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High Frequency Trading

Costs and Benefits in Securities Trading and its Necessity of Regulations

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1 Introduction

Recent publications reveal that high frequency trading (HFT) is responsible for 10 to 70 per cent of the order volume in stock and derivatives trading (Gomber et al. 2011; Hendershott and Riordan 2011; Zhang 2010). This observation leads to a controversial debate over positive and negative implications of HFT for the liquidity and efficiency of electronic securities markets and over the costs and benefits of and needs for market regulation. Currently the European Union (EU) is considering the introduction of a financial transaction tax to curtail the harmful effects of HFT strategies. The consideration behind this market policy is based on the assumption that the very short-term oriented HFT trading strategies lead to market frictions. This current discourse shows that the arguing parties do not homogeneously define HFT. Reasons for this are the proponents' different but intertwined perspectives, which lead to new unanswered questions in numerous subjects of expertise. From a macroeconomic point of view the question arises if HFT constrains or supports the allocation function of financial markets. Capital market research and information management research raise questions about the future form of intermediation in securities trading and the coming architecture of markets, about the HFT's impact on liquidity and about price volatility. Financial authorities and regulators discuss whether HFT has a stabilizing or destabilizing function on financial systems and how a future regulation should be shaped.

This collection of articles shall help to develop a common definition of HFT and contribute to the ongoing discussions. To that end we have collected articles from representatives of information systems, business management, the Deutsche Bundesbank and the Deutsche Boerse AG. The following scientists and practitioners participated in the discussion (in alphabetical order):

- Prof. Dr. Hans-Peter Burghof and Arne Breuer, Chair of Business Economics, especially Banking and Financial Services, University of Hohenheim, Germany.
- Prof. Dr. Peter Gomber, Chair of Business Economics, especially e-Finance, Johann Wolfgang Goethe-University of Frankfurt, Germany.
- Dr. Joachim Nagel, Member of the Board of Directors, and Dr. Rafael Zajonz, Central Market Analysis, Portfolio, Deutsche Bundesbank, Frankfurt, Germany.
- Rainer Riess, Managing Director of the Frankfurter Wertpapierbörse (FWB), and Michael Krogmann, Executive Vice President of Xetra Market Development of Deutsche Börse AG, Frankfurt, Germany.
- Prof. Dr. Ryan Riordan, Institute for Information Systems and Management, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

HFT is a part of algorithmic trading. Gomolka (2011) defines algorithmic trading as the processing and/or execution of trading strategies by the means of intelligent electronic solution routines (known as algorithms). Thus algorithmic trading encompasses computer-supported trading as well as computer-generated sell-side and buy-side market transactions. Algorithmic trading strategies can be both short-term and long-term oriented.

In general, HFT is defined as real-time computer-generated decision making in financial trading, without human interference and based on automatized order generation and order management. HFT encompasses short-term trading strategies, which – in extreme cases – operate in the range of microseconds using minimal price differences. HFT thus results in minimal profit margins per transactions and exhibits very short holding periods of securities positions.

However, HFT definitions vary and various properties of HFT are not consistently discussed in the literature. Aldridge's (2009) definition of HFT holding periods range from milliseconds to one day. Durbin (2010) on the other hand describes HFT as trading strategies, which covers seconds or milliseconds only. According to Brogaard (2010), HFT is extremely short-term buying or selling with the intention to profit from minimal price fluctuations.

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Further characteristics are often mentioned but are not always included in HFT definitions, such as the exclusive usage by professional/institutional investors in proprietary trading, real-time data processing and direct market access (Dacorogna et al. 2001). Another controversial issue is the avoidance of overnight risk (Aldridge 2009). Other definitions underline the role of HFT as financial intermediary (Hendershott and Riordan 2011) or try to find differences among the implemented trading strategies (Ye 2011).

On the basis of the broad HFT definition given before the authors in this article will shed light on the following questions: (1) How does HFT influence the liquidity and efficiency of electronic securities markets? (2) What are the costs and benefits of, and what are the needs for a HFT regulation?

Peter Gomber analyzes HFT from a market microstructure perspective, and finds HFT to be a central element of the value creation chain in securities trading. As part of the value creation chain, HFT contributes to increased efficiency and reduced explicit and implicit transaction costs. In his eyes, regulation of HFT could lead to dramatic changes in market behavior, while an inappropriate regulation might even be counterproductive for market quality. Gomber sees the problems for profound research on HFT in the lack of data available for empirical studies. Again this leads to adverse effects in discussions of the topic in the public, in the media, and with regulators.

Ryan Riordan also looks at HFT from the perspective of market microstructure and interprets HFT as one form of technological financial intermediation which contributes to the efficiency of operations in exchange trading. In his eyes, HFT plays an important role in the process of price formation and influences the size of transaction costs in securities trading. According to him, one cannot yet say whether HFT will have a positive or a negative impact on the capital markets. However, he sees major advantages in a highly technologized market. It is no alternative for him to turn back the wheels and return to a backward oriented, artificially slowed, regulated trading, which is based on human intermediation.

