



Discussion Paper

Demystifying High-Frequency Trading

A focus on issues facing capital market practitioners

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Summary of Findings on High-Frequency Trading (HFT)

Effect on Market Quality

Question Does the presence of HFT lead to a deterioration of overall market quality?

Findings Research results show that indicators of market quality such as liquidity, market depth, and price discovery have generally improved since the rise of high-frequency trading. Findings about HFT in situations of short-term volatility are still inconclusive.

HFT and Market Abuse

Question Are HFT employing market impairing strategies and if so, what is their impact?

Findings Widespread evidence may be found of market abusive HFT strategies (primarily evolving around “quote stuffing” and “momentum ignition”). As of today, there is no conclusive research concerning the extent and market impact of abusive strategies.

Impact on Institutional Investors

Question Is there a tangible adverse impact of HFT on institutional investors?

Findings While alternative asset managers widely applaud the new market participants, traditional asset managers have mixed feelings towards HFT. Evidence of decreased implementation shortfall and the great time difference in trading horizons indicate that traditional asset managers are not disadvantaged by the new class of traders.

Policy and Regulation

Question Does current regulation address the activities of HFT prudently?

Findings Many HFT strategies are a step in the organic evolution of electronic markets and are prudentially addressed by current regulation. Some abusive strategies, such as quote stuffing, are already prohibited, shifting the need of new rules to the need of more rigorous enforcement of existing rules.

» Objective

As the title of this document suggests, the article tries to put the much talked about phenomenon of HFT into perspective. The primary objective is to explain high-frequency trading (HFT) and the impact it has, in a holistic yet concise manner. As such it should not be understood as an evaluation of the positive or negative effects HFT may have on markets from a macro-economic point of view. However, after studying the material the reader should have a better idea of the origin of HFT, its functionality and its net contribution.

» Rise of High-Frequency Trading

High-frequency trading has come to the forefront of public awareness as a result of the Dow Jones' Flash Crash in 2010 and has since captured further attention with events such as the flawed algorithm inflicting trading losses in excess of 440m USD on Knight Group in the summer of 2012. Intriguingly, despite the circumstance that EU markets have been spared from similar events, several regulatory initiatives are lined up and ready for implementation. Also many industry participants are aware of the presence of HFT, but are struggling to gain a firm grip on the subject. Worries about HFT spark controversies over affected market quality, adverse impacts on institutional investors, and fear of manipulative market strategies. This discussion paper aims to shed light on these pressing issues, facing market participants and regulators alike.

The introduction of the EU's Markets in Financial Instruments Directive (MiFiD) in 2004 and its US counterpart, Regulation National Market System (Reg NMS), brought substantial change to capital markets. For instance the abolition of the 'concentration rule', in which member states could previously require investment firms to route client orders through regulated markets, helped multilateral trading facilities and systematic

internalisers compete against already established exchanges. As a consequence, liquidity is no longer concentrated on one exchange but instead it is spread across multiple venues, resulting in a highly fragmented marketplace. This fragmentation lead traders to utilize more sophisticated trading strategies and opened up new opportunities to arbitrage between trading venues. Henceforth, one may conclude that HFT is a direct reaction to the market fragmentation triggered by the regulation of the early 2000s. Today, HFT is an integral component of capital markets and all stakeholders have to find ways to adapt to the new phenomenon in an appropriate manner.

The first HFT firms entered capital markets in the early 2000s and are using a combination of sophisticated algorithms and state-of-the-art technology to conduct trades. Despite their heterogeneity, most HFT share the following features: Orders are placed and withdrawn rapidly, average ticket sizes are fairly low, positions are rarely held overnight, and algorithms are employed for analysing data and employing trading strategies. The use of algorithms and automated trading is not limited to HFT, institutional investors and investment banks have also embraced similar means for trade execution in the past decade. Consequently, HFT should not be seen as revolutionizing capital markets, but more sensibly as a step up the evolutionary ladder towards fully electronic and automated stock exchanges.

