



universität
wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Does HFT contribute to consolidating fragmented
European equity markets?“

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of
Master of Science (MSc)

Wien, 2016 / Vienna 2016

Studienkennzahl lt. Studienblatt /
degree programme code as it appears on
the student record sheet:

A 066 914

Studienrichtung lt. Studienblatt /
degree programme as it appears on
the student record sheet:

Masterstudium Internationale Betriebswirtschaft

Betreut von / Supervisor:

Univ.-Prof. Dipl.-Vw. Thomas Gehrig, PhD

Acknowledgements

I would like to thank Univ.-Prof. Dipl.-Vw. Thomas Gehrig, PhD for introducing me to the topic of High-Frequency Trading during his university seminar, which motivated me to examine the issues surrounding this topic further. Furthermore, I am thankful to him for his guidance during the thesis writing process, as well as for encouraging me to think critically about the research done on HFT.

I am also thankful to my family, especially my parents, for their constant support and patience.

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List of abbreviations

CAC	Cotation Assistée en Continu
CCP	central counterparty
CN	crossing network
CSD	central securities depository
CTA	Consolidated Tape Association
CTP	consolidated tape provider
DJIA	Dow Jones Industrial Average
EU	European Union
FFI	FFI
FTSE	Financial Times Stock Exchange
FTT	financial transaction tax
HFT	high-frequency trading
IBEX	Índice Bursátil Español
ITS	intermarket trading system
LSE	London Stock Exchange
MiFID	Markets in Financial Instruments Directive
MiFIR	Markets in Financial Instruments Regulation
MTF	Multilateral Trading Facility
NASDAQ	National Association of Securities Dealers Automated Quotations
NBBO	National Best Bid and Offer
NYSE	New York Stock Exchange
OTC	over-the-counter
OTF	Organized Trading Facility
RegNMS	Regulation National Market System
RM	regulated market
S&P	Standard & Poor's
SBF	Société des Bourses Françaises
SI	systematic internalizer
SIP	Security Information Processor
SORT	Smart Order Routing technology
TRF	trade reporting facility
US	United States
USD	United States Dollar

List of symbols

α	level of HFT in a market
C	cost of HFT technology
C_{ext}	adverse selection costs towards market-makers
Δ	difference in expected gains between fast and slow traders
K_A, K_B	number of market-makers in markets A, B
p_A, p_B	prices set by market-makers in fragmented markets A, B
p	price set by market-maker in a consolidated market
q_A, q_B	uninformed order size in markets A, B
q	consolidated uninformed order size
$\bar{\rho}$	risk aversion coefficient
σ_v	standard deviation of security, informational advantage of informed trader
σ_A, σ_B	standard deviation of uninformed order flow in fragmented markets A, B
v	fundamental value of security
x_A, x_B	size of an informed order in fragmented markets A, B
x	size of an informed order in a consolidated market
W	welfare function

1. Introduction

High-Frequency Trading's (HFT) rise to notoriety arguably came in the aftermath of the events taking place on May 6th, 2010, which are now known as the "Flash-Crash".¹ In just a brief period of 36 minutes, the E-Mini Standard & Poor's (S&P) 500 futures contracts experienced a decline of almost 55%, dropping its value from around 6 billion USD to 2.65 billion USD.² The percent changes of the Dow Jones Industrial Average (DJIA), the National Association of Securities Dealers Automated Quotations (NASDAQ) and the S&P indices are illustrated in **figure 1**. Although the market mostly recovered from the drop in value shortly thereafter, the idea that such a dramatic change in prices could occur in such a brief period of time was shocking. An examination of the events pointed to the involvement of HFT: sophisticated computer algorithms that are able to trade large amounts of orders at very fast speeds, faster than any human trader could.

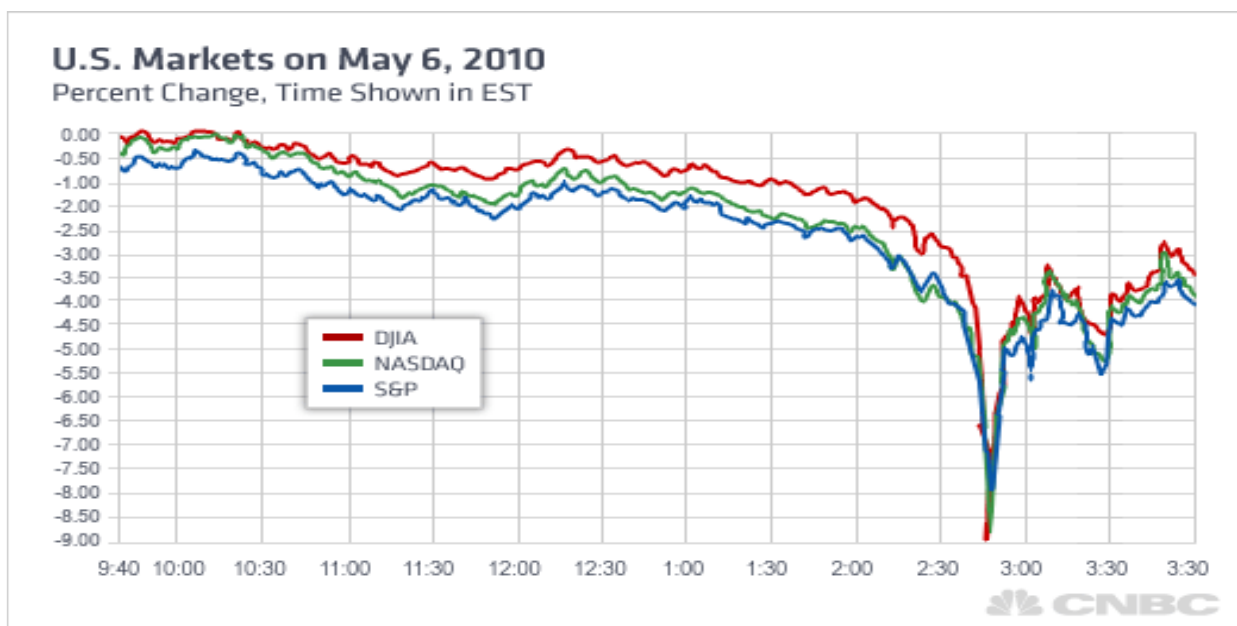


Figure 1: May 6th 2010 flash-crash episode³

The controversial nature of HFT has then come to light in the publication of "Flash Boys", a book by Michael Lewis that came out in March of 2014, and which heavily criticized HFT due to their potential to front-run and essentially 'scalp' money from other traders due to HFT's speed advantage. Lewis' main criticism is, on the one hand, the low-latency nature of HFT, whereby orders can be submitted within a couple of milliseconds, and on the other hand, the

¹ Goldstein, Kumar, Graves (2014), p. 181

² Gillan, O'Rourke, Chesnais (2015), p. 1

³ Source: CNBC, retrieved from Hudak (2015)

extreme lengths that HFT firms went to increase their speed advantage, even if just by one or two milliseconds. For instance, HFT firms would move their servers closer to exchange servers by a few meters, or replace wire materials that would provide a fraction of a millisecond increase in speed. The issue of HFT is then seen as an unfair competition between ultra-fast computers and the average, slow human trader.

As financial markets were becoming increasingly faster over the last decade, they would at the same time become increasingly more fragmented, meaning that order flow would be divided between more trading venues entering the market. New types of trading venues would begin competing against traditional exchanges, from electronic trading platforms to ‘dark pools’ – venues where orders could be submitted anonymously and thus ‘hidden’ from the public before they would get executed. Market fragmentation also became a concern for regulators at the time, as it was feared to cause an erosion in market quality, in terms of impeding the price discovery process and dividing liquidity among too many venues to detriment of liquidity demanders. These two trends are recent developments in financial markets, and a source of some contention even amongst researchers. Of particular note is the effect that HFT might have on the market fragmentation of European equity markets, raising the following question – *does HFT consolidate equity markets, or do they further contribute to the fragmentation of financial markets?*

This thesis focuses on the issue of HFT and market fragmentation in the European Union equity markets from 2007 until the present. To understand the issue fully, each of the topics is examined separately to see their underlying impact on financial markets, and are then analyzed together to comprehend their combined effect on market quality. The thesis is organized as follows: in section 2, the issue of HFT is introduced, describing the characteristics of HFT such as their trading strategies, and subsequently examines the welfare impact of HFT on the market as a whole. In section 3, market fragmentation is then examined, from the drivers that incited the demand for more trading venues to the regulatory measures that ultimately fostered the increase in trading venue competition. Furthermore, the balance between market fragmentation and consolidation is analyzed regarding their impact on market liquidity, following with an analysis and comparison of the European Union (EU) and United States (US) fragmented equity markets. In section 4, the issue of HFT and market fragmentation is combined to see how one influences the other, and whether HFT is able to act as a form of consolidation mechanism, and what potential barriers HFT face which could inhibit this role. The last section then concludes this thesis.

2. High-Frequency Trading

In the first section of this thesis, the focus will be on HFT and how they evolved from a demand for increasingly lower latency trading. This section will also provide an analysis of HFT characteristics and its prevalence in today's financial markets, as well as a theoretical and empirical analysis of their impact on overall market quality and social welfare, which will be crucial to understanding later sections of this thesis.

2.1 Rise of low latency trading

The issue of reducing latency of information transfer and of trading is not a new one in financial markets. Scholars discussed this topic as far back as the 13th century, with Thomas Aquinas debating the fairness of wheat sellers arriving earlier to the market than their competition.⁴ The argument was that by coming to the market sooner than other wheat sellers, they could unfairly charge higher prices than if they had to compete against other traders directly. With the development of communication technologies also came faster means of transmitting and receiving financial market data, thus decreasing latency. Traders with access to market information sooner than their competition would naturally be afforded an advantage over them. Various means would be used throughout history to transfer market data as fast as possible. For instance, carrier pigeons were used as an information transmission tool, allowing a London bank to short French bonds after being informed of Napoleon's loss in Waterloo in 1815.⁵ Telegraph lines were another advancement in information transmission technology, with Edison inventing the stock ticker with the sole purpose of providing stock market data through telegraph. Even in the age of telegraphs, carrion pigeons would still be used in instances where telegraph lines were not feasible to be constructed, such as between Berlin and Paris.⁶

The highest increase in communication speed would occur with the advent of computer technology, however. It would also change the structure of financial markets, with most financial markets experiencing some form of automation.⁷ Trading, which was still until fairly recently a manual process where brokers met on the trading floor of exchanges and matched orders from their clients, slowly started to adapt by introducing computerized systems, namely electronic limit order books.⁸ While some exchanges such as the Toronto Stock Exchange and

⁴ Müller (2015), p. 77

⁵ <http://www.forbes.com/forbes/2010/0927/outfront-netscape-jim-barksdale-daniel-spivey-wall-street-speed-war.html>

⁶ Müller (2015), p. 78

⁷ Foucalt, Pagano, Röell (2013), p. 37

⁸ Foucalt et al. (2013), p. 37

the Paris Bourse transformed into electronic limit order book markets quite early, others such as the New York Stock Exchange (NYSE) only did so quite recently, in NYSE's case in 2006.⁹ Automated exchanges, even in their various hybrid forms, increased the speed at which traders were able to communicate and trade with one another. It is therefore apparent that an improvement in this communication technology has naturally lead to the evolution of HFT.

The success of HFT was predicated on ultra-fast computer technologies, with transmission latency being measured in just a few milliseconds. Expensive communication lines would be constructed in recent years to accommodate such high speeds, even if the end result is a decrease in latency by only a couple of milliseconds. For instance, the construction of a communication line between New York and Chicago, which necessitated a tunnel being drilled through the mountains in Pennsylvania (costing hundreds of millions of dollars),¹⁰ resulted in an increase in speed by around 3 milliseconds. Other examples include under-sea cables such as the Hibernian Express in 2014, reducing latency between New York and London by 5 milliseconds, or microwave technology such as Perseus Telecom's network between London and Frankfurt that reduced latency from 8.35 to 4.6 milliseconds.¹¹ However, fast communication lines is only one part of how HFT firms were able to reduce latency. Another facet of HFT are colocation services, meaning that to improve their latency even further, HFT firms will situate their servers as close to the servers of the trading exchange as possible. Exchanges would become aware of this demand by HFT firms, and start offering colocation services. For example, the Tokyo Stock Exchange offers different colocation services with latencies ranging from several milliseconds on standard services, to 260 microseconds for priority services and lastly to 15 microseconds for colocating at the primary site, with higher fees naturally being charged for these improvements.¹² The high costs over such a small speed improvement therefore illustrates how greatly HFT value even fractional increases in speed.

⁹ Foucalt et al. (2013), p. 38

¹⁰ <http://www.forbes.com/forbes/2010/0927/outfront-netscape-jim-barksdale-daniel-spivey-wall-street-speed-war.html>

¹¹ O'Hara (2015), p. 259

¹² O'Hara (2015), p. 259

2.2 HFT descriptive statistics

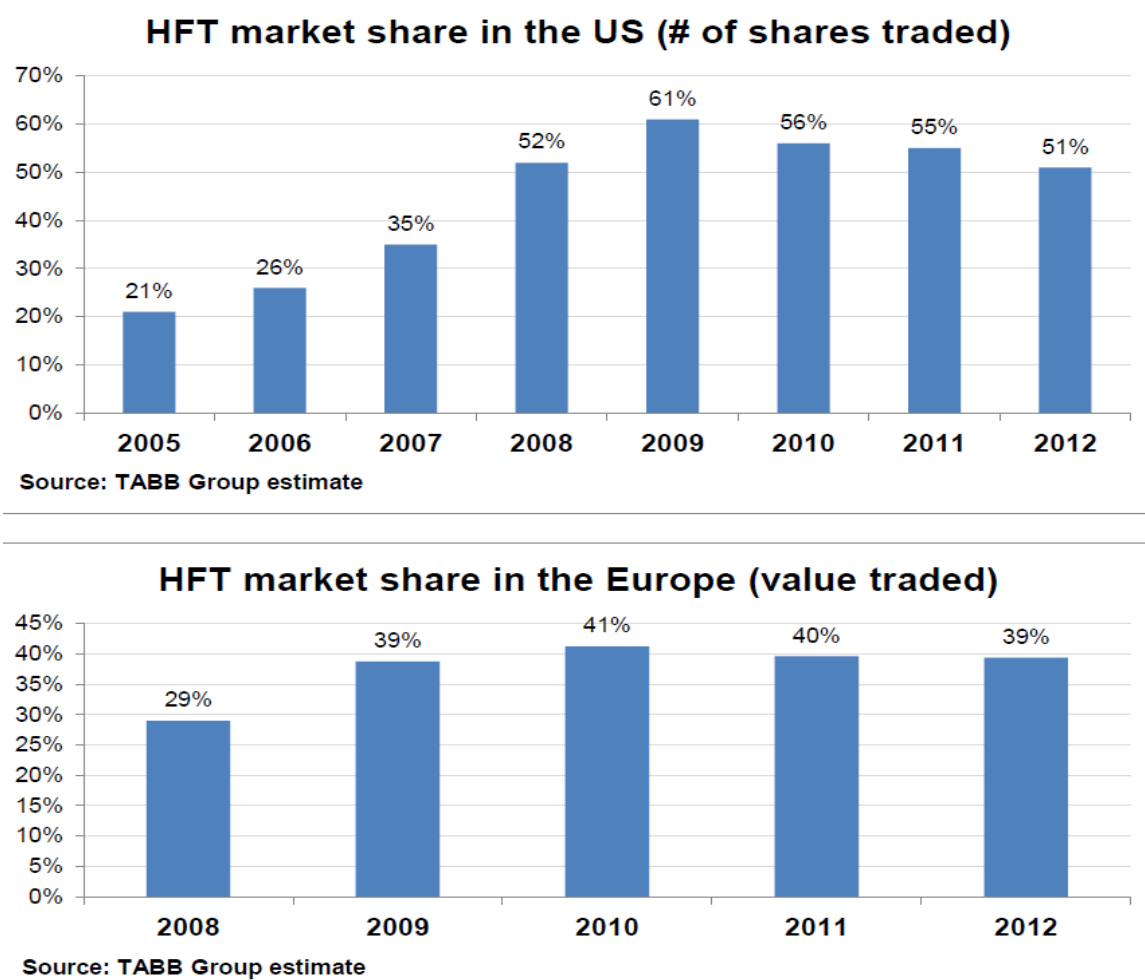


Figure 2: HFT market share in the US and the EU¹³

Since the start of 2000s, computerized trading started to gain ground in financial markets, and we can see that HFT would rise in prevalence over the course of the decade. The peak of HFT's market share came around 2009/2010, when it was estimated that 61% of equity trading in the US in 2009 was attributed to HFT and 41% of value traded in the EU in 2010, as seen in **figure 2**. In 2009, an estimated 5 billion USD was suggested to have been generated by the whole HFT industry, earning a profit of 0.001 USD per share traded.¹⁴ However, HFT experienced a fall in market share and profits after the peak years of 2009/2010. In 2012, market share in the US dropped to around 50%. Gains from HFT activity also suggest to have declined to 1 billion USD in 2012, and the profits per share traded suggest to have halved to 0.0005 USD. Individual

¹³ Source: TABB Group, retrieved from World Federation of Exchanges (2013), "Understanding HFT" Executive Summary

¹⁴ Serbera, Paumard (2016), p. 273

HFT firms also experienced large declines in market share, with GETCO releasing information that their market share dropped from 19% in 2009 to 3% in 2013.¹⁵ The decline in HFT profitability could be attributed to the rise in competition between HFT firms in recent years. These statistics serve to illustrate that even though HFT activity declined, it is still prevalent in financial markets today, and therefore they could pose a significant role in further evolution of financial markets, especially regarding the issue of market fragmentation, which this thesis will explore in later sections.

