2016

Analyzing Information and Value Flows in High-Frequency Capital Markets

Tobias Engel
University of Applied Science Neu-Ulm, tobias.engel@hs-neu-ulm.de

Andreas Englschalk
Technische Universität München, englschalk@mytum.de

Natascha Bell
Technische Universität München, natascha.bell@gmail.com

Markus Böhm
Technische Universität München, markus.boehm@haw-landshut.de

ANALYZING INFORMATION AND VALUE FLOWS IN HIGH-FREQUENCY CAPITAL MARKETS

Completed Research

Engel, Tobias, University of Applied Science Neu-Ulm, Neu-Ulm, Department of Information Management, Germany, tobias.engel@hs-neu-ulm.de

Englschalk, Andreas, Technische Universität München, München, Department of Information Management, Chair for Information Systems - I17, Germany, englschalk@mytum.de

Bell, Natascha, Technische Universität München, München, Department of Information Management, Chair for Information Systems - I17, Germany, natascha.bell@gmail.com

Böhm, Markus, Technische Universität München, München, Department of Information Management, Chair for Information Systems - I17, Germany, markus.boehm@in.tum.de

Abstract

High-frequency trading has significant influence on today's capital markets and has received massive attention in the media. This research aims to provide a conceptual understanding of high-frequency capital markets by analysing information and value flows between relevant high-frequency trading market participants. In a first step, market participants including traders, brokers, market platforms, technology providers, information providers, and clearing agencies are introduced. Second, the trading process is described focusing on the three most important phases, namely the information phase, order routing phase, and order matching phase. Furthermore, we review widely adopted high-frequency trading strategies such as market making, arbitrage trading, and pinging. Expert interviews are used to provide practical insights on the perception of high-frequency trading and the necessity for improved regulation. We merge theoretical knowledge and our findings from practice to develop the HFT Value Information Framework visualizing information and value flows between market participants. We discuss the interrelations between market participants in current high-frequency capital markets and describe implications for different stakeholders. Finally, the implications for regulatory bodies are discussed and possible future research opportunities are identified.

Keywords: High-Frequency Trading, HFT, Information Flow, Value Flow.

1 Introduction

In January 2007, the New York Stock Exchange (NYSE) introduced a hybrid market enabling investors to choose between executing market orders via a broker or an automated exchange system. The introduction of the automated exchange system decreased average execution time of (large-stock) market orders from nine seconds to less than one second per trade (Hendershott & Moulton, 2007). Investors have since continued to automate trading processes using computer generated trading decisions, electronic order submissions, and post-trade order management (Brogaard, 2010; Hendershott & Riordan, 2009). Simultaneously, market platforms have replaced traditional floor trading by electronic limit-order books and electronic order matching engines (Jain, 2005; Liu, 2005). Hence, increasing execution speeds have enabled various high frequency trading (HFT) strategies such as high frequency (HF) market making, pinging, and arbitrage trading (Cvitanic & Kirilenko, 2010). In 2010, the economic and financial impact of HFT was reflected in a 300 million dollar investment into a fibre-optic cable, which accelerated order transmissions between the Chicago Mercantile Exchange and the NASDAQ stock exchange by three milliseconds (Kauffman, 2013).

The significant risks which accompany these technological advancements became apparent in the following market irregularities. On May 6, 2010, the Dow Jones Industrial Average dropped over 1,000 points in intraday trading during the so called 'flash crash' resulting in a public discussion about the necessity of increased regulation for HFT (Easley, de Prado, & O'Hara, 2012; Rose, 2011; Wah & Wellman, 2013). In August 2012, an automated stock trading algorithm of the Knight Capital Group repeatedly bought and sold millions of shares leading to 440 million dollars in losses within less than one hour (Adler, 2012). The bestselling book 'Flash Boys' has recently contributed to a controversial debate about the influence of HFT on the economy and its effect on the wealth of private investors in the United States (U.S.) (Lewis, 2014). However, a clear understanding of the interdependent information flows in HFT markets and their influence on different stakeholders still represents a gap in recent literature.

Representing approximately two percent of all operating trading firms in the U.S., HFT firms account for 73% of U.S. equity trading volume (Iati, 2009; Rose, 2011). HFT has significant influence on the financial markets and its relevance continues to grow (Haldane, 2010; Iati, 2009; Zubulake & Lee, 2011). This research aims to contribute to the conceptual understanding of HFT by identifying relevant market participants, analysing three widely adopted HFT strategies and providing a conceptual framework for information and value flows in HFT financial markets. A more profound understanding of HFT may support the introduction of improved financial regulation as well as financial risk management.

The rest of the paper is structured as follows. Chapter 2 provides the theoretical and institutional background identifying information and value flows in HFT capital markets from existing literature. Chapter 3 describes our qualitative research approach and provides information about the sample, context, and data analysis. In chapter 4, we present our findings including the HFT Information Value Framework. Chapter 5 discusses our research results followed by stating the implications, limitations, and opportunities for future research. Finally, we draw conclusions in chapter 7.

2 Theoretical and Institutional Background

In this chapter, relevant market participants and interrelations between them are identified. Moreover, basic concepts such as the HFT trading process and three widely adopted HFT strategies are introduced.

HFT represents a subcategory of algorithmic trading, which is defined by an electronic automation of trading decisions, order submissions, and post-trade order management (Brogaard, 2010; Hendershott, Jones, & Menkveld, 2011). HFT can be differentiated from algorithmic trading by shorter holding pe-

riods of securities and lower latency (Aldridge, 2013; Wah & Wellman, 2013). Latency describes the time interval between the submission of a trading decision and the arrival of the order at a market place. For example, one HF trader in a study by Menkveld (2013) uses an upper-bound latency of 1.67 milliseconds which emphasizes the importance of speed to HF traders.

