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NBIM DISCUSSION NOTE

High Frequency Trading – An Asset Manager's Perspective

In this note we review the rapidly expanding literature in the area of market microstructure, high frequency and computer-based trading. On the back of this and based on our own investment and trading experiences, we highlight issues of concern to large long-term global investors.

Main findings

- The nature of equity markets has evolved with the advent of computer-based trading (CBT) and high frequency trading (HFT). Some market observers have been critical of HFTs and this topic has become controversial.

- HFTs do not constitute one coherent entity and their trading strategies can vary. It is therefore important to address their contribution to and impact on market quality and efficiency with such differences in mind.

- There is little consensus yet on what constitutes an appropriate framework for assessing market quality. More emphasis can be put on time-variation in trade-related measures including market impact across trade horizons that is more typical of large institutional order flow.

- Regulatory policies should try to take into consideration intended as well as unintended consequences given complexity in market microstructure. Introduction of new policies should consider potential negative impact on liquidity provisioning without robust alternatives in place.

- In our view, issues of concern to large, long-term investors more deserving of attention include
  - Anticipation of large orders by some HFTs leading to potential adverse market impact
  - Transient liquidity due to high propensity for HFTs to rapidly cancel quotes real-time
  - Un-level playing field amongst market makers from low latency ultra HFT strategies

- On the broader implications for well-functioning markets, we address three aspects – implicit transaction costs, market abuse and equality, and endogenous and systemic risk. In our view, more research and debate is needed in these areas.

- Markets will continue to evolve. The recent emergence of HFTs is an indication that continued research and development of trading strategies, as well as debate on appropriate market structure, are important responsibilities of asset managers and other market participants.

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1 Motivation

The essential role of marketplaces such as the equity market has ancient roots – it brings together investors to buy and sell in a centralised marketplace. The specifics, however, can change – both in terms of market participants and in terms of how price discovery operates. The nature of market making has evolved following the advent of computer-based trading (CBT) and high frequency trading (HFT). Similarly, the market microstructure has changed, driven by technology, connectivity and alternative trading venues.

Large, long-term, global investors depend on robust and well-functioning financial markets for their long-term investment returns (see NBIM Discussion Note (2012) on this topic). Market participants, regulators and researchers have focused on the impact of technological changes and the emergence of HFT in particular, on market quality and integrity, resilience against systemic risk as well as on execution costs. Well-functioning financial markets depend on interventions to correct for market imperfections, according to standard microeconomic theory. However, interventions not soundly based on evidence and research risk being ineffective or may lead to unintended consequences.

In this paper, we first review and discuss the rapidly expanding literature on HFT and CBT in equity trading[1]. Our approach here is to review and comment on key questions currently being posed by researchers, investors and regulators. Second, we highlight and discuss issues of concern to large buy-side institutions in the current market environment. We are mindful that the issues we raise may not be relevant to all institutional investors, and their validity may be difficult to address with precision due to a variety of factors, not least access to reliable data for the required empirical analysis. However, we believe that raising awareness and research-based engagement can lead to further discussion and debate on this topic.

Chart 1 presents the lifecycle of a trade from the viewpoint of a typical institutional investor with a long-term horizon. It illustrates the complexity of the interaction with algorithmic trading systems, market makers, HFTs and trading venues. This may not be representative of all institutional order flow – we deliberately leave out other interactions. Our aim is to focus on the key building blocks. Traders first receive instructions (order and benchmark price) from portfolio managers, and execute either algorithmic or block trades. For electronic trades, the trader's algorithm choice is usually dependent on a number of variables such as trade urgency, level of liquidity and general view on the market state. The broker provides a smart order router that sends the orders generated by the algorithm to either lit exchanges or dark pools[2], aiming for best execution. Finally, a post-trade analysis reviews the performance of the algorithms against some pre-calibrated cost model.

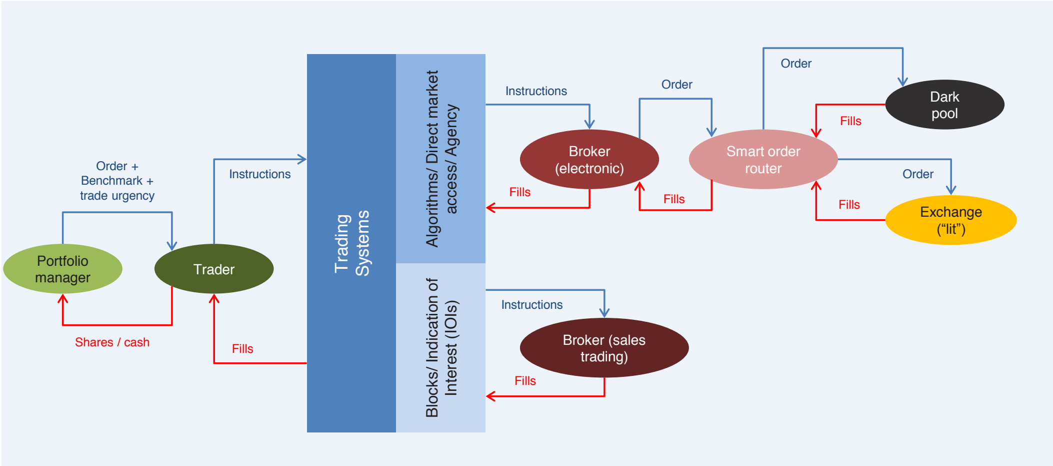
The paper is structured as follows. Section 2 introduces the evolution of market microstructure and trading driven by a combination of institutionalization in asset management, market fragmentation and technological advances. We then look at how interaction between liquidity consumers and liquidity providers has evolved in the marketplace. Section 3 addresses the variety of possible definitions of HFTs. CBT has multiple facets, and we make the distinction between HFT and algorithmic trading (AT) in Section 3.1. Within HFT (Section 3.2), we compare the characteristics of different trading styles and aggressiveness levels. In Section 4, we address the alternative viewpoints on the impact of CBT and HFT on market quality with reference to academic literature. We then go on to introduce broader issues that HFTs may raise to well-functioning markets, including implicit transaction costs[3], market abuse and equality, and market risk. Section 5 summarizes the corresponding responses put forward by regulators. In Section 6, we highlight issues of concern to large long-term investors, provide opinions and raise relevant research questions. Section 7 concludes.

1 While HFT is likely to be present in other classes, our focus in this note is on equity markets.

2 According to Buti et al (2011), dark venues are characterised by limited or no pre-trade transparency, anonymity, and derivative (almost exclusively mid-quote) pricing. Dark pools can be classified as systems such as broker crossing networks that cross orders without displaying them ("internalisation"), and trading venues such as regulated markets and MTFs (multilateral trading facilities) which are waived from pre-trade transparency.

3 Implicit costs typically include bid-ask spreads, impact costs and timing risk costs. Impact costs arise as larger orders cannot be absorbed at the best bid and ask prices and are typically inversely related to timing risk costs. Timing risk may arise as traders minimize impact costs by increasing their trade horizon, during which the security may move for or against them.

Chart 1: Life cycle of a trade – A simplified view[4]



2 Evolution of market microstructure and trading

2.1 Market participants and liquidity profile

The market is a set of interacting participants who seek and provide liquidity at differing times. Long-term investors aim to meet their trading objectives with minimum cost, subject to risk limits, while other market participants offer short-term liquidity for a price. Investors differ by size of assets under management, holding period/rebalance frequency, risk tolerances, and their liquidity requirements (size and immediacy). Market makers, on the other hand, have also evolved in the advent of HFT and changes in the market microstructure driven by technology, connectivity and alternative trading venues.

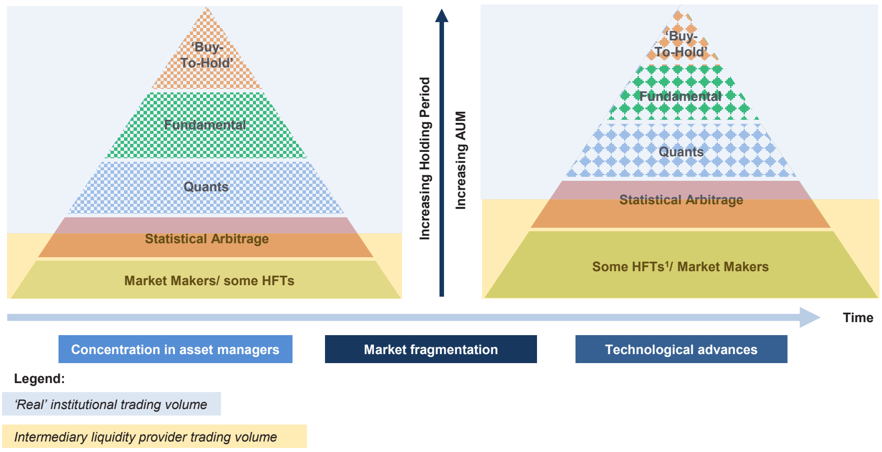
Chart 2 provides a schematic view of the evolving market structure as a set of interacting liquidity seekers and providers over time who differ in the length of their investment horizon and size of assets under management (increasing from bottom to top in both cases). Market participants higher up in the pyramid may act as short term liquidity demanders when they trade, but provide liquidity over the longer term. This schematic is simplified and is not meant to be a comprehensive reflection of the market place which is clearly much more complex.

Over time, a concentration in asset management, coupled with market fragmentation and technological advance, has resulted an increase in the fraction of volume executed by short-term traders (HFT and market makers) and a decrease in the fraction of volume executed by long-term fundamental and buy-to-hold investors. This development has also resulted in fewer, but larger and more challenging individual trading decisions. This has meant that the likelihood of a "natural" match between a long-term buyer and seller has decreased. Emrich and Crow (2012) show that institutional buys and sells accounted for 47% of exchange traded volume between 2001 and 2006, but only 29% of trading volume since 2008. The authors go on to show that direct household ownership of US corporate equity has fallen since 2000, implying less retail flow. This reduction in natural liquidity was further exacerbated by the drop in activity following the credit crisis in 2008. Some institutions that trade in size have since partially turned to dark pools and other non-exchange venues which allow natural liquidity to come together with some probability. However, intermediaries such as broker/dealers, and

4 Some of the standard terms in the chart are summarized in this footnote. Indication of interest (IOI) refers to a buyer's non-binding interest in buying a security in the stock market, often before it is available for purchase. Block trades typically involve a large number of shares or bonds being traded at an arranged price between parties, outside of the open markets. Direct market access refers to buy-side institutions managing the trades themselves by utilizing the information technology infrastructure and market access of sell-side firms such as investment banks. Algorithmic trading refers to a trading system that utilizes mathematical models for making transaction decisions in the financial markets. Agency trading is the buying and selling by a broker on behalf of a client.

liquidity providers such as dedicated market makers or, more recently, HFTs are growing in importance to ensure that markets clear.