2.3 Characteristics of HFT

Although HFT are understood to be algorithms that trade at low latencies, they could be defined as a subcategory of algorithmic trading in general. This is due to the fact that other algorithmic trading is performed that do not share similarities to HFT, such as ones utilized by institutional investors to optimally divide orders to minimize their price impact.¹⁶ How do we define HFT then? Research has characterized HFT in multiple ways, but we can define HFT generally in the following manner: *“(1) the use of extraordinarily high-speed and sophisticated computer programs for generating, routing, and executing orders; (2) use of co-location services and individual data feeds offered by exchanges and others to minimize network and other types of latencies; (3) very short time-frames for establishing and liquidating positions; (4) the submission of numerous orders that are cancelled shortly after submission; and (5) ending the trading day in as close to a flat position as possible (that is, not carrying significant, unhedged positions overnight).”*¹⁷

A unique characteristic of HFT is the rapid submission and cancellation of orders, often in quick succession, as can be observed in **table 1**. This characteristic arguably sets it apart from other forms of algorithmic trading, and is often used as a basis for identifying HFT in statistical data. This order submission/cancellation strategy has become a method for HFT to extract information from the market by ‘pinging’ it with a series of small orders that are soon cancelled as to avoid execution. Therefore, the use of small order sizes is also considered typical of HFT,¹⁸ as well as their concentration in stocks with large market capitalization.¹⁹

¹⁵ Serbera, Paumard (2016), p. 274

¹⁶ Hagströmer, Nordén (2013), p. 742

¹⁷ Securities and Exchange Commission (2010), p. 3606

¹⁸ Bouveret, Guillaumie, Roqueiro, Winkler, Nauhaus (2014), p. 11

¹⁹ Pagnotta (2014), p. 47

Panel A: ADCT order activity starting at 9:51:57.849

Time	Message	B/S	Shares	Price	Bid	Offer
09:51:57.849	Submission	Buy	100	20.00	20.03	20.05
09:52:13.860	Submission	Buy	300	20.03	20.03	20.04
09:52:16.580	Cancellation	Buy	300	20.03	20.03	20.04
09:52:16.581	Submission	Buy	300	20.03	20.03	20.04
09:52:23.245	Cancellation	Buy	100	20.00	20.04	20.05
09:52:23.245	Submission	Buy	100	20.04	20.04	20.05
09:52:23.356	Cancellation	Buy	300	20.03	20.04	20.05
09:52:23.357	Submission	Buy	300	20.04	20.04	20.05
09:52:26.307	Cancellation	Buy	300	20.04	20.05	20.07
09:52:26.308	Submission	Buy	300	20.05	20.05	20.07
09:52:29.401	Cancellation	Buy	300	20.05	20.04	20.07
09:52:29.402	Submission	Buy	300	20.04	20.04	20.07
09:52:29.402	Cancellation	Buy	100	20.04	20.04	20.07
09:52:29.403	Submission	Buy	100	20.00	20.04	20.07
09:52:32.665	Cancellation	Buy	100	20.00	20.04	20.07
09:52:32.665	Submission	Buy	100	20.05	20.05	20.07
09:52:32.672	Cancellation	Buy	100	20.05	20.04	20.07
09:52:32.678	Submission	Buy	100	20.05	20.05	20.07
09:52:32.707	Cancellation	Buy	100	20.05	20.04	20.07
09:52:32.708	Submission	Buy	100	20.05	20.05	20.07
09:52:32.717	Cancellation	Buy	100	20.05	20.04	20.07
09:52:32.745	Cancellation	Buy	300	20.04	20.04	20.07
09:52:32.745	Submission	Buy	100	20.05	20.05	20.07
09:52:32.746	Submission	Buy	300	20.05	20.05	20.07
09:52:32.747	Cancellation	Buy	100	20.05	20.05	20.07
09:52:32.772	Submission	Buy	100	20.02	20.05	20.07

Table 1: Rapid order submission and cancellation strategy by a HFT algorithm on October 2nd, 2007 ²⁰

2.3.1. Strategies

This thesis will now look at some defining strategies utilized by HFT. Firms generally keep their specific HFT strategies secret, however certain HFT behavior and strategies can be observed from market data, some of which is considered to be less harmful or even beneficial towards market liquidity, and some considered more harmful towards market quality, with some bordering on unethical or even illegal behavior.

2.3.1.1 Market-making

Market-making is a strategy that involves the trader posting both a buy and a sell limit order in the order book. The aim is to earn the bid-ask spread, that is to buy at the lower bid prices and sell at the higher ask prices posted in the order book. There are two main reasons why HFT are more likely to adopt market-making strategies when trading. First, the biggest risk that market-makers face when posting their limit-orders is that they are going to trade against an informed trader. Market-makers traditionally have to adjust their prices to avoid this adverse selection deferring the costs onto uninformed traders in the form of the bid-ask spread.²¹ However, HFT

²⁰ Source: Hasbrouck, Saar (2013)

²¹ Glosten, Milgrom (1985)

have the advantage of speed, meaning that they are able to adjust their limit-orders faster to reflect potential informed traders' valuation of the security. This diminishes their risk of being adversely selected by informed traders.²² Second, many exchanges and trading platforms provide what are known as 'liquidity rebates', giving rebates to liquidity providers (and charging fees to liquidity demanders), meaning that a HFT is able to earn more through their market-making strategy than by being a liquidity demander.²³ Market-making is suggested to be a dominant strategy used by HFT, meaning that they preference this strategy over others. An analysis of Dutch index stocks from 2007 to 2008 show that four out of five of HFT's trades were pursuing a market-making strategy, or in other words supplying liquidity to the market, as other strategies proved to be less profitable.²⁴

2.3.1.2 Arbitrage trading

Another strategy that HFT can engage in is arbitrage trading. This is a strategy where the trader searches and takes advantage of a mispricing between two financial instruments that should be valued the same. There are different types of arbitrage strategies HFT may engage in. For instance, statistical arbitrage depends on HFT's ability to calculate the mispricing of two financial securities that are closely correlated to one another. Due to the algorithmic and high-speed nature of HFT, they are able to take advantage even of an infinitesimal, short-term mispricing of securities. Two identical instruments may be valued differently in two separate markets (i.e. as a result of market fragmentation), which again poses arbitrage opportunities for HFT. Other arbitrage strategies rely on the delay in information that is incorporated into the prices of financial instruments. For instance, event arbitrage strategies involve HFT monitoring the news and evaluating its effect on financial markets based on textual analysis.²⁵ Buy or sell orders are submitted by HFT based on whether they identify positive or negative keywords within the news stories, and are able to do so faster than other market participants, gaining an advantage over them. Furthermore, latency differences between trading venues pose arbitrage opportunities for HFT, since they are able to observe price changes faster than other market participants and act on the mispricing faster as well, making latency arbitrage strategies feasible for HFT.²⁶

²² Jones (2013), p. 6

²³ Jones (2013), p. 6, 7

²⁴ Menkveld (2013), p. 736

²⁵ Goldstein et al. (2014), p. 186

²⁶ O'Hara (2015), p. 260

Arbitrage trading serves a purpose in financial markets, in that aids in creating efficient prices by correcting possible mispricings based on available information. However, criticism has been raised regarding HFT using arbitrage strategies, since the slight increase in price efficiency may not sufficiently compensate other, slower market participants for the higher adverse selection costs they have to face due to HFT activity. Additionally, HFT competition could be characterized as ‘winner-take-all’ in nature, since even a millisecond advantage over other HFT allows them to gain the majority of the profit.²⁷

2.3.1.3 Directional trading

Some of the more controversial strategies employed by HFT involve directional trading, where HFT are able to ‘front-run’ other traders due to their speed advantage. Specific front-running strategies include, for instance, ‘order anticipation’ and ‘quote matching’.²⁸ Order anticipation involve HFT predicting if large orders will be submitted and then profiting from the anticipated price movement. For example, if HFT can predict a large buy order coming to the market, they may front-run the trader by buying the shares beforehand, thus raising the price for the trader. Subsequently, if the demand for the shares is still present, HFT may resell their newly purchased shares to the trader at the higher price. The way in which HFT may predict these incoming orders may be through pinging the market with small orders and identifying through a series of executed orders if a trader (typically a buy-side institution) is attempting to sell or buy large quantities of shares. However, it should be mentioned that this was a concern for institutional traders even before HFT, as moving large orders would carry the risk of being front-run by other market participants as well if the information about such orders was leaked.²⁹ The difference is in the speed and efficiency in which HFT are able to front-run other traders.

Quote matching, on the other hand, involves HFT trading ahead of limit orders posted by slow traders. The strategy thus involves placing limit orders only a couple of cents ahead of the best bid and ask prices, and exiting their positions quickly if they anticipate that the price will move against them.³⁰ Additionally, HFT are able to ‘pick-off’ limit orders posted by slow traders, since they can react to changes in prices due to new information faster than slow traders, thus being able to take advantage of ‘stale’ limit orders. Again, these are strategies that existed before the advent of HFT, although the more sophisticated technology behind HFT allows for more

²⁷ Jones (2013), p. 7

²⁸ <https://blogs.cfainstitute.org/investor/2013/04/24/what-to-do-about-high-frequency-trading/>

²⁹ Jones (2013), p. 9

³⁰ <https://blogs.cfainstitute.org/investor/2013/04/24/what-to-do-about-high-frequency-trading/>

efficient, safer execution of these strategies. Buy-side institutions have also adapted to this new competition by using algorithms and programs to hide large orders by dividing them into smaller ones. The issue then becomes whether such a ‘game’ between HFT and buy-side algorithms is detrimental to social welfare, and whether a regulatory approach, such as limiting order submission and cancellation rates, should be considered. The issue of HFT’s effect on social welfare will be examined in greater detail in sections 2.4 and 2.5.

2.3.1.4 Illegal HFT strategies

Accusations have been made against HFT suggesting that some HFT utilize illegal strategies to generate profit. Momentum ignition, for example, is an illegal strategy where HFT purposely incite other market participants to aggressively push a price in a certain direction by submitting multiple orders in the same direction. HFT would take a position beforehand, and after the price has changed they could quickly profit from the movement before the price inevitably reverts back to the previous level. The price change may be small and short-term, however they can still be a source of profit for HFT.³¹ Other illegal strategies, such as quote stuffing or spoofing, have HFT purposely manipulating other market participants or misleading competing algorithms in order to incur a profit for themselves due to short-lived, manipulated price changes.³² The strategies also question whether HFT is more beneficial, or detrimental to market quality.

2.3.2 Technical malfunctions

Although HFT are becoming faster and more efficient as technology progresses, it does not prevent from certain technical glitches from occurring, causing huge losses for HFT firms and other market participants alike. The flash crash of 2010 was already mentioned in section 1, and was one of the first instances when HFT played a significant role in a wide-spread market crash. Other examples include the Knights Capital algorithm malfunction, when an error in the HFT algorithm of the Knights Capital firm caused it to start buying large amounts of stock within the first hour of being initiated, causing a loss of 440 million USD for the firm.³³ Smaller flash crashes were also associated with HFT, for instance when Apple shares declined by 2% one minute before the end of trading hours, causing a loss of almost 7 billion USD (Apple shares regained more than half of the lost value in the last seconds before day closed).³⁴ While

³¹ <http://blog.themistrading.com/2012/12/exploratory-trading-and-momentum-ignition/>

³² Hudak (2015), p. 26, 27

³³ Jones (2013), p. 39

³⁴ Goldstein et al. (2014), p. 181

certain regulatory measures were introduced to prevent events such as flash crashes from occurring (for example trading halts if the price fluctuates above a certain threshold), these episodes serve to illustrate that HFT is not without fault, and new technology could bring with it opportunities for further technical failures.

2.4 HFT effect on market quality

In order to understand HFT and its effect on market consolidation, it is important to first look at the effect that HFT has on the market as a whole. However, how is one able to assess the impact of HFT on market quality? Maureen O'Hara says during a discussion regarding HFT that: *"When we [financial economists] talk about market quality, we generally talk about liquidity and price discovery, where we have metrics for liquidity and price discovery. When economists talk about market quality, they often want to bring in concepts like social welfare. And social welfare really does get you into the two-handed problem, because these people are made better off, and these people are worse off, whereas finance often looks at the issue and says – I'm not sure who is better or worse off because I can't weigh everybody, I'm going to look at minimizing transaction costs and enhancing efficiency."*³⁵ While it is important to analyze the effect of HFT on market quality by looking at its impact on market liquidity indicators and price discovery, this thesis will go beyond looking at the impact on transaction costs and also take into account the impact of HFT on the welfare of other market participants. This will provide a fuller picture as to the role of HFT in financial markets.

2.4.1 Theoretical models

To better understand HFT and its effect on overall market quality and welfare, this thesis will look at some theoretical models used to analyze this issue. This thesis will focus on two models, one which measures optimal levels of HFT regarding social welfare as well as market fragmentation (which will be used again in later sections),³⁶ and the second which analyzes the impact of HFT in the role of liquidity providers.³⁷ Both of these models look at the issue of HFT from the point-of-view of asymmetric information, with HFT acting as informed traders in the theoretical models, since they are able to observe or identify the true value of a security

³⁵ Source: <https://www.youtube.com/watch?v=NSdQ0fiWB3M>, timestamp 19:16

³⁶ Biais, Foucalt, Moinas (2015)

³⁷ Hoffman (2013)

before slower, uninformed traders do. The two models will be compared in the following section, with the focus being primarily on intuitive explanations of these complex models.³⁸

2.4.1.1 Equilibrium level of HFT

It is assumed that one asset is traded in a market of both fast and slow traders. Since HFT are able to observe information faster than slow traders, it is implied that they are informed traders since they can infer insider information from order flow, categorizing the market into slow uninformed traders, and fast, informed traders. The technology used by HFT has a cost which affects traders' decision to either become fast or remain slow.³⁹

The dynamic between informed and uninformed traders is then reflected in the formation of the bid-ask spread. Since HFT pose adverse selection costs for market-makers, they need to compensate for their potential losses to informed traders by widening their spread. If we assume that market-makers adjust their quotes to be competitive (gain zero profit), then the uninformed traders bear the full weight of the adverse selection costs. The losses of the uninformed traders are equal to the gains of HFT, meaning that HFT could pose a negative externality on slow traders. Ultimately, the model predicts that an increase in HFT activity leads to wider spreads.⁴⁰

Market volatility may pose offsetting effects on the profitability of HFT according to the model. First, since HFT are able to observe the fundamental value of the security, a higher volatility of the security's value gives them a higher informational advantage, which translates into more profit opportunities. Second, higher volatility also results in market-makers widening their spread, which has a negative effect on HFT profits. The model suggests that when the level of HFT is low in the market, profitability of HFT is increasing in market volatility, however as there is more competition among HFT due to higher levels of HFT in a market, the profitability of HFT is then lowered.⁴¹

Considering now the social welfare of all market participants, the model calculates the optimal welfare as a function of the level of HFT in a market. **Figure 3** illustrates the utilitarian welfare function,

³⁸ Cigan (2015), p.2

³⁹ Biais, et al (2015), p. 293, as cited in Cigan (2015), p.3

⁴⁰ Biais, et al (2015), p. 297, as cited in Cigan (2015), p.3

⁴¹ Biais, et al (2015), p. 309, as cited in Cigan (2015), p.4

$$\frac{\partial W(\alpha)}{\partial \alpha} = \underbrace{\Delta(\alpha)}_{\text{Social Value of Fast Trading}} - \underbrace{(C + C_{ext}(\alpha))}_{\text{Social Cost of Fast Trading}}.$$

Figure 3 Utilitarian welfare maximization function⁴²

where Δ represents the difference between the expected gains of fast and slow traders (which is a positive value), C designates the cost of HFT technology, C_{ext} the total negative externality posed by HFT and α represents the level of HFT in the market.⁴³

The model suggests that HFT may pose both a positive, as well as a negative effect on social welfare. The ‘Social Value of Fast Trading’ part of the equation as seen in **Figure 3** describes the potential positive effect on social welfare by HFT. This is suggested to be due to the HFT’s ability to increase overall trading opportunities for all market participants, since they are able to search multiple markets faster and find trading opportunities that would otherwise not be realized, as well as because HFT might engage in trades that other, slower market participants would not due to their advanced information.⁴⁴ The negative effect on social welfare posed by HFT (‘Social Cost of Fast Trading’ in **Figure 3**) is due to their adverse selection costs, which cause an increase in spread and therefore lower profits for all market participants, as well as the cost of HFT technology which fast traders need to pay in order to become (or remain) HFT.⁴⁵ However, it is also pointed out in the model that social optimal levels of HFT in a market may be larger than zero, although the equilibrium level of HFT may not correspond to the socially optimal level. The model provides two general equilibrium outcomes to the level of HFT: as the cost of HFT technology increases, so will the social cost of HFT, and the equilibrium level of HFT will reduce to zero. If volatility in the security’s return increases, so will the social value of HFT, potentially outweighing the costs associated with adopting HFT technology, resulting in an equilibrium level of HFT equal to 100%. The two equilibrium outcomes represent underinvestment and overinvestment in HFT technology, respectively.⁴⁶

⁴² Source: Biais, et al (2015), p. 303

⁴³ Biais et al. (2015), p. 303, as cited in Cigan (2015), p.5, 6

⁴⁴ Biais et al. (2015), p. 302, as cited in Cigan (2015), p.5, 6

⁴⁵ Biais et al. (2015), p. 303 as cited in Cigan (2015), p.5, 6

⁴⁶ Biais, et al (2015), p. 303, as cited in Cigan (2015), p.5, 6

2.4.1.2 Market-making HFT

In the following model, HFT are analyzed additionally from their role as market-makers, meaning that they are allowed to post limit orders in the order book. The speed of HFT grants them an advantage by allowing them to change their limit orders based on new information faster than slower market-makers, meaning that the probability of HFT being picked-off (having their limit order executed unfavorably) is reduced, meaning that they face lower adverse selection compared to slow market-makers. Slow market-makers also have to adjust their strategy given the presence of HFT in a market – they have to post either aggressive quotes to target both slow and fast traders, increasing their execution probability but also their chance of being picked-off by HFT, or less aggressive quotes, which reduces their execution probability, but also reduces the probability of unfavorably being picked-off by HFT.⁴⁷

In contrast to the previous model, it is suggested that HFT may reduce adverse selection costs given certain circumstances. In a market without HFT, slow traders are wary of the ‘winner’s curse’, which describes the scenario where the trader overbids on a security even if a much lower bid would have won them the security, resulting in slower traders posting more cautious limit orders.⁴⁸ HFT can post limit orders that are closer to the fundamental value of the security, since they are not worried about being picked-off by slower traders on the arrival of new information. This reduces the winner’s curse, which therefore reduces the adverse selection cost inefficiencies stemming from it. However, this assumption holds true for only a small number of fast traders in a market, since as the number of fast traders increases, so does the probability of them having their limit orders picked-off by other fast traders, which reintroduces the winner’s curse problem.⁴⁹

Concerning market volatility, this model also suggest that higher volatility provides more opportunities for HFT to profit off of slower traders due to their speed advantage, allowing them to pick-off limit orders posted by slower traders that became out-of-date after the arrival of new information. Slow traders can change their strategy and post more cautious limit orders in periods of higher volatility, however, which diminishes the profit opportunities of HFT.⁵⁰

Social welfare is also addressed by this model, which similarly suggests that the equilibrium level of HFT resulting from the model assumptions is higher than the socially optimal level, as

⁴⁷ Hoffman (2013), p.5, as cited in Cigan (2015), p.3

⁴⁸ Hoffman (2013), p. 16, as cited in Cigan (2015), p.4

⁴⁹ Hoffman (2013), p. 16

⁵⁰ Hoffman (2013), p. 15, 16, as cited in Cigan (2015), p. 4

higher levels of HFT lead to them possessing higher bargaining power of slower traders, reducing the share of the surplus of slower traders. The social optimal level of HFT is also dependent on the cost of HFT technology, and also suggests that an increase in HFT technology costs leads to a social optimal level of HFT equal to zero. Furthermore, if costs diminish, and every trader becomes HFT, then this results in a social loss as well, since the majority of HFT profit is reliant on picking-off slow traders, the all-fast-trader market is equal to the all-slow-trader market, with an additional cost equal to the investment in HFT technology by all market participants.⁵¹

2.4.2 Empirical Research

Research is still being conducted on the topic of HFT, which is a relatively new trend affecting financial markets today. In this section, the thesis will look at some of the empirical research done of HFT as it relates to its effect on market liquidity indicators, such as spreads, price impact, market depth, as well as price discovery, volatility and market stability.

2.4.2.1 Positive impact of HFT

A significant amount of research conducted in the last years seems to suggest that there is a positive correlation between the recent increase in HFT activity and an improvement in market liquidity in terms of narrower spreads, deeper markets and lower volatility (although correlation may not signify causation, as will be discussed in section 4.1). These studies generally attribute the improvement in market liquidity to the market-making activities of HFT.