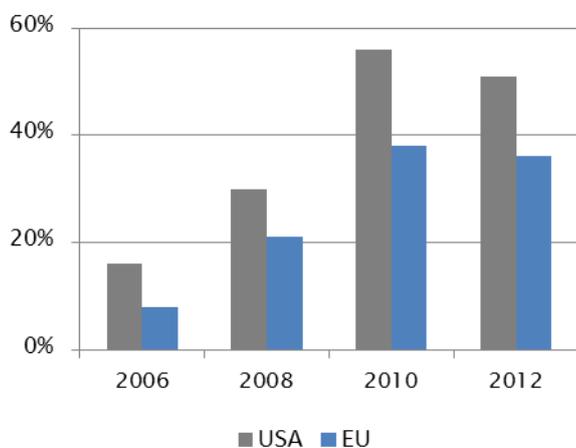
This discussion paper includes a brief **market analysis**, framing the current status quo before a glimpse at different **HFT strategies** will address the question how HFT are actually generating revenues. As a heated debate has evolved around several questions such as the adverse effect of HFT on overall **market quality**, impact on **institutional investors**, and **abusive strategies**, each controversial issue shall be examined in turn. Last but not least, a chapter on **policy and regulation** will discuss the current progress and efficacy of potentially game-

changing regulatory initiatives. The report is primarily discussing the role of HFT in European markets, only drawing on US examples when necessary.

» Market Overview

The HFT industry has experienced rampant growth until 2010, but stagnated in recent years. However, its share maintains a high plateau, making up more than a third of all European equity trading in 2012 (see Exhibit 1). Current trends indicate that competition is becoming increasingly intense and profit margins are eroding as new shops are spawned by the initial wave of success, costs for technology investments increase, and regulatory burdens loom larger than ever. HFT insolvencies are increasing and even established players are struggling. For instance, as the latest SEC filings of industry giant GETCO LLC indicates, the company experienced an increase of 55% in colocation expenses (from 55m to 84m USD) and a simultaneous decrease of 30% in trading revenues (from 856m to 551m USD) leading, among other positions, to a net income decrease from 126m to 32m USD between 2010 and 2012.

Exhibit 1: HFT Percentage of Equity Trading

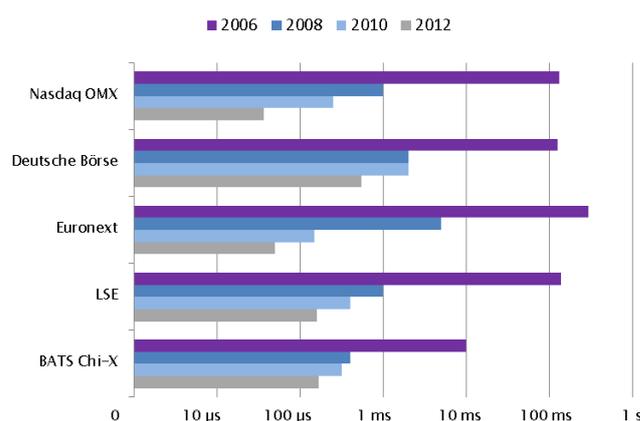


Source: TABB Group 2012

Colocation expenses, referring to the practice of HFT being ‘co-located’ in physical proximity of exchanges, are a mounting technological expense for HFT firms. Office space is rented in the same operations centre of exchanges to minimize the distance of HFT servers to the servers of the exchange. This brawl for the lowest latency (i.e. the fastest execution possible for trades), where the party able to conduct a trade microseconds faster than its opponent may hold a defining competitive edge, also requires extremely powerful and sophisticated matching engines. Exchanges are propelled by HFTs into a notorious race for speed and are competing to provide the lowest round-trip latency for their members. Execution venues have invested heavily in technology, dramatically lowering their latency by a factor of around 2000 from 2006 to 2012 (see Exhibit 2). While in 2006, the best round trip latency ranged within 200–300 milliseconds (ms), the benchmark to beat in 2012 was 100 microseconds (µs). Consequently, not only HFT firms need to invest heavily in new technology but also execution venues have to keep up with the demands of their most active members.

