

# Characterization of High-Speed Trading\*

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## Summary

In this report, we analyzed the characteristics of high-speed trading activities conducted by high-speed traders registered with the competent authorities pursuant to the Financial Instruments and Exchange Act, by using transaction data on cash equity market trading (approximately 4,000 issues) from November 2019 to the end of March 2021 (343 business days). The transaction data used in this analysis includes information indicating that high-speed traders conduct high-speed trading, making it possible to grasp the actual status of trading conducted by registered high-speed traders. The results of the analysis suggest that (1) most of the high-speed trading activities are conducted through high-frequency trading, and that the number of market orders (orders without limit) placed through high-speed trading is limited; (2) the ratio of the number of orders placed through high-speed trading to the total number of orders placed on the TSE (Tokyo Securities Exchange) was about 70% during the relevant period, whereas the ratio of the trading value of high-speed trading activities to the total trading value on the TSE was about 40%, and the ratio of the number of IOC orders placed through high-speed trading to the total number of IOC orders placed on the TSE was about 80%; and (3) there is no specific difference in the trading status of high-speed trading in each phase of the market, and even in fluctuating phases (especially in a market environment where the impact of COVID-19 in March 2020 became serious and stock prices fell

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globally), the coverage rate of trading stocks was as high as 98% of all stocks, providing liquidity in terms of spread (narrowing of bid-ask spreads).

**Keywords : high-speed trading, high-frequency trading, HST, HFT, cash equity market, algorithmic trading, dedicated (exclusive) virtual server, non-dedicated (shared) virtual server, manual order, market order, algorithm criterion, IOC orders, liquidity, spreads, market fluctuations, averaging-down/up (selling-/buying-off) contribution ratio analysis**

# 1. Introduction

Amid the worldwide development of information technology alongside the growth of online trading by individual investors and the systematization of trading orders by institutional investors, the Tokyo Stock Exchange (hereinafter referred to as "TSE") has promoted its system development under the slogans of "creating a reliable and attractive market" and "enhancing competitiveness among international markets." The TSE's introduction of "arrowhead,"<sup>1</sup> and of co-location services<sup>2</sup> in January 2010 significantly reduced order processing time and trading latency, and accelerated the entry of high-speed/-frequency traders (hereinafter referred to as "HFTers," whereas high-speed/high-frequency trading will be referred to as "HFT") into the Japanese market. Among the effects of HFTs on the market, for example, 永田・乾 (2014) and 太田 (2015) pointed out that bid/ask (bid-offer) spreads dropped significantly around the introduction of "arrowhead," encouraging competition among liquidity suppliers. Kubota and Takehara (2015) also pointed out that HFTs' liquidity supply for large-cap stocks increased.<sup>3</sup> In addition, orders placed at short intervals tend to continue after orders with a large impact, such as a market order (no-limit orders) (田代・川口 (2017)<sup>4</sup>). If, for some reason the market price deviates from the equilibrium price, the market with HFTers tends to adjust to the equilibrium price faster (Hendershott et al. (2014) and O'Hara (2015)).

However, at 2:40 p.m. on May 6, 2010, just after the TSE's introduction of "arrowhead," there was a price fluctuation in the U.S. stock market, in which the involvement of HFT was suspected. This phenomenon was a "flash crash"<sup>5</sup> that disrupted the market and shocked the world by causing the Dow Jones Industrial Average to plummet by \$570 in a matter of minutes, reverse, and then surge by \$540 in a few minutes again. Against this backdrop, financial regulatory authorities and international organizations in various countries have started discussions on the effects of HFTers on market instability, which is a potential risk of HFTers, including the system impact on exchanges and erroneous orders. In Europe, for example, the MiFID II (Markets in Financial Instruments Directive II) (enacted in January 2018) requires HFTs to be registered and mandates the preservation of trading records and the provision of information on algorithmic trading strategies. In the U.S. futures market, for example, in addition to futures traders and other registered traders, there are regulations requiring the registration of algorithmic traders who

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<sup>1</sup> TSE's stock trading system. Arrowhead has accelerated order response time within the TSE and order information delivery time to the outside.

<sup>2</sup> A co-location service is a service that provides space and a network for setting up trading servers, etc. in a co-location area within the primary site where the TSE trading system is located. By using this service, the distance between the TSE's trading system and the market information distribution system is minimized, and the time to obtain quote information and transmit orders can be reduced to a few microseconds each way. This service is designed to be fair and to prevent some participants from buying up land around the trading system.

<sup>3</sup> There are some indications overseas that argue for a similar conclusion in the process of improving the system processing capacity of exchanges (Chordia et al. (2011)).

<sup>4</sup> 田代・川口 (2017) point out that this trend has been particularly strong since the renewal of "arrowhead" on September 24, 2015, when further speed improvements (doubling of system processing power) were realized.

<sup>5</sup> Kirilenko et al. (2016) concluded that the HFT was not the cause of the flash crash, but that the unstable liquidity caused by the transient supply of HFT increased market volatility in the process of the event. A joint report (2010) by the SEC and the CFTC concluded that "there was no specific causal action, but rather a complex of factors triggered by one large order."

have direct access to exchanges on their own accounts, requiring the preservation of trading records. The U.S. has also been studying and building a consolidated audit trail system, CAT,<sup>6</sup> to monitor HFTs (近藤 (2021) and SEC (2020)).

On the other hand in Japan, under the framework of the Financial Instruments and Exchange Act (hereinafter referred to as the "FIEA") at that time, while activities of HFTs could be indirectly confirmed through securities companies, the regulatory authorities did not have the authority to directly request reporting from HFTers unless they were suspected of unfair trading (齋藤・田原 (2017)), and it was difficult to capture the actions of HFTers in a comprehensive and timely manner. In response to this, a registration system for high-speed trading<sup>7</sup> was introduced in April 2018, following discussions by the Working Group on Financial Markets Under the Financial System Council.<sup>8</sup> The registration system newly defined "high-speed trading," requiring those who conduct high-speed trading to register with the competent regulatory authorities, so that the authorities can ascertain the actual status of HFTers (high-speed/high-frequency traders) on stock markets and of other financial instruments business operators engaging in high-speed trading. (Hereinafter those who are registered with the competent regulatory authorities are referred to as "registered HFTers" (high-speed/-frequency traders), whereas the high-speed trading executed by the registered HFTers is referred to as "registered HFT," thereby differentiating "HFTers (high-speed/-frequency traders)" and "HFT (high-speed/-frequency trading)" in the overall general terms).<sup>9</sup>

In addition to requiring registered HFTers to (1) develop a communication management system and risk management system, and (2) take measures related to a framework for providing information to the competent regulatory authorities, the regulations also require broker dealers to (3) prohibit the acceptance of HFT orders/offers from unregistered HFTers.

Under the amendments to the FIEA and other relevant and applicable regulations, trading strategies of the registered HFTers are classified into: (i) Market Make, (ii) Arbitrage, (iii) Directional, and (iv) Others. Registered HFTers are required to submit a summary of each of the trading strategies (i) through (iv). In addition, under the operational rules of the TSE (Tokyo Stock Exchange) and other exchanges, trading participants are required to disclose the (details of) high speed trading activities conducted by the registered HFTers when placing orders.

The "Guidelines for Supervision of High-Speed Traders,"<sup>10</sup> which came into force at the same time as the enforcement of the said amendments to the FIEA, states that the purpose of the supervision of the

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<sup>6</sup>An abbreviation for Consolidated Audit Trail.

<sup>7</sup> The issues and regulatory trends about HFT are summarized in 大墳 (2016) and in Chapter 9 of 神作・小野・湯山 (2018).

<sup>8</sup> The working group published its report in December 2016 (2016).

([https://www.fsa.go.jp/singi/singi\\_kinyu/tosin/20161222-1.html](https://www.fsa.go.jp/singi/singi_kinyu/tosin/20161222-1.html): last viewed on May 31, 2021)

<sup>9</sup> When a financial instruments business operator engages in high-speed trading activities, it is required to submit a notification of change in registered matters, etc.

<sup>10</sup>Comprehensive Guidelines for Supervision of Financial Instruments Business Operators, etc. (Separate Volume) (URL reference: <<https://www.fsa.go.jp/common/law/guide/hft/hft.pdf>> Last viewed on May 31, 2021).

registered HFTers is to "understand the actual situation of algorithmic HFT (high-speed trading) by HFTers (high-speed traders), to ensure the appropriate management of HFTers' (high-speed traders) business operations, to ensure that HFTers appropriately demonstrate their functions and to create a market with sufficient depth so that diverse investors can participate with confidence". By doing so, HFTers should be regulated and supervised in Japan. In addition, JFSA's "Policy Assessment and Strategic Priorities"<sup>11</sup> released in 2018 (Heisei 30) clearly states JFSA's efforts and work plans since the enforcement of the amendments to the FIEA and other relevant and applicable regulations. The outline of the "Policy Assessment and Strategic Priorities" is as follows: (i) confirm the status of the registered HFTers' operational structure, including systems of order execution management and communication management; (ii) accumulate information on the registered HFT, and quantitatively understand the actual status; and (iii) improve the efficiency and sophistication of JFSA's screening methods in monitoring registered HFT in close cooperation with exchanges.

One of the major issues in HFT analysis so far is the judgment on what (sort of trading/transaction) constitutes a conduct of HFT. In previous academic studies, high-frequency/-speed trading was inferred from various viewpoints in terms of extracting high-frequency/-speed trading, whereby an analysis was conducted by defining high-frequency or high-speed trading. For example, 中山・藤井 (2013) defined transactions via co-location as HFT, 保坂 (2014) defined orders from virtual servers with a contract rate of less than 25% and a cancellation rate of 20% or more as HFT, and 大山・津田 (2020) identified the virtual servers of HFT based on the definition of JFSA (referred to as the "algorithm criterion"). In response to the amendments to the FIEA and other regulations regarding the registration of HFT, the TSE's data collection system (the flag system) made it possible to identify orders that a registered HFTer has identified as a registered HFT. This paper is an analysis using such order data, and this is the novel feature of the analysis in this paper.

An outline of the results of this analysis is as follows. The data used for the analysis in this paper is the TSE's most granular data on stock quote listing replication details, and the data extraction period is from November 2019, when the registration of companies subject to transitional measures was completed,<sup>12</sup> to the end of March 2021. As in the analysis by 大山・津田 (2020), we conducted a survey of all stocks for

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<sup>11</sup> (Please note that the following publications are available in Japanese. There is no full English translation for them, but the outlines/summaries are available in English. Also, the following titles are all provisional English titles). "Providing Better Financial Services in the Era of Transition: Assessments and Strategic Priorities (Past Practices and Future Policies of the Financial Services Agency)" (September 2018), available at <<https://www.fsa.go.jp/news/30/20180926.html>> (Last viewed on May 31, 2021). cf. p. 65; "JFSA's Initiatives for User Oriented Financial Services in a New Era - Financial Services Policy: Assessments and Strategic Priorities (Past Practices and Future Policies of Financial Administration)" (August 2019) <<https://www.fsa.go.jp/news/r1/20190828.html>> (Last viewed on May 31, 2021) cf. p. 47; and "JFSA Priorities: Fight Against COVID-19 and Develop a Better Post-COVID-19 Society" (August 2020), available at <<https://www.fsa.go.jp/news/r2/20200831.html>> (Last viewed on May 31, 2019), cf. p. 52.

<sup>12</sup> After the amendments to the FIEA in April 2018, HFTers (excluding financial instruments business operators) that had been conducting high-speed trading activities before the amendments to the FIEA came into effect were required to submit an application for registration within six months (until October 2018) after the law came into effect as a transitional measure. In October 2019, the registration of all of these parties was completed (excluding those who withdrew their registration applications), and the scope of analysis was set to begin in November 2019.

the period under study, analyzing trading data for 343 business days for approximately 4,000 stocks with four-digit codes<sup>13</sup> (hereafter referred to as "cash equities"). This analysis revealed that most of the registered HFT were in the category of high-frequency-like trading, market order placement was limited, the number of registered HFT orders accounted for about 70% of the total number of orders on the TSE during the target period, the trading value of registered HFTs accounted for about 40% of the total trading value on the TSE, and the number of IOC orders<sup>14</sup> of registered HFTs accounted for more than 80% of the total number of IOC orders on the TSE. Moreover, there was no specific difference in the trading conditions of registered HFT at each phase of the market. In particular, during the rapid decline (fluctuation) phase following the spread of COVID-19 and other factors in March 2020, there was a view that "registered HFTers may have stopped providing liquidity, resulting in fewer trading orders,"<sup>15</sup> but rather, the trading value of registered HFT was the highest in March, and the coverage ratio of traded issues remained unchanged from the normal level of around 98% of all traded issues. In addition, for the six stocks with the highest intraday volatility in March (two each of large-, mid-, and small-cap stocks), the spread (the best bid-offer spread, or BBO spread) was narrowed, suggesting that the spread played a role in providing liquidity. However, since we did not track the trading behavior of registered HFT traders for every stock in minutes, seconds, or milliseconds, we will need to continue further discussion and analysis.

The above understanding is based on the acquisition of registered HFTs that fall under the "high-speed trading acts" under the FIEA. It should be noted that not all trading by registered HFTers, including trading that does not fall under the "high-speed trading acts" under the FIEA, can be completely understood by the amendments to the said Act and other applicable regulations. For example, even if registered HFTs are involved in market manipulation and trading that lead to greater market volatility, not all of this trading may be conducted through trading that requires high speed. In other words, even if the authorities are aware of trading that requires high speed by registered HFTers, there is a possibility that registered HFTers are involved in unfair trading through a combination of trading strategies that require high speed and those that do not. Although the possibility of unfair trading combined with trading strategies that do not require high speed is subject to monitoring by exchanges and the Securities and Exchange Surveillance Commission (SESC), based on the above, there is still room for efforts to enhance data analysis and expand the scope of data acquisition in order to accurately understand the entire trading by registered HFTers. Therefore, in order to understand HFTs from a multi-faceted perspective, we would like to discuss HFTs in light of the HFT definitions in previous studies.

Chapter 2 presents the definition of high-speed trading, and Chapter 3 presents the results of previous studies (保坂 (2014) and 大山・津田 (2020) that used data prior to the introduction of the registration

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<sup>13</sup> Non-four-digit stock codes, such as preferred stock, are excluded.

<sup>14</sup> IOC order is an abbreviation for "Immediate or Cancel order," a conditional order that allows for the immediate execution of part or all of the volume at a specified price or a more favorable price, and immediate expiration of the unexecuted order volume.

<sup>15</sup> 星野・山本・水田・八木 (2020) analyze the problem of HFTs holding back from supplying orders when the market becomes unstable, which may be spurring market instability.

system in 2018. In addition, the results of previous studies were updated and the actual conditions of registered HFTers were analyzed. Chapter 4 presents an analysis of the order placement and liquidity supply of registered HFTers during periods of “*nagi*”, rising, falling, and fluctuations in market prices. The final chapter, Chapter 5 presents a summary and future issues.

**Table: Key Developments in Regulations on HFT, etc.**

April 1999	The TSE systemized all trading
August 2007	"SBI Japannext Co., Ltd." (hereinafter referred to as "Japannext") began operating a proprietary trading system (hereinafter referred to as "PTS") (initially for night-time sessions only).
October 2008	Japannext launched a daytime session for PTS
January 2010	The TSE launched new trading system arrowhead The TSE launched a co-location service The TSE introduced continuous trade orders
January 2010	Japannext resized bid-ask prices in J-Market
July 2010	Chi-x launched PTS
February 2011	The Osaka Securities Exchange (hereinafter referred to as the "OSE") launched a new DTM trading system, J-Gate.
June 2012	Japannext launched X-Market
October 2012	PTS trading has been exempted from the "5% Rule"
January 2013	Launch of the JPX Group
May 2013	JPX started providing the JPX co-location service (all)
July 2013	The OSE cash equity market merged into the TSE
January 2014	The TSE reduced the threshold (bid-ask price quote) units for TOPIX100 stocks
January 2014	Japannext narrowed (bid-ask price quote units for) TOPIX100 index in the X-Market
March 2014	Integration of the TSE's derivative market into the OSE
July 2014	The TSE introduced a unit of TOPIX100 constituents with a nominal price of less than JPY 1.
July 2014	Japannext narrowed the TOPIX100 index in the X-Market
September 2015	The TSE revamped the "arrowhead" trading system <sup>16</sup> The TSE changed the unit of bid-ask prices of TOPIX100 constituents. The TSE changed the system for continuous contract quotations. <sup>17</sup>

<sup>16</sup>The upgrade adds more processing power, faster order response times (old: about 1.0 ms, new: less than 0.5 ms) and faster information delivery times (old: about 2 to 2.5 ms, new: less than 1.0 ms) (<http://www.jpx.co.jp/corporate/news-releases/0060/20150924-01.html>; last viewed May 31, 2021).