Chart 2: Investment strategy pyramid - Schematic



(1) Note that HFTs may engage in both market making activities and opportunistic arbitrage opportunities, and therefore act as liquidity providers and liquidity consumers from time to time.
(2) In terms of band width, participants further down the pyramid have increasing volume of transactions

Concentration in asset managers

The past decade has seen significant changes in equity ownership. Asset management has become more institutionalised. Emrich and Crow (2012) show that institutional management of US equity portfolios has increased from 54% to 81% over the period 2001-2011. At the same time, the share of trading volume coming from "real" institutional managers relative to intermediary market makers has fallen. Retail investors have increasingly outsourced their wealth to institutional managers (e.g. through mutual funds or ETFs). The concentration in asset managers and resulting homogeneity in trading decisions, partly driven by benchmarking, have led to larger parent[5] order sizes relative to instantaneous liquidity. This change in the liquidity supply landscape meant sourcing for a natural counterparty has become more difficult and intermediary liquidity providers in the form of HFTs and statistical arbitrageurs filled the liquidity gap. These participants act as intermediaries in time and provide an alternative to pure broker intermediation.

Market fragmentation

Both Europe and the US have enacted regulation over the last decade or more that have introduced increased competition between trading venues, which has led to increased fragmentation in liquidity. The timeline in Chart 3 illustrates some of the milestones.

In the US, a series of regulations have promoted the growth of alternative trading venues. Amongst the most significant are

- Regulation Alternative Trading Systems (Reg ATS, 1998): Non-exchange trading venues, including electronic exchanges, could coexist with their primary counterparts
- Decimalisation (the move from 1/8th of a dollar to 1 cent minimum increment, 2001) which reduced minimum tick sizes
- Regulation National Market System (Reg NMS, 2005) which introduced the Trade Through Rule whereby market orders must be matched at the National Best Bid and Offer (NBBO).

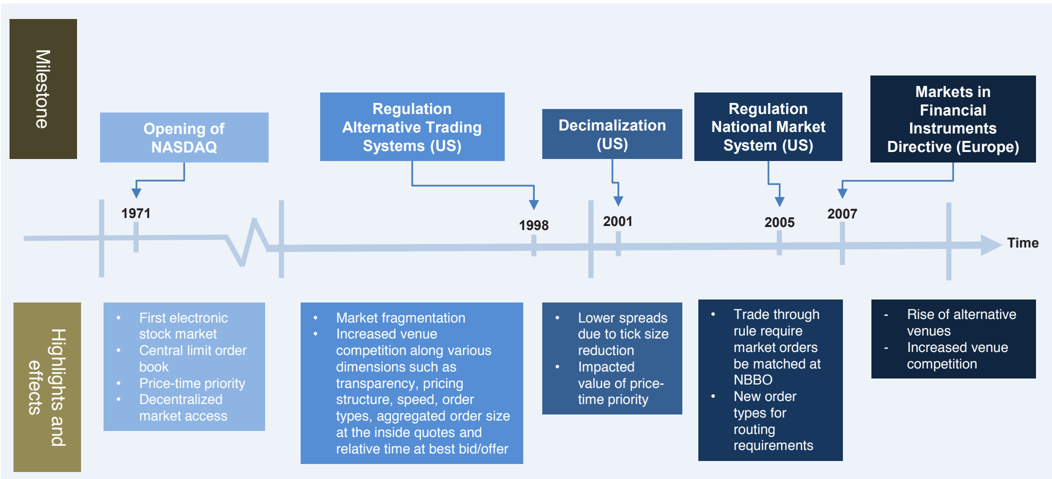
5 Normally, algorithms slice larger "parent" orders into smaller "child" orders before they are sent for execution.

There remain significant differences in regulations across regions. In Europe, the Markets in Financial Instruments Directive (MiFID) was introduced in 2007 to promote competition between trading venues, but left the definition of "best execution" at the discretion of the investment firm.

Following these reforms, venues compete along various dimensions such as pricing structures, speed (lower latency[6] on data feeds and execution) and order types, all of which are intended to attract more volume from market participants (whether HFTs or not). As a result of market fragmentation, opportunities for proprietary traders and HFTs grew, gaining ground over traditional, slower market-making activities. Kumar et al (2011) estimates that HFTs account for over 70% of all US equity exchange trading volume, an increase from 10% in 2000. Estimates for Europe are between 30% and 40% of equities and futures trading volume; in Asia the estimate is between 5% and 10% of equity volume.

Much of the difference in HFT volumes between the US and Europe can be attributed to the differences in fragmentation, but also to the Trade Through Rule in the US. Fragmentation among lit venues is higher in the US, while both regions have comparable numbers of dark pools. The Trade Through Rule implies an obligation for each venue to onward route a client order to a venue offering price improvement (not accounting for fees). This feature of the US market has opened up opportunities in rebate and latency arbitrage that firms such as HFTs can exploit.

Chart 3: Timeline of milestones leading up to the rise of CBT



Technological advances

Leveraging latency differences between market participants has always been a key competitive advantage. What has changed is the time scale – latency differences are now measured in nanoseconds. Recent investment in fibre optic links between exchanges, and between exchanges and their clients, are testament to the value of speed. The development of microwave links to further decrease latency shows that we are approaching hard physical limits on what is possible.

Latency minimisation has historically been important, since equity limit order books typically operate with price-time priority, whereby limit orders are first sorted by price, then by arrival time. This makes being first in receiving and processing information, and if necessary adjusting limit orders, critical. Decimalisation in the US, combined with better electronic connectivity, led to the "democratisation" of market making – the near-monopoly of designated market makers was gradually replaced by many, smaller market makers. Fragmentation of liquidity following new regulations and policies in the US and Europe led to more opportunities for venue and latency arbitrage.

The continuing trend of globalisation has led to tighter linkages between markets. The increase in message traffic due to opportunistic traders, such as HFTs and statistical arbitrageurs, has led to a

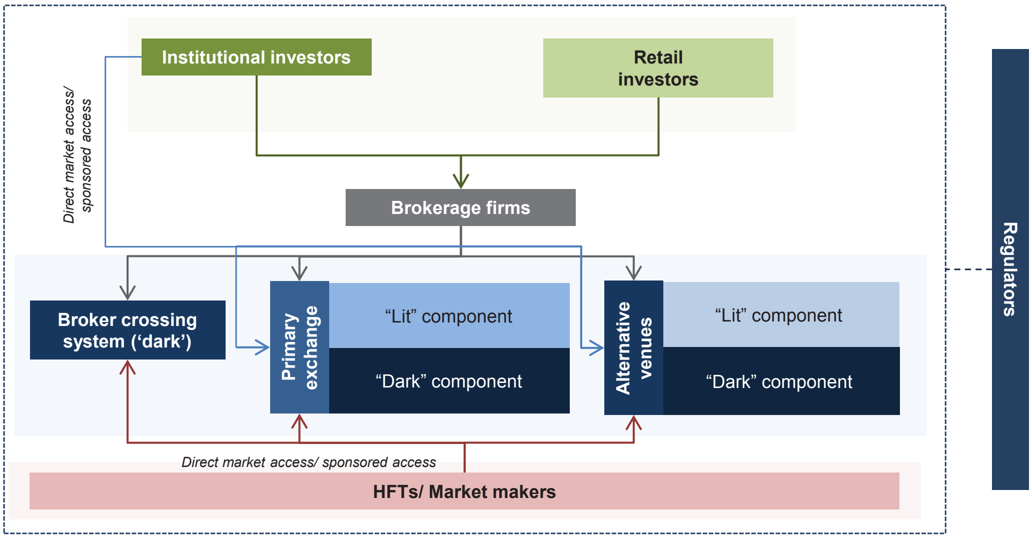
6 According to Hasbrouck and Saar (2010), latency is defined as the time it takes to observe a market event (e.g. a new bid price in the limit order book) through the time it takes to analyse this event and send an order to the exchange that responds to the event.

growing accumulation (and flow) of financial data, which drives institutional investors towards greater investments in technology and faster computer processing capacity.

2.2 Equity trading ecosystem

To illustrate the dynamics of the equity trading ecosystem, we show a schematic view of order flow interaction between liquidity consumers (institutional and retail investors), liquidity providers (some HFTs and market makers) and different trading venues in Chart 4. The schematic is illustrative of the evolution of the market place and its participants, and its impact on institutional investors. We deliberately exclude further complexities that are present in the system – our aim is to highlight the increasing interaction between different sets of participants. This leads to feedback loops, not all of which are well understood and researched.

Chart 4: Equity trading ecosystem (schematic)



Note: A lit market is one where orders are displayed on order books and are therefore pre-trade transparent. On the other hand, orders in dark venues are not pre-trade transparent. Broker crossing systems allow trades to be crossed between clients of the broker without information dissemination to the exchange

Market participants

Liquidity demanders such as large institutional investors are typically interested in executing large orders while minimising cost. Broadly speaking, this involves a trade-off between opportunity cost (trade urgency) and market impact. Computer-driven portfolio rebalancing and trading algorithms are used increasingly to optimize this trade-off. This creates potentially exploitable predictability in order flow (see Section 6.3 for a detailed discussion). Intermediary liquidity providers, such as HFTs, similarly use automated trade generation and execution strategies, but are typically characterised by much shorter holding periods and strategies that are more reactive. There are other liquidity providers, such as broker/dealers providing capital in a dealer capacity, as well as other market participants such as retail, but large institutional investors and intermediary liquidity providers jointly account for the vast majority of trading volume.

