creates the first autonomous computer buying and selling securities without any human intervention. Thomas Peterffy is considered by many like the founding father of the computer-assisted trading.

¹¹ Popular theory according to which a trader may have inadvertently made a mistake in typing his order on the computer, confusing million and billion and feeding the algorithms with incorrect data that reacted in consequence.

According to their investigations¹², the reason for such a gigantic crash was a withdrawal of a big *sell* order from a high-frequency trader. The orders of the fundamental buyers potentially interested by this large order were not filled in. **This *mismatch* of orders took out a large quantity of liquidity from the market.** The algorithms reacted immediately to this withdrawal by, in turn, taking back their orders and their own liquidity. The market went short of depth and, above all, of money in a few minutes, crashing the whole system. Using the circuit breaker stopped this snowballing effect and, at 2:47pm, the market started working as usual again.

After further research, regulators have shown that the Dow Jones' flash crash of 2010 was not the first one. It has not been the last one either. According to a research made by NANEX, an American financial data services provider, done on all flash equity failures from 2006 to 2011, the number of little flash crashes is much greater than expected. Those flash crashes often happened on single stocks and with very little impact on their daily performance. NANEX LLC shared on its website¹³ a particularity of these flash crashes: some crashes made the stock value rise rather than fall.

Year	Downside crashes	Upside crashes
2011	69	70
2010	1,041	777
2009	1,462	1,253
2008	4,065	4,354
2007	2,576	2,456
2006	254	208

¹² Official report available here: <http://www.sec.gov/news/studies/2010/marketevents-report.pdf>

¹³ Data and picture collected from the NANEX official website: http://www.nanex.net/FlashCrashEquities/Flash-CrashAnalysis_Equities.html

The previous chart represents the number of downside and upside *flash deviations* the market has experienced from 2006 to 2011. Here is another market picture of one of these downside flash crashes:



Source: NANEX official website.

We can see on this picture the rapid decrease and immediate recovery of the value of the stock of Adobe Systems Inc which was up until 09:36:45. The stock was doing quite well but, three seconds later, it lost more than 2% without clear reason and regained it just afterwards. It is easy to understand that it is nearly impossible for a normal investor to notice these crashes.

Nowadays, flash crashes are not always caused by algorithms, high-frequency firms or even traders. On the 23rd of April 2013, another flash crash on the Dow Jones happened.

This time, the cause was a fake tweet from the newspaper *Associated Press* about explosions in the White House and the injury of Barack Obama. Here is a snapshot of the crash from Bloomberg¹⁴:



Graph taken from Bloomberg

Even though the fake tweet had been written by a hacker, the sequence of events, the snowball and the immediate recovery were the same as in 2010. This second crash will be crucial in our analysis of the impact of the HFT strategies on the market (see Chapter 4).

To sum up, Puorro's definition perfectly covers all the details and characteristics of a flash crash without necessarily talking about algorithms or high-frequency trading. Further in his report, he specified that a flash crash can in fact happen **without the presence of algorithms or high-frequency traders**. However, as demonstrated by the SEC and CFTC's investigations, the fall will always be accentuated by the increase in speed brought by those two practices. There is an important snowballing effect.

¹⁴ See J. Keller's article from Bloomberg, 2013.

1.2 High-Frequency Trading

The high-frequency trading technique appeared with the competition between trading venues and investors pushing the limits of technological advancements. High-frequency trading could be simplistically defined as a **faster form of algorithmic trading** but that would be a poor definition that does not encompass the whole singularity of the concept. Unfortunately, this is the definition used by Banca d'Italia's analyst, Alfonso Puorro. According to him, high-frequency trading comes from the same family of algorithmic trading but is just an evolved successor that takes economic advantages from predictable and less-evolved algorithms (Banca d'Italia, 2013).

Furthermore, the MiFID II definition, which is a more legal and more official definition of HFT, is quite similar. The comparison can be found in appendix 1. That MiFID II definition of algorithmic trading actually encompasses many of the elements that characterize high-frequency trading too: **speed, automation and autonomy of the operations and the integration of live market information**. Most of the definitions that I found stick to these three elements, making the strategies used the only difference between the two practices. One of the few studies adding new elements to the definition is the report of Fabozzi, Focardi and Jonas:

(F. Fabozzi, 2010) “[...] A high-frequency system is designed to analyze the market and send thousands of buy and sell messages per second and, depending on the context, to insert execution, cancellation or substitution orders that adapt themselves to the available data. The main objective of such a system is to identify and take advantage of the small and rapid unbalances of liquidity and of the prices’ inefficiencies. A high-frequency trading firm will always end its day contractually flat.”

They introduced, as an element of distinction, the objective of high-frequency trading: **identifying and monetizing the market’s inefficiencies**. Thanks to their speed and the automation of the processes, they rapidly and very easily take advantage of the unbalances. Whereas for AT, it was one of the possible strategies traders could use. It also

appears from this definition that this *forced intermediation* is the principal objective of high-frequency traders.

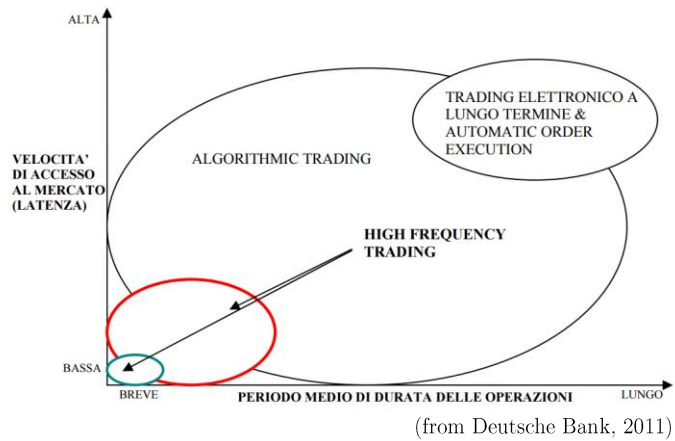
A second and more academic definition adding new characteristics to high-frequency trading is from Jonathan Brogaard, finance professor at the Northwestern University Kellogg School. In one of his papers on HFT impact on market quality, he says:

(Brogaard, 2010) “[...] a large number of orders (which are usually fairly small in size) are sent into the market at high speed, with round-trip execution times measured in micro-seconds. Participants are constantly taking advantage of very small price imbalances; by doing that at a high rate of recurrence, they are able to generate sizeable profits. Typically, a high-frequency trader would not hold a position open for more than a few seconds. Empirical evidence reveals that the average U.S. stock is held for 22 seconds.”

According to Brogaard, this **time reduction in the holding period** of a security is the newest characteristic brought by high-frequency trading on the market: to execute millions of small orders with a minimal gain. Before the rise of computer-assisted trading, the average holding period of a stock in the United States was of three years. Today, according to the Banking, Housing and Urban Affairs Committee of the US, this time has been reduced to less than one minute: only 22 seconds as reported by Brogaard’s research.

To sum up the several definitions, I understood that the main difference between AT and HFT is the **pace**; the speed of the analysis of the market. It is the speed of the execution and the time taken to access the market (*latency*) that creates opportunities. It is about rapidly monetizing actual inefficiencies of the market. High-frequency traders can easily monetize a very large number of those very small imbalances in a very short amount of time.

This graph from Deutsche Bank perfectly represents the difference between the two techniques with on the horizontal axis, the average operational time and on the vertical axis, a latency measure.



Later in this thesis, I will go through a more technical description of the characteristics and the operational strategies of high-frequency trading which cement their time advantage. That fourth chapter will complete the literature review and definitions of this trading technique.

1.3 Dark Pools

Before going through the HFT firms' identification in the second part of this chapter, I want to introduce one last notion: *dark pools*. This concept will be quite important in the following chapters for a more effective understanding of the strategies. *Dark pools* played a fundamental role during the rise of high-frequency trading but also in the strategies implemented by those market players.

According to CFA Elvis Picardo's article on Investopedia (2017), a dark pool is a private platform, forum or market for trading securities. It is not a proper stock exchange because the dark pool is not accessible by the investing public. The main advantage of these dark pools is that they allow the owner (usually institutional investors) to privately and secretly trade large amounts of stock without having to report those trades in real time and releasing the details of those trades.

2 Identification of HFT

There is one more point I want to underline about high-frequency trading firms: *who are they?* As explained in this chapter's introduction, the second topic of this theoretical section will be entirely based on two economic reports of the European Securities and Markets Authority (ESMA) from 2014 and 2016. Only the first one focused on high-frequency trading activities in the EU equity markets and this is the one I am going to concentrate on.

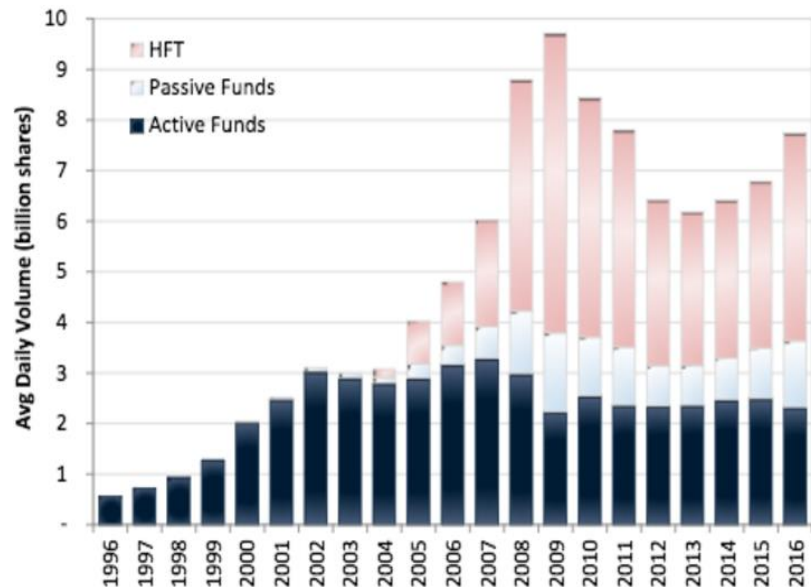
These reports¹⁵ will give a better understanding of what high-frequency firms are and what they are not. I believe that an accurate identification of those firms and actors will allow a more efficient approach of the subject. By doing so, the questions around the impact of high-frequency trading on the financial markets will be more properly answered.