<sup>17</sup>When it was first introduced in 2010, continuous contract (execution) quotations were displayed when a single order generated a continuous contract (execution) at a level that exceeded twice the range of the renewal price from the

September 2015	Japannext changed the target price unit for TOPIX100 stocks in the X-Market
July 2016	The OSE (Osaka Exchange, Inc.) revamped its J-Gate derivative trading system.
May 2017	Amended the FIEA to introduce a registration system for High-Speed Trading
December 2017	Chi-x introduced tick sizes for TOPIX100 stocks and others
April 2018	The amendments to the FIEA were approved and promulgated, introducing the registration system for high-speed traders.
July 2018	The TSE launched the ETF Market-Making System <sup>18</sup>
November 2019	The TSE revamped the "arrowhead" trading system <sup>19</sup> The TSE changed the system for continuous contract quotations. <sup>20</sup>
May 2020	Japannext changed the X-Market's tick size for bid-ask prices to the same as that of the J-market
July 2020	Japannext changed the bid-ask price unit for TOPIX100 stocks in the X-Market
September 2020	Chi-X reduced the TOPIX100 Index by Chi-Select
2022 years	Start of holiday trading of derivatives
	Plan to restructure four market segments into three markets including the "Prime" market
2024 onwards	Plan to revamp the stock trading system

## 2. High Speed Trade (registered HFT)

### 2.1. Definition of high-speed trade (registered HFT)

This section explains the definition of "high-speed trading" in the FIEA, introduces the transition in the number of registered HFTers, and refers to the "requirements for high frequency," which are defined

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immediately preceding contract (execution) price. In 2015, a large number of small orders were placed instantaneously and a continuous contract (execution) occurred. Therefore, continuous contract (execution) quotations were also displayed when stock prices fluctuated over the range of continuous contract (execution) quotations within a certain period of time.

(<https://www.jpx.co.jp/news/1030/nlsgeu0000016dib-att/Japanese2.pdf>: Last viewed date: May 31, 2021)

<sup>18</sup>A system that provides incentives to market makers who meet certain criteria. Applicants must own a dedicated virtual server. (<https://www.jpx.co.jp/equities/products/etfs/market-making/index.html>: Last viewed date: May 31, 2021)

<sup>19</sup>The redesign adds more processing power, faster order response times (old: 0.3 ms, new: 0.2 ms) and faster information delivery times (old: 1.0 ms, new: 0.5 ms). (TSE x website <https://www.jpx.co.jp/corporate/news/news-releases/0060/20191105-01.html>: Last viewed date: May 31, 2021)

<sup>20</sup>In order to control sudden fluctuations in stock prices, the system was changed to one in which the price of continuous contract quotations does not fluctuate by exceeding a certain range (twice the range of renewed quotations) until the monitoring time (60 seconds) has elapsed. In addition, the base price for continuous contract (execution) quotations was distributed in FLEX Full. ([https://www.jpx.co.jp/systems/equities-trading/tvdivq0000002uk-att/arrowhead Upgrade J.pdf](https://www.jpx.co.jp/systems/equities-trading/tvdivq0000002uk-att/arrowhead%20Upgrade%20J.pdf): Last viewed date: May 31, 2021)

differently in the FIEA and European regulations.

The FIEA defines "high-speed trading" as securities and market derivatives trading that satisfies all of the following requirements (including over-the-counter derivatives trading for the purpose of entrusting and managing these trading).<sup>21</sup>

- (1) Decisions on the purchase and sale of securities and market trading of derivatives are automatically made by an electronic data processing system.
- (2) The facility where the electronic data processing system described in (1) above is installed is located in the same place as, or adjacent to, or in close proximity to, the trading system (matching engine) of an exchange, etc.<sup>22</sup>
- (3) A system is in place to prevent orders placed with the trading system described in (2) above from competing with other orders placed.

The above (1) applies to cases in which so-called algorithmic trading of shares, etc. (trading in which a computer system automatically makes investment decisions and places orders) is conducted. The above (2) applies to cases in which a system incorporating an investment algorithm is installed in a co-location area such as an exchange. The above (3) applies to cases in which a virtual server (in the case of the TSE) is used exclusively. However, in response to a public comment on December 27, 2017 (hereinafter referred to as the "Public Comment"), JFSA states that "even if the proprietary system itself is not put in place, for example, if a system configuration substantially equivalent to a dedicated virtual server, etc. is used, it will be considered applicable."<sup>23</sup>

"HFT" is a vague concept that originally refers to high-frequency or high-speed trading, and there is no established standard by which an order form can be uniquely determined as an HFT. The definition of "high-speed trading" in the FIEA in Japan also focuses on the system and communication environment in which the algorithm operates, as opposed to the order form of the trader. On the other hand, Ferber (2012) and 保坂 (2014) have defined specific order forms of HFT using numerical thresholds. However, rapid technology evolution can drive HFT to speed up and change, and as a result, the numerical thresholds can be subject to frequent modifications.

In Europe, the definition of algorithmic trading is that "computer algorithms automatically determine whether or not to place an order, with limited or no human intervention, or do not include a system used only for confirming an order or for executing a trade after the trading." Moreover, high-frequency

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<sup>21</sup>Article 2, Paragraph 41 of the Financial Instruments and Exchange Act, Article 1-22 of the Order for Enforcement of the Financial Instruments and Exchange Act, Article 26 of the Cabinet Office Order on Definitions under Article 2 of the Financial Instruments and Exchange Act, Notification No. 50 of the Financial Services Agency, 2017 (2017), Supervisory Guidelines for High-Speed Traders III-3-1-2 "Points to Consider regarding Methods of Transmitting Information that Constitutes a High-Speed Transaction."

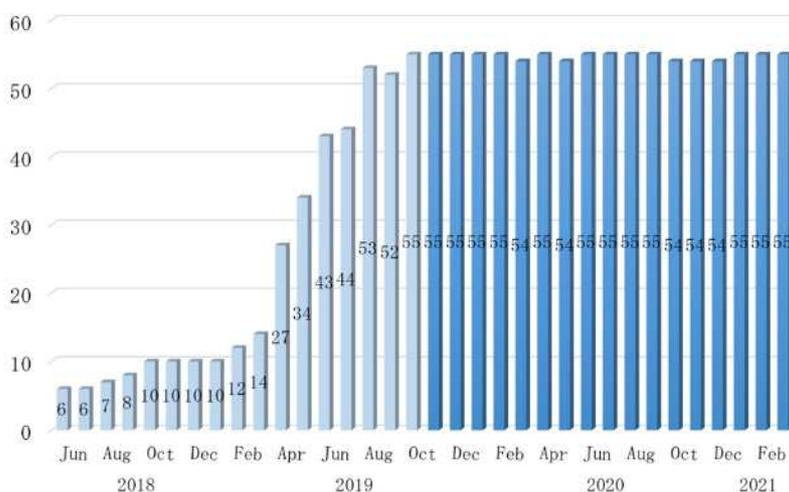
<sup>22</sup>The Tokyo Stock Exchange (TSE), Osaka Stock Exchange (OSE), Nagoya Stock Exchange, Fukuoka Stock Exchange, Sapporo Securities Exchange, and PTS (Japannext and Chi-x) are covered and Tokyo Financial Exchange (TFX) is not covered.

<sup>23</sup>Financial Services Agency, "Publication of finalized amendments to the related Cabinet Orders and Cabinet Office Orders, etc., following the 2017 revision of Financial Instruments and Exchange Act (FIEA)," December 2017 (2017) (<https://www.fsa.go.jp/news/29/syouken/20171227.html>: Last viewed date: May 31, 2021)(One point press release: the FSA Weekly Review No.276 <https://www.fsa.go.jp/en/newsletter/weekly2018/276.html>)

algorithmic trading is defined as a trading method that satisfies the following (1) to (3): (1) the trading system has an infrastructure to minimize data processing delays caused by networks, etc., using at least one or more of the following methods: co-location with the stock exchange, installation of nearby servers, or high-speed direct access; (2) the system determines the commencement, placement, routing/forwarding, and execution of an order for each individual trade/execution without human intervention/involvement; and (3) there is a large amount of (incoming) messages per day consisting of orders, quotes (offers of bids), or cancellations.<sup>24</sup>

The feature of high frequency indicated in (3) is one of the main characteristics of high-speed trading. The FIEA does not require (3) as a requirement, but the FSA clearly stated in its public comment on December 27, 2017, "If high frequency is a requirement, it will be difficult for financial instruments business operators, etc. to confirm the sufficiency of requirements for high-speed trading if investors who conduct high-speed trading place orders among multiple financial instruments business operators, etc., and it will be impossible to ensure the effectiveness of regulations." In other words, this definition has not been adopted in light of the difficulty (湯原 (2017)) in separating regulated (and trading) from non-regulated (and trading) and the effectiveness of the HFT prohibition of accepting HFT contracts from unregistered HFT companies imposed on securities companies (namely, broker dealers).

In the following sections, we examine trends in registered HFTers (dark blue bars) in Figure 2-1 from October 2019, when all the HFTers subject to transitional measures had been registered, i.e., from November 2019 to March 31, 2021.



Source: Prepared by the author from materials published on the FSA website

Figure 2-1 Changes in the number of registered HFTers

## 2.2. Virtual Server

This section describes virtual servers, and then introduces the number of dedicated (exclusive) virtual

<sup>24</sup>For details, see 湯原 (2017), 船津 (2016) and MiFID II (Markets in Financial Instruments Directive II).

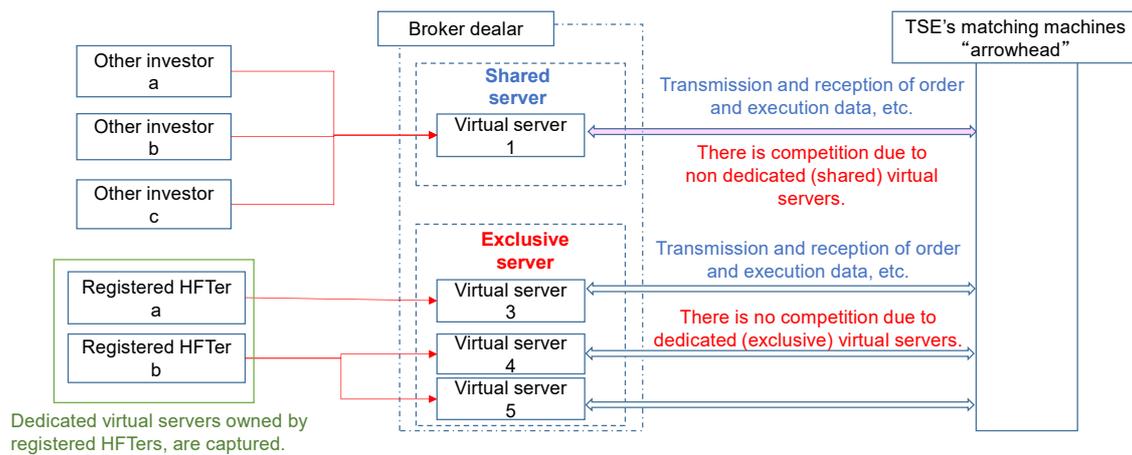
servers owned by registered HFTers and the number of non-dedicated (shared) virtual servers used by others.

A "virtual server" is a logical device implemented by a securities company in order to send and receive data to and from the trading system of the TSE, and is a kind of ID assigned to each securities firm as a link unit (Fig. 2-2). A virtual server establishes a TCP-connection with the trading system. If we limit the focus to virtual servers that are exclusive to investors ("dedicated virtual servers" in Figure 2-2), we can directly observe the trading behavior of investors ("HFTer a" and "HFTer b" in Figure 2-2) by aggregating the trading orders for their respective virtual servers. While the cap on the number of orders that can be placed per second is determined by the type of the virtual server,<sup>25</sup> in order to avoid any competition with other investors and to ensure the execution of orders in overheated markets, investors need to pay an additional fee to occupy a virtual server customized for their use. In particular, it is deemed that HFTers are inclined to keep multiple virtual servers exclusive at an extra cost given the nature of high-speed and high-frequency trading. Therefore, many empirical studies have analyzed HFTs on the basis of identifying HFTs for each virtual server, including 保坂 (2014), who defined HFTs based on the order contract rate and order cancellation rate for each virtual server based on Ferber (2012), Saito et al. (2017), who defined a virtual server that had no distressed sell orders during the noon recess of the futures plunge as an algorithmic trader using speed, and Goshima et al. (2019), who suggested the characteristics of HFT through cluster analysis of virtual servers, and 大山・津田 (2020), who analyzed the characteristics of HFT using the TSE's most granular data (from 2010 to 2015). The amendments to the FIEA made it possible to investigate the registered HFTers' strategies for high-speed trading with dedicated virtual servers (market-making strategies, arbitrage strategies, directional strategies, and other strategies), but there are also virtual servers shared by multiple investors ("shared (virtual) servers" in Fig. 2-2). It cannot be denied that registered HFTers (for non-HFT trading) are trading through shared virtual servers, and therefore, it is not possible to detect all of their transactions by only checking dedicated virtual servers. As mentioned above, even if a proprietary mechanism itself is not implemented, for example, a case in which a system configuration substantially equivalent to a dedicated virtual server, etc. is used falls under the definition (3) of registered HFT.

Figure 2-3 shows the total number of virtual servers, the number of dedicated virtual servers (based on registered HFTs), and the percentage of dedicated virtual servers. The number of active virtual servers showed a discontinuous change on November 5, 2019, when the number of virtual servers was renewed, and on Christmas days in 2019 and 2020. However, under normal circumstances, approximately 70% of virtual servers were dedicated to registered HFTs.

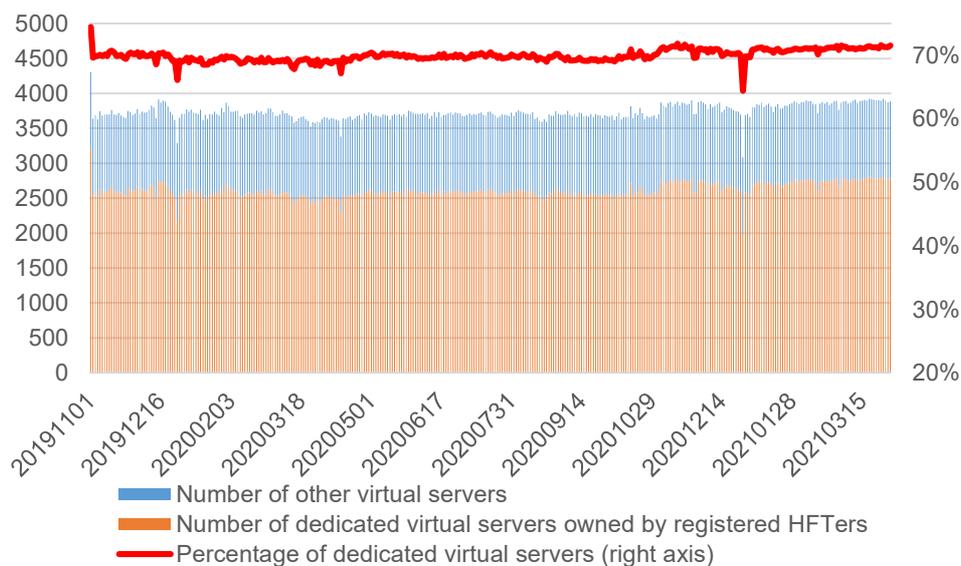
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<sup>25</sup>There are three different types of virtual servers available for orders per second, and you can place up to 200 orders per second.



Source: Prepared by the author

Figure 2-2 dedicated (exclusive) and non-dedicated (shared) virtual servers



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 2-3 Total number of virtual servers and number of dedicated virtual servers owned by registered HFTers

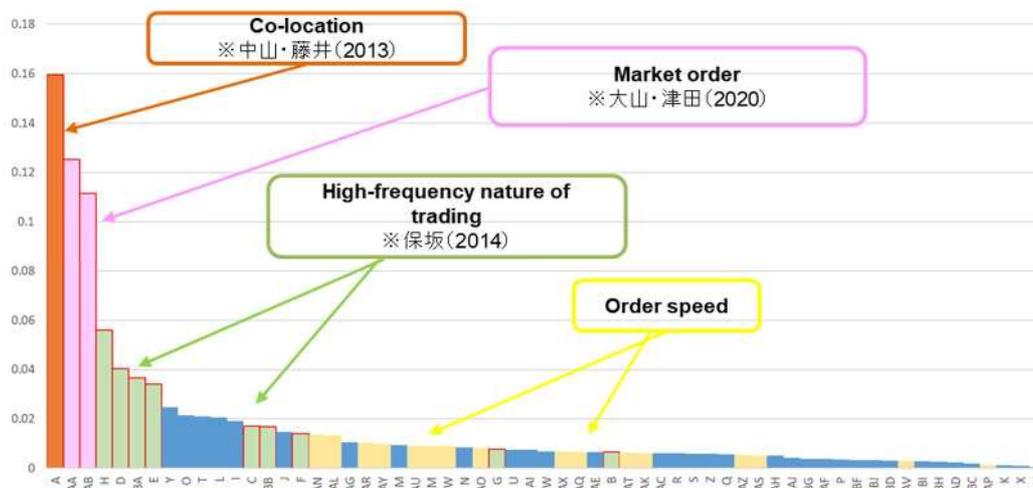
### 2.3. Specifying the Feature Quantity of a Virtual Server Exclusively Owned by a Registered HFTer

In this section, we use random forests<sup>26</sup> to estimate feature quantities which are classified by the

<sup>26</sup>A random forest is a method of machine learning that provides a decision tree for each set of sample data and then integrates the results by a majority vote or on average to make the final classification and prediction. Among many analytical approaches, this approach has the advantage of being less likely to overfit and not requiring assumptions about the linear separability of the data.

dedicated virtual server owned by the registered HFTer or the non-dedicated (shared) virtual server used by other entities.<sup>27</sup>

First, 61 indicators (the number of orders, the number of successful orders, the number of short sales, etc.) were determined as feature quantities/values using TSE's most granular data (for stock quote listings) on August 28, 2020 (the phase of rapid fluctuation in response to the news of the resignation of former Prime Minister Abe); November 2, (the phase of the wait-and-see mood before the U.S. presidential election); and December 30, 2010<sup>28</sup> (the flat market phase in the year-end). Next, about 12,000 samples (about 4,000 virtual servers × 3 days) labeled with the registered HFTers (with or without dedicated virtual servers) and the average loss of impurities calculated from all decision trees (10,000) in the forest were analyzed, and the importance of the feature quantities/values was measured.<sup>29</sup> From Fig. 2-4, it can be concluded that the most effective feature quantity/value for classifying the dedicated virtual server of a registered HFTer or the shared server of other entities among the 61 feature quantity/values is the information on whether or not it is via a co-location location, followed by the information on market orders (without limits). 大山・津田 (2020) used the ratio of market orders (without limits) (and manual orders) as an algorithmic criterion<sup>30</sup> for HFT judgment. It was found that the virtual servers that conduct algorithmic trading and orders from the co-location area, as defined by the HFT in the FIEA in Section 2.1, are highly likely to be dedicated virtual servers used by registered HFTers.