The marketplace

Exchanges, alternative trading venues and brokers facilitate the trading of securities, and hence benefit from the increase in trading volumes. Primary exchanges and alternative trading venues have lit and dark components, although the latter component is smaller on average but growing. Brokerage firms are the main direct clients of trading venues although some operate their own dark pools with broker crossing systems. They serve both institutional investors (e.g. agency trading via algorithms and smart order routing systems, direct market access) and HFTs (e.g. sponsored access, dark pool access). Lit trading venues differentiate themselves by offering even lower latency, asymmetric pricing structures, liquidity rebates and lower tick sizes (in Europe) to attract volume. The European "tick size war" (whereby venues competed by offering relatively lower minimum price increments) has ended, and the reduced tick sizes are now largely uniform across venues in an unregulated environment. Although fees, commissions and spreads are lower than before, large buy-side institutions are now faced with lower trade sizes and challenges in identifying the real depth of the order book. Because block-sized trades are difficult to execute without the risk of being detected, some institutional clients who want minimal market footprint have gone to dark venues. While some dark venues only allow natural liquidity participants with long-term investment objectives, most will attract volume by allowing some participation by high frequency flow while giving their clients some control on minimum execution sizes and the type of flow they want to interact with.

The proliferation of alternative venues, coupled with newer technology and connectivity, and new policy changes has brought about increased competition amongst trading venues. At the same time, the increased complexity has created new opportunities for arbitrage. For example, multiple order books in the same security with different fee structures and order types can be attractive for HFTs, a topic which we will revisit later.

Regulators

The evolving market microstructure is prompting regulators to adapt as they consider provisions necessary for safeguarding the structural characteristics of well-functioning markets. The recent rise of HFTs has received considerable attention from regulators who question the added value they bring to the market, and whether they reduce market efficiency and increase market instability through systemic risk and contagion. However, the scarcity of comprehensive data and time lag between rapid technological developments and research into their effects has made regulation issues more challenging. We examine the regulatory responses related to HFTs in more detail later (see section 5).

3 What is High Frequency Trading?

There is no general agreement on the definition of HFTs, apart from the fact that they trade with higher frequency than other market participants. There are a number of academic and regulatory definitions related to this concept (for an overview, see High Frequency Trading by Gomber et al, 2011 commissioned by Deutsche Börse Group). In general, the term is commonly used to describe firms which conduct proprietary trading at very high frequencies and speed by using computers and algorithms to automate trade signals and executions. Another angle is that HFT is not a new phenomenon but simply builds on more efficient ways to implement old trading strategies (e.g. market making and statistical arbitrage) using the latest technological developments. Finally, Easley et al (2011) argue that absolute speed is not necessarily the main characteristic advantage of HFTs, since they operate under "volume time" in their trading instead of chronological time. This re-definition of time leads to more normally distributed and independent observations, leading to faster calculations using standard statistical techniques. This would theoretically allow HFTs to profit from lower frequency traders even in the absence of low latency arbitrage.

3.1 Differences with algorithmic trading

It is important to distinguish at the outset between HFT and AT although many similarities exist. Some may argue that the former is a subset of the latter. From our perspective, however, AT is a commonly used term for broker-dealers' algorithms that execute orders according to a set of parameters, such as time, price limits, participation rates and benchmark choice in order to express some investment objective (e.g. urgency in trade) and/or minimise market impact. In short, AT operates based on a pre-defined set of rules to finesse trade execution. Basic similarities between them include access to real-time market data, automated order management and direct market access or sponsored access technologies for order routing. In the table below, we highlight some similarities and differences in key characteristics between HFT and AT.

Table 1: Similarities and differences between HFT and AT

	Characteristic Type	HFT	AT	Comment
Similarities	Real-time market data	Yes	Yes	
Similarities	Automated order management and submission	Yes	Yes	
Similarities	Direct market access/ Sponsored access	Yes	Yes	
Differences	Trading objective	Proprietary	Agent	For AT, goal is to minimize market impact (for large orders) referenced to a particular benchmark (e.g. Implementation shortfall, VWAP, etc). For HFT, profit is generated by transacting as intermediaries
Differences	Order frequency	Very high	Varies depending on trade urgency and other factors	HFTs have very high number of orders with rapid order cancellation
Differences	Holding period	Seconds, depending on strategy type	Days, weeks or months, depending on trade size	HFTs do not hold significant overnight risk
Differences	Latency sensitivity	Extremely high	Varies, depending on trade urgency	HFTs typically use co-location/ proximity services and individual data feeds to gain faster access to market data. Most brokers which provide algorithmic trading services for clients also use co-location
Differences	Investment universe	Focus on highly liquid instruments	Instruments across majority of liquidity spectrum, depending on trade profile	

3.2 Types of HFT activity

HFTs encompass a diverse range of strategy types and trade aggressiveness across the different asset classes. We believe it is important to distinguish one from another, and the assessment of HFT impact on market quality should be conducted on homogenous groups exhibiting similar characteristics. This is a challenge, due to data quality (e.g. lack of counterparty identifiers) as well as limited insight into the strategies, given their proprietary nature. A survey of academic literature and broker research available suggests that HFTs can be classified broadly, though not necessarily exclusively, by:

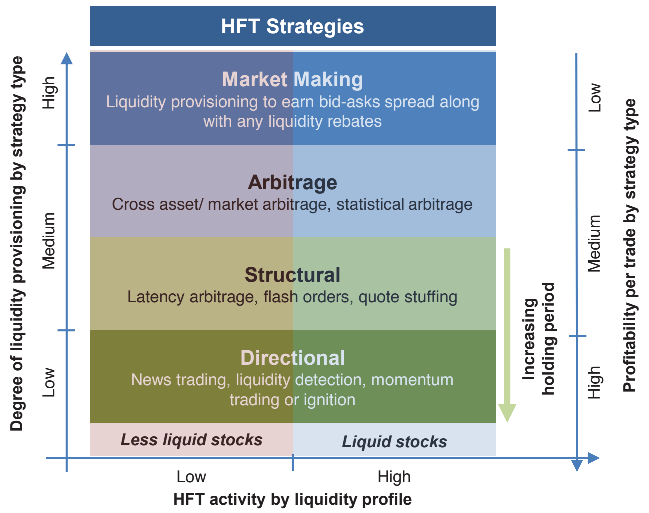
- Strategy types (SEC 2010, Hendershott 2011, Boehmer 2011, Tse et al 2012)
- Trade aggressiveness (Hagströmer and Nordén 2012, Benos and Sagade 2012, Baron, Brogaard and Kirilenko 2012, Kearns et al 2010)
- Latency levels (Hasbrouck and Saar 2012)

This is a very active research area, given the rapid evolution of HFT strategies, as well as other developments in market microstructure. We therefore characterise HFT activities loosely as follows.

Strategy types

It could be argued that HFT strategies in the most part are old strategies in new clothes with some important developments that evolved with changes in technology and market microstructure. Chart 5 classifies HFT strategies into four groups – market making, arbitrage, structural strategies and directional strategies. Market makers earn bid-ask spreads along with any asymmetric fees and liquidity rebates by providing liquidity. Arbitrage strategies aim to profit from small and short-lived discrepancies between securities (e.g. mispricing between indices, ETF and their underlying constituents). These strategies keep prices efficient by correcting mispricing across instruments. Structural strategies aim to exploit structural inefficiencies either in market structure or in the strategies of certain participants. They generally profit from stale prices (e.g. latency arbitrage and quote stuffing, described in Table 2). Directional strategies attempt to get ahead of or trigger a price move and they include news trading, liquidity detection and momentum trading.

Chart 5: HFT activity grouped by strategy type



Note: HFT profitability is a function of a number of parameters which we do not include in this schematic chart.

These strategy types have different characteristics (see axes in Chart 5). The level of liquidity provisioning (primary vertical axis) varies with strategy type. For example, market making strategies are generally considered as liquidity providers, whereas directional strategies tend to be liquidity consumers and may compete with large buy-side institutions for instantaneous liquidity.

The different strategies also correspond to unequal profits according to some of the limited studies carried out so far (secondary vertical axis) – market making activities generate the lowest profits and are arguably the least risky (pure liquidity premium extraction), whereas directional and structural strategies can be more profitable but generally require more risk taking ("alpha" model required and longer holding periods). Across similar HFT strategies, Kearns et al (2010) estimate that profitability is concentrated in the most liquid names.

We note that the proportion of predatory HFT strategies remains unclear; however it is worth highlighting some examples of predatory HFT strategies which are of concern to institutional asset managers (see Table 2, and Tse et al (2012)).

Table 2: Examples of predatory HFT strategies

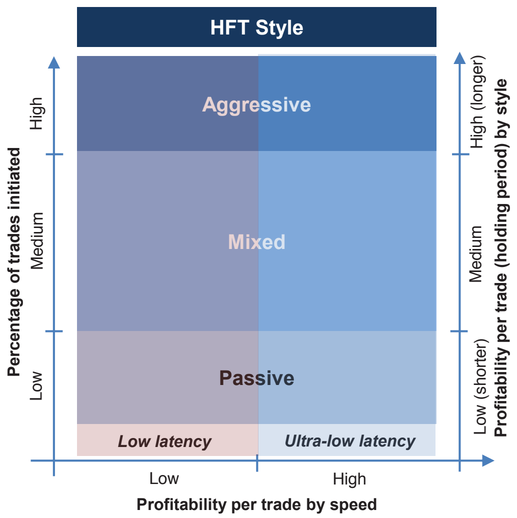
Strategy	Type	Description
Order anticipation	Directional	Detect and trade in front of large trading interests
Momentum ignition	Directional	Initiate a series of orders and trades to ignite rapid price movements. Most harmful in less actively traded stocks with little analyst or public coverage
Layering	Directional	Multiple, large orders are placed passively to "push" the book away which could temporarily create artificially low or high prices that can be acted upon by incoming orders
Quote stuffing	Structural	Large number of orders and cancellations are sent in rapid succession in an attempt to create false mid prices which dark pools use as reference prices, slow down market data to exploit stale pricing or game orders which are based entirely on the best bid or ask
Latency	Structural	Broad strategy which refers to the use of speed through co-location to exploit the structural weaknesses present in the matching engines of trading venues

Trade aggressiveness and latency level

Another approach is to classify HFTs by trade aggressiveness. The strategies can be classified as being passive, aggressive or mixed depending on whether their trades are net liquidity providing or consuming. Benos and Sagade (2012), and Baron, Brogaard and Kirilenko (2012) define trade aggressiveness based on how frequently the HFT firm initiates a transaction. Other studies apply a qualitative approach in classifying HFT trade aggressiveness based on exchange data. Using this approach, Hagströmer and Nordén (2012) find that market making in Swedish securities in their study accounts for 63-72% of total HFT volume and 81-86% of HFT limit order traffic.