Exhibit 2: Roundtrip Latency¹

[time in log scale]



Source: XIExchange 2006, WFE 2010, Celent 2010, Stock Exchanges, publicly available information

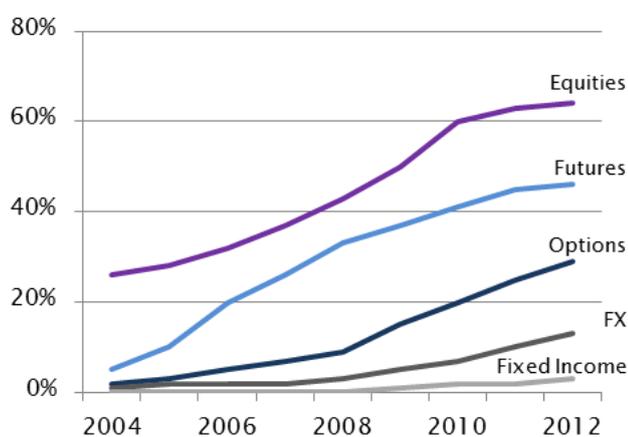
¹ BATS Chi-X Europe latency refers to Chi-X in 2006, and BATS in 2008 and 2010; all figures refer to cash markets.

» HFT Strategies

The HFT market is made up of several types of participants applying a host of different strategies in their business models. The traditional HFT set up encompasses small specialized proprietary trading firms frequently providing liquidity via algorithmic, high-frequency trading. A second group of players are trading desks of investment banks, which utilize similar strategies and technologies as the small HFT firms to make a profit for the bank. The third group consists of hedge funds applying HFT in some of their trading strategies.

HFT are primarily employed in dealing with equities and futures, but in recent years options and FX markets have also attracted HFT (see Exhibit 3). Due to the OTC-nature of fixed-income trading, this instrument has been largely spared, but especially the introduction of electronic fixed-income trading could attract the attention of HFT. The market structure has adapted to new regulations, in the EU namely MiFID, and several new exchanges (such as multilateral-trading facilities – MTF) have created a more entrenched playing field, propelled HFT, and added to the complexities of assessing HFT impact.

Exhibit 3: HFT Percentage of Trading by Asset Class (US markets)



Source: Aite Group 2012

When discussing controversies surrounding high-frequency trading, one must be aware of the different effects certain types of strategies have on markets. Indeed, they are heterogeneous and evidence of academic studies frequently analyzing trading of index values or blue-chip stocks, making it often impossible to isolate HFT strategies yielding only general. Due to the opaque nature of the industry and the vastness of data it is fairly difficult to determine the exact causal effects on markets, but it may be assumed that not all participants are affected equally by HFT activities.

The most prominent strategy employed by HFT is **liquidity provision**. Just like a traditional market maker, the HFT posts a limit bid and ask offer, adding liquidity to the market. The HFT acts entirely as a proprietary trader employing his strategy and attempting to attract liquidity in order to gain the spread. A key difference between traditional market makers and HFT employing this strategy is the omission of permanent quoting duties. Unlike registered market makers HFT may refrain from liquidity provision in exceptional market conditions, such as one side markets. Hence it is not surprising that traditional market makers frown at HFT enjoying that competitive edge – to say the least.

A second group of strategies employed by HFT is **statistical arbitrage**. By no means exclusively used by HFT, it refers to a trading strategy in which historic data analysis is used to discover correlations between two or more related values. Discovered arbitrage opportunities are then exploited by shorting/buying one value and buying/shorting another correlated value and holding both until they converge. Specifically, this process may be applied to the same value traded on multiple trading venues (pure arbitrage), to indices and their basket of underlyings (cross-asset arbitrage) or to related instruments such as two correlating indices (index arbitrage).