2.1 Market Participants

HF traders: There are several important differences between regular traders and *high frequency (HF) traders*. HF traders submit and cancel massive quantities of orders, execute high trading volumes, trade in and out of positions very quickly, and aim to close each trading day without significant open positions (Brogaard, 2010; Cvitanic & Kirilenko, 2010; Gomber & Haferkorn, 2013). Further, HF traders only engage in proprietary trading (Menkveld, 2013). There are three groups of HF traders: Traditional broker-dealers who trade on HFT strategies in addition to their client business, hedge funds, and proprietary trading firms who generate the majority of HFT trading volume (Ye, 2010; Zubulake & Lee, 2011).

Market platforms include exchanges, over-the-counter (OTC) markets, electronic communication networks (ECNs) and dark pools. Among the main responsibilities of market platforms are order matching and maintaining the limit-order book. ECNs, also referred to as light pools, have introduced electronic limit-order books and have automated order matching using algorithms (McAndrews & Stefanadis, 2000; Smith, 2010). In the past years, the majority of trading volume including derivative assets has moved from traditional exchange trading floors to ECNs (Ortega 2007; Markham 2008). Private trading networks, also referred to as dark pools, are not required to disclose public quotes. Relevant information such as order size and traders' identity is not published until a trade is completely executed (Kratz & Schöneborn, 2013; Smith, 2010). Market platforms generate revenues through transaction fees, typically charging liquidity removers while providing liquidity providers a small credit (Foucault, Kadan, & Kandel, 2013). In addition, many market platforms provide services such as proximity services and data-feed services to generate further revenues. Proximity services include co-location, which describes the installation of a trader's hardware in close proximity to the data centre of the market platform leading to a 100-200 millisecond latency reduction (Arnuk & Saluzzi, 2009). Revenues from additional services such as market data fees represent an increasingly important source of revenue. In 2006, market data fees accounted for 50% of the NYSE Group's total revenue and approximately 80% of NASDAQ's total revenue (Markham & Harty, 2007).

Clearing members: Trading on the order book of market platforms is restricted to *registered clearing members* such as *brokers* (Clark, 2010). Due to the high fragmentation of financial markets, brokers play an important role in providing access to a variety of market platforms (Stoll, 2001). Even sophisticated HF traders often require a broker to submit their orders. The traditional way of submitting orders through a broker to the order book is not suitable for HF traders due to the high level of latency. HF traders use direct market access. Direct market access permits HF traders to access execution platforms directly, without intervention from a broker's trading desk (Udatha, 2011). Three different types of direct market access are identified in recent literature. First, *automated order routing* permits traders to transmit orders electronically to a market platform using a broker's IT infrastructure and market-member ID. Traders obtain real-time market data such as order book information from the broker enabling the implementation of computer-based trading strategies. Intermediary brokers are financially responsible for orders, which are submitted using their infrastructure. Therefore, they reserve the right to monitor and stop orders before execution. Moreover, brokers oblige traders to meet strict capital requirements and to contribute to a loss-sharing pool (Clark, 2010; Udatha, 2011). Second, *sponsored access* allows the customers of a broker to access the market platform's matching engine directly without using the broker's IT infrastructure. Hence, the intermediary broker is not able to apply control mechanisms such as monitoring and cancelling of orders (Udatha, 2011). The SEC has banned sponsored access in the U.S. and requires brokers to set up risk management controls (Callcott & Foley, 2011). Third, *direct access by non-intermediary market-members* describes unregistered and non-intermediary traders such as hedge funds, proprietary trading firms and other HF traders. All of

them connect directly to the market platform's matching system using their own infrastructure and member ID. However, these non-registered members still require a clearing arrangement with a clearing member intermediary broker (Udatha, 2011).

Information service providers include market platforms providing data-feed services and external information service providers offering consolidated feeds. Furthermore, customized and machine-readable economic data and corporate news are made available to support electronic trading systems.

Technology providers support HF traders with various services to ensure low latency. For instance, communication-service providers offer low latency network connectivity services in metropolitan regions as well as long-haul routes. Furthermore, software developers distribute solutions for automated trading decision-making, smart order routing, and general trading tools as well as direct interfaces to information service providers, brokers, and market platforms. HFT firms further integrate proprietary trading software with external trading software using software development environments. In addition, hardware providers offer state-of-the-art computer hardware systems which further contribute to high execution speeds (Markham & Harty, 2007).

Clearing agencies are responsible for the clearing and settlement of trades and include clearing corporations and depositories. Clearing corporations perform the confirmation, settlement and delivery of transactions while depositories maintain ownership records, hold securities, certificates, and transfer positions between participants (Reference).

2.2 Trading Process

This chapter provides details about HFT processes, which consist of four phases: Information phase, order routing phase, order matching phase, and clearing phase. Since the clearing phase of HF trades is identical to regular trades, we will focus on the information phase, order routing phase, and order matching phase.

In the *information phase*, HF traders initially determine a strategy and set up the necessary IT infrastructure, and software systems in collaboration with technology providers. Proprietary trading firms, which represent the majority of HF traders, typically lack the resources to set up two systems; therefore focusing on one strategy (Brogaard, 2010; Ye, 2010). As a next step, HF traders use smart order routing systems to select automatically the optimal order type, market platform, and broker for order execution while taking real-time market conditions and historical reference data into account. This allows the calculation of transaction costs, the detection, and prediction of liquidity (StreamBase, 2014). The execution parameters are highly relevant regarding the execution speed and execution costs of an order. Thereby, smart order routing systems aggregate the necessary input data for the decision from the information service providers. Next, the underlying algorithms determine trading quantity and volume. This allows traders to split orders into smaller parts in order to avoid losses due to distorting effects on the market (Paskelian, 2010). For this process traders often use the volume-weighted average price or time-weighted average price algorithms, which are often accompanied by proprietary algorithms (Bansal, Mishra, & Pachouri, 2010). Finally, smart order routing systems are used to submit orders to market platforms electronically using standardized interfaces (FIXProtocol, 2014).

