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BUS3001 Dissertation 2019

An assessment of the effects of high-frequency trading on market efficiency and resiliency; with insights from primary research on Directive (2014/65/EU)[1]?

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2nd May 2019

[1] Directive 2014/65/EU is also known as MiFID II.

Executive Summary

In a speech (4th June 2014) former-CEO of the FCA, Martin Wheatley offered an illuminating depiction of high-frequency trading (HFT). He argued that HFT was not a new phenomenon, but a trading strategy existing for centuries – with the very first high-frequency trade occurring on: the London Stock Exchange (19th June 1815). On this day, Nathan Rothschild utilised his spy network and faster horses to receive intelligence on the Battle of Waterloo (1815) before market competitors (Wheatley, 2014). Effectively, Rothschild 'colocated' himself on the LSE. Subsequently, he shorted small parcels of gilts creating downward market (momentum-ignition) before proceeding to buy-up and profit; all before position-news reached market. Rothschild's actions are the same as witnessed with HFT today. In essence, while the horses have been replaced by fibre optics, the trading strategy has not changed – only the speed boundaries (Ibid).

Since this speech, much has been written on HFT although the economic community is far from consensual in multiple areas. This paper seeks to contribute to the debate in three areas of vital importance. Firstly (1), provide clarity on HFT, including trading strategies, key regulation and internalisation. Many interpretations of HFT have been proposed, with none taking precedence. My literature review concludes that HFT is a branch of algorithmic trading (AT) experiencing relentless technological innovation against a backdrop of favourable regulation and structural market changes – however, HFT has acted as a locus for market abuses and market transparency issues.

This paper secondly (2) focuses on HFTs' effects on market efficiency and resiliency. Using Samuelson (1965) and Fama's (1965, 1970) variables, HFT has improved market efficiency and liquidity. Nevertheless, the rise in 'flash crashes' suggests HFT increases volatility in stressed conditions – undermining market resilience. Lastly, I thirdly (3) critically appraise the latest regulation of HFT, Directive (2014/65/EU) utilising interviewees from finance – my primary research finds several shortcomings and suggestions for improvement. In this paper, it is concluded that regulators must vigilantly regulate HFT without suppressing market innovations.

Dissertation Declaration

This dissertation is the result of my own work. Material from the published or unpublished works of others, which is referred to in this dissertation, is credited to the author in question in the text. Interviews were conducted in line with the businesses HR codes of conduct and the University of Exeter ethical requirements. The main body of this dissertation is below 10,000 words in length[2].

[2] Excluding – figures, table of contents, appendices, references and list of: abbreviations tables and figures.

Acknowledgement

I would like to thank my dissertation supervisor, Thomas Sisk, for his invaluable guidance and support throughout the dissertation writing process.

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Abbreviations

AT Algorithmic Trading

BO Back Office

BoE Bank of England

CHI Chicago

CME Chicago Mercantile Exchange

CFTC Commodity Futures Trading Commission

DEX Decentralised Exchange

DIJA Dow Jones Industrial Average

DOT Designated Order Turnaround System

ECN Electronic Communication Network

EMH Efficient Market Hypothesis

EU European Union

ETF Exchange-Traded Fund

FBI Federal Bureau of Investigation

FCA Financial Conduct Authority

FO Front Office

HFT High-Frequency Trading

IB Investment Bank

IEX Investors Exchange

LSE London Stock Exchange

MAR Market Abuse Regulation

MiFID II Directive (2014/65/EU)

MIT Massachusetts Institute of Technology

M/S Milliseconds

NMS National Market System

NYC New York City

PFOF Payment For Order Flow

PTN Proprietary Trading Network

SEC Securities Exchange Commission

US United States

1 Introduction

1.1 Context

HFT has become far more prominent in global markets: instigating 10-40% of trading volume in equities and 10-15% of foreign exchange and commodities volume globally (Aldridge & Krawciw, 2017). Yet, since SEC analysis (2010) concluded that HFT was a culpable factor for the Flash stock-market crash (6th May 2010) – an intense “spotlight” has been shined on HFT (Rowland, 2015).

Consequently, there is support within the investor and economic community; championed notably by Buffet, Munger and Gates that HFT makes markets more dangerous – particularly predatory HFT strategies (Crippen, 2014). Furthermore, influential financial-journalist Michael Lewis was incriminating of HFT in his novel *Flash Boys* (2014), which charted the establishment of the Investors Exchange (IEX). Subsequently, IEX CEO Katsuyama has pledged that it will be the “world’s fairest stock-trading venue” (Bullock, 2016). Ultimately, the establishment of IEX and damning criticisms of HFT from prominent sources is concerning.

Yet, there is a need for further clarity regarding plenty of HFT strategies and permutations – Xhang (2010), Zhang and Riordan (2011) have emphasised the need for more literature on HFT. Indeed, if regulators do not outlaw HFT – it is important for market participants to have an understanding of HFTs’ strategies and for regulators to keep afoot with the latest market innovations. The knock-on effects can hardly be overstated: efficient, transparent and fair markets are integral for the functioning of the developed world (HM Treasury, 2012).

Despite the economic belief advocated by Greenspan, Lucas and other Chicago-school economists: that markets are naturally self-regulating and efficient (Krugman; Cassidy, 2009; Mallaby, 2016), significant market failures have occurred partially as a consequence of AT and HFT. Notably, the 1987 Black Monday Crash and 2010 Flash Crash (figure 1.1a and 1.1b), both events undermined market confidence and cost almost $1 trillion (SEC, 2010).

Figure 1.1a: DIJA (June 19th 1987 – January 19th 1988) [adapted from Carlson (2006)]

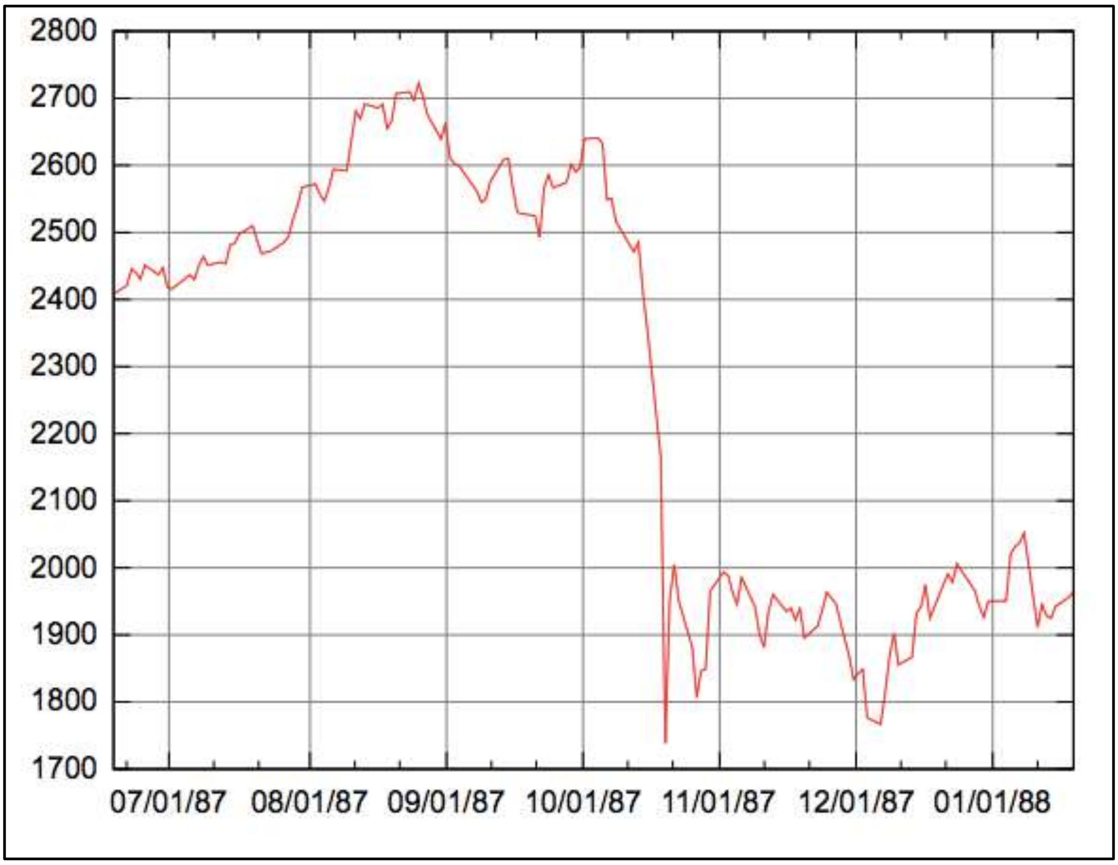
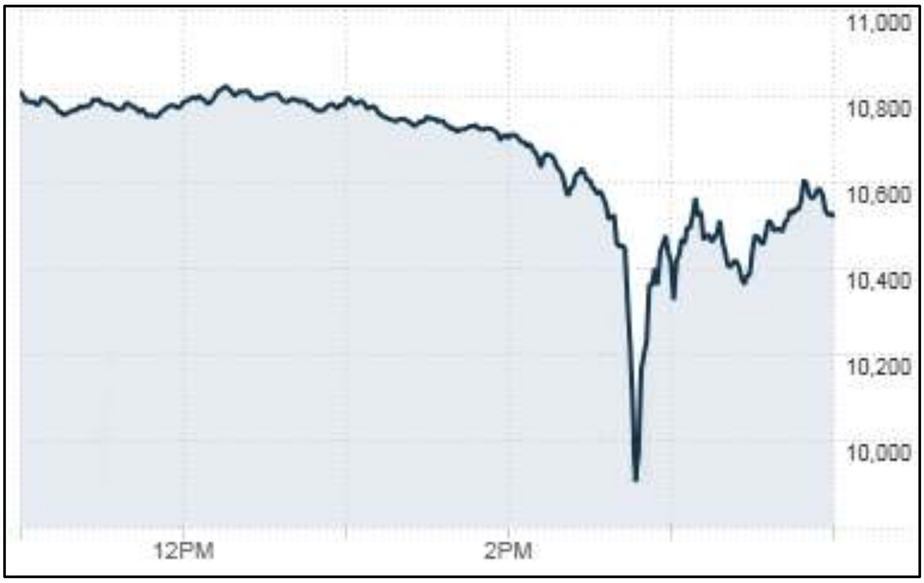


Figure 1.1b: DIJA (May 10th 2010) [adapted from SEC (2010)]



1.2 Aims

This paper seeks to achieve three goals. Firstly, (1) provide clarity on HFT – including a historical background of HFT, strategies, terminology, regulation and structural market changes. There is not yet a unified consensus on defining HFT and surprisingly little literature on this trading strategy.

Next, my paper is dedicated towards the more contentious second and third goals. The second goal (2) involves an initial discussion of Fama (1965, 1970) and Samuelson's (1965) efficient market hypothesis including essential random walk models. Followed by analysing HFTs' effect on market efficiency. Thus, I will contrast and debate relevant economic analysis on the effects of HFT within global markets. Including, considering the effects of HFT on market resilience in chapter 4.

Chapter 5 discusses my third goal (3) – a critical appraisal of the effectiveness of Directive (2014/65/EU) based on interview findings. Lastly, the overall conclusions of the paper and suggestions for future research are provided in chapter 6.

1.3 A race for low-latency

Although the first HFT-trade occurred in 1815, the term, literature and majority of sources contained in this essay are from post-financial crisis (2007-8) – with HFT's increasing prominence within global markets. Even despite the Black Monday Crisis (1987) serving as a premonition of the disastrous consequences arising from the misfire of algorithmic trading within markets (Carlson, 2006).

This paper implores more economists to publish material on HFT, especially with the troubling developments involving Robinhood Markets Inc. (Rooney, 2019). For this reason conclusions must be considered tentative to an extent. In time, if further flash crashes, scandals occur – more will be published on HFT, from which increasingly concrete conclusions can be drawn. Furthermore, this paper has used prominent financial authors. Nevertheless, I accept the limitations and hyperbole of these authors. Therefore the works cited are mainly from distinguished economists within the field of HFT.

Ultimately, this paper adds to the academic understanding of HFT including providing a critical evaluation of present regulation. This will provide two key benefits: (a) enable regulators to make informed future decisions and (b) close information gaps arising between institutional investor or customer, broker, and wholesaler.

Lastly, whilst attempts have been made to draw global conclusions as far as possible, there is a distinct focus on European and US markets within this paper. Academic sources in particular tend to appear US and EU-centric at times – this is in accordance with the home bias of academics within the field. Finally, Directive (2014/65/EU) is a EU regulation set in January 2018 and the most recent directive relevant to HFT globally.

2 Literature Review: Understanding HFT

2.1 Chapter introduction

Economists have approached HFT from many angles, yet there is still not clear consensus on its definition. However, a key commonality between all points of analysis is that technological innovation will always be an essential factor in the development of financial markets. Consequently, HFTs computerisation and automation of the trading process has significantly altered financial markets (Zhang & Riordan, 2011). In this chapter, I firstly discuss prominent definitions of HFT and its relation to Algorithmic Trading (AT) and secondly contextualise with a timeline of HFT. Before thirdly, discussing predatory strategies, the rise in HFT-related market abuses and dark pool fines.

2.2 Automated trading

2.2.1 Financial algorithms

Computer algorithms to support trade decisions has become commonplace in markets globally (Xhang, 2010). Hendershott and Riordan (2011) refine our understanding of AT by defining it as the use of computer algorithms to make trading decisions, submit orders and manage those orders after submission. Thus HFT is a distinct subcategory of AT (Carrion, 2013) – dependent on colocation strategies, latency, connection and processing speeds of computers using algorithm methodologies without human interaction (SEC, 2010).