<sup>27</sup>Of course, if it is possible to capture on a per-investor basis rather than on a per-virtual server basis, it is possible to grasp the feature quantities of the order form of the HFTer and the order form of the general investor, thereby enabling more detailed analysis.

<sup>28</sup>In the previous two days, the index had risen by more than 900 yen. There was no significant change in the value of the Nikkei Stock Average during the day due to a mixture of selling for profit determination and buying for economic recovery in the following year. (The daily range of the Nikkei Stock Average is around 234 yen)

<sup>29</sup>It is implemented in Python using scikit-learn, an open source machine learning library.

<sup>30</sup> To be precise, HFT is defined as a virtual server that satisfies the requirement for a "market order ratio of less than 1% and manual order ratio of less than 0.1%" for at least 20% of the operating days.

via colocation or not	A	Number of Funari(※)	P	Number of orders with 100 shares	AE	Percentage of total limit orders canceled within one minute	AT
Total number of records (sum of the numerators of C to H below)	B	Number of IOC( Immediate or Cancel Orders)	Q	Number of orders with 1,000 shares	AF	Percentage of total limit orders canceled within one second, and up to one minute	AU
New order rate (denominator: B)	C	Number of make orders	R	"AE"/"B"	AG	Percentage of total limit orders canceled within 0.5 seconds, and up to one second	AV
Execution rate (denominator: B)	D	Number of take orders	S	Number of types of trading units	AH	Percentage of total limit orders canceled within 0.1 seconds, and up to 0.5 seconds	AW
Change rate (denominator: B)	E	Manual orders rate	T	number of short sales (price regulated)	AI	Percentage of total limit orders canceled within 10 milliseconds, and up to 0.1 seconds	AX
Cancellation rate (denominator: B)	F	Number of buy-price match (within the special quote display price range)	U	number of short sales (price non-regulated)	AJ	Percentage of total limit orders canceled within one millisecond, and up to 10 milliseconds	AY
Expired rate (denominator: B)	G	Number of buy-price match (not within (outside) the special quote display price range)	V	Number of limit orders within one hour of execution	AK	Percentage of total limit orders canceled within one millisecond	AZ
Cancellation and new order rate (denominator: B)	H	Number of sell-price match (within the special quote display price range)	W	Percentage of total limit orders executed within one hour	AL	Execution rate (sum of the numerators of "D"/sum of the numerators of "C" + "E" + "F")	BA
Number of closing transactions	I	Number of sell-price match (not within (outside) the special quote display price range)	X	Percentage of total limit orders executed within 10 minutes, and up to one hour	AM	Cancellation rate (sum of the numerators of "D" + "B"/sum of the numerators of "C" + "E" + "F")	BB
Ratio of orders during auction session hours	J	Margin transactions rate	Y	Percentage of total limit orders executed within minute, and up to 10 minutes	AN	Whether orders are placed from multiple virtual servers to the same order	BC
Number of closings in closing auction sessions (closing prices not approved)	K	Principal and agent rate	Z	Percentage of total limit orders executed within one second, and up to one minute	AO	Trading value (= "BG" - "BF") (Unit: one million yen)	BD
Number of closings (closing prices approved)	L	Number of market orders	AA	Percentage of total limit orders executed within 0.5 seconds, and up to one second	AP	Trading value of buying (Unit: one million yen)	BF
"L"/("K"+"L")	M	Ratio of market orders to executions	AB	Percentage of total limit orders executed within one millisecond, and up to 0.5 seconds	AQ	Trading value of selling (Unit: one million yen)	BG
Number of orders with opening conditions	N	Number of orders with 1 share (trading unit)	AC	Percentage of total limit orders executed within one millisecond	AR	Total trading volume (= "BI" + "BJ") (Unit: ten thousand yen)	BH
Number of orders with closing conditions	O	Number of orders with 10 shares (trading unit)	AD	Number of limit orders cancelled within one minute	AS	Total trading volume of buying (Unit: ten thousand yen)	BI
						Total trading volume of selling (Unit: ten thousand yen)	BJ

※Funari : Limit orders that become market orders at the closing auction session if not already executed.

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 2-4 Feature quantities/values by random forest analysis

(Upper figure: rank (importance) of feature quantity, lower figure: each index)

In the random forest method, when the correlation between two or more feature quantities is high, the rank (importance) of one feature quantity is very high, but the remaining feature quantity may not be sufficiently reflected in the rank. Therefore, the minimum index and the minimum number of indices necessary for avoiding overfitting of the model and ensuring the accuracy of the HFT discrimination (95% or more in the test data) are identified (among about 12,000 data samples, 70% will be used as a training data set, whereas 30% will be used as a test data set) by using sequential backward selection<sup>31</sup>. As a result of the analysis using all of the indices shown in Figure 2-4, three indexes were extracted: "via co-location," "total number of records," and "change rate." When "via co-location" and its highly co-related features are removed, four indices were extracted: "percentage of market orders out of total orders executed," "percentage of new orders" and "percentage of executed orders," and "percentage of all orders executed within one millisecond." The important indexes for identifying the virtual servers used by registered HFTers were (i) (whether or not they are) via co-location, (ii) market order information, and (iii) information on the percentage of types of orders executed, and the results are generally the same as in the random forest analysis. In other words, the difference between the dedicated virtual servers used by registered HFTers and non-dedicated (shared) virtual servers used by other entities generally appear in the system environment (the degree of ≡(i)); the degree of algorithmization (≡(ii)); and the high-frequency nature of trading (≡(iii)).<sup>32</sup> In the next chapter, the status of registered HFTers' trading is outlined for each

<sup>31</sup> Algorithms for feature selection are summarized in papers of Guyon and Elisseeff (2003) and of Raschka (2017).

<sup>32</sup> (i), (ii), and (ii) are used by 中山・藤井 (2013), 大山・津田 (2020), and 保坂 (2014), respectively, in their HFT criteria.

of (i) to (iii).

### 3. Factual analysis of registered HFTs

#### 3.1. Co-location Usage of Virtual Servers Owned by Registered HFT Operators

In this section, we examine the actual status of registered HFTs from the viewpoint of the co-location usage of virtual servers owned by registered HFTers and virtual servers used by other entities.

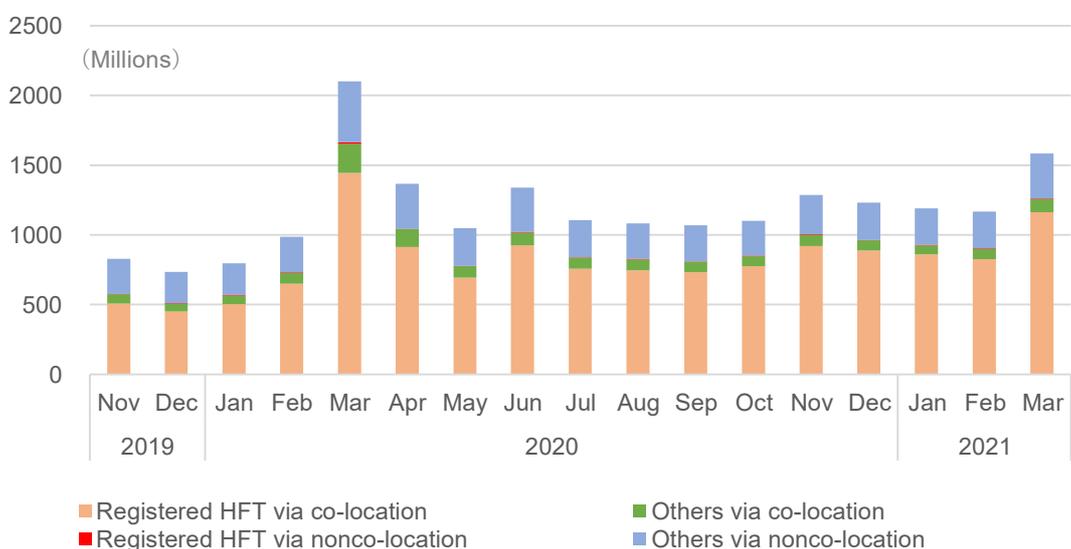
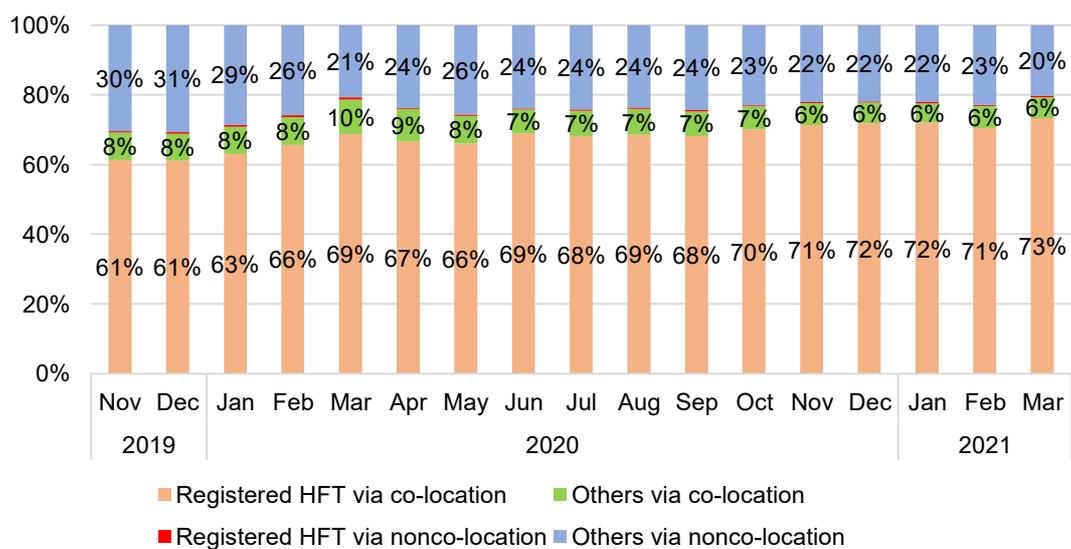
As shown in Figures 3-1 and 3-2, the number of orders for virtual servers via co-location and the trading value (orange bar + green bar) accounts for about 75% (monthly average) of all orders and about 45% (monthly average) of all trading value. In the previous section, information (1) on whether or not to use co-location is the most important feature to distinguish between the order form of dedicated virtual servers by registered HFTers and that of shared virtual servers by other entities or investors. In fact, as shown in Figure 3-1, the number of registered HFT orders accounted for more than 90% (orange bar) of the number of orders via co-location (orange bar + green bar), whereas the number of registered HFT orders accounted for less than 1% (red bar) among the number of orders that did not go via co-location (blue bar + red bar). As for the trading value (Figure 3-2), the number of registered HFT orders accounts for about 85% (orange bar + green bar) of the trading value via co-location, while the number of registered HFT orders accounts for less than 1% (red bar) of the trading value not via co-location (blue bar + red bar). 中山・藤井 (2013) defines HFT as trading via co-location, but it is clear that trading by registered HFT are almost never included in trading that are not at least via co-location<sup>33</sup>.

We would like to discuss in more detail about Others via co-location (non-registered HFT trading, green bars), which account for 5-9% of the total value of trading. Since this trading is through co-location but not registered HFT trading, it is considered to be trading that does not satisfy at least one of (1) and (3) except for (2) in the HFT definition in Section 2.1. First, if definition (1) does not apply, the trading is unlikely to be an algorithm. Non-algorithm trading means trading where a computer system does not automatically make investment decisions and place orders, and is not completed by an automated system, that is, it is trading involving human intervention. Physically, since the ordering party cannot reside in the co-location, it is likely to go through the access point (not co-location) that is closest to the place where the ordering party places orders. Therefore, trading from dedicated virtual servers through the co-location are assumed to be algorithmic trading. In other words, it can be assumed that "orders from shared servers competing with orders from other investors" that do not satisfy HFT definition (3) in Section 2.1 can be considered to account for the majority of the total value of trading through co-location.<sup>34</sup>

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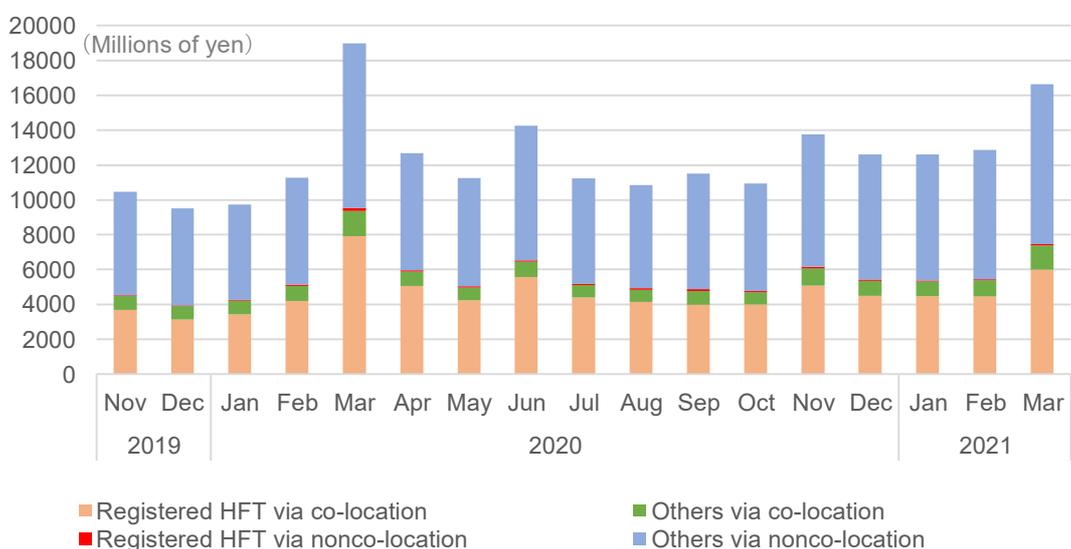
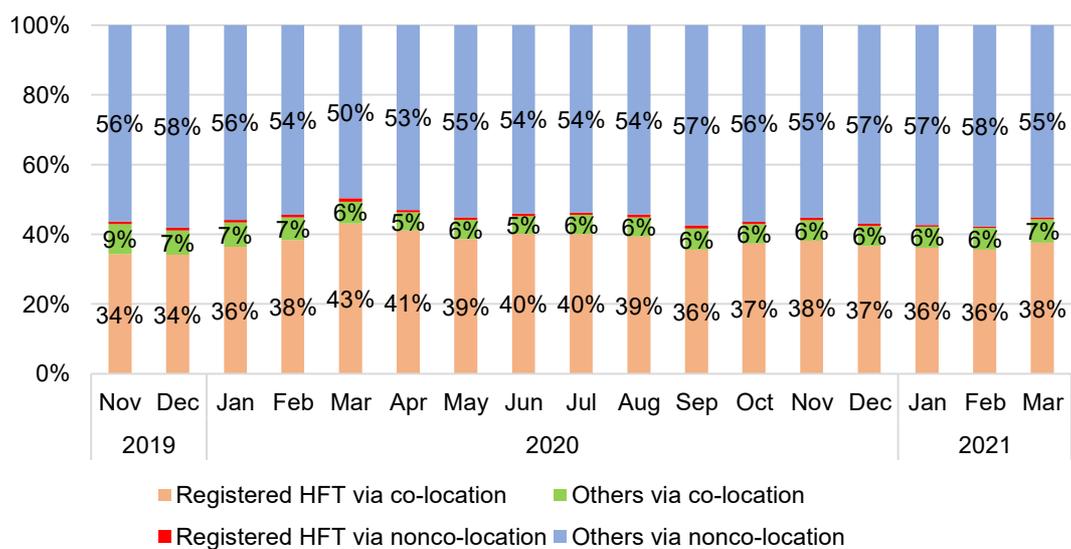
<sup>33</sup>In the subsequent analysis, we do not refer to whether or not trading by registered HFTers are through co-location because almost all trading of registered HFT is through co-location.

<sup>34</sup> In addition, it is hardly conceivable that a virtual server would be monopolized at an additional cost in order not to compete with orders from other investors in trading via non-co-location that do not require speed. Therefore, it is assumed that orders other than "HFT registered via co-location" in Figs. 3-1 and 3-2 are placed from a shared server.