Rainer Riess and Michael Krogmann describe HFT as the highest evolutionary level of securities trading. In their opinion HFT leads to faster processing of information, to an increase in liquidity, and thus added values for the overall economy. The authors describe how HFT is currently technically realized and integrated into trading operations at the exchange, and deduct their arguments accordingly. From the point of view of Deutsche Börse, HFT is mainly used by institutional investors in proprietary trading and focuses on highly liquid stocks. The authors correlate the rise of HFT with a continuous improvement of the electronic trading system XETRA, which – from the point of view of Deutsche Börse – benefits all market participants in the same way. In the eyes of Riess and Krogmann, a future regulation of HFT should primarily focus on equal chances of competition in the EU-area, in order to create "a level playing field". From the point of view of Deutsche Börse, it is necessary not only to implement security mechanisms on the side of exchanges but also with HFT-firms.

Arne Breuer and Hans-Peter Burghof also recognize that, due to HFT, information can be processed more perfectly and faster than ever before. They look at the topic from the perspective of financial economics. This point of view leads them to believe that more and faster information does not necessarily lead to a correct determination of the intrinsic value of financial instruments. Rather HFT processes short-term information, which primarily is made of short-term volume and short-term time series data, and thus does not contribute to the evaluation of the intrinsic values. The authors vote for a stricter regulation of HFT. However, before this can be done, more analyses should be conducted. For this, more data are necessary.

Finally, Joachim Nagel und Rafael Zajonz argue from the perspective of regulators. A blanket judgment on HFT is from the regulators' point of view neither adequate nor would it lead to improvements of the regulatory framework regarding transparency, stability, and efficiency. The impact of HFT on the efficiency of securities trading is – due to the absence of a scientific discussion – still unclear for the regulators. The possibility to destabilize the market due to HFT in volatile market situations is regarded as critical but should be looked into in detail. From the point of view of the authors "market friendly" strategies exist, a fact which can be judged positively. But there are also "unfriendly strategies", which – from their perspective – can be categorized as potentially harmful. In the center of their article, the authors formulate the wish that this complex topic may be discussed more intensely by the scientific community in the future, in order to better understand which fundamental, regulatory measures should be applied to HFT.

If you would like to comment on this topic or another article of the journal Business & Information Systems Engineering, please send your contribution (max. 2 pages) to the editor-in-chief, Prof. Hans Ulrich Buhl, University of Augsburg, Hans-Ulrich.Buhl@wiwi.uni-augsburg.de.

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2 High Frequency Trading Regulation Required at a Reasonable Level

It is uncommon for a specific subject in the field of securities trading and IT-innovation to draw as much public attention as high frequency trading (HFT) has been doing in recent months. Merely a special field for a small group of experts prior to 2010, it is now a frequent part of the general news coverage. Against the background of the recent debt crisis, the current volatility and market turmoil as well as the "US Flash Crash" on May 6, 2010 lead to this extreme attention. Several parties attempt to exert pressure on politics and regulation by making HFT responsible for that crisis and the high market volatility. In reaction to the aforementioned incidents and to the subsequent public discussions, the regulatory authorities of international financial centers have debated the adoption of various regulatory measures and now propose regulatory procedures, which currently substantiate especially in Europe and will presumably be approved in 2012 in the context of the revision of the Markets in Financial Instruments Directive (MiFID).

Basically, the trading strategies based on HFT can be subdivided into active

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and passive ones. Whereas passive strategies provide other market participants with trading opportunities in terms of quotes and limit orders (e.g. electronic market making), active strategies primarily attempt to exploit imbalances of asset prices in fragmented markets (e.g. primary market and multilateral trading facilities), discrepancies in valuation between different asset classes (e.g. between derivatives and their underlyings) or deviances of current asset valuations compared to historical correlations (e.g. in the so-called pairs trading) immediately after the emergence of these trading/arbitrage opportunities.

The emerging academic literature, which analyzes the effects of HFT based strategies on market quality, shows mostly positive impact (for a systematic outline of academic research concerning HFT see Gomber et al. 2011). Regarding price discovery, liquidity and volatility, most studies discover positive effects of HFT. Only a few publications indicate that HFT can increase the adverse selection problem under specific circumstances, and in the case of the "US Flash Crash" another survey (Kirilenko et al. 2011) reveals that HFT can increase volatility.

The growing market efficiency and a reduction of explicit and implicit transaction costs triggered by HFT is an obvious issue particularly for those market participants who used to capitalize on intermediary services and broad bid/ask spreads in a formerly less efficient and less liquid trading environment. In contrast to off-exchange trading via internalization and so-called dark pools, i.e. non-transparent execution venues, HFT market-making strategies on lit markets face relevant adverse selection costs as they provide liquidity on the market without knowing their counterparties. Within their internalization systems and dark pools in the OTC field, banks and brokers are aware of their counterparties' identities and can benefit from this information. Contrary to this, HFTs in lit markets are not aware of the toxicity of their counterparts and are – analogous to market makers – exposed to the problem of adverse selection.

