

Algorithmic and High-frequency Trading in Hong Kong's Equity Market:

Adoption, market impact and risk management

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FOREWORD

Global equity markets have been increasingly adopting algorithmic trading (AT) and high-frequency trading (HFT) technologies over the past two decades, thanks to the digitalisation of securities trading as well as advancements in sophisticated proprietary trading algorithms, high-speed computer systems and co-location services. Machines can now assist in executing high-speed trading strategies that are difficult for humans to implement manually. The rise and adoption of AT/HFT technologies have changed the way trading takes place in financial markets. High volumes of smaller, shorter-term buy and sell orders now move rapidly in and out of markets, reacting more instantaneously to information and changes in market conditions. These new trading behaviours are likely to bear important consequences for equity markets, and it is important to investigate their implications for investor protection and the overall market quality.

This report, after providing an overview of AT/HFT across international financial markets, explores its interactions with equity market liquidity and volatility, two key aspects of market quality. This complex link is then investigated in the context of Hong Kong's equity market. The report also shows the results of a survey, commissioned by the Hong Kong

Institute for Monetary and Financial Research (HKIMR), which gathered the insights of equity market participants on their views about AT/HFT in Hong Kong. The study is concluded by a detailed review of the potential risks emerging from AT/HFT and discusses the mitigating measures and best practices used to monitor and manage these risks and the current regulatory oversight of AT/HFT activities.

We hope that this report serves as a useful starting point towards a better understanding of AT/HFT in Hong Kong and it is able to offer meaningful insights regarding the challenges and risks emerging from AT/HFT.

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survey on *Algorithmic and High-frequency Trading in Hong Kong's Equity Market* in July 2020, for conducting interviews with market participants, and for contributing to Chapter 2 of this report. We thank the Securities and Futures Commission (SFC) of Hong Kong, and the Hong Kong Monetary Authority (HKMA) Communications Division for their valuable comments and suggestions, and the HKIMR Council of Advisers for Applied Research for their continuing support and guidance on the research activities of the Institute.

EXECUTIVE SUMMARY

With the advancements of electronic trading platforms and high-speed communication networks, algorithmic trading (AT) and high-frequency trading (HFT) technologies are now used to place and execute orders at a speed that was unimaginable just a decade ago. **AT refers to electronic, computerised trading that automatically executes orders according to predetermined parameters and rules.** Using trading algorithms, machines can easily perform trading strategies that humans find difficult to manually implement. As a subset of AT, **HFT aims to trade securities at extremely high speed, from microseconds to nanoseconds, while maintaining very tight intraday inventory positions.**

A large body of research highlights that AT/HFT has become an important part of securities trading across asset classes and geographical locations, especially for equity trading. Because of this prevalence, various studies have explored the intertwined relationship between AT/HFT and several aspects of market quality. The existing evidence suggests that **AT/HFT generally improves market liquidity**, an important aspect of market quality. **However, this increased liquidity may not be resilient** and, in some cases, AT/HFT may even reduce the overall liquidity available to institutional investors. **In addition, with higher liquidity co-movements across markets due to intense AT/HFT activities, there are potential implications for systematic risk, as the speed of shock transmission across different markets may increase.** The research evidence is inconclusive as far as the relationship between AT/HFT and market volatility is concerned, as **higher levels of AT/HFT activities are not clearly associated with higher market volatility.** **Nonetheless, some studies have highlighted the risks of AT/HFT exacerbating periods of unusual market stress.** Most of these research findings have been recorded for international

markets but little evidence is present for Hong Kong's equity market, despite its substantial size and role among equity markets in the Asia-Pacific region and globally.

This report focuses on AT/HFT in Hong Kong's equity market. **The main goal is to understand the prevalence of AT/HFT in this market and whether AT/HFT technologies exert any impact on market liquidity and volatility.** The report complements the statistical evidence **with the views of market participants regarding the current AT/HFT landscape in Hong Kong, its benefits and the existing challenges and risks.** This is done through the survey on *Algorithmic and High-frequency Trading in Hong Kong's Equity Market* and interviews commissioned by the HKIMR and conducted in July 2020. The report is concluded by a review of the salient risks emerging from AT/HFT adoption that have been highlighted by international market participants and regulators. Then, it discusses the measures that have been proposed or implemented with an aim of mitigating risks associated with AT/HFT adoption and the regulatory oversight of AT/HFT activities observed in international markets.

Our research, based on a statistical estimation of AT/HFT participation, finds that about 11% of all cash equity trades occurring on the Main Board can be attributed to AT/HFT. The total number of orders on the Main Board is about seven times of the total number of trades executed, and **overall AT/HFT activities have remained modest and stable over the period between August 2018 and July 2020.** Regarding the impact of AT/HFT on key aspects of market

quality, our preliminary estimations show that, **during the two-year period, a higher level of AT/HFT activities is not associated with a deterioration of market liquidity or increased market volatility.** Nonetheless, given the relatively short period of time covered in our analysis, **further validation is needed to gather evidence regarding the resilience and stability of liquidity provided by AT/HFT participants as well as the impact of AT/HFT on market volatility during turbulent times.** Furthermore, it is natural to hypothesise that the market impact and the risks associated with AT/HFT may potentially increase when its participation and prevalence grows over time.

The survey and interview findings show that respondents adopting AT/HFT technologies in Hong Kong use them mostly for automating their trading, dynamically tracking benchmarks, minimising market impact of large orders, and performing agency trading. **The benefits of AT/HFT adoption include the acquisition of the ability to perform back-testing and diagnose trading algorithms, the achievement of higher trading accuracy, consistency and efficiency, and a reduction in the impact of human biases in trading.** However, survey respondents also pointed to **the reliance on data and technologies deployed, requirement of capabilities for managing data, software, hardware and computer network, and the exposure to potential technical risks associated with failure of hardware or software, or network outage as main challenges of adopting AT/HFT technologies.**

The adoption of AT/HFT technologies can give rise to new sources of risks that equity market participants and regulators have to confront with. To encourage an effective management of the potential risks associated with the adoption of AT/HFT technologies and to maintain market integrity, market participants and trading venues have proposed or implemented measures to mitigate the risks and enhance the effectiveness of traditional risk management practices. **These mitigating measures include adhering to best practices when adopting AT/HFT technologies, upholding the integrity of trading strategies and algorithms, raising risk awareness, establishing proper and robust internal controls, maintaining robust governance over AT/HFT adoption, implementing volatility control mechanisms, restraining AT/HFT and establishing sandboxes for assessing the impact of changes in market design, policies and regulations.**

Furthermore, **international regulators have also adjusted compliance requirements to integrate the monitoring of AT/HFT activities into their supervisory framework.** They have strived to strengthen their monitoring tools in overseeing AT/HFT for maintaining market quality and financial stability. The existing regulations in Hong Kong are consistent with these international practices.

In view of the high speed, large volume of order and trade data and complexity involved in AT/HFT, **continuing efforts to develop market quality metrics and enhance data analytics capabilities for surveillance and policy developments are desirable goals to pursue in the near future.**

Chapter 1

ALGORITHMIC AND HIGH-FREQUENCY TRADING IN INTERNATIONAL FINANCIAL MARKETS: A BIRD'S EYE VIEW

Characteristics and impact on the quality of financial markets

- 1.1: What is algorithmic trading and high-frequency trading?
- 1.2: AT/HFT growth in international financial markets
- 1.3: Equity market quality and AT/HFT



1 ALGORITHMIC AND HIGH-FREQUENCY TRADING IN INTERNATIONAL FINANCIAL MARKETS: A BIRD'S EYE VIEW

CHARACTERISTICS AND IMPACT ON THE QUALITY OF FINANCIAL MARKETS

◆ HIGHLIGHTS: ◆

- ▶ **Algorithmic trading (AT) uses pre-programmed instructions to electronically trade securities automatically; high-frequency trading (HFT) further emphasises high speed and aims to maintain very tight intraday inventory positions.**
- ▶ **Research studies show that global equity markets have experienced a widespread adoption of AT/HFT technologies.**
- ▶ **Existing evidence suggests that AT/HFT generally improves market liquidity. However, this increased liquidity may not be resilient. Furthermore, with higher liquidity co-movements across markets due to intense AT/HFT activities, there are potential implications for systematic risk, as the speed of shock transmission across different markets may increase.**
- ▶ **The evidence relating AT/HFT to market volatility is mixed and inconclusive. Some studies have highlighted the risks of AT/HFT exacerbating period of unusual market stress.**
- ▶ **More research is needed to understand these complex relationships.**

International financial markets have adopted electronic trading platforms and high-speed communication networks. Replacing most floor trading, electronic trading has become the standard mechanism for securities trading. Digitalisation and expansion in computational capacity of trading platforms has naturally fostered the growing use of algorithmic and high-frequency trading technologies in capturing potential opportunities across securities, asset classes and markets.

1.1 WHAT IS ALGORITHMIC TRADING AND HIGH-FREQUENCY TRADING?

Algorithmic trading (AT) refers to electronic, computerised trading that automatically executes orders according to predetermined parameters and rules.¹ Using trading algorithms' pre-programmed instructions, machines can

easily perform trading strategies that humans find difficult to manually implement. One AT strategy commonly used is to split buy and sell orders into smaller portions to hide trading footprint and minimise price impact. With high computational power, AT technologies can react instantaneously to news about securities, asset classes and markets. AT technologies can also examine prices from several markets simultaneously and search for liquidity among multiple trading venues in the course of identifying profitable opportunities.

AT uses pre-programmed instructions to trade securities automatically.

¹ Australian Securities and Investments Commission (2013).

High-frequency trading (HFT) is a subset of AT.² HFT aims to trade securities at extremely high speed, from microseconds to nanoseconds, while maintaining very tight intraday inventory positions.³ Some HFT strategies aim to earn the bid-ask spreads by deliberately placing numerous buy and sell orders at various prices to expedite the order-execution process in trading venues. In these trading strategies, HFT participants are voluntarily performing market making.

As a subset of AT, HFT trades securities at extremely high speed while maintaining very tight intraday inventory positions.

HFT technologies use three tools to achieve higher speed: (i) sophisticated proprietary trading algorithms; (ii) high-speed computer systems; and (iii) co-location services.⁴ HFT users do not accumulate positions and most of their orders are of very short-term investment horizon. Enhanced computer systems enable HFT users to rapidly send a large amount of buy and sell orders, amendments, and cancellations to the electronic platforms of trading venues, moving in and out of short-term positions at high volumes aiming to capture often a fraction of a cent in profit on each trade. To make up for the thin profit margins, the success of HFT relies on huge volume of trades, which may affect the dynamics of liquidity in financial markets.

1.2. AT/HFT GROWTH IN INTERNATIONAL FINANCIAL MARKETS

AT/HFT adoption has gained significant attention in international financial markets. Time has passed since the International Joint Conference on Artificial Intelligence in 2001, where a team of IBM researchers experimentally showed that trading driven by algorithms under an electronic auction environment can perform as effectively as, and in some cases, better than trading conducted by human traders.⁵ This and more compelling findings have propelled a deeper and broader exploration of trading algorithms in financial markets around the world. In order to understand the role and extent of AT/HFT in international financial markets, we present key information for both AT and HFT and their relevance across various asset classes and different geographical regions.

² Lin (2014); Tradeworx (2010).

³ Bank for International Settlements (2016).

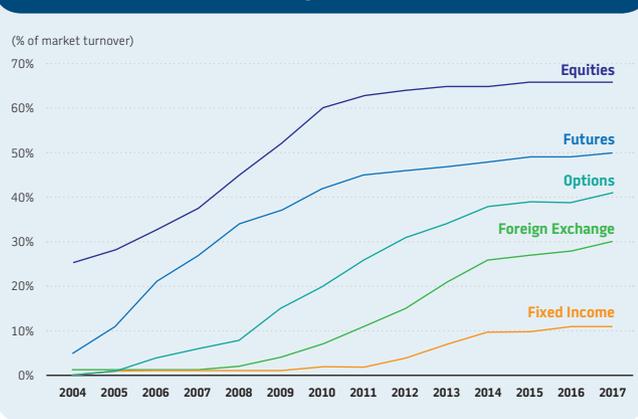
⁴ Co-location service locates a trader's computing equipment within a trading venue's primary data centre and clearing system. The physical proximity reduces delay in information flow.

⁵ Das, Hanson, Kephart, and Tesauro (2001).

AT

AT is most popular in the global equity market, accounting on average for about 65% of total market turnover in 2017, up from 25% in 2004 (Chart 1.1). In derivatives markets, AT accounts for nearly half of total turnover in the futures market and 40% in the options market. In foreign exchange and fixed income markets, the share of AT in market turnover increased notably to 30% and 10% respectively in 2017, compared to less than 2% in 2004.