Spread reduction is often cited as a beneficial outcome of HFT activity. Spreads did witness a decline in recent years in equity markets, for instance, the median S&P 500 spread has declined from 0.025 USD in 2003 to below 0.015 USD in 2009.⁵² The argument is made that this correlates with the rise of HFT activity in equity markets, namely with their market-making activities. In a sample of 120 US stocks between 2008 and 2010, research suggest that HFT frequently supply liquidity at inside quotes, providing inside quotes 65% of the time in total trades and 80%-85% of the time in large cap stocks.⁵³ This suggests that HFT's market-making activity lead to more efficient quotes being posted more often. However, it is also noted that the depth provided by HFT is lower than those posted by other liquidity providers.⁵⁴

⁵¹ Hoffman (2013), p. 24, as cited in Cigan (2015), p.6

⁵² Angel, Harris, Spatt (2010) p. 11, citing Knights Capital Group

⁵³ Brogaard (2010), p.11

⁵⁴ Brogaard (2010), p. 40

An analysis of a data sample of top 500 NASDAQ stocks, from the periods of October 2007 (a stable period), and June 2008 (an unstable period), suggests that an increase in HFT activity lead to narrower spreads, increased market-depth and a decline short-term volatility.⁵⁵ The main reason why HFT contribute to improving market liquidity is suggested to be their liquidity providing activities as market-makers, who are able to provide more efficient quotes due to lower adverse selection costs. Their speed advantage also allows them to update their limit orders after the arrival of new information instead of cancelling them, meaning that they can function longer as market-makers than slow liquidity providers, which has a positive impact on liquidity.⁵⁶ It is also suggested that during volatile market periods, HFT choose to stay in the market because higher volatility leads to more profit opportunities for HFT, creating positive market liquidity effects even in volatile times.⁵⁷ Price efficiency increase is also suggested to be positively correlated with HFT activity, as is suggested by NASDAQ data from the periods of 2008 to 2010.⁵⁸

Regarding volatility, HFT market-making suggests to have decreased short-term volatility in certain European trading venues. This is demonstrated in the OMXS 30 index (index of 30 Swedish large capitalization stocks), whose trading volume is divided mainly between NASDAQ-OMX (55%-65%) and BATS Chi-X Europe (25-30%), measured between the periods of February 8th, 2010 and March 31st, 2012.⁵⁹ An event study of changing tick sizes suggests that HFT in the role as market-makers represented 80% of all HFT activity, and contributed to the reduction of short-term volatility in the OMXS 30 index.

2.4.2.2 Negative impact of HFT

As noted before, liquidity increase is suggested to have coincided with the entry of HFT. Causation is sometimes difficult to assess however, as there are different factors that may have improved market quality in the same period, such as more competitive trading venues or a general improvement in technology. Additionally, research analyzing the decrease in latency in NYSE in March 2010 by 800 milliseconds suggests that improvements in execution are observed by HFT but less so for other market participants,⁶⁰ meaning that the improvements in liquidity may asymmetrically favor HFT more than other traders.

⁵⁵ Hasbrouck, Saar (2013), p. 648, 650, as cited in Cigan (2015), p.7

⁵⁶ Hasbrouck, Saar (2013), p. 661, as cited in Cigan (2015), p.7

⁵⁷ Hasbrouck, Saar (2013), p. 670, 673, as cited in Cigan (2015), p.7

⁵⁸ Carrion (2013), p. 708, as cited in Cigan (2015), p.8

⁵⁹ Hagströmer, Nordén (2013), p. 746

⁶⁰ Jiang, McInish, Upson (2012), p. 19

Another point of contention in research is that HFT do not always act in the capacity as market-makers, especially when the market needs it the most. In periods of higher market stress and large order imbalances, it becomes more costly for HFT to act as market-makers (outweighing their potential gains from volatility), which in turn causes HFT to provide less liquidity.⁶¹ There may be two implications stemming from this observation. First, HFT may be providing “phantom liquidity”,⁶² meaning that markets may appear to be liquid, however, as soon as slower market participants start demanding liquidity in periods of higher market stress, HFT could exit the market as liquidity providers in a matter of milliseconds in order to avoid being adversely selected against. Additionally, HFT post limit orders in several trading venues simultaneously, and cancel an order if one is executed in a certain venue, again causing more liquidity to be displayed than is actually available.⁶³ Therefore, HFT may not be providing a valuable market function in stressful periods. Second, HFT may contribute to further market instability if their actions are highly correlated, as evidenced by recent flash crashes and mini-flash crashes. Research suggests that although the 2010 Flash Crash episode was not initiated by HFT, they have contributed to the extraordinary high volatility that was witnessed in the flash-crash period.⁶⁴

The impact of HFT on volatility is also mixed. The issue of HFT and volatility is of significance, since HFT have more to gain from volatile markets if we assume that they act as informed traders. Studies suggest that although an increase in the level of HFT resulted in better price discovery, it also resulted in higher volatility, as observed in 42 different markets based on Thomson Reuters data.⁶⁵ This is explained by the assumption that since HFT incorporate information into prices faster than other market participants, this is suggested to lead to more efficient, but volatile prices.⁶⁶ It is also observed that the HFT activity correlated with higher volatility in stock of all market capitalization sizes, while only improving liquidity for stocks belonging to the “two largest and least volatile terciles.”⁶⁷ However, the causality of this relationship is difficult to assess, since HFT could either cause higher volatility themselves through their trading activity, or they may be simply attracted to more volatile market periods

⁶¹ Boehmer, Fong, Wu (2014), p. 28, as cited in Cigan (2015), p.8

⁶² Gillan et al. (2015), p. 7

⁶³ Körber, Linton, Vogt (2014), p. 13

⁶⁴ Kirilenko, Kyle, Samadi, Tuzun (2014), p. 2, as cited in Cigan (2015), p.8

⁶⁵ Boehmer et al. (2014), p. 11, as cited in Cigan (2015), p.8

⁶⁶ Boehmer et al. (2014), p. 3, as cited in Cigan (2015), p.8

⁶⁷ Boehmer et al. (2014), p. 26

to take advantage of their high-speed potential, although research suggest that the former to be the case.⁶⁸

2.5 Welfare implications for non-HFT traders

The previous section analyzed HFT and its impact on market quality by examining both theoretical and empirical research. Some of the research may have provided some contradictory or ambiguous outcomes concerning HFT impact, however the majority of research seems to suggest that the welfare of slow traders is negatively affected by HFT activity.⁶⁹

In section, 2.4.1, the theoretical models used to analyze HFT suggest that HFT pose a negative externality on slow traders due to increased adverse selection costs, where the gains from trade by HFT are equal to the losses of uninformed, slower traders. Additionally, it is implied that if costs of HFT technology are high, the social loss from HFT might outweigh the social value that they provide by executing additional trades. This might reflect the real-life situation of HFT, as some of the examples in section 2.1 showed just how costly it can be to invest in high-end HFT technology, from colocation service fees to paying for the construction of low latency communication lines. Furthermore, even an increase in social welfare as implied in the function of **Figure 3** does not make it clear how the gains from trade are divided among slow and fast traders. An increase in expected gains by HFT could lead to higher social welfare, despite the fact that slow traders may only witness marginal increases in utility. Lastly, both of the models presented in section 2.4.1 suggested that the equilibrium levels of HFT lie above the socially optimal levels of HFT, meaning that from a liquidity demanding as well as a liquidity providing standpoint, markets would theoretically overinvest in HFT.⁷⁰

Section 2.4.2 looked at the empirical evidence of the impact of HFT on market liquidity. It is hard to generalize a result from these studies, especially since causality is difficult to test given HFT and its impact on market liquidity. However, HFT are suggested to provide market quality improvements in the form of narrower spreads, smaller price impact and deeper markets, but could also have a negative impact on market volatility and stability. For slow traders however, the incremental improvements in market liquidity indicators (such as a small basis point improvement in the spread) may not be sufficient to cover the negative externality posed by HFT. It is suggested that the ultimate result of HFT might have been an increase in trading

⁶⁸ Boehmer et al. (2014), p. 25, 26

⁶⁹ Cigan (2015), p.8

⁷⁰ Cigan (2015), p.9

turnover and reduced holding times, leading to an increase in financial intermediation as opposed to a welfare benefit of slow, uninformed traders.⁷¹

To sum up, due to the winner-takes-all nature of HFT as well as the enormous expenditures necessary to be able to compete against other HFT firms, HFT could have a negative effect on overall social welfare and on the welfare of slow traders. This competition could ultimately lead to an inefficient ‘arms-race’⁷², since HFT are incentivized to invest into costly technology to reduce their latency by milliseconds in an effort to out-speed their competition. Therefore, regulators should consider if the investments in HFT could be allocated more efficiently to improve social welfare.⁷³

⁷¹ Stiglitz (2014), p. 6

⁷² <http://www.theatlantic.com/business/archive/2014/04/everything-you-need-to-know-about-high-frequency-trading/360411/>

⁷³ Cigan (2015), p.10

3. Market Fragmentation

The focus of the following section will be on market fragmentation of European equity markets. Market fragmentation is, put simply, the phenomenon where order flow is divided between several markets or trading venues. For instance, this could occur if a stock is listed on different exchanges, making traders that are interested in the stock have to choose which venue to purchase it from. This section will look at why European markets have become fragmented in recent years, as well as which economic mechanisms drove this outcome. Furthermore, this section will examine theoretical and empirical research to see the effect of fragmentation on market quality, which will be crucial in analyzing the role of HFT in consolidating equity markets in the subsequent sections.

The key concepts that will be looked at are '*price dispersion*', where an asset is priced differently in two fragmented markets, '*trade-throughs*', where an order is routed to a trading venue that executes it at a worse price than a competing trading venue would, '*internalization*', which describes when orders are executed against a broker's own inventory instead of in an open market, and '*dark pools*', which are trading venues where quotes are posted anonymously and are not publicly announced before the trade occurs,⁷⁴ and which contribute to the so-called '*dark fragmentation*' of financial markets.

3.1. European fragmented equity markets and regulation

The European equity market experienced a surge of fragmentation in the last decade. **Figure 4** shows how traditional, incumbent exchanges would start to lose their market share to newer, alternate trading venues from 2007 onwards. This illustrates the increasing fragmentation of order flow in European financial markets. And although market fragmentation is a phenomenon that has been occurring for a long period of time in financial markets, fragmentation in Europe started to pick up speed after 2007, the same year as the introduction of the Markets in Financial Instruments Directive (MiFID). MiFID was introduced in an effort to foster competition among trading venues by setting forth measures to spur the entry of new venues into the European market. The outcome of these measures would be a more fragmented equity market, since more trading venues would be competing for trader's order flow. We can see from **figure 4** that after the introduction of MiFID, competition did indeed grow among trading venues in Europe, as the once dominant incumbent exchanges were losing their market share to newer, alternate

⁷⁴ Gresse (2012), p. 6

trading venues such as Turquoise, BATS and Chi-X around 2007 and 2008.⁷⁵ However, the rapid fragmentation of markets was also met with the trend of market consolidation in the form of trading venue mergers in following years, for instance the merger of the London Stock Exchange (LSE) and the Borsa Italiana in 2007, the merger of Euronext and the NYSE in 2007, and the merger of BATS and Chi-X in 2011.⁷⁶ Despite this, European equity markets are still considered to be fragmented when compared to the pre-MiFID period.

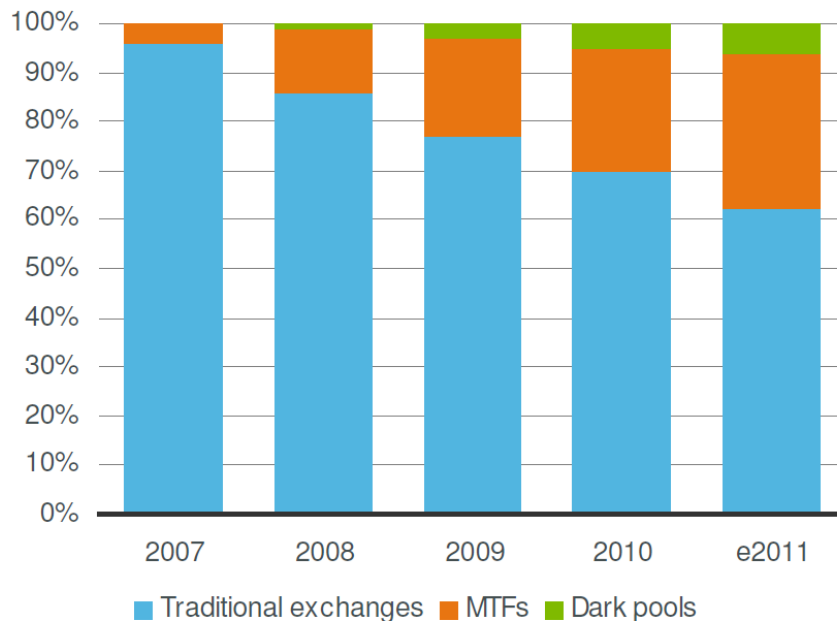


Figure 4: Trading venue market share in EU (percentage of average daily trade value)⁷⁷

What were the measures that stimulated this sudden fragmentation, however, and did they harm or improve market quality? To understand this, this thesis will look briefly at the mechanics of market fragmentation and its effect on financial markets.

3.1.1 Drivers of market fragmentation

Market fragmentation could be considered a market inefficiency, since economic principles suggest that a market tends toward natural monopolies, as marginal costs diminish once liquidity is consolidated in one market.⁷⁸ Inefficiencies arise in fragmented markets, such as adverse selection costs, price dispersion or trade-throughs, which then pose increased implicit

⁷⁵ Gresse (2012), p. 5, 6

⁷⁶ Gresse (2012), p. 7

⁷⁷ Source: Aite Group, retrieved from Blackrock (2011)

⁷⁸ Gresse (2012), p. 4

costs for liquidity providers and demanders. Therefore, “liquidity begets liquidity”⁷⁹ suggests that liquidity should aggregate in one market, which would then provide positive externalities to all market participants.

However, market consolidation provides benefits only if all market participants’ trading needs are uniform, which often is not the case. Traders’ needs may vary based on execution speed, price priority, etc. These varying needs drive market fragmentation, as different trading venues are established to satisfy different market participants’ demands. With increased competition among trading venues, this creates benefits for traders in the form of reduced explicit costs – trading venues improve their fees, technology and services to compete for order flow.

A trade-off therefore occurs between consolidated and fragmented markets, with consolidation reducing marginal costs for trading venues and fragmentation providing more competitive fees and services. Ideally, a balance would exist where market participants would be able to enjoy the benefits of consolidation, as well as fragmentation of financial markets. Starting from a premise of a fragmented financial market, we can identify two ways in which we could reduce market fragmentation inefficiencies. First, through consolidation, meaning that trading venues either merge or are reduced to an equilibrium amount where consolidation benefits outweigh fragmentation costs. Second, by granting traders access to all markets with low costs, we are able to retain the number of trading venues and instead focus on ‘virtual consolidation’ of fragmented markets via technology. A virtually consolidated market, which the EU and the US have tended towards, is able to enjoy the benefits of fragmentation, as well as positive consolidation externalities due to informational linkages.⁸⁰ For instance, consolidated tape providers (CTPs) are able to monitor all of the trading venue prices, which then could be used to route traders’ orders to the ones displaying the best available prices. The advancement in technological development was conducive in creating such a market, since the fixed costs associated with setting up and running electronic trading venues have diminished.⁸¹ The implications on market quality of such a market will be discussed in the following sections.

3.1.2 Markets in Financial Instruments Directive

Where does regulation fit into the development of market fragmentation then? As we saw in the previous section, the main drivers for market fragmentation – varying trader needs and

⁷⁹ Foucalt et al.(2013), p. 254

⁸⁰ Blackrock (2014), p. 1

⁸¹ Gresse (2012), p. 4

technological advancement – were already present in the market without the need of regulatory intervention. However, regulation was necessary to eliminate barriers of entry for new trading venues, encouraging more competition among exchanges. MiFID, which was introduced in 2007, aided in reducing costs of entry and allowed new trading venues to compete against incumbent exchanges, which lead to the increase in market fragmentation that we witness today.

To begin with, it is necessary to note that MiFID created a categorization for three types of trading venues based on their functionality and requirements towards regulatory bodies. First, Regulated Markets (RMs) are authorized exchanges which trade regulated financial instruments.⁸² Incumbent primary exchanges, such as NYSE-Euronext and Deutsche Börse, fall under this category. Second, Multilateral Trading Facilities (MTFs), are trading systems similar to RMs, which can also serve as primary listings for firms, however, the instruments traded on MTFs are not designated regulated financial instruments.⁸³ Examples of MTFs are Chi-X and BATS Europe. Third, Systematic Internalizers (SIs) are broker-dealers or other investment firms that trade on behalf of their clients outside of RMs and MTFs, either against their own inventories or other clients' orders.⁸⁴

The first measure that should be mentioned is the cancellation of the 'concentration rule'. The 'concentration rule' was part of the Investment Services Directive, introduced in 1993, that allowed member states to force the execution of domestic equity orders on regulated, national exchanges. This rule was enforced by some member states, such as Spain, France and Italy.⁸⁵ In essence, this meant that primary exchanges would face little competition from non-domestic trading venues. With the concentration rule abolished, incumbent exchanges were no longer protected and would have to face competition from newer trading venues entering the European market. However, the concentration rules were employed to a certain extent to combat internalization, since orders would have to be executed on regulated exchanges rather than within a broker's inventory. Therefore, the abolition of the concentration rules allowed more for more internalization of order flow.⁸⁶

Another crucial measure was the introduction of order protection rules. In a fragmented market, traders might have their orders executed in an unsatisfying manner. For example, an order might be routed to a primary exchange which executes it at a worse price than a competing trading

⁸² Gresse (2012), p. 5

⁸³ Gresse (2012), p. 4

⁸⁴ Gresse (2012), p. 4

⁸⁵ Foucalt et al. (2013), p. 272

⁸⁶ Weaver (2014), p. 4, 5

venue, or perhaps the order takes longer to execute at one exchange than at another. This is known as a trade-through, where the order is routed to an exchange that executes it sub-optimally given trader's preferences. To protect traders from trade-throughs, MiFID requires that orders be executed given 'best execution rules', which are characterized as firms *"tak[ing] all reasonable steps to obtain, when executing orders, the best possible results for their clients taking into account price, costs, speed, likelihood of execution and settlement, size, nature or any other consideration relevant to the execution of the order"*.⁸⁷

Lastly, several transparency measures were also introduced with MiFID. First, it required firms to reveal their client's unfulfilled limit orders to the public, making it possible for other market participants to execute the outstanding limit orders.⁸⁸ Second, SIs are required to publish firm quotes during normal trading hours. The SI quotes received by the clients must be executed at the quoted prices, meaning that price improvements given by SIs to their clients are prohibited or limited in certain cases. SIs are therefore encouraged to publicize the liquidity that they have available.⁸⁹ Lastly, all financial transactions, including over-the-counter (OTC), are subject to post-trade transparency rules, which can be either reported to the primary exchange or designated trade reporting facilities (TRFs). These transparency measures serve to increase competition among market-makers, broker-dealers and other market participants, as well as to increase the transparency of financial transactions, especially given trades done in 'dark' trading venues.