Inappropriate regulation of HFT based strategies or an impact on HFT business models due to excessive burdens might turn out to be counterproductive and lead to unforeseeable consequences for the quality of markets. However, abusive strategies have to be combated effectively by the regulators. Particularly the analysis of the "US Flash Crash" with its discussed solution approaches can hardly be transferred to the European situation, since the issues related to the "US Flash Crash" primarily result from the US market structure. In Europe, where a more flexible best execution regime is implemented and a share-by-share volatility safeguard regime has been in place for two decades, no market quality problems related to HFT have been documented so far. Therefore, a European approach to the subject matter is required, and Europe should be cautious about addressing and fixing a problem that exists in a different market structure and thus creating risks for market efficiency and market quality.

Any regulatory interventions in Europe should try to preserve the benefits of HFT while mitigating the risks as far as possible by assuring that (i) HFT firms are able to provide documentation on their algorithms upon authorities' request and to conduct back-testing, (ii) markets are capable of handling peaks in trading activity and apply safeguards to react to technical issues of their members' algorithms, (iii) a diversity of trading strategies prevails to prevent systemic risks, (iv) co-location and proximity services are implemented on a level playing field, (v) regulators have a complete overview of the possible systemic risks which could be triggered by HFT, and have employees who have the knowledge and the tools to assess the impact of the trading algorithms on market quality and the associated risks. Furthermore, it is crucial that market places in a fragmented environment develop coordinated safeguards und circuit breakers, which mirror the HFT reality and enable all market participants to react adequately even in market stress.

Regulatory proposals demanding continuous liquidity provision by HFT in the sense of market marking obligations or minimum quote lifetimes miss the mark and are not suitable to improve market stability or market integrity. They rather contribute to a decrease in market quality and higher transaction costs.

At first sight, demanding obligations for HFTs to provide quotes seems an appropriate measure to tackle the problem of a sudden liquidity withdrawal. However, it is highly doubtful whether any rule can force market makers to buy in the face of overwhelming selling pressure. In such a situation they might rather take the risk of being fined for not fulfilling their obligations. Many HFT strategies are characterized by rapid closing of built-up positions to minimize risk. Hence, an obligation to provide liquidity and thereby risk capital is in sharp contrast to many HFT business models. Due to the significant regulatory costs those obligations would potentially lead to a retreat from the market and thus to a notable loss of liquidity.

Also a minimum order lifetime, which at first glance appears to be useful to avoid fast order submissions and immediate cancellations, would lead to a significant change in market behavior. Market participants are then no longer able to react quickly and adequately to market-exogenous information (e.g. ad-hoc news) and the necessity to keep an order in the order book presents a free option for other market participants. Besides, the existence of minimum order lifetimes would lead to an implementation of trading strategies capitalizing on the "lock in" of orders. HFT would anticipate the accompanied risks and costs and attempt to compensate these costs with higher spreads, which again would have negative effects on market quality. In this debate it should not be neglected that speed is the key tool for HFTs' risk management.

HFT is an important factor in markets that are driven by sophisticated technology on all layers of the trading value chain. However, discussions on this topic often lack sufficient and precise information. A remarkable gap between the results of academic research on HFT and its perceived impact on markets in public, media and regulatory discussions (European Commission 2010) can be observed. Here, the provision of granular and reliable data by the industry can assist empirical research at the interface of finance and IS to provide important contributions to a reasonable regulation of HFT. This regulation should eventually minimize the inherent risks of the technology in question without hindering the indisputably existing positive effects for market quality.

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3 High Frequency Trading (HFT) – A New Intermediary

Financial markets require intermediaries to provide liquidity and immediacy for

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other participants. These intermediaries, often called market makers or specialists, were often afforded special status and located on the trading floor, or close to the trading mechanism of exchanges. The automation of financial markets has increased their trading capacity and intermediaries have expanded their use of technology. This has resulted in a reduced role for traditional human market makers and led to the rise of a new intermediary, referred to as high frequency traders (HFTs).

This development has been made possible by the technological innovations in recent years. HFT strategies usually make use of the high speed technologies to build up and unwind positions within milli- and microseconds. Prerequisites for this development were the reduction of system latency and the increase of computing power and data processing capabilities of computers. Next to the large investments in HFT, exchanges have also invested large amounts of money in their IT infrastructure. For example, the costs of a high-speed connection between Chicago and New York are estimated around \$200,000 per mile (Forbes 2010). The question remains whether these investments are justified with regard to the increase of overall market quality and welfare that results from higher HFT activity on the market.

Like traditional intermediaries HFTs hold little inventory, have short holding periods, and trade often. Unlike traditional intermediaries, however, HFTs are not granted preferential access to the market not available to others and they employ advanced and innovative technology to intermediate trading. Without such privileges, there is no clear basis for imposing the traditional obligations of market makers on HFT. The substantial, largely negative media coverage of HFT and the so called “flash crash” on May 6, 2010 raise significant interest and concerns about the role HFT play in the stability and price efficiency of financial markets. The predominantly negative coverage seems mostly unfounded.

Overall, HFTs’ impact is similar to that of other intermediaries and speculators. Speculators can improve price efficiency by obtaining more information on prices and by trading against pricing errors. Manipulative strategies and predatory trading could decrease price efficiency. Reducing pricing errors improves the efficiency of prices. HFTs’ informational advantage, which is driven by the technology they employ, is short-term. It is unclear whether or not this short-term information and intraday reductions of pricing errors facilitate better financial decisions and resource allocations by firms and investors. If the short-term information – that HFTs price in – would not otherwise become public microseconds later, HFT clearly plays an important role (Hendershott and Riordan 2011). It would be an important positive role of smaller pricing errors if these corresponded to lower implicit transaction costs by long-term investors.