Table 2.1a [adapted from Jones (2013) et al.]

Common characteristics of AT and HFT
1. Pre-designed trading decisions
2. Professional traders
3. Observing market data in real-time
4. Automated order submission
5. Automated order management
6. Without human intervention
7. Use of direct market access

2.2.2 AT versus HFT algorithms

Hasbrouck and Saar (2013) provide a key distinction between AT and HFT: the difference between agency algorithms and proprietary algorithms. Buy-side institutions and brokers typically use agency algorithms to minimise the cost of executing trades and implementing changes to their investment portfolios. On the other hand, proprietary algorithms encompass the subset employed by HFTs. Thus HFTs trade their own capital, turnover positions rapidly at very high speeds (2–3m/s) and rarely hold inventory overnight (Carrion, 2013).

Table 2.1b [adapted from Jones (2013) et al.]

Specific characteristics of HFT
1. High order volume
2. Rapid order cancellation
3. Proprietary trading
4. Profit from buying and selling
5. Flat position at end-of-trading-day
6. Short holding periods
7. Low margins per trade
8. Low-latency requirement
9. Use of co-location/proximity services and individual data feeds
10. Focus on high liquid instruments

2.2.3 Changes in market competition

HFT has resulted in competition between investors moving from the trading pits to the server rooms of exchanges and alternative trading venues where computers are co-located (Lewis, 2014). Broadly speaking, competitive edge is now in terms of speed, data and algorithmic sophistication (Zhang & Riordan, 2011). The boundaries of market competition have completely changed – with fast reaction times to market data, low-technical time delay (latency), close physical connection to exchanges (co-location) and technical innovation the key facets of competition (Gomber, 2013).

Former HFT system-engineer, Durbin (2010) stresses that HFTs software and data systems are self-built with a sophisticated yet efficient computer infrastructure. Thus HFT is a natural evolutionary process in the adoption of new technologies triggered by market innovation, competition and regulation (Gomber, Arndt, Lutat, & Uhle, 2011). Providing opportunity for greater profit, yet equally new operational risk exposures. In essence, HFT employs the latest technological advances in market access and order routing to maximise the return of established algorithmically driven trading strategies (Gomber et al., 2011).

2.2.4 *Market share*

In equity trading venues, there has been an eclectic range of results regarding the HFT market share[3]. Table 2.2 demonstrates the disparity of figures from multiple literature sources, however HFT conclusively represents between 50-70% of US and 30-50% of EU equity trading.

Table 2.2: HFT market share

Source(s)	US Equity Market	European Equity Market
AITE Group (2012)		45%
Brogaard (2010)	68%	
Carrion (2013)	68.30%	
Celent (2013)	42%	
Chi-X (2011)		40%
European Bank Federation		50%
F. Zhang (2010)	78%	
Jarrnecic & Snape (2010)	19%	
LSE		33%
Menkveld (2013a)	> 50%	
Riordan (2011)	> 60%	
Rosenblatt Securites (2012)		40%
Rothman (2009)	73%	
S. Zhang (2011)	> 60%	50%
SEC Flash Crash (2010)	36.6%-50.3%	
Swinburne (2010)	70%	
Tabb Group (2009)	61%	
Tradeworx (2010)	40%	

[3] Contingent on market-maturity.

Figure 2.1: HFT timeline [adapted from Smith (2010) et al.]

1960s: NASDAQ offers first computerised exhcange after repeated paperwork crises.

1970s: Computerised order-flow intrdouced under designated order turnaround system (DOT, 1976) and super-DOT (1984).

1980s: Demise of Cold War instigates brain-drain of engineers, computer scientists and mathematicians into finance. Electronic markets and program-trading becomes widespread. The 1987 crash blamed on program trading, in particular stock-index arbitrage.

1990s: Electronic communication networks (ECNs) under Reg. ATS proliferate order-execution by algorithms and the first HFT firms.

2000s: HFTs account for 10% of US equity trading. Decimalisation of exchanges (2001) and the stock tick size decrease from $0.01 to 1/16th of a dollar increases liquidity and AT. US Reg. NMS and EU Mifid (2005) fracture markets and HFTs increase.

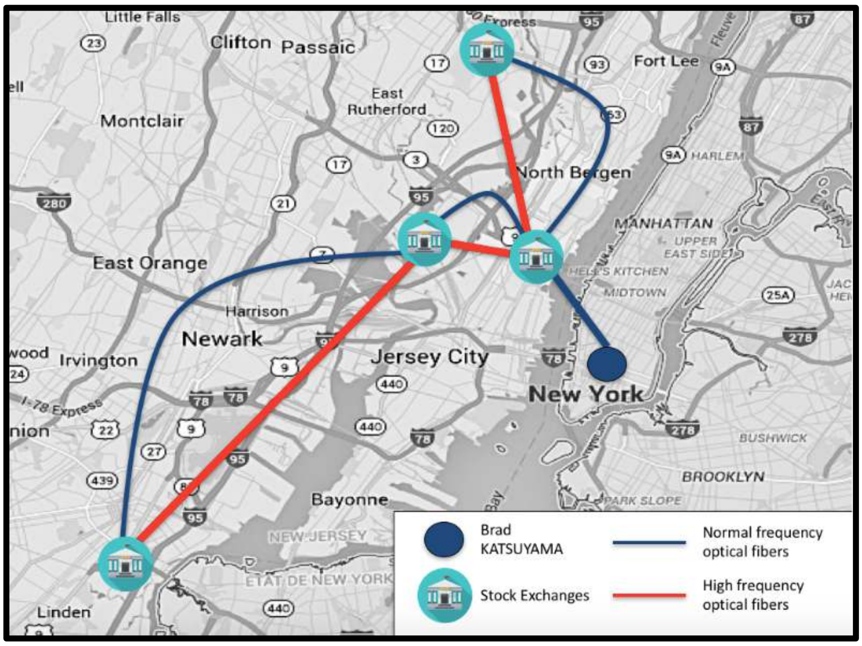
2010s: HFTs account for 70% of US equity trading. Dataminr compliles social media news into actionable trading signals - news reaches market 54 mins faster. Social media news in financial announcements is banned (2013). MIT review (2018) stipulates HFT will execute trades atthe speed of light harnessing neutrinos.

2.3 HFT trading strategies

2.3.1 Order strategy

Firstly, HFT's are proprietary traders – trading their own accounts utilising independent trading strategies (Xhang, 2010). Secondly, HFTs update orders very quickly – this rapid submission of cancellations and deletions generates small profits per trade. Consequently, Gomber et al. (2011) notes that HFTs trade at high volumes on liquid instruments.

Figure 2.2: Co-located HFTs including straight 'latent' optical fibres in NYC



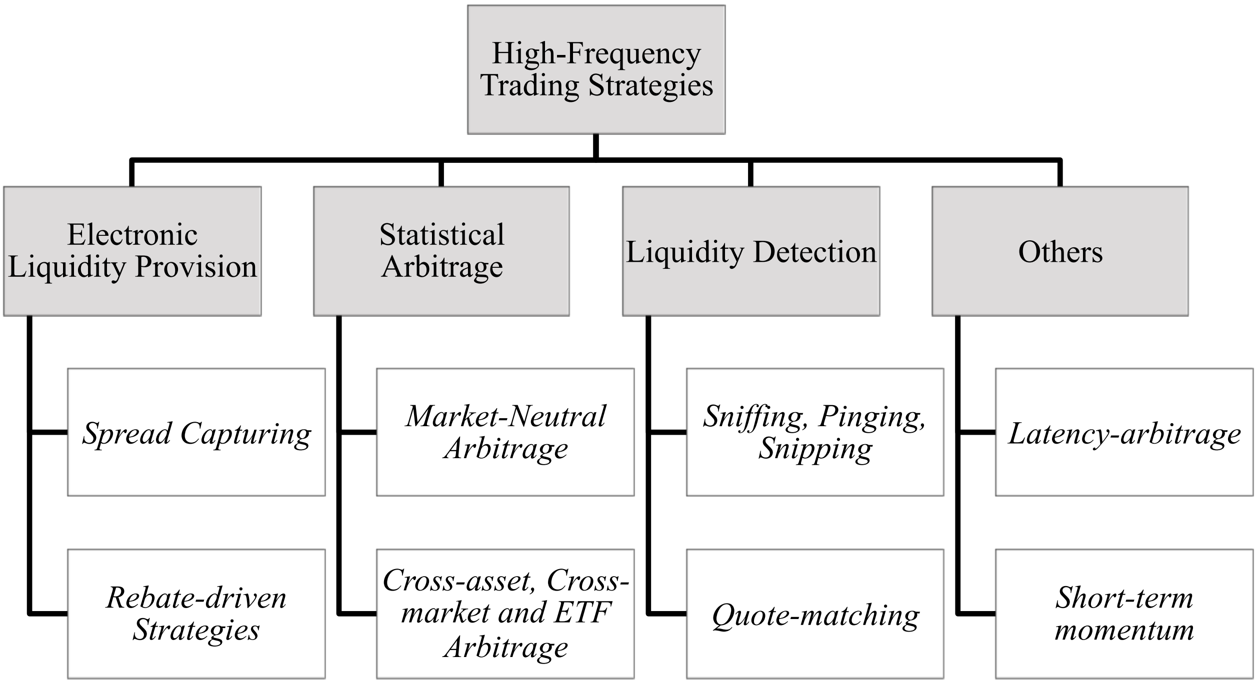
[adapted from Lewis (2014)]

2.3.2 Low-latency and co-location

Durbin (2010) argues that HFTs entire trading strategy is premised on faster speeds than market rivals. Equally, Hasbrouck and Saar (2013) considers low-latency the hallmark of HFT. The SEC (2010) defines low-latency as: trading-strategies responding to markets within a single-digit millisecond. Compared to slower human reaction times of 200m/s (Kosinski, 2010). Analysis from Jones (2013) found that inter-HFT competition is ruthless and winner-takes-all. Thus HFTs significantly investment in computer hardware, straight cables (see figure 2.2) and algorithms to minimise latency or the time it takes to receive signals from trading venues, make decisions and transmit order messages back to the venue (Durbin, 2010).

Menkveld (2013b) finds that HFTs had minimised trade signals to 3.81m/s between New York and Chicago through straight fibre optic cables. More recently, Menkveld et al. (2016) notes that HFTs have minimised exchange latency to nanoseconds via microwaves between NYC and CHI. Aside from technical proficiency, Jones (2013) specifies that this speed is also from co-locating computers as close as possible to the trading venue servers. For high fees, trading venues offer server space to HFTs – providing them with the fastest market access (Menkveld & Zoican, 2016).

Figure 2.3: HFT trading strategies graphical overview [adapted from Gomber (2011) et al.]



2.3.3 Spread capturing

Spread capturing refers to the HFT strategy of quoting a simultaneous buy and quote for a financial instrument in order to profit from the bid-ask spread. However, Jones (2013) importantly identifies that market-makers run the risk that they lose money to an informed counter-party. Gomber (2013) adds that this strategy could also be profitable to earn rebates or maker fees.

2.3.4 Rebate-driven strategies

Within certain markets (table 2.4), liquidity providers earn rebates referred to as 'maker-fees' (Riordan & Park, 2012) – incentivising HFTs to improve market quality via providing liquidity and earning maker-fee rebates. Many trading venues have even adopted asymmetric pricing to further incentivise liquidity provision (Lutat, 2010).

Consequently, HFTs adding liquidity: earn ‘rebates’, whilst members removing liquidity: are charged ‘taker-fees’ (Foucault, 2012).

Table 2.3: Make-Take pricing for 100 shares in cents per round lot [adapted from Traders’ Magazine (2011) and Foucault (2012)]

Trading Platform	Tape A – NYSE Stocks		Tape B – Other Stocks		Tape C – NASDAQ Stocks	
	Make Fee	*Take Fee*	*Make Fee*	*Take Fee*	*Make Fee*	*Take Fee*
NYSE Arca	-21	30	-22	30	-21	30
NDAQ	-20	30	-20	30	-20	30
NDAQ OMX BX	14	-18	14	-18	14	-18
NDAQ OMX PSX	-13	18	-13	18	-13	18
NYSE	-15	23	n/a	n/a	n/a	n/a
BATS BZX	-27	28	-27	28	-27	28
NYSE AMEX	n/a	n/a	-16	28	-30	27
BATS BYX	0	-3	0	-3	0	-3
EDGX	-26	30	-26	30	-26	30
Lava Flow	-24	28	-24	28	-24	28

2.3.5 Short-term momentum

Literature consensus defines short-term momentum as: HFTs leveraging their technology to perform classical trader strategies. For instance, HFTs could conduct short-term momentum relative value trading[4] at a low-latency e.g. upward move in the oil futures price enables HFTs to short airline stocks at a lower-latency and faster speed than slow-footed market rivals (Jones, 2013).

[4] Pioneered by hedge funds - relative value trading enables HFTs to profit when two closely related securities temporarily diverge.

2.3.6 *Market-neutral and cross-market arbitrage*

Arbitrage strategies are built upon price differentials between two financial instruments, which share a similar pay-off structure. Aldridge (2013) neatly subdivides HFTs' arbitrage strategies into – market neutral (e.g. pairs trading that uses current deviations from the historical price correlations of stock pairs), cross-market (e.g. simultaneous purchase and sell of the same financial instrument in different markets), and cross-asset strategies (e.g. purchase of an exchange traded fund and shortening the underlying stocks).

2.3.7 *Latency-arbitrage and directional trading*

Carrion (2013) cites an example regarding latency-arbitrage of market price e.g. if price does not behave uniformly and efficiently across multiple exchanges, HFTs' use their superior speed and processing to lock-in profits on price differentials between two securities. In contrast, directional trading infers that HFTs utilise algorithms to electronically parse news releases and directionally trade on the latest news before other market participants (Zhang & Riordan, 2011).