Chart 1.1: Global AT as a share of market turnover by asset classes

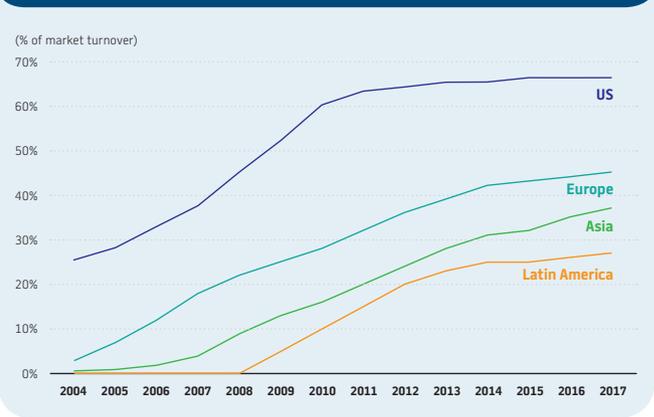


Sources: Aite Group and Goldman Sachs Global Investment Research.

AT in equity trading has seen growth in market shares across various geographical regions over the period 2004 to 2017. Partly underpinned by policies and regulations that helped facilitating competition⁶, participants in the US and European financial markets were early adopters of AT technologies.⁷ In these markets, AT has grown quickly since 2004, contributing to 65% of equity market turnover in the US and 45% in Europe in 2017 (Chart 1.2). Research studies estimate that AT now accounts for

around 60% to 73% of equity trading in the US.⁸ AT has also gained momentum outside the US market. In Asia and Latin America, AT increased significantly over the past decade, and now accounts for 35% and 25% of equity market turnover, respectively. Despite faster growth in emerging markets, the US and European markets remain the ones with the most AT activities in recent years.

Chart 1.2: AT as a share of equity trading across geographical regions



Sources: Aite Group and Goldman Sachs Global Investment Research.

The trend of AT adoption in international markets is evident: AT has become an important part of securities transactions for most asset classes, with equity trading leading the way. The rise of institutional investing has also played a role in promoting AT adoption. Due to the vast amount of assets under management, institutional investors often need to trade a large volume of securities on a daily basis. AT technologies enable institutional investors to reduce trading costs and improve profitability, therefore they found it efficient to use trading algorithms to manage their investment portfolios. AT technologies can also help institutional investors implement various types of trading strategies, such as arbitraging price differences of the same securities in different trading venues.⁹

⁶ For example, the Regulation National Market System in the US and the Markets in Financial Instruments Directive in Europe.
⁷ Competition can alter how trading venues charge fees. For example, the shift from fixed fee per trade to ad valorem fee (fee proportional to transaction value) makes it less costly for trading algorithms to split large orders into smaller ones. Beside, market fragmentation (multiple trading venues) motivates the use of trading algorithms to search for liquidity and best quotes.
⁸ See, for example, Mordor Intelligence (2020).
⁹ Mordor Intelligence (2020).

HFT

Similar to the patterns exhibited for AT developments, the US and Europe also lead in terms of HFT adoption. In the US, HFT, as a share of equity market turnover, increased from 20% in 2005 to 60% in 2009 before stabilising at 50% in recent years (Table 1.1).¹⁰ In Europe, the share of HFT in equity market turnover climbed from just 1% in 2005 to nearly 40% in 2011, before stabilising at 25% in 2014. In Australia, statistics compiled by Australian Securities and Investments Commission (ASIC) show that the

share of HFT in equity market turnover has remained largely stable at 20–30% over the past few years. Other scattered evidence indicates HFT accounted for 40% of equity trading in Canada in 2011, and 36% in Japan in 2013. In contrast, HFT only contributed to 6% of equity market turnover in Brazil and 5% in Asia (ex Japan) in the past decade.¹¹

Table 1.1: Market share of HFT in equity trading in US, Europe, and Australia equity markets (% of market turnover)

	2005–2008	2009–2013	2014–2019
US equities	34%	54%	51%
European equities	9%	33%	25%
Australian equities	–	27%	26%

Note: Average market share of HFT in equity trading over the period. – denotes data not available.

Sources: Tabb Group, Kauffman, Hu and Ma (2015), and Australian Securities and Investments Commission (2013, 2015, 2018).

¹⁰ The difference in terms of estimated market shares of HFT in equity trading in the US in 2009 reported in Chart 1.2 and Table 1.1 are likely due to different AT/HFT definitions and data samples used by the different sources.

¹¹ The Investment Industry Regulatory Organization of Canada (2012) provided the figures for Canada. The Japan Exchange Group (2014) provided the figures for Japan. The Financial Times provided the figures for Brazil and Asia (ex Japan).

1.3. EQUITY MARKET QUALITY AND AT/HFT

The widespread use of AT/HFT technologies has changed the way trading is undertaken in equity markets. It is therefore crucial to understand the impact of AT/HFT on the quality of these markets. In general, financial markets are said to be of a high quality when they have a secure, reliable trading environment, information transparency, and the prospects for investors to successfully have their orders executed at competitive prices that accurately reflects the equities' underlying values, with immediacy and in volume and at low cost. Put differently, an equity market with a high quality exhibits deeper market liquidity, lower market volatility, and better price discovery and efficiency. A vast body of literature has explored the interactions between AT/HFT and market quality. In what follows, we selectively review the salient aspects of this literature.

The impact of AT/HFT on equity market liquidity

Market liquidity refers to the ability to buy or sell a large amount of an equity security quickly, with low trading cost, when investors want to trade.¹² Research studies find that AT/HFT participants are usually net providers of market liquidity in equity markets. In other words, AT/HFT generally provides more liquidity than it takes, increasing the likelihood of investors' equity orders being executed at competitive prices. For example, in the Canadian equity market, it is estimated that 10–41% of AT/HFT

provides liquidity, while 11–23% takes liquidity. Around 80% of AT/HFT in the Dutch equity market and 64% of the Japanese equity market provide liquidity. In the Australian equity market, AT/HFT contributes approximately 20% of market liquidity for the largest 200 equities. On a global scale, co-location services, which facilitate AT/HFT, also help improve market liquidity. In fact, 42 equity markets have experienced higher market liquidity after having introduced co-location facilities.¹³

However, this increased liquidity may not be resilient, especially when the liquidity comprises small, fleeting orders and ghost liquidity.¹⁴ In addition, AT/HFT participants making markets are usually not registered market makers and they can participate in and withdraw from providing liquidity at their discretion.¹⁵

Research studies have also found that AT/HFT may help reduce bid-ask spreads, leading investors to trade equities at a lower cost when AT/HFT is present. These studies show that bid-ask spreads in the US, Canadian and Dutch equity markets have narrowed since AT/HFT has become more active and prevalent.¹⁶

¹² Harris (2003).

¹³ Hendershott and Riordan (2013); Brogaard, Hendershott, and Riordan (2019); Menkveld (2013); Japan Exchange Group (2014); Australian Securities and Investments Commission (2013); Boehmer, Fong, and Wu (2020).

¹⁴ Fleeting orders are those that rest in the order book very briefly. Ghost liquidity refers to liquidity observed on the trading screen, but vanishes before one can take it. See Degryse, De Winne, Gresse, and Payne (2019), European Securities and Markets Authority (2016) and Hasbrouck and Saar (2009).

¹⁵ See, among others, Australian Securities and Investments Commission (2010b) and O'Hara (2015).

¹⁶ Hendershott, Jones, and Menkveld (2011); Malinova, Park, and Riordan (2013); Menkveld (2013).

It is instructive to note that lower bid-ask spreads may not be meaningful to every investor. For example, institutional investors consider the execution costs accumulated over a series of trades executed over multiple hours or days, rather than only the cost of a single trade. A research study on the Swedish equity market shows that HFT provides market liquidity to institutional investors only in short-lived trades (seven hours or less). For long-lived orders, HFT participants trade in the same direction as institutional investors, which face lower market liquidity and higher execution costs. Furthermore, a research study on the Canadian equity market finds that higher levels of HFT activities are associated with lower retail but higher institutional trading costs. Therefore, AT/HFT may even reduce the overall liquidity available to institutional investors in some cases.¹⁷

In addition, intense AT/HFT activities may lead to higher liquidity co-movements across markets. As automated trading of simultaneous large orders may exert common pressure on market maker inventories, and AT/HFT participants with similar trading algorithms may exhibit correlated trading patterns, common changes in inventory pressure across markets may occur.¹⁸ Therefore, AT/HFT has potential implications for systematic risk, as the speed of shock transmission across different markets may increase.

Research studies find that AT/HFT generally improves market liquidity. However, this increased liquidity may not be resilient and higher liquidity co-movements across markets may increase the speed of shock transmission.

¹⁷ van Kervel and Menkveld (2019); Korajczyk and Murphy (2019).

¹⁸ Chordia, Roll, and Subrahmanyam (2000); Karolyi, Lee, and van Dijk (2012).

The impact of AT/HFT on equity market volatility

Market volatility refers to the tendency of equity prices to fluctuate sharply within a period of time. An incident of extreme swings in short-term equity prices coinciding with heightened AT/HFT activities was the “Flash Crash” on 6 May 2010, where major US indices in both cash and futures markets experienced a 9% loss within minutes only to recover a large part of the loss after 30 minutes. The impact of this kind of events, which occurred again at later dates in different markets across asset classes, has spurred a large literature aiming to understand the implications of these extreme price movements for regulators and market participants.

Research studies have examined the association between market volatility and AT/HFT. The results are, however, mixed and inconclusive. On the one hand, some studies have shown that HFT passive market making strategies can reduce short term volatility in the NASDAQ-OMX Sweden market, and to some extent in the US equity market. However, on the other hand, some have also shown that AT can amplify short term volatility in various asset markets globally and highlighted the risks of AT/HFT exacerbating periods of unusual market stress.¹⁹

AT/HFT and other aspects of equity market quality

In addition to market liquidity and volatility, AT/HFT may affect other aspects of market quality, such as the speed of price discovery and the extent of price efficiency. Price discovery refers to the process through which new information is incorporated into equity prices, and price efficiency refers to a status where all the information relevant for an equity security has been reflected into its price. The reason AT/HFT relates to price discovery and price efficiency is that it is able to arbitrage price differences away across different securities or market segments. However, such trading is typically implemented within very short-time frames but does not represent the majority of the total AT/HFT volume. Research findings suggest that the relationship between AT/HFT and price discovery or price efficiency varies across markets.²⁰ While HFT helps incorporate available information into prices in the NASDAQ and Canadian equity market, AT is found to have reduced information content in US equity prices. Such a disconnect also occurs in other asset markets.²¹ In addition, during market stress, AT/HFT may exacerbate price movements because of price discovery activity, if large amount of trades floods in responding to opaque or incomplete information.

¹⁹ Boehmer, Fong, and Wu (2020); Hagströmer and Nordén (2013); Hasbrouck and Saar (2013); Securities and Exchange Commission (2020).

²⁰ Brogaard, Hendershott, and Riordan (2014); Brogaard, Hendershott, and Riordan (2019); Weller (2018).

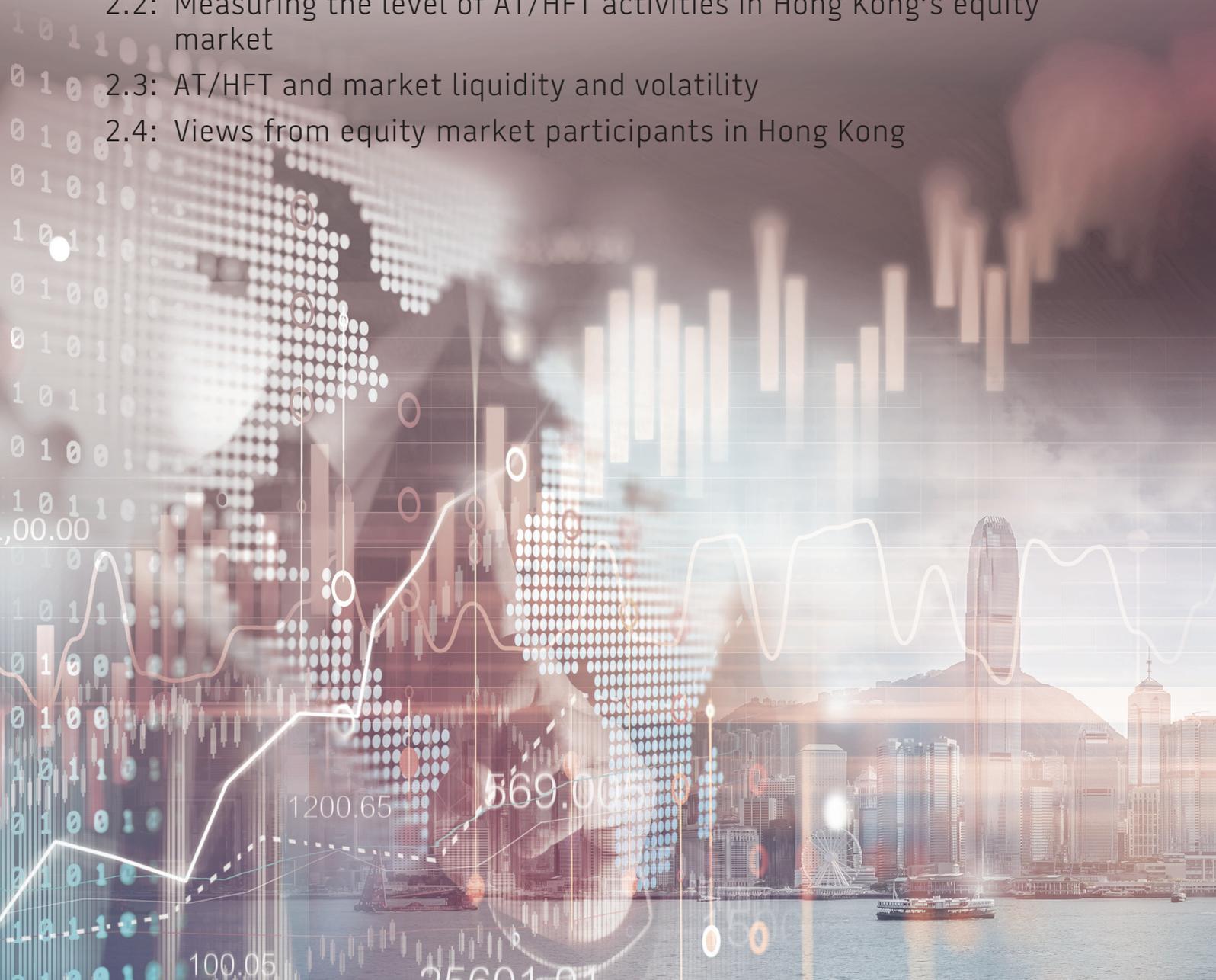
²¹ For US Treasuries see Jiang, Lo, and Valente (2018).