One important point left unaddressed thus far is whether or not HFTs engage in manipulative or predatory trading. Their use of technology may allow HFTs to manipulate prices at speeds that are undetectable by slower traders. A manipulative strategy might be the ignition of a price movement in one direction only in order to trade on the opposite side of the market as proposed by the SEC (2010) and therefore cause significant pricing errors. As is frequently done, one can argue whether the underlying problem of possible manipulation lies with the manipulator or the market participant who is manipulated. In the SEC example, the passive manipulation could not succeed if there were no price matching. The manipulation stories could be tested with more detailed data identifying each market participant’s orders, trading, and positions in all markets.

Despite the strong evidence of the positive role of HFT for the efficiency of price determination and trading costs (Hendershott et al. 2011; Brogaard 2010; Zhang and Riordan 2011), regulators and the media are certain that they must be regulated. It is, however, unclear and also debatable how we should regulate HFT. Assuming that some, or most, of their activities contribute positively to liquidity and price efficiency, which parts of their trading should we regulate? There are controversially discussed suggestions to restrict HFTs’ mostly passive trading or to enforce a minimum order life on limit orders. Restricting HFTs’ ability to trade actively necessarily impedes their ability to manage the risks associated with intermediation. This may lead to less intermediation and lower liquidity. Imposing minimum order lives on limit orders may also negatively impact HFTs’ ability to manage trading risks during volatile market periods that existed before HFT dominated the equity market.

Finally, the discussions of US and European regulation should take into account specific differences of both markets. Despite the high market fragmentation, the European market has maintained a comparably high degree of efficiency. This is also due to the help of HFTs. They make use of arbitrage strategies to dissolve existing price deviations within seconds which results in an interconnectedness of European markets.

A final point is a more general one on technology investments. HFTs must make a large and long-term investment in technology, both hardware and software. This investment in technology seems to have to paid-off both for HFTs and the equity markets. If regulation were to negatively impact the returns on investments in HFT technologies by reducing the profitability of intermediation, fewer firms will be willing to invest in these technologies. This may lead to a situation in which one or two highly specialized firms dominate intermediation, which ultimately leads to less competition, lower liquidity and reduced price-efficiency. Competition, ease of market entry and the use of specialized and innovative technology seem to be the best guarantors of market stability.

It is hard to imagine a situation in which HFTs are able to artificially manipulate prices for longer periods of time given the intense competition other HFTs. HFTs are one type of intermediary. When thinking about the role HFT plays in markets it is natural to try to compare the new market structure to the previous market structure. Some primary differences are that there is free entry into HFT, HFTs do not have a designated role with special privileges, and HFTs do not have special obligations. When considering the optimal industrial organization of the intermediation sector, which includes regulation, market structure, technology and incumbency, HFT more closely resembles a highly competitive environment than traditional market structures. A central question is whether there were benefits of the more highly regulated and less technology intensive intermediation sector which outweigh the costs of lower innovation and higher entry costs typically associated with regulation. The answer to this question seems thus far to be a resounding “no”.

Prof. Dr. Ryan Riordan
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4 High Frequency Trading – An Exchange Operator's Perspective

4.1 High Frequency Trading – Myth and Reality

On 2010-09-30, the U.S. Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC) (2010) issued a joint report showing that the so-called "flash crash", a sequence of events which made prices plunge throughout the US stock market, was caused by an incorrectly programmed trading algorithm of a traditional investment company which did not use high frequency trading (HFT). Nevertheless, HFT has gained massive public attention ever since. The news media, as well scientists and regulatory authorities, are busy discussing and analyzing the effect of HFT on the global capital markets. While the public perception of HFT is largely critical – and driven by headlines demanding a HFT ban or, at least, strict regulation – scientific analysis comes to rather different conclusions (see Gomber's discussion above). According to Brogaard's (2010) study of HFT, blaming HFT for the US flash crash is not the only popular fallacy regarding the role of HFT in securities trading. Brogaard's analysis of NASDAQ data showed that for 65% of the time HFT accounted for the best bid and ask quotes. Also, Broogard found no evidence suggesting that HFT firms systematically engage in market abuse, e.g. by illegally taking advantage of information about client orders, the so-called "front running". Since HFT firms are proprietary traders, they do not have any clients. Generally, scientific analysis did not find a correlation between HFT and market abuse. The Netherlands Authority for the Financial Markets (AFM 2010) considers HFT as a legitimate trading method which is not market abusive under normal circumstances. According to Gomber, academic papers mostly could not find evidence for negative effects of HFT on market quality. Moreover, the Germany-based Karlsruhe Institute of Technology (KIT) concluded their study based on analysis of NASDAQ data with the finding that HFT even worked as a buffer against plunging stock prices during the crisis years 2008 and 2009 (Zhang and Riordan 2011).