The EU was not the only market to have addressed the issue of market fragmentation through regulation – the US have also introduced regulation of this nature, named 'Regulation National Market System' (RegNMS), with the aim of promoting competition among trading venues, which also lead to an increase in fragmentation in the US around the same time as in the EU. For this reason, we can look at what makes these regulatory approaches different based on the measures they have adopted. First of all, order protection measures differ between the two regulations. While MiFID employs 'best execution rules', which requires that orders be executed given a wide range of trader preferences, RegNMS is more specific in its order protection rules. RegNMS requires that share orders be executed at best prices available, and only if they are instantly accessible,⁹⁰ essentially prioritizing price and speed of execution. To achieve this, RegNMS needed to create a system to keep track of all market share prices,

⁸⁷ European Parliament and Council Directive (2004), article 21

⁸⁸ European Parliament and Council Directive (2004), article 22

⁸⁹ European Parliament and Council Directive (2004), article 27

⁹⁰ Foucalt et al., (2013), p. 269

calculate the best available ones, and ensure that orders are rerouted to the exchanges offering them. The intermarket trading system (ITS) and the Consolidated Tape Association (CTA) were devised to accomplish this task, with the ITS in charge of routing orders to the exchanges offering best available prices, and the CTA collecting market data to calculate the National Best Bid and Offer (NBBO).⁹¹ The EU does not currently have consolidated tapes to keep track of best available prices, nor the infrastructure necessary to reroute orders such as the ITS, meaning that trade-throughs are still more prevalent in the EU compared to the US (which will be addressed in section 3.3.3). Second of all, the clearing and settlement systems in the EU and US differ as well, with the US having one central counterparty (CCP) for clearing all equity trades and one central securities depository (CSD) for settling them, while the EU has multiple CCPs and CSDs that are used by different trading venues.⁹² This creates costly barriers for trading between different countries in the EU, therefore making domestic trading more feasible than cross-market trading.

Some of the issues described above are to be addressed in new regulatory measures introduced by the EU, namely through and extension to MiFID titled MiFID 2, as well as new regulation, the Markets in Financial Instruments Regulation (MiFIR). The goal of these measures is to redirect OTC trading onto designated exchanges, for instance by introducing Organized Trading Facilities (OTFs), which serve the purpose of capturing trading activity by venues which did not fall under the MTF or RM category (and hence were trading OTC), or by setting quantitative measures for SIs in order to categorize more broker-dealer activity as being SIs (since the EU faces the problem of too few internalizers registering as SIs already).⁹³ Furthermore, pre- and post-trading transparency measures are to be extended to more financial instruments and trading venues, as well as the establishment of CTPs by data service providers and other reporting entities.⁹⁴ The deadline for the adoption of MiFID 2 and MiFIR is set to 3rd of January, 2018,⁹⁵ meaning that the issue of market fragmentation is still far from settled, and will still have to be faced by future researchers in the years to come.

3.1.3 Dark pools

While up until now we have examined exchanges that were considered to be ‘visible’ or ‘lit’ (since orders submitted to them are able to be observed by the public), the thesis will now shift

⁹¹ Foucalt et al. (2013), p. 268, 269

⁹² Foucalt et al., (2013), p. 274

⁹³ Raffan et al. (2014), p. 2, 3

⁹⁴ Strachan, Lovejoy, Rana, Fergusson (2014), p. 6

⁹⁵ http://europa.eu/rapid/press-release_IP-16-265_en.htm

focus towards ‘dark pools’. Dark pools could be described as trading venues which do not publically display anonymous orders by traders before they are executed. This is an advantage for example for large institutional traders, who want to trade large quantities of shares and who want to avoid the price impact such a trade would have on a regular exchange. Furthermore, the advantage of such a venue is that the execution costs are lower than in visible exchanges since they do not charge exchange fees and execute trades typically at the midpoint of the best bid and offer prices,⁹⁶ however, the trade-off is that the probability of executing the order becomes lower as well. There are many different types of trading venues that could be considered dark pools, however we can categorize them into three groups, which fall under different categories designated by MiFID.

The first group of dark pools could be categorized as crossing networks (CNs), which generally refer to electronic trading venues that match anonymous order submissions from buyers and sellers, with the price of execution based on the midquote of regulated, visible exchanges.⁹⁷ Block-trading alert systems, which perform a similar function to CNs but only serve to alert traders of potential buyers and sellers interested in trading with them, also fall into this category of dark pools. Under MiFID, these dark pools are recognized as MTFs. The second category of dark pools are broker-dealer owned dark trading venues, generally operating as continuous limit order books,⁹⁸ with the execution prices being derived from the order flow of their customers.⁹⁹ These are generally owned by large institutions, such as Goldman Sachs, Morgan Stanley, or Credit Suisse. MiFID does not categorize these types of broker-dealer dark pools, therefore they are designated as OTC trading venues.¹⁰⁰ The third category of dark pools operate as inter-dealer brokers, trading with other broker-dealers.¹⁰¹

Dark pools have become a topic of discussion surrounding market fragmentation, since they contribute to the so-called dark fragmentation of financial markets as they fragment order flow that would otherwise be executed on visible exchanges. This is a separate issue from visible fragmentation because dark pools affect market liquidity in a particular manner. For instance, the issue of price discovery in dark pools is a concern to researchers, since they fear that moving trading to less transparent trading venues may harm the overall price formation process.¹⁰²

⁹⁶ Easthope, Ray (2014), p. 5, 6

⁹⁷ Nimalendran, Ray (2014), p. 233

⁹⁸ Gresse (2012), p. 6

⁹⁹ Zhu (2014), p. 753

¹⁰⁰ Gresse (2012), p. 6

¹⁰¹ Gresse (2012), p. 6

¹⁰² Gillan et al. (2015), p. 7

Internalization of orders by broker-dealers also might pose issues, as trades that could be executed on visible exchanges are instead executed against the broker-dealers inventories, also potentially harming price discovery. It is important to note however that much like in visible fragmentation, dark pools arose due to specific trader needs, and so dark pools may vary depending on the different types of services or technology that they provide, as well as differ on the effect they have on market liquidity.

3.2 Theoretical models

This section will delve deeper into mechanics of market fragmentation, looking at theoretical research that seeks to understand the benefits and costs of fragmentation, and attempt to explain the model assumptions intuitively for the most part.

Market fragmentation became the focus of attention after the introduction of MiFID in 2007 due to perceived negative effects that a fragmented equity market might pose for market participants, both liquidity providers and liquidity demanders. This section will assume the definition of fragmented markets to be one that does not allow any interaction between its uninformed traders (where the markets are essentially ‘cut off’ from each other), which will serve to better understand the full extent of fragmentation costs. In the following part, the thesis will look at some intuitive explanations of more complex theoretical models to understand the costs of fragmentation, with three groups of market participants in mind – market-makers, uninformed traders and informed traders.

3.2.1 Informed trading:¹⁰³ let us take into consideration a model of two fragmented markets with two separate groups of uninformed traders and risk-neutral market makers, who cannot trade between markets, and one informed trader who can trade on both markets. The uninformed order flow in the two markets is not correlated, and is random with a mean of zero and non-zero variance. The informed trader’s strategy is to place orders simultaneously on the two markets, so that the price in one market does not adjust to the price movement in the second market. If market-makers could base their price on the order flow of the other market, the price would be identical to one in a consolidated market. Because the quotes and the uninformed trader’s demand are not correlated between the two markets, two separate equilibrium prices emerge due to the difference in uninformed order flow. The emerging of two separate prices can be described as ‘price dispersion’. Market depth is also lower in both fragmented market, as there is less overall liquidity available in each market. This is in contrast to consolidated

¹⁰³ Based on the model by Foucalt, Pagano, Röell, (2013), p. 242

markets, since demand for liquidity is higher, and thus there is more liquidity available for all traders. As a result, the price impact of orders is smaller in a consolidated market than in a fragmented one. The gains from trade of informed traders is equal to the losses of uninformed traders, and their gains are higher in a fragmented market.¹⁰⁴ This could be explained for instance by the informed trader being able to exploit their informational advantage in two separate, uncorrelated markets. On the other hand, price discovery in this model is higher in two fragmented markets, as the prices emerging in the two markets provide different, uncorrelated signals, providing more information in the price discovery process than in a consolidated market.

3.2.2 Risk-sharing among market-makers:¹⁰⁵ Taking into consideration a model of multiple, risk-averse market-makers in two fragmented call markets, we come to a similar result as in the previous model. The price impact is higher in fragmented markets than in a consolidated market, since in a consolidated market there is a higher number of active market-makers, which increases their risk-sharing capacity. This means that market-makers are able to share the burden of risky inventories between themselves, which translates into lower trading costs for liquidity traders. Market fragmentation divides market-makers into two separate markets, which therefore reduces the risk-sharing capacity among market-makers. The assumption for this model to hold, however, is that traders are not able to optimally divide their orders between multiple markets, if so, then they would receive the same price as in a consolidated market.¹⁰⁶

¹⁰⁴ Based on the mathematical model of Kyle (1985), Foucalt, Pagano, Röell, (2013), p. 242, 243 show that the unconditional expected profit of an informed trader in a fragmented market is equal to $E[x_A(v - p_A) + x_B(v - p_B)] = \sigma_v \sigma_A / 2 + \sigma_v \sigma_B / 2 = \sigma_v \sqrt{\sigma_A^2 + \sigma_B^2 + 2\sigma_A \sigma_B} / 2$, which is greater than the unconditional expected profit in a consolidated market, equal to $E[x(v - p)] = \sigma_v \sqrt{\sigma_A^2 + \sigma_B^2} / 2$. The symbols are described as follows; x_A and x_B is the informed order size in market A and B, p_A and p_B are the prices set by market-makers in markets A and B, v is the fundamental value of a security observed by the informed trader, σ_v is the standard deviation of the security, and σ_A and σ_B are the standard deviations of the uninformed order flow in markets A and B. Symbols x and p represent uninformed order flow and prices in a consolidated market.

¹⁰⁵ Based on the model presented in Foucalt, Pagano, Röell, (2013), p. 246

¹⁰⁶ Based on the mathematical model by Foucalt, Pagano, Röell, (2013), p. 246, 247, the authors show that if traders are able to split their order q between two markets, so that $q_A + q_B = q$, then they receive an execution price equal to one in a consolidated market. This is because traders minimize trading costs by placing larger orders in deeper markets based on the ratio of market-makers K_A and K_B in market A and B, so that $q_A^* = \frac{K_A}{K_A + K_B} q$, $q_B^* = \frac{K_B}{K_A + K_B} q$, thus receiving two prices equal to $p_A(q_A^*) = p_B(q_B^*) = \mu + \frac{\bar{\rho} \sigma_v^2}{K_A + K_B} q$, where $\bar{\rho}$ is the risk-aversion coefficient of the market-maker in this model. This execution price is an improvement over one gained

3.2.3 Monopolistic market-makers:¹⁰⁷ in a fragmented market, market-makers are able to act as imperfect competitors, and thus exert more influence in their respective market. This may result in wider spreads as market-makers can impose higher mark-ups on their quotes in a fragmented setting. In a consolidated market, there are more market-makers in competition against each other, resulting in lower price impact and mark-ups for traders. This inefficiency could be overcome if uninformed traders could split orders between markets, or if all market-makers can be active in all markets without barriers.

3.2.4 Competition for order flow:¹⁰⁸ if we now assume that traders are able to split orders between multiple markets, then market fragmentation may provide benefits to traders due to increased competition between trading venues, as well as liquidity providers. This is opposite to the monopolistic ‘market-maker effect’, since in that scenario market-makers did not have to worry about competing for order flow from different markets-makers. First, market fragmentation increases competition among venues, resulting in reduced trading costs for traders, since venues could charge monopolistic fees due to a lack of competition. Furthermore, trading platform technology, as well as other services may improve or change to accommodate different trading needs to better compete for order flow. Second, liquidity providers themselves face more competition due to market fragmentation, resulting in a higher amount of total limit orders placed at a certain price if the number of orders is summed up between markets.

3.2.5 Dark pools:¹⁰⁹ a key aspect in modelling dark pool dynamics is to understand the trade-off between lower trading costs and lower execution probabilities (and thus higher costs associated with delayed execution). Considering a two period model of risk-neutral uninformed traders, informed traders that observe the true value of an asset, a visible exchange and a dark pool with an execution price fixed to the midpoint of the visible exchange (i.e. a crossing network), then the volatility of prices has an effect on the market participation of each trading venue. Uninformed traders may face a delay cost not executed in period 1, while informed traders also face a delay cost since if they do not execute their trade in period 1, the true value of the asset is revealed in period 2 and they lose their informational advantage. We also assume that higher volatility leads to wider spreads due to the fact that market-makers try to compensate

when, for instance, a trader in market A cannot split orders, since then $p_A = \mu + \frac{\bar{\rho}\sigma_p^2}{K_A}q$, meaning that the price impact of the order is larger when the trader cannot split orders, as $K_A + K_B > K_A$.

¹⁰⁷ Based on the model presented in Foucalt et al. (2013), p. 248

¹⁰⁸ Based on the model presented in Foucalt et al. (2013), p. 259. There are numerous assumptions that need to be true in order for this model to hold, which can be found in greater detail in Foucalt et al.(2013), p. 259-264

¹⁰⁹ Based on the model by Zhu (2014)

for higher adverse selection costs that they face from informed traders. If volatility is low enough, then the spreads on the visible exchange are low, and thus informed traders choose to trade on visible exchanges. They do not trade on dark pools because the lower trading costs on dark pools do not compensate them sufficiently for the costs of delayed execution. For high enough volatility, wider spreads cause informed traders to start trading in dark pools, introducing adverse selection costs in the dark pool. These increased adverse selection costs inside dark pools, in other words the probability that an informed trader is at the opposite end of the transaction, cause uninformed traders to turn to regulated exchanges. On the other hand, as correlated informed traders start to move to dark pools, they begin to cluster on one side of the trade, thus lowering their own probability of execution, and again forcing some informed traders to trade on regulated exchanges once again. Therefore, the dark pool market share is increasing in volatility when volatility is low, however, if volatility is sufficiently large, dark pool market share decreases in volatility as regulated exchanges may surpass dark pool in trading volume. The non-monotonic relationship between volatility and dark pool market share is described in **figure 5**.

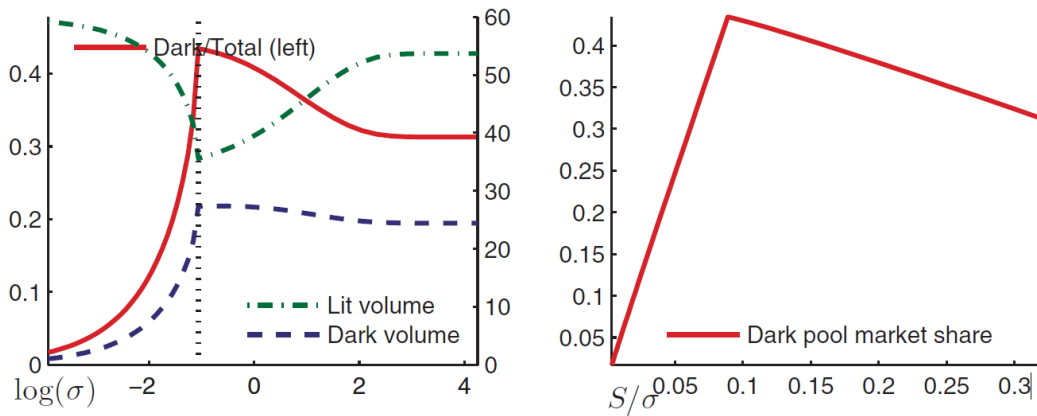


Figure 5: dark pool market share as a function of volatility¹¹⁰

3.2.6 Internalization: We can categorize internalization into two types – direct or indirect. Direct internalization describes when an intermediary executes a client’s order against their own inventory, acting as a dealer in this scenario. The order does not have to be internalized completely, however; they may choose to internalize only a fraction of the order, and route the rest to the market. According to regulation, the price at which the broker-dealer

¹¹⁰ Source: Zhu (2014), p. 766

internalizes the order has to be the market price.¹¹¹ This creates a trade-off for the intermediary acting as a broker-dealer: they can earn a margin for a portion of the trade they internalize, but they also decrease the price impact of the rest of the order they execute in the market, and since they have to internalize the order at market prices this results in a worse execution price for the broker-dealer.¹¹² Theoretically, direct internalization can have a negative effect on bid-ask spreads: because uninformed order flow which would normally be routed to market-makers is internalized, market-makers face a greater ratio of informed orders which causes the spread to widen due to higher adverse selection costs.¹¹³

Indirect internalization, on the other hand, refers to broker-dealers that sell the access to their customers' order flow to third parties, meaning that their customers' orders are indirectly internalized by other dealers or traders. This is also known as 'payment for order flow'. A similar argument can be made towards indirect internalization, since market-makers paying for order flow are attempting to execute against uninformed traders, meaning that other market-makers again face higher adverse selection costs due to a larger ratio of informed traders in their order flow.¹¹⁴ Internalization can therefore be seen as an agency problem as well, since the customers of the internalizing broker-dealer may not be sure if they executed their order at the optimal price.¹¹⁵

3.3 Empirical research

This section will look at the empirical research done on the topic of market fragmentation and its effect on market quality. The assumptions that were necessary to hold in the theoretical section no longer necessarily apply in real markets. The European equity market could be ideally described as 'virtually consolidated', where fragmented trading venues are linked together due to technology, which allows traders to operate in multiple markets, thus reaping the benefits partly of fragmentation, and partly of consolidation. However, there are barriers that still exist between European equity markets which prevent traders from optimally cross-trading between member states, and which therefore gives rise to market inefficiencies. This could be due to, for instance, differences in transparency, differing trading hours between venues, or agency problems posed by brokers.¹¹⁶ To better understand the specific

¹¹¹ Foucalt et al. (2013), p. 251

¹¹² Foucalt et al. (2013), p. 252, 253

¹¹³ Weaver (2014), p. 2, 3

¹¹⁴ Foucalt et al. (2013), p. 253

¹¹⁵ Foucalt et al. (2013), p. 252

¹¹⁶ Foucalt et al. (2013), p. 247

characteristics of EU fragmentation, the next section will compare it to the US fragmented equity market at the end of the section.

3.3.1 Visible fragmentation

Numerous studies have been published analyzing the effects of market fragmentation since the introduction of MiFID in the EU. Overall, research generally suggests that market fragmentation has had a positive effect on market liquidity in the EU and the US.¹¹⁷ More specifically, several market liquidity indicators have suggested to have improved after market fragmentation since 2007.