Chapter 2

ALGORITHMIC AND HIGH-FREQUENCY TRADING IN HONG KONG'S EQUITY MARKET: STATISTICAL EVIDENCE AND MARKET VIEWS

Prevalence, relationship with the liquidity and volatility of the equity market and views from market participants

- 2.1: Institutional and regulatory framework for trading securities in Hong Kong
- 2.2: Measuring the level of AT/HFT activities in Hong Kong's equity market
- 2.3: AT/HFT and market liquidity and volatility
- 2.4: Views from equity market participants in Hong Kong



2 ALGORITHMIC AND HIGH-FREQUENCY TRADING IN HONG KONG'S EQUITY MARKET: STATISTICAL EVIDENCE AND MARKET VIEWS

PREVALENCE, RELATIONSHIP WITH THE LIQUIDITY AND VOLATILITY OF THE EQUITY MARKET AND VIEWS FROM MARKET PARTICIPANTS

◆ HIGHLIGHTS: ◆

- ▶ Our analysis, based on the period between August 2018 and July 2020, shows that about 11% of all cash equity trades occurring on the Main Board can be attributed to AT/HFT. The Main Board's order-to-trade ratio is about 7:1 and overall AT/HFT activities have remained modest and stable over the two-year period.
- ▶ Our research also suggests that AT/HFT does not deteriorate market liquidity and it is not associated with increased market volatility. However, further validation is needed to gather evidence regarding the resilience and stability of liquidity provided by AT/HFT participants as well as the impact of AT/HFT on market volatility during turbulent times.
- ▶ Survey findings show that while participants have benefitted from AT/HFT adoption, the reliance on data and technologies deployed, requirement of capabilities for managing data, software, hardware and computer network, and the exposure to potential technical risks associated with failure of hardware or software, or network outage have been the main challenges of adopting AT/HFT technologies.

This chapter first presents the results from an empirical study commissioned by the HKIMR aiming to measure the level of AT/HFT activities in Hong Kong's equity market and better understand the relationship between AT/HFT and market liquidity and volatility. The latter part of the chapter discusses the results of a survey conducted by the HKIMR to gather the views of market participants regarding the benefits and challenges of AT/HFT adoption in Hong Kong's equity market.

2.1 INSTITUTIONAL AND REGULATORY FRAMEWORK FOR TRADING SECURITIES IN HONG KONG

As a preliminary background, it is useful to understand the institutional settings and the regulatory framework of securities trading in Hong Kong. The Securities and Futures Ordinance sets out the key regulations governing securities trading in Hong Kong, and the Securities and Futures Commission

(SFC) of Hong Kong is the regulatory body overseeing and supervising securities firms, brokers and asset managers registered in Hong Kong. Under the Securities and Futures Ordinance, the Hong Kong Exchanges and Clearing Limited (HKEX) owns and operates the one and only stock exchange for listing and trading of cash equity and other securities in Hong Kong.²²

There are two platforms for listing equities in Hong Kong, the Main Board for blue chips and more established companies, and the Growth Enterprise Market for new start-ups or small to mid-sized enterprises. The Main Board accounts for 99% of total market capitalisation and turnover of Hong Kong's equity cash market²³ and, as of February 2021, cash equity trading covers about 84% of the total turnover for all securities trading in Hong Kong's equity market.

²² Other securities include derivative warrants, callable bull/bear contracts, inline warrants and unit trusts (including exchange traded funds).

²³ See https://www.hkex.com.hk/Mutual-Market/Stock-Connect/Statistics/Hong-Kong-and-Mainland-Market-Highlights?sc_lang=en#select3=0&select2=9&select1=13 for more statistics.

The HKEX has implemented a number of system enhancements to maintain the competitiveness and its position as one of the world's leading exchanges. In 1993, the HKEX introduced the Automatic Order Matching and Execution System (AMS). The HKEX then introduced the third generation of the AMS (AMS/3) in 2000, aiming to meet different market needs by including multiple products and trading methods and flexible connections.²⁴ In 2018, the HKEX established the Orion Trading Platform – Securities Market (OTP-C) to replace AMS/3 in order to further enhance its trading capacity and flexibility to support new business and functionalities²⁵. In addition, market participants can co-locate their trading systems within the HKEX since 2012.²⁶

2.2 MEASURING THE LEVEL OF AT/HFT ACTIVITIES IN HONG KONG'S EQUITY MARKET

We measure the level of AT/HFT activities in Hong Kong's equity market from 1 August 2018 to 31 July 2020 based on the messages in the historical full limit order book and other daily data obtained from the HKEX Market Data Services. In absence of publicly available data on AT/HFT participation in Hong Kong's equity market, we rely on statistical measures proposed in existing research studies and broadly discussed in the academic and policy

literatures.²⁷ More specifically, we select and use in this analysis two key measures: the percentage of fast trades and the order-to-trade ratio.

The first measure is the percentage of fast trades, that is defined as the fraction of transactions that are executed after the previous trade within an extremely short-time span (40 milliseconds).²⁸ This measure captures the speed aspect of AT/HFT activities as firms adopting AT/HFT technologies may perform trades in response to changing market conditions at a very high speed. When a trade is executed within a very short period of time (say, 40 milliseconds), the instruction is unlikely to be initiated by a human trader.²⁹ Therefore, using the speed of trade execution is an effective measure to distinguish AT/HFT from human trading.³⁰ A non-zero percentage of fast trades can be interpreted as an indication that some AT/HFT is taking place. When AT/HFT is more active, the percentage of fast trades is higher.³¹

The second measure adopted in the analysis is the order-to-trade ratio, which is defined as the total number of orders received divided by the total number of trades (i.e., orders that are executed).³² Depending on market conditions, AT/HFT algorithms usually place large batches of orders at different prices. When AT/HFT is

²⁴ See https://www.hkex.com.hk/News/News-Release/1999-SEHK/990720news?sc_lang=en.

²⁵ See https://www.hkex.com.hk/News/Market-Communications/2018/180123news?sc_lang=en.

²⁶ See <https://www.hkex.com.hk/Services/Connectivity/Hosting-Services> for the details of the co-location service.

²⁷ For a discussion on this matter, see Chakrabarty, Comerton-Forde, and Pascual (2021) and the references therein.

²⁸ This measure is developed in the spirit of the academic literature proxying AT/HFT activities with the percentage of limit orders with fast adjustment (see, among others, Hasbrouck and Saar (2013), Liu, Lo, Nguyen, and Valente (2018) and the references therein). However, the measure used in this report compute such percentage in terms of trades/transactions in order to align the resulting estimates with the anecdotal evidence linking AT/HFT participation to measures of trading (i.e., trading volume, turnover, etc.).

²⁹ For example, human eyes need 400 to 500 milliseconds to respond to visual stimuli.

³⁰ This measure uses 'time' as key factor to approximate AT/HFT activities. Although this is certainly a feature of HFT, some may argue it is not necessarily true for AT, whose principal aim is to improve the efficiency of execution. Nonetheless, AT has become more sophisticated over time and also uses speed and time to accomplish its goals. Hence, state-of-the-art AT cannot be easily distinguishable from HFT with the sole use of trading and quoting records reported in publicly available sources.

³¹ To test for the robustness of the empirical findings we have also computed a percentage of orders with fast adjustment, defined as the fraction of orders that are cancelled or modified within 40 milliseconds of their placements. Similar to the speed argument we use for the main measure of AT/HFT activities, when an order is cancelled or modified within a very short period of time, the instruction is unlikely to be initiated by a human trader. Therefore, using the speed of order cancellation or amendment is also an effective measure to distinguish AT/HFT from human trading.

³² To compute the statistics, in line with existing studies, we do not differentiate between orders and trades submitted by computers or human traders. See Eurex (2020).

more active, a large number of orders initiated by computers may not result into trades, leading to the order-to-trade ratio to be higher than in the case when AT/HFT is less active.³³

Although this statistical approach is able to provide some preliminary insights regarding AT/HFT participation to equity trading, it must be noted that, because of the limitations of the existing data and methodology, the measures adopted in our analysis can only capture AT and HFT jointly as a homogenous group.³⁴ Furthermore, the statistical measures likely capture aspects related to the liquidity supply rather than liquidity demand originating from AT/HFT, as the latter requires account level information that is not publicly available.

We compute the two measures for all individual equities listed on the Main Board on a daily basis over the period between August 2018 and July 2020.³⁵ The results of the statistical investigation show that the average percentage of fast trades computed across all equities listed on the Main Board equals to 11% over the period investigated. The average order-to-trade ratio for these equities equals to 7:1 over the same period (Table 2.1).³⁶ These findings are consistent with a modest level of

AT/HFT activities in Hong Kong's equity cash market. Furthermore, the estimates of the two measures have remained relatively stable during the period investigated. In fact, both the percentage of fast trades and the order-to-trade ratio have remained modest and stable around their average values over the two-year period (Chart 2.1).

Our research shows that about 11% of all cash equity trades occurring on the Main Board can be attributed to AT/HFT. The Main Board's order-to-trade ratio is around 7:1 and overall AT/HFT activities have remained modest and stable over the period between August 2018 and July 2020.

Table 2.1: Level of AT/HFT activities in Hong Kong (August 2018–July 2020)

	Percentage of fast trades	Order-to-trade ratio
 Equities listed on the Main Board	11%	7:1

Note: Average level of AT/HFT activities computed over the sample period.

Source: HKIMR staff compilation.

³³ In light of the MiFID II regulation, trading venues in Europe are obliged to calculate and monitor the order-to-trade ratio on each trading day and for each financial instrument to prevent disorderly trading conditions.

³⁴ See also Foresight: The Government Office for Science, London (2012) for further discussion on this issue.

³⁵ Our analysis has been carried out using 1.3 million trade messages and 8.4 million order messages on average per day for 494 trading days.

³⁶ Although there are no specific guidelines regarding natural levels of order-to-trade ratios, recent measures have been introduced in various international equity markets to curb high quoting activity. Fees were imposed on traders whose order-to-trade ratios were higher than 70:1 (in the case of Norway) or 100:1 (in the case of Italy). For further details, see Jørgensen, Skjeltop, and Ødegaard (2018) and Friederich and Payne (2015).

Chart 2.1: Evolution of the AT/HFT activities over time

Note: Monthly average level of AT/HFT activities computed over the sample period.

Source: HKIMR staff compilation.

These statistical findings regarding the AT/HFT participation in Hong Kong's equity market are consistent with the anecdotal evidence suggesting that computer-based fast trading in Hong Kong's equity cash market represents about 10% of market turnover. The statistical approach used in this study does not allow us to disentangle how much of this participation is due to AT or HFT separately, and mostly captures the high-speed activity put in place by HFT participants and some AT algorithms. Nonetheless, anecdotal evidence suggests that AT is more prevalent than HFT, with the latter only representing a smaller fraction of the overall turnover in Hong Kong's equity cash market.

2.3 AT/HFT AND MARKET LIQUIDITY AND VOLATILITY

The experience recorded for international financial markets suggests that AT/HFT may

affect the quality of equity markets. To better understand this relationship, we explore whether there is a significant association between the level of AT/HFT activities and different statistical measures of market liquidity and volatility in Hong Kong's equity cash market.

Given that market liquidity is inherently a multifaceted concept, we adopt multiple statistical measures to gauge some of its different dimensions, namely share trading volume, dollar trading volume and bid-ask spread. For ease of interpretation, when market liquidity increases, the share trading volume and the dollar trading volume would be higher, and the bid-ask spread would be lower. For market volatility, the daily standard deviation of equity returns is used as a suitable statistical proxy.³⁷

³⁷ The share trading volume is defined as the number of shares traded on an equity within the day. The dollar trading volume is defined as the dollar amount (HKD) traded on an equity within the day. The bid-ask spread is an inverse measure of liquidity, computed as $(ASK - BID) / (2 * (ASK + BID))$, where BID is the closing bid price and ASK is the closing ask price of an equity at the end of the day. The return volatility is the standard deviation of intra-daily returns of an equity measured from open to close of the day, and converted into an annualised term.