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-1 Trends in the order volume ratio (top) and order volume (bottom) by co-location and registered HFT



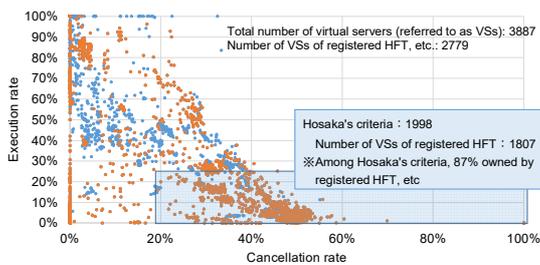
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-2 Trends in trading value ratios (top) and trading value (bottom) by co-location and registered HFT

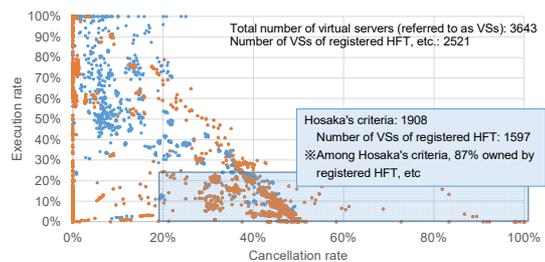
### 3.2. Current Status of Registered HFTs from the Viewpoint of Frequency

In this section, we examine the actual status of registered HFTs from the viewpoint of the ratio of order types (③), which is one of the important features in Section 2.3, particularly in terms of the cancellation rate and the execution rate, which suggests high frequency. 保坂 (2014) defined high-frequency trading as that with a cancellation rate of 20% or more and an execution rate of less than 25%. Figure 3-3 shows scatter charts of the cancellation rate and the execution rate of trading from each virtual server for the following four business days: November 5, 2019, when the new virtual server was installed; March 31, 2021, the last day of the analysis period; March 17, 2020, when the number of orders was the highest; and December 25, 2019, when the number of orders was the lowest. In each chart, the points in the blue box area represent the virtual servers that meet the Hosaka criteria. For all virtual servers (blue points), only the virtual servers owned by registered HFTers are filled in orange. If you fill them in orange, you can see that they are mostly distributed inside the Hosaka criteria.

(The business day when the virtual server was renewed)

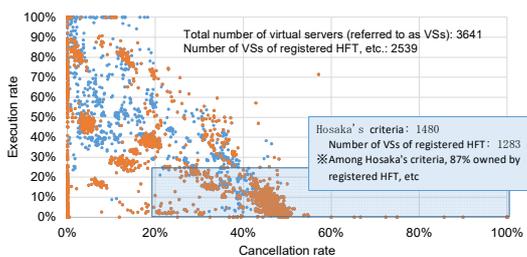


(The business day with the lowest number of orders)

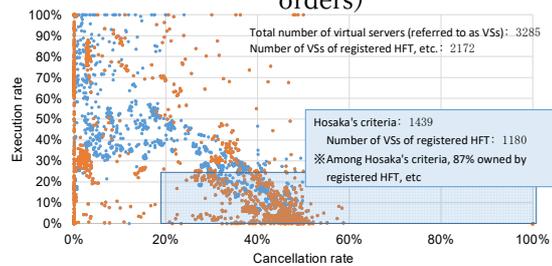


Left: March 31, 2021 Virtual server scatter, Right: March 17, 2020 Virtual server scatter

(The last business day of the analysis period)



(The business day with the largest number of orders)



Left: November 5, 2019 Virtual server scatter, Right: December 25, 2019 Virtual server scatter

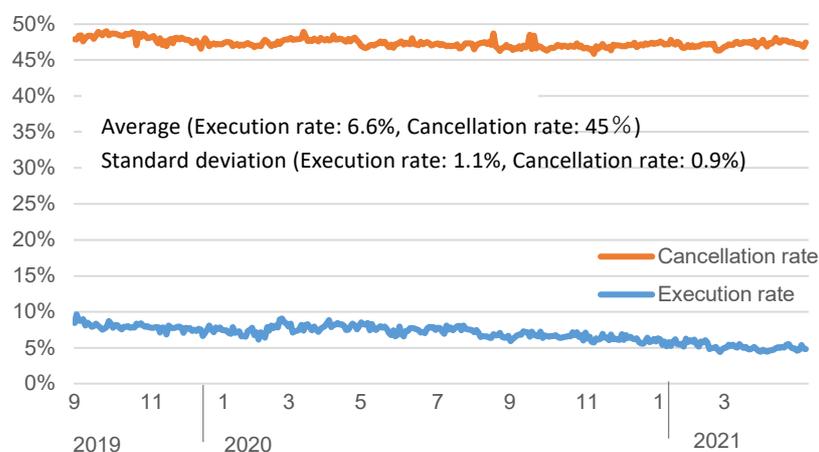
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-3 Virtual server distribution based on 保坂 (2014)

As long as the definition of high-frequency trading in 保坂 (2014) is different from that of the amendments to the FIEA, the results of this analysis do not verify the accuracy of the Hosaka Standard. However, almost 85% to 90% of high-frequency trading defined by 保坂 (2014) are conducted on dedicated virtual servers owned by registered HFTers, indicating that many registered HFTers conduct

high-frequency trading via their dedicated virtual servers. On the other hand, a large number of virtual servers owned by registered HFTers are found in the vicinity of the cancellation rate of 0%. It is considered that these virtual servers mainly use IOC orders frequently. IOC orders, by their nature, do not sit on stock quote listings, and inevitably have a cancellation rate around zero. Therefore, by adding the IOC order element to the Hosaka standard, it can be said that a larger number of virtual servers owned by registered HFTers can be captured. IOC orders are conditional orders that were introduced on January 24, 2012, and it is considered that they were orders that were not widely seen in 2012 and 2013, the data periods used in 保坂 (2014). In addition, when performing analysis using stock quote listings information (data with rough information content as opposed to TSE's most granular data), there is a possibility that the expiration information of IOC orders cannot be captured.

Fig. 3-4 shows the actual transition of the execution rate and cancellation rate of registered HFTs. The contract/execution rate is shown as the number of execution/(number of new orders + number of change orders + number of cancellation orders), and the cancellation rate is shown as (number of cancellation orders + number of expirations)/(number of new orders + number of change orders + number of cancellation orders). This figure shows that many registered HFTers have a high cancellation rate of about 45% and a low execution rate of less than 10%, indicating that the messages constituting the order trading are exchanged frequently, i.e., trading is conducted frequently.<sup>35</sup>



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-4 Contract rate and cancellation rate of registered HFTs

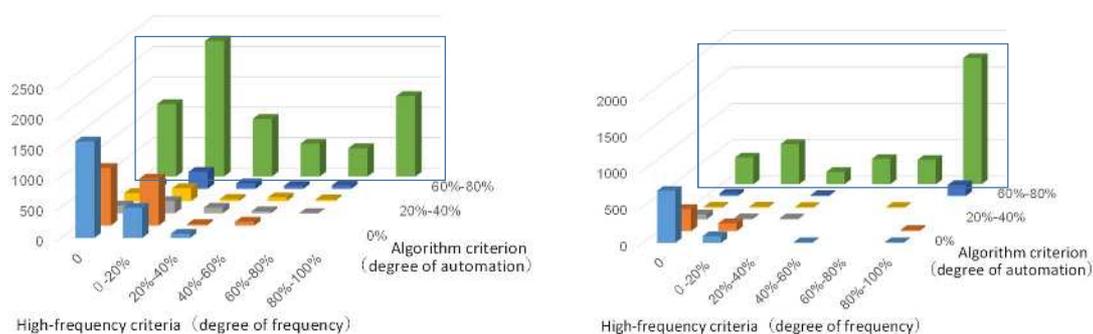
### 3.3. Consideration of Order Types Based on Frequency and Degree of Algorithmization

<sup>35</sup> For each order ID, there is a reasonable way to calculate the execution rate and cancellation rate, considering whether the order was cancelled or a part of it was agreed upon. This paper basically follows 保坂 (2014) and takes into account the number of expired IOC orders.

In this section, we will examine the actual status of registered HFTs from the viewpoints of both "Market Order" (②) and "High-Frequency" (③) among the order types, which were important feature quantities in section 2.3, following the example presented by 大山・津田 (2020). In the analysis by 大山・津田 (2020), among approximately 1,400 business days for each virtual server, the number of business days satisfying the high-frequency criteria and the algorithm criterion is counted, and the ratio of these business days is used to make an HFT judgment. In this paper, we conducted the same analysis with the updated data of 342 business days from November 5, 2019, when the virtual servers were completely updated, to March 31, 2021. As a result, the overall trend shows a relative increase in the number of high-frequency virtual servers (high-frequency criteria 80% - 100% and the algorithm criterion 80% - 100%) (the boxed portion in Fig. 3-5). With respect to the figure on the right-hand side in Figure 3-5, when the distribution of registered HFTs and other virtual servers is created separately, the result is shown in Fig. 3-6 (the left figure in Fig. 3-6 shows dedicated virtual servers by the registered HFTs, and the right figure shows other virtual servers by other entities or the others). As pointed out by 大山・津田 (2020), the trading on the virtual servers of registered HFTers is basically judged as HFT (HFT judgment: yellow bar + red bar, non-HFT judgment: gray bar) with the algorithm criterion of 20% or more. However, further scrutiny reveals the following:

- Some of the registered HFTers' virtual server groups (Fig. 3-6, left panel) have a low-frequency/low-algorithm criterion (gray bars with a high frequency criterion of less than 20% and an algorithm criterion of less than 20%).
- Some of the servers that are not virtual servers of registered HFTers (Figure 3-6, right panel) belong to the high-frequency/high-algorithm criterion (red bar chart with a high-frequency criterion of 60% or higher and an algorithm criterion of 40% or higher).

As for the latter, since many of its virtual servers go through co-location, it is assumed that these are the shared (virtual) servers within the co-location mentioned in Section 3.1 (competing with other investors).



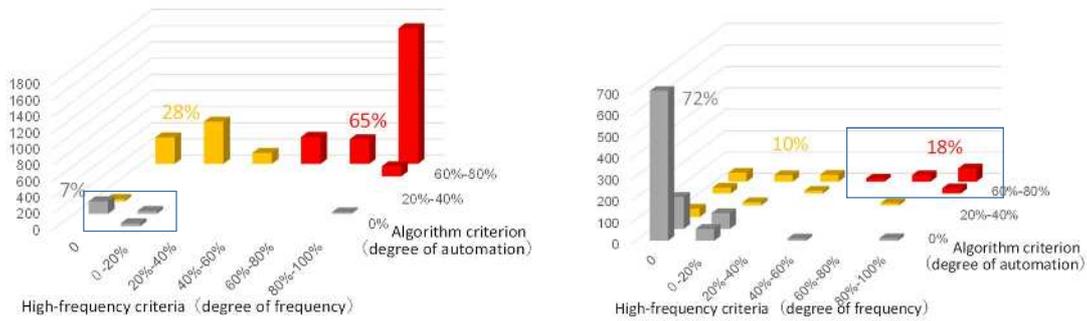
Left: Data period January 2010 - September 2015, Right: Data period November 2019 - March 2021<sup>36</sup>

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-5 Distribution of Virtual Servers Based on 大山・津田 (2020)

<sup>36</sup> The bar graphs on the right-hand side of Fig. 3-5 and in Fig. 3-6 with less than 10 virtual servers are shown in white.





Left: Registered HFTers' virtual servers (73%), Right: Number of other virtual servers (27%)

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-6 Distribution of virtual servers based on 大山・津田 (2020)

Figure 3-8 and Figure 3-15 show the number of orders placed from the virtual server in Figure 3-6 and the trading value in order to grasp the actual status of the registered HFT. By adding together the changes in Figure 3-9 and Figure 3-14, the ratio of the number of orders and the trading value of the registered HFT to the total orders and the total trading value are estimated to be approximately 69% and 39%, respectively. On the other hand, the HFT rates based on the HFT judgment of 大山・津田 (2020) are estimated to be as high as 81% (Figure 3-8: yellow and red bars of both graphs) and 48% (Figure 3-15: yellow and red bars of both graphs), respectively. Since the HFT judgment/determination by 大山・津田 (2020) captures the overall algorithmic trading (all with an algorithm criterion of 20% or higher), it is assumed that the HFT includes the actual registered HFT. For example, a securities company may be executing orders entrusted by institutional investors using algorithms such as VWAP (Volume Weighted Average Price), and even a virtual server with an extremely large number of orders and high frequency trading may be a business that is seriously considering entering the HFT in the future (such as moving to a co-location area or switching from a shared virtual server to a dedicated virtual server). In addition, some registered HFTs may not require much speed, and these are included in the algorithm criterion of 20% or higher in the panels on the right-hand side of Figure 3-8 and Figure 3-15.

It can be seen that the number of orders for a group of high-frequency and high-algorithm criterion based virtual servers (the red bars in Figures 3-8 and 3-15) of registered HFTs is extremely high compared with the trading value (or the number of executions). Delving into the number of orders and executions at the level of individual stocks, we surveyed approximately 1.37 million (342 business days times about 4,000 stocks), and found that there were approximately 8,754 stocks<sup>37</sup> with more than

<sup>37</sup>For example, in Figure 3-7, where the number of orders is 100,000 or more and the number of contracts (execution) is less than 10 (indicated in pink), the percentage of HFT orders is 99.98%, and all of the six contracts (executions) are made by investors other than registered HFTers. When the percentage of counterparties to registered HFTs was examined monthly (January to March 2020), it was found that approximately over 30% of registered HFTers and nearly 70% of other investors were counterparties, similar to the trading value ratio. However, it is necessary to conduct a more detailed analysis, at short intervals, on the question of whether or not counterparties would be biased toward the stocks for which the percentage of

10,000 orders that had almost no executions/contracts (less than 100) (Figure 3-7). The percentage of change orders by registered HFTs in the target period (Figure 3-11) has risen from approximately 30% to over 60%. The main factor (more than 90% of the increase) can be explained almost entirely by the number of registered HFTs placed against a dozen or more certain stocks.<sup>38</sup> Under the current Act (FIEA), trading that may cause market fluctuations with the purpose of inducement is considered market manipulation,<sup>39</sup> but the repetition of orders as high-frequency trading makes it difficult to immediately recognize the purpose of inducement. However, additional analysis may be necessary to determine whether the purpose of inducement is unrecognized, whether it leads to market manipulation, or whether the market has become a testing ground for trading strategies to repeat meaningless trading.

		Total orders		
		< 50 K	50 K- < 1mil.	1 mil.-
Total executions	50- < 100	2,042	70	27
	10- < 50	3,790	128	20
	< 10	2,474	20	3

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-7 8754 stocks with low contract volume and high order volume

As shown in Figure 3-17, the number of IOC orders is mostly from virtual servers with a high algorithm criterion, and registered HFT orders account for 80% to 90% of IOC orders (Figure 3-18). IOC orders are suitable for taking at the fastest speed (take orders<sup>40</sup>) when orders placed near the BBO spread are immediately detected, and with the accelerating update speed of stock quote listings, the use of these orders may be heavily weighted toward registered HFTs,<sup>41</sup> for having a significantly higher speed. As for the number of market orders, the percentage of registered HFT in Figure 3-20 has been around 1%. As pointed out by 大山・津田 (2020), in general, HFTers constantly monitor stock quote listings information and place orders at a price range where they want to buy or sell the number of shares they need. It is more natural to assume that registered HFTs are reluctant to accept market orders that could be executed at unexpectedly high (or low) prices.

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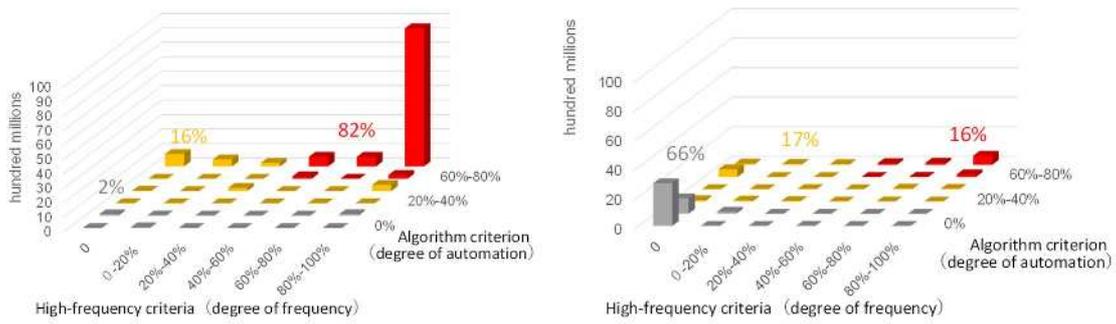
registered HFT orders increased.

<sup>38</sup>Almost all of the change orders were orders that had no impact on the stock price or number of shares.

<sup>39</sup>Article 159, Paragraph 1 of the FIEA prohibits "manipulation of fluctuations, etc., for the purpose of misleading others into believing that transactions are actively conducted or for the purpose of causing others to misunderstand the status of such transactions" as an act of market manipulation.

A take order is a limit order or a market order (no-limit order), which is a type of new order that makes an immediate contract with a stock quote listing.