First, spreads in European equity markets have narrowed since the introduction of MiFID. A total of 130 stocks not pertaining to the financial sector and belonging to the FTSE 100, CAC 40 and SBF 120 indices were analyzed in the months of October 2007, and January, June and September of 2009. The result was a narrowing of quoted spreads from 2007 up until September of 2009, with the most significant narrowing being witnessed in the FTSE 100 index, from 9.21 to 5.43 basis points in the average consolidated quoted spread.¹¹⁸ Spreads in Dutch large and mid-cap stocks have improved from 2006 to 2009 by around 2 to 3 basis points when using multiple spread measures, with the sample median being around 13 basis points.¹¹⁹ Stocks with higher fragmentation indices belonging to the Stoxx Europe 50 Index were found to have lower daily relative quoted spreads compared to less fragmented stocks from 2008 to 2010 (**figure 6**).¹²⁰ Also, comparing a control group of less fragmented stocks (30 IBEX35 stocks) to more fragmented stocks (30 FTSE100 stocks) in two periods, 2007 and 2010, the annual average of the relative quoted spreads is shown to be lower for more fragmented stocks in both periods (**table 2**).¹²¹ Second, market depth has also seen improvement after market fragmentation. Stocks in the FTSE 100, CAC 40 and SBF 120 indices from 2007 to 2009 have increased greater depth, however, mid-cap stocks belonging to the SBF 120 have shown (with weak significance) to be negatively affected by market fragmentation¹²². Market depth at best prices as well as deeper in the order book in Dutch mid to large-cap stocks is shown to have improved in Dutch stocks from 2006 to 2009.¹²³ Third, price impact is another measure of liquidity that showed

¹¹⁷ Securities and Exchange Commission, Division of Trading and Markets (2013), p. 9

¹¹⁸ Gresse (2012), p. 20

¹¹⁹ Degryse, de Jong, Kervel (2014), p. 5

¹²⁰ Fiorovanti, Gentile (2011), p. 18-20

¹²¹ Fiorovanti, Gentile (2011), p. 22-23

¹²² Gresse (2012) p. 22

¹²³ Degryse et al. (2014), p. 4

improvement due to market fragmentation. For Dutch stocks between 2006 and 2009 however, price impact is shown to be positively correlated to fragmentation, suggesting that an increase in fragmentation leads to an increase in price impact.¹²⁴ Using the Stoxx Europe 50 index, stocks that experience more fragmentation are shown to have reduced price impact (measured as a ratio of daily return and trading volume, see **Table 2**).¹²⁵ While some researchers were worried that the introduction of new venues such as MTFs would harm the price discovery process as they would capture order flow away from primary exchanges, studies suggest that secondary markets such as MTFs also contribute towards the price discovery process, implying that trading venue fragmentation does not harm price discovery.¹²⁶

It is important to note that the sample period used by researchers to measure the effect of market fragmentation on liquidity coincides with the financial crisis of 2007/08. However, research methods used generally controlled for the effects of the crisis to assess the effect of fragmentation on liquidity.

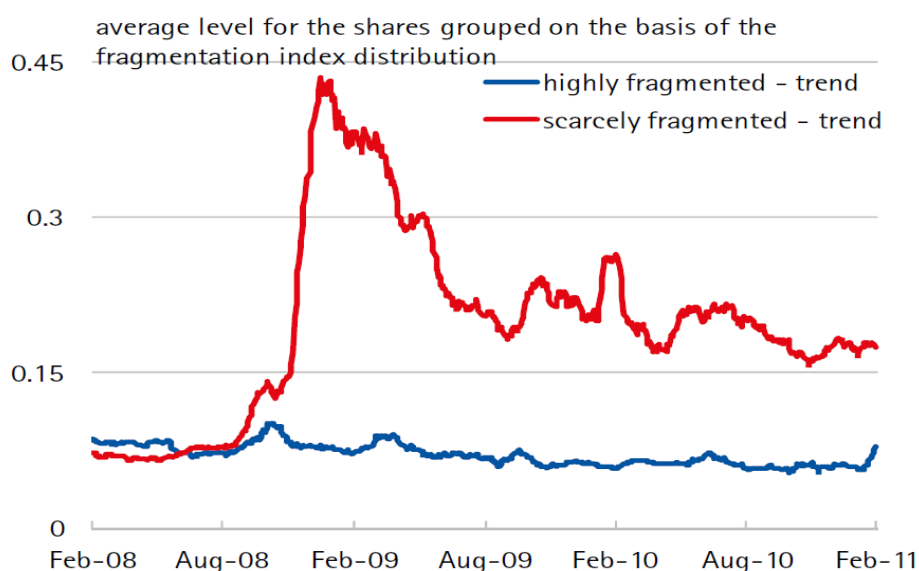


Figure 6: high vs low level of fragmentation impact on relative quoted spreads in Stoxx Europe 50 Index¹²⁷

¹²⁴ Degryse et al. (2014), p. 25

¹²⁵ Fiorovanti Gentile (2011), p. 18, 23

¹²⁶ Gresse (2012), p. 31

¹²⁷ Source: Fiorovanti, Gentile (2011), p. 20

	Relative Quoted Spread (%)	Price impact	Volatility (% annual basis)	Daily average of trading volume (mln. of euro)	Daily average of capitalisation (bln of euro)
2007					
Control sample	0.142	0.049	26.987	132.714	20.274
Fragmented stocks	0.112	0.007	25.399	309.263	54.870
2010					
Control sample	0.083	0.086	31.749	132.565	20.243
Fragmented stocks	0.061	0.018	26.987	301.284	54.287

Table 2: Difference in difference analysis of control group of less fragmented stocks vs. fragmented stocks of Stoxx Europe 50 Index¹²⁸

However, research also points out that visible fragmentation might have an adverse effect on market quality as well, especially given certain circumstances. First, it is suggested that after an equilibrium level of fragmentation is reached, marginal gains from fragmentation start to diminish. Stocks in FTSE 100, CAC 40 and SBF 120 between 2007 and 2009 are shown to have experienced lower marginal gains in liquidity after exceeding an equilibrium level of fragmentation.¹²⁹ Overall market depth in Dutch stocks between 2006 and 2009 is shown to have a non-monotonic relationship with fragmentation, with the function between the two variables resembling an inverted ‘U’.¹³⁰ Second, the market capitalization of stocks also affects how fragmentation impacts the liquidity of stocks, with small-cap companies exhibiting lower gains from fragmentation compared to large-cap companies, as well as the depth of smaller stocks being negatively affected by fragmentation.¹³¹ Third, it is suggested that local liquidity, meaning liquidity available only at the primary exchange, could be negatively affected by fragmentation, which would have adverse effects on traders who are not able to submit orders to other, competing venues beyond traditional exchanges.¹³² Lastly, fragmentation also may have a negative effect on other market quality indicators. For instance, price discovery is suggested to be negatively affected by increasing market fragmentation, based on stocks belonging to the Stoxx Europe 50 index between 2008 and 2011.¹³³

¹²⁸ Source: Fiorovanti, Gentile (2011), p. 23

¹²⁹ Gresse (2012A), p. 32

¹³⁰ Degryse et al. (2014), p. 23

¹³¹ Gresse (2012), p. 20, 32

¹³² Degryse et al. (2014), p. 12, 34

¹³³ Fiorovanti, Gentile (2011), p. 31

3.3.2 Dark fragmentation

Although the EU has seen an increase in the number of dark pools in recent years, as is shown in **figure 7**, we can also see that its share in overall equity trading is small, peaking at 6.5% in 2014. **Figure 8** illustrates that in the year 2015, dark pools amounted to 7.79% of total dark trading volume, and systemic internalizers to only 2.03%, with the remaining 90.18% of trades being done OTC. Also, average trade sizes have dropped significantly over the last years, as can be seen in **figure 9**, which is contrary to the suggestion that dark pools are used to trade large volumes of shares. One reason for this change might be due to algorithmic trading, which optimized its trading strategies to divide large orders into smaller groups, thus increasing their execution probabilities,¹³⁴ as well as potential increase in HFT activity.

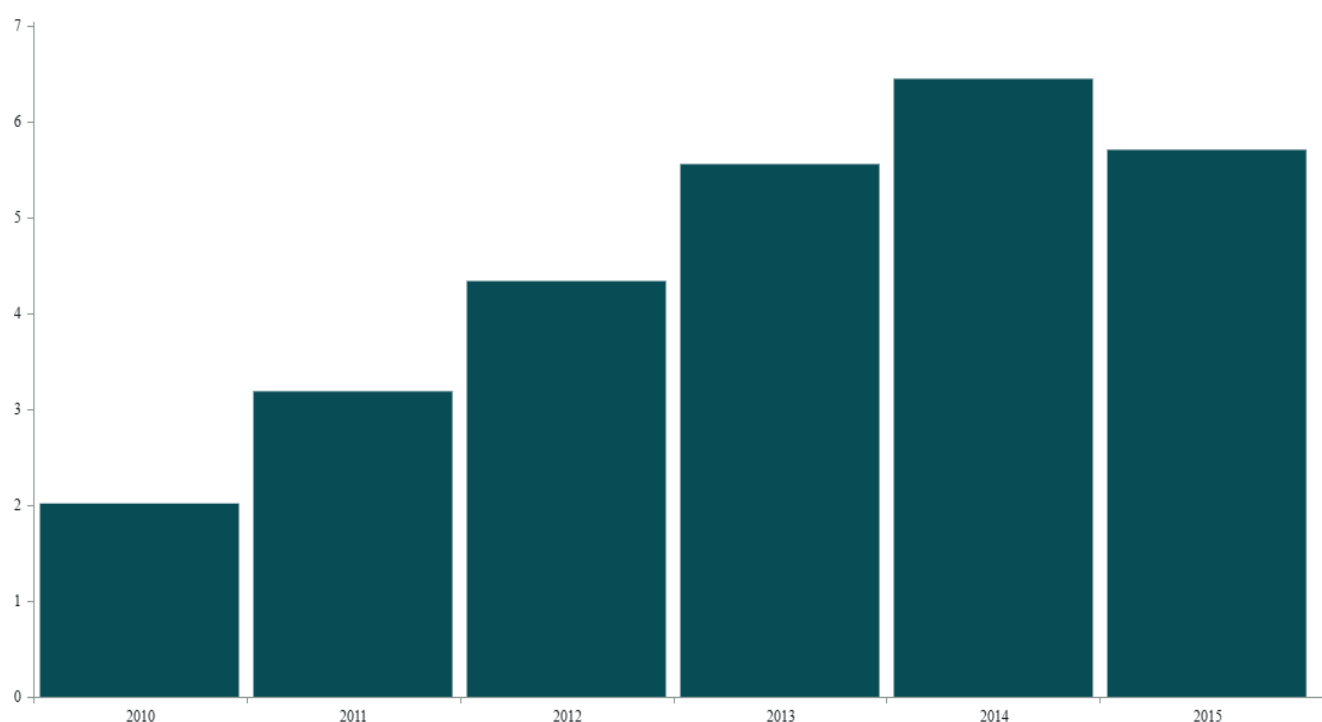


Figure 7: Market share of dark pools in EU equities trading (in %)¹³⁵

¹³⁴ Easthope, Ray (2014), p. 10

¹³⁵ Source: Rosenblatt Securities, retrieved from: <https://city.wsj.com/stories/8e15dfb4-1955-4527-981b-be1e3c70b1c8.html>

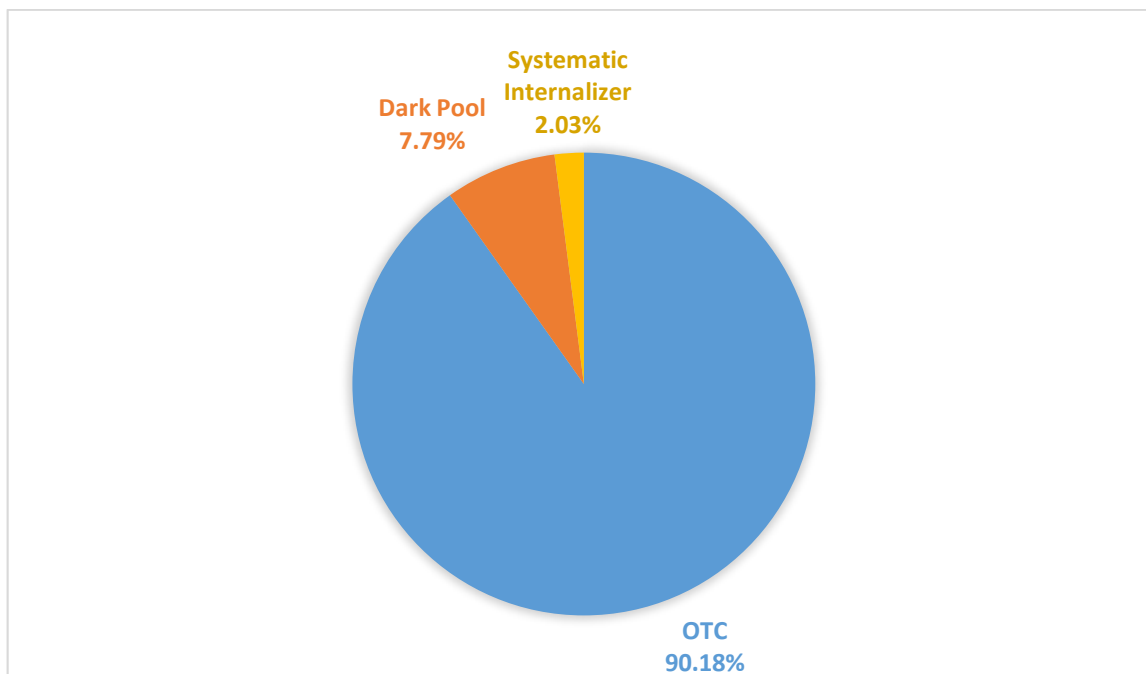


Figure 8: Dark trading volume in EU from 1.1.2015 to 1.1.2016 ¹³⁶

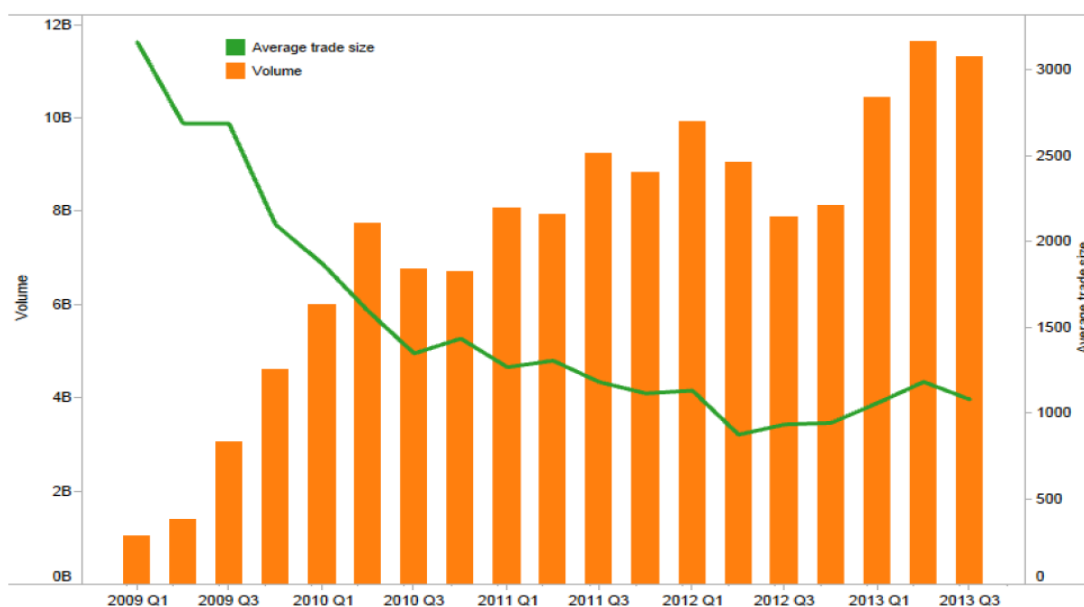


Figure 9: Volume traded and average trade size in dark venues by quarters in the EU¹³⁷

Looking at empirical research done on dark fragmentation in European financial markets, studies that analyzed this topic generally suggest that it has a mixed to negative effect on market quality, with research differing on what the causes of these negative effects are.¹³⁸ One reason

¹³⁶ Source: fragmentation.fidessa.com

¹³⁷ Source: Fidessa (2013), 'European Dark Trading Analysis', p. 2

¹³⁸ Securities and Exchange Commission (2013), p. 10

for this discrepancy in research might be due to the fact that ‘dark pools’ is a broad category which encompasses many types of trading venues. As we examined in section 3.2.5, dark pools might differ based on the membership rules, technology, customer base or the services provided to their clients. For instance, crossing networks have a different impact on market liquidity compared to the internalization activities of broker-dealers, as both dark pools use different means to execute trades.¹³⁹ This may be the reason why some research conflicts with one another, and why caution should be taken when generalizing the overall empirical implications of dark fragmentation on market liquidity.

For Dutch stocks between 2006 and 2009, dark fragmentation (which encompasses OTC trading, internalization and dark pools) was found to have a negative effect on spreads, price impact as well as market depth, with one standard deviation increase in dark trading leading to a 7% reduction in global depth.¹⁴⁰ Considering internalization in the FTSE 100 and SBF 120 indices, a panel regression in the period after the introduction of MiFID has shown that internalization has a positive effect on depth, but a negative effect on spreads.¹⁴¹ Dark fragmentation in FTSE-100 stocks between 2008 and 2011 has shown to reduce volatility, although at the same time increasing the variability of volatility, as well as increasing trading volume.¹⁴²

Dark trading is suggested to have positive effects on market quality, however, this is suggested to only be the case if the ratio of dark trading to overall trading is below a certain threshold.¹⁴³ Reductions in spread and increase in market depth are supposed to be associated with dark trading activity, however, research is not unified on what this threshold is, with thresholds of around 50%¹⁴⁴ to below 10%¹⁴⁵ being cited as potential turning points after which dark trading has a negative impact on market quality. Caution should be taken when considering these metrics, as thresholds may vary based on the market (i.e. the US and EU), as well as the fact that dark trading encompasses different activities, including OTC, dark pools and internalization. Therefore, even if the dark trading ratio surpasses a certain threshold, it is unclear which dark trading component is responsible for the decline in market quality.

¹³⁹ Gresse (2012) p. 22

¹⁴⁰ Degryse et al. (2014), p. 4

¹⁴¹ Gresse (2012), p. 30

¹⁴² Körber et al. (2014), p. 4

¹⁴³ Biedermann (2015), p. 84-86

¹⁴⁴ Preece, Schacht, Allen, Rosov (2012), p. 7

¹⁴⁵ Comerton-Forde (2012), p. 4

3.3.3 EU vs. US

In order to understand the situation of market fragmentation in EU equity markets more deeply, this section will provide a comparative analysis to the US equity market, which also experienced market fragmentation around 2007 due to the introduction of regulatory policies aiming to foster fragmentation. Although the two markets are similar in this regard, there is a significant difference in fragmentation levels, with the US experiencing more market fragmentation than the EU. The purpose of this analysis is to compare and contrast the fragmentation process in the two markets, and to identify the determinants that lead to different fragmentation effects on market liquidity in the EU compared to the US.

	Index	FFI	
		Week ending: 9.1.2015	Week ending: 8.1.2016
US	Dow Jones Industrial Average	4.58	4.37
	NASDAQ 100	3.61	3.94
	S&P 500	4.45	4.29
EU	FTSE 100	2.52	2.56
	CAC 40	2.25	2.19
	DAX	2.23	2.32

Table 3: Market fragmentation in the EU and the US in 2015 to 2016, measured according to the FFI¹⁴⁶

We can compare the level of fragmentation between the two markets using the Fidessa Fragmentation Index (FFI), which is increasing in the level of market fragmentation.¹⁴⁷ Generally, it can be observed that the US market experiences more fragmentation than the EU market, as can be seen in **table 3**, which compares the FFI of major US and EU share indices over the year 2015. We can see that the FFI of all major US share indices are significantly higher than those of the EU. This result is in line with some of the theoretical and empirical research examined in previous sections.

¹⁴⁶ Data retrieved on 14th January from <http://fragmentation.fidessa.com/>

¹⁴⁷ The FFI is the inverse of the Herfindahl-Hirschman Index, which is calculated as the sum of a trading venue's squared market share in a security. The FFI ranges therefore from 1, when all trading is concentrated in one market venue, to the maximum number of trading venues trading the security.