2.4 Predatory HFT strategies

2.4.1 *Liquidity detection*

HFT liquidity detection strategies entail concerns for institutional investors taking large market positions (Chistalla, 2011). HFTs try to discern the patterns of rival market participants and profit at their expense. Specifically, HFTs try to detect: sliced orders, hidden orders, patterned execution algorithms or information about rival-electronic limit order books (ASIC, 2010; 2011).

For instance, an HFT via pinging random orders often in lit and unlit trading venues (dark pools) – may identify a sequence of large buy orders[5] over several minutes (Durbin, 2010). With the knowledge that a large order is being made by a market rival – HFTs will drive up the price. Enabling the HFTs to profit on price rises or even sell purchased shares back to the institutional trader (Gomber, et al., 2011). Harris (2013) also identified a high-speed quote matching strategy in which HFTs hedge against a known large order within the order book – enabling HFTs to substantially limit losses.

[5] Known as an iceberg.

To thwart these HFT strategies, institutional traders have to cryptically disguise their trading intentions. Yet, it is important to note that – information leakage and tit-for-tat between market participants is not a new phenomenon. Even when pit trading was common practice, disguise often involved standing brokers at different trading posts on the NYSE floor to try and permeate confusion (Jones, 2013).

2.4.2 A level playing field?

HFTs' co-locating negatively affects market quality because it leads to asymmetric information and adverse selection across market participants. Menkveld and Zoican's (2016) systematic modelling found that co-location provides HFTs with large informational advantages over rival market participants. Perpetuating scenarios in which better-informed HFTs buy low and sell high: earning profits. Whilst less-informed traders buy high and sell low: generating losses – resulting in long-term losses in market liquidity.

However, Hasbrouck and Saar's (2013) research disputes this – concluding that it is hard to quantify the economic advantage of co-location. Indeed, Gaffen (2009) has only found that in the US, where markets rely on the 'national best bid and offer' (NBBO) do co-located arbitrageurs have ample opportunity to profit from their speed advantage. Yet, I would dispute this line of argument. Undeniably exchanges selling data-feeds at different latencies promulgates adverse selection and a tiered system of investors.

Boyan and Menkveld (2015) agree that co-location certainly creates adverse selection; yet their research has somewhat-reassuringly found that it is contingent on HFTs trading strategy. In scenarios where HFTs passively trade (chapter 2.3) – the effects of adverse selection are negligible. In contrast, when HFTs aggressively trade (chapter 2.4) – adverse selection is maximised for non-colocated participants.

2.4.3 Banned strategies

Exchanges previously offered flash orders, which allowed HFTs or 'flash traders' to view orders of other market participants – fractions of a second before the information was widely available to others in the marketplace. This provided flash traders with the advantage of being able to recognise movements in market sentiment before other traders (Gomber et al., 2011, p.42).

Order stuffing and spoofing involves HFTs submitting a high volume of orders, most of which are cancelled prior to execution – thus exchanges become congested and slower traders' information unreliable (Prewitt, 2012). HFTs then trade against the misinformed orders. For instance, Michael Corsica of Panther Trading LLC was fined $4.5million for using HFT to spoof commodity markets (CFTC, 2013).

2.5 Key regulation and structural market changes

2.5.1 Reg. NMS (2005)

Initially, Reg. ATS (1998) authorised alternative-trading venues – due to a broad dissatisfaction with the NYSE and NASDAQ duopoly (Smith R., 2010). Yet, Reg. NMS furthered this change by driving firms to innovate and divert volume from the incumbent NYSE and NASDAQ exchanges. Crucially, Mcgowan (2010) adds that this body of regulation decreed that markets immediately execute at the NBBO – establishing more HFT firms (e.g. GETCO).

Granular analysis finds that Reg. NMS' trade through rule (rule 611), access rule (rule 610), sub-penny (rule 612) and market data rules were the key drivers of equity market fragmentation, setting the stage for the current electronic trading revolution (Bell & Searles, 2014). As Smith (2010) concludes, Reg. NMS facilitated the rise in orders being removed entirely off exchanges onto MTFs and directed through proprietary trading networks (PTNs) or unlit exchanges called 'dark pools' – enabling 'safer' environments[6] for large-block trade orders.

2.5.2 MiFID (2004)

With regards to the EU, MiFID sought to replicate equity market fragmentation much like the US' Reg. NMS. Therefore the EU equity market landscape has equally changed with: competition, MTFs, PTNs and dark pools all increasing. However, an essential difference between MiFID and Reg. NMS is the European principles-based execution regime versus the US rules-based approach (Bell & Searles, 2014). In addition, MiFID does not enforce an NBBO, rather MiFID requires investment firms to "take all reasonable steps to obtain when executing orders, the best possible result for clients taking into account price, costs speed… or any other consideration relevant to the order" (European Comission, 2004).

[6] SEC-FCA has found this not to always be the case.

2.5.3 MiFID II (2018)

MiFID II accepts deficiencies in MiFID I most notably – investor protection and shortcomings with market transparency. Busch (2017) argues that MiFID II strengthens regulations via: expanding the term ‘investment firm’, tightening dealings with clients, improving execution, reducing conflicts of interest, reporting OTC-derivatives and installing further obligations for recording electronic communications. These strict regulations improve information flows, market integrity and transparency – ensuring more investor and client protection (ESMA, 2018).

MiFID II, much like the German HFT Act (BaFin, 2013), ensures requirements for HFTs internal systems and controls – they must be: (a) resilient (b) sufficient capacity (c) subject to appropriate thresholds (d) prevent sending out erroneous orders (e) function in a way that does not contribute to a disorderly market (Busch, 2016). Furthermore, HFTs face requirements for stress testing, staff training on market abuses and monitoring of IT outsourcing. These changes contribute to the overall aim of improving securities market quality (Yeoh, 2019).

2.6 Internalisation and dark pool trading

2.6.1 Lit versus dark trading venues

A dark pool of liquidity is a crossing network, which provides liquidity that is not displayed on order books. Dark pools are useful for traders moving large volumes of shares anonymously, without revealing themselves to the open market. In contrast, HFTs typically face adverse selection costs as they are providing liquidity on lit-markets without knowing their counterparts (Gomber, et al., 2011). Whilst, in dark pools brokers know the identity of their counterparts and are able to “cream skin” of uninformed order flow and evade lit-market HFTs.

Despite this, Tuttle (2013) has found that most participants use algorithms to execute dark trades. Therefore, post-Reg NMS and MiFID, dark pools prevalence and opaqueness have troubled lawmakers (Foley & Putnins, 2015). Indeed, Putnins and Comerton-Forde (2015) add to these concerns by finding that dark pools typically match orders without providing any pre-trade transparency. Subsequently, SEC-FCA investigations have found numerous abusive market practices occurring within opaque dark pools – regularly involving HFTs ‘sharking’ and detecting the liquidity of rival slow investors anonymously (figure 2.4).

Figure 2.4: Notable market abuses and fines - since January 2016 for HFT/dark pools[7] /spoofing [adapted from SEC-FCA statements]

Credit Suisse and Barclays pay $150million over dark pool charges - the largest penalty ever imposed by the SEC (February 2016)

↓

Deutsche Bank pays $37million fine for dark pool routing (December 2016)

↓

Citi fined $25million for spoofing US treasury futures (January 2017)

↓

Ex-Citi traders fined $550k for spoofing US treasury future markets (March 2017)

↓

Japanese bank fined for spoofing treasury and Eurodollar futures (August 2017)

↓

Interactive Brokers fined $4.5million for algo-trading system failures (February 2018)

↓

Citi accused of spoofing as Japanese regulator pursues $1.2million fine (March 2019)

↓

Citi fined $500,000 for dark pool system failures (July 2018)

↓

Citi fined $12million for misleading investors about HFTs in its dark pool (September 2018)

↓

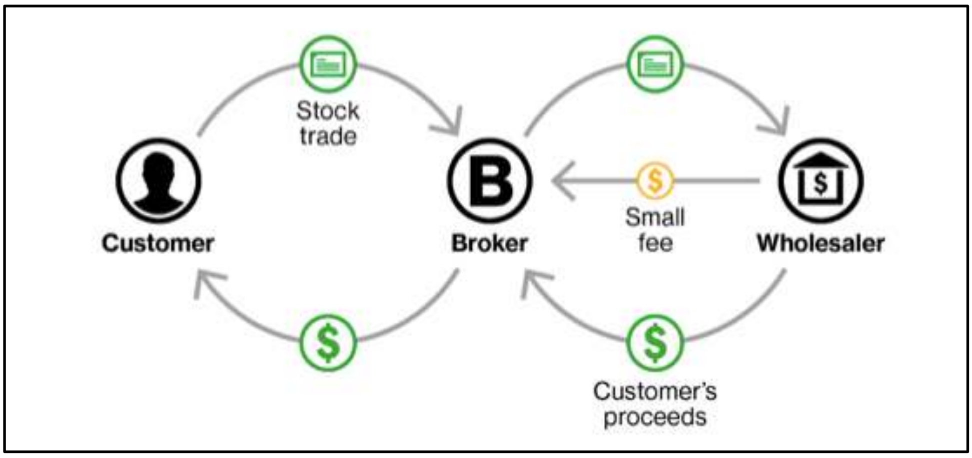
ITG agrees to $12million dark pool settlement (November 2018)

[7] Not all fines are included such as blue sheet data fines for failed reporting and some settlements remain undisclosed.

2.6.2 Payment for order flow

Tabb Group research (2017) found that: wholesalers 'best execute'[8] 20% of trades in the US stock market (figure 2.6a). Regulators have rightly questioned whether this represents a conflict of interest, especially with front-running HFT strategies (Massa, 2017).

Figure 2.5: Payment for order flow [adapted from Foxman et al. (2018)]



Order: (1) Customer order to broker (2) Broker to wholesaler
(3) Wholesaler 'best execution' for customer

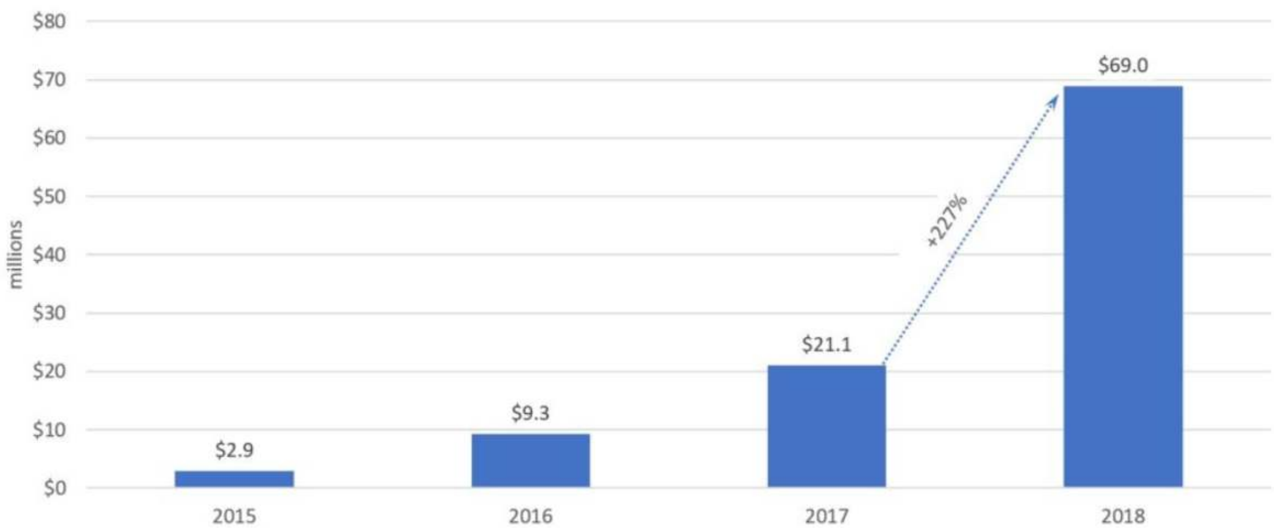
Consequently, in October 2018, it was revealed that more than 40% of Robinhood Markets Inc. revenue (figure 2.6b) came from selling its customer orders to HFT firms or high-speed market makers (Foxman, Verhage, & Woolley, 2018). Subsequently HFTs via PFOF would front-run Robinhood's slow-footed retail traders – earning small amounts off their transactions. These HFTs were clearly taking advantage of information asymmetries between customer and wholesaler. Regulators have tried to rectify this malpractice via fines[9] and open letters (SEC, 2017; FCA, 2017).

[8] This vague term could mean: fastest, lowest price or best completed.
[9] For example, Citadel Securities has been fined $22.6 million by the SEC for order internalisation.

Figure 2.6a: US equity markets, order routing revenue

[both adapted from Alphacution (2019)]

Figure 2.6b: Robinhood markets financial revenue



2.7 Chapter conclusions

This chapter has taxonomised the literature – offering a consensual and wholesome understanding of HFT strategies, historical context, structural market changes and regulation. In addition, I have introduced HFT concerns with market abuse and transparency including: predatory strategies, dark pools and PFOF. The next chapter focuses on HFT and market efficiency.

3 HFT and market efficiency

3.1 Chapter introduction

Efficient market hypothesis (EMH) can be traced back to French broker Regnault (1863) and mathematician Bachelier (1900). Equally, Taussig (1921) observed that markets do not follow the laws of supply and demand, but are subject to manipulation from unknown information. Yet, EMH is most strongly associated with two economists' proposals from 1960-70, Fama and Samuelson.