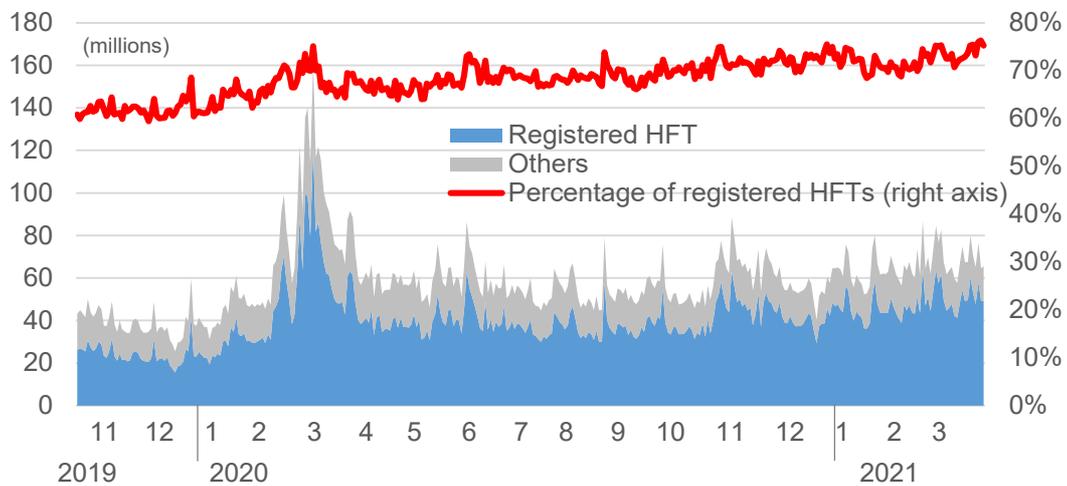
<sup>41</sup>In addition to limit orders, IOC orders can also be used for market orders, which is a form of order that is provided for the convenience of a wide range of investors.



Left: Distribution of registered HFT orders (69%), Right: Distribution of other orders (31%)

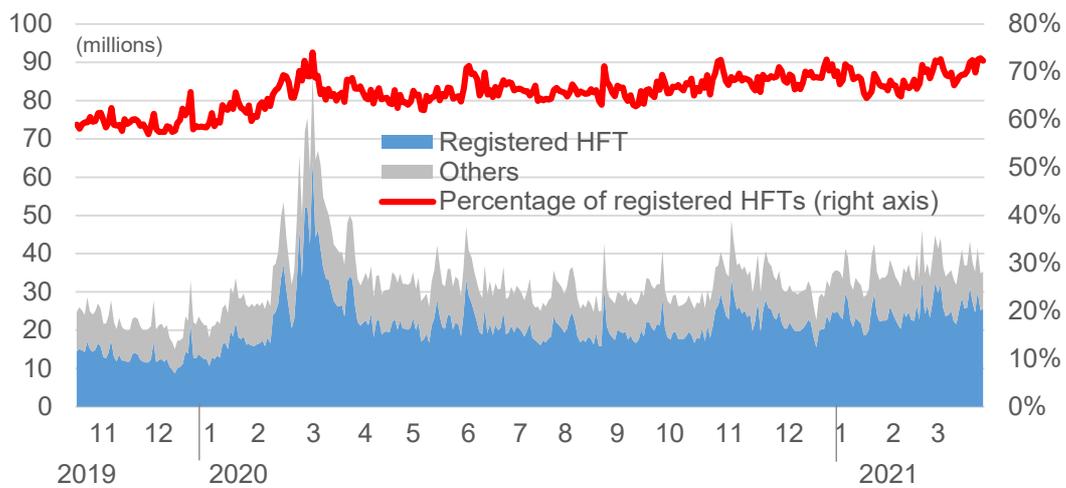
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-8 Distribution of Orders Based on 大山・津田 (2020)



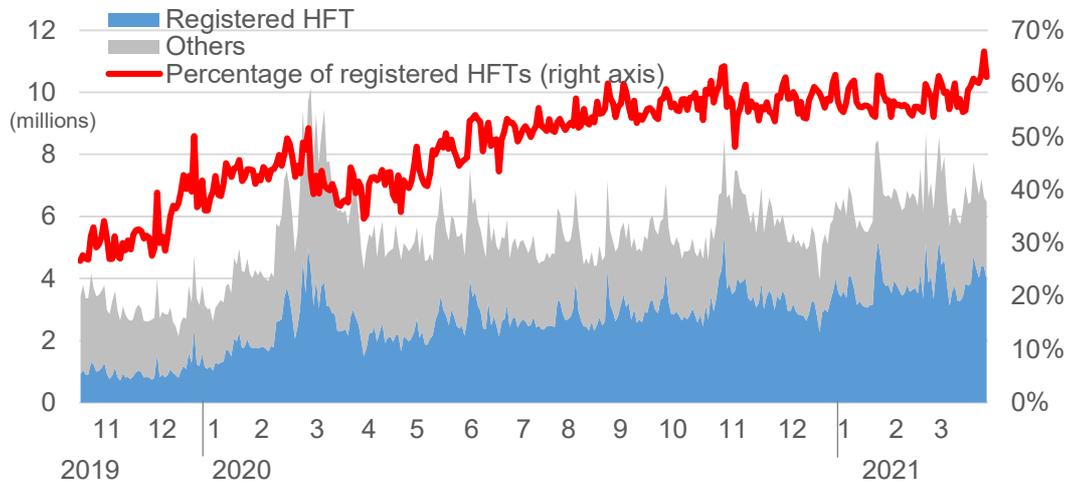
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-9 Registered HFT and Other Orders



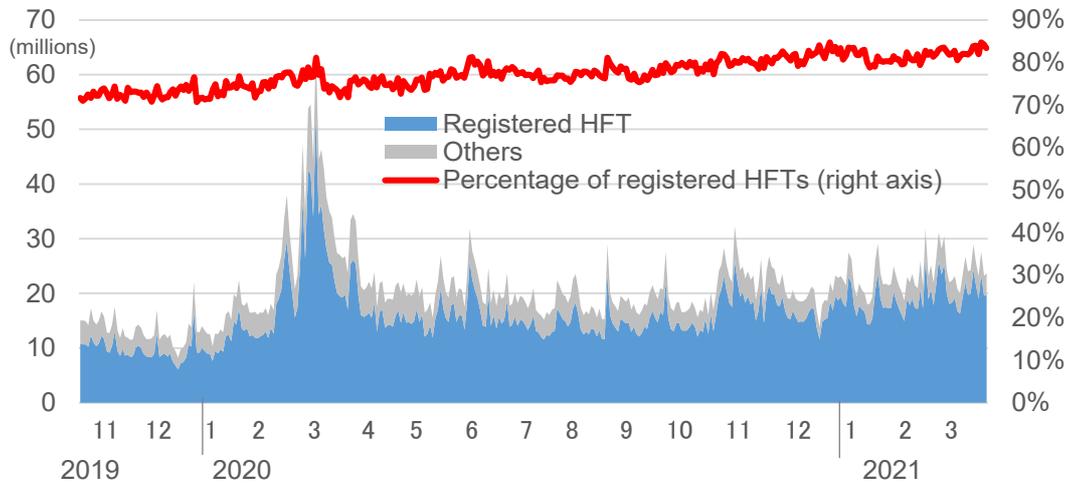
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-10 Registered HFT and other new orders



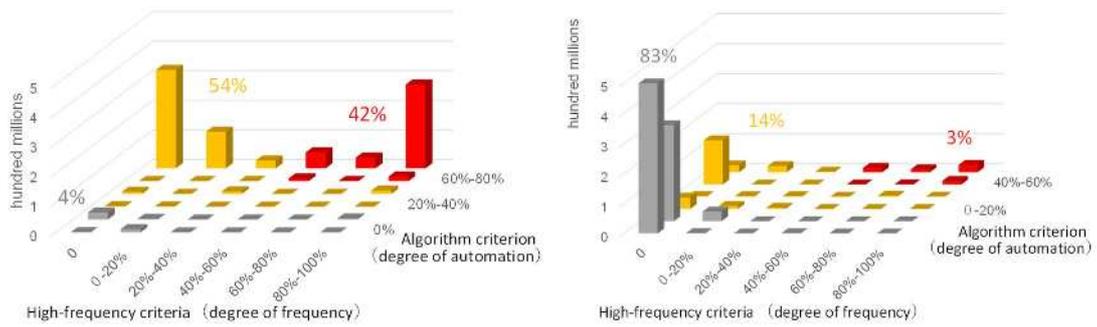
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-11 Registered HFTs and other change-orders



Source: Compiled by the author from Tokyo Stock Exchange data

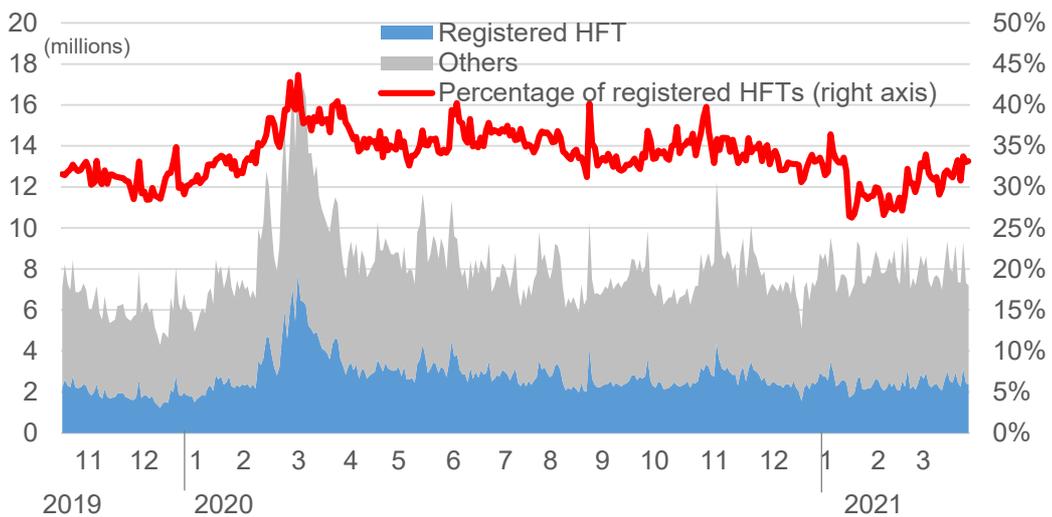
Figure 3-12 Number of Registered HFTs and other cancelled orders (excluding expired orders)



Left: Distribution of the number of contracts (executions) (35%) for registered HFTs, Right: Distribution of the number of contracts (executions) (65%) for other HFTs

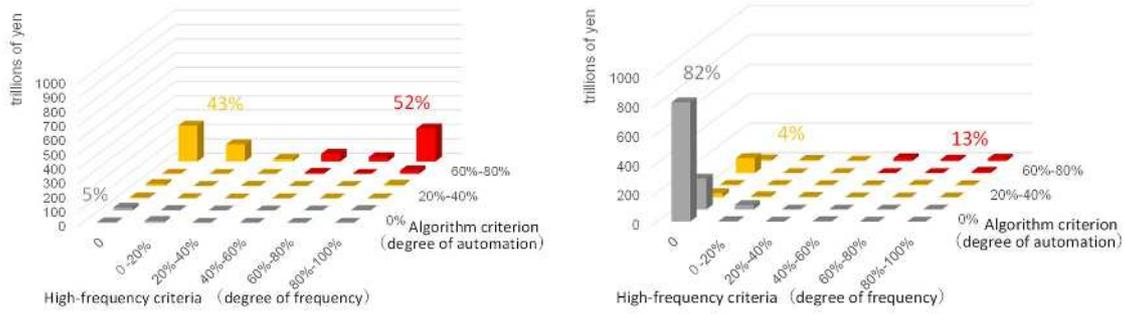
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-13 Distribution of contract numbers based on 大山・津田 (2020)



Source: Compiled by the author from Tokyo Stock Exchange data

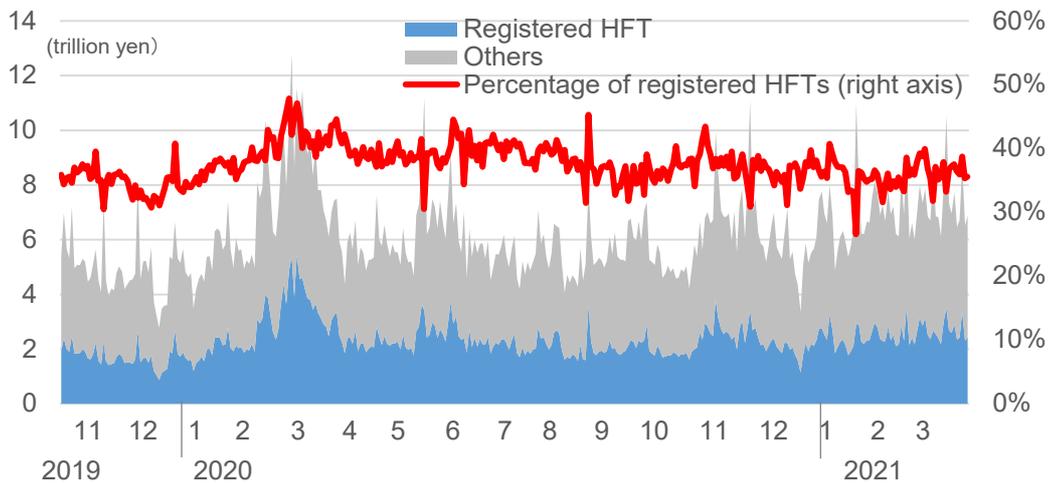
Figure 3-14 Registered HFTs and other contracts (executions)



Left: Distribution of trading value (39%) of registered HFTs, Right: Distribution of trading value (61%) of other HFTs

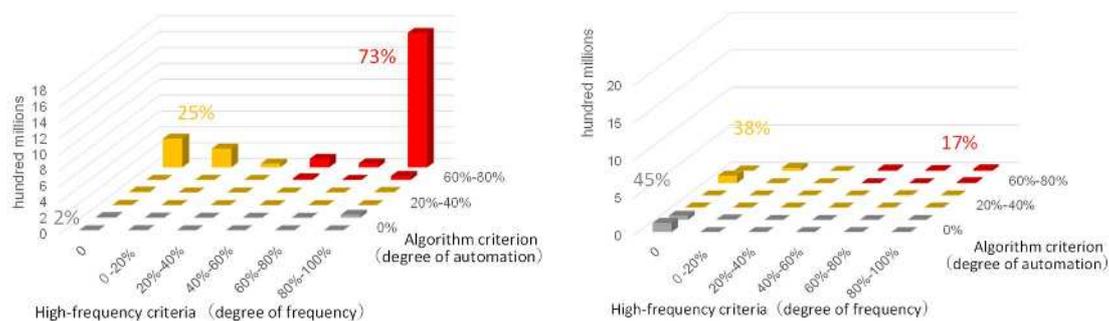
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-15 Distribution of trading value based on 大山・津田 (2020)



Source: Compiled by the author from Tokyo Stock Exchange data

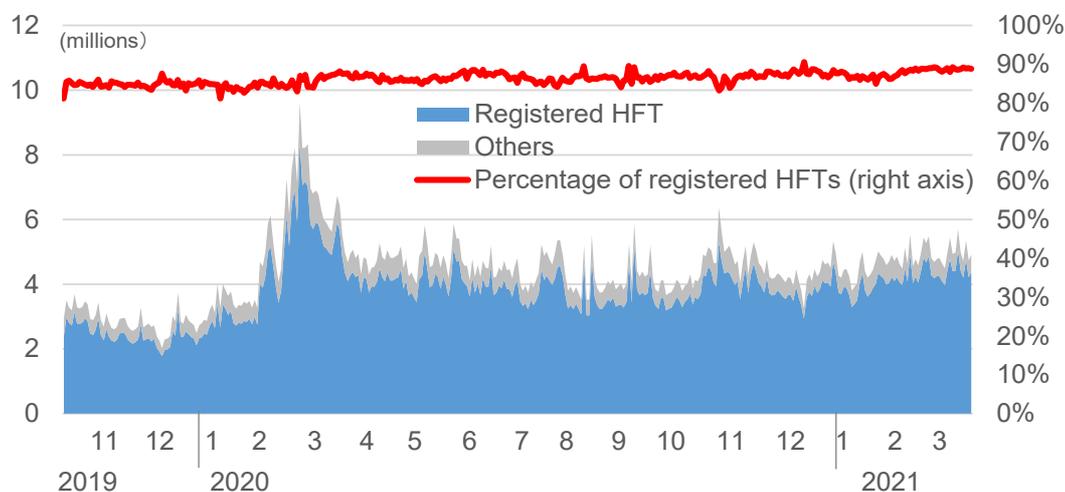
Figure 3-16 Registered HFT and other trading value



Left: Distribution of registered HFT IOC orders (86%), Right: Distribution of other IOC orders (14%)

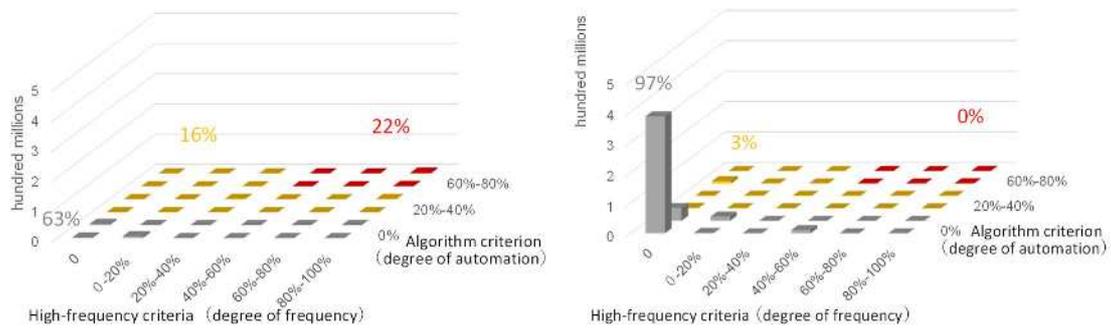
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-17 Distribution of IOC orders based on 大山・津田 (2020)