In the *order routing* phase, the smart order routing system submits the order according to the routing decision, which was computed in the information phase. As the routing decision is highly relevant to the execution speed as well as execution costs of the trade (Paskelian, 2010), execution parameters comprise the selection of an execution venue. An order can be routed to an exchange, OTC market, ECN, or dark pool. The HF trader may have access to the market platform through direct membership, but most likely an intermediary broker provides access to the market platform. Using direct market access models, HF traders can route each trade to a different market platform using different market access models (see also chapter 2.1). Furthermore, execution parameters include the order type. Market orders can be used to buy or sell securities immediately at the best available price (SEC, 2014b). Limit orders are used to buy securities below a pre-specified price or to sell securities above a pre-

specified price. Limit orders which have not yet been executed are maintained by the market platforms in the limit-order book until they are executed or cancelled (SEC, 2014a). Furthermore, limit orders may include validity constraints such as "good-for-day", "good-until-cancelled", or "immediate-or-cancel" (Harris & Hasbrouck, 1996).

During the o*rder matching* phase, buy and sell orders are matched electronically in the market platform's matching engine. Opening and closing prices of financial assets are often determined by auctions, while price during continuous trading are determine using priority rules (Eurex, 2014). Priority rules define the sequence of order matching if there are multiple possibilities to match orders. The most common priority rule is price-time priority. In this case, the order with the best price is executed first. If multiple orders in the book have the same price, the first submitted order, is executed first (Stoll, 2001). Under the price-time priority rule, large orders can prevent smaller orders from being executed if intraday price volatility is low (Eurex, 2014). HF traders have no direct influence on the order matching phase. However, since order matching mechanisms differ between market platforms, knowledge about the matching algorithms is highly relevant for order routing decisions in order to implement HFT strategies.

2.3 HFT Strategies

Section 2.3 provides the theoretical background on the three most relevant trading strategies in HFT: Market making, arbitrage trading and pinging. *Market making* represents the most common strategy in HFT and improves market quality by providing liquidity (Easley et al., 2012; Hagströmer & Nordén, 2013; Menkveld, 2013; Zubulake & Lee, 2011). Traders acting as market makers provide liquidity to position takers by placing passive orders, and profit from the spread between bid and ask prices. On electronic exchanges, every trader can submit limit orders in the system; thereby effectively acting as a market maker (Avellaneda & Stoikov, 2008). However, market makers are exposed to position risks, also referred to as inventory risk. Inventory risks emerge from the volatility of asset prices. Therefore, market makers balance personal risk considerations with the market environment. More specifically, the market maker derives bid and ask quotes by a two-step procedure. First, a personal indifference valuation for the stock is done considering the market maker's current inventory. Second, the trader calibrates his bid and ask quotes to the limit-order book using the probability of the execution of his quotes (Avellaneda & Stoikov, 2008). In addition, market makers are also exposed to order-flow toxicity. In this case, market makers may be unaware that they are providing liquidity at a loss, while informed traders may have knowledge about the future price of an asset due to asymmetric information. However, order-flow toxicity in high frequency markets can be measured and volatility can be reduced using a volume synchronized probability of informed trading toxicity metric (Easley et al., 2012).

Arbitrage strategies exploit disparities in the price at which an equivalent financial instrument is traded; either in different markets (statistical arbitrage), or at different times (latency arbitrage) (Wah & Wellman, 2013). *Statistical Arbitrage* strategies profit from small price differences between two market platforms. Arbitrageurs take advantage of the different conditions by buying and selling the same security on both market platforms at the same time profiting from the spread between the two prices. Although the opportunities to gain profits with this strategy have decreased significantly due to increased competition, there are still revenues generated (Zubulake & Lee, 2011). HF traders use algorithms to implement statistical arbitrage strategies as arbitrage opportunities exist merely for fractions of a second. Traders that use arbitrage models are mainly takers of liquidity (Arnuk & Saluzzi, 2012). To increase efficiency, HFT firms use so called neural networks which are able to simulate thousands of scenarios in order to detect arbitrage opportunities (McGowan, 2010). Statistical arbitrage opportunities can also arise between individual stocks and their underlying index. These opportunities are also very short lived. The competition for such trades is an essential component of how HF traders contribute to market efficiency (Zubulake & Lee, 2011). *Latency Arbitrage* is based on differences in execution speeds. HF traders can achieve profits through an advantage in access and response times (Wah & Wellman, 2013). HF traders try to forecast market movements using real-time newsfeed data, and react faster than competitors using fast execution speeds. Latency arbitrage in fragmented financial mar-

kets reduces total surplus leading to improved allocative efficiency but negatively impacts liquidity (Cohen & Szpruch, 2012; Wah & Wellman, 2013).

Pinging strategies describe automated passive orders, which are cancelled almost immediately, if no response from the market is available. If an order is executed, the trader gains information that he can use to his advantage (McGowan, 2010). In other words, pinging represents the use of "immediate-or-cancel" orders to look for liquidity in markets lacking transparency such as dark pools. The trading centre that receives an "immediate-or-cancel" order will execute the order immediately if it has available liquidity and the order can be matched with an order in the limit-order book. Otherwise, the trading centre will immediately respond to the order with a cancelation. Therefore, pinging is highly valuable for HF traders to gather information about the orders of other investors in dark pools (Rose, 2010). As pinging is valuable for HF traders, some dark pools have implemented ways to identify pinging and charge traders for their pinging activities (Aldridge, 2013; Kratz & Schöneborn, 2013).

3 Research Method

This research examines interactions between stakeholders in HFT markets. While existing research often focuses on individual aspects of HFT (Arnuk & Saluzzi, 2009; Easley et al., 2012; Iati, 2009), our research aims to link prior research and to provide a comprehensive conceptual model of HFT markets. We used a qualitative research approach being suited to address "how" questions and derive in-depth insights (Pratt, 2009; Yin, 2014).