The visual association between AT/HFT and market liquidity and volatility for equities listed on the Main Board is presented in Chart 2.2.³⁸ More specifically, we define three levels of AT/HFT activities represented by a high, medium and low percentage of fast trades.³⁹ Then the average values of the market liquidity and volatility measures for different levels of AT/HFT activities are reported.

Our findings, based on the period between August 2018 and July 2020, suggest that a higher level of AT/HFT activities is not associated with a deterioration of market liquidity.⁴⁰ In fact, both the share trading volume and dollar trading volume are found to be higher when the level of AT/HFT activities is higher. Meanwhile, lower bid-ask spread tends to be associated with a higher level of AT/HFT activities. These empirical results are similar to those recorded for other international equity markets. The increased market liquidity associated with higher AT/HFT participation may be the result of AT/HFT participants in Hong Kong's equity market being net liquidity providers. However, it is important to highlight that this increased liquidity may not be resilient, as AT/HFT participants are usually not registered market makers and they can provide liquidity at their discretion. Further validation is therefore needed to gather evidence regarding the resilience and stability of liquidity provided by AT/HFT participants during turbulent times.

The relationship between AT/HFT and market volatility is less clear. Our estimates show a weak association between return volatility and the level of AT/HFT activities for equities listed on the Main Board.⁴¹ This empirical result once again suggests that the relationship between AT/HFT and market volatility is complex and more research is needed to understand

its implications and bearing for the smooth functioning of financial markets as well as the impact of AT/HFT on market volatility during turbulent times. Furthermore, it is natural to hypothesise that the market impact and the risks associated with AT/HFT may potentially increase when its participation and prevalence grows over time.

Our research shows that a higher level of AT/HFT activities is not associated with a deterioration of market liquidity or increased market volatility. However, further validation is needed to gather evidence regarding the resilience and stability of liquidity provided by AT/HFT participants as well as the impact of AT/HFT on market volatility during turbulent times.

Table 2.2 summarises the main findings of the research exercise.

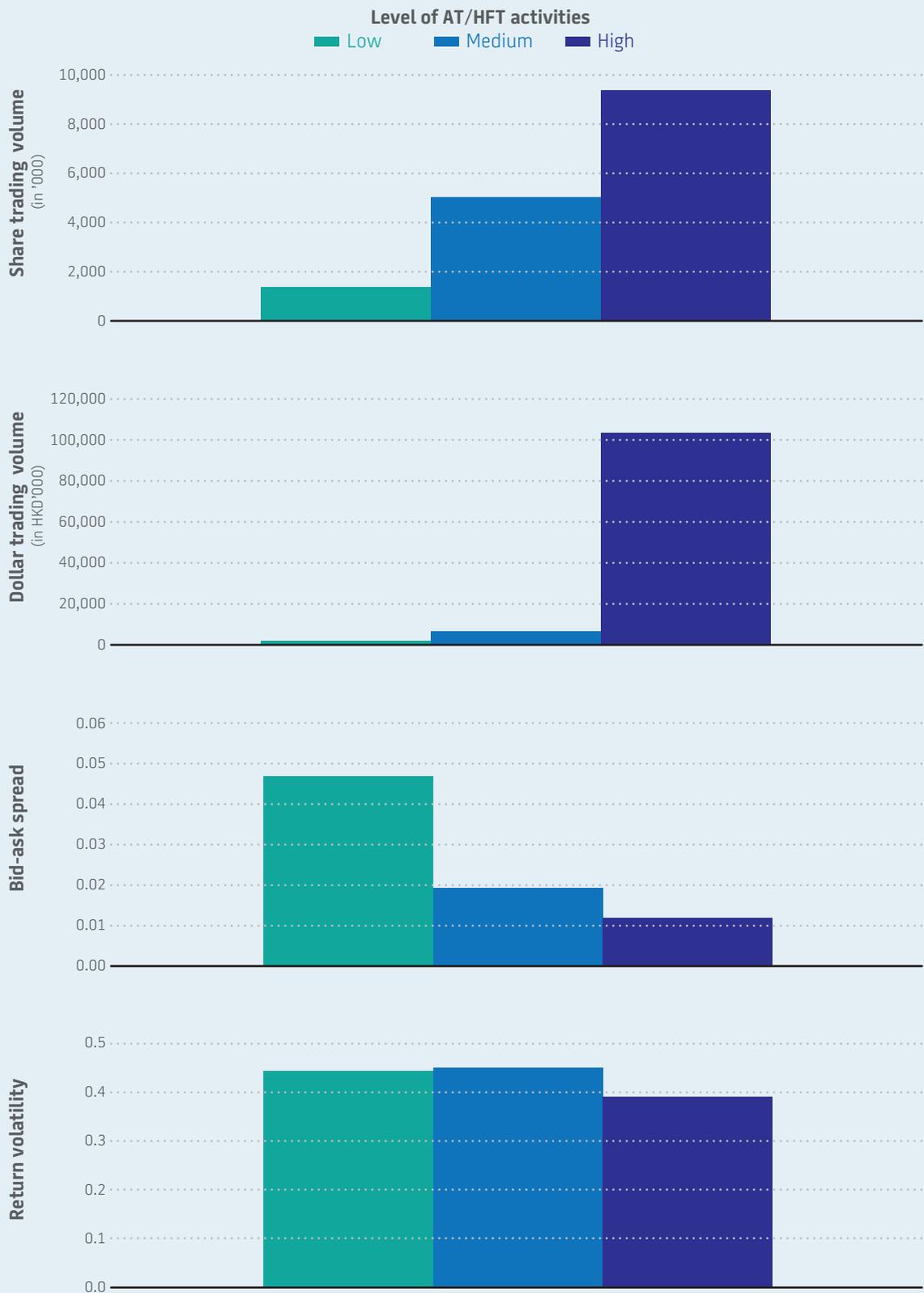
³⁸ Alternatively, the relationship could be analysed by using a regression model. Appendix A presents further analysis when a regression model is used.

³⁹ The levels of AT/HFT activities for individual equities are labelled as 'high' if their average percentage of fast trades is greater than 15%, as 'medium' if their average percentage of fast trades is greater than 5% but less than or equal to 15%, and as 'low' if their average percentage of fast trades is less than or equal to 5%.

⁴⁰ To assess the robustness of the empirical analysis, we split the sample period into two sub-periods (August 2018–May 2019 and June 2019–July 2020), and similar evidence is obtained. We also computed the same evidence for a period of high volatility (March 2020), qualitatively and quantitatively confirming the results reported in Chart 2.2.

⁴¹ As market volatility is affected by many factors, our preliminary analysis does not rule out the possibility that AT/HFT may increase risks by exacerbating market volatility under periods of stress.

Chart 2.2: Market liquidity and volatility and AT/HFT



Source: HKIMR staff compilation.

Table 2.2: AT/HFT interaction with liquidity and volatility in Hong Kong's equity market

		When the level of AT/HFT activities increases	
 Market Liquidity	 Share trading volume*	↑	 Non-deterioration of market liquidity
	 Dollar trading volume*	↑	
	 Bid-ask spread*	↓	
 Market Volatility	 Return volatility	No clear pattern is observed	

* Increase in share trading volume and dollar trading volume and reduction of bid-ask spreads represent an increase in liquidity. Source: HKIMR staff compilation.

2.4. VIEWS FROM EQUITY MARKET PARTICIPANTS IN HONG KONG

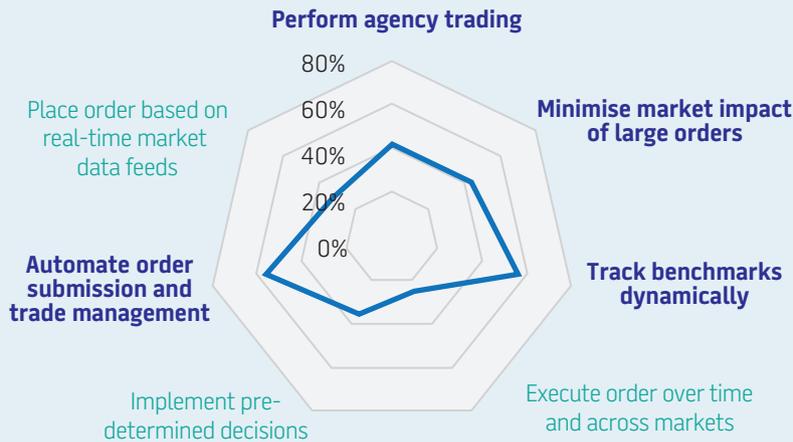
To supplement the statistical evidence reported in the previous sections, the HKIMR also conducted the survey *Algorithmic and High-frequency Trading in Hong Kong's Equity Market (AT/HFT Survey)* in July 2020.⁴² A selection of equity market participants was invited to share their experience and views on AT/HFT adoption in Hong Kong through questionnaires and interviews. The respondents included banks, brokers, agency brokers, market custodians, registered market makers, proprietary traders, fund managers and investors, and industry bodies, whose trading represents 68% of the trading volume of Hong Kong's equity market.⁴³

The survey results suggest that most of the survey participants have adopted AT/HFT technologies in Hong Kong. The major motivations for them to adopt AT/HFT technologies included automating order submission and trade management (shared by 56% of the respondents), dynamically tracking benchmarks (56%), minimising market impact of large orders (44%), and performing agency trading (44%) (Chart 2.3).

⁴² The survey and interviews have been conducted with the help and collaboration of Mr Robert Rooks.

⁴³ Appendix B provides the background of the AT/HFT Survey.

Chart 2.3: Motivations for performing AT/HFT

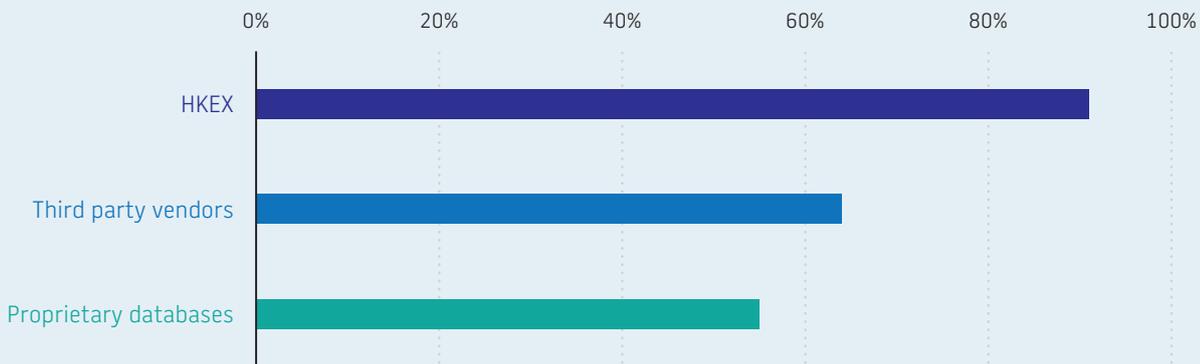


Source: HKIMR staff compilation.

Access to accurate market data is deemed important for market participants to adopt and efficiently use AT/HFT technologies. Survey participants mentioned that they have used three main channels for the provision of market data: data feeds from the HKEX, third party vendors, and their proprietary databases. When considering the relative importance of these channels, the survey results show that while the majority of respondents adopting AT/HFT technologies obtained their market data from the HKEX, about half of them also sourced market data from third party vendors and used data from their own proprietary databases (Chart 2.4).

AT/HFT adoption also relies on the availability of technologies needed to implement trading algorithms. Around 60% of the surveyed market participants stated that they have used direct market access for trading purposes. Over 50% of the respondents have used the co-location services provided by trading venues as well as the interfaces provided by third party vendors, and 40% stated that they have used their own proprietary interfaces for accessing the market (Chart 2.5).⁴⁴

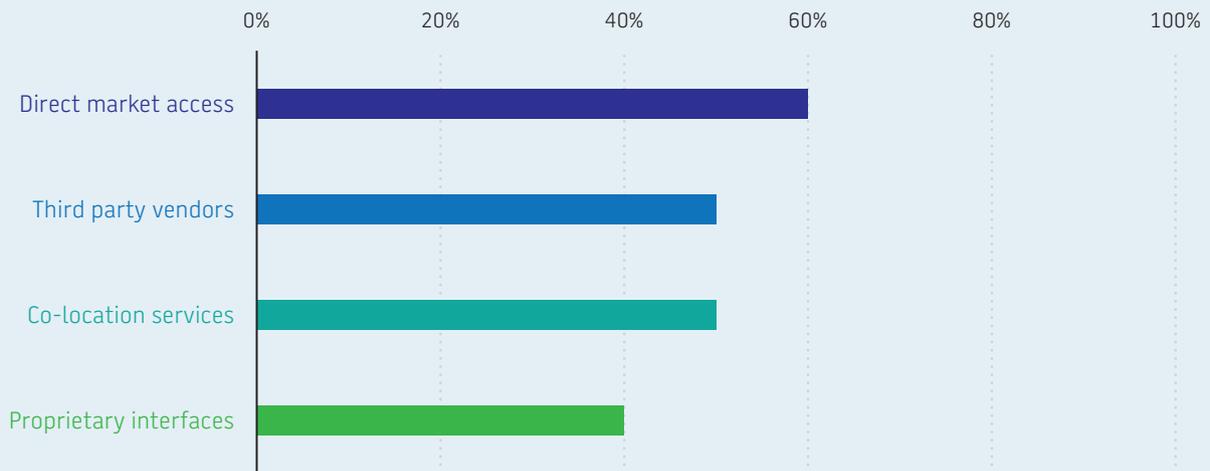
Chart 2.4: Sources of market data



Source: HKIMR staff compilation.