Chart 6 shows that aggressive (passive) HFTs initiate the highest (lowest) percentage of their trades (primary axis), are the most (least) profitable and have the longest (shortest) holding periods (secondary axis). Baron, Brogaard and Kirilenko (2012) show empirically for S&P 500 E-Mini futures that speed (latency reduction) and total HFT profits are positively correlated for a given level of trade aggressiveness. Classifying HFTs by trade aggressiveness is used in many studies when assessing their impact on market quality and related regulatory responses, which we will discuss in the next section.

Chart 6: HFT activity grouped by level of aggressiveness



4 Market quality

The key question for market participants, regulators and researchers is whether CBT and in particular HFTs, impact market quality and the price formation process[7]. Market quality has been defined using a number of market microstructure metrics such as liquidity, bid/offer spreads, intraday volatility, queue priority and transaction costs. However, we note that there is no clear consensus on the precise definition of market quality since its interpretation varies across different investor types. The evidence in the literature is broadly based on empirical analysis of time series data or on theoretical models of the impact of HFT activity on the price discovery process.

In Table 3, we summarise the market quality measures commonly used by both academics and regulators, and make some comments on each.

Table 3: Summary of key market quality measures

Market Quality	Measure	Comments
Transaction cost	Commissions, bid-ask spreads (raw vs. cum quote) and intraday volatility	Further analysis required on trading costs for large order sizes in an environment of reduced trade size and increased HFT activity (e.g. quote matching by HFTs to arbitrage large order sizes, greater difficulty in hiding market footprint)
Liquidity	Tightness: Bid-ask spreads (effective, realized and price impact); Depth: Order book depth; Resilience: Price change per unit volume	Excessive message traffic and subsequent high order cancellation rate mean real liquidity may be much lower than apparent. Because HFTs react so quickly to market dynamics, liquidity is now a moving target in a fragmented marketplace and is more difficult to track
Price efficiency	Variance ratios and autocorrelation coefficients	Are prices primarily driven by fundamentals or pure statistical processes? Most academic papers agree that HFT benefits price discovery in terms of information being impounded in prices and smaller pricing errors. Other contrarians are questioning the added value in correcting prices almost instantaneously. Market fragmentation has added complexity required for price efficiency, with potentially unforeseen arbitrage opportunities
Intraday volatility	Highest midquote in an interval minus the lowest midquote in the same interval, divided by the midpoint between the high and the low	Benos and Sagade (2012) differentiate between informational ("good") and excessive ("noise") volatility and defines an informationally efficient market as having more "good" volatility and less "noise". The authors find that HFT have a statistically higher ratio of information to noise contribution than other market participants
Adverse selection	Difference between execution price and mid-price at some future time, difference between execution price of an n-share execution with the average transacted price of market executions following the execution in question up to n shares	Adverse selection is the risk of trading with a more informed counterparty (i.e. gamed by better players). This implies that informationally inferior traders may spread their trades over the day using scheduled algorithms to minimize this risk. The change in market structure led to more gaming opportunities for HFTs who attempt to profit from the footprints of large buy-side orders using scheduled algorithms
Complexity	Increase in order types over time	Trading venues may compete for liquidity by implementing new order types at the request of market participants, which typically benefit only a subset of market participants. Additional order types risk introducing additional complexity without much incremental value
Endogenous and systemic risk	No consensus measure but there exists some interesting work done such as order flow toxicity by Easley et al (2011)	Amplification of periodic illiquidity due to feedback loops inherent in HFT strategies during market stress, leading to widespread instabilities in the broader market

7 Our focus here and elsewhere in relation to the impact of HFT and CBT more broadly on capital markets does not address another important dimension of well-functioning markets which is related to raising capital for new companies by listing their shares. This topic is beyond the scope of this note.

4.1 Academic evidence

In this section, we summarise the main conclusions drawn from both empirical and theoretical studies on the effects of HFT on market quality. Most of the early academic literature arrives at positive effects of HFT on market quality. In particular, some empirical work shows positive effects on liquidity and short term volatility generally under normal market conditions. Some of the key conclusions are:

- Liquidity has improved (Angel et al 2010, Hendershott 2011, Menkveld 2012)
- Prices have become more efficient (Hendershott & Riordan 2012)
- Transaction costs have fallen (Angel et al 2010, Menkveld 2012)
- Price volatility has not risen, with some evidence that it has fallen (Hasbrouck and Saar 2012)

In contrast, numerous buy side institutions have had mixed views on the impact of CBT and HFTs on their overall execution costs (see Oliver Wyman survey commissioned by Foresight, 2011). Concerns include issues related to "phantom quotes", an increase in quote and price volatility, liquidity imbalance during distressed market conditions, and the potential for market abuse (e.g. quote stuffing). Hasbrouck (2013) shows empirically that quote volatility has increased on time scales of up to a few minutes.

Trading venue fragmentation makes a comprehensive analysis of HFT impact challenging, particularly if some of the trading venues are dark. Most academic papers have focused on exchange data only, with limited number of studies exploring dark trading data independently. Buti et al (2011) show that for US stocks dark pool activity is concentrated in liquid stocks, possibly due to higher HFT activity in these names. The authors further show that increased dark pool activity improves some market quality measures such as spreads, depth and short-term volatility. However, they also point out that the relationship between dark pool activity and price efficiency is complex and requires further research. On the other hand, by differentiating fragmentation resulting from visible and dark trading, Degryse et al (2011) find that for large and mid-cap Dutch stocks dark trading has a detrimental effect on the market quality of visible markets. Constructing a consolidated view of HFT activity across multiple lit and dark venues continues to be a challenge for the research community. Hence, the power of any conclusions from current studies will be reduced.

In addition to the empirical evidence, a few theoretical models on the impact of HFTs have been proposed. These point to either side of the argument, and some have challenged the findings of the empirical literature. Cartea and Penalva (2012) and Jarrow and Protter (2011) arrive at a negative view of HFT activity in terms of their impact on market quality. The former concludes that the presence of HFTs increases the price impact of long-term investor trades, while increasing the microstructure noise of prices. The latter finds that ultra-HFTs can create a mispricing that they unknowingly exploit to the disadvantage of ordinary investors, and that market volatility increases.

Biais et al (2012) conclude that while HFTs improve institutions' ability to seize trading opportunities which raises gains from trade, they can also generate adverse selection[8]. One ingredient in their model is the fact that HFTs can trade upon new information faster than slow traders and such informed access may generate adverse selection costs. Jovanovic and Menkveld's (2012) model shows that HFT entry can indeed increase welfare (by producing more price quotes) but might also decrease it (by consuming limit orders). Finally, Meng, Kirilenko and Sowers (2012) show that HFTs increase volatility in their stylised model of an order book populated by HFTs and liquidity traders.

The costs and benefits of HFT discussed so far are subject to different statistical interpretation of empirical data as well as model specifications. Alternative viewpoints were put forward by Sornette and Van der Becke (2011) who suggest one could complement the existing evidence by simulating artificial markets to gain insights on how the introduction of HFT-stylised strategies is likely to impact the welfare of all agents. It is fair to say that this area of research can benefit from further investigation.

8 Adverse selection is the risk of trading with a more informed counterparty, resulting in the regret of having bought (sold) prior to a favourable (unfavourable) move in the price of a stock.

4.2 Implications for well-functioning markets

The rise of high-frequency, low latency trading strategies also raises potential issues of equal market access and market abuse. For example, there are many statistical and structural arbitrage opportunities that depend on low latency market access technology – being first matters. Immediate trade and quote data constitutes an informational advantage over other market participants, which can increase the probability of generating positive returns. These opportunities are not available to slower market participants. Does this constitute unfair competition? On the one hand, these arbitrage strategies correct potential mispricing between correlated securities, improving price efficiency. On the other hand, HFTs which exploit the structural differences between venues (latency, fee structures, pricing models, order types) by increasing market complexity may not necessarily be adding economic benefit to the market. Latency arbitrage and quote stuffing are two examples of such structural arbitrage.

Skouras and Farmer (2012) show that HFTs use their speed advantage (co-location, etc.) to be at the head of the queue at the financial expense of others. This leads to a structural advantage over other market participants. In addition, the competition for latency will require even greater spending on technology and force out marginal HFT participants. With fewer active HFTs competing, we may see widening spreads and lower liquidity. The reduction in 'noise' volume might make concealing large institutional orders more challenging. As highlighted in Table 2, quote stuffing involves sending large number of orders and cancellations in rapid succession. This undesirable behaviour may be designed to slow down market data and exploit stale prices at the expense of other market participants. While some of these phenomena are not new, their detection has become more challenging.

Finally, there may be risks – endogenous and systemic – posed by CBTs and HFTs that could destabilise well-functioning markets. Endogenous risk refers to the sudden synchronisation between HFTs in selling or buying the same assets, creating feedback loops which may lead to structural break in prices. Given the low latency and informational features of HFTs, understanding and controlling for their non-linear interactions is challenging.

Systemic risk refers to the widespread instabilities in the broader market which translates into adverse effects on the economy, and can be caused by both endogenous and exogenous risk. Using a 1% price gap within 1 minute as a proxy for market discontinuities, Avramovic (2013) shows empirically that the incidence rate for single stock "mini" flash crashes in the S&P 500 has decreased over time. However, there still exist instances of significant structural price breaks. The CFTC- SEC report identified the automated execution of a large fundamental sell order in the E-mini contract as triggering the events leading up to the "Flash Crash" of May 2010. What then followed were severe liquidity imbalances at both the broad index and single stock levels. Easley et al (2011) show empirically that this liquidity imbalance was slowly developing prior to the collapse and argue that the increase in order flow toxicity[9] caused market makers to withdraw, creating episodic illiquidity. Kirilenko et al (2011) added that HFTs changed from being liquidity providers to liquidity consumers during the latter part of the Flash Crash and may have exacerbated the downward price pressure. Lack of robust testing on new algorithms and strategies by HFTs and other market participants may also lead to instability in prices. This is of concern to regulators and market participants.