This chapter will present essential facets of EMH theory, before acclimatising the theory within the context of HFT. Notably, little economic literature has sought to acclimatise EMH within modern AT/HFT-driven markets. However, my research reaches two conclusions: (1) HFT discredits specific premises of EMH and (2) HFT has significantly improved US-EU market efficiency post-2009.

3.2 Fama's EMH

3.2.1 Defining efficient markets

Fama's (1970, p.383) key definition of an efficient market is, "a market in which prices at any time 'fully reflect' available information is called efficient". Without being overly critical, Fama's use of 'fully reflect' appears to be deliberately vague. Regardless, Fama deduced three models for testing his hypothesis:

3.2.2 Expected return or 'fair game' models

Fama (1970) described all members of the class of "expected return theories" notionally as:

$$(1) \qquad \mathrm{E}\left(\tilde{p}_{\mathrm{j,t+1}} \middle| \Phi_{\mathrm{t}}\right) = [1 + \left(\tilde{r}_{\mathrm{j,t+1}} \middle| \Phi_{\mathrm{t}}\right)\mathrm{p}_{\mathrm{jt}}$$ [10]

Fama makes expected value a measure of a distribution of returns. He concludes that, within his parameters, it is unfeasible for trading-system-returns to exceed equilibrium based on information in Φ_t:

[10] E is expected value operator; $p_{j,t+1}$ is its price at t+1; $r_{j,t+1}$ is the one-period percentage return; Φ_t is general symbol for 'fully reflected' in the price at t.

$$(2) \qquad x_{j,t+1} = p_{j,t+1} - E(p_{j,t+1}|\Phi_t).$$

$$(3) \qquad \text{Then, } E(\tilde{x}_{j,t+1}|\Phi_t) = 0$$

$$(4) \qquad z_{j,t+1} = x_{j,t+1} - E(\tilde{r}_{j,t+1}|\Phi_t).$$

$$(5) \qquad \text{Then, } E(\tilde{z}_{j,t+1}|\Phi_t) = 0$$

Consequently the expectation is,

$$E(\tilde{V}_{j,t+1}|\Phi_t) \sum_{j=1}^{n} \alpha_j (\Phi_t) E(\tilde{z}_{j,t+1}|\Phi_t) = 0.$$

3.2.3 The submartingale model

$$(6) \qquad E(\tilde{p}_{j,t+1}|\Phi_t) \geq p_{jt}$$

Or equivalently,

$$E(\tilde{r}_{j,t+1}|\Phi_t) \geq 0.$$

Fama (1970, p.386) expects (6) to hold as equality and the price sequence to follow a martingale. Ensuring that expected returns conditional on Φ_t are non-negative – meaning that profits cannot exceed buy-and-hold strategies during the periods in question.

3.2.4 The random walk model

Fama (1970, p.387) added two variables to the model which suggests, that successive price variables are independent and identically distributed:

$$(7) \qquad f(r_{j,t+1}|\Phi_t) = f(r_{j,t+1})$$

$$(8) \qquad E(\tilde{r}_{j,t+1}|\Phi_t) = E(\tilde{r}_{j,t+1}).$$

Fama concludes that past or present information cannot be used to predict the market. Thus professional speculators cannot 'beat' the market. Or in, Bachelier's (1900, p.91) terminology, capital markets are efficient if they behave as "fair games" and "the mathematical expectation of the spectacular is zero".

3.2.5 Market conditions consistent with efficiency

Fama (1965, 1970, p. 387) emphasised three fundamentals which are *sufficient* yet not *necessary* for strong EMH:

i) No transaction costs trading securities.

ii) Information costlessly available to all market participants.

iii) All market participants agree on the implications of current information for the current price and future prices of each security.

Thus if these three conditions are satisfied – the current price of a security 'fully reflects' all available information.

3.3 Samuelson's EMH

3.3.1 Samuelson's premises

Initially, Samuelson (1965, p.42) argued it is fundamentally implausible to foresee "an unforeseeable future" – he supports this claim by referring to Kendall's (1953) inability to spot serial correlation in grain prices – Samuelson concludes that it is even a good example of a random walk model.

3.3.2 The basic theorem

Samuelson (1965, p.44) asserts basic premises via equations: 1-6. From these he devises a basic theorem to prove that futures prices will turn out on average to have null upward or downward drift:

$$(7) \qquad \mathrm{E}[\mathrm{Y}(\mathrm{T}-1, \mathrm{t}+\mathrm{T}-1)[\mathrm{X}_{\mathrm{t}}, \mathrm{X}_{\mathrm{t}-1} \ldots] = \mathrm{Y}(\mathrm{T,t}),$$

$$(8) \qquad \text{Or writing, } \mathrm{Y}(\mathrm{T}-1, \mathrm{t}+\mathrm{T}-1) - \mathrm{Y}(\mathrm{T}, \mathrm{t}) = \Delta\mathrm{Y}(\mathrm{T}, \mathrm{t}),$$

$$\mathrm{E}[\Delta\mathrm{Y}(\mathrm{T}, \mathrm{t})] = 0;$$

$$(9) \qquad \mathrm{E}(\Delta^{\mathrm{n}}\mathrm{Y}(\mathrm{T}, \mathrm{t})] = 0, \ (\mathrm{n} = 1, 2, \ldots \mathrm{T}).$$

Therefore, it is not possible to make an expected profit by extrapolating past changes in the futures prices. Indeed, the market quotation '$\mathrm{Y(T,t)}$' already contains all knowable future information, discounting human contingencies. Samuelson's (1965, p.45) principal merit is to prove that the fair game result does not depend on "posited probability distribution for futures prices" as private information becomes reflected in markets well before news – thus stock prices fluctuate randomly and unpredictably.

3.4 Critique and contextualisation of EMH and HFT

3.4.1 Misinterpretations of EMH

Since its inception, Samuelson (1965) and Fama's (1965, 1970) EMH has received much criticism, especially during the 2007-8 GFC (Ball, 2009). This paper does not focus on EMH criticism. However, it is important to establish that there has been both criticism and misinterpretation of EMH. Behavioural economist, Thaler (2009) attributed this misinterpretation to confirmation bias, "some economists took the fact that prices were unpredictable [under EMH] to infer that prices were in fact 'right'. However as early as 1984, Shiller labelled this 'one of the most remarkable errors in the history of economic thought'". Indeed, market prices do not always behave rationally (Shiller & Ackerlof, 2000). Subsequently, Samuelson and Nordhaus (2009, p.171) redefined efficiency as not full-output but that "information is rapidly incorporated" to prevent further misinterpretation.

3.4.2 HFT disputing EMH

Aside from Virgilio (2015) and Bell (2013), few economists have analysed both HFT and EMH together. Although I appreciate that it is implausible to expect Fama and Samuelson to foresee the development of HFT almost sixty years ago. My analysis using their original variables suggests HFT currently: (a) disputes aspects of the theorem yet has (b) significantly improved US-EU equity market efficiency via more market liquidity and better price discovery.

Firstly, HFT does not satisfy Fama's EMH fundamental of costless information readily available to all market participants. Rather, HFT has resulted in the opposite – adverse selection costs. Indeed, market participants face high costs of entry because HFTs enforce latency 'arms races' within markets (Biais, Foucault, & Moinas, 2012) – engendering unnatural exclusivity and a two-tiered market.

Secondly, HFT falsifies Fama and Samuelson's claim that it is unfeasible to 'better' the market and predict future price changes – earning profits, which exceed buy-and-hold strategies[11]. Analysis of HFT's sizeable profits post-GFC nullifies this claim. Indeed, utilising Brogaard et al.'s (2013a) study (appendix for relevant tables), HFT revenues (net of fees) equates to:

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[11] Fractured markets enable HFTs to profitably predict price changes via low-latency arbitrage.

$$\text{Large: \$6,651.03 + Medium: \$173.11 + Small: \$29.86} = \text{\$6,854.66 per stock}$$

$$\$6{,}854.66 \times 40 \text{ stocks in each size category} = \$274{,}186.40 \approx \$275{,}000 \text{ per trading day}$$

$$\text{Sample: 4\% of stocks traded}$$

$$\text{Thus, } \$275{,}000 \times 25 = \$6.875\text{million daily NASDAQ revenues for HFTs}$$

If HFTs' revenues per-dollar traded are similar for off NASDAQ trading – adjusting for NASDAQ's market share implies HFTs' daily revenues are approximately $20 million. Multiplying this by 250 trading days yields $5 billion per year. Dividing across the 26 HFTs in Brogaard' et al. (2013a) sample – revenues are $200 million per firm, if the firms are equal size.

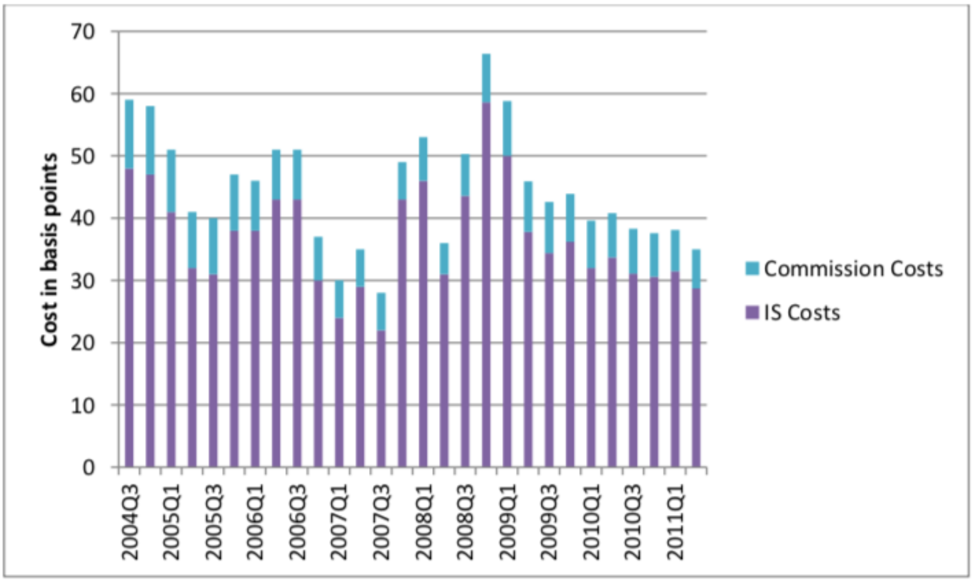
Importantly, HFT profits have partially declined since 2017 as more rival participants mimic HFT speeds (Meyer, Bullock, & Rennison, 2018). Consequently, markets are behaving efficiently and slowly managing the proliferation of HFT[12] (Bell, 2013). Furthermore, HFT satisfies Fama's two other conditions for market efficiency – HFT has significantly lowered transaction costs, bid-ask spreads and pioneered profitable trading strategies reliant on information freely available from social media (chapter 2).

3.4.3 HFT and liquidity

For ten years, HFT has increased sharply concurrently US-EU equity liquidity has also improved. But correlation is not necessarily causation. Yet, a theme throughout this paper has been that a key benefit of HFT is its provision of market liquidity. Jones (2013) argued that the main positive of HFT is that it can intermediate trades at lower costs – thus making markets more efficient according to Fama's fundamentals. This perspective is supported by data from the Financial Information Forum - the average cost of trading one share of stock has plummeted from $0.076 (2000) to $0.038 (2012) (figure 3.1). Moreover, HFT trading strategies of market-making and searching for rebates are highly liquid instruments[13] (chapter 2.3).

[12] Thus, HFT does not falsify EMH as Virgilio (2015) has argued.
[13] Although I accept that liquidity has also been helped by other non-HFT factors, notably: the deregulation of commissions (1970s), automation of stock exchanges, Reg. NMS and others.

Figure 3.1: Trading costs in basis points [adapted from ITG research reports]



Consensus considers HFT primarily responsible for improvements in market liquidity. Indeed, it is hard to find contrarian evidence. Yet, an argument proposed by Foucault, Hombert, and Rosu's (2012) model is that HFT imposes adverse selection on market-makers due to superior speed. Thus potentially preventing liquidity from institutional investors. In addition, in flash crashes, HFTs liquidity is partially illusory as it offers lower order depth and can be abruptly removed (Hendershott, Jones, & Menkveld, 2011).

Despite these models and specific cases, I find that HFTs do improve market liquidity and efficiency[14] – especially in stable market conditions. Boehmer, Fong and Wu (2012) found that the introduction of co-location and HFT firms improves exchange liquidity – corroborating this perspective, Hendershott and Riordan's (2011) data noted that HFT firms add liquidity when bid-ask spreads widen. Brogaard (2013b) in particular offers the most systematic analysis of HFT firms' positive provision of liquidity, particularly on small-cap stocks.

3.4.4 HFT and price discovery

There is limited direct criticism of HFT harming price discovery (Foucault, 2012). However, Xhang (2010) argued that HFT is positively correlated with price volatility thus hindering markets in reflecting fundamental information. Yet, Jones (2013) criticised

[14] According to Fama (1965, 1970) and Samuelson's (1965) methodology.

Xhang's definition of HFT for being too broad and economic consensus opposes Xhang's perspective. Instead, economic analysis purports that HFT has greatly improved: market efficiency, price discovery and proliferation of market-wide information. This is inherently logical as HFT ensures prices behave efficiently by providing information more quickly and arbitraging cross-market.

The very premise of HFT is based upon rational profit-maximising competitors utilising the latest information to transact on the correct market value of individual securities (Bell, 2013). Certainly when Fama and Samuelson stipulated EMH – trading was a far slower strategy. In contrast, HFT provides markets with a high-velocity of information. Indeed, most HFTs trades' correlate with public information, such as macro-news announcements, market-wide price movements and limit order book imbalances (Brogaard, 2010).