2.1 Methodology of identification

The ESMA report starts by explaining the different approaches used in the report to identify whether a market participant can be labelled as a high-frequency trader or not. The methodology is actually very important because of the absence of proper and unique criteria to define a high-frequency trading firm. According to the research, the types of activities and strategies used by trading firms could be a criterion of identification, but they would lead to unduly diverse results. This variety of methods and approaches to estimate HFT activities would never entirely capture the exact number of high-frequency traders. The ESMA specify that their own approaches may also contain some over- and underestimation issues. They noticed that, depending on the identification approach used, the results may be significantly different. This is a general issue which concerns every analysis of HFT activity.

¹⁵ Executive summaries of the first ESMA report is available in the appendix: see appendix 2.

I decided to use this research because the ESMA uses a different approach and focuses on the European Equity Market only. Many similar reports in the literature only study the American market, where high-frequency traders already represent the large majority of the market participants. I then thought that this report would add a bigger added value to my research.



Graph representing the evolution of the presence of high-frequency traders in the US equity market. Taken from BusinessInsider.com

They collected data from May 2013 from the equity market from nine European Countries and used two different approaches to focus on the methodological advantages and disadvantages, both in a general context and in the context of the dataset used (ESMA, 2014).

The first approach used in the research is called the *direct approach*. There are two criteria for this direct identification of HFT activity which are:

- Whether the trading firm can be considered as a *pure high-frequency trading firm*. They analyzed whether the company does, as its **unique and primary business**, high-frequency trading. In the report, the analysts have used the identification list of the types of market participants built by Brogaard thanks

to the information he collected from stock exchanges, other trading platforms and exchanges' supervisors (Brogaard, 2013).

Even though this approach may seem obvious in the identification process, the estimations it generates might not be perfect. Because the approach only identifies the firms *flagged* as HFT because they explicitly claim to do high-frequency trading as its core business, the results might underestimate the real figures.

- The second criterion relies on the **use of low-latency infrastructure**. Analysts looked at whether the trading company used services to minimize its latency when trading or not. These services can range from the use of algorithms, colocation services or simply the access to faster data feeds.

In this first approach, only the first criterion (the *HFT flag*) was used in the conclusions of the analysis. The ESMA abandoned the second criterion in its report because it was insufficient and inflates the statistics since it only relies on low-latency (ESMA, 2014).

However, because of the underestimation issues it may cause, I will use the results of the *HFT flag* approach as a lower bound of an interval. The upper bound will be given by the second estimation approach, which is the *indirect approach*. It focuses on the trading and quoting patterns of the market participants and just like the first approach, this second one uses different factors to identify HFT activities:

- Intraday **inventory management** to have a flat inventory at the end of the day;
- **Lifetime of orders** before they get modified or cancelled by the trader;
- **Order-to-trade ratio** differentiating active from passive investors.

From those three factors, ESMA's analysts decided to use the **lifetime of orders** as the upper bound of the interval. In fact, the first factor may contain insufficient information to properly identify the HFT activities and the order-to-trade ratio does not take speed into account in the results. Using these two factors, the identification process would be biased.

The lifetime of orders will be used as the upper bound because of potential overestimations. This factor will include every market participant that has a minimal time of execution or elapsed before the order is modified or cancelled. This will in fact include every HFT firm, investment bank or trading firm that has shorter lifetime orders: 40% of their orders under 0.2, 5 and 3 seconds respectively. However, it may also include firms that are not flagged as HFT according to the direct approach.

By creating an identification interval, they obtained both an institution-based and a stock-based measure. According to me, using these two approaches is a good idea and gives us a better and more precise view of high-frequency trading presence in the target population (the EU equity market). I will not go through the building process of the database on which they did the analysis because it would not add any value to my thesis.

The results were divided into three categories: *value traded*, *number of trades* and *number of orders*. Thanks to those three categories, we will have a better insight into the presence of high-frequency trading activities in the market.

Here is an abstract of the results:

HFT activity - overall results for the HFT flag and lifetime of orders approaches					C.1
	HFT flag	Lifetime of orders			
		<i>lifetime of orders: total</i>	<i>thereof HFT firms</i>	<i>thereof investment banks</i>	<i>thereof other firms</i>
Value traded	24	43	19	22	2
Number of trades	30	49	25	23	2
Number of orders	58	76	55	19	1

Note: Figures are weighted by value of trades (value traded), number of trades, and number of orders; in %.
Source: ESMA.

In their sample, high-frequency trading represents:

- 24% to 43% of value traded;
- 30% to 49% of the number of trades and;
- 58% to 76% of the number of orders.

In some senses, these results confirm the definition of high-frequency trading: traders are faster and place numerous orders are not always processed and completed. Therefore, the value traded at the end is the **half** of the total number of orders. These results also confirm that high-frequency traders are present in the European equity market and that they might be more numerous than I first thought.

3 Conclusion

To sum up this second chapter, I would like to repeat the importance of this definition and of literature review. It helped me to further deepen and define the several important concepts needed for the global understanding of this paper. We differentiated algorithmic trading from high-frequency trading. We explained the concept of *dark pools* which played a crucial role in the rise of HFT. Furthermore, we used the ESMA analysis to finally understand, with clear numbers, which part of the market high-frequency traders represent.

This second chapter should also have provided the reader with the sufficient knowledge to globally understand the whole paper.

CHAPTER III - Past and Actual Regulatory Framework

High-frequency trading was born in 2007 after, among other things, the consolidation of the computer as the new operational trading instrument. It has become a must in banks and investment firms. These firms' CEOs and brokers/dealers chose the computer because of the alleged transparency it offered. After many scandals involving human errors or traders' greedy behavior, many market participants have apparently been convinced by the electronics and converted their business into a more computer-assisted one.

However, according to many financial markets experts, the turning-point that ushered the birth of this high-speed trading practice is the new regulatory framework: the MiFID in Europe (in November 2007) and the NMS in the United States (two years earlier, in August 2005). The European regulatory framework was inspired by the American one, and both were fostering more competition among investors, trading venues, individual markets and orders.

The technological revolution we talked about in the previous chapter undoubtedly made high-frequency trading developments possible and popular among the market participants. However, regulations have shaped those developments.

Analyzing the regulatory framework has not often been done in the available literature. In my opinion, this is a crucial part and should not be ignored given the impact it has had on the actual situation. In this third chapter, I will go through the past and current regulatory frameworks. Studying the legal framework and changes will certainly help me to understand what exactly made this practice explode and become so popular among traders.

In addition to this, going into greater depth on what exactly has changed in the rules might give some insights and ideas for a future regulatory framework. Those insights will be presented in the following chapters. Because some of the rules are intimately linked to some HFT strategies, I prefer to present their characteristic activities first before going too much into details.

1 Past framework

On grounds of clarity, this first part will be limited to highlights of the rules and decisions that were put in place before and during the 90's. I will be more precise about the specific rules and actors who had a major impact on the appearance of high-frequency trading. As mentioned above, the European framework is fully modelled on the one of the United States. Our starting-point will inevitably be the American scene and all the major changes to the U.S. equity markets.

In the United States, there are two institutional actors managing all the regulations of the financial markets: Congress, and the Securities and Exchange Commission (SEC). The first one created the second one in 1934 with the *Securities Act Amendment* to regulate securities markets. Even though the SEC is an independent federal entity, its rules must follow the guidelines given by the Congress. They both have the same objectives: **to discourage brokers' intermediation and encourage competition among orders and venues.**

The Congress and the Commission collaborated closely until 1975. That year, the Congress approved a new section in the *Securities Act Amendment* that gave regulatory authority and more independency to the SEC. Its main mission became creating and

adopting new rules to spur **the creation of a “national market system”** (NMS)¹⁶. That section stipulated that:

*(Exchange Act §11A(a)(1)(C)(iv), 1975) “[...] a broker holding a customer order to buy or sell a stock **should be able to see** the quotations in every market in which that stock traded and route the order to the market **offering the best price.**”*

Since that amendment, the Securities and Exchanges Commission obtained the ability and authority to pursue efforts and changes to reach their goal. In that section, the two objectives of the new regulation can easily be seen.

The first implementation of the SEC was **informational links**. The first step to create this national market system where investors could find any quotations was to gather all these data into one system. They wanted to create a more consolidated system that would provide information about all transactions and quotations on all stock exchanges. This system was built on **securities information processors** (SIP) which, in theory, regrouped market participants and provided them with all necessary information about:

- Execution prices, quality and speed of execution
- Order routing decisions
- Payment order flow
- Average spread of orders

In practice, following that rule, four SIPs were created, but separately: one for the NYSE, another one for the NASDAQ and OTC securities, a third for other exchanges

¹⁶ Exchange Act §11A

and the last one for listed options (P.G. Mahoney and G. Rauterberg, 2017). They exchanged only core information. It was already a good step forward but **the consolidation was still not perfect.**

This information linkage would then be useful for the second objective pursued by the SEC: the NBBO. Thanks to the information sharing through the SIPs (even though the sharing was not perfect), the SEC had to create something to protect the customers: “*As the national market system developed, a broker holding a customer order had a considerable array of options for executing that order.*” (Rauterberg, 2017).

The Commission introduced this new principle (still in force) which consists of a priority for brokers to look for the best bid (the highest bid) and/or the best offer (the lowest offer). This rule requires the broker to pursue only the investor’s (his client) best interests by guaranteeing him the best prices on the markets and to disclose all information about their decisions¹⁷.

These two new rules showed the SEC’s insistence about transparency and their mission of making the markets more competitive without exposing individual and private investors to too many risks. The synergies of these new NMS rules finally gave to individual investors a way to monitor their brokers and to receive all information about their orders and about the quality of their execution.

¹⁷ Rules 11Ac1-3 to 1-6, as amended, which have been re-designated Rules 605 to 607 of Regulation NMS, 17 C.F.R. §242 (2016)

A few years later, the Securities and Exchange Commission introduced **the Intermarket Trading System (ITS)** with the *Order Handling and Execution* rule. As an encouragement for the separate SIPs to finally consolidate all information into one single and common system and officially implement its national market system, the SEC wanted to surf on the wave of the ongoing technological revolution and create an **electronic network which could link all exchanges together**. By doing so, brokers would have one single place to look at for the best price at the time of the order. The project of the ITS was introduced in 1979. ITS total implementation on the American territory took 20 years after the NYSE exchange finally accepted the integration of the system. The *Order Handling and Execution* rule (which introduced the ITS) was approved in 1999.