3.1 Data

We conducted semi-structured expert interviews to identify and analyse information and value flows among relevant HFT market participants. We further used the expert interviews to ensure the relevance of our research results, and to gain further understanding of the organizational, technological, and conceptual challenges in HFT markets.

Experts are defined by their degree of activity in the field that is relevant to the research (Meuser & Nagel, 1991). We conducted expert interviews with five HFT experts (n = 5) from different stakeholder groups and with different professional backgrounds. The participating HFT experts were chosen based on their industry experience, personal background, and unique position in the market participant's structure. We interviewed a traditional trader working at a private bank focusing primarily on fixed income trading. Further, we interviewed a traditional trader from a retail bank participating primarily in exchange traded funds trading. In addition, we conducted interviews with a manager of a trading office, a managing board director from a stock exchange, and a regulator at the stock exchange in Frankfurt. Table 1 provides an overview of all interviewed experts. All interviews were face-to-face meetings and lasted between 30 minutes to 1.5 hours. With one exception, all participants agreed to a recording of the interview.

Expert	Market participant	Position
Alpha	Trading office (Private bank)	Head of Private Banking Family Trading Office
Beta	Trader (Private bank)	Trader Fixed Incomes
Gamma	Stock exchange (regional)	Managing board
Delta	Trader (Bank)	ETF Sales trading
Epsilon	Stock exchange (national)	Head of Unit Political Analysis; Market Policy & European Public Affairs

Table 1. Overview of the interviewed experts

Interview questions were derived from literature according to the guidelines from Myers and Newman (2007). The suitability of the expert interview questions was checked by two independent researchers.

Questions implying a certain answer and questions solely targeting contextual knowledge were adjusted. Due to the multifaceted backgrounds and positions of the interviewed experts, the questions were further differentiated. All interviewed experts were asked general questions regarding information on the financial markets, and the trading process. Furthermore, each interview partner was asked specific questions regarding their knowledge, their attitude towards HFT, and HFT strategies. All questions were posed as open questions giving the experts an opportunity to emphasize different aspects which they regarded as being the most important.

3.2 Data Analysis

In the course of conducting the expert interviews, we simultaneously collected and analysed the gained data. The analysis of the interviews required the transcription of the recorded interviews. We applied literal transcription following the principle that a transcription system should be easy to write, easy to read, easy to learn and easy to search (Buber & Holzmüller, 2007; Flick, 2006). The expert interviews were translated and the dialect of some experts as well as grammar mistakes were corrected as it is recommended (Mayring, 2006). The data analysis primarily requires coding of the text database, label variables (categories, concepts and propositions), and their interrelationships in an iterative three step process. Open coding represented the *first* step. It captures the naming, categorizing and description of phenomena found in the transcript. *Second*, concepts were derived from the first-order codes, which are the basic units of analysis (Corbin & Strauss, 1990). Axial coding represented the *third* step. It describes the process of relating codes to each other and generating categories. Categories are higher in level and more abstract than the concepts they represent (Corbin & Strauss, 1990). The coding of the data revealed twelve categories. Basic concepts of HFT, Market Participants, Market Access, Services of market platforms, Information Providers, Type of Information, Value of Information, Algorithms and Strategies, Legal, Fairness, Regulatory, Future Outlook. Table 1 presents an excerpt of our coding scheme showing two categories (Market Participants and Services of Market Platforms) including the amount of occurrences during the coding process.

Categories	**Quantity**	**Concepts (separated by ";")**	**First-Order-Codes**
Market Participants	20	• HF traders; Multiple exchanges, market platforms with high amount of liquidity • Grey areas, ancillary markets • Information providers • Networks • Market access providers, order routers (brokers) • Partners to trade with • Providers of predesigned algorithms	• In the end it is all about getting the information. Basically Bloomberg, Reuters and other News providers are the most important co-players of the HF traders. • Trading platforms like ATS were especially designed for HF traders with lower costs for HFT that enable a higher amount of trades. • […]
Services of Market Platforms	7	• Proximity services and co-location • Research information • Matching • Clearing and settlement • Technological services (fast connection to the infrastructure and data products that enable customers to process information efficiently) • Execution quality and the sup-	• Proximity services and co-location were started to make the market place more interesting for HF traders. • Our approach is to offer our clients an all-round package. That starts with providing information, (…) matching, (…) clearing and settlement. We offer the total value chain. One part that rose in importance over the last couple of years is

		port of decision-making	technological services. (…) fast connection to the infrastructure (…) data products that enable customers to process information efficiently. • […]

Table 2. Axial Coding of Qualitative Data (Excerpt)

The *fourth* step is selective coding. Selective coding describes the process of choosing a core category, and relating all other categories to that category; therefore building (generalized) relationships between a category, its concepts, and between discrete categories (Corbin & Strauss, 1990). The relationships between the derived categories are described in the results and later on discussed. The correlations between the categories serve as the basis for the analysis of information and value flows within HFT capital markets. The following categories have been identified and are described in the results section: Market Participants, Market Access, Information Providers, Services of Market Platforms and Algorithms and Strategies.

4 Results

In this chapter, we develop the HFT Information Value Framework drawing from the theoretical background section in which we identified relevant interrelations between market participants. Furthermore, we use interview statements from the expert interviews to analyse information and value flows. We relate the theoretical background and the results from our expert interviews to develop the framework. Thereby, we are able to provide a conceptual understanding of how market participants exchange information and value in HF capital markets. To describe the HFT Information Value Framework, we use the e3-value method. This method is designed to visualize how economic value is created and exchanged within a network of actors (Gordijn & Akkermans, 2001). The e3-value method is suitable to define, derive, and analyse multi-enterprise relationships, e-business scenarios, and operations requirements in both qualitative and quantitative ways. The method focuses on value rather than on processes. This is a main difference between the e3-value method and traditional representations such as UML (Gordijn & Akkermans, 2001).