First, as discussed in section 3.1.2, differences in price protection measures between the EU and the US might be one reason for the discrepancy in fragmentation levels. RegNMS introduced stricter measures on trade-throughs by setting up the NBBO system that monitors best available prices, and routes orders to the exchanges with the best prices via the ITS. Preventing trade-throughs leads to more fragmentation, as orders for one security get executed in a wider range of trading venues.¹⁴⁸ EU's price protection policies differ in that no mechanisms such as CTPs or the ITS were set up to prevent trade-throughs, leading to more trade-throughs occurring in the EU and thus to more trades being executed in fewer exchanges altogether. The most active primary exchange, Euronext Paris, has been shown to experience trade-throughs in 14% of its overall trades between 2007 and 2008,¹⁴⁹ while the US has seen a drop in its trade-through rate from 2% to 0.1% of trades between 2003 and 2014.¹⁵⁰

Another reason for higher fragmentation levels in the US could be due to the difference in clearing and settlement systems between the two markets. While the US has one CCP and CSD for all equity trades, the EU has more than 20 CCPs and CSDs.¹⁵¹ And since different trading venues utilize different CSDs and CCPs, this results in higher trading costs for traders wanting to trade in multiple markets, since they are not able to net their position between markets.¹⁵² Higher cross-market transaction costs leads therefore to more domestic trades on primary exchanges in the EU and thus to less fragmentation.¹⁵³

Additionally, more competitive fees and services introduced by incumbent exchanges may be further reason why fragmentation remained low in the EU. In response to the increasing competition from new MTFs entering the European equity market, incumbent exchanges improved their fees and formed new platforms such as their own MTFs or dark pools to prevent order flow from migrating elsewhere, resulting in less fragmentation in order flow in the EU market.¹⁵⁴

Regarding the impact of visible fragmentation on market liquidity, results suggest to be similar in both markets. The US has seen improvements in spreads, market depth and reduced price impact with the increase in the level of fragmentation in their equities market as well.¹⁵⁵

¹⁴⁸ Pagnotta (2014), p. 6

¹⁴⁹ Ende, Lutat (2011), p. 20

¹⁵⁰ Securities Exchange Commission (2015), 'Rule 611 Memorandum', p. 13

¹⁵¹ Foucalt et al. (2013), p. 274

¹⁵² Menkveld (2013), p. 715

¹⁵³ Foucalt et al. (2013), p. 273

¹⁵⁴ Gresse (2012), p. 9

¹⁵⁵ Securities and Exchange Commission, Division of Trading and Markets (2013), p. 12-20

However, small-cap stocks seem to react differently in the two markets, with US small-cap stocks reacting positively to the increase in market fragmentation, while EU small-cap stocks exhibiting either negative market depth effects with increasing fragmentation, or lower positive liquidity effects compared to large-cap stocks.¹⁵⁶

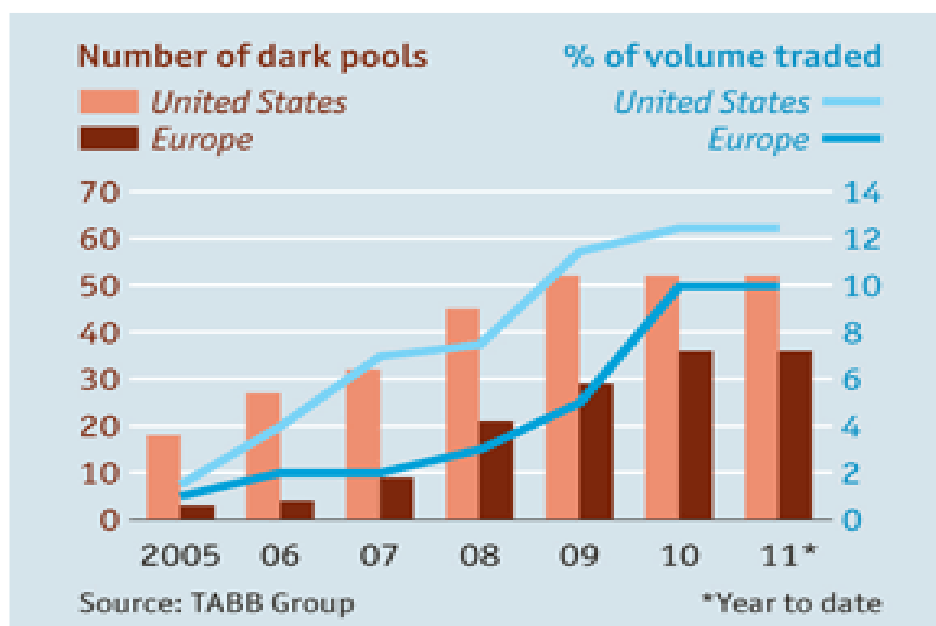


Figure 10: US dark pool number and percentage of volume traded¹⁵⁷

Dark fragmentation levels also seem to differ between the two markets, with the US experiencing higher dark trading levels than the EU. Trading volume in dark pools comprised around 6.5% of overall trades in the EU in 2014 according to Rosenblatt Securities,¹⁵⁸ while the US had a dark pool trading volume of around 14.3% of trades in 2013.¹⁵⁹ **Figure 10** shows a comparative statistic in dark pool number and percentage of volume traded between the US and EU (the discrepancy in trading volume percentages is due to different sources, and thus likely to different measurement approaches used). The difference between the two markets concerning dark pool activity is significant, however research does not point to a specific determinant that causes this discrepancy. However, the difference could likely be due to different regulatory approaches used by both markets concerning dark pools, since Regulation Alternate Trading Systems (ATS) in the US categorizes dark pools as an ATS and consequently

¹⁵⁶ Gresse (2012), p. 31

¹⁵⁷ Source: TABB Group, retrieved from Hudak (2015)

¹⁵⁸ <https://city.wsj.com/stories/8e15dfb4-1955-4527-981b-be1e3c70b1c8.html>

¹⁵⁹ Biedermann (2015), p. 81

as broker-dealers,¹⁶⁰ while broker-dealer operated dark pools in the EU are categorized as unregulated and categorized as OTC under MiFID.

Furthermore, there also might be a difference in the size of trades executed in dark pools between the two markets. As we can see from **figure 11**, the average trade size in US dark pools has dropped to around 200 share in 2013, while **figure 9** showed that in the EU, the average dark pool trade size is still around 1000 shares. Again, this discrepancy might be due to the difference in the volume of algorithmic trading between the two markets.

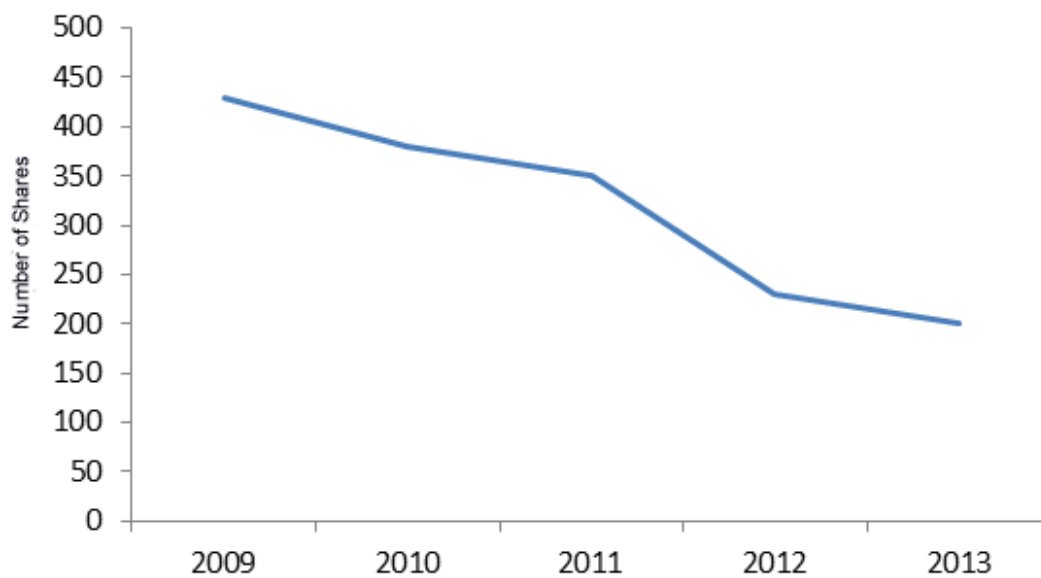


Figure 11: average execution sizes at US dark pools¹⁶¹

¹⁶⁰ Boskovic, Cerruti, Noel (2010), p. 10

¹⁶¹ Source: <http://www.celent.com/reports/dark-pools-eye-storm>

4. HFT and Market Fragmentation

The following, penultimate section of this thesis will address the issue of HFT and their role in either consolidating, or further fragmenting European equity markets. While in the previous sections we examined these two topics separately to understand their individual impact on market liquidity, this section will attempt to fuse these two topics together utilizing previously discussed research to understand whether HFT in European equity markets serves to exacerbate or, on the other hand, limit market fragmentation effects.

4.1 MTF and HFT relationship

The entrance of new trading venues into the European market, namely MTFs, was one of the main driving forces behind the fragmentation of order flow in the EU. Chi-X, BATS and Turquoise were early entrants into the market after the MiFID adoption, and were able to successfully compete against incumbent exchanges, increasing their market share from zero to 18%, while decreasing incumbent exchanges' market share from 64% to 45% between 2008 and 2011.¹⁶² There are several reasons behind the rapid success of MTFs in the post-MiFID period in European markets, however, and HFT and their relationship with MTFs could be regarded as one of the key determinants. In order to attract the highest amount of market share available, MTFs were targeting a new, rising segment of traders, namely HFT. First, their pricing structure relied on liquidity rebates for liquidity providers, while charging fees for liquidity traders. As mentioned in section 2, a large portion of HFT's activity is in market-making, meaning that HFT were more incentivized to provide liquidity in MTFs with such a fee structure. The MTF offering liquidity rebates would compensate with fees charged for taking liquidity, netting them on average a profit of 0.1 basis points per trade,¹⁶³ but the large trading volume provided by HFT could still make it profitable for MTFs. This stood in contrast with incumbent exchanges, which at the time would still charge a higher, fixed fee for both liquidity providers and liquidity demanders alike.¹⁶⁴ Second, MTFs would have more advanced technology available to HFT compared to incumbent exchanges, especially in terms of reducing order submission latency. Naturally, this would be another incentive for HFT to trade on MTFs, as HFT profitability relies not only on low-latency technology, but also on being faster than their competition. Third, MTFs would offer new services in the form of new, advanced order

¹⁶² Fiorovanti, Gentile (2011), p. 8

¹⁶³ Fiorovanti, Gentile (2011), p. 11

¹⁶⁴ Fiorovanti, Gentile (2011), p. 11

types that would cater to HFT.¹⁶⁵ These orders are specifically suited to HFT to take advantage of their low latency trading strategies, and serve little purpose to non-HFT market participants, indicating that the intention by MTF was to attract HFT with these new order types. The issue thus becomes more complicated, as one could argue that HFT are unfairly favored by MTFs, even at the expense of slower traders, who are then targeted by newer, more sophisticated strategies by HFT utilizing new orders.

Trading venue	Liquidity taker	Liquidity provider	Net trading fee
Chi-X	0.30	-0.20	0.10
Turquoise	0.28	-0.20	0.08
Bats Europe	0.28	-0.18	0.10
LSE	0.31	0.31	0.62
Deutsche Borse	0.48	0.48	0.96
Euronext	0.65	0.65	1.30
Borsa Italiana	0.40	0.40	0.80
Bolsa de Madrid	0.40	0.40	0.80

Table 4: Trading fees (in basis points) at EU trading venues in 2010¹⁶⁶

The relationship between market fragmentation and HFT could therefore be considered synergetic, with HFT contributing to the rise in market share of MTFs and thus to an increase in market fragmentation, as well as MTFs providing a low-latency, low-cost platform for HFT to proliferate on. In the EU, it is suggested that HFT are concentrated in large cap stocks (section 2.3), and market fragmentation is suggested to favor large cap rather than small cap stocks (section 3.3.3), further providing evidence of positive correlation. Interestingly, most of the studies done on both HFT and market fragmentation focus on the period after the adoption of MiFID, and find that market liquidity increased as a result. It is therefore necessary to be cautious when identifying causation rather than correlation when examining the evidence on the impact of market fragmentation or HFT on market liquidity, as the two variables may be very closely correlated.

4.2 Price synchronization

As we discussed in section 3, price dispersion may result from market fragmentation. The thesis will now examine HFT's potential to consolidate fragmented markets through reducing price

¹⁶⁵ Lewis (2014), p. 155

¹⁶⁶ Source: Chesini et al (2010), retrieved from Fiorovanti, Gentile (2011)

dispersion. There are a couple of reasons why price synchronization might be beneficial for market quality in fragmented markets. First, if a security incorporates all of the available information, both public and private, this aids in creating an efficient market. This in turn helps investors, especially in a fragmented setting, optimally allocate their resources in a security,¹⁶⁷ as well as decreasing agency issues with brokers, since traders may face the issue of brokers executing their orders sub-optimally (section 3.2.6). As fragmentation increases, so does the execution time of an order because traders have to search markets for optimal quotes, which can pose a significant cost for the trader.¹⁶⁸ Second, price synchronization among highly correlated securities is able to decrease transaction costs, since informed investors trading in correlated securities are forced to compete with each other as these securities become synchronized.¹⁶⁹ Price synchronization could be of value especially in the EU, as it currently does not have consolidated tape mechanism with which it would be able to ‘virtually’ consolidate their equity markets as in the US, thus providing a non-regulatory mechanism for market consolidation.

4.2.1 Theoretical assumptions

One of the key HFT strategies is to act in the capacity as an arbitrageur to take advantage of mispriced stocks.¹⁷⁰ Since fragmented markets may exhibit price dispersion between markets, this opens up arbitrage opportunities for HFT. The advantage of HFT compared to non-HFT is their technology; on the one hand, they are able to search multiple trading venues faster with search costs being close to zero due to their algorithmic nature,¹⁷¹ and on the other hand, they can capitalize on a found arbitrage opportunity quicker than non-HFT market participants. Also, HFT can act as more efficient market-makers in fragmented markets, due to the fact that market-making costs are substantially reduced due to their high-speed, technological advantage. Costs associated with holding inventories might also decrease as a result of HFT speed advantage, allowing them to quickly measure trader interest in a market in order to sell risky or costly inventories.¹⁷² As such, HFT could serve as a price synchronization mechanism in fragmented markets.

¹⁶⁷ Gerig (2012) p. 5

¹⁶⁸ Biais et al. (2015), p. 292

¹⁶⁹ Gerig (2012), p. 3

¹⁷⁰ Hafekorn (2015), p. 4

¹⁷¹ Menkveld (2013), p. 737

¹⁷² Menkveld (2013), p. 717

Looking more deeply into this assumption, we explained in section 3.2 how market fragmentation under specific assumptions can exert costs for market participants, for example traders not being able to split orders between multiple markets due to market barriers. HFT could serve to mitigate these negative fragmentation effects. First, looking at the effect of ‘informed trading’ as discussed in section 3.2.1, we can see that fragmentation costs arise when market-makers are not able to adjust their quotes based on the order flow of the second market. In a real world scenario, this assumption could hold true due to, for example, the slow speed of information transfer between two markets.¹⁷³ Because of this, two equilibrium prices emerge in the two markets, leading to price dispersion. With HFT acting as market-makers, the ‘informed trading’ effect is reduced due to the high-speed trading capacity of HFT, who are able to almost instantly observe price changes in the second market. Second, another assumption that leads to fragmentation costs is that traders are not able to act in multiple markets simultaneously, for example, by splitting their orders between two markets, as discussed in section 3.2.2. In the real world, this could be due to barriers between markets that make it unfeasible for traders to split orders between them. HFT reduce this cost due to their ability to optimally divide orders between markets and submit them at low latencies, as they can search markets for optimal prices at low costs. This ability to optimally divide orders between markets may then results in a single equilibrium price in the two markets.

4.2.2 Empirical evidence

Empirical evidence suggests that HFT is indeed a significant factor in synchronizing prices in European fragmented markets. **Figure 12** illustrates that HFT among all other market participants react the most to price movements in two correlated stocks,¹⁷⁴ showcasing their use of arbitrage strategies and speed in which they are able to take advantage of these arbitrage opportunities. Furthermore, since HFT are considered to be the most dispersed group of traders in fragmented markets, this suggests that HFT are more active than other market participants in trading between multiple trading venues, and therefore being the most likely to synchronize prices across trading venues.¹⁷⁵

The reduction of spreads through market-making activities by HFT could also be argued to be an effect of price synchronization performed by HFT, as they generally perform their activities in multiple markets simultaneously. For example, the entry of a single HFT market participant

¹⁷³ Foucalt et al. (2013), p. 242

¹⁷⁴ Gerig (2012), p. 2, 3

¹⁷⁵ Bouveret, et al. (2014), p. 10, 16

in Chi-X in 2007 correlated with the decline of the spread in Dutch stocks by 50%.¹⁷⁶ The empirical evidence suggests that the lone HFT market participant was primarily trading as a market-maker in 80% of trades, as opposed to an arbitrageur. Since the HFT was active on both the Chi-X and Euronext in this period, it is also suggested that their action resulted in price synchronization among the two venues, ultimately resulting in a narrower spread (a reduction from 3.21 to 2.44 basis points) on Chi-X once HFT started to trade.¹⁷⁷

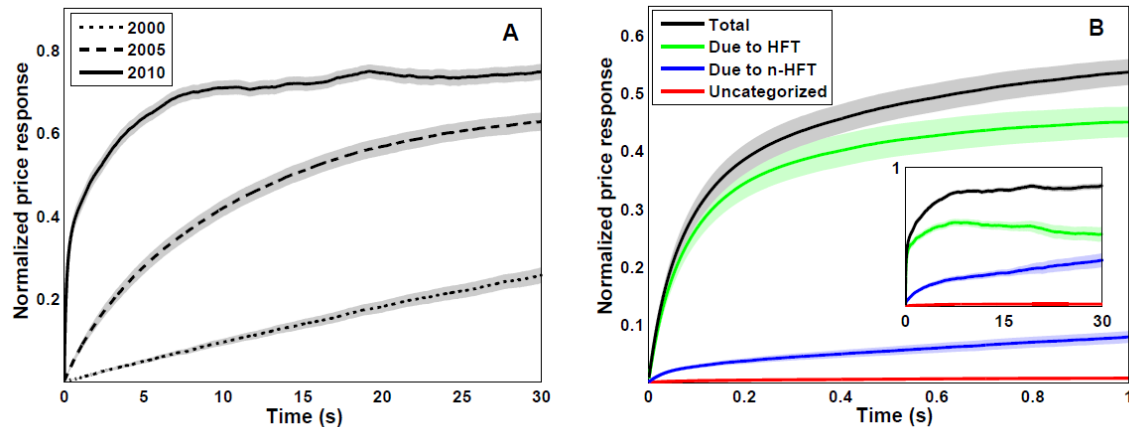


Figure 12: Normalized mean price response of one stock to the price movement of another stock for 35 US stocks during the last February week in 2000, 2005, and 2010¹⁷⁸

HFT is also suggested to alleviate end-of-day price dislocation, which is seen as a manipulation tactic used by traders to manipulate prices in their favor before the trading day ends.¹⁷⁹ An analysis of 22 countries between January 2003 and June 2011, including EU countries such as Germany, the United Kingdom and Sweden, suggests this result. The method in which this was examined was by categorizing countries into HFT countries (those where there was a significant, identifiable presence of HFT in the market), and non-HFT countries. Subsequently, an effective starting day was calculated to see when HFT began to have a significant impact on a market's quality, as well as other factors such as order cancellation rates and so forth. **Figure 13** illustrates that after the effective start date of HFT activity, end-of-day price dispersion declined in HFT countries as opposed to non-HFT countries. Again, since proxies were used to identify HFT activity, these results may again suggest correlation rather than causation between HFT activity and end-of-day price dispersion.