4.2 Insights of an Exchange Operator

We live in a technology-driven society, continuously striving to further improve and advance the achievement potential of our economy as well as of nearly every aspect in our everyday life: can anyone imagine a commercial flight today without the aid of an autopilot, or modern microsurgery without robotics? These advancements are by no means ends in themselves but serve a greater good. Just the same goes for the ever increasing speed in securities trading – a development which leads to continuously improving general market quality and also to more efficient risk management for every market participant. The faster the market data transmission, the faster investors are able to adapt to ongoing market developments. This does not only have a very positive effect on the safety in securities trading but also on transaction cost: faster trading leads to tighter spreads and, therefore, to higher liquidity. The implicit transaction costs of every securities trade are determined mainly by liquidity and account for up to 80 percent of the overall transaction costs, while the explicit transaction costs – commissions, fees, taxes – are of minor significance. With this in mind, Deutsche Börse started long before the advent of HFT to improve the trading infrastructure of its electronic trading platform Xetra, especially in view of ever decreasing systemic latency. At the same time, Deutsche Börse further developed the security mechanisms and technologies respectively adapted them to the increasing demands of a more and more sophisticated and faster trading system, one of them being the very effective instrument of the volatility interruption, introduced in 1999. This security mechanism is used in extremely volatile market phases and leads to higher price stability: whenever an indicative price is outside the price range – which is pre-defined for every security traded on Xetra – a volatility interruption will be initiated around the reference price.

While continuously advancing the technical infrastructure, Deutsche Börse expanded its offer of individually selectable bandwidths for market participants connected to Xetra from 512 Kbit/sec up to 2 Mbit/sec for their Values API interfaces. In 2008, for Xetra members requiring even faster market data transmission and more order book depth, an additional interface with a bandwidth of 1 Gbit/sec was implemented, called Enhanced Broadcast Solution respectively Enhanced Transaction Solution. Today, bandwidths of up to 10 GBit/sec are available. With the introduction of the so-called "non-persistent" orders in 2009, Deutsche Börse further enabled Xetra members to optimize their response times to price changes thanks to even faster data processing. "Non-persistent" orders are not saved in exchange systems and are thus designed not be executed after volatility interruptions.

In late 2011 Deutsche Börse complemented its connectivity portfolio with the FIX (Financial Information Exchange) gateway. Market participants using this protocol now are able to connect to Xetra far more easily.

However, there was one latency factor left that even the most sophisticated technology could not overcome: the propagation delay due to physical distance. For every 100 km which a market participant's trading engine and the trading system of Xetra are physically apart, transaction latency increases by 1 msec approximately. This could mean a true competitive disadvantage for market participants relying on ultra low latency. Deutsche Börse addressed this growing market demand by introducing its proximity services in 2006. By placing the trading engine of distant Xetra members not only virtually but physically close to the exchange back end – a process called co-location – the travel time of the market data could be drastically reduced. Today, 141 Xetra members take advantage of Deutsche Börse's co-location offer.

Thanks to a continuously perfected trading infrastructure and the introduction of proximity services, Deutsche Börse has not only remained competitive on an international level but has also prepared Xetra optimally for the needs of HFT firms. Over the last few years, systemic latency on Xetra has been further reduced notwithstanding a dramatic increase of technical transactions – an advantage to all market participants alike: a fair, equal access to Xetra and the pre- and post-trade transparency characteristic of a regulated exchange make sure that every investor enjoys all advantages Deutsche Börse's trading platform has to offer.

While being a minority, HFT firms nevertheless play an important role in improving the order book quality on Xetra, e.g. by bundling the very heterogenic order flow. There are three orga-

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nized forms of HFT on Xetra: the proprietary trading of investment firms, hedge funds, and proprietary trading companies. Two types of trading prevail: first of all, the so-called electronic liquidity provision. In this case, HFT firms act as voluntary market makers, adding liquidity to a multitude of securities. The second type of HFT on Xetra is called statistical arbitrage which leads to improved price discovery. Both types of HFT account for tighter spreads and, ultimately, improved market efficiency on Xetra. So far, Deutsche Börse could find no evidence of HFT having lead to destabilizing markets during periods of market turmoil, e.g. by strengthening trends. During the highly volatile market phase in August 2011, the trading volume on Xetra increased temporarily to 107 million transactions on one single day. Despite up to 30 volatility interruptions, the average transaction processing took only 0.4 msec longer than usual. System availability was guaranteed at all times, Xetra members did not have to face any restrictions, let alone system failure. Deutsche Börse's market security mechanisms made sure that all trading activities could be executed properly and continuously while price stability was guaranteed even during market turmoil.

Thus, Deutsche Börse succeeded in advancing the Xetra infrastructure in terms of continuously decreasing systemic latency and, at the same time, met the permanently increasing needs regarding safety and speed of its trading system even before the term HFT came up.