Source: Compiled by the author from Tokyo Stock Exchange data

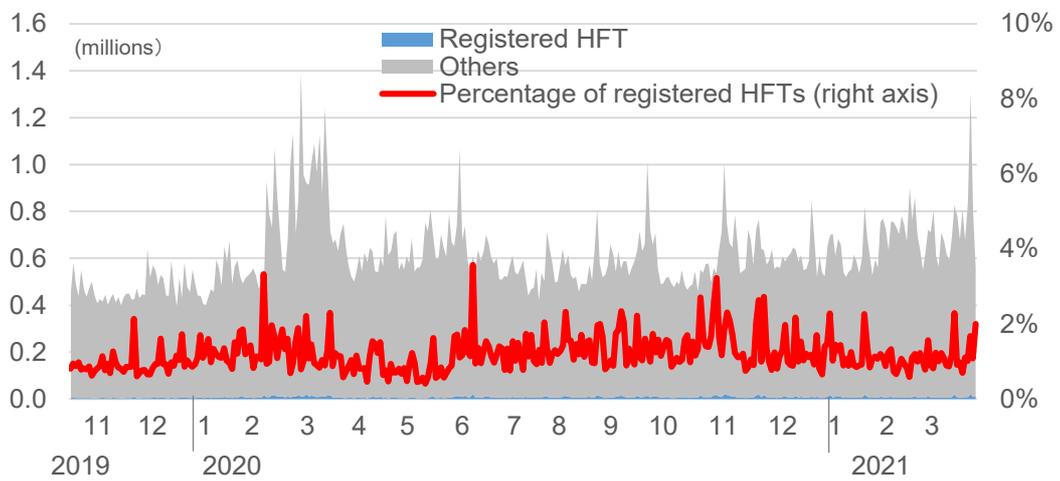
Figure 3-18 Registered HFTs and other IOC orders



Left: Distribution of registered HFT (4%), Right: Distribution of other HFTs (96%)

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-19 Distribution of the number of market orders<sup>42</sup> based on 大山・津田 (2020)



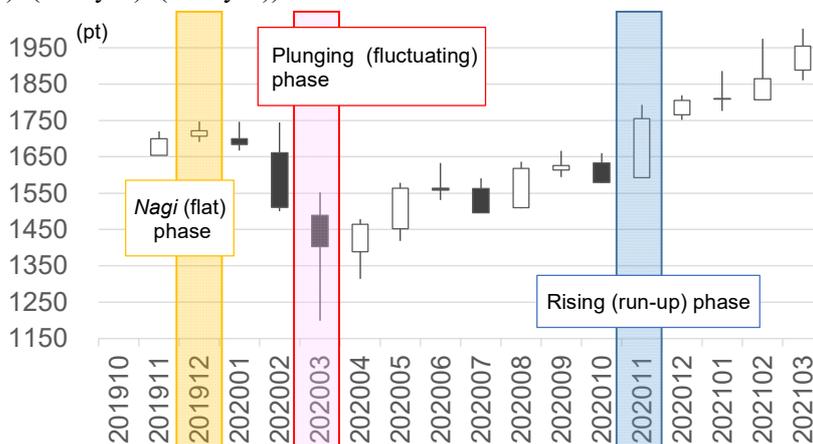
Source: Compiled by the author from Tokyo Stock Exchange data

Figure 3-20 Registered HFT and other market orders

<sup>42</sup> The number of market orders in Figure 3-19 includes not only new/modified/canceled orders but also system processing items, such as executed/expired/canceled new orders, while the number of market orders in Figure 3-20 is the sum of the number of new/modified/canceled orders.

## 4. Registered HFT Trends in Market Phases

In the previous chapter, we reviewed the forms of registered HFTs during the period from November 2019 to March 2021. In this chapter, we discuss the analysis on the trading status of registered HFTs on a daily basis in terms of the number of orders, trading value, and the range of scale up/down (selling/buying) prices, in response to the indications that HFTers restrained trading at floating rates and encouraged market fluctuations, whereby we extracted 850 stocks during the *nagi* (flat), rising (run-up) and plunging (fluctuating) phases on the TSE. Figure 4-1 shows the TOPIX monthly chart. Based on monthly fluctuations,<sup>43</sup> we selected the *nagi* (flat) phase in December 2019, the plunging (fluctuating) phase in March 2020, and the rising (run-up) phase in November 2020. To identify the entities that aggressively increased price volatility,<sup>44</sup> we calculated the "range of scale down (selling prices)" and the "range of scale up (buying prices)" for each phase. The "range of scale down (selling prices)" is the cumulative total<sup>45</sup> of the range of selling prices when each entity lowered its share price by selling, and the "range of scale up (buying prices)" is the cumulative total of the range of buying prices when each entity raised its share price by buying. The contribution rate of scale up/down (selling/buying prices) is the ratio of the range of scale up/down (selling/buying prices) of a particular entity to the total range of scale up/down (selling/buying prices). For example, if the price fluctuation is shown in Figure 4-2 and the share price of a particular entity (subject A) declined twice to pink (plummeting phase) as a result of selling, then the range of scale down (selling prices) of a particular entity (subject A) is (10-9 yen)+(11-8 yen)=4 yen. The contribution rate of scale down (selling prices) of a particular entity is ((10-9 yen)+(11-8 yen))/((10-9 yen)+(11-8 yen)+(10-9 yen))= 80%.



Source: Chart generated by the author from QUICK Data, Inc.

Figure 4-1 TOPIX monthly chart

<sup>43</sup> Monthly volatility of individual stocks at closing prices (TOPIX) calculated as (monthly high minus monthly low) ÷ (monthly high plus monthly low) ÷ 2.

<sup>44</sup> As an indicator of the degree of influence on market fluctuations, the contribution ratio of scale up/down (selling/buying prices), as well as the involvement ratio of trading value and trading volume, are considered to be appropriate.

<sup>45</sup> This is the sum of the decline in stock price due to sell orders, and the target of sell orders here is limited to sell take orders.

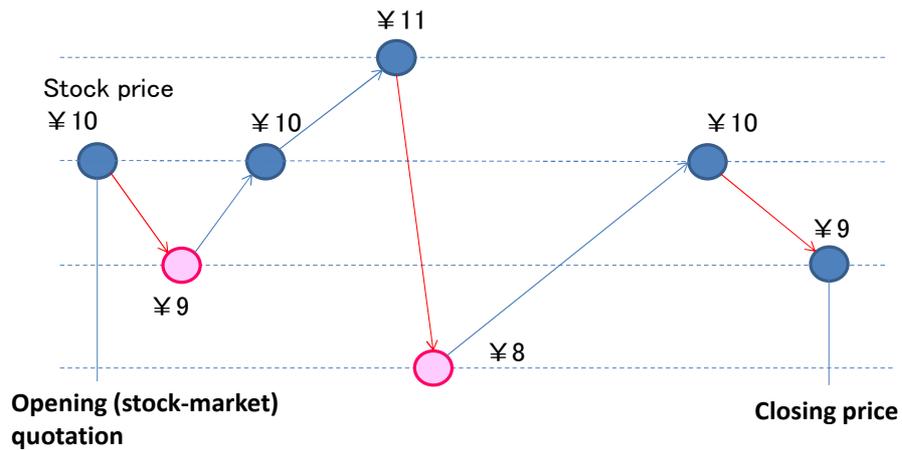
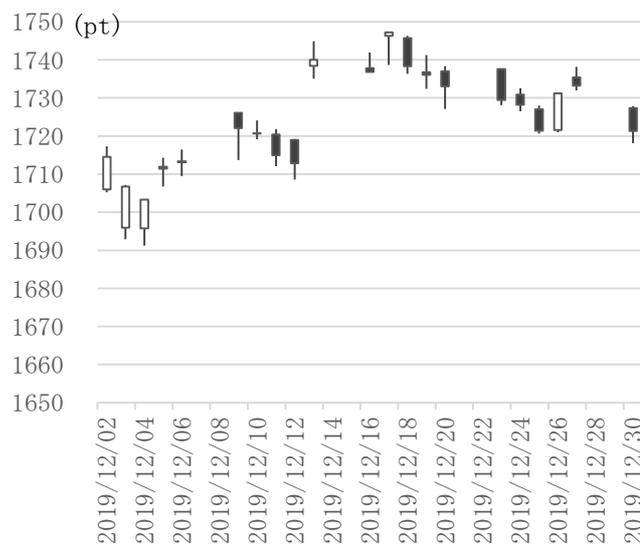


Figure 4-2 Image of contribution rate (Subject A's selling price: pink)

#### 4.1. Registered HFT Trends in the *Nagi* (Flat) Phase

In the *nagi* (flat) phase in December 2019, the TOPIX index rose 1.29% from the end of the previous month, and the monthly volatility was 2.54%, the lowest level in the analysis period. In the first half of the month, the index rose due to the rise in US stocks, mainly backed by the progress made in trade talks between the United States and China. In the second half of the month, however, with the year-end holiday approaching, the index slowed down. As a result, the overall market environment for the month was stable (Figure 4-3).



Source: Charts generated by the author from QUICK Data, Inc.

Figure 4-3 TOPIX Daily chart

The trading value and the number of orders for registered HFTs during the *nagi* (flat) phase accounted for 33% and 60% of the total, respectively. When compared with the total period (trading value ratio: 38%, order number ratio: 67%), it can be seen from Table 4-1 that they were relatively small. Table 4-2 shows the range of selling price during the *nagi* (flat) phase (for 21 business days) and the contribution rate of registered HFTs by size of TOPIX constituents (large stocks, medium stocks, small stocks) and by strategy. Since the contribution rate of registered HFTs (27% - 36%) is not much different from the trading value ratio of registered HFTs (33%) during the *nagi* (flat) phase, it can be seen that trading with registered HFTs is not the kind of trading that can significantly move the entire market. In addition, among the 10 stocks with particularly large fluctuations in each size of TOPIX, the registered HFTs' contribution rate of scale down (selling prices) was about 53% at the most (Table 4-3).

	Ratio of trading value		Ratio of orders		Ratio of cancellation orders	
	Registered HFT	Others	Registered HFT	Others	Registered HFT	Others
<i>Nagi</i> (flat) phase (12/2019)	33%	67%	60%	40%	73%	27%
All phases (11/2019~3/2021)	38%	62%	67%	33%	78%	22%

Source: Compiled by the author from Tokyo Stock Exchange data

Table 4-1 Trading status of registered HFTs in the *nagi* (flat) phase

Scale down of selling prices (yen)													
Price scale (10 thousand yen)									Contribution rate				
Date	Size	Others	Registered HFT				Others	Registered HFT					
			(sum of ① to ④)	①MM Strategy	②AR Strategy	③DR Strategy		④other Strategy	(sum of ① to ④)	①MM Strategy	②AR Strategy	③DR Strategy	④other Strategy
12/2019	Large	-151	-85	-23	-12	-36	-13	64%	36%	10%	5%	15%	6%
	Medium	-228	-85	-31	-10	-36	-8	73%	27%	10%	3%	12%	2%
	Small	-361	-148	-52	-13	-80	-4	71%	29%	10%	3%	16%	1%

Source: Compiled by the author from Tokyo Stock Exchange data

Table 4-2 Registered HFTs' scale down (selling price) ranges for large, medium, and small TOPIX stocks and their contribution rates<sup>46</sup>

Scale down of selling prices (yen)															
Phase	Size	Date	Issues	Others		Registered HFT (sum of ① to ④)		①MM Strategy		②AR Strategy		③DR Strategy		④other Strategy	
				Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate
<i>Nagi</i> (flat)	Large	12/18/2019	LA	-1281	47%	-1445	53%	-561	21%	-107	4%	-723	27%	-54	2%
		12/09/2019	LB	-1102	53%	-980	47%	-219	11%	-58	3%	-637	31%	-66	3%
		12/18/2019	LC	-2262	54%	-1910	46%	-559	13%	-140	3%	-1105	26%	-106	3%
	Medium	12/05/2019	MA	-902	62%	-542	38%	-248	17%	-28	2%	-226	16%	-40	3%
		12/18/2019	MB	-886	68%	-421	32%	-182	14%	-4	0%	-204	16%	-31	2%
		12/03/2019	MC	-247	68%	-115	32%	-35	10%	-18	5%	-62	17%	0	0%
	Small	12/05/2019	SA	-930	80%	-229	20%	-81	7%	-3	0%	-145	13%	0	0%
		12/12/2019	SB	-3428	83%	-722	17%	-369	9%	-2	0%	-350	8%	-1	0%
		12/13/2019	SC	-3064	85%	-523	15%	-305	9%	-18	1%	-195	5%	-5	0%

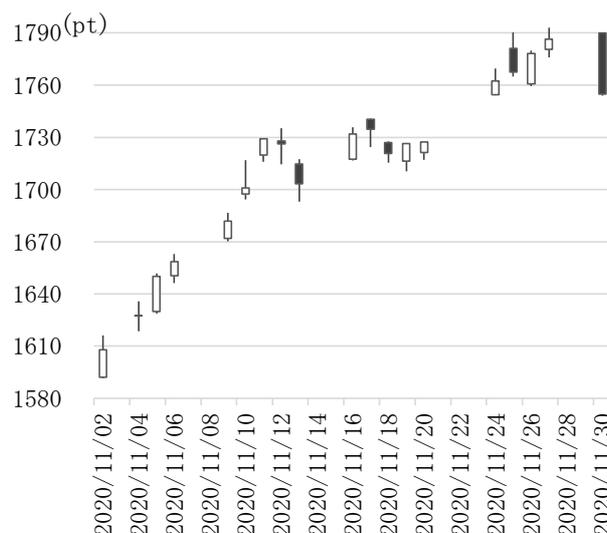
Source: Compiled by the author from Tokyo Stock Exchange data

**Table 4-3** Three stocks with a high contribution ratio of registered HFTs' scale down (selling prices) of large, medium, and small TOPIX stocks

<sup>46</sup> In Tables 4-2 and 4-3, “MM strategy,” “AR strategy,” “DR strategy,” and “other strategy” refer to market making strategy, arbitrage strategy, directional strategy, and other strategy, respectively.

## 4.2. Registered HFT Trends in the Rising Phase

During the market upswings in November 2020, the TOPIX rose by 11.11% from the end of the previous month, the monthly volatility rate was 10.52%, and the monthly gain was 175 points, the largest in the analysis period. The rise in Japan's stock market was believed to be supported by the rise in the US stock market following the US presidential election and reports on the development of a COVID-19 vaccine, as well as by expectations of improved earnings of Japanese companies. As a consequence, the TOPIX rose significantly for the entire month (Figure 4-4).



Source: Charts generated by the author from QUICK Data, Inc.

Figure 4-4 TOPIX Daily chart

Registered HFTs accounted for 37% of trading value and 70% of orders during the rising (run-up) phase, which is similar to the overall period (38% of trading value and 67% of orders), as shown in Table 4-4. Table 4-5 shows TOPIX constituents by size (large, medium, medium-cap stocks, and small-cap stocks) and by strategy. The range of buying price during the rising (run-up) phase (for the 19 trading days) and their contribution rates are calculated separately for registered HFTs and others. Since the 40% to 45% contribution of registered HFTs' scale up (buying prices) is not much different from the 37% of trading value accounted for by registered HFTs during the rising (run-up) phase, it is clear that trading by registered HFTs is not the kind of trading that can significantly affect the overall market. In addition, looking at the stocks with the highest contribution rate of scale-up (buying prices) among the 10 stocks with particularly large fluctuations in TOPIX (Table 4-6), the contribution rates of trading by registered HFTs were about 55% at the most.