This new regulatory framework, which removed any barriers to competition between markets, led to the appearance of new trading strategies: the NASDAQ has been the first one to use **market making**. With the introduction of the new rules, the type of competition changed: “Competition comes from the existence of multiple market makers in a stock, not from direct interaction of customer orders” (Rauterberg, 2017).

Market making is a trading strategy where the brokering firm decides to hold a certain amount of stocks (and the risks of holding them) on its account and hope to find a counterparty with whom to trade them afterwards. The principle of this strategy is based on the objective to capture the whole *bid-ask spread* in his favor by taking the opposite position of individual investors. A concrete example can be found in Appendix 3.

2 Current framework

The appearance of this new way of making trades pushed the Securities and Exchange Commission to accelerate the regulation of the market. The speed at which the market participants adapted to the new frameworks and adopted new unconventional and often undesired techniques or behaviors, took the Commission by surprise on several occasions.

The SEC did many updates to its *Order Handling and Execution* rules especially on transparency and disclosure to limit and structure market making. However, most of their actions enhanced new types of competitions among market participants, exchanges, trading platforms and so on. The turning point arrived in 2005 with the update of the NMS rules, principles and objectives¹⁸ and the adoption of the regulation for *Alternative Trading Systems* (ATS). These regulations form together the framework shaping the market structure known today.

The *Alternative Trading Systems* rule consisted of a recognition of all trading system substitutes. Its main aim was to bring them (with all the data about their best bids and offers) into the public quote stream inside the electronic communication networks of the national market system and to give the opportunity to individual investors to pass orders against them (Mahoney and Rauterberg, 2017).

This new regulation applied to all the alternative trading networks and platforms **that accounted for a sufficient portion of trading** in the stock market. In “a sufficient portion”, the rule included all the networks big enough to *trigger the order display and fair access requirements* (Mahoney and Rauterberg, 2017). It is safe to bet that after this regulation, many of the biggest dark pools changed their business model in order to avoid falling into that category and to continue their own business.

Furthermore, the most important update was the revision of the NMS regulations. This update was composed of four different rules: The *Order Protection* rule, the *Access* rule, the *Sub-Penny* rule and the *Market Data* rules and plans. However, only two of

¹⁸ To have a look at the official SEC document giving supplementary information about the rules structuring the market, visit: <https://www.sec.gov/rules/final/34-51808.pdf>.

them are determinant when talking about high-frequency trading. I will therefore exclusively focus on these two:

- 1- **Rule 611**, the *Order Protection rule*, is an update and a reinforcement of the NBBO principle proposed in the ITS plan. In addition to implementing the legal obligation of brokers and dealers to obtain the best prices for investors in the whole national market system (the market and the new electronic communication networks)¹⁹, the updated rule also protected investors from *trade-throughs*²⁰. In other words, this rule 611 was another layer of protection against new and unconventional techniques emerging from the brokerage environment.

- 2- **Rule 612**, the *Sub-Penny rule*, was a change in the quoting increment overall national market system. As explained above in the concrete example, the minimum price increment went from 12.5 cents to 1 cent. This decimalization tightened the *bid-ask spread* on every security and made financial intermediation less interesting: the profit margin dropped sharply.

The last reform was signed by former U.S. President, Barack Obama in July 2010: *the Dodd-Frank Wall Street Act*²¹. It aims at protecting consumers, promoting financial stability and transparency in the financial markets. The new regulation was a reaction to the financial crisis.

¹⁹ See page 5 of the regulation: <https://www.sec.gov/rules/final/34-51808.pdf>

²⁰ Brokerage firms' technique according to which brokers obtaining a price inferior to the one of a displayed quotation (lower than the NBBO) still execute the investor's order at the NBBO.

²¹ Legal text available on: http://www.cftc.gov/idc/groups/public/@swaps/documents/file/hr4173_enrolledbill.pdf

Despite the fact that they were not a direct measure against high-frequency traders, the changes in the American financial regulatory structure did affect the new form of trading. They banned several trading strategies that were characteristic of HFT firms.

3 Conclusion about the European Framework

The American frameworks of 2005 and 2010 were the basis of the European regulations that followed two years later. Most of the regulations set for the U.S. equity market were simply copied by the European Securities and Market Authority. The ESMA is, in other words, the European SEC. In 2007, they introduced MiFID 2, which is an update of their directives on *Markets in Financial Instruments*²².

The goals of this directive are identical to the American ones: the creation of a single market and the improvement of the competitiveness of the markets. The directives are also very similar:

- 1- The creation of *Multilateral Trading facilities*, which had the same structure as the American electronic communication networks, allowing alternative trading system (ATS) to consolidate the quote stream into one network (Frediani and Santoro, 2008).
- 2- The insertion of the obligation to respect the *Best Execution* (equivalent to the NBBO principle).

According to many specialists, these new regulatory frameworks, both in the U.S. and Europe (with MiFID 2 and the EMIR²³), were the trigger to the appearance of HFT practices. When taking a better look at what has been said previously, I notice what

²² The official page of the ESMA presenting the directives: <https://www.esma.europa.eu/policy-rules/mifid-ii-and-mifir>

²³ EMIR is the Dodd-Frank EU equivalent.

attracted this new type of traders: the obligation to respect the NBBO, the NMS grouping the several exchanges, trading platforms and other ECNs gathered into one place and accessible by anyone (all quotations of the whole equity market, available in one place), the decimalization decreasing the spread and the costs but also the risks of intermediacy and increasing the chance of new trading opportunities.

In conclusion, all these phenomena, arising from the changes in regulations, pushed the market participants to develop and invest in new and more technological tools and infrastructures to guarantee to the broker access to the best price on the market at any moment (Mahoney and Rauterberg, 2017). Traders then entered into a competition, where the objective was to be more efficient than the others.

CHAPTER IV - HFT practices and their impact on market quality

In the literature review, we concluded that the main difference between *algorithmic* and *high-frequency trading* was **time**: the speed of analysis, of access, of execution and of other operational aspects. However, this fundamental comparison can omit some practices and strategies that are specific to high-frequency trading. They play a crucial role in the debate around the impact of the form of trading on the market quality.

In this chapter, I will explain these new and sometimes unconventional trading strategies that appeared with this technologically more advanced trading practice and, more importantly, I will analyze their **positive and negative consequences** on market quality and soundness.

1 HFT technical characteristics

High-frequency trading differs from other existing forms of trading due to the technological competitive advantage it has over them. As Bradley Katsuyama said in his interview with the Canal+ crew, the order's speed offered by the logistical and electronic supports, discovers market inefficiencies that high-frequency traders will opportunistically take profit of (Macaux, 2015).

Speed as a competitive advantage, is obtained thanks to two characteristics that I already mentioned: *latency* and *co-location*. These two notions are the only two components making all the difference and offering to HFT firms this so-important few-millisecond advantage.

1.1 Latency

In the first chapters, latency has been defined as the speed of accessing the financial markets. To be more precise, the definition can be enlarged to the operational speed necessary to convert an investment decision into effective execution of an order (Alfonso Puorro, 2013). Speed (and therefore also latency) has a role in each step of the decision-making process:

- Information from the market received faster and in larger quantity;
- Faster analysis of that information;
- Prompt investment decision based on the data received;
- Faster execution of orders;
- More rapid negotiation of the trade's technical parameters with the broker;
- Order quickly sent to the market and information divulged to other traders.

It is then easy to understand that high-frequency traders will always opt for a **latency as low as possible** and will heavily invest in technological infrastructures and hardware to maintain tight speed competition: the lower the latency is, the faster the speed will be.

These investments push the speed at which data travel in a fiber-optic physical cable or by radio microwaves, nearly to the limits of known physics. The example of a Telecom engineer named Stéphane Tyc can illustrate this speed. In 2015, this ex-Harvard alumnus succeeded in beating his high-frequency competitors by diminishing by half the time an order took to go from the New York stock exchange to the one located in Chicago: from 13 milliseconds to 8 milliseconds: “It might not seem an enormous deal but in that amount of time, computers do an enormous number of things” (Macaux, 2015).

It should be reminded that there are 1000 milliseconds in a second and that it takes 300 milliseconds for someone to blink.

1.2 Co-Location

The first element was time. The second feature is its biggest rival: **distance**. In basic physics, the biggest obstacle to speed is the distance data must travel to reach their destination. Given a determined high-speed infrastructure made of either fiber-optic or radio-waves, the distance will inevitably influence negatively the speed. High-frequency traders have therefore implemented a new concept to gain some milliseconds: **co-location**.

Because the only limit to their speed was the distance that separated them from the trading venues, high-frequency trading firms decided to install their computers within the exchange. Having a physical presence next to the exchange's servers created important competitive opportunities for them. This practice gained even more popularity thanks to the privatization of the trading venues. High-frequency traders started to pay in order to benefit from those services.

There is an important **synergy** between the presented characteristics of the HFT companies. Being closer to the trading venues, the whole investment decision-making process has become faster and more efficient than ever before. Without each other, these practices would be less efficient. This synergy is furthermore the particularity of high-frequency trading.

2 HFT operational strategies

These two characteristics also allow trading firms to implement operational strategies that algorithmic trading would not be able to do. I am now going to present these evolved strategies while focusing especially on their impact on the market and on liquidity²⁴. This

²⁴ In jargon, the *liquidity* is not intended only as the width of the bid-ask spread in the negotiation book (financial literature definition), but it also considers the number and the volume of buying or selling orders incoming on the market (Alfonso Puorro, 2013).

impact analysis will be done in two steps: a first approach looking at the immediate and objective impact on the market. The ethical and controversial sides of the practices will be discussed in the second part.

2.1 Latency arbitrage

This first strategy has already been mentioned previously. As a reminder, this very **passive arbitrage strategy** consists of identifying and exploiting the small differences among stock exchanges. Because they are the first to identify the market inefficiencies, they are the first to absorb them. This is a quite natural strategy driven by low latency and co-location, which offers high-frequency trading firms a global advantage with low risks. This strategy is more interesting in environments where the number of trading venues increases.

A University of Michigan doctoral candidate has estimated at \$3.03 billion the potential annual profit of such a strategy on the S&P500 stocks and some stock from the Russel 2000 Index²⁵ (Herbert Lash, Reuters, 2016). We need to be cautious when reading that number: it does not mean there is \$3 billion free to be taken.