⁴⁴ By deploying multiple market gateways for trading purposes, traders are likely to increase the ability to trade at higher speeds and volumes and to reduce throughput and network bottlenecks in periods of increased trading.

Chart 2.5: Interfacing technologies to access the market



Source: HKIMR staff compilation.

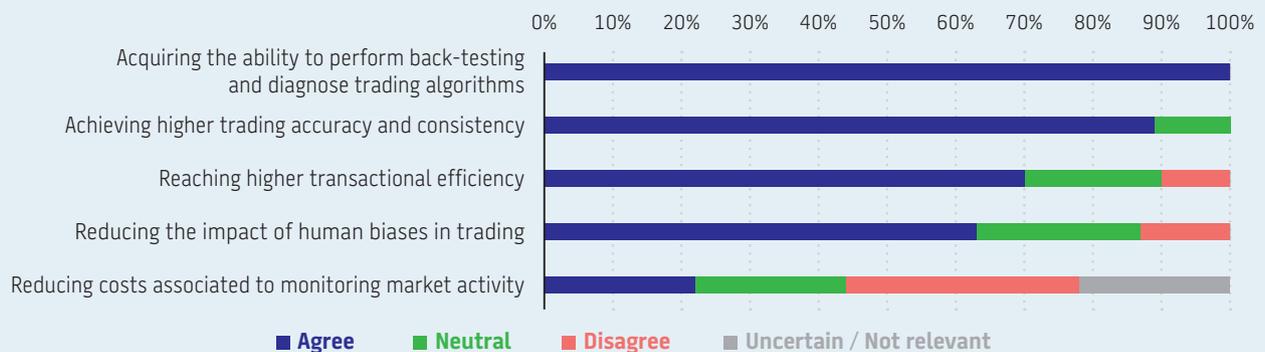
Benefits and challenges of AT/HFT adoption

In the AT/HFT Survey, respondents were invited to assess potential benefits of adopting AT/HFT technologies. All respondents adopting AT/HFT technologies indicated that AT/HFT adoption has provided them with additional ability to perform back-testing and diagnose potential failures in trading algorithms. They also stated that AT/HFT technologies have allowed them to achieve higher trading accuracy and consistency (89%), reach higher transactional efficiency (70%), and reduce the impact of human biases in trading (63%). However, few respondents viewed that AT/HFT

adoption has reduced the operational costs associated with monitoring market activity (Chart 2.6).

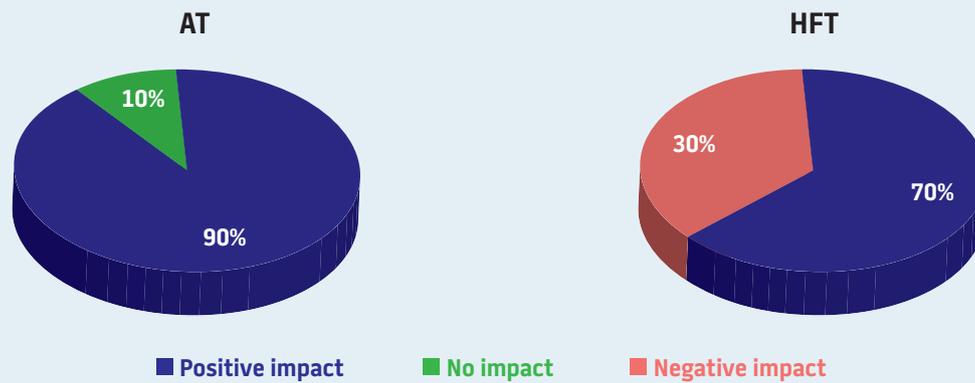
When asked about the perceived impact of AT/HFT adoption in Hong Kong's equity market, the participants surveyed mostly held a positive or neutral view. Nonetheless, 30% of the survey participants deemed the impact of HFT adoption in Hong Kong's equity market as negative. Some interviewees added that the cost of adopting these technologies and high-speed nature of the trading strategies may leave some investors in a disadvantageous position (Chart 2.7).

Chart 2.6: Perceived benefits of AT/HFT adoption



Source: HKIMR staff compilation.

Chart 2.7: Perceived impact of AT/HFT adoption in Hong Kong's equity market

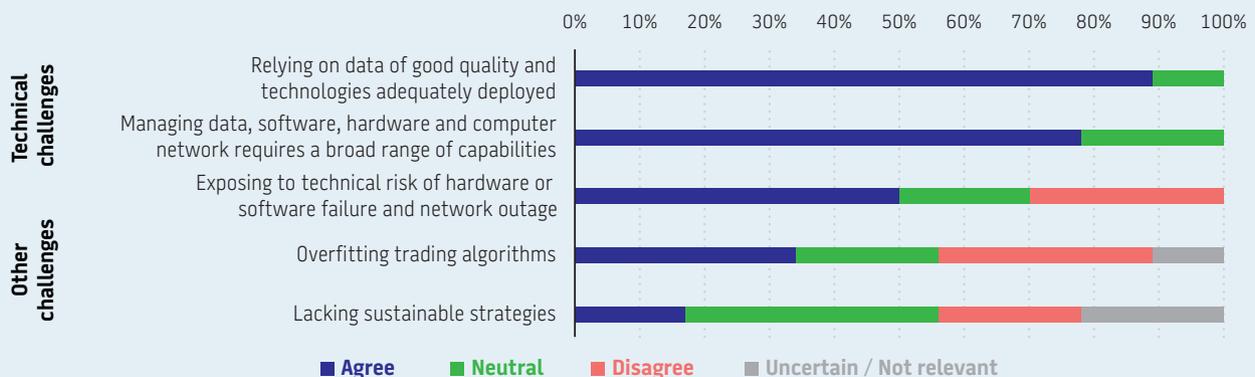


Source: HKIMR staff compilation.

Regarding the challenges associated with adopting AT/HFT technologies in Hong Kong, respondents widely agreed that the costs associated with AT/HFT technologies have limited their adoption only to a small percentage of market participants. In fact, to use algorithms for securities trading, market participants are required to invest in and enhance their infrastructure capabilities in order to manage and execute trades effectively and efficiently. Furthermore, survey participants also suggested an increased vulnerability to new types of risks arising from the adoption of AT/HFT technologies as a part of their operations. These risks include the potential for hardware or software failures, network outages and the possibility of overfitting their trading algorithms.

In the AT/HFT Survey, nearly 90% of the respondents viewed the reliance on data of good quality and technologies adequately deployed for AT/HFT adoption as the main challenges. A broad range of capabilities required for managing data, software, hardware and computer network as well as the exposure to the potential technical risks associated with failure of hardware or software, or network outage may also represent additional challenges (Chart 2.8). Some interviewees also noted that when more technologies have been deployed for AT/HFT adoption, the potential hardware or software failure has become a risk that the firms must face and control. Recognising the risks associated with AT/HFT adoption, respondents mentioned that they have already deployed systematic and quantitative strategies for risk management purposes.

Chart 2.8: Perceived challenges of AT/HFT adoption



Source: HKIMR staff compilation.

Interviewees also commented on the potential risks that AT/HFT has brought to the equity market such as the market risk due to AT/HFT deploying similar trading strategies at the same time. Some interviewees did not consider this as a major concern for Hong Kong for the time being, noting that the existing AT/HFT regulations in Hong Kong require market participants trading electronically to have good planning and documentation, and establish a robust governance and control environment. Some interviewees also believed that there would still be a diverse range of market participants providing market liquidity in the midst of turbulent events.

The messages from the AT/HFT Survey are clear: while respondents adopting AT/HFT technologies have experienced benefits, they have also identified some challenges and risks arising from AT/HFT adoption. The preliminary actions put in place by the survey participants to mitigate such risks are reassuring. Nonetheless, it is important to explore the existing tools available to both regulators and trading venues to mitigate such risks to better understand their impact towards a smooth functioning of financial markets. Towards this aim, the next chapter of this report comprehensively reviews the potential risks associated with AT/HFT adoption and discusses risk management measures and best practices associated with monitoring such risks.

Survey respondents viewed AT/HFT adoption beneficial to their operations and the market under normal conditions, but also acknowledged that there have been challenges and risks to be monitored and managed.

Chapter 3

RISKS EMERGING FROM ALGORITHMIC AND HIGH-FREQUENCY TRADING AND MITIGATING MEASURES

Potential risks, mitigating measures and regulatory oversight

- 3.1. Risks associated with AT/HFT adoption
- 3.2. Mitigating AT/HFT risks by market participants and trading venues
- 3.3. Oversight of AT/HFT activities: the role of regulators



3 RISKS EMERGING FROM ALGORITHMIC AND HIGH-FREQUENCY TRADING AND MITIGATING MEASURES

POTENTIAL RISKS, MITIGATING MEASURES AND REGULATORY OVERSIGHT

◆ HIGHLIGHTS: ◆

- ▶ **Potential risks associated with AT/HFT adoption include market liquidity risk during market stress, technical risk, market integrity risk, shock transmission risk, and risk of undermined risk management.**
- ▶ **Measures to mitigate AT/HFT risks include adhering to best practices when adopting AT/HFT technologies, upholding the integrity of trading strategies and algorithms, raising risk awareness, establishing proper and robust internal controls, maintaining robust governance over AT/HFT adoption, implementing volatility control mechanisms, restraining AT/HFT and establishing sandboxes for assessing the impact of changes in market design, policies and regulations.**
- ▶ **Extended market quality metrics and enhanced data analytics capabilities can help strengthen the capacity of overseeing AT/HFT.**

The growth of AT/HFT adoption in the equity markets around the world has occurred as the natural consequence of automation in markets and developments in market infrastructure. The previous chapter has also documented that AT/HFT technologies have been successfully deployed in Hong Kong's equity market.

While AT/HFT adoption can positively affect equity market quality, because of the potential for an increased market liquidity and reduced transaction costs, AT/HFT adoption can also give rise to new sources of risks and challenges that equity markets have to confront with. This chapter reviews the salient risks associated with AT/HFT adoption that have been identified in different international jurisdictions. Depending on the stage of AT/HFT adoption in equity markets, a wide range of measures have been proposed or implemented towards effectively managing risks associated with AT/HFT adoption. Regulators have also adjusted compliance requirements and strengthened their monitoring tools in overseeing AT/

HFT, with an aim of upholding market quality and financial stability in the presence of AT/HFT.⁴⁵ Although most measures have already been implemented in international equity markets, this chapter discusses some of these experiences and draws some preliminary implications for Hong Kong's equity market.

3.1. RISKS ASSOCIATED WITH AT/HFT ADOPTION

To foster effective risk management in the context of AT/HFT adoption, international regulators and policy makers have identified and assessed risks that can potentially affect the functioning of equity markets. These risks include market liquidity risk, technical risk, market integrity risk and shock transmission risk. In addition to these risks, AT/HFT adoption can also transform existing risks associated with securities trading, undermining the effectiveness of traditional risk management practices (Table 3.1).

⁴⁵ Bank for International Settlements (2011, 2016); Bank of England (2018); FICC Market Standards Board (2020); Financial Conduct Authority (2018); Hong Kong Monetary Authority (2020); Treasury Market Practices Group (2015); US Department of the Treasury, Board of Governors of the Federal Reserve System, Federal Reserve Bank of New York, Securities and Exchange Commission, and Commodity Futures Trading Commission (2015).

Table 3.1: Risks associated with AT/HFT adoption

Risk	Nature
Market liquidity risk during market stress 	Algorithms may amplify the extent of large market gyrations and exacerbate the evaporation of market liquidity
Technical risk 	Erroneous order flows can interfere with the market by producing excessive message traffic, short term volatility and unwanted exposures
Market integrity risk 	False impressions of market depth, trading volume, and prices, both intended and unintended, can undermine market integrity
Shock transmission risk 	Problems experienced in one security or market can spill over to others
Risk of undermined risk management 	Mitigating measures and controls traditionally used for risks associated with securities trading may become less effective. The identification and assessment of risks can become more challenging

Source: HKIMR staff compilation.

Market liquidity risk during market stress

AT/HFT adoption is typically associated with non-detrimental effects on market quality during normal times. However, both computer and human traders may respond to turbulent events by changing their trading strategies and then adjust parameters of algorithms or deploy different algorithms causing unintended effects to market liquidity.⁴⁶ As AT/HFT technologies may not be structured with the formal obligation of market making, algorithms may amplify the extent of large market gyrations because of their embedded liquidity-seeking techniques. The evaporation of market liquidity can be exacerbated when algorithms react to market events in a similar fashion.