	Ratio of trading value		Ratio of orders		Ratio of cancellation orders	
	Registered HFT	Others	Registered HFT	Others	Registered HFT	Others
Rising phase (11/2020)	37%	63%	70%	30%	80%	20%
All phases (11/2019~3/2021)	38%	62%	67%	33%	78%	22%

Source: Compiled by the author from Tokyo Stock Exchange data

**Table 4-4** Trading status of registered HFTs in rising (run-up) phase

		Scale up of buying prices (yen)													
		Price scale (10 thousand yen)							Contribution rate						
Date	Size	Others	Registered HFT					Others	Registered HFT						
			(sum of ① to ④)	①MM Strategy	②AR Strategy	③DR Strategy	④other Strategy		(sum of ① to ④)	①MM Strategy	②AR Strategy	③DR Strategy	④other Strategy		
11/2020	Large	277	226	33	33	62	98	55%	45%	7%	7%	12%	20%		
	Medium	327	222	29	19	77	97	60%	40%	5%	3%	14%	18%		
	Small	488	357	19	25	208	105	58%	42%	2%	3%	25%	12%		

Source: Compiled by the author from Tokyo Stock Exchange data

**Table 4-5**

Registered HFTs' scale-up (buying prices) ranges for large, medium, and small TOPIX stocks and their contribution rates

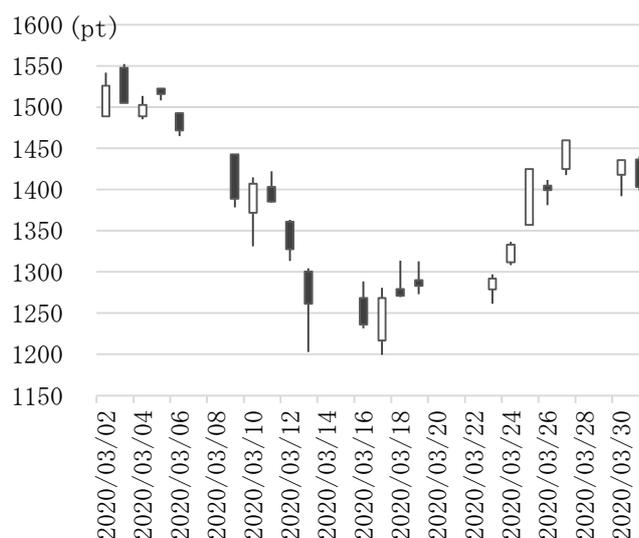
		Scale up of buying prices (yen)													
		Others		Registered HFT (sum of ① to ④)											
Phase	Size	Date	Issues	Price scale	Contribution rate	Registered HFT (sum of ① to ④)		①MM Strategy		②AR Strategy		③DR Strategy		④other Strategy	
						Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate
Rising	Large	11/09/2020	LA	2224	45%	2727	55%	549	11%	655	13%	581	12%	942	19%
		11/02/2020	LB	6133	58%	4485	42%	364	3%	290	3%	1856	17%	1975	19%
		11/06/2020	LC	1347	63%	780.5	37%	74	3%	57.5	3%	252	12%	397	19%
	Medium	11/10/2020	MA	1338	49%	1374	51%	227	8%	82	3%	528	19%	537	20%
		11/10/2020	MB	3254	68%	1522	32%	149	3%	61	1%	368	8%	944	20%
		11/11/2020	MC	1231	61%	790	39%	64	3%	26	1%	399	20%	301	15%
	Small	11/11/2020	SA	5718	79%	1537	21%	106	1%	72	1%	818	11%	541	7%
		11/27/2020	SB	3065	86%	481	14%	4	0%	7	0%	132	4%	338	10%
		11/09/2020	SC	222	92%	20	8%	7	3%	1	0%	12	5%	0	0%

Source: Compiled by the author from Tokyo Stock Exchange data

**Table 4-6** Three stocks with high contribution of registered HFTs to purchases of large, medium, and small TOPIX stocks

### 4.3. Trends in Registered HFTs during the Sharp Decline (Fluctuation) Phase

In March 2020, the TOPIX declined by 7.13% from the end of the previous month, and the monthly volatility was 20.96%, the largest in the analysis period. The spread of COVID-19 caused a plunge in global stock prices. However, it is believed that stock prices recovered in the second half of the month due to monetary easing and economic stimulus measures taken by each country. Meanwhile, the TOPIX fell by 5.61% from the previous day on March 9 and rose by 6.87% from the previous day on March 25, indicating a rapidly changing market environment for the entire month (Figure 4-5).



Source: Charts generated by the author from QUICK Data, Inc.

Figure 4-5 TOPIX daily chart

	Ratio of trading value		Ratio of orders		Ratio of cancellation orders	
	Registered HFT	Others	Registered HFT	Others	Registered HFT	Others
Plunging phase (3/2020)	43%	57%	67%	32%	77%	23%
All phases (11/2019~3/2021)	38%	62%	67%	33%	78%	22%

Source: Compiled by the author from Tokyo Stock Exchange data

Table 4-7 Trading status of registered HFTs in plummeting and fluctuating phases

		Scale down of selling prices (yen)													
		Price scale (10 thous yen)								Contribution rate					
Date	Size	Others	Registered HFT						Others	Registered HFT					
			(sum of ① to ④)	①MM Strategy	②AR Strategy	③DR Strategy	④other Strategy	(sum of ① to ④)		①MM Strategy	②AR Strategy	③DR Strategy	④other Strategy		
3/2020	Large	-597	-606	-216	-109	-189	-91	50%	50%	18%	9%	16%	8%		
	Medium	-599	-600	-198	-64	-294	-44	50%	50%	17%	5%	25%	4%		
	Small	-785	-634	-176	-65	-380	-12	55%	45%	12%	5%	27%	1%		

Source: Compiled by the author from Tokyo Stock Exchange data

Table 4-8 Registered HFTs' scale-down (selling prices) ranges for large, medium, and small TOPIX stocks and their contribution rates

Scale down of selling prices (yen)															
				Registered HFT (sum of ① to ④)											
Others				① MM Strategy		② AR Strategy		③ DR Strategy		④ other Strategy					
Phase	Size	Date	Issues	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate	Price scale	Contribution rate
Plunging	Large	03/13/2020	LA	-4103	39%	-6497	61%	-2767	26%	-992	9%	-2221	21%	-517	5%
		03/19/2020	LB	-1369.5	40%	-2050	60%	-824.5	24%	-277	8%	-736.5	22%	-212	6%
		03/13/2020	LC	-3967.5	42%	-5492	58%	-2540.5	27%	-1020	11%	-1466.5	16%	-465	5%
	Medium	03/19/2020	MA	-162	12%	-1164	88%	-287	22%	-242	18%	-162	12%	-473	36%
		03/23/2020	MB	-1449	39%	-2291	61%	-1166	31%	-326	9%	-436	12%	-363	10%
		03/19/2020	MC	-2114	49%	-2192	51%	-1107	26%	-86	2%	-912	21%	-87	2%
	Small	03/19/2020	SA	-377	43%	-507	57%	-167	19%	-2	0%	-338	38%	0	0%
		03/19/2020	SB	-976	51%	-946	49%	-66	3%	-4	0%	-876	46%	0	0%
		03/19/2020	SC	-1568	56%	-1209	44%	-534	19%	-4	0%	-671	24%	0	0%

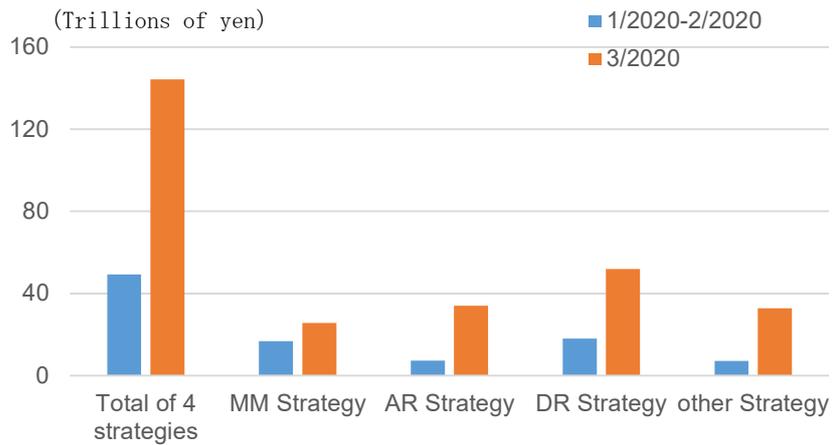
Source: Compiled by the author from Tokyo Stock Exchange data

**Table 4-9** Three stocks with a high contribution ratio of registered HFTs' scale down (selling prices) to large, medium, and small TOPIX stocks

Registered HFTs accounted for 43% of total trading value and 67% of total orders during the sharp decline (fluctuation) phase. Compared with the entire period (38% of total trading value and 67% of total orders) including both the upside (run-up) and downside (run-down) phases, Table 4-7 shows that the ratio was relatively large. On the other hand, the 45% - 50% contribution rate of registered HFTs' scale down (selling prices) was not much different from the 43% contribution rate of the trading value of registered HFTs during the sharp decline (fluctuation) phase. Therefore, it is difficult to say that trading by registered HFTs would have a large impact on the overall market. However, in regard to the trading value of registered HFTs by strategy, it is apparent that there was a notable increase in trading of arbitrage and directional strategies during the plunging (fluctuation) phase compared to the previous month (Figure 4-6). The increase in arbitrage strategy trading is considered to be due to an increase in opportunities for the price difference between cash equities and futures to diverge in volatile markets, while it cannot be denied that trading based on directional strategies may have contributed to market fluctuations.<sup>47</sup> In addition, among the 10 stocks with particularly large fluctuations in each size of TOPIX, the contribution rate of registered HFTs' scale-down (selling prices) (Table 4-9) for the stocks with the highest contribution rate of scale-down (selling prices) (medium-sized stock MA, March 19, 2020) reached 88% at the maximum. In light of these points, directional strategies and stocks with high scale-down (selling prices) contribution rates should continue to be analyzed and examined from multiple perspectives. Figure 4-7 shows that the new order coverage rate and the contract (execution) coverage rate<sup>48</sup> of registered HFTs during the plummeting (fluctuation) phase remained unchanged, at about 99% and about 95%, respectively, indicating that registered HFTers did not change the stocks they traded and placed orders for a wide range of stocks during the plummeting decline (fluctuation) phase.

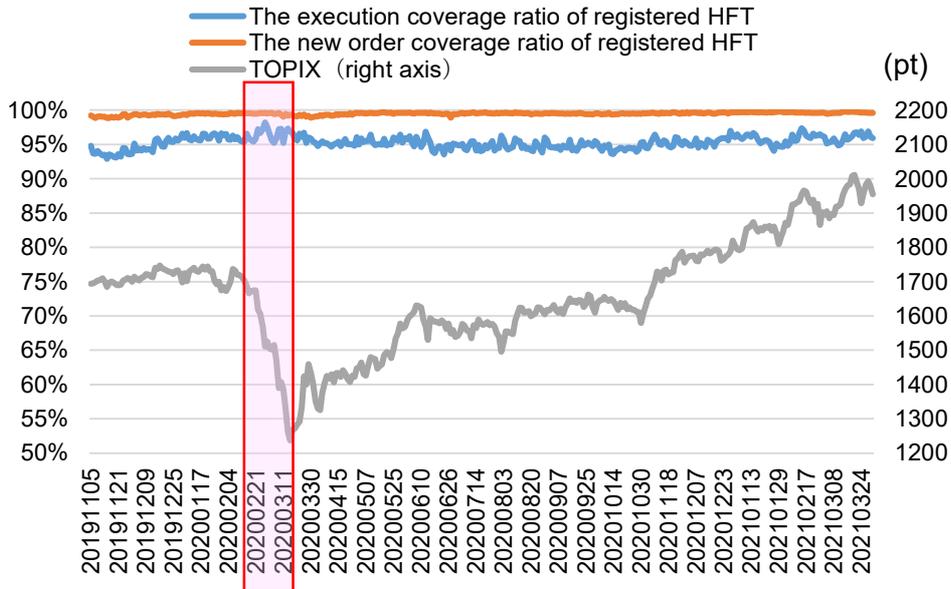
<sup>47</sup> Other possible reasons include an increase in the central regression factor of the moment.

<sup>48</sup> The new order coverage ratio is calculated as the percentage of issues among cash equities that were ordered to be sold or bought by registered HFTers at least once during the day (the number of issues with orders ÷ the number of issues for cash equities). The contract (execution) coverage ratio is calculated as the ratio of the number of issues for which there was an execution for selling or buying by registered HFTers at least once during the day (the number of issues for which there was an execution ÷ the number of issues for cash equities).



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-6: Registered HFT trading value by strategies



Source: Compiled by the author from Tokyo Stock Exchange data

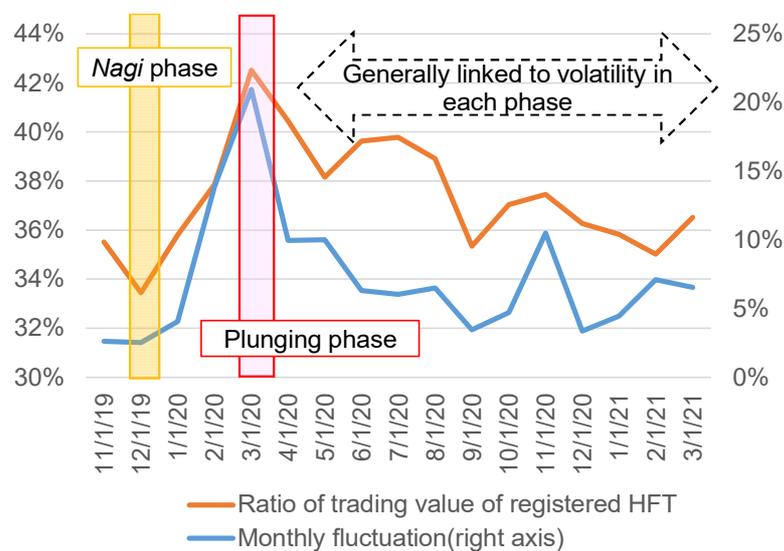
Figure 4-7: Coverage ratio of registered HFTs (new order and execution) and TOPIX

#### 4.4. Registered HFTs linked to market fluctuations

In this section, we examine whether registered HFTs provided liquidity during market fluctuations without holding back trading, through additional analysis of correlations between the daily order ratio and market fluctuations, as well as stock quote listings replication.

Through the analysis of 4.1 and 4.3 above, it was found that the trading value of registered HFTs tended to decrease slightly during the *nagi* (flat) phase (cf. Section 4.1), while it tended to increase slightly during

the plummeting (fluctuation) phase<sup>49</sup> (cf. Section 4.3). Looking at periods other than these two phases, as shown in Figure 4-8, it can be seen that the ratio of the trading value of registered HFTs per month (vs total) and the fluctuation rate (monthly fluctuation rate) were trending in tandem, with a high correlation (0.73). In addition, the ratio of the number of daily orders of registered HFTs between November 1, 2019, and March 31, 2021 (vs total) was positively correlated with the expected fluctuation rate of the market (the Nikkei Average Volatility Index:<sup>50</sup> hereinafter referred to as the "Nikkei Average VI"). The correlation coefficient for the sample of 300 business days excluding March-April 2020 was 0.51 (blue dot in Figure 4-9, t-value of 10.5, P-value of 0.001% or less). As the ratio of the number of orders of registered HFTs increased with the rise in the Nikkei Average VI, it seemed that registered HFTs provided liquidity to the stock market. On the other hand, the correlation coefficient for the period between March and April 2020, when the Nikkei Average VI rose extremely high, conversely decreased to 0.34 (orange dots in Figure 4-9).

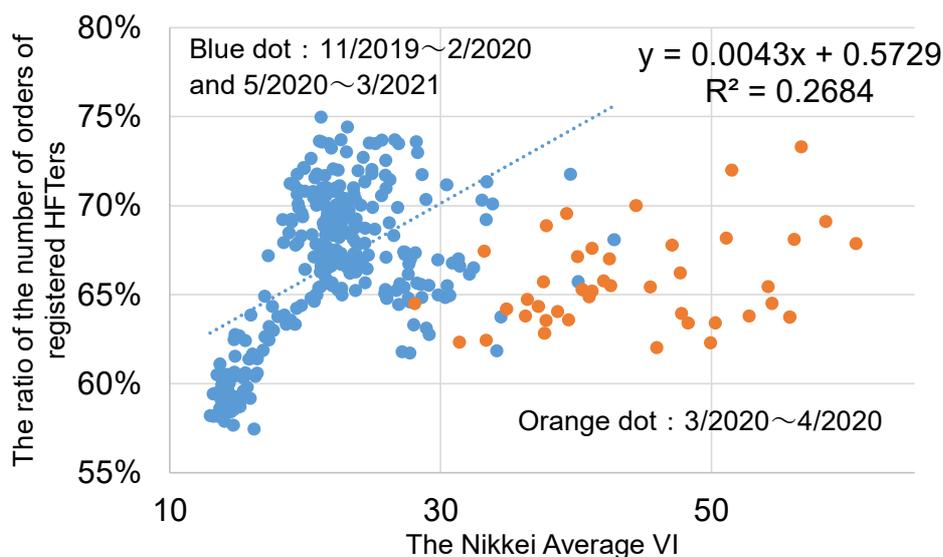


Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-8 Registered HFT trading value ratio and monthly fluctuation rate

<sup>49</sup> In section 4.3, the market includes elements of both sudden declines and sudden fluctuations, and it has been pointed out that, in general, there is a time-series correlation in stock price fluctuations, and there is a tendency for a fluctuating market to continue for some time after a sudden, large decline (高岡・大山 (2011)).

<sup>50</sup> The Nikkei Average VI is a measure of investors' expectations of the future volatility of the Nikkei Stock Average, calculated based on the prices of Nikkei 225 futures and Nikkei 225 options listed on the OSE.



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-9 Correlation between the ratio of the number of daily orders of registered HFTs and Nikkei Average VI

In order to further examine the liquidity provided by registered HFTs, we conducted an additional analysis (Figure 4-10, Figure 4-11, and Figure 4-12) of whether registered HFTs directly contributed to the narrowing of BBO spreads during the market phase between January and March 2020, when the rate of market fluctuations increased (including March 2020). The analysis methods are as follows.