4.3 Regulatory Recommendations

Within a national economy it is the explicit function of a securities exchange to facilitate the most efficient employment of capital, ensuring best possible corporate financing and re-financing. HFT, as it is today, supports faster processing of economically relevant data and leads to higher liquidity in the trading of company shares. Thanks to a stable, high-performance trading system, Deutsche Börse was able to integrate HFT successfully and to use the positive effects of HFT to improve overall market quality. This would not have been possible without Deutsche Börse's principle of equal access and a fair set of rules applying to every market participant trading on Xetra alike. From a regulatory perspective – and keeping MiFID's ultimate goal of creating an EU-wide "level playing field" in mind – comprehensive rules regarding HFT definitely would make sense. Therefore, Deutsche Börse supports all measures to enhance transparency, e.g. the complete registration of all market participants and a full recording of all their trading activities – traditional trading and HFT alike. The Deutsche Börse (2011) has come to the conclusion that regulatory intervention in HFT must not hurt the proven positive effect on market quality HFT has to offer. In particular, the variety of HFT strategies should be preserved, as systemic risk should be prevented. To achieve these goals, HFT firms themselves may have to implement security mechanisms – just as exchange operators as Deutsche Börse already have.

Whichever regulatory rules may be implemented in the end, the regulators will have to make sure that these rules apply to every European market and to every market participant in Europe to the very same extent.

Rainer Riess
Michael Krogmann
Deutsche Börse AG

5 Paradigm Change Through Algorithmic Trading

5.1 Introduction

Algorithmic trading nowadays often accounts for more than half of trade volume and order volume at large stock exchanges. Its net effects are generally found positive by researchers. Only few voices from the scientific community – more, however, from traders – point out negative effects of algorithmic trading. A notable difference lies between empirical findings – that usually find positive effects – on the one hand, and some theoretical works and especially the sentiment of traders, who often express their frustration about their computerized counterparts, on the other hand.

5.2 Availability of Data

Most scientific studies about algorithmic trading share one fundamental problem: data about algorithmic trading are scarce. As one of the few stock exchanges, Deutsche Börse had for some time quite reliable data on algorithmic trading. Their "Automated Trading Program" (ATP), which was in effect from 2007 to early 2009, enabled them to distinguish between algorithmic orders and human ones (Deutsche Börse 2009). Hendershott and Riordan (2011), Gsell (2009), Groth (2009), and Maurer and Schäfer (2011) analyze such datasets which contain flags for orders placed within the ATP environment. Their research questions differ, but they all more or less conclude that the overall effect of algorithmic trading is positive.

A fundamental critique of such analyses is that algorithms usually work well in "normal" markets and then show the often-found positive effects. The models that algorithms base on are abstractions of reality and must fail to reflect it in its entirety. If a market situation is not part of the possibility space of the model, several options are possible: The algorithm halts trading and waits until the market is "normal" again, thereby facing the risk to generate possibly considerable losses. Another option is to continue trading using the usual model, thus failing to trade optimally and possibly worsening the situation. Since the flash crash on May 6, 2010, there have been repeated miniature flash crashes that did not affect the whole market but only individual stocks. For both phenomena, algorithms are blamed to be the cause of the market irregularities.

However, an effective approach to regulation should base on well-established results. A lot of work has to be done here. Above all, the insufficient availability of appropriate data confines scientific progress. The deduction of the effect of algorithmic trading on the market from anonymous order book data can only be very rudimentary. In our current work, we attempt to find a way to analyze algorithmic trading activity whilst only using anonymous order book data (Breuer and Burghof 2011). A mandatory flagging of algorithmic orders would be desirable. Only then would it be possible to independently analyze algorithmic trading from many points of view and estimate the effect on the market. The restrictive handling of historic ATP data by Deutsche Börse does not build confidence but could increase the probability that the sentiment towards AT is influenced by irrational fears.

5.3 Information Efficiency

Recent studies (Hendershott and Riordan 2011; Gsell 2009; Groth 2009; Maurer and Schäfer 2011) analyze rather short-term aspects of market microstructure in an AT environment. Indeed, its existence

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alters behavioral incentives of other market participants fundamentally and in the long run. It is apparent that algorithms process new information ever faster and – assuming normal market conditions – probably calculate its price impact better than humans. It is still to be seen, however, how accurate trading algorithms process information without slow human traders monitoring them. Sometimes, the superfast processing of news can be undesirable. An example for this is the news about the bankruptcy of United Airways. The airline's stock price plummeted until it became clear that the news was already a couple months old. Because the possibility to extract yields from new information has a very short and decreasing half-life, systems tend to react hastily and without challenging the information. Especially in delicate market situations, rumors can develop a destructive power.

The effect that is likely to be most important has however escaped scientific analysis so far. Capital markets are a highly efficient instrument of capital allocation, especially because a large number of actors feed information into the price via their trading activity. This information comes from various sources; it may be obtained haphazardly or with some effort. Algorithmic trading uncovers trade activity which is caused by that information and uses this knowledge to pocket a considerable part of the information yield. The better these algorithms work, the less money the informed person will make out of this information. In the long run, this could mean that the costly generation of information turns unprofitable, and in an extreme case even the trade based on incidentally obtained information does not pay anymore.

In such a hypothetical market, ever less information is traded ever more perfectly and faster. The market draws nearer and nearer the weak form of market efficiency (Fama 1970) or eventually even the semi-strong form of market efficiency. At the same time, it moves away from the strong form of market efficiency, because the incentive to feed information into the market becomes considerably less powerful. It is this very effect that traders witness when they trade against algorithms. They know that information-based strategies are detected rapidly and thwarted by appropriate front-running strategies (Biais et al. 2010; Cvitanic and Kirilenko 2010). Surly, there is still a need for theoretical as well as empirical analysis here, because due to these thoughts, the usefulness of algorithmic trading is subject to scrutiny.

