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From Algorithms to Market Dynamics: A Literature Review on High-Frequency Trading

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Abstract: High-frequency trading (HFT) uses advanced technologies and sophisticated algorithms to make transactions at unprecedented speeds, which could significantly impact modern financial markets. This literature review examines the technological foundations, primary trading strategies, market impacts, regulatory environment, risk management practices, and future research directions in HFT. The findings reveal that HFT could increase market liquidity and price discovery but also increase volatility during periods of high market stress. Regulatory frameworks such as the SEC's Market Access Rule and MiFID II aim to monitor and control HFT activities, at the same time effective risk management practices are crucial for maintaining market stability. Future research should focus on emerging technologies such as AI, ML, quantum computing, and blockchain, along with a better understanding of market structure and global regulatory coordination. This review provides valuable insights for market participants, regulators and researchers, contributing to a balanced perspective on HFT's role in contemporary financial markets.

Keywords: High-frequency trading (HFT), Market liquidity, Trading algorithms, Risk management.

1. Introduction

High-frequency trading (HFT) refers to when investors take advantage of advanced computing technology and high-speed networks to execute large volumes of trades within an extremely short time, which makes their trading speeds surpass other ordinary computers by milliseconds and ordinary human traders by whole seconds, thereby profiting in rapidly changing markets. With the development of the internet, HFT emerged in the early 2000s, and HFT has become a significant force in the financial markets. Statistics show that HFT accounts for 30% to 50% of trading volume in the U.S. stock market and also has a significant impact on other financial markets such as futures or foreign exchange markets [1].

The rapid development of HFT has caused widespread attention from both academia and the public, due to its significant role in improving the efficiency and changing structure of the whole market, understanding the HFT also makes economy profits for the investors. On the one hand, HFT is believed to enhance market liquidity and price discovery [2]. On the other hand, HFT also could bring potential risks and impacts on market stability, which could also cause considerable debate [3].

This paper aims to review a series of existing literature to analyze the technological foundations, primary strategies, and market impacts of HFT, and provide a reference for future research. This

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paper is structured as follows: section 2: Explores the technological foundation of HFT, which includes the algorithm design, computational speed, and data processing techniques; Section 3: Explores the primary strategies of HFT and the optimization methods; Section 4: Discusses the impact of HFT on market liquidity, market efficiency and market volatility; Section 5: Discusses the regulatory and risk management issue related to the HFT; Section 6: Look forward to future research directions in HFT; Section 7: Finding and conclusion.

2. Technological foundations of High-Frequency Trading

High-frequency trading (HFT) relies heavily on sophisticated algorithms to execute trades at extremely high speeds and volumes unattainable by human traders. So the design and implementation of these algorithms are crucial for the success of HFT strategies. Statistical arbitrage algorithms exploit price inefficiencies between correlated assets. These algorithms use statistical methods to identify groups of assets in which price movements are historically correlated but have temporarily diverged, the mean-reversion methods are often used, where the algorithm takes long positions in undervalued assets and short positions in overvalued assets, expecting the prices to revert to their historical relationship [4]. Market making is another algorithm that provides liquidity to the market by continuously quoting bids and asking prices. This algorithm profits from the bid-ask spread by simultaneously placing buy and sell orders. The primary challenge for market-making algorithms is to manage the inventory risk that arises from holding positions in assets [5]. Order flow analysis algorithms predict future price movement by analyzing the flow of orders in the market. These algorithms monitor the order book and use machine-learning techniques to identify patterns that precede price changes [6]. By short-term price movements, these algorithms could place advantageous trades and make profits.