Technical risk

With the adoption of AT/HFT technologies, market participants could reach higher trading speed and volume, and at the same time mitigate the impact of human biases in trading. However, AT/HFT adoption is subject to technical issues ranging from hardware or software failure, network outage, overfitting and malfunction of algorithms, incorrect deployment of algorithms, inaccurate and low quality data used in algorithms and unintended reaction of algorithms to unexpected data. The erroneous order flows submitted by faulty algorithms can interfere with market functioning by overloading trading venues with excessive message traffic. Other algorithms that operate normally may also respond to these erroneous order flows at high speed, generating sharp, transitory spikes in equity prices. The counterparties of erroneous trades may suffer from transactions being cancelled or unfulfilled, leaving them with unwanted exposures and potential losses.

⁴⁶ In addition, research studies suggest that equity trading hence market liquidity could shift from secondary trading venues to stock exchanges during turbulent events. See, for example, Guillaumie, Loiacono, Kern, and Winkler (2020).

Market integrity risk

Advanced technologies accompanying AT/HFT adoption may equip non-bona fide agents with new tools for committing unlawful equity trading actions, such as spoofing, layering and wash trading.⁴⁷ When there is a concern for the creation of misleading impressions of market depth, trading volume, and prices, disruptive trading and other frauds, market integrity may be affected.

Shock transmission risk

One of the key benefits that AT/HFT adoption provides is the facilitation of trading across securities and geographical regions. This helps incorporate fundamental information quickly into prices across different securities and markets, and enhance price discovery. However, this also strengthens the integration among securities and markets, and therefore the potential of increased contagion in turbulent times. When shocks occur due to erroneous trades or other idiosyncratic reasons, AT/HFT can potentially transmit the shocks from the originating securities or markets to others, amplifying short-term market volatility and creating systemic impacts in a purely mechanical way. For example, during the “Flash Crash” in 2010, the shock triggered by orders in the equity futures market also prompted large price swings in other segments of the equity market and to other asset classes.

Risk of undermined risk management

The high speed of trade execution due to AT/HFT can reduce the effectiveness of traditional mitigating measures and controls for known risks inherently present in financial transactions. The existing internal controls of market participants and trading venues, such as trade and position monitoring systems, pre-trade system controls and risk limits such as price limit and average daily volume limit, may not be sufficient to fully prevent erroneous orders and unintended exposures. Trading margins may be insufficient if an exposure grows faster than the speed at which margins can be collected (usually daily). Moreover, the way that the aforementioned risks play out can change over time. The increasing innovations and advanced technologies pursued by AT/HFT adoption can also have potential disruptive consequences that remain unknown to the equity market. These uncertainties pose additional challenges to market participants and regulators alike in identifying and assessing and monitoring risks that need to be managed.

⁴⁷ Spoofing and layering involve false bidding and asking with the intent to cancel the bids or offers before their execution. Wash trades generally are intentionally manipulative false transactions that do not result in a change in the beneficial ownership of the equity.

3.2. MITIGATING AT/HFT RISKS BY MARKET PARTICIPANTS AND TRADING VENUES

In order to mitigate the risks originating from AT/HFT adoption, a number of measures have been proposed or implemented by market participants and trading venues. This section presents and reviews a set of measures adopted in international jurisdictions aiming at

addressing AT/HFT risks in a holistic way. These mitigating measures include adhering to best practices when adopting AT/HFT technologies, upholding the integrity of trading strategies and algorithms, raising risk awareness, establishing proper and robust internal controls, maintaining robust governance over AT/HFT adoption, implementing volatility control mechanisms, restraining AT/HFT and establishing sandboxes for assessing the impact of changes in market design (Table 3.2).

Table 3.2: Mitigating measures for the risks associated with AT/HFT adoption

Measure		Mechanism
Adhering to best practices when adopting AT/HFT technologies		Develop algorithms with human trading experience and judgement, proper monitoring and appropriate documentation
Upholding the integrity of trading strategies and algorithms		Avoid trading strategies that might accidentally compromise market integrity and have mechanisms that can mitigate the adverse effects on market quality and financial stability due to algorithms abruptly changing strategies
Raising risk awareness		Continually identify and document new risks that need to be managed
Establishing proper and robust internal controls		Timely resolve trading errors and detect emerging risks inherent in the algorithms as the adoption of AT/HFT technologies changes
Maintaining robust governance over AT/HFT adoption		Uphold various aspects including accountability, development, senior management approval, validation, monitoring, change management, and issue escalation and management when adopting AT/HFT technologies
Implementing volatility control mechanisms		Build up resilience against turbulent market events using trading halts that hold back panic selling
Restraining AT/HFT		Curb AT/HFT to avoid its potential adverse effects on market quality and financial stability in extreme market situations
Establishing sandboxes for assessing the impact of changes in market design, policies and regulations		Examine new trading features to ensure proper market functioning and a level playing field for market participants

Source: HKIMR staff compilation.

Adhering to best practices when adopting AT/HFT technologies

Market participants can internally develop a code of conduct and a set of policies and procedures to avoid unintentional and potentially disruptive effects of algorithms on the proper functioning of the market. When developing AT/HFT technologies, human trading experience and judgement can be

applied in creating algorithms, setting initial parameters, and overseeing the calibration of trading models. Market participants adopting AT/HFT technologies can also thoroughly back-test their algorithms, monitor them in real time, and update their parameters accordingly. Efforts can also be put into ensuring compliance with applicable guidelines and regulations, and maintaining appropriate documentation in developing and deploying algorithms.

Upholding the integrity of trading strategies and algorithms

AT/HFT adopters can implement measures to ensure the ethical use of their algorithms. In designing and using AT/HFT technologies, it is important for market participants to uphold integrity and avoid trading strategies that might accidentally compromise market integrity by creating a false sense of market liquidity and misleading prices. Market participants can also evaluate how changes in strategies triggered by algorithms impact market quality and financial stability and build into algorithms mechanisms that can mitigate the adverse effects on proper market functioning due to the possible abrupt shifts in trading strategies driven by algorithms.

Raising risk awareness

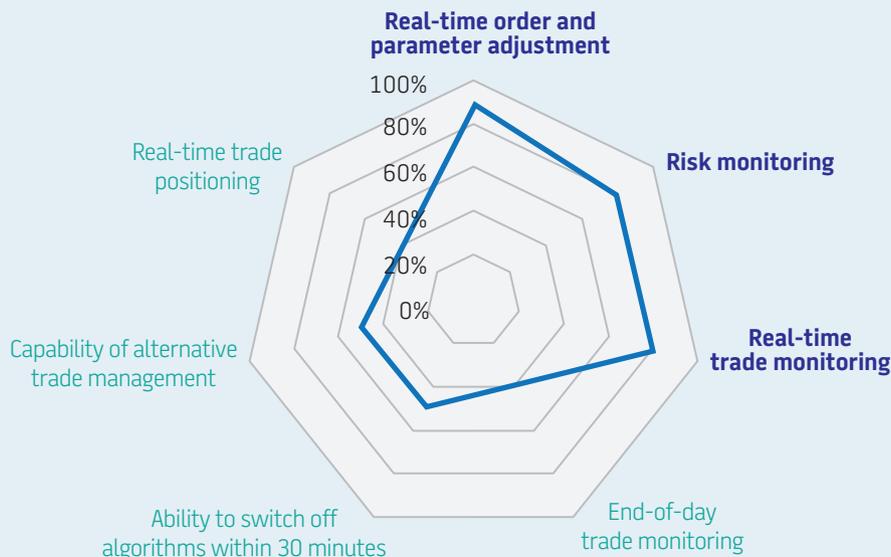
As the starting point for managing risks associated with AT/HFT adoption, market participants and trading venues can increase risk awareness within their organisations and continuously identify, understand and monitor the new risks inherent in their adoption of AT/HFT technologies. The recognition of risks can start with staff involved in generating trading ideas and designing algorithms. Further potential issues can then be identified along the workflow process from data engineering, algorithm deployment and system maintenance.

Establishing proper and robust internal controls

After uncovering the inherent risks in their AT/HFT adoption, market participants can conduct in-depth risk analysis and develop and maintain internal risk controls. A proper risk control system can resolve erroneous order flows timely and prevent disruptive trades from reaching the markets. A robust internal control environment enables market participants to detect emerging risks inherent in the algorithms as their adoption of AT/HFT technologies changes. These safeguards can be properly documented, regularly reviewed for their effectiveness, and promptly updated according to technologies and innovations used in the adoption of AT/HFT technologies.

According to the AT/HFT Survey, market participants who have adopted AT/HFT technologies in Hong Kong’s equity market have developed and maintained internal risk controls. The most commonly used means to control the inherent risks are real-time order and parameter adjustment, risk monitoring, and real-time trade monitoring. Other means include real-time trade positioning, end-of-day trade monitoring, capability of alternative trade management and ability to switch off algorithms within 30 minutes (Chart 3.1).

Chart 3.1: Internal controls used to cope with AT/HFT risks in Hong Kong’s equity market



Source: HKIMR staff compilation.

Maintaining robust governance over AT/HFT adoption

Market participants can maintain a robust framework to govern their AT/HFT adoption involving the aspects of accountability, development, senior management approval, validation, monitoring, change management, and issue escalation and management. To ensure the accountability in developing and deploying algorithms, market participants can define suitable lines of responsibilities. Ownership can be assigned for each algorithm and its risk control such that the person responsible for overseeing the proper execution of the algorithm can be clearly identified.

To maintain sound governance on developing trading algorithms, market participants can establish a clear methodology for designing, testing and revising algorithms. An approval mechanism can be incorporated into the governance framework to request senior management authorise the rollout of new algorithms and the revamp of existing algorithms. Algorithms can also be validated before deployment, monitored for the performance after deployment and regularly re-validated in order to ensure the algorithms are operating appropriately. Market participants can also have a set of management procedures in place to handle changes on algorithms, as well as effective processes for issue management, such as clear channels for escalating critical issues to senior management and facilitating timely communications within the organisation.

Implementing volatility control mechanisms

Trading venues can develop resilience against turbulent events and market breakdowns. To hold back panic selling and prevent market crashes, trading venues around the globe have already implemented various forms of volatility control mechanism (VCM). The US market has supplemented circuit breakers with “limit up/limit down” rules with an aim of avoiding halting trading altogether. These additional rules temporarily suspend the trading of an

individual equity when its price moves beyond a dynamically adjusted price zone.⁴⁸ Research findings suggest that the use of these trading pauses has given market participants a chance to re-evaluate their positions and helped stabilise volatile markets.⁴⁹

In Hong Kong, the HKEX introduced a VCM in 2016 to safeguard the equity market from sudden and extreme price movements of individual equities. In May 2020, the HKEX expanded the coverage of VCM from about 80 constituents of the Hang Seng Index and the Hang Seng China Enterprises Index to all the Hang Seng Composite Indices constituents (more than 500 equities) to widen the market safeguards (see Box 3.1). There have been over a dozen of cooling-off periods triggered by the VCM since then. Trading of the affected equities was found to be orderly during and after these cooling-off periods. The HKEX has further enhanced the VCM arrangement in March 2021 by removing the current restriction of at most one trigger of the VCM in each trading session. This aligns the HKEX’s practice with the ones of major overseas markets, where multiple triggers of the VCM are generally allowed within a single trading session.⁵⁰

Box 3.1: The VCM arrangement in Hong Kong’s equity market

The VCM arrangement in Hong Kong’s equity market is applicable to constituent equities of the Hang Seng Composite LargeCap, MidCap and SmallCap Indices. It is triggered if a potential transaction price for a constituent equity in these indices deviates by more than 10%, 15%, and 20%, respectively, away from the traded price recorded five minutes previously. When the VCM is triggered, there will be a five-minute cooling off period, and trading is permitted within a predefined price zone during the period. Normal trading will resume following the end of the cooling off period, instead of halting all trading. The VCM arrangement in Hong Kong’s equity market maintains market stability by safeguarding against extreme price volatility arising from trading incidents.

⁴⁸ See, for example, <http://www.luldplan.com/> for further discussion.

⁴⁹ Hughes, Ritter, and Zhang (2017).

⁵⁰ See https://www.hkex.com.hk/-/media/HKEX-Market/Services/Trading/Securities/Overview/Trading-Mechanism/Trading-Mechanism-for-VCM_E.pdf for further details.

Restraining AT/HFT

In circumstances where AT/HFT exerts adverse impact on market quality and financial stability, trading venues can consider curbing AT/HFT. Trading venues and regulators have proposed

or put into place some measures that curb AT/HFT, including periodic call auctions, minimum resting times, speed bumps and limits on the number of orders and fees on order cancellation (Table 3.3).⁵¹

Table 3.3: Measures curbing AT/HFT

Measure	Mechanism	Adoption
Periodic call auctions 	Batch and execute orders periodically (for example, every 50 milliseconds to 100 milliseconds) instead of executing orders as soon as possible (such as in continuous markets)	Aquis Exchange, UK and France Cboe Europe, UK and Netherlands
Minimum resting times 	Impose a requirement on the minimum duration of orders with an aim of preventing AT/HFT participants from cancelling orders too rapidly, or provide incentives to them for keeping their orders in the order book longer	Nasdaq, United States Toronto Stock Exchange, Canada
Speed bumps 	Slow down the processing of all or selected orders by imposing an intentional split-second delay before executing orders	Investors Exchange, United States NYSE MKT, United States TSX Alpha Exchange, Canada Aequitas NEO Exchange, Canada Eurex Exchange, Germany
Limits on number of orders and fees on order cancellation 	Introduce limits on order-to-trade ratios, or fees for order cancellations	Oslo Stock Exchange, Norway Italian Stock Exchange, Italy

Source: HKIMR staff compilation.