5.4 Regulation and Regulatory Instruments

Regulatory considerations have to distinguish between the different types of algorithms. Limit orders which are bogus orders or part of quote-stuffing techniques have to be considered under the light of laws against market manipulation (e.g., §20a (1) No. 2 of the German Securities Trading Act [WpHG]). Other strategies improve the price quality by arbitraging prices and equalizing them across different trading venues. Because of the market power of algorithms, there is the risk that overly mechanic thinking and potent algorithms may perturb the price formation process. Naturally it would be desirable to capture the positive effects of algorithmic trading and to dampen the potentially negative ones. There may be more than one way to reach this aim.

A simple ban of algorithmic trading, as sometimes demanded by certain political circles, cannot serve to reach this difficult aim. This would mean to also destroy many preferable effects of algorithmic trading. Of course, a distinction of algorithmic and "normal" trading is not easy. And certainly market participants would program algorithms that operate in the gray area to hide their true nature.

Currently, regulatory bodies are discussing possible means (Dombert 2011). The often contemplated lower boundary for limit order lifetimes is regarded sceptically. The comprehensible reason is that an efficient risk management of orders would be drastically complicated – especially, but not exclusively, in volatile markets. Dombert (2011) proposes an alternative that is worth discussing. With an order-transaction-ratio, the number of orders divided by the number of transactions would have to remain above some exogenous constant.

In our view, a European regulatory framework is desirable that defines the playground for all market participants. Within this framework, it should be left to the trading venues how they wish to treat algorithmic trading in the context of their business model. Then it would be up to them if they wanted to attract algorithmic trading or to limit it in specific market conditions. Such a "menu-approach" leaves it in essence to the individual trader if he or she wishes to face the competition from algorithms with all their positive and negative effects or evade them by trading on trading venues with appropriate restrictions that apply always or under specific market conditions.

5.5 Conclusion

As long as algorithms operate in the dark, there is a profound uncertainty about the effect of their activities. Therefore, algorithmic trading is partly in contradiction to fundamental principles of stock exchanges: bringing buyers and sellers together in a transparent manner. On stock exchanges, trust is paramount. The opacity of algorithmic trading – as comprehensible it may be from the point of view of their operators – undermines this principle. Currently, there is no level playing field. However, it is equally important to enable technical progress, which algorithmic trading with its high-quality information processing definitely is. An improved availability of data and associated scientific research can help to develop reasonable regulatory frameworks for algorithmic trading. With the increasing importance of this way of trading in mind, there is less and less reason to doubt that the implementation of appropriate regulatory frameworks should have a high priority.

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6 High Frequency Trading – A Central Bank View

The capital markets are currently at an important juncture in their development. Roughly half of all stock and foreign exchange trades conducted on the major exchanges are no longer initiated by human traders; instead, they are the product of computer algorithms that are able to analyze large volumes of data and initiate hundreds of orders in fractions of a second. Humans are increasingly being eliminated from the immediate decision-making process relating to the sale and purchase of assets and being replaced by software programs.

The speed with which orders are executed has become to be the most important factor and is now measured in milli- and microseconds. New practices such as "co-location" or "quote stuffing" – placing huge quantities of buy or sell orders which the instigator intends to cancel almost immediately before they are executed – have become important instru-

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ments in the battle for the most rapid order execution. Fundamental data on the value of the respective securities or currencies are of no, or only subordinate, importance for HFT algorithms.

In HFT, positions are usually held for between a number of milliseconds and several hours. In today's high-speed markets, the scales are no longer tipped in favor of the investor who is best able to assess the true value of an asset, but of the investor able to trade fastest. True investments are becoming increasingly rare.

Since the "flash crash" of May 6, 2010 (a roughly 15-minute phase of unusual and irrational volatility on the New York Stock Exchange), HFT has been called to the attention not only of the general public but also of regulators and central banks.

Numerous observers regard HFT as a new technical means of executing existing trading strategy rather than a strategy in its own right. Advantages in terms of speed have, they say, always been an essential component of many successful trading strategies. Seen from this perspective, HFT is not a completely new phenomenon, but rather a technical evolution of the securities markets. HFT should be regarded merely as an overarching term covering a multitude of different fields of use. Among the many tactics, several of the most important are based on providing liquidity in stock market trading (market making). Others can be included under the category "statistical arbitrage" and use algorithms to swiftly identify and exploit profitable trading opportunities based on price data. Others belong to a category known as liquidity detection, in which traders try to seek out hidden large orders in order books. Many critics term this "predatory trading", and it is suspected of being unfair and potentially damaging to the market.

Against this complex background, any assessment of HFT and all discussion relating to potential regulation should, where possible, be limited to the underlying HFT strategy. From a central bank perspective, a sweeping judgment on HFT is therefore neither appropriate, nor would it serve to improve the regulatory framework for transparency, stability and efficiency. That means that both the advantages and disadvantages of HFT need to be evaluated very specifically. Statements that HFT is in general either good or bad for the market should therefore be viewed with caution.