We focus our analysis on the interrelations between HF Traders and their most relevant business partners including Brokers, Market Platforms, Information Providers, and third-party Technology Providers. The value flows between these stakeholders include information flows, monetary flows, and technology exchange. Regulatory Bodies and Clearing Agencies were not part of our analysis since they do not directly exchange information or value with HF Traders during the trading process.

Based on the analysed data, we were able to visualize interrelations between market participants in HFT markets. Figure 1 visualizes the results and represents the HFT Value Information Framework. Since HF traders and Market Platforms are the most relevant market participants, the framework is described from their perspective.

HF Trader perspective: HF Traders pay fees (monetary flow) to Market Platforms in exchange for real-time market information (information flow). Moreover, HF Traders obtain market data, historical data as well as unstructured news (information flow) from external Information Providers in exchange for a payment (monetary flow). Further, HF traders receive hardware, software and other technology from third-party Technology Providers (technology exchange) while Technology Providers receive monetary flows from HF Traders. Finally, HF Traders interrelate with Brokers and Market Platforms to gain market access for a nominal fee (monetary flow).

The following statements from expert interviews are used to validate the identified interrelations between HF Traders and other market participants. According to experts Alpha and Beta, the main objectives of HF Traders are fast decision-making and efficient order submission. Therefore, HF Traders interrelate with Market Platforms as well as Information Providers such as Bloomberg and Reuters,

which offer real-time market data and historic data to ensure fast decision making. In addition, HF Traders pay premium fees (monetary flow) for *"special customer services"* and receive information before regular traders (information flow). *"The more you pay, the earlier you receive information"* (Expert Alpha). To leverage the available information, HF Traders interrelate with third party Technology Providers such as Morgan Stanley which offer trading software and algorithms. *"There are algorithms that only place orders, […] log orders, […] and algorithms that analyse the market"* (Expert Beta). *"Algorithms can be clustered into non-intelligent and intelligent algorithms"* (Expert Beta). The availability of real-time information and trading algorithms enables HF Traders to realize fast decision making. An efficient order submission is obtained by direct market access, either using the Broker's IT infrastructure to access a Market Platform or using direct market access via membership for Market Platforms that are regularly used. These services require the payment of fees (monetary flow). Traditional Brokers are used for *"more exotic securities"* and provide access to less frequently used market platforms (Expert Alpha). HF traders interrelate with Market Platforms to make use of proximity services such as co-location to decrease latency (technology exchange).

Market Platform perspective: The primary obligation of Market Platforms is the electronic matching of orders from different registered clearing members that are obliged to pay a membership fee (monetary flow). In addition, Market Platforms provide data feed services and supply real-time market data to HF Traders and Information Providers (information flow). While some data feed services are free, Market Platforms receive monetary flows for special services such as real-time market data. Market Platforms have further introduced proximity services such as co-location (technology exchange) to minimize latency times, and to increase their appeal to HF traders. For these additional technological services, Market Platforms charge high fees (monetary flow). *"Technological services have increased in importance in recent years […] The data [feed] services […] are more and more important […] for [market platforms'] revenues, so the portfolio has changed massively in the last five to ten years"* (Expert Epsilon). Finally, Market Platforms and Clearing Agencies interrelate in the process of clearing and settlement.

The HFT Value Information Framework provides the basis for the discussion regarding the perception of HFT and the necessity for regulation in the subsequent chapter.

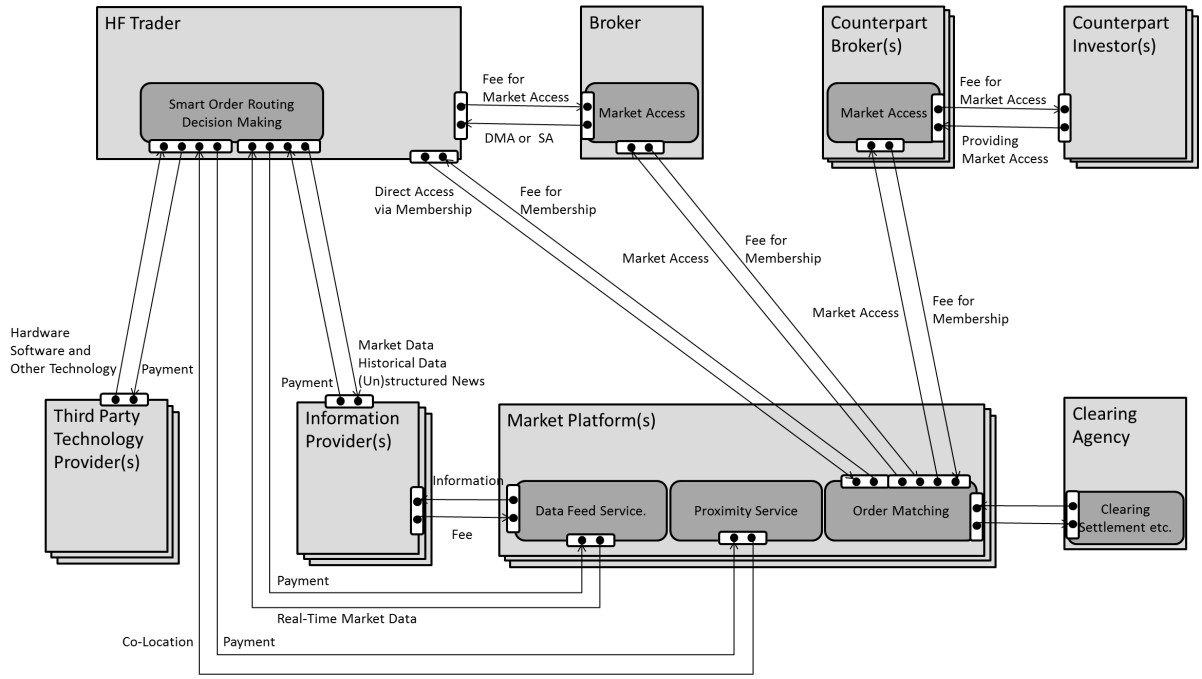

Figure 1: HFT Value Information Framework

5 Discussion

In this section, we discuss our results combining our insights from practice and theory. Thereby, we use our visualization of the information flows to discuss interrelations in HFT markets. Our data and the visualization allow us to discuss different HFT strategies as the visualization contributes to a better understanding of the influence and the interdependencies between algorithms, stakeholders, and machine-to-machine communication. Finally, we discuss the necessity of increased regulation in German and U.S. HFT capital markets.