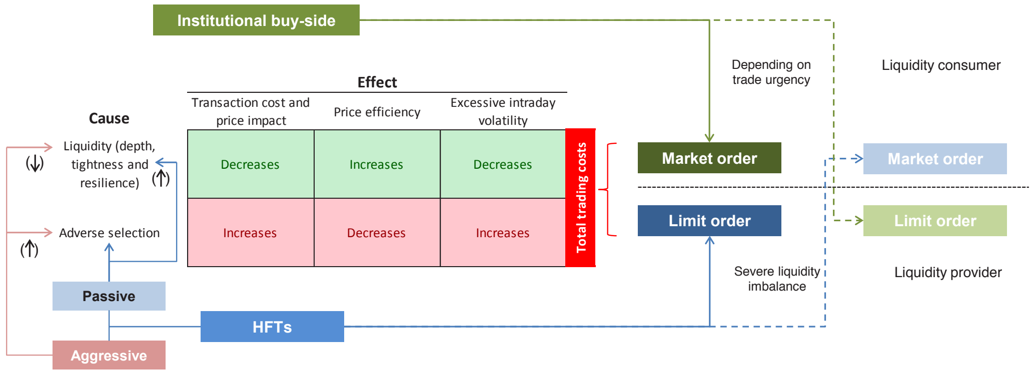
4.3 An asset manager's perspective

An evaluation of the key market quality indicators resulting from trading by institutional asset managers who interact with HFTs is not straightforward and may be conditional on other state variables such as market conditions and HFT type. Chart 7 highlights some cause-effect dependencies and interactions between institutional asset managers and HFTs, under normal market conditions. Total trading costs, a key metric for institutional investors, are a function of several market quality indicators. We further note that liquidity and adverse selection is related to the type of HFT activity (passive vs. aggressive – see left most part of Chart 7). For example, an increase in "real" liquidity (i.e. order book depth, tightness in bid-ask spreads and price resilience) as a result of greater "passive" HFT activity in general will lower transaction costs and price impact, improve price efficiency and reduce excess intraday volatility.

9 According to Easley et al (2012), order flow is toxic when it adversely selects market makers who may be unaware they are providing liquidity at a loss.

However, this may not always hold if HFTs exhibit high cancellation rates particularly during stressed times. As we noted earlier, Kirilenko et al (2011) show that HFTs can become liquidity consumers in their analysis of the flash crash and further amplify the price impact of an order when there is a severe liquidity imbalance (as illustrated by the dashed blue arrow in Chart 7).

Chart 7: Loose dependencies between key market quality measures



The jury is still out. Given the significant changes in market microstructure in recent years, more empirical and theoretical work on effective measures[10] of market quality is needed. There is little consensus yet on what constitutes an appropriate framework for assessing market quality and on a precise definition of HFTs by type of activity. This in our view has led to differing conclusions from the empirical and theoretical work on the impact that HFTs have had on market quality. We will re-visit areas of interest to institutional asset managers in section 6.

Closely associated with the impact of HFT on market quality are the potential externalities they may cause. As previously noted, market-making entities (HFTs or otherwise) perform an important service in well-functioning markets. They ensure continuous price quotation and provide liquidity in a fragmented market. However, HFT growth may produce potential costs – implicit transaction costs (and its corollary, HFT profitability), unequal market access and the potential for market abuse, and market risk (endogenous and systemic).

As institutional investors, we are interested in the drivers of total transaction costs including an understanding of the overall market impact of large orders over some trade duration. Traditional measures of price impact may no longer be sufficient to assess the total transaction costs for buy-side institutions, as implicit transaction costs increase. Some empirical evidence suggests HFTs lower explicit transaction costs but do not completely address the impact of HFTs on implicit costs (e.g. price impact of large trades). We believe that buy side asset managers have a role to play in addressing this open question given their own trading experiences and transaction cost analysis.

The profitability of HFT is imprecise given high dispersion amongst the findings in the literature. Satchell (2012) estimates US HFT profitability to be in the order of USD 12 billion per year from surveying different academic papers and commercial reports. As reported by the New York Times (2012), Tabb Group and Rosenblatt Securities estimate that HFT profitability in the US has been falling since 2009, in part driven by declining volumes. Accurately gauging HFT profitability is challenging as it requires numerous assumptions but it may be argued that the lower spreads today may be offset by HFT profitability. Given their role as intermediaries between natural buyers and sellers, this profit may be a fair compensation. However, the presence of HFTs and increasingly fragmented markets has led to additional, mandatory complexity-related costs for long-term investors with low urgency.

Regulating and managing this complexity and its costs is challenging – for example, a sudden absence of HFTs without credible alternative liquidity providers could be disadvantageous to all market participants. In our view, buy-side institutions should continuously enhance their transaction cost analysis based on execution data to better determine the components of their implicit costs.

10 Effective measures of market quality take into account market impact, an important component to transaction costs. On the other hand, traditional, observed market quality such as quoted bid-ask spreads and depth at best quote are based solely on the order book.

5 Regulatory responses

The emergence of HFTs has changed the market microstructure landscape which will continue to evolve with technological advances. As discussed earlier, the jury is still out on whether HFT activity is beneficial in parallel with the technological and other market developments discussed earlier. Whilst the potential for systemic risk is a key consideration for regulators who have been looking at various alternatives to limit such a possibility, regulatory responses should also take into account other considerations such as the promotion of fairness amongst market participants and reduction of "non-fundamental" volatility. Although the latter objectives are important for well-functioning markets, we note that they may be difficult to measure and enforce.

In this section, we summarise the potential regulatory responses, and group them according to their objectives (more details can be found in Table 4):

- Manage trade-off between cost and level of liquidity provisioning: Tick size policy
- Increase order book execution predictability: Minimum execution ratios and minimum resting times
- Reduce systemic and endogenous risk: Circuit breakers and notification of algorithms
- Promote liquidity: Market-making obligations and regulation of internalisation
- Reduce latency advantage of HFTs: Periodic call auctions
- Reduce HFT role: Limit maker-taker pricing and introduction of financial transaction tax

It is worth highlighting that there are some microstructural differences across markets that make global policy measures more challenging to apply. In the US, decimal-based pricing increment is already in place. In Europe where tick sizes are governed by individual exchanges, a coherent tick size policy (e.g. similar to the one proposed by the Federation of European Securities Exchanges) based on an optimal trade-off between spread reduction and liquidity provision may provide adequate compensation for liquidity providers and offer sufficient transaction cost reduction for institutional investors. It is unclear as to consequences of such action on market participants' behaviour or market quality.

Circuit breakers designed to limit periodic illiquidity caused by temporary liquidity imbalances may reduce systemic risk associated with feedback loops inherent in HFT strategies. Although some venue-specific circuit breakers are already in operation, there is a need for coordination of circuit breakers during market stress as insufficient coordination and harmonisation across venues could create additional instability or arbitrage opportunities. In general, however, circuit breakers seem logical as they offer market-wide limits on price ranges, and perhaps the least controversial relative to other regulations being proposed.

Proponents of financial transaction taxes argue that it promotes long-term investing and market stability. On the other hand, Auten and Matheson (2010) and Matheson (2011) review the available literature and finds that transaction taxes reduce liquidity, slow down price discovery, increases the cost of capital and lower asset prices. However, we note that the implications from any proposed tax regime is heavily dependent on its specifications. Pension funds are also exempt, which implies that volume declines are likely from other market participants; for example, traditional statistical arbitrageurs (multi-day investment horizon) and short-term derivative hedgers. For a pension fund, this represents status quo but with reduced liquidity and less heterogeneous order flow. A recently imposed levy on high-frequency traders by the Italian regulators may, however, change the picture.

Periodic call auctions[11] reduce the speed advantage of HFTs and hence allow natural buyers and sellers to interact directly during the trading session. Although periodic call auctions may lower liquidity during continuous trading and limit hedgers who operate on a continuous basis, they reduce opportunistic low-latency HFT activity and decrease the likelihood of periodic illiquidity. By design, periodic call auctions attract less toxic order flows and may suit long-term investors with low trade urgencies. One perhaps unintended consequence of introducing auctions at the expense of other forms of trading is that they could create a "winner takes all" type game with some venues losing out, which in turn could reduce price competition. Further research in this area is warranted in our view.

A topic less discussed, but arguably deserving more attention, is the proliferation of different order types as a means for market makers to create bespoke trading strategies and potentially for venues to attract volume. Under such a setting, venues allow the implementation of new custom order types which for most market participants offer marginal benefits at the cost of greater market complexity. In our view, regulators should take a more proactive approach and be selective on the order types entering the market.

In summary, regulatory policies require a thorough cost-benefit analysis before implementation with due consideration of intended as well as unintended consequences. We have included a number of regulatory proposals in Table 4, highlighting some pros and cons with selected references to relevant literature. From the table below, we can clearly see that policy specifications can have both positive and negative effects on the market structure, and may also introduce unintended consequences that may not be immediately obvious. While it is helpful to curb the undesirable properties of HFT as with other market anomalies that may have an adverse effect on quality, one should be mindful that excess intermediation may drive some market-making HFT activity away and reduce liquidity in an environment of fewer natural counterparties. It is worth noting that the table reflects our interpretation of the rules currently in force or under consideration. Given the highly dynamic nature related to this topic, the notes in the table reflect the state of play at the time of writing, and are likely to be subject to changes and future innovations.

11 Call auctions are alternatives to continuous matching of orders where limit orders are collected and processed over a fixed period, such that the price that enables the largest number of orders to be executed is chosen.