¹⁷⁶ Menkveld (2013), p. 721

¹⁷⁷ Menkveld (2013), p. 721, 732

¹⁷⁸ Source: Gerig (2012)

¹⁷⁹ Aitken et al. (2015), p. 331

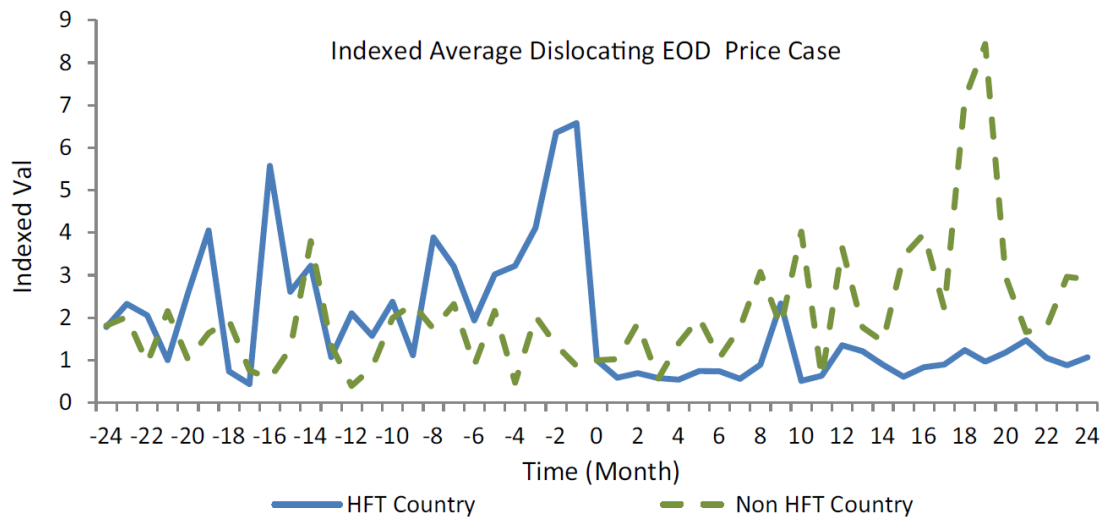


Figure 13: graph of average, market-cap weighted end-of-day price cases. The X-axis identifies the effective start date of HFT activity with the value 0¹⁸⁰

Measuring the midpoint price dispersion in the French blue chip index CAC 40 on two competing venues during 2013, Euronext Paris and BATS Chi-X Europe, it is shown that HFT activity is negatively correlated with price dispersion,¹⁸¹ suggesting that an increase in HFT activity lead to more synchronized prices. The causality of HFT's effect on price dispersion is also tested by looking at regulatory measures introduced in Germany concerning HFT, known as the German HFT Act. By comparing the DAX 30 and the CAC 40 indices and analyzing the changes in price dispersion before and after the introduction of the German HFT Act in 2013, it is shown that price dispersion did increase after the HFT Act, suggesting that HFT leaving the market had a significant effect on price dispersion increasing between multiple venues.¹⁸²

However, some criticism can be levied on the assumption that HFT is beneficial to market quality by synchronizing asset prices. Price synchronization is a way to diminish the negative effects of market fragmentation, but it can also be a cause of market instability, since erroneous information can spread quicker if there is a high correlation between price information of securities.¹⁸³ This could lead to the formation or exacerbation of bubbles and flash-crashes as we saw in previous sections. Furthermore, there is a possibility that during periods of stress in financial markets, HFT firms would not synchronize prices anymore and instead leave the

¹⁸⁰ Source: Aitken et al. (2015), p. 337

¹⁸¹ Hafekorn (2015), p.8

¹⁸² Hafekorn (2015), p. 12

¹⁸³ Gerig (2012), p.1

market.¹⁸⁴ It is also questionable to what extent an average trader is able to benefit from higher price synchronicity, especially if prices experience an adjustment of a few basis points. The increase in price efficiency may not compensate slower traders sufficiently for the increase in adverse selection costs and ‘phantom liquidity’ provided by HFT. This issue will be discussed in the following section.

4.3 Migration into dark due to HFT

The previous section made the case of HFT acting as a mechanism for price synchronization in fragmented markets, thus leading to more efficient prices and lower transaction costs. However, we also saw that HFT are not willing to do this task for free, meaning that they need to generate profits from arbitrage opportunities or other market-making strategies to keep trading in financial markets. And as was mentioned in previous sections, it is suggested that the gains generated by HFT are equal to the losses of non-HFT market participants, or ‘slow traders’. One way to look at this issue is to consider HFT activities as a form of tax that other market participants have to pay to HFT to consolidate fragmented markets.¹⁸⁵ This is in line with research that suggests that HFT pose a negative externality on slow traders, decreasing their total gains.¹⁸⁶ This section will therefore look at HFT exerting a negative externality on slow traders, which could lead them to abandon visible exchanges in favor of trading venues where they would not be picked-off or front-run by HFT. One such alternative could be dark trading venues such as dark pools, which would suggest that if slower traders move their trading activities to dark pools due to HFT, then HFT could be partly causing further dark fragmentation in financial markets.

4.3.1 Theoretical assumptions

Continuing from the discussion in section 2.4, we analyze how slow market participants might respond to HFT imposing a negative externality on them in the form of adverse selection costs in a fragmented setting.¹⁸⁷ This could lead to slow traders moving their trading activities to slower markets such as dark pools, if the negative externality is not addressed through regulatory means such as the imposition of a Pigovian tax.¹⁸⁸ In a theoretical framework, the migration of slow (uninformed) traders to dark pools would pose costs for slow traders and

¹⁸⁴ Gerig, (2012), p. 2

¹⁸⁵ Chordia, Goyal, Lehmann, Saar (2013), p. 641

¹⁸⁶ Wah, Wellman (2013), p. 3

¹⁸⁷ Biais et al. (2015), p. 293

¹⁸⁸ Biais et al. (2015), p. 294

HFT remaining on regulated exchanges – spreads would widen due to higher adverse selection costs facing market-makers because of the migration of uninformed order flow, and HFT would generate lower profits due to the migration of slow traders.¹⁸⁹ There would be two equilibrium outcomes resulting from the migration: either all traders would migrate to dark pools, or all traders would turn to HFT technology. The two outcomes depend on the cost of HFT technology, since if this cost is too high, the migration of slow traders into dark pools would prove to be too costly for HFT to trade against each other in a solely fast market, as they are not able to profit from slow traders anymore. If the cost is low enough, then all traders will adopt HFT technology. However, these outcomes would then lead to either underinvesting or overinvesting in HFT technology (respectively) as related to the socially optimal level of HFT in a market.¹⁹⁰ Overinvesting in HFT technology leads to a social welfare loss because traders are forced to invest in costly HFT technology with marginal increases in market quality resulting from it as more traders turn to HFT, while underinvesting leads to a social welfare loss as well since some of the benefits of HFT are not fully taken advantage of.

Market participants, both slow and fast, are also affected by the level of market fragmentation. As we saw in section 3.2.1, if we consider HFT informed traders, an increase in fragmentation leads to higher gains for HFT, which are equal to the losses of uninformed traders. Additionally, if market fragmentation increases, then HFT are more likely to find and execute a trading opportunity instead of slow traders (due to HFT's speed advantage in searching multiple markets), which increases adverse selection costs for market-makers, thus increasing the spread. However, an increase in fragmentation affects slow traders more severely than HFT if there is a low number of HFT in the market (because of low competition among HFT), which is the case when the cost of HFT technology is high, meaning that in this case being a HFT would be more profitable than being a slow trader. This would mean that despite high costs of HFT technology, traders might still opt to invest in the technology since it is still more profitable than staying a slow trader, thus raising the ratio of HFT in the market. If there is a high number of HFT in the market on the other hand, possibly because of low technology costs, then an increase in fragmentation may have the opposite effect, since there is more competition among HFT, this would lower their profitability as they compete for slow, uninformed order flow.

Furthermore, HFT also impose negative externalities to non-HFT market participants through potential opportunistic trading, which can be related to the level of fragmentation in a market.

¹⁸⁹ Biais et al. (2015), p. 307

¹⁹⁰ Biais et al. (2015), p. 294

For instance, let us look at the US market in which there is a single consolidated tape and strict price protection rules. Price protection rules in the US mandate that orders be executed at the NBBO, which is calculated by the Security Information Processor (SIP) in the US. Utilizing their speed advantage and computing capabilities, HFT could calculate an estimate of the NBBO before the SIP,¹⁹¹ even just by a couple of milliseconds, and use it to their benefit by front-running slower market participants that are waiting for the SIP to update the NBBO. Theoretical models analyzing this potential trading strategy conclude that it results in a trade-off between shorter execution times and higher spreads due to adverse selection costs, however, the maximum decrease in execution time is suggested to be 30 milliseconds, which may not be welfare increasing for slow traders.¹⁹² In addition, this trading strategy by HFT might also negatively impact the NBBO, due to the increase in adverse selection costs.¹⁹³ This is a concern if the technology used by regulators is even slightly out of date compared to HFT technology. This assumption may hold true, if one examines the investment of HFT firms in technology to decrease latency by even a few milliseconds. The EU does not possess such a price protection mechanism yet, however, it may not be free from opportunistic trading strategies by HFT either. An increased rate of trade-throughs, as experienced in the EU due to a sufficient lack of order protection, may make trade-through routes predictable, creating an opportunity for HFT to front-run orders that are being traded through. In essence, any means which result in higher predictability of order flow, be it a system that calculates the NBBO, lack of trade-through protection or payment for order flow, could pose an opportunity for HFT to gain profit.

4.3.2 Empirical evidence

Empirically, we can find some evidence of HFT imposing a negative externality on non-HFT market participants, given the increase in dark fragmentation over the past decade as well as a reduction of profitability among HFT firms.

Qualitative evidence suggests that some investors reacted to the increase in HFT activity by moving into dark pools. Some reports suggest that they have deliberately chosen to start trading in dark pools because they feel less trustful of bigger regulated exchanges, citing the prevalence of HFT and associated technical glitches as the source of this distrust.¹⁹⁴ Due to this apparent rise in demand for slower markets with no HFT participation, some dark pools decided to cater

¹⁹¹ Wah, Wellman (2013), p. 2

¹⁹² Wah, Wellman (2013). p. 13

¹⁹³ Wah, Wellman (2013). p. 13

¹⁹⁴ http://www.nytimes.com/2013/04/01/business/as-market-heats-up-trading-slips-into-shadows.html?ref=business&_r=3&

to this group of slow traders. The IEX, for example, was founded in 2013 with the specific intent to protect slower traders from HFT by introducing a speed delay of 350 microseconds.¹⁹⁵ While the market share of the dark pool remains around 2%,¹⁹⁶ the IEX experienced a steady rise in market share since 2014, which suggests that demand does exist for a slower, dark trading venue. Similarly, the European trading venue Aquis Exchange Ltd. has experienced a sudden rise in market share after they placed a ban on latency arbitrage trading strategies, which they see as a potentially harmful HFT strategy.¹⁹⁷ Following the ban on February 6th, 2016, the market share of Aquis doubled from 0.4% to 0.8% (as seen in **figure 14**), suggesting that by limiting potentially harmful HFT behavior, slow traders were more willing to trade in this particular trading venue.



Figure 14: market share of Aquis Exchange Ltd.¹⁹⁸

Quantitative research also provides evidence that HFT activity may have forced traders to move to dark trading venues, as a positive correlation between increased market speed and the use of dark trading venues can be observed. For instance, a regression analysis of a speed increase at the NYSE by 800 milliseconds on March 10th, 2008, has shown that the speed change alone has resulted in an increase of dark trading volume by 3.9%.¹⁹⁹ Studies on EU markets have not focused on the direct correlation between HFT activity and dark trading volume, however, by examining descriptive statistics we can observe that there might be a link between the two

¹⁹⁵ <http://www.ft.com/cms/s/0/97d676f2-d115-11e5-92a1-c5e23ef99c77.html#axzz4985ZAAoF>

¹⁹⁶ <https://www.iextrading.com/stats/>

¹⁹⁷ <http://www.bloomberg.com/news/articles/2016-03-08/banning-some-hft-strategies-helped-this-market-grow-chart>

¹⁹⁸ Source: <http://www.bloomberg.com/news/articles/2016-03-08/banning-some-hft-strategies-helped-this-market-grow-chart>

¹⁹⁹ Jiang et al. (2012), p. 19

variables in the EU as well. If we look at **figure 13**, we see that HFT activity in EU shares peaks around 2010, after which HFT activity starts to decline. As we saw in **figure 10** from section 3.3.3, dark trading volume experienced a rise since the beginning of 2005, coinciding with the increase in HFT activity, as seen in **figure 13**. This suggest that the two may have experience some correlation in the beginning periods. However, dark trading volume continued to rise even after the decline in HFT activity after 2009. This could be explained through the assumption that as uninformed traders continued to move to dark trading venues, HFT were not able to profit off of slow traders anymore, which, coupled with increasing competition from other HFT firms, may have lead to the decline in overall HFT activity. If we assume that European HFT firm revenues mirror that of their US counterparts, then according to **figure 15** we can observe that revenues of HFT do decline with the increase in dark trading volume, which could support the argument that the movement of uninformed traders may have affected HFT revenue.

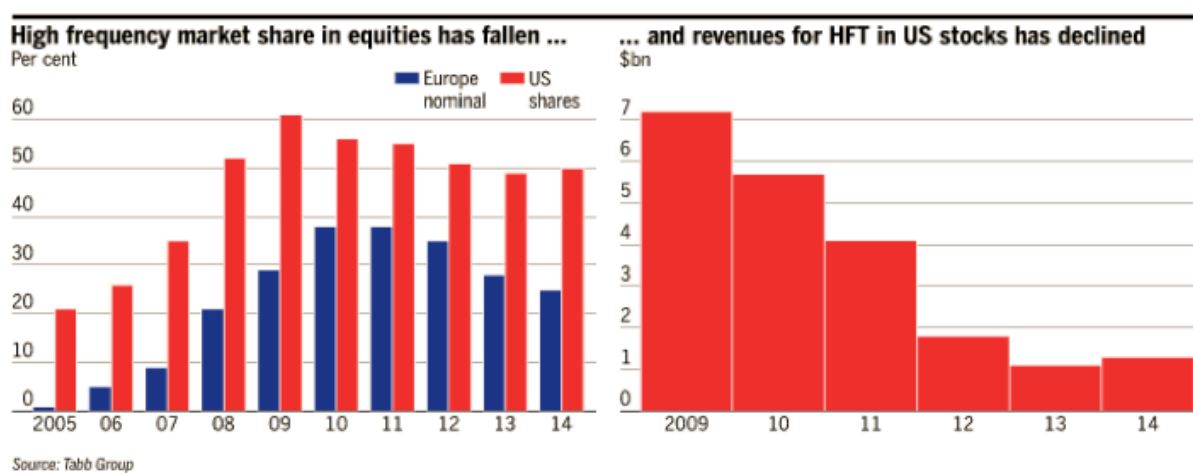


Figure 15: HFT market share in the EU and US, and HFT revenues in the US²⁰⁰

Caution should be taken when considering this analysis, as a more thorough regression analysis would have to be conducted to verify the significance of this apparent correlation, as dark trading volume could have risen independently from HFT activity. Other factors, such as the HFT tax introduced in EU countries, could also have influenced the decline in HFT market share in this period (which will be discussed in section 4.4). The analysis in this section also relies on the assumption that dark pools are more immune to predatory trading strategies by HFT, as orders are not revealed to the public before the trade is executed. However, HFT's pinging strategy may still be effective in dark pools as well, as series of smaller orders being

²⁰⁰ Source: TABB Group, retrieved from <http://www.vox.com/2014/4/15/5616574/high-frequency-trading-guide-real-problems-explained>

executed could indicate to HFT that a larger order is being hidden in the dark pool,²⁰¹ and use their advanced informational advantage to profit off of uninformed traders even in dark pools. This suggests that slow traders are not completely safe in dark pools that do not possess specific safeguards against HFT, such as IEX's speed limits on order submissions.

4.4 Barriers to HFT consolidation

Up until now we were looking at the role of HFT in either consolidating or further fragmenting markets. In this section, we explore market barriers specific to HFT that prevent them from fulfilling this role in some capacity.

4.4.1 HFT tax

Following the discussion on HFT's potential negative impact on overall welfare, it is not surprising that regulators from different countries would begin to address this issue. We can see this in countries such as France, Italy and Germany, which implemented a tax or other measures to regulate HFT activity (since we already covered the effect of the German HFT Act in section 4.2.2, this section will focus on the French and Italian markets). The impact on the markets after the introduction of HFT-specific regulation was a decline in HFT activity and also of market quality,²⁰² although to different degrees depending on the market. Either way, it is suggested that even small tax rates may have a significant effect on HFT, since it can greatly affect their profitability due to their arbitrage strategies that rely on the correction of small mispricing in assets.²⁰³ Thus we can see that taxes or other forms of regulation on HFT might be a significant barrier for them, which could then impact their ability to potentially consolidate European fragmented markets through price synchronization.

4.4.1.1 The case of France

France was one of the EU countries that lead the way in regulating financial markets, and adopted a financial transaction tax (FTT) of 0.02% on French equity with a market capitalization of 1 billion euros as well as a tax on HFT with a rate of 0.01% in 2012. This HFT tax was aimed at HFT firms based in France, and on HFT activity characterized by order resting times of lower than 500 milliseconds. Additionally, an order-to-trade ratio higher than 5:1 results in an application of the tax to each additional order that is modified or cancelled.²⁰⁴

²⁰¹ Biedermann (2015), p. 80

²⁰² Hafekorn (2015) p. 10, 12

²⁰³ Coelho (2014), p. 22, 23

²⁰⁴ Colliard, Hoffman (2013), p. 6

Exempted from this tax, however, was market-making HFT activity, as it is considered to be part of the beneficial aspects of HFT activity on market quality. Despite this, market quality is suggested to have declined in France after the adoption of the taxes. Trading volume declined by 7% within 2 months after the tax rates adoption,²⁰⁵ and market quality indicators such as market depth, price impact and price efficiency were also shown to have decreased,²⁰⁶ while the market has not experienced a significant reduction in volatility.²⁰⁷ Spreads also increased slightly, however it is suggested that a more significant widening of the spread was averted due to market-making activity exemptions.²⁰⁸ Regarding price synchronization, it is suggested that the HFT tax worsened price dispersion in French stocks traded in different venues.²⁰⁹ This follows from the previous discussion in section 4.2, which suggests a significant correlation between HFT activity and price synchronization.

Furthermore, the tax is suggested to have had a significantly higher impact on French dark trading than on visible trading. It is shown that dark trading volume decreased by 38% after the adoption of the HFT and the FTT.²¹⁰ One explanation for the large decrease in dark trading could be due to the suggestion that as OTC trading decreased, liquidity in electronic limit order markets increased, suggesting a migration from on venue to another.²¹¹ Although this might support the assumption proposed in section 4.3 that a decline in HFT activity would result in slow traders leaving dark pools and returning to regulated exchanges due to a reduction in negative externalities in the form of HFT activity, there is no empirical evidence in regards to the French market to suggest a direct, causal link between these two factors.