5.1 Perception of HFT strategies

In the course of our research, we identified a total of seventeen trading strategies that are used by HF traders. Most of these strategies are not new to the market and were used long before the emergence of HFT. HFT does not represent a strategy but a technological evolution that allows traders to adopt and align existing strategies and to make them more profitable. The discussion on HFT in the public press and in academic literature mainly focuses on the impact of HFT on market fairness and market quality (Lewis 2014). While these aspects are not the main focus of this research, we found that the most widely adopted HFT strategies are market making and arbitrage trading (Easley et al., 2012; Hagströmer & Nordén, 2013; Zubulake & Lee, 2011). Both of these strategies are perceived as beneficial to the market quality, particularly considering the high level of market fragmentation (Expert Gamma).

Traditional traders among the interviewed experts expressed negative perceptions regarding HFT. For instance, the informational advantages that enable HF traders to make faster trading decisions than regular traders are perceived as being *"unfair"* and lacking transparency (Expert Alpha). *"You look at the screen and suddenly there's a lot going on. Somebody is pushing the market without the rest of the market having the information available. All you can do is watch"* (Expert Alpha). *"We experienced high-frequency trading in relation [to stock trading], unfortunately rather negatively, in that we ourselves were exploited by an algo[rithm]"* (Expert Beta). According to Expert Alpha, transparency and fairness in stock exchanges have to be ensured, otherwise trading volume will shift to other trading platforms such as dark pools. *"If the development continues like this […], more volume will move from relatively transparent markets […] to private trading venues"* (Expert Alpha). These statements correlate with similar criticism in recent literature. Lewis (2014) describes different scenarios in which HF traders gain advantages over traditional traders.

On the other hand, expert Gamma expressed the view that the majority of algorithms have positive effects. For example, algorithms *"decrease the market impact of big institutional orders by splitting orders leading to a better price for the customer and more price stability in the market"* (Expert Gamma). Furthermore, passive market making strategies have a positive effect on the market due to increasing liquidity (Expert Gamma). However, there are also algorithms with negative effects. *"There are opportunistic algorithms […]"* (Expert Gamma). *"The market maker has to use technology in order to react to market situations"* (Expert Epsilon). According to Expert Epsilon, the introduction of harmonized regulation across the European Union in 2007, has increased the fragmentation of stock markets in Germany. As a result, Expert Alpha emphasizes the need for traders to reach out to a variety of market platforms to trade stocks including ECNs such as Xetra, Eurex, M-DAX and S-DAX. Therefore, Expert Epsilon suggested that HFT is a natural reaction to arbitrage opportunities that arise from increased market fragmentation. *"The reason why HFT has boomed in stock markets is of course the fragmentation in the stock market and therefore the opportunity for arbitrage revenues"* (Expert Epsilon). Due to arbitrage trading and market making, HFT strategies have a positive effect on markets. *"The strategies exist for a long time, and they are very positive. Also, speculation is good for markets"* (Expert Epsilon). *"Since 2007, we have a fragmented landscape and without HFT, there are big price differences between the markets"* (Expert Epsilon). Expert Epsilon further suggests that prices in HFT capital markets are fair. *"For the normal investor, it usually is not about the third decimal in the price and therefore it is still a fair price that takes place"* (Expert Epsilon).

The different experiences and perceptions of our experts reflect the controversial discussion about HFT in current literature. On the one hand, there are very negative perceptions about HF traders regarding unfair advantages. However, experts also acknowledge that HFT fulfils an important function of arbitrage trading in highly fragmented capital markets. It was also suggested that traders have an obligation to invest in technology in order to compete in HFT markets. *"Many market participants are very critical […] about HFT. If you want to play in this market, of course you have to invest [in technology] to be able to compete"* (Expert Epsilon). The necessity to use technology in order to compete in HFT markets might present a problem to smaller investors who do not have the resources to buy appropriate technology.

5.2 Regulation in HF capital markets

Regulation is a highly relevant topic highlighted by the recent introduction of the "Hochfrequenzhandelsgesetz" in Germany in May, 2013 (Gomber & Nassauer, 2014). This law aims to make HF trades more transparent. Algorithmic orders are "flagged" and can therefore be easily identified and analysed. The data about flagged algorithmic orders can be used by researchers to further investigate the topics of market fairness and market quality.

The opinions of the interviewed experts on the necessity for increased regulation of HFT are closely correlated to their views on the impact of HFT on market fairness. The experts that considered HFT as unfair urged for stricter regulation. Traditional traders identified a high urgency for increased regulation in order to improve market transparency and ensure fair prices for every market participant (Expert Alpha). *"There are social disadvantages if many market participants are settled with not entirely fair prices; or if some yield an advantage"*. (Expert Alpha). They suggested that the positive and negative effects of HFT on capital markets should be researched in more detail. *"It would also be interesting to find out, whether HFT really harms the market as it is always stated"* (Expert Beta).

On the other hand, Expert Gamma being a market platform representative suggested a step-by-step approach towards regulation to ensure the goal of optimal resource allocation through capital markets. He emphasized the necessity to further investigate HFT before introducing new regulation. *"First, regulation needs to comprehend HFT. To do that, there are the flagging of algo-orders and the excessive usage fees now. One should first look at these results now and regulate less"* (Expert Gamma).