Other empirical research conducted in the US-EU corroborates that HFT significantly improves price discovery and market efficiency. Utilising Hasbrouck and Saar's (2010) methodology, Brogaard (2010) undertook a systematic survey of 26 HFT firms within the US equities market (68.5% of the dollar-volume traded) and found that they 'substantially' improved the price discovery process. Strengthening Brogaard's conclusions – he conducted the same survey during the SEC Short Sale Ban of 799 stocks (September 2008), providing a data set without HFTs trading. In this period, without HFTs, they found a sizable decrease in price discovery within US equities (Brogaard, Hendershott, & Riordan, 2013b).

Proponents of Brogaard's analysis, Hendershott et al. (2011) used the same methodology to determine EU HFTs' affect on the price discovery of 30 DAX stocks in the Deutsche Boerse (January 2008). They systematically found HFTs – placed more efficient quotes and demanded liquidity to move the prices towards the efficient price. These conclusions have been further supported by Jones et al.'s (2011) secondary studies on behalf of the ECB. Also international analysis conducted by Boehmer, Fong and Wu (2012) found that exchanges offering co-location for HFTs from 2001-9 had significantly better price discovery.

3.5 Chapter conclusions

This chapter has defined EMH and limitations with the theory. My research finds that HFT has had a positive effect on market efficiency and liquidity via reduced transaction costs and better price discovery from faster information. However HFT also nullifies some of Fama (1965, 1970) and Samuleson's (1965) premises – HFT currently proliferates a two-tiered market because of high costs of entry and offers a lucrative and low-risk strategy, which is better than buy-and-hold stock market strategies. Moreover, in the ensuing chapter 4, I discuss whether HFT ensures that markets are: resilient and stable.

4 HFT and market resilience

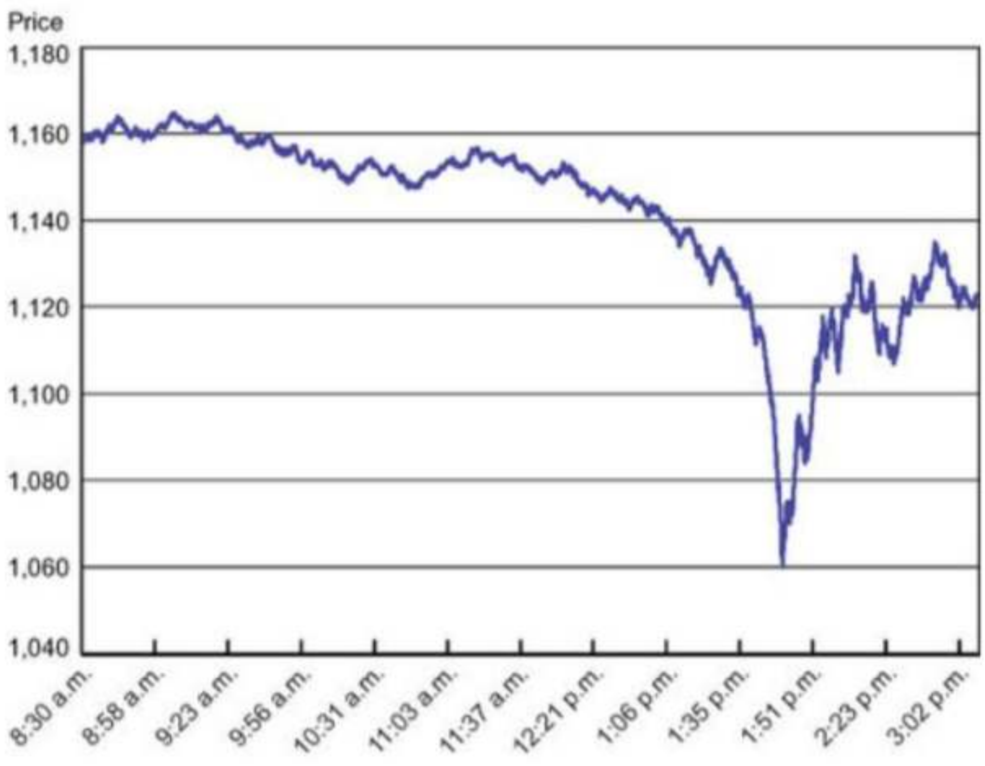
In line with HFT-research, this paper analyses the effects of HFT on markets using data and case studies. Having already viewed insights into HFTs' effect on market efficiency and price discovery; I shall now present empirical insights on the effects of HFT in chapters: 4.1 Flash Crash; 4.2 Volatility. These metrics will provide a good understanding of the effects of HFT on market resilience.

4.1 Flash Crash

4.1.1 Context from SEC-CFTC investigations (2010)

On May 6th 2010, US stock markets experienced what has become termed as a 'flash crash'. Stocks initially fell due to Eurozone macroeconomic concerns, and by 2:30 PM ET – the DIJA was down 2.5%. Suddenly, stocks began to fall far more rapidly. During a 13-minute window from 2:32PM to 2:45:27PM, the E-mini S&P 500 futures fell 5.1%. In the next second, a flurry of sell orders caused the futures price to drop by an additional 1.3%. Subsequently, the CME imposed a 5-second trading halt. The rest of the trading-day was characterised by extreme price movements and drops in liquidity – with a total of 20,761 trades at the most extreme prices cancelled.

Figure 4.1: E-Mini S&P 500 futures prices during the Flash Crash



[adapted from Thomson Reuters (2010)]

4.1.2 Is HFT to blame?

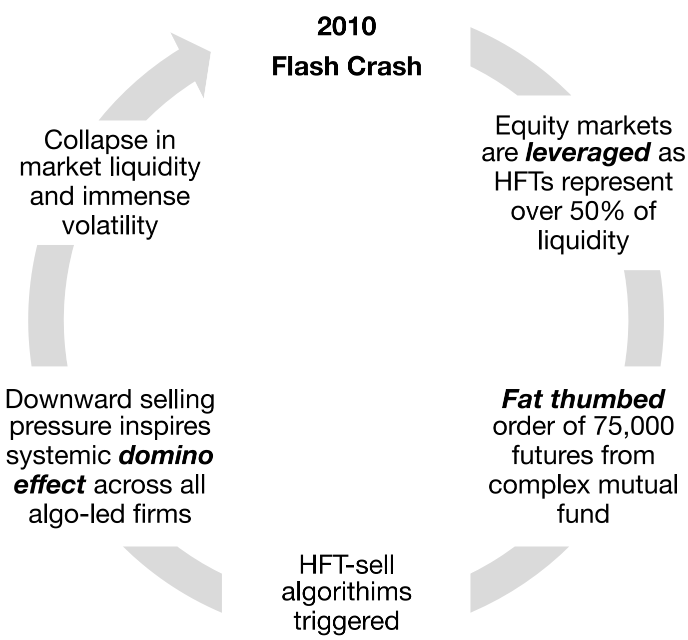
Domowitz (2010) noted that a similar flash crash occurred in 1962. In addition, I would add the crash of 1987. Significantly, these two occurrences were before the advent of HFT. Yet, with respect to the Flash Crash, British-trader Navinder Singh Sarao was arrested for layering or spoofing via his automated trading platform (Coombs, 2016). Although Sarao is guilty of market abuse, I strongly support Aldrich et al. (2016) in concluding that: (a) one individual could not cause an event of such magnitude and (b) his activities were merely correlational and not the fundamental cause – rather HFT exacerbated the slump.

Consequently, the CFTC-SEC investigation (2010) considered the proximate cause of the flash crash a 2:32PM ET order from a complex mutual fund to sell a total of 75,000 e-mini S&P 500 Futures. Yet, HFTs were culpable for the subsequent sudden and volatile drop in supplied liquidity (Kirilenko, Kyle, Tuzun, & Samadi, 2011). Indeed, HFTs can retract liquidity from the market very quickly – due to their algorithm-driven low-latency trading infrastructures.

In this respect, although HFT did not trigger the Flash Crash, HFTs downward selling pressure exacerbated the crash and worsened market volatility. Adapting analysis from Shiller (2000; 2008) on negative feedback cycles during market failures[15] I strongly agree with Kirlenko et al.'s position (2011). Certainly, HFTs algorithmically-driven speed of response to downward selling pressure perpetuated incredibly aggressive negative feedback cycles (figure 4.2), which rippled throughout the market (Menkveld & Yueshen, 2016). This is supported by Jarrow and Protter's (2011) analysis into HFT herding behaviour.

[15] Most notably occurred during the 2007-8 GFC in particular during: subprime crisis and bank-runs.

Figure 4.2: HFT negative liquidity feedback loop in Flash Crash



[adapted from Shiller (2000; 2008)]

HFTs made up half of market liquidity (SEC, 2010) – thus their algorithmically-driven rapid shorting, in response to a fat thumb, rippled throughout the macroeconomy. Perpetuating a domino effect in which investors sold and extricated themselves from the market. Indeed, it is clear that financial markets were overly ‘leveraged’ on HFT-liquidity. Easley et al. (2011) support this analysis: they find order imbalances were especially severe in the minutes prior to the flash crash, supporting the conclusion that HFT overwhelmed the market with downward selling pressure. In addition, due to the cross-market and cross-asset nature of HFT-strategies (chapter 2.3), Haldane (2011) adds that HFTs rapidly propagated price dislocations on many different stocks, trading platforms and exchanges – producing a systemic crash.

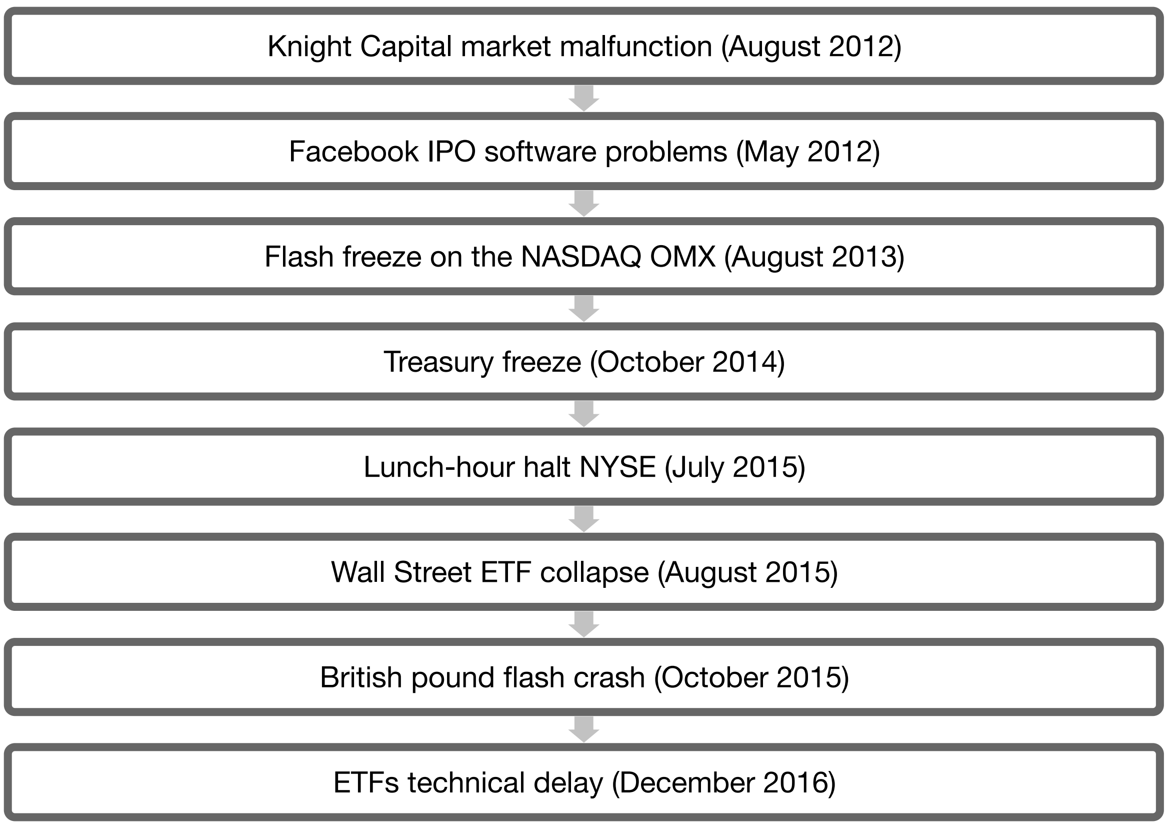
However, Bell (2013) and Brogaard et al. (2015) have argued against HFT-culpability for the Flash Crash – instead they find that market structure (including ETFs and market fragmentation), regulatory changes and the failure of large market-makers to stabilise market conditions as the primary cause for the 2010 Flash Crash. Although I agree that market-fragmentation and lack of circuit breakers are fair counter-arguments for market volatility; large market-makers could not easily stabilise market conditions with the decline in proprietary trading post-GFC, therefore Bell (2013) and Brogaard et al.’s (2015) conclusions underplay the role of HFT in the Flash Crash. Instead Gao and Mizrach

(2016) reached the correct conclusion: that during stressful market conditions HFTs tend to be harmful and volatile.

4.1.3 Regulatory Response

Sornette and Von der Becke (2011) stipulated that HFT would cause further future market breakdowns. Pro-HFT critics deemed this perspective as scaremongering. Especially with the SEC and FCA introduction of: (a) single stock circuit breakers to halt transaction prices with moves of more than 10% in 5-minute windows, (b) a ban on stub quotes and (c) new regulation (SEC, 2011; FCA, 2017). Yet, financial markets have continued to be susceptible to breakdowns and glitches:

Figure 4.3: Notable market glitches post-Flash Crash [adapted from Reklatis (2018)]



In these cases HFT was not always the proximate cause, yet the prevalence of glitches suggest markets are far more susceptible to market failure from software malfunction. Consequently, this paper aligns with Gao and Mizrach (2016) in concluding that empirical evidence suggests that: reckless HFTs or computer-led innovations and automations – have the capacity to undermine market resilience by worsening volatile conditions.