Table 4: Summary of regulatory responses

Policy	Description	Pros	Cons	Empirical evidence	Comment
Tick size policy	Implementation of overall optimal tick size policy across venues by considering the trade-off between transaction cost and liquidity effects	Well-chosen minimum tick sizes can prevent exchanges and liquidity providers (HFTs and market makers) from making excessive profits, and prevent sub optimality from excessive tick size reduction due to venue competition. Higher minimum tick sizes encourages liquidity provisioning, may lead to more stable order books and reduce the value of price-time priority	Higher minimum tick sizes widen spreads and reduce the probability of price improvement, which may force liquidity consumers to alternative venues such as dark pools or internalizers. Lower minimum tick sizes may induce opportunistic HFT activity away from market making	Academic research finds that a reduction in tick size reduces spreads but also depth. Furthermore, Hagstromer and Norden (2012) show that tick size reduction (increase) leads to increased (decreased) opportunistic HFT activity and decreased (increased) market making HFT activity	In Europe, securities may trade publicly under different tick size regimes, whereas in the US, this is only possible in dark venues
Minimum execution ratio (MER)	Restrictions on excessive message traffic by imposing upper limit on ratio of orders to executions	Greater clarity on price and order book depth, reduce burden on exchange's infrastructure and related systemic risk	Wider spreads and reduced liquidity, reduce market efficiency as a result of greater price discrepancy between related securities, less transparent limit order book due to more hidden orders	Hagstromer and Norden (2012) show that cancellation ratios are higher for market making HFTs than for opportunistic HFTs, implying that MERs may reduce liquidity provision	Exchange-specific measures which control message activity already in place. A tiered system may be required as high MERs may not be binding. SEC has only sounded out the possibility of introducing MER
Minimum resting times	Minimum resting time refers to the minimum time limit orders must remain active. Proposed restriction motivated by increasingly shorter time intervals between posting and cancelling of orders by HFTs	Increase likelihood that current quotes are tradable (i.e. increase order book predictability), reduce some aspects of market manipulation (e.g. quote stuffing) and reduce speed advantage of HFTs	Wider spreads and reduced liquidity (order book depth) as market making becomes less attractive (i.e. adverse selection risk), more opportunistic HFT activity and reduction in price efficiency	Limited empirical evidence. Brewer et al (2012) examined effects of minimum resting times in a simulated environment and did not recommend its adoption. Hasbrouck and Saar (2012) find low-latency executions associated with higher price efficiency	Some HFTs or other market participants may readjust their algorithms to exploit stale orders. SEC has brought up the proposal on MER a few times since 2010
Circuit breakers	Limit or halt trading in the event of severe temporary liquidity imbalances (non-fundamental). Greater coordination across venues (regulatory involvement) and promote systems operating on an ex-ante basis	Reduce unexplained volatility due to mechanical trading, provide window of opportunity for certainty resolution to allow counterparties to participate, prevent bottlenecks at exchange servers	Slow down fundamental price discovery process which may create additional uncertainty, excessive price impact just before trading halt, contagion effect on other securities (e.g. hedging, arbitraging), lack of corrdination across venues may introduce new arbitrage opportunities	Research points to general negative effects of circuit breakers but are based on pre-HFT regime. Limited evidence post-HFT era. Chicago Mercantile Exchange's forward looking circuit breaker was attributed to stopping the US Flash Crash	In the US, stock by stock circuit breakers are implemented for stocks in the Russell 1000 index. In Feb 2013, SEC enhanced this by introducing the limit up/ limit down system which avoids halting trading unnecessarily for erroneous trades. In addition, SEC has tightened thresholds for existing market wide circuit breakers following the "Flash Crash" of May 2010
Notification of algorithms	Provide annual description of strategies, trading parameters, risk control and due diligence	Educate regulators and improve their ability to detect market abuse, contribute to maintenance of orderly markets	Potentially resource and cost intensive, and may not significantly reduce systemic risk due to the nonlinear interactions and dynamic nature of many algorithms	Little empirical evidence on cost and benefit available	Rapidly changing area which makes its monitoring challenging

Table 4: Summary of regulatory responses (Cont'd)

Policy	Description	Pros	Cons	Empirical evidence	Comment
Market-making obligations	Obligation for HFTs to provide meaningful liquidity regardless of market conditions (e.g. maximum spread restrictions, minimum quote size, minimum quote time)	Lower spreads, accelerates price discovery process and greater liquidity in both normal and stressed market conditions	Imposing market making obligations without due compensation is likely to reduce liquidity and increase spreads as HFTs exit the market	Empirical studies on adequately compensated market maker obligations improve market quality. Compulsory market making obligations (without compensation) have not been studied. Furthermore, Kirilenko at al (2011) show that HFTs did not change their trading behaviour during the Flash Crash	Specification of requirements for market makers (e.g. stub quotes which may accelerate large price movements). Note that stub quotes are already banned in the US. Regulators may also be considering introducing some market making obligations for HFTs
Regulate internalization	Reduce internalization and increase its pre-trade transparency	Improve market quality (greater liquidity, better price discovery and less toxic flow) on public venues	Lower probability of trading opaquely and potentially higher transaction costs	Conflicting empirical evidence so far - O'Hara and Ye (2011) show US stocks with greater proportion of trades reported to trade reporting facilities had lower spreads and greater informational efficiency, whereas Larrymore and Murphy (2009) show that the banning of internalization in Canada led to lower spreads and volatility, and greater depth	In the case of dark pools, a report commissioned by ASIC (2013) shows empirically that dark liquidity is impairing market quality for some securities in the Australian market
Periodic call auctions	Sequence of intraday auctions that accumulate orders and then execute a single price using a pro rata approach	Removes the speed advantage of HFTs and related manipulative strategies, decrease likelihood of periodic illiquidity	Reduce incentives for market makers to supply liquidity, limit hedgers who operate on a continuous basis, potential concentration of liquidity to a single venue	Amihud et al (1997) finds that the transition from auction only to auction followed by continuous trading improves market quality	Further research is warranted. Well executed call auctions can over time attract liquidity as some large institutional order flow may find this route appealing
Limit maker-taker pricing	Maker-taker pricing refers to asymmetric fee structures whereby liquidity providers receive rebates for their executed orders while liquidity consumers pay for executing against these limit orders	Reduce reliance on HFTs for liquidity provisioning and hence lower probability of periodic illiquidity, lower taker fees for institutional investors as they can now post meaningful limit orders, increase transparency of order routing decisions	Decrease liquidity, increase spreads, reduce venue competition, competition between venues may shift to other strategic variables such as latency and differentiation on priority and order types	Empirical evidence suggests maker-taker pricing improves depth and trading volume without negatively impacting spreads (including fees). Malinova and Park (2011), Anand et al (2011), Berkman et al (2011) and Lutat (2010) point to improved liquidity and trading activity. Hendershott and Riordan (2011) show that HFTs lose money in the absence of rebates	Further research in this area would be helpful to guide regulators and market participants
Financial transaction tax	Aims to discourage transactions that do not enhance the efficiency of financial markets	Reduce opportunistic HFT activity, promote long-term investing and market stability	Reduce liquidity, slow down price discovery, increase cost of capital and lower asset prices when transaction taxes are applied across the board	Review by Matheson (2010, 2011) shows that transaction taxes reduce liquidity, slow down price discovery, increases cost of capital and lower asset prices. Reviews by Matheson (2010) and Hemmelgarn and Nicodeme (2010) show that the effect on volatility is ambiguous. Using the Swedish transaction taxes imposed in 1984, Umlaf (1993) examined its negative impact and concluded that equity prices, on average, declined and significant trading volume migrated out of Stockholm. Campbell and Froot (1993) show that in the presence of transaction taxes investors will shift trading to other markets or untaxed assets, or simply reduce trade volume.	France and Italy have already implemented financial transaction taxes. Possible introduction of a European "Tobin tax"

6 Issues of concern to large long-term investors

In this section we discuss some of the issues with HFT activity that are of particular concern to large long-term asset managers. Our objective here is to highlight the issues, refer to any relevant literature and raise specific research questions. We are mindful that the potential impact of the issues we raise may differ across institutional investors. The complexity of today's market structure, and a lack of comprehensive data in many cases, makes a definitive empirical analysis of the causal linkages a challenge.

6.1 Challenges in trading "HFT stocks"

According to a recent report by Pragma (2012), highly liquid stocks may experience "crowding" from HFT market makers at the best bid/offer. As discussed earlier, Kearns et al (2010) estimates that HFT profitability is concentrated in the most liquid names. This could mean queue lengths (number of limit orders at the same price level) for more liquid names are relatively longer. For institutional limit orders, this implies greater difficulty in completing trades under price-time priority. In the case of market orders, the effects of longer queue lengths on execution costs are complex and can depend on trade size and dynamics of the order book. For urgent trades that have to be completed within a given timeframe, more aggressive algorithms will then have to be used, translating into higher executions costs for a long-term investor as the spread will be crossed more frequently. On the other hand, the greater depth from longer queue lengths could mean that larger market orders can be absorbed without entering the next price level, therefore partially offsetting execution costs. While the incremental liquidity from HFTs in such securities may appear beneficial for aggressive trading styles, there is likelihood that market making HFTs may widen their spreads or even withdraw from the market in the presence of a large liquidity-consuming order, driving costs up for the investor. We believe a more granular analysis of "HFT stocks" and their characteristics such as time variation in liquidity is warranted, leading to concrete recommendations on asset managers' trading strategies under prevailing market conditions.

6.2 "Phantom" vs. "real" liquidity

One of the most common critiques against HFT is that the liquidity they provide on order books is transient. Buy-side traders face new challenges in assessing posted liquidity. This is driven by a number of factors including latency differences between venues, and rapidly changing order book dynamics given the high propensity for HFTs to post and cancel orders. This means available liquidity in an order book is really much lower than it would appear. As a result, institutional investors are concerned that greater HFT activity may have increased implicit trading costs. Brogaard et al (2013) show that execution costs (as measured by effective spreads) did not fall after latency changes made by the London Stock Exchange. Hasbrouck (2012) shows that variance ratios[12] for US stocks are larger for the most liquid names at different time scales (larger for smaller time scales), implying that short-term quote volatility is higher for more liquid names with higher HFT activity.

The high ratio of cancellations to limit orders is apparently characteristic of HFT activity, and does not apply to agency related AT which typically trade in one direction. Hagströmer and Nordén (2012) use data from the Swedish stock exchange to show that the quote-to-trade ratios for HFTs vary between 10 and 15, while non-HFT firms have corresponding ratios that range between 1.5 and 3 (quote-to-trade ratio of 10 means 1 in 10 quotes result in a trade). A corollary to this market microstructure feature is that much of the apparent depth based on posted liquidity could disappear faster than it takes a market order to reach the exchange matching engine. Sending more aggressive orders that consume most of the posted liquidity in a single execution removes the possibility of limit orders to be cancelled but this may translate into greater price impact.

12 Variance ratios are frequently used to assess the variation in return volatility over time and across markets. The author computes the ratios to high frequency data and assesses the excess HF volatility relative to what would be implied by a random walk.

Another concern related to high cancellation ratios is the risk of system overload experienced by exchanges due to excessive message traffic (sometimes referred to as quote stuffing). This would imply greater systemic risk and introduce latency arbitrage opportunities in the event of a delay in the market data feed. Deliberately causing an exchange to slow down would constitute a case of market abuse that should be regulated. However, the enforcement of such rules depends on the regulators' ability to detect this activity as such monitoring systems can be costly.

We believe that any regulation attempting to limit unwanted quoting activity should distinguish between economically sound and less proper motives for cancellations. It may be the case that most of the cancellations fall in the former category; however manipulative HFT activities such as quote stuffing should be discouraged. In our view, a preferred means of achieving this would be through trade surveillance, and by enforcing rules on market abuse, rather than imposing minimum resting times for limit orders. Further debate and analysis are warranted in this area given the difficulty in identification and proper enforcement.