The success of HFT is mostly dependent on the speed of execution. Therefore, substantial investments are made in computational infrastructure to achieve minimal latency. Low-latency networks are essential for HFT firms to gain speed advantages. Technologies such as fibre-optic cables and microwave communication are used to transmit data as quickly as possible between trading venues. This network reduces the time for trade orders to reach exchanges, providing competitive advantages in executing trades. Efficient software plays an important role in the HFT. Programming languages such as Python and C++ are commonly used in high-frequency trading systems due to their performance advantages [7]. At the same time, Lockwood et al. state that some software providers such as Mantara, Ullink and QuantHouse could offer customizable trading software which could minimise the latency [8]. Additionally, low-latency APIs are utilized to streamline the interaction between trading algorithms and exchanges. To achieve high-frequency trading, high-performance computing systems are commonly used in reality. Field-Programmable Gate Arrays (FPGAs) offer higher performance of low latency and flexibility compared to other platform such as Application-Specific Integrated Circuits (ASICs) and Graphics Processing Units (GPUs) [8]. These specialized hardware components are optimized for the rapid calculations required in HFT.

HFT requires a high-speed data processing and analysis system and sophisticated techniques to make split-second trading decisions. Real-time data acquisition is important for HFT. Market data such as price quotes, trade volumes and order book information is continuously collected from exchanges. HFT firms try to collect premium data seed to find up-to-date information. Machine learning (ML) and artificial intelligence (AI) as new advanced data modelling techniques, are used to identify trading opportunities. These model could used to analyzed historical and real-time data to forecast market movements and inform trading decisions. Fischer and Krauss showed that machine learning models, such as neural networks and decision trees, are particularly useful in detecting complex patterns in large datasets [9].

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3. Strategies and methods in High-Frequency Trading

High-frequency trading strategies operate under various market conditions, so the strategy design is crucial for the HFT firms which will help them to make profits. At the same time, the strategies' design and implementation could directly influence the trading performance. So we analyse some main strategies in today's market and try to find some inspirations. Arbitrage strategies exploit the price inefficiencies in the market by simultaneously buying and selling correlated assets. The arbitrage method is mainly divided into statistical arbitrage and cross-market arbitrage. Statistical arbitrage strategies are based on the historical correlation of asset prices, and using short-term price deviation to make profits [4]. Cross-market arbitrage captures the differences between different markets to get profits [10]. Market makers provide liquidity to the market by continuously quoting buy and sell prices, earning profits from the bid-ask spread. Ho and Stoll explained that market-making strategies require constant quote updates to respond to market price fluctuations [5]. The key elements of success for market-making strategies depend on efficient risk management and quick reaction capabilities. Order flow analysis strategies could predict short-term price movements by analysing the flow of orders in the market. HFT firms could use ML and AI techniques to identify the flow of order flow, which will help these firms predict price change and make profits.

Understanding these methods could help the HFT firms to make profits in the market, but how to adjust these methods and find the strategies optimization is another aspect that we need to consider. Machine learning as a new advanced modelling system is widely used in the optimization of HFT strategies. Algorithms learn patterns from historical data and automatically adjust strategy parameters to improve trading performance [9]. Risk management is another efficient method to adjust strategies in HFT. Common risk management techniques include stop-loss strategies, dynamic position adjustment, and real-time risk monitoring [1]. These techniques could ensure that trading strategies remain stable under extreme market conditions.

4. Impact of High-Frequency Trading on markets

Market liquidity refers to the ease of asset which an asset can be bought and sold in the market without affecting the asset's price. High-frequency trading has a significant impact on the market due to HFT could increase or decrease liquidity depending on the different market conditions.

HFT firms as a kind of market makers, providing liquidity by continuously quoting buy and sell prices. Studies have shown that HFT could improve liquidity by narrowing bid-ask spreads and increasing the depth of the order book [11]. This enhanced liquidity can lead to more efficient markets and lower transaction costs for all market participants. Although HFT could bring some benefits to the market, it also could lead to sudden liquidity withdrawals during the period of high market stress. HFT algorithms could simultaneously pull out the market, reduce volatility and create flash crashes. The "Flash Crash" of May 6, 2010, in the U.S. is a famous example in the financial market, an algorithm that precipitated the loss of $1 trillion of the US market capitalisation in a 10-minute-long cascade of falling prices. However, without any human intervention, the markets recovered to the previous levels in the following 15 minutes. KIRILENKO et al. analyzed the "Flash Crash" and explained how HFT could contribute to extreme volatility and rapid price declines [3].