4.2 Volatility

4.2.1 HFT and volatility

The Flash Crash has led to an intensification of concerns for HFT and market volatility. Yet a consistent problem with my research has been economists' divergent definition of HFT volatility. This has led me to taxonomise into two distinct forms of HFT volatility. Firstly, (1) 'stressed volatility' is volatility in periods of market turbulence. Secondly, (2) 'normal volatility' is HFT-induced volatility in normal market conditions.

4.2.2 Stressed volatility

In tumultuous market conditions – there is concrete evidence that HFT adds further market volatility. Indeed, SEC-CFTC (2010) Flash Crash conclusions suggested that HFT firms performed 'hot potato' transactions by repeatedly selling at low prices promulgating abnormal declines in the E-Mini index. In addition, arbitraging HFTs aggressively sold S&P 500 stocks reinforcing the illusion of a market crash – scaring buyers from the market.

Intriguingly Brogaard et al. (2015) contend SEC-CFTC research and conclude that HFTs stabilise markets as they trade against extreme price movements, supplying liquidity to non-HFTs. Yet, I find problems with their findings – Brogaard et al. (2015) avoid explaining the 2010 Flash Crash. Consequently, Brogaard et al.'s sample is cherry-picked and fails to include sufficient samples of HFTs rapidly removing liquidity. Therefore, I would conclude that Brogaard et al.'s analysis underplays HFTs perpetuation of negative feedback cycles, which I emphasised in chapter 4.2.2. In further retaliation to Brogaard's findings, research conducted by Golub, Keane, Poon (2013) – collectively found that mini-stock market crashes have increased tenfold post-GFC and they directly attribute this correlation to the rise of HFT.

4.2.3 Normal volatility

Easely et al. (2011) empirically found that stocks traded frequently by HFTs are causally linked to greater volatility. Similarly, Xhang (2010) argued that HFT is correlated with stock price volatility – preventing market prices from reflecting fundamental information. Consistent with these findings, research by Haldane for the BoE (2011) has found that higher cross-stock correlation (as a proxy for HFT-activity) is strongly correlated with increased volatility.

Nevertheless, Brogaard's (2015) research refutes these perspectives arguing that HFT dampens normal market volatility – this is supported by Hendershott and Riordan (2011). Moreover, a far-reaching study by Chaboud, Hjarmalsson et al. (2009) in the foreign exchange market found very little correlation between HFT and volatility. Gsell's model (2008) supports this and stipulates that low-latency of algorithmic traders reduced normal market volatility. This position is corroborated by Bell (2013) in finding that market volatility from the 2010 Flash Crash could be partially attributed to post-GFC (2007-8) turmoil.

Although, I cannot help but think Bell's (2013) conclusions are exaggerated – I appreciate investor uncertainty post-GFC would be high, thereby potentially leading to a prevalence of investor overreactions and overcorrections inspiring volatility. Ultimately, there is not conclusive evidence that HFTs cause or prevent normal volatility and thus further empirical study is needed.

4.3 Chapter conclusions

To conclude I find that HFTs induce market-wide 'stressed volatility'; yet there is not conclusive research on HFTs perpetuating everyday 'normal volatility' (Prewitt, 2012). With regards to the Flash Crash, HFTs: perpetuated negative feedback loops, herded and leveraged liquidity. Thus, vigilant regulation is required to prevent further market-breakdowns. Consequently, chapter 5 focuses on the latest HFT-regulation.

5 Primary research: effectiveness of Directive (2014/65/EU) or Mifid II within the context of HFT

5.1 Why interviews?

Concrete conclusions cannot be drawn on the small sample of collectable empirical data post-MiFID II. Therefore, interview findings are certainly useful – to revise and add to future econometric conclusions. However, texturizing research with interview-narrative, rather than remaining rigidly quantitative contends conventional economic methodologies (Bewley, 2002). Yet in response to this, I would argue that solely econometric analysis does not thoroughly analyse the effectiveness of MiFID II. Indeed, the effectiveness of regulation is not entirely determined by quantitative metrics – rather conjecture, opinion and day-to-day applicability etc. In short, has MiFID II improved or hindered firms' line of business? Has it improved global market transparency? Or, ensured better market integrity? Consensus from interviews will certainly raise a valid and usable set of policy recommendations.

5.2 Methodology

My set questions were devised beforehand and interviews were deliberately loosely-structured on themes within chapter 5.4. From this narrative format, I sought to parse out points of consensus and informative suggestions. Observations of the randomly-selected interviewees were made and I documented respondents' biases. Some of the individuals previously-worked at HFT firms, whilst others worked at regulators, ensuring a divergent response of backgrounds and opinions. Anonymity of organisation and person was maintained due to HR requirements – it also enabled honest responses.

5.3 Sample

The setting was 4 corporate offices in London: 1 investment fund, 1 investment bank and a regulatory firm. The firms varied in sizes. All interviews were in private offices or meeting rooms. Interview times ranged from 27 to 45 minutes. In total 11 individuals were interviewed.

Table 5.1: Overview of interviewees

Firm and Division	Roles	Biases
Investment Bank (IB): *Front Office* (FO)	1. Equity Research 2. Electronic FX Trader 3. Electronic Equity Trader	Interviewees appeared very assured – perhaps overly confident. The highest number of former-HFT employees worked within this division.
Investment Bank (IB): *Back Office* (BO)	4. Market Surveillance Division 5. Equity Compliance 6. Global Compliance 7. Electronic Compliance	Less assured and quick to reach conclusions than FO counterparts. Certainly, the most sceptical group of market and regulatory improvements.
Regulator	1. Equity Conduct Supervision 2. Electronic Specialist	Confident with a far harsher perspective on: broker, HFT and market participants' general behaviour. Supportive of recent regulatory changes.
Investment Fund	1. Institutional Client Manager 2. Compliance Consultant	Frustrated at broker dealings and dark pool fines. Harshest perspective of HFTs in particular market volatility and latency arms races. Reasonably sceptical of market and regulatory improvements

5.4 Results: shortcomings and consensus points

5.4.1 Dark pools

Despite MiFID II, regulators, IB BO and investment fund interviewees noted that market opaqueness prevents collectable empirical data on patterns of market behaviour. Consequently, interviewees across all 3 firms believed that MiFID II was a necessary regulatory development to improve market-wide transparency. However, IB BO and investment fund respondents were sceptical of improvements in market transparency post-MiFID II. Indeed, lit exchanges only had a 50.85% share of European equity trading for 2018 versus a 50.28% average in 2017 (Reid, 2018).

In contrast, regulator and IB FO interviewees were less sceptical. Instead, regulator interviewees emphasised the fall in price swings in lit markets, more uniform client treatment by brokers, rise in dark block trades (figure 5.1) and the decrease in dark pool trading volume (figure 5.2). Equally, IB FO interviewees emphasised significant improvements in institutional client strategy post-MiFID II and that dark pools were still necessary to best-execute block orders on behalf of clients. Thus MiFID II's outcome on dark pools has divided opinion.

Figure 5.1: Surge in dark block trading post-Mifid II [adapted from Reid (2018)]

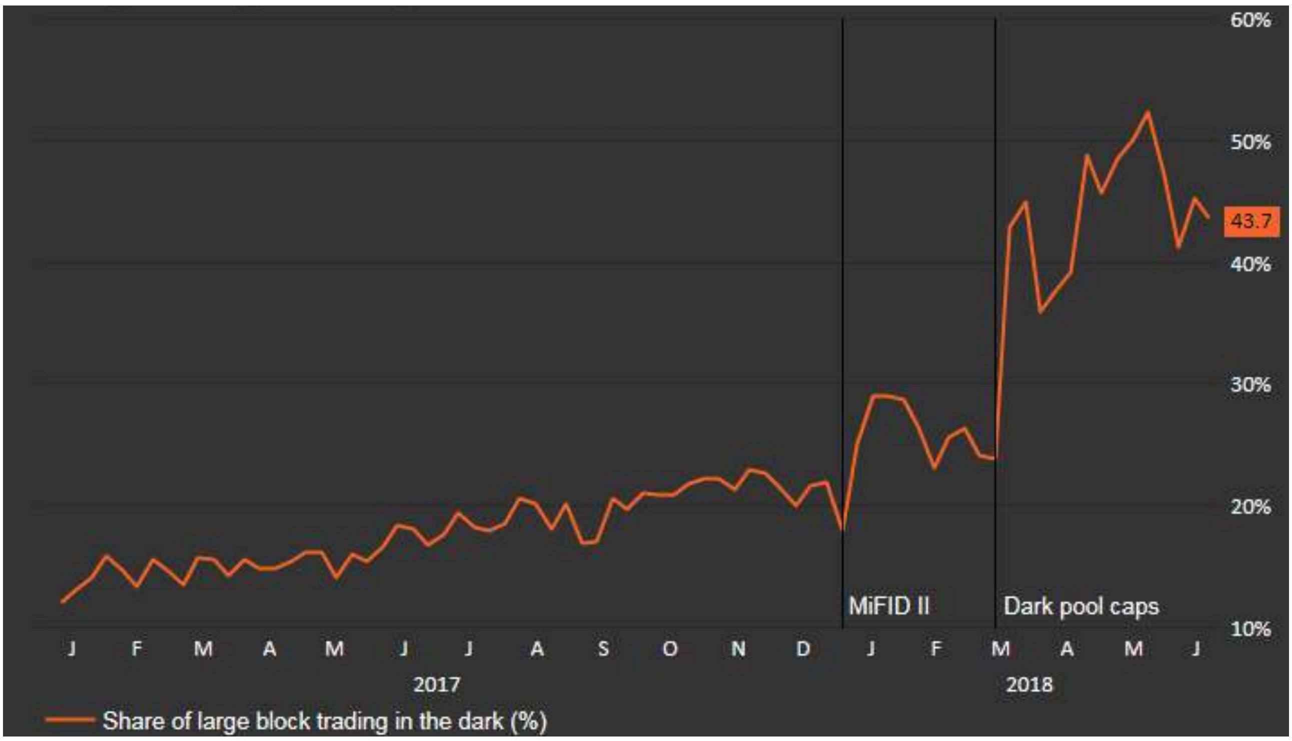
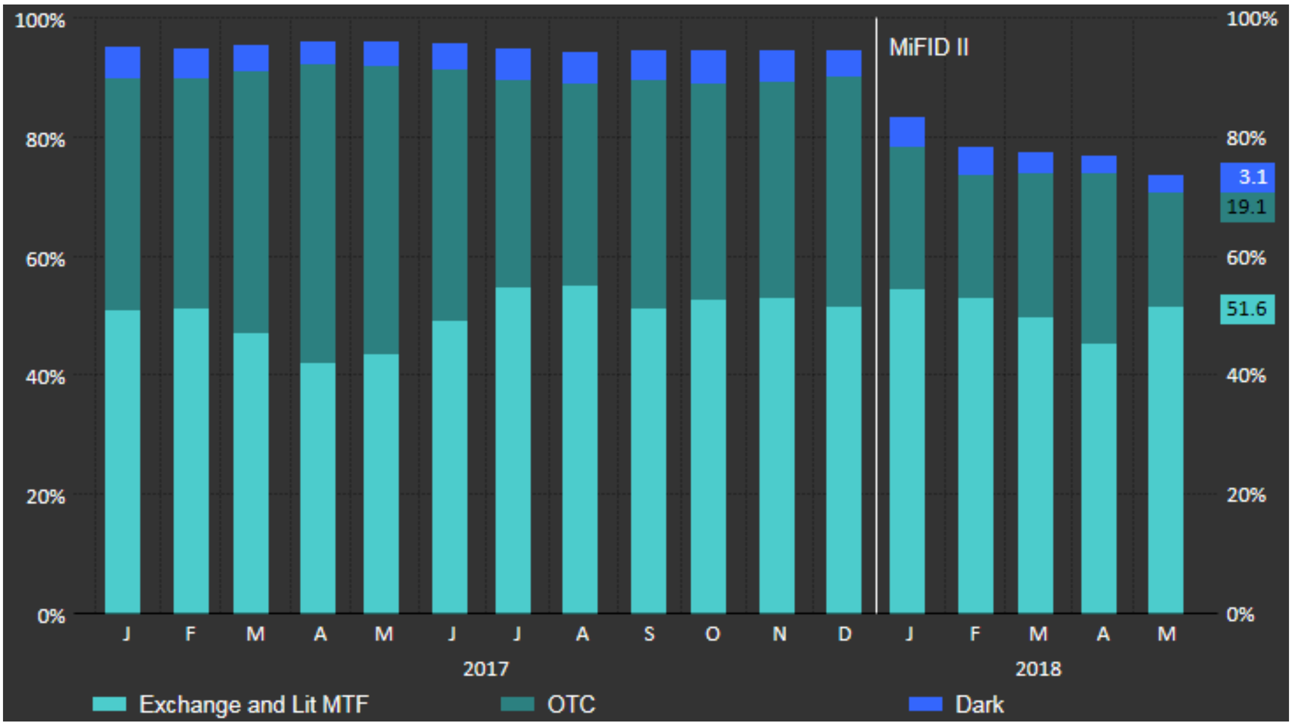