One serious problem in capital markets is market manipulation. However, this is perceived as an independent problem from the technological advancements of HFT. *"Market manipulation […] is of course negative but that has nothing to do with the technology. These things are simply harming behaviour in general […] that has to be prohibited"* (Expert Epsilon). Due to the positive effects of arbitrage trading and market making strategies on market quality, regulation should not completely dismiss HF traders. *"If we prohibit [HFT] right now, e.g. through a transaction tax […], the spreads would go apart and there would be greater peaks in certain market phases"* (Expert Epsilon). In that sense, we consider the analysis of information and value flows between market participants as valuable starting point for the investigation of future regulation.

Several experts expressed strong scepticism about the ability of regulatory bodies to implement the appropriate regulation. Expert Alpha pointed out that the best university graduates prefer joining trading firms over regulatory institutions. *"The regulatory bodies lack the competency to regulate in a differentiated manner"* (Expert Gamma). Nevertheless, experts agree that in the future, there will be more regulation in HFT markets. *"There will be very strong regulation in the future."* (Expert Delta). There are also significant differences in regulation between Europe and the United States. *"Germany has a front role in regulation since the introduction of the Hochfrequenzhandelsgesetz on May 15, 2013"* (Expert Epsilon). *"The U.S. have to implement what we already have in Europe […] There are security measures that have to be maintained by market venues. How can you let 70% of the trading volume be done only by HF traders or algo[rithmic] traders without security measures?"* (Expert Epsilon).

While there is a discrepancy between the experts for the need to regulate HFT, it can be assumed that solely local regulations will not change HFT behaviour. Nonetheless, the HFT Value Information Framework provides a first attempt to make processes and value creation transparent within the HFT value network. In consequence, firms can use our visualization to improve their own business processes and adapt or modify their business model. On the other hand, it can be used by institutions to address certain aspects affecting the macro environment.

6 Implications, Limitations and Further Research

We base our research on theory and enrich our results by conducting expert interviews. Based on our data, we develop and evaluate the HFT Information Value Framework. In consequence, the main contribution of our research can be seen in linking theoretical pieces of a puzzles into a generic framework. While we analyse (value) relations, further research should enrich our framework with specific technical details.

The topic of HFT is a very current topic in IS research that offers many opportunities for future research such as qualitative and quantitative research on a more technical level. The negative perception of HFT among regular traders indicates that further research needs to investigate the fairness of HFT markets. Similar to prior studies that have been conducted in the field of HFT, we experienced limitations in finding HFT experts. Including experts with a professional background in HFT such as employees of proprietary trading firms would provide a more balanced perspective on the issue. This presents a research opportunity for future research to conduct a study from an insider perspective on HF traders. Further, as stated by Expert Beta, HFT strategies, their amount of usage, and their impact on financial markets should be further analysed in order to gain a more concrete evaluation. Here our HFT Information Value Framework can be taken as base. This would allow regulators to develop and implement appropriate regulations such as the “Hochfrequenzhandelsgesetz”, which incorporates first regulatory steps. From a researchers perspective, studies on HFT from different perspectives such as IS, economics, and business administration would improve our comprehensive understanding of HFT.

Based on our results, we contribute to a conceptual understanding of HFT covering information and value flows between algorithms, stakeholders, and machine-to-machine communication. Thereby, we visualize interdependencies, the importance of information flows, and their influence. In consequence, our results can be useful in different fields and for different stakeholders including practitioners, researchers, and regulatory bodies. From an IS perspective, interfaces between the information technology of different market participants are visualized allowing an optimisation and analysis of processes, used technology, and organizational aspects relating to IT-Governance.

7 Conclusion

The relevance of HFT in today’s capital markets is considerable having increased rapidly over the last few years. Research in this field is available but primarily focuses on the influence of HFT on market quality. Our research contributes to a generic understanding of information and value flows between HFT stakeholders by developing a HFT Information Value Framework. In consequence, this research offers a more precise understanding of value flows in HFT capital markets. Furthermore, this research provides insights about the three most commonly used HFT strategies: Market making, arbitrage trading and pinging. In addition, this research creates a basis for further qualitative and quantitative studies covering different aspects of HFT capital markets in greater detail.

References

Adler, J. (2012). Raging bulls: How Wall Street got addicted to light-speed trading. *Wired Magazine*.

Aldridge, I. (2013). *High-frequency trading: a practical guide to algorithmic strategies and trading systems*: John Wiley & Sons.

Arnuk, S., & Saluzzi, J. (2009). Latency arbitrage: The real power behind predatory high frequency trading. *Themis Trading white paper*.

Arnuk, S., & Saluzzi, J. (2012). *Broken Markets: How High Frequency Trading and Predatory Practices on Wall Street are Destroying Investor Confidence and Your Portfolio*: FT Press.

Avellaneda, M., & Stoikov, S. (2008). High-frequency trading in a limit order book. *Quantitative Finance, 8*(3), 217-224.

Bansal, A., Mishra, K., & Pachouri, A. (2010). Algorithmic Trading (AT)-Framework for Futuristic Intelligent Human Interaction with Small Investors. *International Journal of Computer Applications, 1*(21), 01-05.

Brogaard, J. (2010). High frequency trading and its impact on market quality. *Northwestern University Kellogg School of Management Working Paper*, 66.

Buber, R., & Holzmüller, H. H. (2007). *Qualitative Marktforschung: Konzepte--Methoden--Analysen*: Springer-Verlag.

Callcott, W. H., & Foley, T. C. (2011). SEC approves rule banning "naked access" to trading centers. *Journal of Investment Compliance, 12*(1), 62-64.

Clark, C. (2010). Controlling risk in a lightning-speed trading environment. *Chicago Fed Letter, 272*.

Cohen, S. N., & Szpruch, L. (2012). A limit order book model for latency arbitrage. *Mathematics and Financial Economics, 6*(3), 211-227.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative sociology, 13*(1), 3-21.