Ultimately, the HFT tax in France lead to HFT either canceling their orders less often, increasing the use of market orders, or exiting the French market in favor of other, non-taxed markets.²¹²

4.4.1.2 The case of Italy

A similar picture arises in Italy, where a FTT of 0.2% for OTC trades and 0.1% for regulated trades was adopted in March 2013 and included an HFT tax of 0.02%. The HFT tax applies to

²⁰⁵ Hafekorn, Zimmerman (2013), p. 3

²⁰⁶ Colliard Hoffman (2013), p. 2

²⁰⁷ Hafekorn, Zimmerman (2013), p. 3

²⁰⁸ Colliard Hoffman (2013), p. 2

²⁰⁹ Hafekorn, Zimmerman (2013), p. 2

²¹⁰ Colliard Hoffman (2013), p. 19

²¹¹ Colliard Hoffman (2013), p. 24

²¹² Colliard Hoffman (2013), p. 17

orders submitted and cancelled within 500 milliseconds, as well as to order-to-trade ratios exceeding 60%.²¹³ The tax is suggested to have had negative effect on market quality, due to an increase in spread and volatility following the adoption of the tax.²¹⁴ Dark trading was even more affected than in the case of France, since the FTT in Italy is twice the rate of the French FTT, causing a decline of 85% in OTC trades in Italy.²¹⁵ While some research suggests that French dark trading volumes recovered following the months after the adoption of the taxes, dark trading volume in Italy is suggested to have declined permanently following the taxes.²¹⁶

4.4.2 Short-selling regulation

The issue of short-selling regulation may also affect HFT and their ability to trade in EU equity markets. The EU has introduced regulation in 2012 to restrict investors from entering into uncovered short positions, creating therefore restrictions to short-selling activities.²¹⁷ While research suggests that HFT short-selling can harm liquidity, it also notes that short-selling might be an important facet of HFT's ability to manage risk and therefore to supply liquidity.²¹⁸ It is also suggested that even though market-makers, such as specialists, had similar short-selling constraints in the past, the difference is that past specialists had "guaranteed access to order flow", without which HFT is limited in their market-making capabilities, and which would be further exacerbated by a short-selling ban.²¹⁹

4.4.3 Limits to arbitrage for HFT

In order for HFT to consolidate markets, it arguably needs to perform arbitrage trades to correct potential mispricings and thus synchronize prices. However, there are a couple of reasons why these arbitrage strategies might not be profitable for HFT to perform. First, transaction costs may simply outweigh gains from arbitrage opportunities.²²⁰ This could be the result of higher transaction costs in certain stocks or specific time periods, or because of declining profits due to increased competition among HFT firms or other factors discussed previously. Second, clearing fees and margin requirements could also pose limits to arbitrage. In the case of the EU

²¹³ Rühl, Stein (2014), p. 26

²¹⁴ Rühl, Stein (2014), p. 32

²¹⁵ Coelho (2014), p. 49

²¹⁶ Coelho (2014), p. 15, 16

²¹⁷ <http://www.fca.org.uk/firms/markets/international-markets/eu/short-selling-regulations>

²¹⁸ Brogaard, Hendershott, Riordan (2015), p. 26, 27

²¹⁹ Brogaard et al. (2015), p. 26, 27

²²⁰ Storkenmaier, Wagener (2011), p. 18

market this problem becomes exacerbated due to the fact that there are multiple CCPs utilized by the various fragmented trading venues, making it more costly for traders to net their position between them. Research suggests that clearing fees in fragmented markets with multiple CCPs can be up to 100 times higher than in a market with a single CCP, or one where the trader is allowed to net their position between CCPs.²²¹ Therefore, such constraints impair significantly the ability of HFT to function in the market, and thus their capacity to affect market fragmentation.

4.5 Discussion and implications

The goal of this thesis was to analyze the role that HFT play in consolidating European equity markets. After examining the theoretical models and the empirical evidence provided by current research, it is apparent that the relationship between HFT, market fragmentation and market liquidity is quite complex. However, from the evidence and analysis provided in the thesis, it could be argued that although HFT contribute to the consolidation of markets through price synchronization, the overall results of this consolidation may not create positive externalities large enough for other market participants to outweigh the negative externalities posed by HFT.

Price synchronization seems to be the sole argument for HFT's involvement in market consolidation. That does not mean however that HFT's activities are insignificant. Empirical evidence suggests that HFT create more efficient prices and reduce dispersion by incorporating information at near-instantaneous speeds. Such high-speed price efficiency is only beneficial for financial markets, however, when everyone is in possession of high-speed technology, otherwise there will be traders at a disadvantage who will ultimately have to pay for low latency trading. And although uninformed traders always had to bear the burden of adverse selection costs in the form of higher spreads due to informed trading, HFT are suggested to have an unfair advantage in this scenario, since it is assumed that all HFT automatically become informed traders due to their monitoring and analysis of order flow information in a matter of milliseconds. The narrowing of spreads and improvement in other market liquidity indicators is suggested to be positively correlated with HFT activity. For non-HFT market participants, however, the question becomes how much they value improved price efficiency as an aspect of market consolidation. For slow investors, it may be hard to rationalize the marginal improvements in price informativeness. As we saw in **figure 12**, the price response is dominated by HFT in the millisecond area, but as time increases to over 30 seconds, the price response

²²¹ Menkveld (2013), p. 737

between HFT and non-HFT slowly converge. If we make an assumption that, for example, the price response is equal between HFT and non-HFT at one minute, we could argue that for slow investors a one minute delay may not represent a large setback if it meant not facing hFT externalities. However, it could be argued that if markets experience higher levels of fragmentation, more efficient, synchronized prices reduce the costs for investors of allocating their resources at optimal prices. This could be especially significant for traders that want to reduce agency issues related to brokers executing the trader's orders sub-optimally due to dispersed prices. The counterpoint to this argument is that HFT do not have to be the only non-regulatory means to synchronizing prices in a fragmented market. Increasingly more sophisticated technology and algorithms are being made available to slow traders as well, with the purpose of addressing the issue of finding the most optimal execution prices in multiple trading venues, for example what Smart Order Routing technology (SORT) allows users to do. This means that HFT's 'search' value, one of the key values described in the theoretical model in section 2.4, could be made redundant by competing technology.

It is also becoming apparent that a regulatory response needs to be considered to address the complexities of HFT and market fragmentation. This is due to the assumption that HFT pose a negative externality in the form of adverse selection costs towards slower, uninformed traders, who essentially have to pay a 'consolidation tax', so to speak, to HFT. However, it is difficult to assess the increase in adverse selection costs due to HFT directly, as market data suggests that bid-ask spreads, which theoretically should increase due to adverse selection costs, may have narrowed over the last years.²²² Nonetheless, we can find some evidence to suggest that slower, uninformed traders exit visible markets in favor of dark pools as a response to increased HFT activity, as discussed in section 4.3. The migration into dark pools that put limits to low latency trading may be beneficial to slow traders, as they reduce their risk of being front-run by HFT, however it also increases market fragmentation, as traders move from venue to venue to avoid HFT. This could be a source of market inefficiencies. Therefore, a regulatory approach that internalizes the potential negative HFT externality may limit the scope of visible and dark fragmentation in markets, as well as curbing the negative social welfare impact of HFT.

What are some regulatory approaches that are being considered currently in the EU? The issue of HFT has presently been addressed through individual member state regulation, such as taxing HFT activity in Germany, France and Italy, since MiFID currently does not impose a tax on

²²² Jones (2013), p. 15, 16

HFT. This will change with the introduction of MiFID 2, which seeks to address some of the inefficiencies arising in Europe's fragmented markets. As discussed in 3.1.2, greater transparency will be introduced through MiFID 2 which will attempt to capture more dark trading activity to fall within regulatory structures, for example through OTFs. Additionally, MiFID 2 will also propose new regulation for HFT activity in Europe. It will include reporting requirements for HFT activity that fulfill specific criteria, increasing transparency of HFT in Europe. More importantly, MiFID 2 will also require market-making HFT to be present in markets experiencing volatile episodes, thus trying to solve the issue of 'phantom liquidity' that would potentially evaporate due to HFT exiting markets during turbulent periods.²²³ The question then becomes whether this will be sufficient to fully reduce the negative externality posed by HFT. The issue of HFT's front-running potential will still be present after the introduction of MiFID 2, which is arguably a major source of adverse selection costs for slow traders. This implies that individual member states will have to address this issue on their own, as they already have through introducing taxes, to limit excessive order submission and cancellation rates by HFT. The problem with this approach is that by not creating EU-wide regulatory measures to address HFT, the European market may become more fragmented as each member state will have to decide on how to regulate HFT activity separately, potentially creating further cross-border barriers. The result of such an approach could be the migration of HFT activity to neighboring states or non-EU countries, leading to less consolidated EU markets, and if the assumption of HFT's causal positive relationship with market liquidity holds true, a negative impact on EU market quality.

So does HFT consolidate European equity markets? This thesis suggests that the issue is more complex than a simple yes or no answer, as there are several forces that act contrary to one another. HFT could synchronize prices and create a more virtually consolidated market, however the negative externalities posed by them might not make this consolidation approach welfare improving, even causing more fragmentation. This thesis argues therefore that other approaches should be considered instead of relying on HFT to consolidate equity markets. Newer technology utilized by slower traders, such as SORT, could resolve price dispersion problems without imposing negative externalities on them, leading to market consolidation. Regulatory measures, such as the ones proposed in MiFID 2, could lead to consolidated markets without HFT, such as the setting up of CTPs. In order for this virtually consolidated market to work however, certain boundaries should be set on HFT so as to not let algorithms exploit

²²³ <http://www.nortonrosefulbright.com/knowledge/publications/115236/mifid-ii-mifir-series>

fragmented markets for their own gain through opportunistic trading strategies (as is potentially experienced in the US due to the NBBO). In the end, HFT could create benefits in the form of price synchronization and liquidity provision in fragmented markets, but only if the adverse effects of HFT are kept in check as well.

4.6 Research limitations

Following the discussion on HFT's potential to consolidate or further fragment the market, it is important we point out that there are several limitations to the assumptions and conclusions made in the research used in this thesis. First, the studies used for research were conducted some years apart from each other, and while they do not constitute large timespans, even a difference of four years between studies may still be a long time period, especially considering the field of technological development. The landscape of HFT also changed significantly over the last years, with more competition amongst HFT firms meaning that the profitability of HFT activities is not a guarantee anymore. Therefore, a study from 2010 might produce different results regarding HFT and market fragmentation than one from 2015.

Second, empirical research differs on the methods that are used to identify HFT in market data, as opposed to other algorithmic trading activities used by buy-side institutions or traders using SORT. Proxies have to be devised to identify which trades belong to HFT, and thus different outcomes may be produced by researchers utilizing different HFT proxies, which should be taken into account when evaluating empirical studies.²²⁴

Lastly, several studies mention the problem of endogeneity when analyzing HFT and market fragmentation, especially since the two issues are so closely related. Indeed, several factors have had an impact on financial markets in recent years, especially in light of the worldwide financial crisis, as well as the sovereign debt crisis in Europe. Additionally, individual European member states implemented their own regulations concerning HFT, which also may have lead to false equivalences when comparing the market quality between states if these circumstances are not accounted for. As can be seen, studying HFT and market fragmentation is complicated if one is attempting to isolate the effects of one variable from the other.

²²⁴ Bouveret et al. (2014), p. 6-8

5. Conclusion

This thesis set out to analyze the role of HFT in consolidating fragmented equity markets in the EU, both by analyzing each of the topics individually, and then jointly to assess their overall impact on financial markets. In section 2, the issue of HFT was examined regarding their characteristics and its welfare implications on other market participants. It was discussed that although several market liquidity indicators have been positively correlated with HFT activity, research suggests that there are still drawbacks regarding market stability, phantom liquidity, as well as the negative impact on slower uninformed market participants, who experience losses equal to the gains made by HFT. Following in section 3, the issue of market fragmentation was addressed by analyzing its drivers, mechanics and theoretical as well as empirical research. Market fragmentation in Europe was driven by new trading venues entering the market providing new services and technology for traders. The measures introduced by MiFID served to foster the increase in competition between trading venues through several ways, resulting in the market fragmentation that European equity markets experience today. However, the EU differs in their market fragmentation from the US significantly, since the EU does not possess a regulatory market mechanism to virtually consolidated their markets as in the US, and also experiences more trade-throughs, as well as increased fragmentation in the clearing and settlement process. Lastly, in section 4, the theoretical and empirical research used up until that point is utilized to see whether or not HFT consolidates EU equity markets. It is argued that HFT consolidate equity markets by acting as arbitrageurs and market-makers between markets, effectively synchronizing prices between fragmented venues. However, it is also argued that HFT pose a negative externality on other market participants, who essentially have to lose to HFT in order for them to consolidate markets. Because of these higher adverse selection costs posed by HFT, some slower, uninformed traders migrate to the dark venues as to avoid these costs, resulting in an increase in dark fragmentation. Lastly, an argument is made that due to certain barriers, either regulatory or other limits to arbitrage, HFT are not willing to continue trading in those markets, and thus abort their role as a mechanism for virtually consolidating EU equity markets.

The issue presented in this thesis is still fairly new, and research continues to be published regarding benefits and costs of HFT and market fragmentation. However, this thesis argues based on the current state of research that HFT may not be the most effective, socially optimal means of consolidating EU equity markets. This is due to the argument that although HFT synchronize prices across venues, the marginal increase in price efficiency benefits other HFT

the most at the expense of slower market participants. For slow traders, small improvements in a couple of basis points do not offset the large adverse selection costs, as well as other issues i.e. ‘phantom liquidity’ that they face as a result of HFT. It is also becoming increasingly apparent that HFT, especially in the EU equity market, are not going to continue consolidating markets as more regulatory barriers are raised and more competition is being faced by newer HFT firms, as well more sophisticated technology used by other market participants. In that regard, regulatory bodies should consider approaching this issue and considering different mechanisms of virtual market consolidation, such as the ones introduced in the US (which seems to be the case judging by the measures being contemplated for MiFID 2). In order to avoid the pitfalls faced by the US concerning consolidated tapes and the NBBO in regards to HFT, preventive measures should be introduced to stop HFT from exploiting the predictability of such systems. Some member countries already chose to act towards this objective by regulating order cancellation rates or introducing a HFT tax. However, completely banning HFT technology is also not socially desirable, and could have an adverse effect on overall market liquidity, perhaps even reverting some of the improvements made in this regard over the last years.

All in all, the issue of HFT and market fragmentation is still ripe for future research, and should be handled carefully and critically as to ensure the improvement of market quality, social welfare of all market participants, and the stability of financial markets as a whole.

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Appendix

Abstract

This thesis examines High-Frequency Trading (HFT) and its role in fragmented European equity markets, specifically whether they act as a mechanism towards consolidating them or not. The first part of the thesis examines HFT's characteristics and trading strategies, as well as its impact on overall market quality and social welfare using theoretical models and empirical research. It is suggested that HFT may improve market liquidity indicators such as spreads, price impact and market depth, but may have a negative effect on volatility, as well as on the social welfare of uninformed, slow traders. The second part of the thesis examines market fragmentation as a recent trend of financial markets where an increasing number of trading venues are competing for order flow, which is suggested to have been spurred by varying trader needs, technological development, and regulatory measures that promoted such competition. The thesis then examines the distinction between visible fragmentation – entry of new, electronic trading venues – and dark fragmentation – entry of venues that do not publically display quotes, such as dark pools and internalizers. The impact of fragmentation on market quality is then examined through theoretical and empirical research, which suggests that market fragmentation may pose market inefficiencies if traders are not able to access all markets, but may provide benefits in the form of more competitive trading fees. The thesis compares and contrasts the fragmentation of equity markets in the EU and the US, and finds that EU experiences relatively lower fragmentation, which could be explained due to the prevalence of trade-throughs and fragmentation in clearing and settlement systems. In the last part, the thesis examines HFT in the EU's fragmented market environment and seeks to analyze its role using previously discussed research. It argues that HFT contribute to price synchronization between European markets via their trading strategies, thus lowering price dispersion and contributing to a more consolidated European market. However, HFT also pose negative externalities towards slower, uninformed market participants, leading them to abandon visible trading venues in favor of dark pools, thus contributing to increased dark fragmentation of European markets. Additionally, it is argued that several barriers exist in the European market, from taxes on low-latency trading to increased clearing fees and margin requirements, which specifically affect HFT and thus hinders their ability to consolidate them.

Zusammenfassung

Diese Arbeit untersucht den Hochfrequenzhandel (HFH) und seine Rolle in den fragmentierten europäischen Aktienmärkten, insbesondere ob HFH als Konsolidierungsmechanismus auf sie wirkt oder nicht. Der erste Teil der Arbeit untersucht die Merkmale und Handelsstrategien von HFH sowie deren Auswirkungen auf die Gesamtmarktqualität und soziale Wohlfahrt durch theoretische Modelle und empirische Forschung. Es wird argumentiert, dass HFH Marktliquiditätsindikatoren wie „Spreads“, Preisauswirkung und Markttiefe verbessern kann, aber hat sowohl eine negative Auswirkung auf die Volatilität, als auch auf die soziale Wohlfahrt der uninformierten, langsamen Händler. Der zweite Teil der Arbeit untersucht die Fragmentierung des Marktes als Trend der heutigen Finanzmärkte, in denen eine wachsende Zahl von Handelsplätzen für Auftragsfluss konkurrieren. Es wird angedeutet, dass die Fragmentierung des Marktes durch variierenden Händlerbedürfnisse, technologische Entwicklung und Regulierungsmaßnahmen vorangetrieben wird. Die Arbeit untersucht danach die Unterscheidung zwischen sichtbarer Fragmentierung – der Eintritt neuer, elektronischer Handelsplätze – und dunkler Fragmentierung – der Eintritt von Handelsplätzen, wo keine öffentlichen Preisangaben angezeigt werden, wie „Dark Pools“ und „Internalisierer“. Die Auswirkungen der Fragmentierung auf die Marktqualität wird dann durch theoretische und empirische Forschung untersucht. Die Forschung deutet darauf hin, dass die Fragmentierung des Marktes Markteffizienzen auslösen kann, wenn Händler kein Zugriff zu allen Märkten haben, aber kann auch Vorteile in Form von wettbewerbsfähiger Handelsgebühren bieten. Die Arbeit vergleicht und kontrastiert nachfolgend die Fragmentierung der Aktienmärkte in der EU und den USA, und stellt fest, dass die EU weniger fragmentierte Märkte besitzt, was durch die Verbreitung von „trade-throughs“ und die Fragmentierung der Clearing- und Abwicklungssysteme erklärt werden könnte. Im letzten Teil analysiert die Arbeit die Rolle der HFH im fragmentierten Marktumfeld der EU. Es wird argumentiert, dass HFH zur Preissynchronisierung zwischen den europäischen Märkten durch seine Handelsstrategien beiträgt. Jedoch stellen HFH auch negative Externalitäten für langsame, uninformierte Marktteilnehmer vor, die dann sichtbare Handelsplätze zugunsten von „Dark Pools“ verlassen, was zur erhöhten dunklen Fragmentierung der europäischen Märkte beiträgt. Weiterhin wird argumentiert, dass mehrere Marktbarrieren für HFH in der EU bestehen, wie z.B. die HFH Steuern und erhöhte Margin-Anforderungen, die seine Fähigkeit hemmen, Märkte zu konsolidieren.