Concerning the direct impact of the practice on the market and its liquidity, the argument is clear: this strategy allows the whole market to respect one of its existential hypothesis on which it is built: The **Efficient Market Hypothesis**²⁶ (EMH). Latency arbitrage exploits the market inefficiencies, cancelling them as soon as they appear on the market place.

²⁵ The S&P500 is the large-cap stocks' index and the Russell 2000 is the small-cap stocks' index.

²⁶ The EMH is an investment theory stating that the financial markets should always be efficient and never present inefficiencies. This theory also states that it should be impossible to *beat the market* because the stock prices reflect all relevant information making the market efficient (Investopedia.com)

2.2 Market making

High-frequency traders act just like a market maker²⁷. They trade, provide liquidity to the market, take legitimate profit from the *bid-ask* spread but they can do it **without having to comply** to the strict rules linked to the traditional market making activities.

These rules concern quotation spreads, quantity or time taken of the orders. The most important of these rules is the obligation for traditional market maker **to be the counterparty of all in-coming orders, no matter what** (Alfonso Puorro, 2013). Market making high-frequency traders have the choice between becoming the counterparty and taking risks on the *bid-ask* spread. In addition, their speed will always ensure them the most advantageous prices on the market.

The market impact of that strategy depends on the volatility at that moment. In period of low volatility, orders and quotations are quite stable and do not present excessive risks for high-frequency investors. This **market making strategy sharply reinforces soundness and stability** thanks to the liquidity provided. However, when volatility increases, and the associated risks too, high-frequency traders very quickly withdraw their liquidity to avoid losses. This makes the market **weaker than expected**. This instantaneous liquidity withdrawal is also the main cause of flash crashes.

2.3 Passive rebate arbitrage

This third strategy is in practice a mixture of the two previous ones but is based on a totally different objective: the traders do market making and/or latency arbitrage in order to benefit from the **fee structures**²⁸ of the different electronic networks of the market.

²⁷ An illustration of the market making strategy with a real-life example is available in appendix 3.

²⁸ In a traditional fees structure, the broker/dealer pays to trade on a determined stock exchange.

As they became private companies competing between each other to attract the largest amount of investors' orders, trading venues created very competitive structures for transaction costs and fee payments. Some venues distributed **rebates** to brokers: they paid investors to trade and to provide liquidity to their ECN.

High-frequency traders were then passively paid to trade (with the previously mentioned strategies), provide the liquidity needed by the market and make the ECN **more robust**. The impact on the markets is then the same as in the two previous strategies.

2.4 Flash trading

Flash trading is undoubtedly one of the most aggressive trading methods used by high-frequency firms. It is also one of the most discussed and criticized by the financial press because of its potential unfairness: high-frequency firms pay the ECN to receive **a flash priority right** over all the orders that cannot be matched at the NBBO.

Concretely²⁹, high-frequency traders pay the trading venues to be the first ones to view any order not matching the best market price. Thanks to their speed, the broker has the opportunity to take advantage from that information and from price arbitrages. In this sense, flash trading is very similar to latency arbitrage. The only difference is that trading venue and high-frequency trader work closely together to collect more profits.

At the end of the operation, by creating and sending that flash order, the service provider (the stock exchange) allowed the orders and the liquidity to remain entirely inside its own ECN, making its market **more robust and efficient** than the others. It

²⁹ Concrete example of the Flash trading strategy, from Alfonso's Puorro research, is available in appendix 4.

also allowed clients to pay a lower price than expected when orders are executed below the NBBO. On average, the *bid-ask* spread has therefore been reduced³⁰.

2.5 Liquidity detection

This trading strategy is very aggressive and has been made possible thanks to algorithms. By testing very technical data, the algorithms can identify the presence of *stop losses* (SL) and *take profit* (TP) orders. Both are orders to sell a security at a known limit price (determined by the individual investor). These orders are *passive*; the investors wait for the orders to activate when a security's price reaches the limit. For that reason, those limit orders are very predictable. Thanks to their fast and technical market analysis, high-frequency traders will send tiny orders to the market **to activate these limit orders and benefit from the arbitrages opportunities created**.

This very aggressive strategy has no impact on the overall market. It just allows high-frequency trading firms to make money and forces the investor to cash-in his order.

2.6 Ignition Momentum

This sixth strategy is a continuation of *liquidity detection*. It is a very **speculative** and aggressive strategy only used during low volatility periods. The idea behind this strategy is to make the market and trading algorithms react to a massive order (in terms of volume) and take advantage of the temporary price fluctuations³¹.

³⁰ When it is said that the client might benefit from a lower price of execution, the reference is in the case where the execution price is below the NBBO. The flash trading strategy does not ensure that the execution will always be lower than the NBBO. Indeed, the front-running process of the strategy might charge a price higher than the NBBO but lower than the second-best price on the same trading venue. On average, this will always decrease the average bid spread: by lowering the upper bound or increasing the lower one.

³¹ Concrete example of the strategy available in appendix 5.

Because in the theory of the strategy, the price of the security will always go back to its initial price level, the high-frequency trader will close his position and make some profits from the price spikes. Just like every speculative strategy, ignition momentum does not improve neither the liquidity level nor the quality of the market. It just adds temporary volatility.

2.7 Quote stuffing

Quote stuffing is more aggressive and more speculative than the previous strategies presented (*liquidity detection* and *ignition momentum*). High-frequency traders **swamp the market with an unmanageable quantity of information** (order executions and/or cancellations) **to slow their competitors down**.

3 Market quality

What are then the positive and negative consequences of high-frequency traders on the market? The most important advantages brought to the market that I identified were the **increase in available liquidity** making the markets more robust to shocks and the **reduction of the *bid-ask* spread**. More in-depth studies of high-frequency trading³² complete this analysis by adding:

- Contraction of operational costs;
- Price information efficiency upgraded;
- Shrinkage of executional, transaction costs and trading' fees;
- Better control on orders;
- Sharp decrease in execution time needed.

In his report, Brogaard focused a lot on the last one. The important technological improvements, leading to this new minimal execution speed, made arbitrage opportuni-

³² See Brogaard (2010), Angel, Harris and Spatt (2010) and Credit Suisse Study (2010).

ties a lot more complicated to exploit. Taking advantage from eventual market mismatches became much more difficult. High-frequency traders made then the market and the price information more efficient (Brogaard, 2010).

Following the same reasoning as Brogaard, I can also conclude that very aggressive HFT strategies (like *flash trading*, for example) did benefit the overall market structure too. Despite the many critiques from the financial press, these aggressive and speculative liquidity-providing strategies did push the *bid-ask* spread to historical lows, making prices more efficient than ever (EMH). “[HFT] provide the best quotes about 45% of the time.” (Brogaard, 2010).

At first sight, it might be said of high-frequency traders that they are *not as bad* as the financial press says, because **they increase market efficiency**. However, by going deeper into my own reasoning and into that of many authors in the financial literature³³, I could find different ways HFT are distorting the market:

- Adverse selection and information asymmetry;
- Dark Pools’ moral inertia;
- Front-running;
- Shadow liquidity;
- Flash crashes.

The soundness and stability of the market seems to be guaranteed only in periods of low volatility. In that specific situation, high-frequency traders provide the liquidity demanded by the market and ensure the stability and efficiency of prices. However, when volatility increases, the story becomes a lot different.

³³ See Jarrow & Potter (2011), Micheal Lewis (2014) and Ivan Macaux (2015).

Even though Brogaard (2010) statistically demonstrated that high-frequency traders have no direct impact on the market's volatility level, he had to underline this fact: high-frequency traders are able to create short periods of high volatility (without influencing the level of the whole market) and actually, make more money during these periods. By creating these temporary volatile time intervals, they push traditional investors to undertake actions they would never have done otherwise. This is called the **adverse selection**. High-frequency traders create a situation where less-evolved traders are in a disadvantaged position because they have access of less information and high-frequency traders will gain from the losses of the traditional traders. This will also be considered as a problem of **information asymmetry** since, with their speed, high frequency traders can take an economic advantage from it.

The financial press also denounced the front-running operated by the brokers-dealers in their *flash trading* strategies. The press compared this practice to another illegal form of **market manipulation**. Because high-frequency traders pay to receive information before others (*flash orders* could be considered as material non-public information), this practice potentially matches with the definition of **insider dealing**³⁴.

Many regulators tried to sanction, limit or even ban front-running practices, but, because of the speed of the transactions and the colossal quantity of information to be collected to prove a market manipulation on a single operation, those practices are still in use. The best known rule in the U.S. was the 2013 FINRA Rule 5270, prohibiting

³⁴ The CFA definition of *insider dealing* is the practice of trading on the stock exchange to one's personal advantage through having access to confidential information. To be considered as confidential, the shared information must be material and non-public, meaning that the information will influence the value of that security and is not yet obtainable by other market participants (Investopedia.com).

front-running on large transactions only. The main weakness of that rule was that regulators could not demonstrate that the HFT transactions were related to a specific customer's large order. The regulators can only monitor on a case-by-case basis. This is obviously not efficient.

Finally, the most dangerous consequence of the high-frequency traders' presence in the financial market is **shadow liquidity**. When the markets are stable and *healthy*, high frequency traders provide a lot of liquidity to the market, which is good. However, traditional investors will take that liquidity for granted whatever the situation. Whenever the volatility rises too much and the high-frequency traders decide not to do anything or to use their liquidity-consuming strategies, the market goes short of liquidity and crashes (*flash crash*). High-frequency liquidity disappears and fluctuates when it is most needed and should be stable. This is why it is called *shadow* liquidity.

4 Strategies conclusion

It should be mentioned that all the above-mentioned strategies are today 100% legal. In recent years and since the Flash Crash of 2010, many other strategies and practices have been judged by the SEC or by other regulators as totally illegal.

Between 2010 and 2016, many practices were banned: *smoking*, *layering* or *spoofing*... The most famous of these was the *pinging* strategy³⁵. These strategies are not very different from each other and are very similar to *ignition momentum*. The goal is to send tons of limit orders (ST or TP) into the market, modify them, cancel them to influence the behavior of traditional investors and less sophisticated algorithms to take advantage

³⁵ This practice has become impracticable since the regulatory reform with the *Dodd-Frank Act* in 2010. Many HFT firms have already been fined for usage of such strategies.

from price fluctuations³⁶. This large quantity of orders pushes investors to do things they would not usually do and force them to accept to forgo a bit of their profit. These strategies had no positive impact on the market and were considered as manipulating the financial markets. This is the main reason why the SEC decided to ban these types of practices.