Thirdly, **directional trading** is used by HFT to exploit the first-mover effect in events effecting stock markets such as macro-economic events, news and studies about corporations and industries or black swan events. For example a word-recognition algorithm may detect any hints in the speech given by the head of a reserve bank indicating a change in interest rates and act within microseconds of certain terms being spoken. However, this strategy may also backfire in case of misinterpreted information.

Perhaps the most controversial HFT strategy is **liquidity detection**. In this case, a HFT analyses data to detect large orders in the stock market and reacts by buying liquidity from other counterparties and selling it instantaneously to the trader who posted the large order. Algorithms may scour multiple exchange venues in search of such orders, which are frequently hidden and executed by encrypting electronic algorithms themselves. While dark pools where considered initially a safe haven for exchanging large orders, practices such as dark pool gaming (see Exhibit 4) have made these trading venues more vulnerable to liquidity detection strategies.

» HFT and Market Quality

Various concerns have been raised that the advent of HFT has distorted and negatively impacted general market quality. Market quality is defined as the liquidity of trade products, transaction costs and price efficiency. A decrease in market quality would thus imply negative changes in liquidity, transaction costs, or market prices; assumptions which shall be discussed individually.

Most academic studies employ a method of defining the complex phenomenon of **liquidity** as the degree to a market's tightness (size of effective spreads), depth (volume that may be traded at current price level), and resilience (speed at which price returns to initial price after trade impact). Various studies

ranging from the US to Sweden² have found all three indicators of liquidity to have improved in the last five years. Bid/ask spreads have shrunk (tightness), the number of orders in order books has increased (depth), and prices have become less responsive to single orders (resilience). Nevertheless, the positive verdict is perturbed by several indications of higher volatility and decreased liquidity in times of short-term market duress.

Secondly, **transaction costs** referring to the cost of trading have decreased. As computers have replaced human beings and spreads have tightened trading has become cheaper over the past few years. Furthermore, increased competition of new trading venues and clearing houses has further decreased transaction costs.

Finally, **price efficiency**, i.e. the degree to which prices reflect fundamental values, has improved due to information disseminated by HFT. Again, academic studies have found HFT to more frequently trade along permanent price changes, enabling a better price discovery. However, there is evidence that in cases of predatory strategies, such as quote stuffing, the opposite may be true.

» Market Abuse

Whether the obscurity of the industry or the spread of rumours have sparked a debate about cases of market abuse by HFT is hard to determine. Critics maintain that HFT sometimes apply abusive strategies (most frequently mentioned are quote-stuffing and momentum ignition), remaining unnoticed from regulators. De facto, only one fine was levied against a HFT (Trillium Brokerage Services, LLC) due to illegal market activities, i.e. for creating a false sense of buy or sell side pressure, which we will later refer to as momentum ignition.

² Selection: Brogaard (2010), Hasbrouck & Saar (2011), Hagströmer (2012), Menkveld (2012)

Perhaps the most controversial abusive strategy employed by HFT is **quote stuffing**. A HFT bombards an order book with orders and cancels them, statistically resting there for less than a second. Especially MTFs and dark pools seem to be preferred venues for this strategy. Now what is the benefit of posting “false” orders in an order book? Firstly, HFT may trick other trading algorithms programmed to trade on best bid/ask prices into conducting a trade and once their order actually reaches the market, the false order is already withdrawn and they pay a higher price than initially expected (frequently referred to as “stale pricing”). Secondly, quote stuffing creates “noise”, a term referring to sometimes ten-thousands of quotes (the current record is held by PSS World Medical share which noted 47k quotes in one second) initiated by HFT to confuse and slow down other algorithms programmed to process all quotes of certain values. HFT may then exploit other trading opportunities, which remain unnoticed by other overpowered competitors or take advantage of arbitrage opportunities, such as false midpoints in dark pools (see Exhibit 4 for an example of a gamed order in a dark pool).