Market efficiency refers to the extent to which asset prices reflect all available information in the market, it is mainly divided into weak forms of efficiency, semi-strong forms of efficiency, and strong forms of efficiency. HFT could influence market efficiency in several ways. Firstly, HFT could improve the ability of price discovery by quickly incorporating new information into asset prices, HFT algorithms analyze market data and execute trades at high speeds, which could ensure that the price reflects all the information in the market [12]. This rapid adjustment of prices to new information could make the market become more efficient. Secondly, HFT could contribute to noise

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trading, where trades are based on short-term price movements rather than fundamental information. This could lead to increased volatility and potential mispricing of assets. The difficulty is distinguishing between trades that contribute to real price discovery and those that could cause noise [13].

Market volatility is another important topic when we consider the impact of HFT. Market volatility refers to the degree of variation in asset price over time. On the one hand, some studies suggest that HFT could increase short-term volatility due to the large volume of trades, which means the presence of HFT could increase price swings during periods of market uncertainty [14]. On the other hand, some research indicates that HFT could reduce market volatility by providing liquidity and stabilizing prices through market-making activities [2]. The effect of HFT on volatility depends on the specific strategies used in the market and the whole market environment.

5. Regulation and risk management in High-Frequency Trading

High-frequency trading could bring some benefits to the whole market, but the challenges with HFT are another important issue that we need to consider. HFT has posed significant challenges for regulators due to its complexity and potential to influence market stability. Different areas implemented different regulatory measures to address these challenges and ensure market efficiency.

In the United States, the Securities and Exchange Commission (SEC) and the Commodity Future Trading Commission(CFTC) have introduced regulations aimed at monitoring and controlling HFT activities. The SEC's Market Access Rule requires brokers and dealers to implement risk management controls to prevent inaccurate trade. The CFTC has also proposed rules to enhance the oversight of automated trading systems, which requires registration requirements and risk management [15].

The European Union also implemented some regulations such as the Markets in Financial Instruments Directive II (MiFID II) to control risk, the MiFID II came into effect in January 2018. MiFID II is a principle-based systemic regulation, with a clear objective of providing more transparency to the financial market structure through uniform EU regulations [16]. At the same time, MiFID II requires firms to store order data and implement circuit breakers, and firms also need to have effective systems to control and manage the risks, associated with algorithmic trading.

Due to the high speed of transactions, how to manage risk effectively is crucial for HFT firms to mitigate risk and maintain market integrity. Firstly, HFT firms implement various pre-trade risk controls to prevent high-risk trades. These controls are mainly divided into order size limits, price collars, and automated stop transactions if activities risk over the thresholds [1]. Secondly, HFT firms implement continuous real-time monitoring of trading activities, which is essential for firms to identify and address potential risks. HFT firms use sophisticated surveillance systems to track order flow, market conditions, and system performance, allowing them to respond quickly to any risk activities [17]. Thirdly, HFT firms could use post-trade analysis to assess the performance of trading strategies and identify the disadvantages. This analysis involves reviewing trade data, and market impact to improve algorithms and risk management practices [18].

The rapid development of HFT also raised many ethical and legal concerns, which prompted people to find more effective regulations and oversight. The first concern is about market manipulation. HFT strategies sometimes could be used to manipulate markets. These practices involve placing large orders but not executing them or creating false signals about supply and demand [19]. So regulators have increased efforts to detect and penalize these activities. Fairness and market access are other concerns that are mostly caused, by the high speed of HFT raising questions about fairness and market access. Critics argue that HFT will create an unfair competitive environment because traditional investors are disadvantaged. To find a fair trading opportunities is another challenge for the regulators.