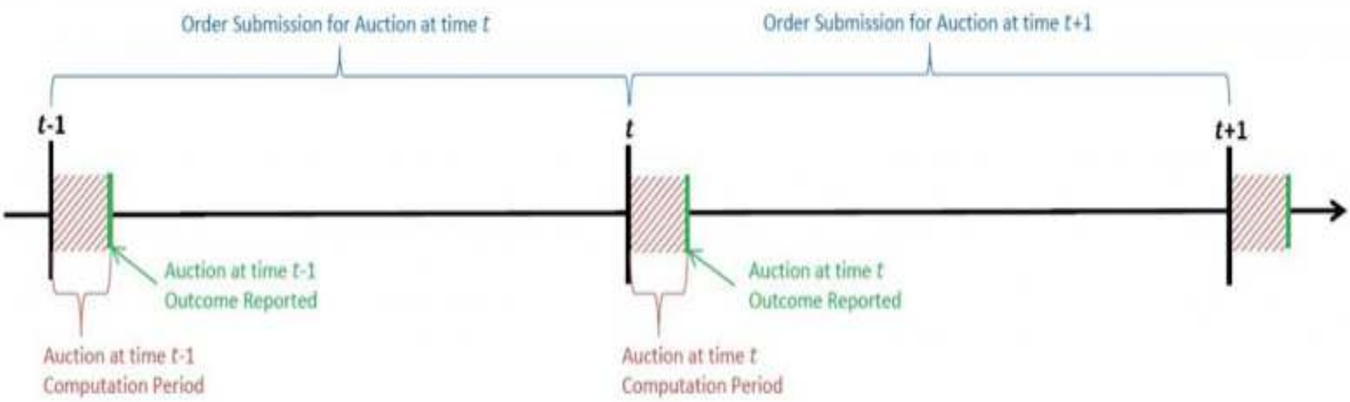
Figure 5.2: Fall in dark and OTC volumes post-Mifid II [adapted from Reid (2018)]



5.4.2 Periodic auctions

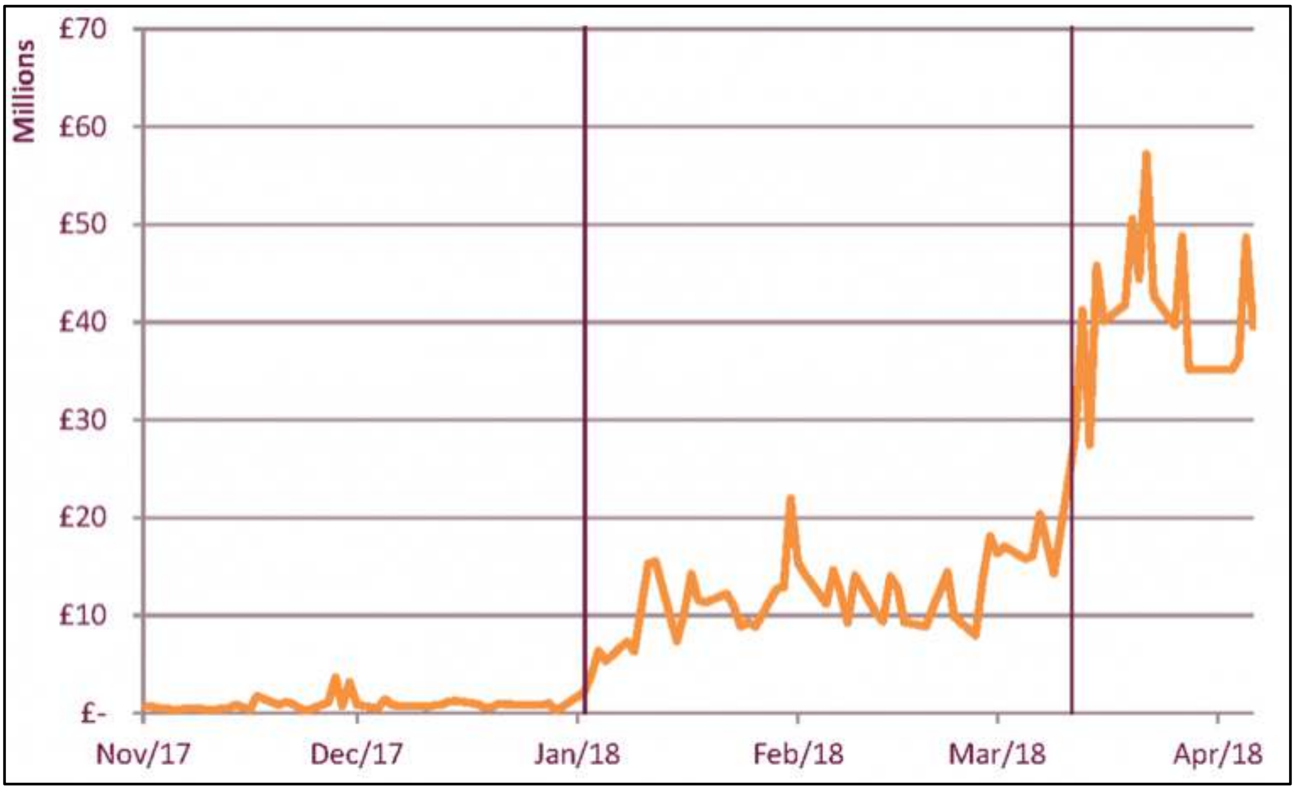
Importantly, the BO compliance and surveillance interviewees noted MiFID II's failure to resolve the loophole of periodic auctions. A variety of periodic auction models exist (Budish, Cramton, & Shim, 2015). Yet, specifically a periodic auction refers to a system in which orders (an instruction to buy or sell a financial instrument) are matched periodically by means of a trading algorithm (figure 5.3).

Figure 5.3: Process flow for periodic auctions [adapted from Budish et al. (2015)]



The rise in periodic auctions post-MiFID II (figure 5.4) is potentially perilous because periodic auctions display pre-trade information later than continuous systems (Budish, Cramton, & Shim, 2014). Thus mimicking dark trading by hiding bids and offers from wider markets and preventing market transparency – enabling the troubling potential for information and latency asymmetries.

Figure 5.4: Popularity of periodic auctions post-MiFID II



[adapted from FCA & Thomson Reuters (2018)]

In contrast, interviewees from the investment fund and regulator rebuked this line of argument and downplayed the rise in periodic auctions. They contended that this trend was due to far less devious factors e.g. institutional investment firms trying to avoid front-running HFTs as periodic auctions deliberately reduce speed and latency compared to normal continuous trading systems (Pagnotta & Phillippon, 2018). Equally, interviewees from the regulator emphasised that FCA research has corroborated this perspective by concluding that, "at first-sight periodic auctions are not used to circumvent any of MiFID II's pre-trade transparency rules" (Gulyas, 2019).

However, in light of other research suggested by IB BO interviewees, I would be sceptical of this retaliation. Indeed, the rise in periodic auctions bares troubling resemblance with the earlier-rise in dubious HFT 'sharking' and liquidity-detection dark-pool practices post-MiFID. In light of this, ESMA (2019) has demanded further research on the rise in periodic auctions. Thus consensus is mixed, yet it is still concerning that effective transparency remains an unresolved dilemma for markets.

5.4.3 Market integrity

Interviewees accept that MiFID II has nobly tried to improve market integrity. Furthermore, all 11 interviewees noted the sizeable decline in EU-US fines for market violations post-MiFID II. IB respondents emphasised that this trend was due to client and institutional strategies improving post-MiFID II. However, IB BO and investment fund respondents rebuked this perspective and argued that the decline in fines post-MiFID II was not necessarily because of better market-wide conduct. For example, they noted the problems with Robinhood Inc. and MiFID II's failure to outlaw firms charging PFOF. Indeed, market manipulations[16] are certainly harder to detect than more simplistic forms of insider trading.

However, interviewees from the regulator criticised this perspective and instead argued that post-MiFID II brokers have almost entirely stopped charging PFOF due to far tighter restrictions (Nikolova, 2018). This perspective is corroborated by harsher FCA controls – including a "Dear CEO letter" and stronger regulation ensuring that all firms act in an agency-like capacity (FCA, 2018). Regulator interviewees further argued that MiFID II has already clamped down on broker charges and conflicts of interest. Despite this, BO and regulator interviewees stressed that market violators continue to evolve and become more deceptive. For instance, they noted that many HFTs post-MiFID II still aggressively ramp closing prices particularly on exchanges at the end of the trading days (Serbera, 2019).

IB interviewees appreciate that unbundling under MiFID II was a necessary change in light of brokers over-charging clients (figure 2.5). However, unbundling research may potentially harm price discovery (FCA, 2019). Equally, the new framework has made pricing research far more difficult – culminating in bureaucratic difficulties for brokers. However, regulator interviewees rebuffed this suggestion, arguing that the FCA has shown flexibility via enabling trial periods whilst unbundling has had an immensely positive impact. In particular, encouraging brokers to self-fund research and re-evaluate pricing research. Subsequently, the FCA (2018) found that dealing commissions have fallen.

[16] Particularly those from HFTs.

5.4.4 Regulation Technology

Regardless of MiFID II, interviewees within the IB BO and investment fund expressed concern that regulation-technology (RegTech) will perpetually lag behind market innovations. For example, current technology fails to regulate (record, analyse and parse) the trade communications (thousands of messages, emails and vocal correspondences) between market participants. Although interviewees accept that MiFID II has demanded far better reporting on communication and market behaviour. It is still implausible to successfully record all communications, in particular: physical one-on-one meetings or analyse market participants intentions (good or bad).

As one IB BO interviewee described it, regulators take “years” to sufficiently investigate and detect market abuses. In simple terms, troubling red flags are hard to find, empirical market data is difficult to collect and even harder to analyse for patterns of abuse. Therefore, regulator, IB and investment fund interviewees collectively noted that: underlying market abuses and failures will continue occur despite MiFID II. In contrast, on a more positive note, interviewees from the IB and investment fund were extremely supportive of regulators sandbox programmes in which regulators invest heavily in SME’s and start-up developments of RegTech (FCA, 2014; 2017). Equally, MIFID II’s insistence on HFTs to engage in more shock-testing was positively received by interviewees.

5.4.5 HFT

Investment fund and IB interviewees suggested that regulators perhaps lacked knowledge about HFT firms – thus from their perspective MiFID II had been too heavy-handed. In particular, former-HFT employees interviewed demonstrated immense concern at regulators insistence of source-code provision under MiFID II guidelines. They deemed it unfair for regulators to pressure HFT firms into providing sensitive code and algorithms. Corroborating this perspective, it appears regulators are perhaps circumventing market dynamics – as one interviewee from the IB FO bluntly described it, “governments do not insist upon Google to provide their sensitive source code”.

In addition, former-HFT employees interviewed considered a range of future developments within HFT – consensus suggests that machine-learning and self-adaptive AI within financial markets is the next logical evolution of HFT-algorithms. Within the context of MiFID II regulation, former-HFT employees interviewed, stressed the need for markets to continue to innovate and optimise. Therefore potentially too heavy-handed regulation could stymie financial innovation.

Yet, in direct contrast to this perspective, regulators and BO IB interviewees stressed that – reckless innovation is still a justifiable global economic concern. Indeed, one IB employee noted that a self-adaptive AI trading machine (without a governance framework) successfully taught itself how to spoof the FX-market on trial runs. Therefore firms and regulators certainly need to remain vigilant in preventing negative economic developments, without limiting AI potential.

Another problem raised by IB and investment fund interviewees is that MiFID II fails to solve HFT latency arms races. Thus with respect to this, an IB FO trader argued that perhaps the equity market could learn from healthy developments within the FX market. In particular, he suggested that the FX markets order randomisation[17] helped solve the arms race for latency between HFTs – eliminating the negative HFT occurrences of asymmetric information and front-running (Thomson Reuters, 2016). From my perspective, this seems an eloquent solution and is similar to IEX's 38-mile coil of optical fibre before its trading engine, which adds a 350-microsecond delay to orders – thus preventing HFT-latency advantages (Lewis, 2014).

5.4.6 Evaluation of interviewees

From a cross-role analysis, there were differences amongst the responses of interviewees. IB BO, investment fund and regulator responses tended to be more cautionary, pro-regulation and reticent to reach positive conclusions regarding MiFID II. In contrast, IB FO staff tended to strongly emphasise positive developments and dismiss the need for further regulation. In accordance with my expectations, regulatory interviewees were more positive in their assessment of MiFID II than other respondents. Equally, periodic auctions, dark pools and unbundling presented the most contentious debates (FCA, 2019). Lastly, IB and investment fund interviewees were more supportive of market innovation over further regulation.

[17] FX order randomisation applies a randomised pause of 20–80 milliseconds on all orders – eliminating latency and speed advantages.

5.5 Chapter conclusions

Although my primary research lacks sufficient econometric evidence to solidify conclusions. Nevertheless, I have provided: shortcomings of MiFID II, several contentious areas for further econometric analysis, suggestions for improvement and more. Thus, my interviews find five key conclusions. Firstly, markets continue to lack transparency, yet brokers need opaqueness to best-execute client block trades. Secondly, periodic auctions represent an unresolved loophole, however PFOF has diminished. Thirdly, price discovery maybe harmed by research-unbundling. Fourthly, market violators exist, yet HFT or computer-driven innovation must and will continue. Lastly, lessons from the FX market could resolve equity-HFT latency arms-races.

6 Conclusion

6.1 Findings

Initially, this paper clarified the academic understanding of HFT – it is a natural evolution of the securities markets, instead of a completely new phenomenon. Equally, I have analysed recent regulatory, structural and market abuses. Regulators have rightly clamped down on, without outlawing: (a) order internalisation via dark pools and (b) PFOF. HFT is currently a profitable trading strategy, which significantly improves price discovery, liquidity and efficiency. At the expense of: unfair HFT strategies such as front-running or liquidity detection and HFT worsening volatile market conditions via negative feedback loops or 'leveraged' liquidity. Lastly, interviewee feedback suggests that MiFID II suffers from shortcomings in particular the loophole of periodic auctions. In addition, regulators face the unenviable task of finding a balance between computerised HFT-like innovation and regulation, particularly as markets introduce AI.