The market impacts of this strategy are frequently higher spreads, increased volatility, and lower average order book depth in the immediate aftermath of such an event. In drastic cases this may lead to “mini-flash crashes” of certain stocks.

Whereas quote stuffing is fairly recognizable and easy to detect, **momentum ignition** strategies are a good deal harder to detect and frequently remain unnoticed. A HFT increases the volume of the order book in one direction suddenly and simultaneously posts orders on the other side of the book to take advantage of the ignited momentum. This may lead to rapid price moves (up to 5%), increased spreads (up to 8bps), and has an average duration of 1–2 minutes.

Due to this spike in prices, large orders that take hours on average, if unprotected by algorithms, may get filled within minutes, and as the stock’s price moves back to equilibrium, the trader will almost certainly fail to reach the correct volume weighted average price (VWAP). To reach a definite verdict on the extent of market abuse and a quantification of the caused damage is virtually impossible. Evidence

Exhibit 4: Quote Stuffing and False Midpoint Gaming

Time	09:10:15.121	09:10:15.122	09:10:15.123	09:10:15.124	09:10:15.125
Lit Exchange	Qty: 100, BID: 49.0, ASK: 51.0, Qty: 100	Qty: 100, BID: 49.0, ASK: 51.0, Qty: 100	Qty: 100, BID: 50.6, ASK: 52.0, Qty: 100	Qty: 100, BID: 50.6, ASK: 52.0, Qty: 100	Qty: 100, BID: 49.0, ASK: 51.0, Qty: 100
	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100	Qty: 100, BID: 50.0, ASK: 52.1, Qty: 500	Qty: 100, BID: 50.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100
	Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 47.0, ASK: 52.1, Qty: 500	Qty: 100, BID: 49.5, ASK: 52.2, Qty: 500	Qty: 100, BID: 49.5, ASK: 54.0, Qty: 100	Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100
	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 52.2, Qty: 500	Qty: 100, BID: 49.0, ASK: 52.3, Qty: 500	Qty: 100, BID: 49.0, ASK: 55.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100
	Qty: 100, BID: 45.0, ASK: 55.0, Qty: 100	Qty: 100, BID: 45.0, ASK: 52.3, Qty: 500	Qty: 100, BID: 48.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 56.0, Qty: 100	Qty: 100, BID: 45.0, ASK: 55.0, Qty: 100
	Dark Pool	Qty: 50, BID: 49.0, ASK: 51.0, Qty: 100	Qty: 50, BID: 49.0, ASK: 51.0, Qty: 100	Qty: 51.3, BID: 49.0, ASK: 51.0, Qty: 100	Qty: 51.3, BID: 49.0, ASK: 51.0, Qty: 100
Hidden Orders		Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100	Qty: 100, BID: 48.0, ASK: 52.0, Qty: 100
Hidden Orders		Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100	Qty: 100, BID: 47.0, ASK: 53.0, Qty: 100
Hidden Orders		Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100
Hidden Orders		Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100
Hidden Orders		Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100	Qty: 100, BID: 46.0, ASK: 54.0, Qty: 100

Original situation from a trader’s point of view	HFT enters multiple orders on one side of the order book without the intention to trade	Other algorithms react, withdrawing ASK quotes and posting new BID quotes. New mid–point is transferred via EBB0 to the dark pool	HFT cancels orders in lit exchange and places a market order in the dark pool and sells 100 shares to a market order for 51,3	Other algorithms withdraw orders and lit exchange reverts to original situation. HFT turns around and buys for 51
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up to date is sparse and inconclusive. Neither is it possible to gauge the percentage of total HFT activity attributed to such practices, nor to quantify the damage done to other market participants. Yet one may state with a degree of certainty, that existing regulation clearly addresses the majority of abusive behaviours discussed and accordingly there is no need for more intrusive regulation, but instead a stricter and better enforcement would do the trick. Furthermore, as Andrew Bowley, Co-Head of Electronic Trading at Nomura, notes the range of lit and unlit exchanges has further complicated this task, since unmasking such strategies may require monitoring and back-tracing market activity on multiple exchanges.