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6. Future research directions in High-Frequency Trading

The rapid development of technology could continue to influence the HFT. Future research about technological innovations could prompt and regulate HFT. For the aspect of technology, Artificial Intelligence (AI) and Machine learning (ML) in HFT algorithms bring significant opportunities in HFT development. Future studies could investigate how AI and ML could improve the accuracy optimize the trade strategies and improve the ability of risk management. Research also explores the ethical implications and regulatory challenges associated with the use of AI. Quantum Computing could revolute the HFT by solving complex optimization problems at high speed. Future research could explore the potential benefits and feasibility methods of quantum computing which improve the reliability of HFT [20]. Yermack stated that the use of blockchain and distributed ledger technology (DLT) in financial markets can enhance transparency and security [21]. Future research could explore how HFT firms use these technologies to improve transaction efficiency and reduce transaction risk.

Understanding the market structure is another aspect that future studies could consider. The behaviour of order books plays an important role in HFT. Researchers could analyse the dynamics of order books in different market conditions to find how the HFT influences market liquidity, price discovery and market stability [22]. At the same time, latency arbitrage exploits small time delays in the market, future research could examine the impact of latency arbitrage on market fairness and efficiency and find appropriate ways to eliminate the risks [23].

Regulatory and ethical considerations attract more attention in reality. So future research could evaluate the existing regulatory frameworks in managing risk associated with HFT. Researchers could propose enhancements to these frameworks to better address emerging challenges and ensure market integrity. Given the global nature of financial markets, international coordination in regulating and monitoring HFT is essential. Future research could focus on how to achieve the global coordination to achieve the goal of safety and effective transaction.

7. Conclusions

HFT relies on sophisticated algorithms, high-speed computational infrastructures, and real-time data processing techniques. Advances in AI and ML, along with the potential of quantum computing and blockchain technology could provide powerful power in the development of HFT. HFT also use multiple strategies such as statistical arbitrage, market making, and order flow analysis. These strategies could use the market inefficient to rapid transactions, while sophisticated risk management techniques could mitigate potential risks [4, 5, 6].

In conclusion, understanding the HFT has many practical implications for market participants, regulators and researchers. For market participants, understanding the technologies and strategies of HFT could improve trade performance and mitigate risk during the transactions. Regulators could benefit from the existing regulations and find more efficient regulations to regulate the financial markets. Researchers could identify higher research directions in HFT. While the literature provides a comprehensive overview, it also has its own limitations. The rapid speed of development of technologies and market changes means some of the discussions in this paper may quickly become outdated. Additionally, the complexity of HFT brings challenges in understanding their impacts.

Future research should focus on empirical studies to validate theoretical models and assess the real-world implications of HFT. Collaboration between academia, industry, and different countries can facilitate a more comprehensive understanding and effective oversight of HFT activities.

References

[1] *Aldridge, I., & Ebrary, I. (2013). High-frequency trading: a practical guide to algorithmic strategies and trading systems. Wiley.*