6.3 Order anticipation

The change in market structure has led some to believe that there are more gaming opportunities for HFTs and other proprietary traders, who attempt to profit from the footprints of large buy-side orders using scheduled algorithms. Detection of presence of large orders and anticipating its execution strategy has been raised as a potential issue that may increase the market impact cost of executing sizeable trades. Detection of order flow is not trivial especially if execution strategy introduces some randomization. However, some research indicates that this might indeed be achievable. Lillo and Farmer (2004) show that large institutional trades that are executed incrementally over time create strong, slowly decaying autocorrelations of trade imbalances that can be recognised. At least in theory, this can be used to probabilistically ascertain trade presence and direction. However, forecasting power may be limited due to market complexity. In many cases, divergences in the return pattern of a stock relative to its highly correlated sector index are also indicative of large orders. We note that strategies based on mispricing between indices and their underlying constituents (e.g. ETFs and futures) are not restricted to HFTs as agency algorithms also use them.

It remains uncertain if HFTs or other traders actively engage in order anticipation, or more aggressively front-run large orders. It could be that market making HFTs change strategy from being a passive market maker to becoming a more aggresive liquidity player once a large order has been detected. We are not aware of any literature that shows HFTs engage in order anticipation. However, Baron et al (2012) show empirically for the e-mini S&P 500 futures contracts that the profitability of aggressive HFTs often exceed that of passive (market making) HFTs. We note that order anticipation is one of several strategies that could in theory be employed by HFTs or others and thus cannot conclude that the profitability of aggressive HFT activity is entirely attributable to detection or adaptation of large orders.

The question of whether increased HFT activity has led to more order anticipation and potential misuse of such information remains unanswered. The testing of any hypothesis related to order anticipation will have to take ultra-high frequency data (order of milliseconds) into account. In any case, the ability to hide large orders and avoid being detected is important to many institutional managers. As long as market making HFTs do not cancel their resting orders when market orders arrive, concealing large orders will be less challenging. More research needs to be conducted in the area of order detection taking into account a number of factors including HFT activity profile in the presence of large orders.

We note, however, that with lower market volumes overall, it can become more difficult to control for and minimise market impact for large orders. Trading such orders more passively is possible, but leads to longer execution times. This, in turn, implies greater timing risk and, possibly, loss of expected excess return. Furthermore, there is some empirical evidence that the participation rate at which orders effectively dominate the flow has been reduced, making passive trading even more challenging. The change in market microstructure is here to stay in our view and buy-side firms trading in size need to adapt their trading strategies to avoid order detection.

For example, it has been suggested that dark pool trading can be a useful complement to passive trading in lit markets. However, trading in dark pools has its own challenges. Dark pools offer execution styles ranging from near continuous execution to matching that could take hours or days. Time to completion depends on the underlying liquidity as well as any minimum acceptable quantity (MAQ) limits imposed by clients of the dark pool. Although many institutions set a high MAQ to avoid leaking information on the hidden order, this has the opposite effect of reducing the likelihood of finding a counterpart in the same dark pool. Because dark pool execution typically takes place at mid-quote which does not reveal information on whether the trade is buyer or seller initiated, it usually results in little or no direct impact on prices, all other things being equal. The assumption here is that orders are not improperly disclosed in dark pools or detected by "pinging" strategies. The risk of adverse selection, or trading with a more informed counterparty, becomes important for dark pool executions. If we observe price reversals following a trade in a dark pool, this can be indicative of having been "gamed".

Large brokers who use electronic trading to service institutional trading continuously invest in improving their algorithms, and many have anti-gaming logic in place to avoid being exploited by predatory algorithms. It is important for institutions to continually understand and assess the quality of these evolving algorithms used by the brokers. The increased presence of HFT has made it more important than ever to ensure that algorithms work as intended. Institutions would benefit from regularly comparing the performance of algorithms against some pre-calibrated cost model, and investigate any anomalies or higher than expected trading costs. However, this modelling exercise may face difficulty in controlling for the effects of trading rules and investment strategies, and hence reduce the power of the study. An alternative approach is to statistically detect trading inefficiencies by running controlled experiments, which is inherently expensive due to the large number of orders and trades required.

6.4 "Mandatory fee" paid to market making HFTs

One potential implication of the growth in HFTs is the relative impact they may have on implicit trading costs for investors with differing liquidity demand urgencies. HFTs tend to act as intermediaries between buyers and sellers for investors in need of immediate liquidity. However, this imposes an unavoidable 'cost' for an investor with low trade urgency. His order might complete faster, but at a higher cost. Fundamental investors have the ability to respond by becoming long-term liquidity providers. While these investors cannot and do not seek to compete in the high frequency domain, we believe their ability to provide longer term liquidity will be beneficial in this environment.

Closely associated with this concept is the maker-taker model. To incentivise liquidity provision and attract volume, some venues have an asymmetric fee model whereby liquidity takers pay a higher fee per share than those providing liquidity. In the US, liquidity providers are generally given rebates. Not surprisingly, this encourages certain market participants (e.g. ultra HFTs) to devise trading strategies to capture liquidity rebates, especially when liquidity provisioning rebates exceed liquidity taking fees. This is likely to distort the true supply and demand price discovery process to the detriment of the market. Quite often, brokers executing agency trades do not pass on rebates to their clients. As a result, brokers may route relatively more flow to venues with rebates than they otherwise should. Transparency on the breakdown of trading costs and rebates should ensure that the broker acts in the best interests of clients when routing their orders to the different venues.

In the case of taker-maker model, exchanges offer trading in limit order books such that takers receive a rebate while makers pay a fee. By construction, these models also facilitate queue-priority for a fee. It may also be possible that each trade costs the exchange when the taker rebate is more than the maker fee charged. Such venues may be attractive for HFTs who want to trade out of a position using market orders at low cost. Taker-maker models may also appeal to some market makers who are willing to pay for the privilege of interacting with "less toxic" order flow.

More research needs to be conducted on the effect of the choice of fee models for institutional orders (both limit and market), as well as the impact of interaction effects when both types of fee structures are present across exchanges.

From our perspective, we appreciate the freedom for exchanges to innovate, especially on price. As a client of exchanges, institutions may have the option to drop a venue if they deem the quality of execution to be low. We note, however, that fees paid to or rebates received from exchanges are generally not passed directly on to investors from their brokers. In addition, fee structures primarily intended to generate volume (maker rebate more than taker fee) are not likely to add value for end investors.

6.5 New order types

There are a number of order types that provide sound economic rationale for use by investors in the various exchanges. These include options such as choice of order display, trading on one or multiple exchanges, and pricing conditioned on market state. However, there is a risk that trading venues could compete for liquidity by implementing new order types on the request of specific market participants that only benefit a select few. In addition, some order types may create a two tiered market. The subsequent growth in custom order types add to market complexity, which in our view may increase both endogenous and systemic risk. Generally, the exchanges apply for approval by the regulator whenever a new order type is considered. It is our view that regulators should be less inclined to approve new order types than they seem to be at present and at least conduct cost-benefit analysis of such new orders. In our view, order types should benefit a wide cross section of market participants and not just a few. This may limit the ability of exchanges to compete through differentiation of their offerings to some extent. However, as noted earlier, we believe regulators should take a more proactive approach and only allow meaningful order types to enter the market. One approach for regulators to take is to allow provisional approval of new order types, and then followed by an evaluation period during which the venue provides detailed documentation on their objectives and usage by market participants.

6.6 Less volume and heterogeneous trading

The complexity of trading in markets has grown with the fragmentation of liquidity and increasing reliance on smart order routers, with Asia a notable exception so far. With fragmentation came the need for monitoring multiple order books simultaneously in order to know where the best price was. However, knowing the best price does not guarantee "best" execution will be obtained due to latency differences. As mentioned earlier, speed is positively correlated to HFT profitability. A by-product of continuously investing in better technology is higher barriers of entry in the HFT space. With fewer new entrants and incumbent firms merging, the increased concentration in the HFT industry is likely to result in a less heterogeneous order flow, with potentially greater market impact for larger trade sizes. The optimal mix of market participants in the ecosystem conducive for efficiency in markets remains a challenging question for researchers.

Some regulatory initiatives are likely to reduce HFT activity in certain markets, and it will be interesting to observe their effects on overall trading volume and how HFT firms adapt to the new regime. From an institutional investor's perspective, lower market volume would make it less competitive and more difficult to execute orders cheaply in the absence of robust alternatives. The "noise" due to heterogeneous trading activity is valuable because it makes it more difficult for HFTs and other traders to detect a large order. All other parameters being equal, trading similar-sized orders in lower volumes would cause larger price impact, and hence higher transaction costs. For large orders, the market impact cost typically dominates broker fees, taxes and other charges.

7 Conclusion

HFTs do not constitute one coherent entity. Their strategies can vary in their trading style (e.g. from market-making to liquidity demanding) and these in turn are likely to be conditioned on trading venue (lit vs. dark), latency level, security choices (liquidity profile), regional trading and regulatory nuances (e.g. Europe vs. US) and market state ("normal" vs. "distressed" conditions). It is therefore important to address their interaction with other participants and their contribution to and impact on market quality and efficiency with such differences in mind. This is a challenging exercise for researchers as control parameters may not be easily isolated given significant interaction effects.

One could also argue that market fragmentation and de-regulation aiming at greater market efficiency has partially led to the development of HFTs and more broadly CBT with growth in number of trading algorithms and order types. It is also clear to us that the effect of HFTs is a function of many parameters, sometimes inter-linked. Further regulation needs to take into consideration the impact of HFT on market quality as well as on market participants' demands across the board – from retail to institutional.

In this paper we broadly highlighted some research questions and issues that are of concern to a large institutional asset manager. We believe that the buy side has a role to play in developing their own research agenda on effective measures of market quality. Institutional investors can rely on their own proprietary data, and leverage this data when working in collaboration with universities and other institutions. Data access remains a challenge for specific research questions. For example, there is little empirical work conducted to our knowledge comparing lit and dark markets, which will require comprehensive and synchronised data across multiple venues that include orders, quotes and executions.

We do not believe that HFTs just spontaneously emerged. Technological and regulatory changes were enablers, but it is also the change in the mix of market participants that created new profit opportunity niches that HFTs exploit. Markets will continue to evolve. Asset managers should continue to develop their research capability and adapt their trading strategies, as well as engage in debates on appropriate market structure.