However, I found it difficult to understand in what way aggressive practices like *ignition momentum* and *quote stuffing* were significantly different from *pinging* and could not have been banned by the SEC. I also do not understand why regulators did not try harder to limit front-running practices. They may have considered the proposed advantages sufficient to excuse and cover the consequences of the speculation. It is true that the **positive efficiency effect** has been undeniable. According to the very methodical and rational difference-in-difference regression analysis made by H.-J. Breckenfelder in 2013 and the analytical conclusions of Fabrizio Puorro, the presence of high-frequency traders on the financial markets made them **more efficient and more liquid** than ever before.

What I am quite sure of is that both the SEC and the Congress did not expect the technology in that very competitive environment to have such an impact on how people trade nowadays. I also think that they did not expect the markets to become so disconnected from reality: two securities do not represent two valuable companies anymore. They only represent two potential valuable exchange to be made.

5 Personal comments

³⁶ For a pure informational purpose, a concrete example of the *pinging* strategy can be found in appendix 6.

In my opinion, it would not be an error if I trusted the reports and answered yes to the question “*Are high-frequency traders improving market quality?*”, because, empirically, prices are more efficient and market liquidity has been improved (especially when volatility is low). However, by already answering the question, I would omit the whole philosophical part of the debate.

All these *sometimes-ethically-questionable* strategies brought many essential elements that analytical reports might not have considered, but that should be taken into consideration to complete our answer to the question. In spite of the moral inertia or the front-running practices, the element disturbing me the most is that high-frequency traders have the power to trade **at the expense of the public interest**. The public interest is the need of a sound and stable equity market that fairly **finances our economies at any moment**.

In this regard, I totally agree with a comment of the cofounder of Finance Watch³⁷, Thierry Philipponnat, saying that high-frequency traders are just “*smarter guys doing legal but philosophically controversial things*” (Macaux, 2015). His main argument is that high-frequency traders create a **decoy**: traditional investors will always notice too late that the price is not the best one. In book *Flash Boys*, Michael Lewis said: “High-frequency trading is all about hoodwinking the common folks” (Lewis, *Flash Boys: A Wall Street Revolt*, 2014).

This is true since they can push traditional investors to trade at their own expense. Partly because of the *shadow liquidity*, their presence changed the environment of the trading system into something traditional investors cannot rely on anymore.

³⁷ European non-governmental company selling expertise and advocacy services for financial regulation.

The main question of my thesis then shifts from “*Are high-frequency traders improving market quality?*” to “*Is HFT really worth it?*”. Can adverse selection or market manipulation be justified by an improvement of market efficiency? I would personally tend to say that **it is not the case**. Since the moment I learned that some trading venues were giving advantages to a few big HFT firms to make them trade only on those exchanges, I have understood that the actual trading system has become completely disconnected from the trading reality.

Even though, I believe high-frequency traders are not the *bad guys* in this story. They just monetize the inefficiencies present on the market and collect some profits thanks to their technologies. Their speculative and too-aggressive trading strategies, however, pushed the financial community to criticize and put the blame on them. In my opinion, the blame must be put also on regulators rather than only on high-frequency traders themselves. It is true they have a large part of responsibility.

The basic business model of a HFT firm is based on a form of *forced intermediation* that does not create any value for the market: they buy to sell a few milliseconds later. As explained in chapter 3, the removal of brokers’ intermediation should have been one of the main objectives of regulators. In my opinion, even if they did not expect such a succession of events, it has been a failure on their side.

The regulators have also been too passive in the managing of the aggressive HFT strategies. Let us take the example of dark pools. In his book, Michael Lewis mentioned the example of Goldman Sach’s dark pool:

(Lewis, *Flash Boys: A Wall Street Revolt*, 2014, p. 139) “*The speed could be used to sell Chipotle Mexican Grill to Rich Gates at a high price in the dark pool while buying it from him at a lower price on a public exchange.*”

According to me, it is **neither fair nor ethically professional** for an investment bank to take advantage of such price arbitrages from their own clients and with such an opaque tool. Two years have passed since Michael Lewis' bestseller but no rules have been created.

To sum up my ideas, I think that the innovation brought by high-frequency traders does and will continue to improve the markets. They made the markets more efficient. They provide about 50-55% of market liquidity (Deutsche Bank, 2016). Markets today depend on their presence and their liquidity.

However, market quality should not be measured only by price efficiency and the level of liquidity. It is, in my opinion, quite insufficient. The **stability** and the **equality of opportunity** among investors should be also be considered as quality factors. The way they operate made the markets become unstable, unequal, unfair and more untrustworthy. In addition, the equality of opportunities is completely inexistent. The way they operate in the overall market is, I think, not efficient and not worth the consequences.

CHAPTER V - Solutions to HFT (IEX Group Case)

In the previous chapters, I discovered the impact of the technological revolution on the financial markets. I underlined the importance of these financial innovations, bringing high-frequency trading on the global scene and changing the current trading model. Wall Street and technology firms used each other to increase their efficiency, but also introduced many sorts of market inefficiencies and took advantage of loopholes in the regulations (Lewis, *The Wolf Hunters of Wall Street*, 2014).

Fortunately, technology has also been used for positive market improvements. Many propositions to limit high-frequency traders and/or to improve the market quality have been introduced since 2014 when Michael Lewis' best-seller *Flash Boys* shook the financial community.

In this last chapter, I will go through some of the most efficient projects already proposed as HFT limitations and more, afterwards, I will describe Bradley Katsuyama's project as the final and best solution to high-frequency trading.

1 Past propositions

In this first section, I will highlight the propositions of many actors that did not succeed in limiting the activities of high-frequency traders. All of them took different perspectives and tried to monitor, limit or even make HFT unattractive.

1.1 MIDAS (Market Information Data Analytics System)

The first move was in January 2013. Willing to catch up with the times and technology, the SEC put out a call for tenders able to develop a tool which would consolidate all information of the market in one single place. A constructor was found and built this new software that was able to see everything on all U.S. equity markets.

At the start, MIDAS was supposed to monitor every market participant's activities on the market. This could have been a crucial tool for the SEC's HFT-monitoring task if only the selection of the constructor had been done with more common sense. Because no firm has a better knowledge of the markets than high-frequency traders themselves, the SEC selected one of the major American HFT firms, called *Tradeworks*.

Allowing the biggest high-frequency trader to build the machine that will be used to monitor high-frequency traders seems more like the beginning of a joke rather than the narration of real-life events. The **conflict of interest** is evident even for a finance novice. The founder of NANEX, Eric Hunsader, commented the episode like this:

(Macaux, 2015) "If I had the data to build the machine, I would precisely know what they [the SEC and regulators] can see and, more importantly, what they cannot. I would make a lot of money giving consulting to firms."

Despite Tradeworks argument that the provided data is analytically undisputable and that conflicts of interests have been well-managed, MIDAS has a big issue: the software does not cover the whole market. MIDAS focuses only on the U.S. equity market making the tool not as useful as it should be. The derivatives or commodity markets are still free and unmonitored. MIDAS is then, according to me, incomplete and insufficient.

1.2 AMF (Autorité des Marchés Financiers)

In Europe, the first actor who tried to crack the whip in the fight against high-frequency trading was the French Authority of the Financial Markets, the AMF. The French regulator created an investigation unit tracking the behaviors of high-frequency traders on the Euronext Paris³⁸ and the stocks in the CAC40 benchmark index.

³⁸ The Euronext Paris is the main French stock exchange.

The main objective of the thirty-person team is to identify and track down any signs of market manipulation in every transaction. However, their main problem was, and still is, linked to the quantity of data that needs to be collected to monitor one single market day. In addition, in an interview with Canal+ (Macaux, 2015), Laurent Coubourieu, the AMF investigation director, explained that in an inquiry, the team has to operate only with past data. This makes it harder for them to do their job properly. For every trading day (starting at 9am and finishing at 5:30pm), they need to look at every single order of the millions sent by one high-speed trader. They also need to find the specific algorithm used at that time.

The complexity of the task is high and increasing since technologies continue to evolve. Showing the very low efficiency rate of such investigation methods, Laurent Coubourieu underlined that, in eight years, only two investigations have succeeded and for very low penalties (Macaux, 2015).

1.3 Speculation Tax

An interesting proposition from Finance Watch, the European financial consulting NGO, got my attention. For more than five years, the NGO has advocated a new reform of the financial markets at the global level. According to them, to have a real impact on the market, any regulation should be made at a continental scale, if not at the global scale: “In fact, nothing will ever change if we don’t apply a new rule common to the whole continent.” (Macaux, 2015).

Their proposal to limit or even eliminate high-frequency trading is to introduce a **tax on orders flow**. Because these traders are sending, changing and cancelling millions of orders every second, imposing on them a very small tax (Finance Watch proposed a cent or even a tenth of a cent) on every order, would destroy the HFT firms’ business model. High-frequency trading would become economically unprofitable (Finance Watch, 2013).

This tax would also impact the traditional investors but in a lighter way. The main impact would remain on speculators and market manipulators.

The only problem with the proposition is the very slow implementation process from the European Institutions. Benoit Lallemand, General Secretary of Finance Watch, has been fighting for the approval of its proposition since 2015. At present, despite the fact that Euro-deputies voted for a more transparent financial market in 2014, the technical details of the norm still have to be discussed (Macaux, 2015).

These details will be essential for the efficiency of a potential EU law. As Mister Lallemand specified during his interview, the details will make the difference between a law impacting high-frequency trading or not at all (Macaux, 2015). Unfortunately, lobbyists pro-HFT are numerous and certainly cause delays in an already-slow process.

As an example of an inefficient tax on market manipulation, I could mention the **speculation tax**, the TOB, Belgium implemented in January 2016 and abolished one year later: capital gains from the sale of listed shares were subject to a 33% tax, if the capital gains were realized within a 6-month period from the date of acquisition of the security (BDO, 2016). In spite of the low revenues collected from it (only €20M rather than the €120M expected), the TOB pushed every investor to not trade anymore (L'Echo, 2016).

This Belgian rule was not a direct measure for high-frequency trading, but a budgetary and fiscal update. It was, however, worth the mention to show that a common and global rule discouraging the high-frequency traders must thus not discourage the traditional investors to trade and completely remove their liquidity from the market.