[2] Brogaard, J., Hendershott, T., & Riordan, R. (2014). High-Frequency Trading and Price Discovery. Review of Financial Studies, 27(8), 2267–2306. https://doi.org/10.1093/rfs/hhu032
[3] KIRILENKO, A., KYLE, A. S., SAMADI, M., & TUZUN, T. (2017). The Flash Crash: High-Frequency Trading in an Electronic Market. The Journal of Finance, 72(3), 967–998. https://doi.org/10.1111/jofi.12498
[4] Avellaneda, M., & Lee, J.-H. (2010). Statistical arbitrage in the US equities market. Quantitative Finance, 10(7), 761–782. https://doi.org/10.1080/14697680903124632
[5] Ho, T., & Stoll, H. R. (1981). Optimal dealer pricing under transactions and return uncertainty. Journal of Financial Economics, 9(1), 47–73. https://doi.org/10.1016/0304-405x(81)90020-9
[6] Cont, R., Stoikov, S., & Talreja, R. (2010). A Stochastic Model for Order Book Dynamics. Operations Research, 58(3), 549–563. https://doi.org/10.1287/opre.1090.0780
[7] Narula, M., & Rohatgi, D. (2021). IMPLEMENTING AUTOMATED ALGORITHMIC COMMODITY TRADING USING PYTHON. Advances and Applications in Mathematical Sciences, 20(10), 2127–2135. https://www.mililink.com/upload/article/254718161aams_vol_2010_august_2021_a8_p2127-2135_meenakshi_narula_and_divisha_rohatgi.pdf
[8] Lockwood, J. W., Gupte, A., Mehta, N., Blott, M., English, T., & Vissers, K. (2012). A Low-Latency Library in FPGA Hardware for High-Frequency Trading (HFT). High Performance Interconnects. https://doi.org/10.1109/hoti.2012.15
[9] Fischer, T., & Krauss, C. (2018). Deep learning with long short-term memory networks for financial market predictions. European Journal of Operational Research, 270(2), 654–669. https://doi.org/10.1016/j.ejor.2017.11.054
[10] Gatev, E., Goetzmann, W. N., & Rouwenhorst, K. G. (2006). Pairs Trading: Performance of a Relative-Value Arbitrage Rule. Review of Financial Studies, 19(3), 797–827. https://doi.org/10.1093/rfs/hhj020
[11] Brogaard, J. (2010). High Frequency Trading and Market Quality. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1970072
[12] HENDERSHOTT, T., JONES, C. M., & MENKVELD, A. J. (2011). Does Algorithmic Trading Improve Liquidity? The Journal of Finance, 66(1), 1–33. https://doi.org/10.1111/j.1540-6261.2010.01624.x
[13] Zhang, F. (2010, December 1). High-Frequency Trading, Stock Volatility, and Price Discovery. Papers.ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1691679
[14] Benos, E., & Sagade, S. (2012). High-Frequency Trading Behaviour and Its Impact on Market Quality: Evidence from the UK Equity Market. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2184302
[15] Johnson, B. (2010). Algorithmic trading & DMA : an introduction to direct access trading strategies. -. https://cir.nii.ac.jp/crid/1130282271924397568
[16] ČUK, T., & VAN WAEYENBERGE, A. (2018). European Legal Framework for Algorithmic and High Frequency Trading (Mifid 2 and MAR). European Journal of Risk Regulation, 9(1), 146–153. https://doi.org/10.1017/err.2018.3
[17] Hasbrouck, J., & Saar, G. (2013). Low-latency trading. Journal of Financial Markets, 16(4), 646–679. https://doi.org/10.1016/j.finmar.2013.05.003
[18] Biais, B., Foucault, T., & Moinas, S. (2012). Equilibrium High-Frequency Trading. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2024360
[19] Bartlett, R. P., & McCrary, J. (2019). How rigged are stock markets? Evidence from microsecond timestamps. Journal of Financial Markets. https://doi.org/10.1016/j.finmar.2019.06.003
[20] Orús, R., Mugel, S., & Lizaso, E. (2019). Quantum computing for finance: Overview and prospects. Reviews in Physics, 4, 100028. https://doi.org/10.1016/j.revip.2019.100028
[21] Yermack, D. (2017). Corporate Governance and Blockchains. Review of Finance, 21(1), 7–31. https://doi.org/10.1093/rof/rfw074
[22] Cont, R., Kukanov, A., & Stoikov, S. (2013). The Price Impact of Order Book Events. Journal of Financial Econometrics, 12(1), 47–88. https://doi.org/10.1093/jjfinec/nbt003
[23] Budish, E., Cramton, P., & Shim, J. (2015). The High-Frequency Trading Arms Race: Frequent Batch Auctions as a Market Design Response. The Quarterly Journal of Economics, 130(4), 1547–1621. https://doi.org/10.1093/qje/qjv027