» Impact on Institutional Investors

Without a doubt, HFT have had a considerable impact on stock exchanges, brokers and traders alike. However, when it comes to the buy-side, the question whether HFT have impacted institutional investors or not becomes difficult to answer. Certainly, strategies such as quote stuffing and events such as the Flash Crash have led to unease among institutional investors³, yet it remains unclear, whether this may be corroborated by concrete evidence or remains largely psychological. Critics presume that due to the higher ratio of posted quotes, which frequently disappear and do not get executed (attributable to massive order cancellations), institutional investors find it harder to conduct block trades and may revert to OTC transactions instead of using lit or dark exchanges.

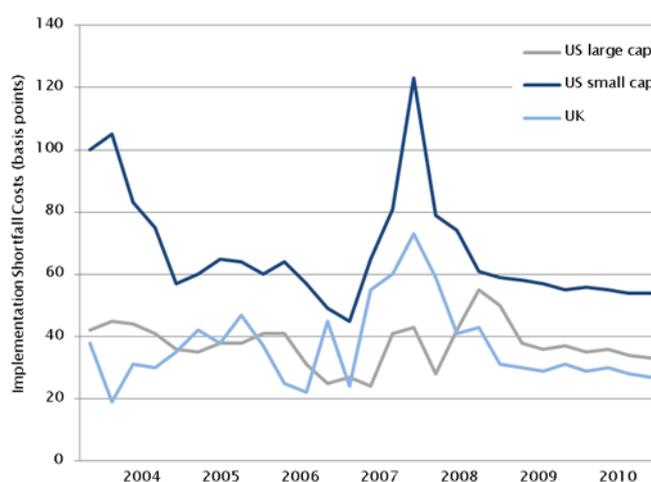
When distinguishing between traditional institutional investors (e.g. asset managers) and alternative investors (e.g. hedge funds), different opinions are voiced. Notably, there is a consensus that overall trading costs decreased. Whereas hedge funds are less concerned about liquidity, market

³ See IOSCO Report (2010), Oliver Wyman (2012), UK Foresight Study (2012)

abuse or transparency issues, opinions of traditional investors indicated unease around these issues.

METIS believes that the impact of HFT on institutional investors is not necessarily harmful. Firstly, the investment horizon of an institutional trader ranges over a long period, making the exact execution prize less relevant for the investor.

Exhibit 5: Implementation Shortfall (US and UK)



Source: ITG (2011)

Furthermore, electronic algorithms are frequently used to break up large orders and the execution may last up to several months. Also, a drop in the implementation shortfall (difference between original and trade price) indicates that institutional investors may actually benefit from HFT (see Exhibit 5). While issues around short-term volatility and market abuse may still stir discomfort among institutional investors, current evidence suggests that they are net benefiterers of the rise of HFT.

» Policy and Regulation

Multiple policies are currently under way to curb high-frequency trading. The first policy aimed at HFT in Europe was a provision to the EU’s Market Abuse Directive in 2010, prohibiting the use of

strategies aimed at manipulating capital markets. The French legislature followed in August 2012 with components of the *Taxe sur les Transactions Financières* (Financial Transaction Tax), specifically targeting HFT. Recently the German Bundestag (Lower House of Parliament) ratified a law amending several capital market laws, commonly referred to as *Hochfrequenzhandelsgesetz* (High Frequency Trading Act), which encapsulates several clauses aimed at restraining HFT and including market infrastructure providers in the regulatory effort. These unilateral moves pre-empt the EU's efforts in setting clear guidelines for HFT with Markets in Financial Instruments Directive 2 (MiFID 2), expected to become effective in 2015 or 2016.