2 IEX, the Investors Exchange

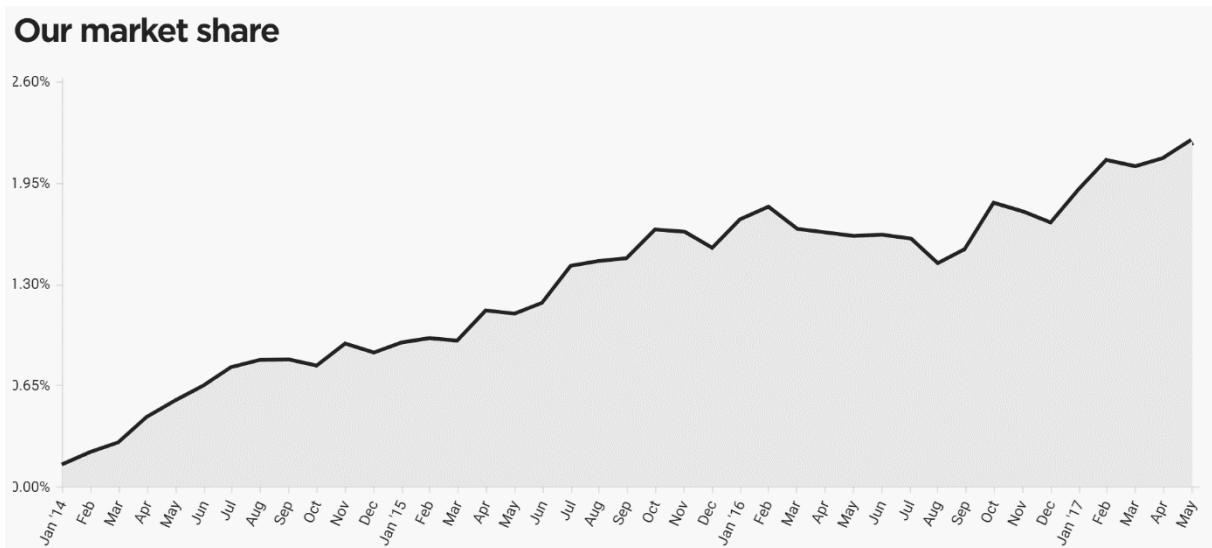
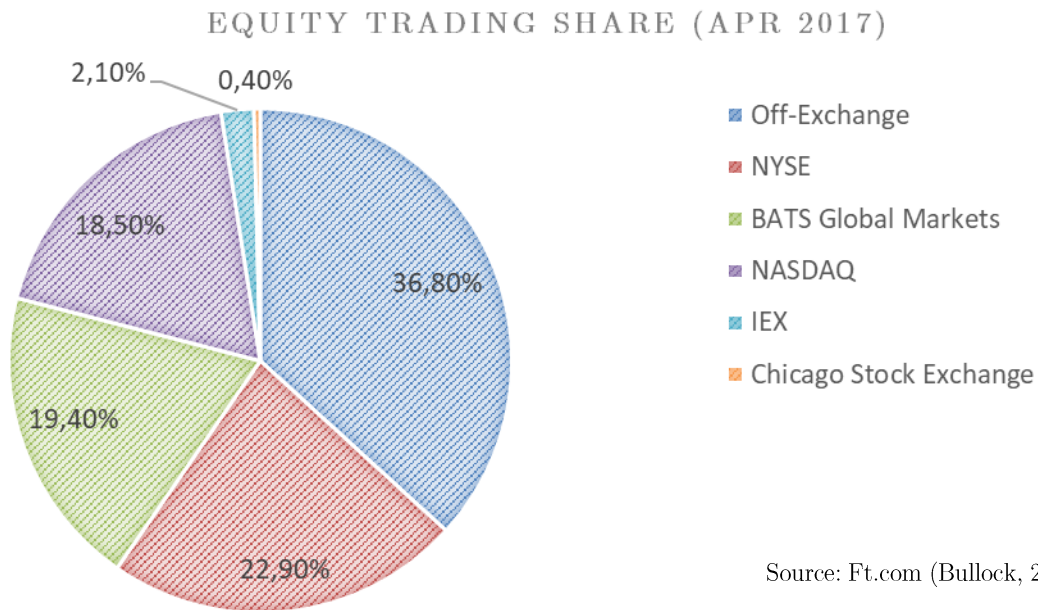
All the above-mentioned propositions were attempts at limiting, monitoring or even legally banning high-frequency trading from the financial markets. However, none of the options suggested **competing with the high-frequency traders** rather than blocking them in some way, except one man: the number one of the new IEX Group, Bradley Katsuyama.

In Chapter 1, I went through the conclusions he came to through investigations with his RBC team. As mentioned above, one of the outcomes was the creation of a program (THOR) adding a *speed bump* (a 350-millisecond artificial delay) to slow down the order flows and cancel the advantages high-frequency traders have with their speed. THOR combined with their routing strategy through microwave fiber connections, convinced Bradley to start his own business. He created a new trading platform (considered as an ATS) which, indeed, was called IEX, the Investors Exchange.

Seeing the enthusiasm for his project, after the publishing of Michael Lewis' bestseller, Bradley started the application process to the U.S. SEC to obtain permission to become an officially recognized stock exchange. After months of debates, in June 2016, the SEC finally approved his proposition. In spite of the fierce lobbying from high-frequency trading firms but also from trading venues themselves, and despite some concessions he had to make, Bradley Katsuyama succeeded in launching the first stock exchange where **transaction speed is limited** and where **fairness** and **transparency** is promoted.

IEX was forced to abandon his strategy of orders routing. Rule 611 about **order protection** wants to avoid conflicts of interests and avoid venues favoring routing to its own venue over others. Therefore, by becoming an operational stock exchange, the group could not keep its own order routers and comply with NBBO principles.

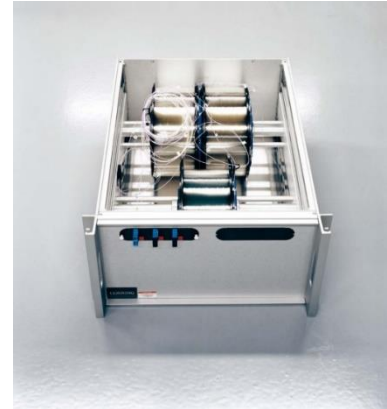
Fortunately, this did not impact Bradley's strategy. In an article in the *Financial Times*, he insisted that they stick to their principles of transparency and fairness. Since the foundation of IEX, things have hopefully turned out in IEX Group's favor. Their market share has been rising to reach 2,216%³⁹ of the U.S. equity market, growing by 56% in just 9 months:



³⁹ Further details available: <https://www.iextrading.com/stats/>

IEX is still a small actor compared to the three main exchanges on the American scene but the company is profitable and has found a lot of support. Several mutual funds, hedge funds or venture capital funds financially supported the project. But, one question remains: “*how does IEX work exactly?*”. The answer to this question is a shoebox.

This shoebox has been described by Ronan Ryan as the *front door of fairness* (Macaux, 2015). It consists of a box with a **sixty-kilometer fiber coil** inside. This box makes THOR work: it allows the program to activate the 350-millisecond *speed bump*.



Source: meanderful.blogspot.be

To be executed in the IEX trading servers, every single order that comes into the platform must go through this fiber. By imposing this delay, any investor’s order, no matter its original speed, will arrive at the same time and be executed in succession.

Their business model built on fairness and transparency also refuses the **payment of rebates** for brokers and dealers. As we have seen in the strategies section, some high-frequency traders modify their routes to benefit from the most interesting incentive structures. Under IEX’s operational structure, this conflict of interest is avoided. According to Bradley Katsuyama, this refusal of rebate payments is one of the major threats to IEX’s short-term growth but consolidates their positioning and market confidence:

(Bullock, 2017) “It [rebates payment] skews execution metrics. But, at the end of the day, that conflict is going to come to a head and we’ll be the beneficiary of that.”

Just like rebates payment, IEX’s structure eliminates the advantages of other strategies high-frequency traders are using. All the speculative and aggressive practices are unenforceable. The most impacted one is **co-location**.

I have shown the importance of the co-location services sold to HFT firms to be the first to access to the market data. In today's equities markets, arriving first means millions of dollars for firms and IEX created a *speed bump* that completely eliminates any advantages of this kind (Lauer, 2015). In his comment letter to the SEC, Dave Lauer, chairman of Healthy Markets Association and involved in the early stages of the creation of IEX, explained more precisely how THOR counters co-location services:

(Lauer, 2015) "In this way, IEX's matching engine is always aware of any price changes at other market centers before the fastest trading participants are able to act on those price changes. In the time it takes data to run through this coil, any advantage of "being first" is lost -- because the rest of the world has already moved on."

The imposed latency, the fact it is an investor-owned only trading venue (no conflict of interests), the interdiction of special access to data through co-location or other fees payments and the refusal to pay rebates to traders are not the only positive sides I have noticed in IEX.

In addition to these factors, IEX decided to allow only four types of orders: market orders (*buy or sell* at best current market price), limit orders (*take profit or stop loss*), mid-point peg orders (orders executed at the mid-point of the bid-offer spread) and the *Fill or Kill* orders (order must be 100%-filled or must be canceled). By allowing only four orders on its stock exchange, IEX wanted to simplify trading, reduce the complexity of a market driven by very aggressive orders created to accommodate HFT firms⁴⁰. I share Dave Lauer's opinion on this point: in an environment where the proliferation of complex

⁴⁰ According to Investopedia's article by Elvis Picardo, CFA, orders like *Post-Only* and *Hide Not Slide* were created with the only objective to create noise in the market's data. These types of orders were very strategic for HFT practices like ignition momentum.

and purely speculative orders has recently come into the focus of the SEC, IEX was the first player to make the decision to limit its offer to investors in order to protect them, and not think only about profitability (Lauer, 2015). They block potential abuses at their very source.

The last advantage I observed in the Investor Exchange is their fight against dark pools against more transparent markets. As I mentioned earlier, dark pools were fundamental for high-frequency trading and the implementation of their strategies. Big investment banks and hedge funds also used these dark pools to do **proprietary trading**: invest on the market for their own interests (rather than for clients). Therefore, some banks traded against their own clients. This practice is totally legal because they are legitimate market participants allowed to trade just like the others.

To avoid any possible conflicts of interests, IEX decided to not engage in proprietary trading at all.