Establishing sandboxes for assessing the impact of changes in market design, policies and regulations

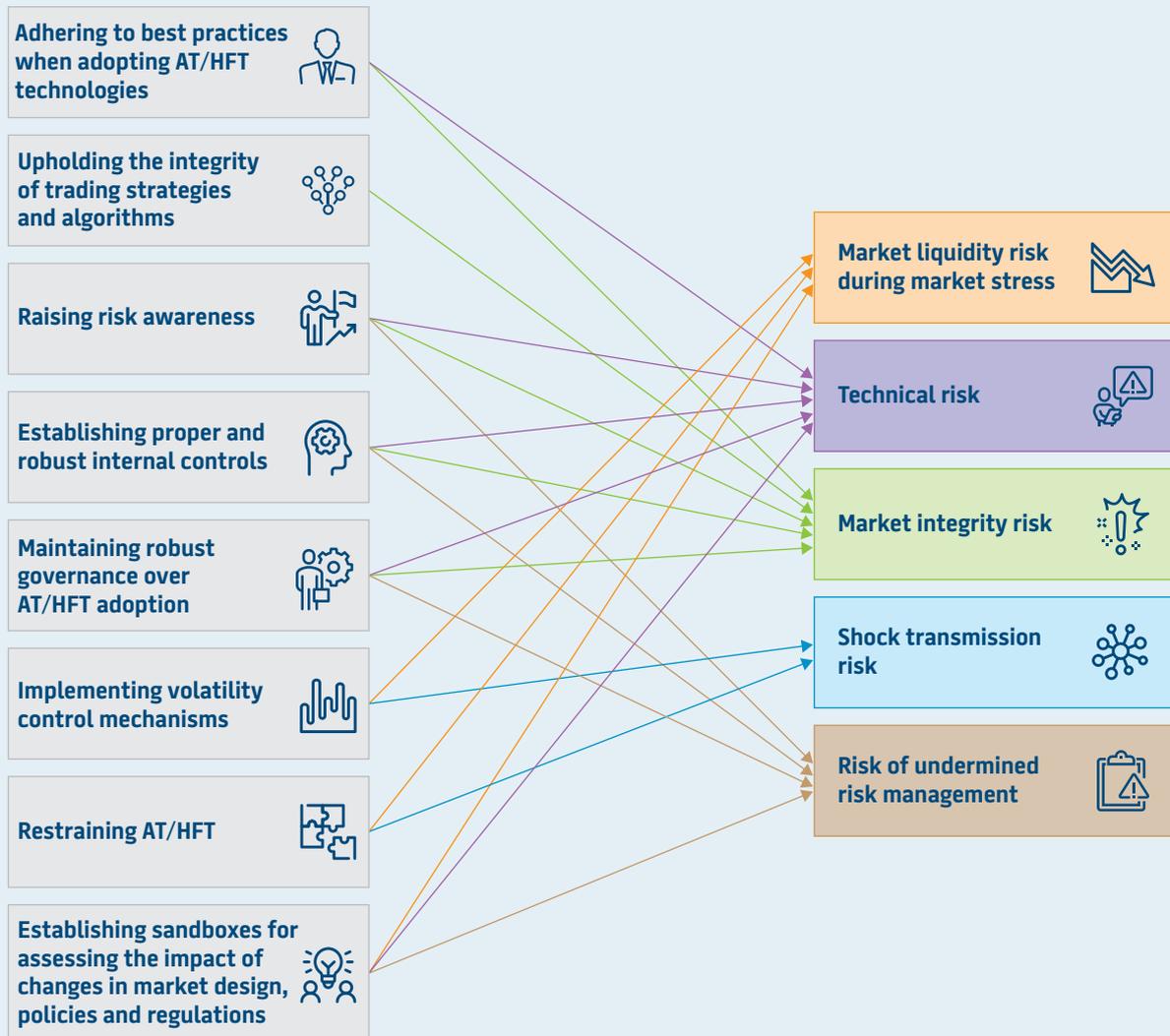
To respond to changes in investor demands and financing needs, facilitate innovations and further develop markets, it is common for trading venues to introduce new trading features. It is also common for policy makers and regulators to revise policies and regulations to enhance market supervision and continuously safeguard financial stability in face of evolving market conditions. Trading venues, in collaboration with policy makers and regulators, can establish sandboxes to examine the proposed market designs,

policies and regulations in order to facilitate market participants' understanding of the new features and to ensure the market maintains proper functioning. Sandboxes can also be used for conducting system testing before the rollout of any new AT/HFT systems. Towards maintaining a fair playing field and appropriate trading environment, sandboxes allow trading venues, policy makers and regulators to evaluate the impact of the proposed changes on various market participants adopting AT/HFT technologies to different extents.

Chart 3.2 presents how the risk management measures discussed in this section correspond to the potential AT/HFT risks presented in the previous section.

⁵¹ Research on these measures by academics and policy researchers in validating their effects are underway.

Chart 3.2: Mapping risk management measures to AT/HFT risks



Sources: HKIMR staff compilation.

3.3. OVERSIGHT OF AT/HFT ACTIVITIES: THE ROLE OF REGULATORS

From a supervisory standpoint, it is important to ensure that the risks known to be associated with AT/HFT adoption are addressed without

hampering innovation. For this reason, supervisory authorities have published various regulatory proposals and consultations in order to consider and seek views on the compliance requirements for integrating the monitoring of AT/HFT activities into their existing supervisory framework.

In January 2010, the US Securities and Exchange Commission (SEC) published a concept release on the structure of the US equity market to solicit the public's views on the oversight of AT/HFT activities. In Europe, the Committee of European Securities Regulators (CESR) issued a call for evidence on microstructure issues in April 2010 and put forward numerous regulatory proposals related to AT in December 2010. In Australia, the Australian Securities and Investments Commission (ASIC) issued a consultation paper in November 2010 on the introduction of competition across exchanges, which also addressed issues arising from HFT. In February 2011, the SEC and Commodities Futures Trading Commission (CFTC) published recommendations on responses to the "Flash Crash" event and the corresponding remedial measures. In April 2011, the Canadian Securities Administrators published a set of rules to seek the industry's comments on the risks associated with HFT.⁵² More recently, in August 2020, the SEC released a *Staff Report on Algorithmic Trading in U.S. Capital Markets*, highlighting the benefits and risks of AT, and presenting appropriate policy responses to maintain market quality and financial stability in the presence of AT/HFT.

As a result, regulators in international jurisdictions typically require market participants to have clearly defined practices and procedures in place to ensure that trading algorithms are adequately tested before being deployed in markets. Traders also need to perform ongoing testing on trading systems including annual self-assessments and stress testing. Some regulators also require market participants to have automated pre-trade filters to prevent erroneous orders from reaching the markets in the first place, and to implement kill switches to disable market participants' trading systems in extreme events where market efficiency or integrity is jeopardised.⁵³

Hong Kong's approach

The existing regulations in Hong Kong are consistent with international practices. The requirements for persons licensed by or registered with the SFC on using AT systems and trading algorithms or providing AT systems and trading algorithms to clients for their use have become effective since 1 January 2014 and are set out in the Code of Conduct.⁵⁴ Paragraph 18 of the Code of Conduct stipulates the general principles and schedule 7 of the Code of Conduct sets out the specific requirements applicable to AT, which are presented in Table 3.4. The aspects regarding the governance of AT include responsibility for orders, management and supervision, adequacy of system, record keeping, qualification, testing, and risk management.

⁵² Australian Securities and Investments Commission (2010a); Canadian Securities Administrators (2011); Committee of European Securities Regulators (2010); Joint CFTC-SEC Advisory Committee on Emerging Regulatory Issues (2011); Securities and Exchange Commission (2010).

⁵³ Refer to, for example, ESMA Regulatory Technical Standard 6, which specifies the organisational requirements of investment firms engaged in algorithmic trading. Australian Securities and Investments Commission (2010a); European Securities and Markets Authority (2011).

⁵⁴ Securities and Futures Commission (2020).

Table 3.4: SFC's requirements on the governance of AT

Aspect		Requirement
Responsibility for orders		A licensed or registered person is responsible for the settlement and financial obligations of orders sent to the market through its AT system and for implementing policies, procedures and controls to supervise the orders in accordance with applicable regulatory requirements
Management and supervision		A licensed or registered person should effectively manage and adequately supervise the design, development, deployment and operation of the electronic trading system it uses or provides to clients for use
Adequacy of system		The integrity of the electronic trading system should be ensured, including the system's reliability, security and capacity. In addition, appropriate contingency measures should be put in place Specifically, effective controls in the AT system should be put in place to enable it, where necessary, to immediately prevent the system from generating and sending orders to the market; and cancel any unexecuted orders that are in the market
Record keeping		Proper records on the design, development, deployment and operation of its electronic trading system should be kept. The audit logs and incident reports should also be properly kept and regularly reviewed for detecting potential problems and planning preventive measures
Qualification		Effective policies and procedures should be established and implemented to ensure that persons involved in the design and development of, or approved to use its AT system and trading algorithms are suitably qualified
Testing		AT system and trading algorithms used or provided to clients for use should be adequately tested to ensure that they operate as designed
Risk management		Controls should be reasonably designed to ensure the integrity of its AT system and trading algorithms, and its AT system and trading algorithms operate in the interest of the integrity of the market In particular, controls that are reasonably designed should be put in place to monitor and prevent the generation of or passing to the market for execution order instructions from its AT system which may be erroneous; or interfere with the operation of a fair and orderly market Furthermore, post-trade reviews of trading should be regularly conducted to identify any suspicious market manipulative or abusive activities; and market events or system deficiencies such as unintended impact on the market which call for further risk control measures

Source: HKIMR staff compilation.

The SFC conducted a thematic review in 2016 with a focus on AT as part of a continuous effort to supervise and monitor licensed corporations to ensure that their AT adoption will not pose undue risks to the market. The SFC has also

provided further guidance to elaborate on the relevant requirements and share with the industry a number of sound and effective risk controls.⁵⁵

⁵⁵ See <https://apps.sfc.hk/edistributionWeb/gateway/EN/circular/intermediaries/supervision/doc?refNo=16EC67> for further details.

In 2019, the HKMA conducted a round of thematic examinations focused on AT, with the objective of assessing the adequacy and effectiveness of HKMA-authorized institutions' risk management practices relating to AT. After observing a number of sound practices, the HKMA set out its expectations on its authorized institutions' management of risks associated with their AT in the aspects of (i) governance and oversight, (ii) development, testing and approval, (iii) risk monitoring and controls, and (iv) documentation.⁵⁶

Regulatory challenges

Market participants adopting AT/HFT technologies continuously innovate. Hence, the effects of AT/HFT on market quality and financial stability also change over time. It is therefore important for regulators to closely monitor the market impact of AT/HFT in order to assess the effectiveness of existing mitigating measures and update the compliance requirements of their supervisory framework. The complexity of the task is vast, owing to the growing adoption of Machine Learning and AI technologies into

trading algorithms. Hence, the measurement of AT/HFT impact and the role played by data analytics are ongoing challenges that regulators have to tackle.

Measuring market quality is challenging because multiple dimensions have to be captured. In addition to market liquidity and volatility, it is equally important to examine the impact of AT/HFT on other aspects of market quality such as price discovery and price efficiency. Furthermore, in examining AT/HFT's impact on each aspect of market quality, a single measure may not be sufficient. For example, trading volume and bid-ask spreads may not always be sufficient for understanding the total impact of AT/HFT on market liquidity and trading frictions. Hence, a comprehensive set of sophisticated measures may be developed for evaluating each aspect of market quality. According to the Bank for International Settlements, to fully examine the impact of AT/HFT, developing market quality metrics in addition to those that are analysed in this report are suggested for capturing its multiple dimensions (Table 3.5).⁵⁷

Table 3.5: BIS suggested additional metrics for holistically capturing market quality

Metric		Definition
Market tightness		Cost of buying and then selling a position of a typical size; also known as the price of immediacy
Market depth		Size of the trade required to change prices by a given amount; also known as the price of volume
Market resiliency		Speed at which a market's tightness or depth recover after market stress
Price efficiency		Accuracy of an equity price as an expression of its value given the available information

Source: Bank for International Settlements (2016).

⁵⁶ See <https://www.hkma.gov.hk/media/eng/doc/key-information/guidelines-andcircular/2020/20200306e1.pdf> for further details.

⁵⁷ More research is needed to ascertain the exact ways to use these metrics to measure market quality, in particular the proper weightings of these metrics when they are used together.