HFT players and exchange operators are at pains to stress that overall HFT perceptibly improves market liquidity and the efficiency of price discovery (McEachern Gibbs 2009). The majority of investors benefit from reduced bid/ask spreads – a common measure of liquidity, they say. This statement is backed up by several scientific studies (Gomber et al. 2011). However, there is increasing evidence to suggest that, especially in very volatile market situations, HFT could prove problematic and could additionally destabilize the market (Brogaard 2010). This must be investigated and, if found to be true, regulators must step in to limit the risks for the financial system.

The flash crash demonstrated that the liquidity generated by HFT market makers, which usually keeps transaction costs low, may suddenly evaporate in difficult market phases (NANEX 2010). Unlike regular "human" market makers, who are obliged to remain in the market even in times of extremely volatile prices, HFT traders are generally not bound by such constraints. In good times, HFT traders therefore crowd out normal market makers and often even perform their role better, to the advantage of all market players. In difficult markets, however, there is a risk that trading flows could collapse with all the attendant problems for the market as a whole, as HFT players withdraw. To many market participants, the narrower bid/ask spreads and higher trading volume generated by HFT therefore only represent "sham liquidity". For this reason there have been calls from various quarters to oblige HFT market makers to remain in the market even in times of high volatility, similar to the obligations imposed on normal market makers (EC 2010). In other words, they should start to take some responsibility for the markets which they have, to date, merely used to their advantage from their superior position.

From a regulatory perspective, HFT has proven problematic not only in these rare but dramatic high volatility events, but also in daily trading activities. While bid/ask spreads have dropped significantly in recent years thanks to HFT market makers, the average period for which such players hold positions has dropped sharply. According to a study on the flash crash, most HFT market makers close out their positions after no more than roughly 10 seconds (Kirilenko et al. 2011). That means that the stabilizing effect in the event of heightened market volatility exerted by "normal" market makers has given way to a "hot potato effect", where falling shares are merely passed around at lightning speed.

As HFT has become more widespread, the number of buy and sell orders has increased dramatically in recent years. The tactic known as quote stuffing, which is used by several HFT algorithms, is particularly problematic. For reasons of trading strategy, the HF trader places a large number of orders per second, only to cancel them again almost immediately before execution. The very high cancellation rate this causes leads to a marked divergence between apparent market liquidity and actual trading volume. An investor placing an order in response to a bid or ask is therefore often unable to carry out the transaction at the limit shown. Although the explicit transaction costs appear low, the implied costs may be much higher. Apparent market liquidity and the size of bid/ask spreads are therefore not by themselves reliable indicators of market liquidity and efficiency.

An analysis of 1,172 trading days on the New York Stock Exchange from 2007-01-01 to 2011-09-14 that was carried out recently by the research firm NANEX showed that there were just 35 billion real transactions for 535 billion quotes. The quotes-to-trades ratio needed to generate US$ 10,000 in real transaction volume moved from roughly 6–7 at the beginning of 2007 to 60–80 in mid-2011. Higher figures indicate a less efficient market: more information is required to achieve the same trading volume. Sudden and dramatic spikes in the number of quotes are increasingly being observed for individual US stocks, with individual HFT algorithms generating several tens of thousands of quotes per second for several seconds. Such bursts of activity are frequently accompanied by what are known as "mini flash crashes", where securities lose 20%, 40% or even more than 50% of their value in a space of seconds for no fundamental reason, only to recover shortly afterwards. For instance, according to the SEC, the United States has witnessed more than 100 such inexplicable crashes since mid-2010 which are suspected of being caused by HFT algorithms.

Sending bids or asks is similar to sending spam email: both are virtually free for

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the sender, but not for the recipient. Forwarding and processing such large volumes of data causes a lot of problems and high costs for exchanges and market participants. Systems are often overloaded, which is seen by many observers as one of the causes of the flash crash. To make matters worse, certain HFT algorithms send some of these quotes only to cause other traders or algorithms to act in a certain way, which they can, in turn, exploit. As a consequence, an ever increasing number of institutional investors are transferring their transactions away from normal exchanges to "dark pools", where it is usually more difficult to make a profit in HFT.

The above-described criticisms intend to show that HFT is a controversial issue, requiring an exact analysis of the details. In addition to "market friendly" strategies that regulators regard as positive for the market – for instance, statistical arbitrage – there are also "unfriendly" strategies that are seen as worrying. Others are basically welcome but when actually applied on the market entail problems and dangers which should be eliminated. HFT market making is just such an example.

When considering the ultimate question of whether there is a correlation between HFT and market efficiency, it should be borne in mind that market efficiency mainly means that the price of an asset adjusts to fundamental changes in its value rapidly. It is not immediately clear how HFT algorithms can contribute to that, as decisions are based only on the status of the order book in the last few seconds or indicators based on technical analysis. A block trade of 10,000 shares between two well-informed large investors represents true price discovery on the market. By contrast, shifting 100 shares back and forth between two HFT algorithms in innumerous times makes no equivalent contribution to trading efficiency, even if this takes place at impressive speed. A market that is mainly dominated by HFT is also a market where most orders have lost all connection to fundamental factors. And this correlation between price and fundamental value is what should, in the main, determine the quality of a market.

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