3 Conclusion

To sum up this last chapter, the IEX group has, in my opinion, many positive reasons to become a big player on the trading scene. Since the SEC's approval, one year ago, IEX has continued to grow without deviating from their focus of fairness and transparency. Many market participants like big investment banks, hedge funds and even some high-frequency firms agreed to play the game and trade on IEX's low-frequency exchange (Macaux, 2015).

Even some trading venues started to imitate their model. On one side, on the 16th of May 2017, the SEC gave the permission to the New York Stock Exchange (NYSE) to implement a 350-millisecond speed bump. As a test, the NYSE Group will first apply

this delay to one of their smaller American stock exchanges: the NYSE MKT (Reuters, 16th May, 2017).

On the other side, the NASDAQ does not plan to follow this trend at the moment. Indeed, the second largest exchange will be the main operator of a new dark pool launched by Goldman Sachs. The new dark pool will allow the clients to choose what type of counterparts they match up with, inside the pool (Reuters, 11th May, 2017). Despite the increasing regulatory pressure on dark pools, rules and practices inside of it are still not very transparent.

IEX brought and is bringing something new to an environment characterized by fierce competition. Unfortunately, it is extremely hard to prove that their business model is actually improving market quality. In my opinion, it is a bit premature and early to find empirical results about their impact.

However, I also think they have all it matters to succeed. Their business model counters every part of high-frequency trading and this is what drives my optimism about their future. I hope they will succeed. Nonetheless, I am pretty sure that IEX did put the competition in the right direction: to transparency and fairness.

I would like to conclude this chapter with a Bradley Katsuyama's statement during an interview with Bloomberg (Levine, 2016): *"I don't think we would have survived if it was just hype."*

General Conclusion

In my analysis of high-frequency trading and its impact on market quality, I have been through all the aspects of the subject that could potentially influence my answer.

I went through the past and current regulatory frameworks and noticed how poor they were. The new rules were too focused on the encouragement of competition rather than promoting fairness and transparency and the regulators decided to remain quite passive against the technological revolution ongoing on the financial markets.

I think this passivity was not the most appropriate strategy at that specific moment. The monitoring and the follow-up of the HFT strategies had to be more pro-active. As I concluded above, the succession of events, the technology and the disconnection of the markets that followed probably exceeded by far their expectations leaving them behind in terms of authority and power over the financial markets.

I then studied the strategies that high-frequency traders have created and implemented. By analyzing them more deeply, I could understand that there were positive and negative sides of high-frequency trading. Without forgetting the other advantages HFT brought to the markets (like the lowering of executional, transaction costs and trading' fees), today's markets seem to be the most efficient ever since the information performance, the price efficiency and the liquidity provided to the market have never been on higher levels.

However, by having a better look and going beyond their first market's quality impacts, I could notice the many downsides of high-frequency trading. From the purely-operational matters (like the use of dark pools or front-running practices) to the more structural ones (like asymmetry of information, adverse selection, shadow liquidity or flash crashes), I concluded that the downsides far outweighed the upsides. This conclusion made me tend for a negative answer when asking whether high-frequency traders and their practices are improving the market quality. In my opinion, just looking at the operational upsides and downsides was quite insufficient to answer properly to the question. Indeed, a more ethically-oriented reasoning better justifies my positioning on the subject.

Last but not least, I went through all the propositions for a solution to better limit, monitor or make high-frequency trading disappear from the markets and I developed the one that seemed to me the best one: IEX, the Investor Exchange.

Advantaged traders were making money only from traditional investors' ignorance and the incomprehensibility of the market, but this did not seem ethically correct to Bradley Katsuyama. Therefore, he decided to launch his own business, try to compete with those high-speed traders and try to solve the new issues of the markets. Thanks to his team, he succeeded in building something that, according to me, has got all the key prerequisites to progress, protect investors as it claims to do, ensure and promote transparency and fairness as the base-elements of the financial markets and, last but not least, end up improving the overall quality of the financial markets on a more global scale.

When discussing about high-frequency trading with some of my colleagues from university and from my internship, some of them thought that my thesis was a way to prove

that high-frequency trading is bad and that the high-speed traders are bad people. As the reader should have understood so far, this is absolutely not the case.

My thesis aimed at discovering and studying their impact on market quality: did the technological advancements that pushed the appearance of HFT, improve the market quality at the end? This is why I chose the title “*High-frequency traders a blessing in disguise?*”. It perfectly reflects my reasoning.

I wanted this paper to help me to better understand the actual financial system shaped by the mix of **passive regulators**, a **computerized-technology revolution** and a lot of **people eager to make money** quickly and in large quantity.

From this analysis, I understood that the synergies between the three created a favorable environment where privileged actors could easily dominate other market participants, sometimes with very aggressive practices. Despite making the market more efficient than ever (**price efficiency** and the level of **liquidity**), these privileged investors did not seem to care about the two other quality factors (information and practices **transparency** and opportunity **equality**) which are, according to me, essential to reach market excellence.

These missing quality factors can then be found in IEX. The new stock exchange represents to me the new way to win investors’ confidence in the markets back after the severe flash crashes of the last years. The last flash crash happened, indeed, not such a long time ago: on the 7th October 2016, the British Pound lost 6% against the U.S. dollar in few minutes and without clear reasons.

More recently, the flash crashes of solid stocks like Amazon or Ethereum must be mentioned. Whereas the Amazon crash, in early June 2017, could be described as a mini-

flash crash since the downside did not exceed 4%, the Ethereum crash is, in some senses, spectacular. On 21st June 2017, the stock valued at \$296 lost 95% of its valuation and entirely recovered in just a few minutes. The stock reached a peak at \$13.



Source: businessinsider.com

Since those flash crashes, algorithmic trading and high-frequency traders have been severely criticized by the financial community because of the unknown introduced by the new technologies.

Many lobbyists speculated that experts and traditional traders feared the constant loss of control over the markets brought by the technology. Just like the popular American films, they feared robots could take control. However, I still believe that they are not the bad guys and that they just benefit from the structural loopholes and opportunities of the markets. But again, this must not be made at the expense of public interest.

We live in a period where information-technology innovation is probably the most prolific it has ever been. IT is, nowadays, present in every activity people do: communicating, socializing, learning and teaching. It was just a matter of time before IT started being used on the financial markets and before someone started using that technology in

an ethically-questionable way, and, with the media starting to interfere, the bomb inevitably exploded. Hopefully, this explosion resulted in Bradley's creation of IEX as the new way to fairness and quality markets.

According to Bradley Katsuyama, the markets needed to change their focus. Rather than think about how much money people are making, the financial community has to look **at how** these people make money: people need to find new way to do things because the world is more receptive to people trying to do things differently (Levine, 2016).

In finance, this is even truer with all the technological developments made with artificial intelligence. Some hedge funds are starting to invest and develop more advanced learning software who will be able to compute investment decisions by themselves.

This increasing digitalization could one day easily replace human professionals or discretionary functions that we always considered safe from the technological revolution. Professionals like asset managers, doctors or even lawyers are starting to be threatened by overall technological innovation.

Therefore, according to me, innovation in general must be encouraged but **global** regulations must be implemented to protect the public interest. Policymakers must carefully examine and meaningfully regulate the new and powerful technological landscape that is and will certainly continue to shape, not only financial markets but, the future of us all.

Appendix

1 Appendix 1: MiFID II definition comparison

MiFID is the Markets in Financial Instruments Directive, a European Union directive. MiFID II is the 2011 update of the first directive that has been applicable since November 2007. This directive was aiming at setting out more conduct, business and authorization requirements to avoid market-abusing behavior and to promote transparency in trades.

The articles 4(1)(39) and 4(1)(40)⁴¹ of MiFID II describes both the algorithmic and high-frequency trading:

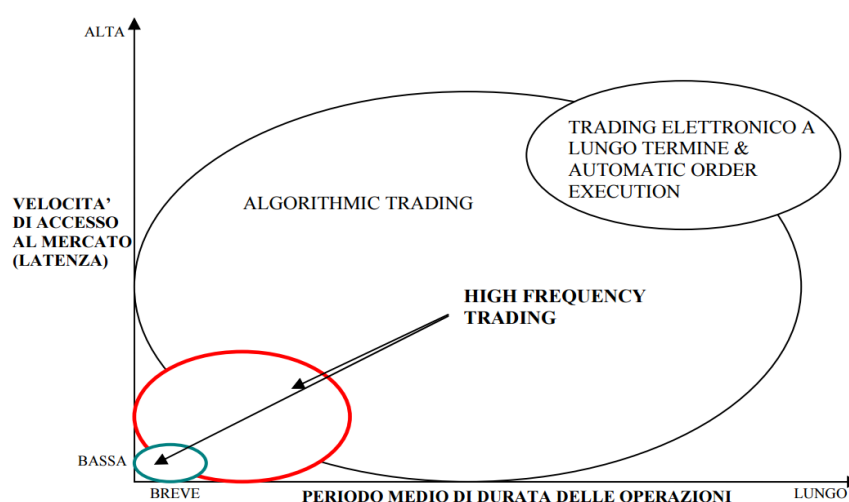
- *Article 4(1)(39): Algorithmic Trading means trading in financial instruments where a computer algorithm automatically determines individual parameters of orders such as whether to initiate the order, the timing, the price or quantity of the order or how to manage the order after its submission, with limited or no human intervention, and does not include any system that is only used for the purpose of routing orders to one or more trading venues or for the processing of orders involving no determination of any trading parameters or for the confirmation of orders or the post-trade processing of executed transactions.*
- *Article 4(1)(40): High-frequency trading is described as an algorithmic trading technique characterized by:*
 - *Infrastructure intended to minimize network and other types of latencies, including at least one of the following facilities for algorithmic order entry: co-location, proximity hosting or high-speed direct electronic access;*

⁴¹ MiFID II text is available here: <https://www.esma.europa.eu/policy-rules/mifid-ii-and-mifir>

- *System-determination of order initiation, generation, meeting, routing or execution without human intervention for individual trades or order;*
- *High message intraday rates which constitute orders, quotes or cancellations.*

We can see similarities in the two definitions: automation and autonomy of operations thanks to computers (absence of human intervention) and the tendency of seeking for faster execution (with technology and infrastructures).