On 22 March 2013 the German Bundesrat (Upper House of Parliament) approved the *Hochfrequenzhandelsgesetz*. The key provisions are:

- Licensing requirement
- Algorithmic trading orders to be flagged
- Order trade ratio
- Minimum tick size
- Market making not exempted
- Excessive usage fee

The law came into force on 15 May 2013 but the application of certain provisions will be subject to transitional periods.

Notably, neither the German nor the French legislation includes the imposition of minimum resting periods on placed orders. A measure that was frequently discussed and is advocated by several political parties, but has not gained sufficient support for implementation. However, minimum resting periods are still on the table for the MiFID 2 regulations and should be closely watched by market participants. Any such imposition would severely impair several HFT strategies. Undeniably, while making markets more liquid and price efficient, HFT have also had negative effects on markets, and even industry associations such as the Association for Financial Markets in Europe (AFME) have called for regulators to step up and set clear rules for fair competition. A closer look at current regulatory initiatives yields a mixed perspective (see Exhibit 6). While some measures, such as the prevention of market irregularities, clearly address pressing dangers, other measures, such as an obligatory registration for HFT with financial authorities, may result in HFT shifting their trading focus to other markets which

Exhibit 6: Assessment of Policies and Regulation

Regulation	Scope	Status	Measures	Assessment
<i>Markets Abuse Directive (MAD)</i>	EU	Effective 2011	List of prohibited market manipulation techniques: - Disruptive or delaying the trading system/venue - Making it more difficult for other people to identify genuine orders - Creating a false or misleading impression about quotes	- First EU response to HFT manipulative trading - Enforcement difficulties due to complex market infrastructure and informational overflow
<i>Taxe sur les Transactions Financières</i>	FRA	Effective Q3/2012	Component on HFT: - Limitation of order-trade ratio - Tax on equity and certain swap (e.g. CDS) transactions	- Slightly increased volatility on French markets - Derivatives trading volumes have increased - Impact is limited because only HFT in France are affected
<i>Hochfrequenzhandelsgesetz</i>	GER	Effective Q2/2013	Legislative changes: - Minimum order-trade ratio - Obligatory registration for HFT at BaFin or EU passport - Reporting obligation upon authority's request - Exchange fee for excessive order placement - Minimum price change quantity - Market participants must prevent market irregularities - Manipulative HFT strategies like "scalping" and "quote stuffing" are prohibited	- Expected direct costs of 0.5-1 m EUR for HFT - Foreign traders may refrain from trading on German markets - Prohibition of manipulative strategies will not have large effect on HFT - Some measures are already practiced and nothing new for market participants (e.g. exchanges applying minimum order-trade ratios, see Xetra Frankfurt or Nasdaq OMX) - Regulators will have difficulties in enforcing new measures

would result in a meaningful impact on market liquidity given HFT's substantial trading share.

Furthermore, it should be mentioned that regulators still lack the technological infrastructure and computational abilities necessary to effectively implement proposed regulation, such as evaluating prohibited trading strategies or assessing the risks of algorithms in their testing phase.

» Outlook

Temporary evidence suggests that HFT has certainly changed capital markets and has led to a slight improvement in market quality. Some manipulative strategies have a negative impact and should be more effectively monitored by regulators. New regulation such as registering HFT and reporting requirements makes perfect sense, yet harsher regulation could impair several HFT strategies and would dampen their positive effects.

The next years are likely to witness a further consolidation of competitors in the HFT arena. Future regulation will curb trading activities of HFT and limit the revenue potential of certain strategies, such as liquidity provision and directional trading. Also, further advances in technology will be closely linked with large investments and will thus make the race for speed and for superior models more demanding. So it is to be expected that HFT will adapt their business venturing out to asset classes or venues which have not been in the focus in the past.