8 References

Amihud, Y., B. Lauterbach and H. Mendelson (1997): "Market Microstructure and Securities Values: Evidence from the Tel-Aviv Stock Exchange", Journal of Financial Economics 45, 365-390.

Anand, A., T. McCormick and L. Serban (2011): "Does the Make-Take Structure Dominate the Traditional Structure? Evidence from the Options Market", SSRN working paper, 27 June 2011.

Australian Securities & Investment Commission (2013): "Dark Liquidity and High-Frequency Trading", Report 331, March 2013.

Auten, G. and T. Matheson (2010): "The Market Impact and Incidence of a Securities Transaction Tax: The Case of the U.S. SEC Levy", Presented at the 103rd Annual Conference of the National Tax Association, Chicago

Avramovic, A. (2013): "The Regulatory Roundup: Are More Trading Glitches Ahead?", Credit Suisse, 17 January 2013.

Bank for International Settlements (2011): "High-frequency Trading in the Foreign Exchange Market", Markets Committee report, September 2011.

Baron, M., J. Brogaard, A. Kirilenko (2012): "The Trading Profits of High Frequency Traders", working paper, November 2012.

Benos, E. and S. Sagade (2012): "High-frequency trading behaviour and its impact on market quality: evidence from the UK equity market", Bank of England Working Paper No. 469, December 2012.

Berkman, H., G. Boyle and A. Frino (2011): "Maker-Taker Exchange Fees and Market Liquidity: Evidence from a Natural Experiment", Working paper, 15 February 2011.

Bershova, N. and D. Rakhlin (2012): "High-Frequency Trading and Long-Term Investors: A View from the Buy-Side", SSRN working paper, November 2012.

Biais, B, T. Foucault, S. Moinas (2012): "Equilibrium High Frequency Trading", SSRN working paper, 15 March 2012.

Brewer, P., J. Cvitanic and C. Plott (2012): "Market Microstructure Design and Flash Crashes: A Simulation Approach", SSRN working paper, 3 December 2012.

Brogaard, J., T. Hendershott, S. Hunt, T. Latza, L. Pedace and C. Ysusi (2013): "High-Frequency Trading and the Execution Costs of Institutional Investors", FSA Occasional Paper Series 43, January 2013.

Buti, S., B. Rindi and I.M. Werner (2011): "Diving into Dark Pools", SSRN Working Paper, November 2011.

Campbell, J. Y. and K. A. Froot (1993): "International Experiences with Securities Transaction Taxes", NBER Working Paper #4587, December 1993.

Cartea, Á. and S. Jaimungal (2011): "Modelling Asset Prices for Algorithmic and High Frequency Trading", SSRN working paper, 24 November 2011.

Cartea, Á., S. Jaimungal, J. Ricci (2012): "Buy Low Sell High: A High Frequency Trading Perspective", SSRN working paper, 30 December 2012.

Cartea, Á. and J. Penalva (2012): "Where is the Value in High Frequency Trading?", Quarterly Journal of Finance, Volume 2 (3), 2012, 1-46.

CFTC-SEC (2010): "Findings Regarding the Market Events of May 6, 2010: Report of the staffs of the CFTC and SEC to the joint Advisory Committee on emerging regulatory issues", 30 September 2010.

CFTC-SEC Advisory Committee (2011): "Recommendations Regarding Regulatory Responses to the Market Events of May 6, 2010, Summary Report of the Joint CFTC-SEC Advisory Committee on Emerging Regulatory Issues", 18 May 2010.

Cliff, D., T. Hendershott, O. Linton, M. O'Hara and J. Zigrand (2011): "The Future of Computer Trading in Financial Markets", Government Office for Science, Foresight.

Cvitanic, J. and A. Kirilenko (2010): "High Frequency Traders and Asset Prices", SSRN working paper, 11 March 2010.

Degryse, H., F. de Jong, and V. van Kervel (2011): "The Impact of Dark Trading and Visible Fragmentation on Market Quality", CEPR Discussion Paper 8630.

Easley, D., M. López de Prado, and M. O'Hara (2011): "The Microstructure of the "Flash Crash": Flow Toxicity, Liquidity Crashes and the Probability of Informed Trading", Journal of Portfolio Management, Winter 2011.

Easley, D., M. López de Prado, and M. O'Hara (2012): "The Volume Clock: Insights into the High Frequency Paradigm", Journal of Portfolio Management, Fall 2012.

Emrich, S. and C. Crow (2012): "Real Trading Volume", Morgan Stanley Quantitative and Derivatives Strategies, 11 April 2012.

Farmer, D., A. Gerig, F. Lillo, and H. Waelbroeck (2012): "How Efficiency Shapes Market Impact", Working paper.

Foresight (2011): "End-user Perspective on Computerised Trading", UK Government Office for Science

Foresight (2012a): "The Future of Computer Trading in Financial Markets - An International Perspective", Final project report, UK Government Office for Science.

Foresight (2012b): "What is the Economic Impact of the MiFID Rules Aimed at Regulation High-Frequency Trading?", UK Government Office for Science.

Foucault, T. (2012): "Pricing Liquidity in Electronic Markets", Foresight Driver Review, Government Office for Science.

Gomber, P., B. Arndt, M. Lutat, T. Uhle (2011): "High-Frequency Trading", Goethe Universität. Commissioned by Deutsche Borse Group.

Hagströmer, B. and L. Nordén (2012): "The diversity of high frequency traders", SSRN Working Paper, 27 September 2012.

Hasbrouck, J. and G. Saar (2012): "Low-Latency Trading", SSRN Working Paper, July 2012.

Hasbrouck, J. (2013): "High Frequency Quoting: Short-Term Volatility in Bids and Offers", Working Paper, 22 February 2013.

Hemmelgarn, T. and G. Nicodème (2010): "The 2008 Financial Crisis and Taxation Policy", CEPR Discussion paper 7666.

Hendershott, T. (2011): "High Frequency Trading and price Efficiency", Foresight Driver Review 12, UK Government Office for Science, 3 August 2011.

Hendershott, T., C. Jones, and A. Menkveld (2011): "Does Algorithmic Trading Improve Liquidity?", Journal of Finance Volume 66 Issue 1 Pages 1-33, February 2011.

Hendershott T. and R. Riordan (2011): "Algorithmic Trading and Information", Working paper, 21 June 2011.

Hoffman, P. (2013): "A Dynamic Limit Order Market with Fast and Slow Traders", European Central Bank(ECB), 28 January 2013.

International Organization of Securities Commissions, IOSCO (2011): "Regulatory Issues Raised by the Impact of Technological Changes on Market Integrity and Efficiency", Consultation report CR02/11, July 2011.

Jarrow, R. and P. Protter (2011): "A Dysfunctional Role of High Frequency Trading in Electronic Markets", SSRN working paper.

Jovanovic, B. and A. Menkveld (2012): "Middlemen in Limit-Order Markets", SSRN working paper, 8 November 2012.

Kearns, M., A. Kulesza and Y. Nevmyvaka (2010): "Empirical Limitations on High Frequency Trading Profitability", SSRN working paper, 17 September 2010.

Kirilenko, A., A. Kyle, M. Samadi, and T. Tuzun (2011): "The Flash Crash: The Impact of High Frequency Trading in an Electronic Market", SSRN working Paper, 26 May 2011.

Kumar, P., M. Goldstein, F. Graves and Borucki, L. (2011): "Trading at the Speed of Light: The Impact of High-Frequency Trading on Market Performance, Regulatory Oversight, and Securities Litigation", The Brattle Group, Finance: Current Topics in Corporate Finance and Litigation, Issue 02 2011.

Larrymore, N. L. and A. Murphy (2009): "Internalization and Market Quality: An Empirical Investigation", Journal of Financial Research, 32, 337-363.

Lillo, F. and Farmer, J.D (2004): "The Long Memory of the Efficient Market", Studies in Nonlinear Dynamics & Econometrics, 8(3).

Lutat, M. (2010): "The Effect of Maker-Taker Pricing on Market Liquidity in Electronic Trading Systems - Empirical Evidence from European Equity Trading", SSRN working paper, 1 January 2010.

Malinova, K. and A. Park (2011): "Subsidizing Liquidity: The Impact of Make/Take Fees on Market Quality", SSRN working paper, 23 November 2011.

Matheson, T. (2011): "Taxing Financial Transactions: Issues and Evidence", IMF working paper, WP/11/54, March 2011.

Meng, X., A. Kirilenko. and R.B., Sowers (2012): "A Multiscale Model of High-Frequency Trading", SSRN working paper, 23 April 2012.

Menkveld, A. (2012): "High Frequency Trading and the New-Market Makers", SSRN working paper, 6 February 2012.

NBIM Discussion Note (2012): "Well-functioning markets", No. 13, 19 November 2012.

New York Times (2012): "Declining U.S. High-Frequency Trading", 15 October 2012.

O'Hara, M., and M. Ye (2011), "Is Market Fragmentation Harming Market Quality?", Cornell University Journal of Financial Economics 100.

Pragma Securities (2012), "HFT and the Hidden Cost of Deep Liquidity", Technical note

Satchell, S. (2012): "An Assessment of the Social Desirability of High Frequency Trading", JASSA The Finsia Journal of Applied Finance, Issue 3, 2012.

Securities and Exchange Commission (2010): "Concept Release on Equity Market Structure", 14 January 2010.

Skjeltorp, J.A., E. Sojli, and W.W. Tham (2012): "Sunshine Trading: Flashes of Trading Intent at the NASDAQ", AFA 2012 Chicago Meetings Paper.

Skouras, S. and J.D., Farmer (2012): "The Value of Queue Priority", Preliminary work presented at Market Microstructure: Confronting Many Viewpoints conference sponsored by ILB

Sornette, D. and S. Von der Becke (2011): "Crashes and High Frequency Trading", Foresight Driver Review 7, Government Office for Science.

Tse, J., Lin, X. and D. Vincent (2012): "High Frequency Trading – The Good, The Bad, and The Regulation", Credit Suisse AES Analysis, 5 December 2012.

Tse, J., X. Lin and D. Vincent (2012): "High Frequency Trading – Measurement, Detection and Response", Credit Suisse AES Analysis, 6 December 2012.

Umlauf, S. R. (1993): "Transaction Taxes and the Behavior of the Swedish Stock Market", Journal of Financial Economics 33 (2): 227-40.

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