In the two definitions, we however notice a difference of approaches in defining the two terms. Because of their similarity, the difference is made in the strategies put in place by the trading firm. Whereas the AT investor will only be using the computer's algorithms to automatically set the parameters, the HFT one will use them faster and with more sophisticated structures.



Graph from Deutsche Bank. 2011.

According to me, therefore defining HFT is way more complicated than I expected it to be. This is also why I chose to separate the definition part in chapter 2 and the strategies section in chapter 4. I preferred to go deeper into the strategies rather than on a definition really close to the AT one.

2 Appendix 2: ESMA reports executive summaries

2.1 ESMA, 2014 – High-frequency trading activity in the EU Equity Market

The objective of this report is to shed further light on the extent of high-frequency trading (HFT) in EU equity markets. We use unique data collected by ESMA, covering a sample of 100 stocks from nine EU countries for May 2013. Our study complements the HFT literature by looking at equity markets across several EU countries. Most of the HFT studies published so far focus either on the US or on a single country within Europe.

One of the challenges faced by empirical studies is the operational definition of HFT. There is a variety of approaches in the literature to estimate HFT activity. None of these approaches can exactly capture HFT activities and they lead to widely differing levels of HFT activity. This is an important issue for the analysis of HFT activity and its impacts. It is also a significant challenge for regulators who need to define what constitutes HFT activity. The approach taken in this report is to provide a lower and an upper bound for HFT activity.

Two main approaches have been used in the literature: i) a direct approach based on the identification of HFT firms according to their primary business or the types of algorithms they use, and ii) an indirect approach based on statistics such as lifetime of orders or order-to-trade ratio.

We provide estimations for HFT activity based on the primary business of firms (direct approach) and based on the lifetime of orders (indirect approach). The first proxy is an institution-based measure (each institution is either HFT or not), while the second proxy is a stock-based measure (an institution may be HFT for one stock but not for another one).

The results based on the primary business of firms provide a lower bound for HFT activity, as they do not capture HFT activity by investment banks, whereas the results based on the lifetime of orders are likely to be an upper bound for HFT activity.

In our sample, we observe that HFT activity accounts for 24% of value traded for the HFT flag approach and 43% for the lifetime of orders approach. For the number of trades the corresponding numbers for HFT activity are 30% and 49%, and for the number of orders 58% and 76%. The difference in the results is mainly explained by HFT activity of investment banks which is captured under a lifetime of orders approach, but not under a HFT flag approach (see table C.1).

HFT activity - overall results for the HFT flag and lifetime of orders approaches					C.1
	HFT flag		Lifetime of orders		
		<i>lifetime of orders: total</i>	<i>thereof HFT firms</i>	<i>thereof investment banks</i>	<i>thereof other firms</i>
Value traded	24	43	19	22	2
Number of trades	30	49	25	23	2
Number of orders	58	76	55	19	1
Note: Figures are weighted by value of trades (value traded), number of trades, and number of orders; in %. Source: ESMA.					

Our results also show that the level of HFT activity varies widely between trading venues. We also observe that HFT activity is linked to market capitalization with HFT activity increasing with the market capitalization of stocks.

This report describes the results of the first part of the ESMA research on HFT. Further research is needed regarding — the drivers of HFT activity, — to assess the actual contribution of HFT to liquidity, and — to analyze potential risks and benefits linked to HFT activity.

3 Appendix 3: Concrete example of a *market marking* strategy

When reading the quotations, the reader should remember that, before 2005, the minimum price increase in a quotation was 12.5 cents. Even though nowadays, this minimum price increase decreased to 1 cent, the concrete example will be built on that period's quotation system. Furthermore, the Apple quotations have been invented to make the example easier to be fully understood.

Let's assume a market maker which already has in its book several stocks of Apple which on the market are quoting \$150.00 bid and \$150.25 ask. This means that:

- An individual investor might be ready to buy the stock at \$150 and sell it at \$150.25;
- The marker-making broker is ready to sell the stock at \$150 and buy it at \$150.25.

Assume now that the broker receives an order from an individual investor to buy the stock at \$150.25. The broker would immediately execute the order and cash-in the spread. This is an easy scenario to understand because the broker taking the counterparty of the orders, is in a dominant position.

But what about the sell scenario? Assume that the broker receives an order from another investor to sell the stock but this time, at \$150.125. The broker is no more in a dominant position. He (the broker) then has two options:

- He decides to fill in the order and improves his price offers. He might think that the stock will sharply increase, accept a reduction in his spread-profit and takes the risks;
- He decides to not take any risks and wait for the market bid to rise to \$150.125.

This second example might be more technical and more complex. Its total understanding will not be essential for the global understanding.

4 Appendix 4: Concrete example of a *flash trading* strategy

This concrete example will be built just like the previous one and is totally inspired by Alfonso Puorro's research in the Banca d'Italia report (Puorro, 2013).

Let's assume an individual investor sent on the NASDAQ a *buy* order for 5000 Apple shares for a limit price of \$150.05. However, on the NASDAQ stock exchange, only 1000 shares are available for sale at \$150.00 (which is then considered as the NBBO on that ECN). The following best price is \$150.04 per share.

The first 1000 shares will be executed at \$150.00. However, because of the NMS regulation, the NASDAQ is obliged to send the information to the market for the 4000 shares left to look for the new NBBO: let's assume it's on the BATS at \$150.03 per share. The NASDAQ should logically send the orders there but...

Before sending them on the BATS (a NASDAQ's competitor), they will create a **flash order** for those 4000 shares at a price more interesting than the one on BATS: let's say \$150.02 per share. They will then send this flash orders to their subscribed HFT clients. The interested trader may then decide to become the counterparty of the order and will sell the remaining 4000 shares.

The HFT broker decides to enter that exchanges depending on its actual book position at that specific moment: he saw an arbitrage opportunity or he wanted to liquidate its *long* position⁴². Remember that a HFT trader will only enter a position if he is sure that

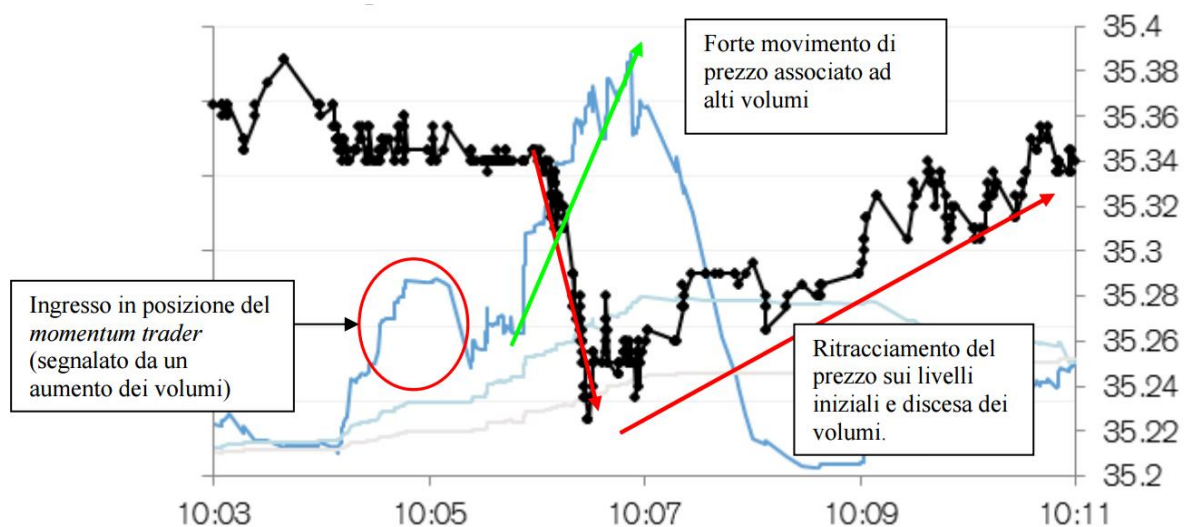
⁴² This means that he bought in the past those 4000 shares and wanted to sell them.

he will make a profit out of it (even really small). This profit might count on the fees structure offered by the trading venue rather than the operation itself.

In the end, by creating and sending that flash order, the NASDAQ allowed the orders and the liquidity to remain entirely inside its ECN, making it more robust and efficient than the others. It also allowed the clients to pay a lower price than expected.

5 Appendix 5: Concrete example of *ignition momentum* strategy

This concrete example will be again built just like and is totally inspired from Alfonso Puorro's research in the Banca d'Italia report (Puorro, 2013). The example will illustrate the graph here below illustrating an ignition momentum strategy acted on a *short* position⁴³.



Graph taken from Alfonso Puorro analysis.

The first step is the *ADD* phase. The investor starts to accumulate selling orders on his position. When he finished this first phase and evaluate volatility as desirably low,

⁴³ The *short* position consists in a willing to sell the stock. In the example, because the HFT trader firstly sell the stock, he must buy it afterwards to close the position.

he sends one big order. The orders must be big enough to make the other investors trading on that stock willing to immediately sell the security too and close their position. The *ignitium momentum trader* will then buy from them to a lower price and close his *short* position.

The acquisitions will then cover the selling orders made in the first step and give the trader a little profit. As the reader may guess it, it is pure speculation.

6 Appendix 6: Concrete example of *pinging* strategy

This concrete example will be again built just like and is totally inspired from Alfonso Puorro's research in the Banca d'Italia report (Puorro, 2013).

We are going to follow the behavioral changes in a traditional investor. Let's assume this less-evolved trader wants to implement a strategy where he will simply follow the *microtrends* of the markets in the short-term. His behavior is then very easily predictable: when the liquidity available on a security starts to decrease, he will sell because that means the security's price might be starting to fall.

This kind of traditional investor is a very easy target for high-frequency traders. The first HF trader who identified him, will slowly and gradually start to simulate a decrease of the liquidity on that security. Diminishing his quantity on the book will seem to the traditional trader just like real selling market orders. It will mistakenly push him to sell too, whereas the high-frequency trader will take the counterparty of that order.

After acquiring a sufficient position, the high-frequency trader will do exactly the opposite: taking out his selling orders and increasing his liquidity on the security. This will have a positive effect on the security's price. All the order traditional investors will be willing to buy the security again. The back-up of the security reinforces the losses of the

traditional investor who will buy it again to avoid a further increase in the loss (and eventually get fired⁴⁴).

⁴⁴ In the Canal+ documentary, *pinging* has indeed been presented as a way high-frequency traders used to “play” with the traditional ones who could get fired because of the heavy losses on those securities.

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