The build-up of suitable data analytics capability presents another challenge to regulators. In fact, given that AT/HFT is carried out at fast pace and generates a large volume of data, surveillance of it requires the access to more comprehensive, granular data on an ongoing basis. The analysis of big market data related to AT/HFT can be extremely demanding and calls for expanding data processing capabilities.

In response to this challenge, international regulators have strived to enhance their data analytics capabilities to maintain an effective oversight of AT/HFT activities. For example, following May 2010's "Flash Crash" in the equity market, the US SEC set up the Consolidated Audit Trail to compile granular data on orders and trades in the US equity and options markets. These data are made available with the aim of providing consolidated information that identifies transactions conducted in different markets and trading venues when necessary and allow regulators to oversee trading holistically and more efficiently. Furthermore, to improve transparency in market surveillance, the SEC has also publicly shared the data compiled by their Market Information Data Analytics System (MIDAS). These data allow market participants to raise their awareness about AT/HFT and help them monitor their own trading more efficiently.⁵⁸

In Australia, the ASIC has enhanced data collection for regulatory purposes, providing inputs into their surveillance system and helping the adoption of a data-driven and evidence-based approach in market analysis. In France, the Autorité des marchés financiers has also built up an extensive data analytics capacity

to undertake in-depth study of important policy issues, including those related to AT/HFT and market microstructure. In addition to analysing data internally, the Investment Industry Regulatory Organization of Canada (IIROC) has also engaged with the academia and provided its database to perform research studies in order to address issues that carry important policy implications, providing new insights related to the impact of AT/HFT on the financial market.⁵⁹ These developments suggest that continuing efforts to develop market quality metrics and enhance data analytics capabilities for surveillance and policy developments are desirable goals to pursue in the near future.

Extended market quality metrics and enhanced data analytics capabilities can help strengthen the capacity of overseeing AT/HFT.

⁵⁸ Visit <https://www.catnmsplan.com/> for further information.

⁵⁹ See Australian Securities and Investments Commission (2013, 2015, 2018); Autorité des marchés financiers (2017, 2018, 2020) and Medcraft (2018). See also Investment Industry Regulatory Organization of Canada (2012, 2015a, 2015b, 2018).

CONCLUSIONS

Amid the digitalisation of securities trading, and the advancements in sophisticated proprietary trading algorithms, high-speed computer systems and co-location services, AT/HFT has been increasingly playing an important role in international financial markets and has become an important part of securities trading across asset classes and geographical locations, especially for equity trading. AT uses machines to assist humans in executing trading strategies. As a subset of AT, HFT rapidly places large amounts of orders and some HFT participants perform market making.

In this report we carry out a statistical investigation based on the period between August 2018 and July 2020, and find that about 11% of all cash equity trades occurring on the Main Board in Hong Kong's equity market can be attributed to AT/HFT. The Main Board's order-to-trade ratio is about 7:1 and overall AT/HFT activities have remained modest and stable over the two-year period. The findings of our survey and interviews corroborate this evidence showing that trading algorithms are indeed a growing part of the respondents' investment infrastructure.

Furthermore, our research shows that while the level of AT/HFT activities in Hong Kong's equity market does not deteriorate market liquidity, there is no clear pattern that associates AT/HFT to market volatility. Although these results are broadly consistent with the existing research findings recorded for major international markets, it is important to highlight that, because of the short-time span of our sample period, further validation is needed to gather evidence regarding the resilience and stability of liquidity provided by AT/HFT participants as well as the impact of AT/HFT on market volatility during turbulent times. In addition, it is natural to hypothesise that the market impact and the risks associated with AT/HFT may potentially increase when its participation and prevalence grows over time.

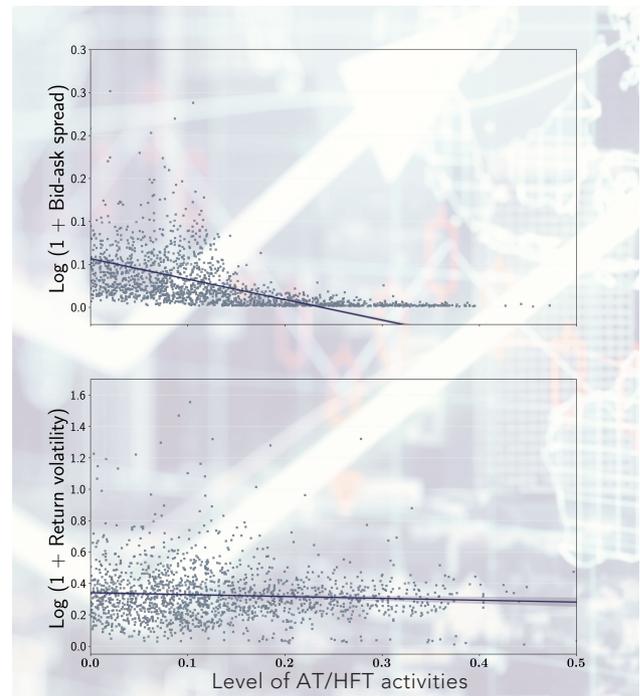
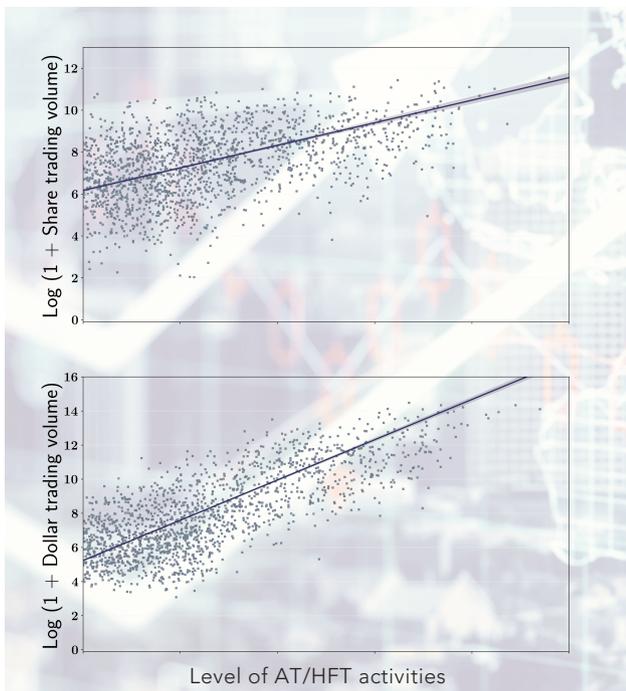
The findings of our survey and interviews show that equity market participants in Hong Kong have benefited from the adoption of AT/HFT technologies, but they also faced emerging challenges. In fact, the adoption of AT/HFT technologies can give rise to new sources of risks to equity market participants and regulators. In order to effectively manage these new risks, market participants and trading venues have proposed or implemented a number of mitigating measures aiming at addressing AT/HFT risks in a holistic manner. Regulators have also integrated the monitoring of AT/HFT activities into their existing supervisory framework and strengthened their monitoring tools in overseeing AT/HFT for upholding market quality and financial stability.

Although several academic and policy studies have improved our understanding of the complex links relating to AT/HFT and the different dimensions of market quality, more is needed to ascertain the potential risks and their impact on market integrity and financial stability. In view of the high speed, large volume of order and trade data and complexity involved in AT/HFT, continuing efforts to develop market quality metrics and enhance data analytics capabilities for surveillance and policy developments are desirable goals to pursue in the near future.

APPENDIX A: STATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN ALGORITHMIC AND HIGH-FREQUENCY TRADING AND MARKET LIQUIDITY AND VOLATILITY

Additional statistical analysis is conducted by using a univariate linear regression model to study how market liquidity and volatility are associated with different levels of AT/HFT activities.⁶⁰ The following charts plot the observations of a market liquidity or volatility variable, computed as discussed in Section 2.3, against those of the level of AT/HFT activities proxied by the percentage of fast trades for all equities listed on the Main Board of the Hong Kong's equity market. The charts also plot the regression line that describes how market liquidity or volatility changes with the level of AT/HFT activities.⁶¹

The findings confirm the ones reported in Chapter 2. The share trading volume and the dollar trading volume have positive relationships, the bid-ask spread has a negative relationship, and the return volatility has a relatively flat relationship with the level of AT/HFT activities. The empirical evidence shows that a higher level of AT/HFT activities is not associated with a deterioration of market liquidity or increased market volatility.



Source: HKIMR staff compilation.

⁶⁰ The natural logarithms of variables, i.e., share trading volume, dollar trading volume, bid-ask spread, and return volatility, are used for the regression.

⁶¹ The shaded area around the regression line represents the 95% confidence band constructed with a bootstrap methodology. The detailed procedure used to construct the confidence bands is available upon request.

APPENDIX B: BACKGROUND OF THE ALGORITHMIC AND HIGH-FREQUENCY TRADING SURVEY

The AT/HFT Survey is designed to collect AT/HFT adoption status and insights from market participants in Hong Kong’s equity market. The HKIMR approached a selection of market participants, distributed electronic questionnaires to survey participants, and interviewed the respondents in person. To encapsulate as many views as possible, the AT/HFT Survey covers eight broad categories of market participants.

GROUPS OF MARKET PARTICIPANTS SURVEYED



The respondents include executives of the securities departments of international and domestic financial institutions. All of the respondents have an international presence and can assess the strengths and weaknesses of the trading practices in Hong Kong’s equity market in relation to other major global markets. The table below summarises the profiles of the respondents.

	Fund Managers and Investors	Brokers and Agency Brokers	Banks	Registered Market Makers and Proprietary Traders
Number of orders submitted per day	Low (Low volume but high value orders)		High (Over 500,000)	
AT adoption			Yes	
HFT adoption	N/A	No	Occasionally	Yes
Order cancellation rate	Minimal	Low	Medium	High

APPENDIX C: GLOSSARY OF TECHNICAL TERMS

Term	Meaning
algorithmic trading	Electronic, computerised trading that automatically executes orders according to predetermined parameters and rules
bid-ask spread	The difference between the bid price and the ask price
circuit breaker	A type of volatility control mechanism implemented by trading venue to halt or pause trading when a price movement meets the pre-determined threshold
continuous market	The trading venue executes orders as soon as possible
co-location service	A service that locates a trader's computing equipment within a trading venue's primary data centre and clearing system, thus the physical proximity reduces delay in information flow
direct market access (or DMA)	The access provided by a registered market participant to a client (other than internet trading), which allows the client to transmit orders, under the market participant's identifier, directly to the order book of the trading venue
high-frequency trading	A subset of algorithmic trading that trades securities at extremely high speed, from microseconds to nanoseconds, while maintaining very tight intraday inventory positions
kill switch	A type of post-trade control that cancels all orders of a trading venue, a trader, or a trading algorithm when the pre-determined criteria are met
liquidity co-movement	Market liquidity of different securities increase or decrease simultaneously
market depth	Size of the trade required to change prices by a given amount Also known as the price of volume
market fragmentation	The dispersion of trading a security across multiple trading venues
market liquidity	The ability that an investor can buy or sell a large amount of a security quickly, at low cost, when the investor wants to trade
market volatility	The tendency of equity prices to fluctuate sharply within a period of time
market maker	A market participant that provides liquidity to the market by standing ready to buy or sell a security in the market Can be either as a formal role that is registered with the exchange, or as an informal role based on the market participant's own business plan

Term	Meaning
market resiliency	Speed at which a market's tightness or depth recover after some event
market tightness	Cost of buying and then selling a position of a typical size Also known as the price of immediacy
millisecond	One millisecond is equal to one thousandth (1/1000) of a second
minimum resting time	A measure that imposes a requirement on the minimum duration of an order
order book	A list of outstanding buy orders and sell orders of a security
order-to-trade ratio	The overall number of orders received in any given day divided by the overall number of transactions
periodic call auction	The trading venue batches orders and executes them periodically
price discovery	The process through which new information is incorporated into equity prices
price efficiency	The extent to which the equity price reflects all the information relevant for the equity
proprietary trader	Market participant that trades solely with their own capital and does not execute trades for others
speed bump	A measure that imposes an intentional split-second delay before executing orders
systematic risk	The undiversifiable risk inherent to the entire market which affects all securities
volatility control mechanism	A risk management measure that seeks to minimise market disruption triggered by events such as clearly erroneous orders, large aggressive orders, and positive feedback loops

APPENDIX D: REFERENCES

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ABOUT THE HONG KONG ACADEMY OF FINANCE (AOF)

The AoF is set up with full collaboration amongst the HKMA, the Securities and Futures Commission, the Insurance Authority and the Mandatory Provident Fund Schemes Authority. By bringing together the strengths of the industry, the regulatory community, professional bodies and the academia, it aims to serve as (i) a centre of excellence for developing financial leadership; and (ii) a repository of knowledge in monetary and financial research, including applied research.

ABOUT THE HONG KONG INSTITUTE FOR MONETARY AND FINANCIAL RESEARCH (HKIMR)

The HKIMR is the research arm of the AoF. Its main remit is to conduct research in the fields of monetary policy, banking and finance that are of strategic importance to Hong Kong and the Asia region. The Applied Research studies undertaken by the HKIMR are on topics that are highly relevant to the financial industry and regulators in Hong Kong, and they aim to provide insights on the long-term development strategy and direction of Hong Kong's financial industry.

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