Cvitanic, J., & Kirilenko, A. A. (2010). High frequency traders and asset prices. *Available at SSRN 1569075*.

Easley, D., de Prado, M. M. L., & O'Hara, M. (2012). Flow toxicity and liquidity in a high-frequency world. *Review of Financial Studies*, hhs053.

Eurex. (2014). eurexchange.com/exchange-en/trading/market-model/matching-principles/. Retrieved 14.11.2014

FIXProtocol. (2014). fixtradingcommunity.org/pg/main/what-is-fix. Retrieved 14.11.2014

Flick, U. (2006). *Qualitative Forschung*.

Foucault, T., Kadan, O., & Kandel, E. (2013). Liquidity cycles and make/take fees in electronic markets. *The Journal of Finance, 68*(1), 299-341.

Gomber, P., & Haferkorn, M. (2013). High-Frequency-Trading. *Business & Information Systems Engineering, 5*(2), 97-99.

Gomber, P., & Nassauer, F. (2014). Neuordnung der Finanzmärkte in Europa durch MiFID II/MiFIR: White Paper Series.

Gordijn, J., & Akkermans, H. (2001). Designing and evaluating e-business models. *IEEE intelligent Systems, 16*(4), 11-17.

Hagströmer, B., & Nordén, L. (2013). The diversity of high-frequency traders. *Journal of Financial Markets, 16*(4), 741-770.

Haldane, A. (2010). *Patience and finance.* Paper presented at the Remarks at the Oxford China Business Forum, Beijing, available at bankofengland.co.uk/publications/speeches/2010 /speech445.pdf.

Harris, L., & Hasbrouck, J. (1996). Market vs. limit orders: the SuperDOT evidence on order submission strategy. *Journal of Financial and Quantitative analysis, 31*(02), 213-231.

Hendershott, T., Jones, C. M., & Menkveld, A. J. (2011). Does algorithmic trading improve liquidity? *The Journal of Finance, 66*(1), 1-33.

Hendershott, T., & Moulton, P. (2007). The shrinking new york stock exchange floor and the hybrid market: Technical Report, UC Berkeley Working Paper.

Hendershott, T., & Riordan, R. (2009). Algorithmic trading and information. *Manuscript, University of California, Berkeley*.

Iati, R. (2009). The real story of trading software espionage. *Advanced Trading*.

Jain, P. K. (2005). Financial market design and the equity premium: Electronic versus floor trading. *The Journal of Finance, 60*(6), 2955-2985.

Kauffman, N. (2013). Have extended trading hours made agricultural commodity markets riskier? *Economic Review*(Q III), 1-28.

Kratz, P., & Schöneborn, T. (2013). *Optimal liquidation in dark pools.* Paper presented at the EFA 2009 Bergen Meetings Paper.

Lewis, M. (2014). *Flash boys: a Wall Street revolt*: WW Norton & Company.

Liu, S. (2005). *Electronic Trading (ET): new method in financial markets.* Paper presented at the Proceedings of the 7th international conference on Electronic commerce.

Markham, J. W., & Harty, D. J. (2007). For Whom the Bell Tolls: The Demise of Exchange Trading Floors and the Growth of ECNs. *J. Corp. L., 33*, 865.

Mayring, P. (2006). *Einführung in die qualitative Sozialforschung*.

McAndrews, J., & Stefanadis, C. (2000). The emergence of Electronic Communications Networks in the US equity markets. *Current Issues in Economics and Finance, 6*(12), 1-6.

McGowan, M. J. (2010). Rise of Computerized High Frequency Trading: Use and Controversy, The.

Menkveld, A. J. (2013). High frequency trading and the new market makers. *Journal of Financial Markets, 16*(4), 712-740.

Meuser, M., & Nagel, U. (1991). *ExpertInneninterviews—vielfach erprobt, wenig bedacht*: Springer.

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and organization, 17*(1), 2-26.

Paskelian, O. G. (2010). The impact of algorithmic trading models on the stock market. In G. N. Gregoriou (Ed.), *The handbook of trading: strategies for navigating and profiting from currency, bond, and stock markets* (pp. 275): McGraw Hill Professional.

Pratt, M. G. (2009). From the editors: For the lack of a boilerplate: Tips on writing up (and reviewing) qualitative research. *Academy of Management Journal, 52*(5), 856-862.

Rose, C. (2010). Dark Pools And Flash Orders: The Secret World Of Automated High-Frequency Trading. *Journal of Business & Economics Research (JBER), 8*(8).

Rose, C. (2011). The Flash Crash Of May 2010: Accident Or Market Manipulation? *Journal of Business & Economics Research (JBER), 9*(1).

SEC. (2014a). sec.gov/answers/limit.htm. Retrieved 14.11.2014

SEC. (2014b). sec.gov/answers/mktord.htm. Retrieved 14.11.2014

Smith, R. D. (2010). Is high-frequency trading inducing changes in market microstructure and dynamics? *arXiv preprint arXiv:1006.5490*.

Stoll, H. R. (2001). Market fragmentation. *Financial Analysts Journal*, 16-20.

StreamBase. (2014). Smart Order Routing. *streambase.com/industries/capitalmarkets/smart-order-routing/*. Retrieved 14.11.2014

Udatha, B. C. (2011). Report on Direct Market Access and Ultra Low Latency Trading Facilities in India. *Available at SSRN 1795782*.

Wah, E., & Wellman, M. P. (2013). *Latency arbitrage, market fragmentation, and efficiency: a two-market model*. Paper presented at the Proceedings of the fourteenth ACM conference on Electronic commerce, Philadelphia, Pennsylvania, USA.

Ye, G. (2010). *High frequency trading models+ website* (Vol. 480): John Wiley and Sons.

Yin, R. K. (2014). *Case study research: Design and methods*: Sage publications.

Zubulake, P., & Lee, S. (2011). *The High Frequency game changer: how automated trading strategies have revolutionized the markets* (Vol. 486): John Wiley & Sons.