6.2 Recommendations for future research

Clearly, more focused empirical data is needed on the effects of MiFID II. Indeed, markets would benefit from clear information and transparency. Equally, further research on applying FX order randomisation to global equity markets would open up the possibility for lasting improvements to global market structure.

Additionally, research is also lacking on: HFTs perpetuation of 'normal' market volatility, market misconduct (e.g. PFOF and periodic auctions). Also further research to (a) improve RegTech and (b) understand market evolutions will be important to ensure the continued status quo of functioning global markets. Lastly, researchers could study the effects of HFT within modern crypto-exchanges.

6.3 Concluding remarks

At the time of writing, initial investigations suggest that HFTs have been front-running retail customers on cyrptocurrency exchanges, notably decentralised DEX exchanges[18] (Greenspan; Kharif & Hajric, 2019). Thus HFT certainly seems to court controversy, criticism and potentially act as a locus for market abuses. Indeed, many have suggested that HFT should be banned, whilst MiFID II (2018) has ensured tighter

[18] Researchers at Cornell University have labeled this 'Flash Boys 2.0' (Darian et al., 2019).

HFT regulation. I believe, markets must continue in this trend of vigilant regulation so as to continue reaping the benefits of market innovations like HFT. In response to those keen to ban HFT: I agree that HFT-abuse must be stopped, yet not at the expense of suppressing market innovation – regulators and investors should remember this going forward.

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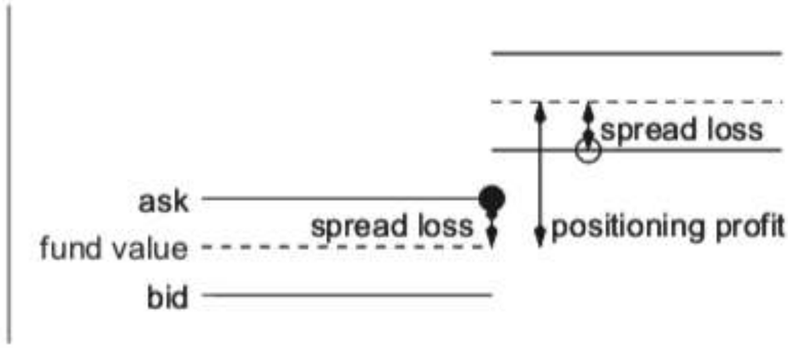
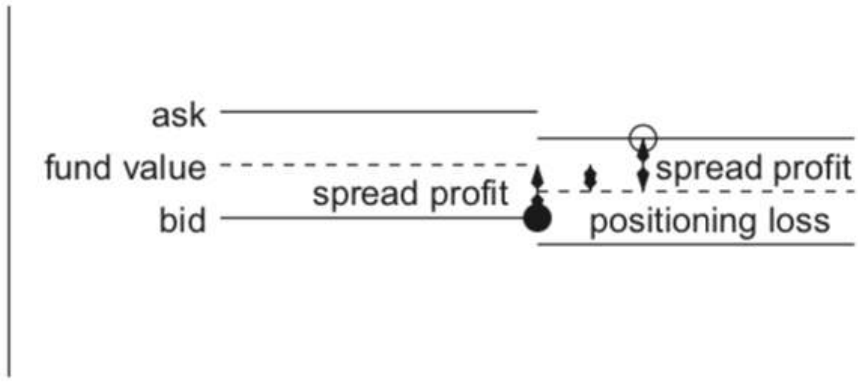
7 Appendices

7.1 HFT trade revenue decomposition from Menkveld (2013a)

HFT profit realisation	
HFT passive market making strategy	
HFT aggressive speculation (short-term momentum)	

7.2 Table 1 from Brogaard et al. (2013a, p.39) HFT descriptive statistics

			Calendar Time (TAQ NBBO)			Event Time (NASDAQ BBO)		
Summary Statistics	**Units**	**Source**	**Large**	**Medium**	**Small**	**Large**	**Medium**	**Small**
Market Capitalisation	$ Billion	Compustat	52.47	1.82	0.41	52.47	1.82	0.41
Price	$	TAQ	56.71	30.03	17.93	57.24	30.22	17.31
Daily Midquote Return Volatility	bps.	TAQ	3.58	9.93	24.09	2.26	9.35	24.41
Bid-Ask Spread	$	NASDAQ	0.03	0.04	0.07	0.05	0.1	0.23
Relative Bid-Ask Spread	bps.	TAQ	4.72	14.61	38.06	9.96	34.4	85.75
NASDAQ Trading Volume	$ Million	NASDAQ	186.61	6.52	1.18	205.33	7.02	1.42
$\mathbf{HFT^{All}}$ **Trading Volume**	$ Million	NASDAQ	157.76	3.61	0.43	172.4	4.23	0.52
$\mathbf{HFT^{D}}$ **Trading Volume**	$ Million	NASDAQ	79.24	2.37	0.3	85.1	2.84	0.36
$\mathbf{HFT^{S}}$ **Trading Volume**	$ Million	NASDAQ	78.52	1.24	0.13	87.3	1.39	0.16
$\mathbf{nHFT^{All}}$ **Trading Volume**	$ Million	NASDAQ	215.46	9.44	1.92	238.52	9.8	2.32
$\mathbf{nHFT^{D}}$ **Trading Volume**	$ Million	NASDAQ	107.37	4.15	0.88	120.15	4.9	1.06
$\mathbf{nHFT^{S}}$ **Trading Volume**	$ Million	NASDAQ	108.09	5.29	1.04	118.1	4.9	1.26

This table reports descriptive statistics that are equal weighted averages across stock days for 118 stocks traded on the NASDAQ for 2008-9. Each stock is one of three market capitalization categories: large, medium and small.

7.3 Table 5 from Brogaard et al. (2013a, p.44) HFT revenues

	Trading Revenues			Trading Revenues Net of Fees		
	Large	**Medium**	**Small**	**Large**	**Medium**	**Small**
$\mathbf{HFT^{All}}$ **(t-stat)**	\$5,642.27 (3.99)	\$227.80 (3.07)	\$55.23 (2.18)	\$6,651.03 (4.68)	\$173.77 (1.96)	\$29.86 (1.18)
$\mathbf{nHFT^{All}}$ **(t-stat)**	-\$5,642.27 (3.99)	-\$272.80 (3.07)	-\$55.23 (2.18)	-\$7,624.71 (-5.35)	-\$234.45 (-2.64)	-\$44.96 (-1.78)
$\mathbf{HFT^{All} - nHFT^{All}}$ **(t-stat)**	\$11,284.53 (3.99)	\$545.60 (3.07)	\$110.46 (2.18)	\$14,275.74 (5.02)	\$408.22 (2.30)	\$74.82 (1.48)
This table presents results on HFTs trading revenue with and without NASDAQ trading fees and rebates. Revenues are calculated for all liquidity demand and liquidity supplying HFT and nHFT.						

7.4 Tables of SEC Robinhood Financial. order routing findings

Securities Listed on the NYSE

Routing Venue	Total Orders (%)	Market Orders (%)	Limit Orders (%)	Other Orders (%)
Apex Clearing Corporation	0	0	0	0
Citadel Securities, LLC	35	31	36	30
Two Sigma Securities, LLC	12	21	10	22
G1 Execution Services, LLC	6	10	4	11
Wolverine Securities, LLC	21	17	23	17
Virtu Financial, Inc.	26	21	27	20
Total	100	100	100	100

100% of total customer orders were non-directed orders

15% of total non-directed client orders were market orders 79% of total non-directed client orders were limit orders 6% of total non-directed client orders were other orders

Securities Listed on Nasdaq

Routing Venue	Total Orders (%)	Market Orders (%)	Limit Orders (%)	Other Orders (%)
Apex Clearing Corporation	0	0	0	0
Citadel Securities, LLC	30	27	30	30
Two Sigma Securities, LLC	8	15	6	16
G1 Execution Services, LLC	5	9	4	9
Wolverine Securities, LLC	30	26	31	23
Virtu Financial, Inc.	27	23	29	22
Total	100	100	100	100

100% of total customer orders were non-directed orders

15% of total non-directed client orders were market orders 80% of total non-directed client orders were limit orders 5% of total non-directed client orders were other orders

Securities Listed on the NYSE MKT or Regional Exchanges

Routing Venue	**Total Orders (%)**	**Market Orders (%)**	**Limit Orders (%)**	**Other Orders (%)**
Apex Clearing Corporation	0	0	0	0
Citadel Securities, LLC	22	20	22	21
Two Sigma Securities, LLC	6	11	5	10
G1 Execution Services, LLC	5	10	5	9
Wolverine Securities, LLC	40	36	40	39
Virtu Financial, Inc.	27	23	28	21
Total	100	100	100	100

100% of total customer orders were non-directed orders

14% of total non-directed client orders were market orders 82% of total non-directed client orders were limit orders 4% of total non-directed client orders were other orders

7.5 US data centres offering colocation

State	Number of colocation data centres
Alabama	12
Arizona	46
Arkansas	3
California	233
Colorado	45
Coneticut	16
Delaware	4
District of Columbia	8
Florida	106
Georgia	44
Hawaii	5
Idaho	6
Illinois	82
Indiana	29
Iowa	11
Kansas	13
Kentucky	17
Lousiana	13
Maine	3
Maryland	24
Massachussets	41
Michigan	43
Minnesota	33
Mississippi	3
Missouri	41
Montana	3
Nebraska	10
Nevada	18
New Hampshire	7
New Jersey	62
New Mexico	8
New York	106
North Carolina	48
Ohio	76
Oklahoma	15
Oregon	29
Pennsylvania	52
Rhode Island	5
South Carolina	11
South Dakota	3

Tennessee	35
Texas	184
Utah	26
Vermont	3
Virginia	77
Washington	62
West Virginia	3
Wisconsin	27
Wyoming	5
Total	**1756**

7.6 EU data centres offering colocation

Country	Areas	Number of colocation data centres
Austria	Vienna	34
	Graz	8
	Klagenfurt	5
	Regional	5
	Linz	4
	Innsbruck	3
	Salzburg	3
	Total	62
Belgium	Brussels	39
	Regional	17
	Antwerp	7
	Ghent	5
	Liege	5
	Total	73
Czech Republic	Prague	19
	Regional	10
	Brno	8
	Ostrava	4
	Zlin	3
	Total	44
Denmark	Copenhagen	31
	Regional	7
	Kolding	4
	Arhus	3
	Total	45

Estonia	Tallinn	9
	Jõhvi	1
	Total	10
Finland	Helsinki	22
	Regional	6
	Tampere	3
	Kajaani	2
	Total	33
France	Paris	107
	Regional	56
	Lyon	19
	Lille	15
	Marseille	11
	Nantes	9
	Strasbourg	8
	Rennes	8
	Bordeaux	7
	Nice	7
	Toulouse	6
	Grenoble	5
	Montpellier	5
	Rouen	4
	Total	267
Germany	Frankfurt	104
	Regional	81
	Munich	51
	Hamburg	35
	Berlin	27
	Stuttgart	25
	Dusseldorf	24
	Nuremberg	20
	Cologne	11
	Hanover	9
	Leipzig	7
	Dortmund	7
	Dresden	7
	Bremen	6
	Karlsruhe	4
	Kiel	3

	Biefeld	3
	Total	424
Hungary	Budapest	10
	Regional	5
	Nyíregyháza	1
	Total	16
Italy	Milan	41
	Regional	32
	Rome	21
	Turin	11
	Padova	5
	Arezzo	3
	Total	113
Latvia	Riga	16
	Regional	1
	Total	17
Lithuania	Vilnius	11
	Regional	1
	Total	12
Netherlands	Amsterdam	97
	Regional	44
	Rotterdam	26
	Utrecht	13
	Almere	12
	Eindhoven	10
	Groningen	10
	Maastricht	9
	Apeldoorn	6
	Zwolle	6
	Ede	5
	Enschede	4
	Arnhem	4
	Total	246
Norway	Oslo	18
	Regional	12
	Trondheim	3
	Total	33

Poland	Warsaw	27
	Regional	16
	Poznan	10
	Katowice	9
	Krakow	6
	Lodz	6
	Gdansk	6
	Wroclaw	5
	Total	85
Portugal	Lisbon	13
	Porto	8
	Regional	2
	Total	23
Spain	Madrid	40
	Regional	27
	Barcelona	26
	Valencia	9
	Total	102
Sweden	Stockholm	49
	Regional	18
	Malmo	10
	Gothenburg	9
	Lulea	3
	Linkoping	2
	Total	91
Switzerland	Zurich	44
	Regional	22
	Geneva	14
	Lausanne	7
	Bern	5
	Basel	4
	Lucerne	4
	Total	100
United Kingdom	London	164
	Regional	74
	Manchester	34
	Birmingham	16

Reading	9
Portsmouth	8
Milton Keynes	8
Newcastle Upon Tyne	8
Leeds	8
Bristol	7
Liverpool	6
Glasgow	6
Nottingham	6
Cambridge	6
Woking	5
Sheffield	5
Edinburgh	5
Leicester	5
Cardiff	4
Hemel Hempstead	4
Belfast	4
Northampton	4
York	4
Bracknell	3
Sunderland	3
Southampton	3
Newbury	3
Telford	3
Aberdeen	3
Brighton	3
Swindon	3
Crawley	2
Total	426