First, statistics (average (mean), standard deviation, and 90/99% tile point) on the daily BBO spread are calculated for six stocks with high intraday volatility in March (two stocks each are selected for large-cap, medium-cap, and small-cap). For example, in Figure 4-10, the "LA" stock, the number of daily stock quote listing updates<sup>51</sup> during the normal period (January-February 2020) was about 100,000, while the number of daily stock quote listing updates in March was about 200,000. By replicating the stock quote listings during the entire analysis period, we can calculate the BBO spread for each number of stock quote listing updates during the target period. Therefore, the daily transition of the statistics (average (mean), standard deviation, and 90/99% tile point) is shown on the left side of each figure. Next, we remove only the stock quote listings information updated by the registered HFT from the stock quote listings, and again, we show the daily transition of the BBO spread statistics on the right side of each figure. From the analysis so far in Chapter 4, we can infer that the registered HFT provides a certain amount of liquidity to the market in the big picture (given their large share of trading value) regardless of the market environment, but we could not deny the possibility that registered HFTs were temporarily weighted toward "take-orders (market orders/orders without limit)" during market volatility, thereby reducing liquidity. However, when the stock quote listings information updated by the registered HFT disappears from the stock quote listings, the BBO-

<sup>51</sup> Each time an order is placed, the number of stock quote listings updates is counted up by one along the time line, and the same number of stock quote listing updates is set for changes in the order book (stock quote listings) that occur at the same time (such as multiple price volume changes due to execution).

spread is uniformly widened. This suggests that registered HFTs continue to provide liquidity (make orders<sup>52</sup>) to the stock quote listings in the vicinity of the BBO, and that registered HFTs contribute to liquidity in terms of spreads.<sup>53</sup> In particular, the contribution of registered HFTs in terms of spread during the plummeting (fluctuation) phase in March (pink frame) was higher for large-cap stocks and weaker for mid-cap and small-cap stocks. This is due to the fact that mid-cap and small-cap stocks are generally less liquid than large-cap stocks. While HFT does not carry positions or market risk until the next day, it may be difficult for HFT to continue to provide liquidity to stocks that are difficult to unwind (close out) positions once they are taken/held. The reasons why registered HFTers continue to trade even when the market plummets may be partly due to the fact that the sources of profits for HFTers, etc. are (1) the widening of BBO spreads, and (2) the number of stock quote listing updates, etc.

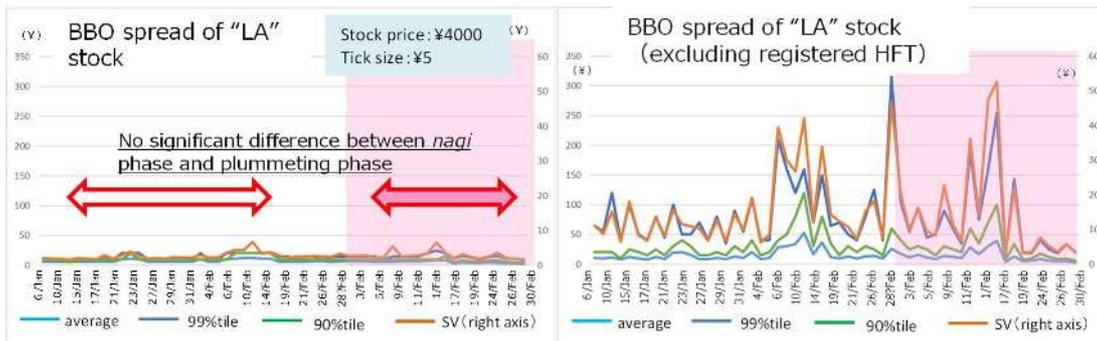
If the BBO-spread referred to in (1) deviates, the market making strategy, which is the main strategy of HFTers, could increase the profit for the BBO spread. Also, the more the number of stock quote listing updates referred to in (2) increases, the more profit opportunities thereof will increase. Thus, a widening of the BBO spread linked to market fluctuations is considered to generate profits to HFTers. Conversely, the widening of BBO spreads by encouraging healthy competition among HFTers may lead to a reduction in BBO spreads and a reduction in stock price fluctuations. However, this section focuses on the supply of liquidity at the spread level, and the discussion in this paragraph only suggests one hypothesis. It does not consider whether a sound competitive environment is put in place among HFTers, i.e., whether there is an adverse selection effect due to information asymmetry (such as Glosten and Milgrom (1985)), or whether there is a contribution to the exchanges' stock quote listings thickness.<sup>54</sup> In the future, it will be necessary to consider a wider range of factors, including these factors.

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<sup>52</sup> A make order is a type of new limit order that does not execute immediately against stock quote listings.

<sup>53</sup> This analysis does not calculate the BBO spread when there are virtually no registered HFTs, but is merely a simple analysis that removes only the orders of registered HFTs. Therefore, it cannot be denied that the opposite result, i.e., a reduction in the BBO spread, may be obtained by eliminating information asymmetry, etc., if a market environment without HFTs is reproduced after constructing an appropriate theoretical model. Theoretical models include Kyle (1985) and Hayashi and Nishide (2019).

<sup>54</sup> Please refer to 大山・津田 (2020) for more information on the characteristic involvement of HFTs in spreads and depths. Additional analysis using information from registered HFTs was conducted for large-, mid-, and small-cap stocks, but no different conclusions from 大山・津田 (2020) were obtained. Although registered HFTs place orders near the BBO, their contribution to the thickness of the board is not high.

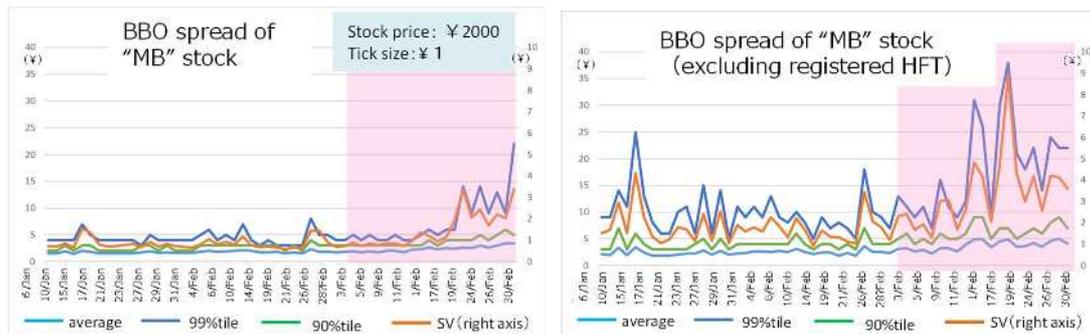
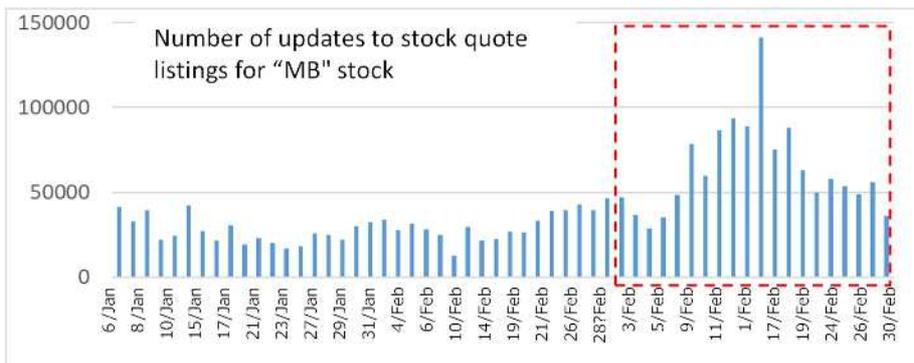
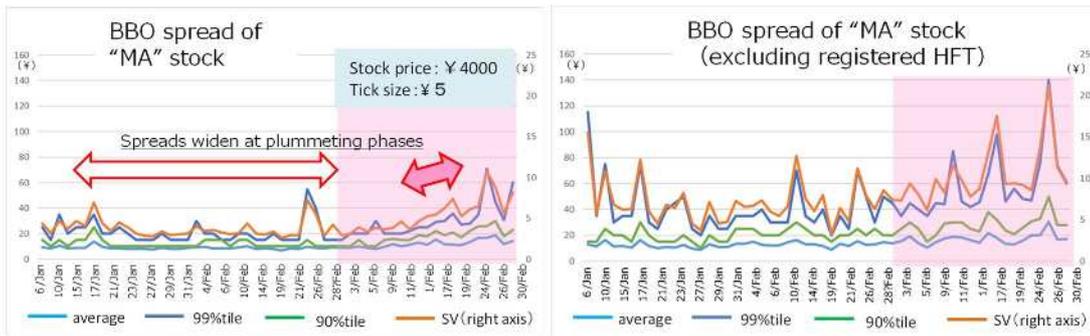


Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-10 Two large shares

Daily BBO spread statistics (mean, standard deviation, 90/99% tile points)

Left: All trading, Right: Trading excluding registered HFTs

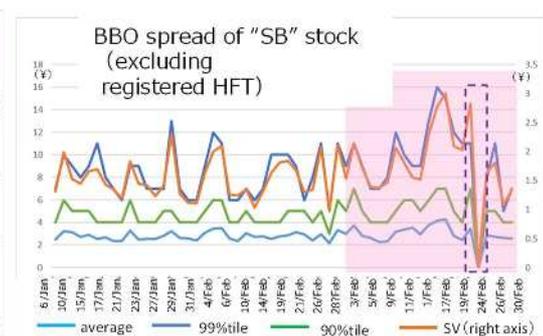
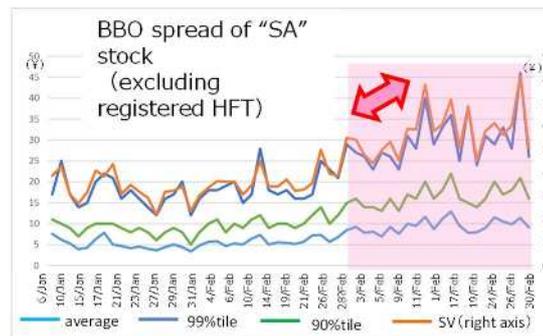
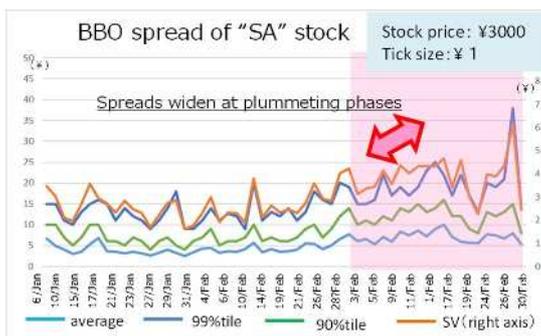
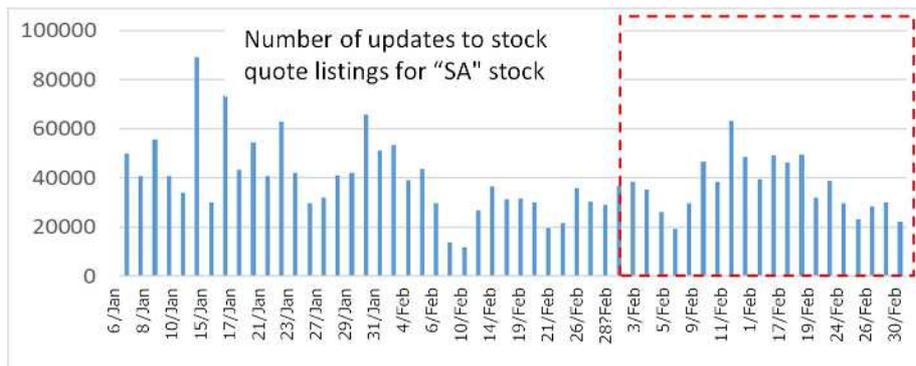


Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-11 Two medium-sized stocks

Daily BBO spread statistics (mean, standard deviation, 90/99% tile points)

Left: All trading, Right: Trading excluding registered HFTs



Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-12 Two small-cap stocks

Daily BBO spread statistics (mean, standard deviation, 90/99% tile points)

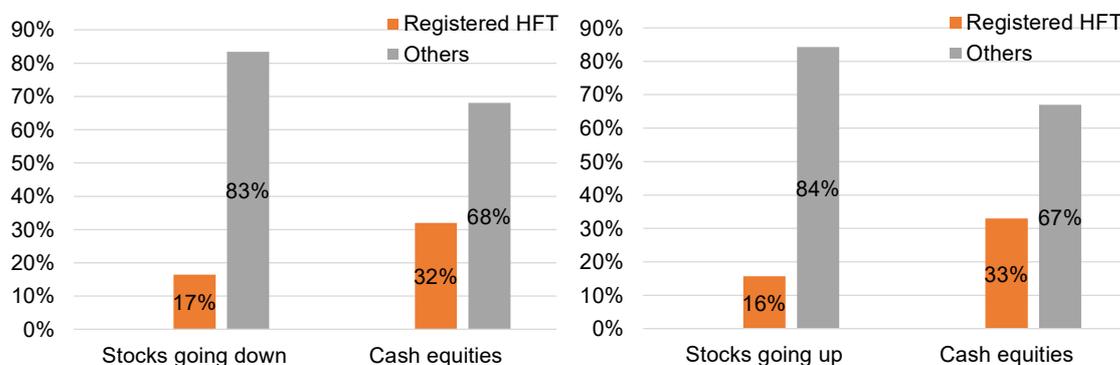
Left: All trading, Right: Trading excluding registered HFTs



#### 4.5. Analysis on the contribution ratio of Scale-down/scale-up to surging or plunging in stocks prices

Since the positive correlation between the ratio of the number of registered HFT orders (vs. total) and the market volatility (Nikkei Average VI) in Section 4.1 does not refer to a causal relationship, we analyze whether registered HFT expanded during market volatility, and whether the expansion of registered HFT amplified market volatility. Therefore, we analyzed whether there are active trading activities by registered HFTers in terms of scale-down/up stocks that have plummeted or surged, by calculating the contribution ratio of registered HFT's scale-down/scale-up by extracting 850 stocks with a high daily rate of increase and stocks with a high daily rate of decrease from TOPIX constituents throughout the analysis period.

Specific stock selection criteria are as follows: Daily sampling of all TOPIX constituents with intraday price fluctuations (individual stock fluctuations<sup>55</sup>) of 10% or higher for the analysis period from November 2019 to March 2021, where the stocks are divided into two groups: (a) stocks that fell from the previous day and (b) stocks that rose from the previous day. The number of stocks of (a) and (b) varied depending on the market, and the number of stocks of (a) having 53 in the *nagi* (flat) phase in December 2019 was the smallest, when compiled for each month. Therefore, in order to keep the number of stocks constant for each month, the number of stocks of (a) and (b) each month was limited to 50, and random sampling was performed every month. For example, in the case of (a) in December 2019, the random sampling would select 50 stocks out of 53. Therefore, in the analysis period of 17 months from November 2019 to March 2021, the total number of stocks of (a) and (b) is 850 (50 stocks for 17 months).



Left: Contribution ratio of scale-down (selling down), Right: Contribution ratio of scale-up (buying up)

Source: Compiled by the author from Tokyo Stock Exchange data

Figure 4-13 Registered HFTs and other contribution rates for declining and rising stocks (850 stocks each) and cash equities (about 1,370,000 stocks)

Figure 4-13 shows that the 32% to 33% contribution rate of registered HFTs to scale-down/up sales of

<sup>55</sup> The intra-day volatility of individual stocks calculated as  $(\text{intraday high} - \text{intraday low}) / (\text{intraday high} + \text{intraday low}) / 2$ .

all stocks for spot trading (about 1,370,000 stocks of about 4,000 stocks by 343 business days) is smaller than the 67%-68% contribution rate of other investors. In particular, the 16% to 17% contribution rate of selling or buying by registered HFTs to the rising and falling stocks of TOPIX is significant. The contribution rate of selling or buying by registered HFTs to the rising and falling stocks of TOPIX is about 25%,<sup>56</sup> which is larger than the 16% to 17% contribution rate of selling or buying by registered HFTs to the rising and falling stocks of TOPIX. This result suggests that the registered HFTs are not necessarily directly linked to the amplification of market fluctuations,<sup>57</sup> but rather that registered HFTs play a role in countering (absorbing) the market fluctuation orders of other investors.

## 5. Summary and Future Issues

This paper gives an overview of the status of registered HFTs, the analysis of the actual trading situation, and the status of trading in each phase of the market. Registered HFTs account for a high percentage of all orders (about 70%) and trading value (about 40%). It is not an exaggeration to say that registered HFTers are the core investors in the current trading market. On the other hand, the analysis of the status of trading in registered HFTs in each phase of the market showed no particular difference, suggesting that even during the fluctuation phase (especially during the sharp decline (fluctuation) phase in response to the spread of the new coronavirus disease in March 2020), they are supplying liquidity in terms of the spread (narrowing of the BBO spread).

However, the analysis<sup>58</sup> in this paper only concerns the movement of registered HFTs as a whole, and the movement of registered HFTers is not necessarily the same. On the other hand, although there are two examples of recommendations for administrative disciplinary actions<sup>59</sup> against market manipulation cases that work on algorithms and recommendations<sup>60</sup> for administrative disciplinary actions against market manipulation cases that use algorithms, there are no examples of recommendations for

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<sup>56</sup> In addition to sampling by the "individual stock fluctuations" in this section, we will also need to try various sampling methods to capture market fluctuations.

<sup>57</sup> The conclusion of this section suggests that the contribution of registered HFT to scale down/up (selling/buying) for stocks with large price volatility is relatively small, or stocks with relatively small contribution of registered HFT to scale down/up (selling/buying) have large price volatility. The former is assumed, but even if the latter is the case, it is assumed that the results do not confirm the causal relationship mentioned at the beginning of this section that "the expansion of trading by registered HFTs has amplified market fluctuations."

<sup>58</sup> There are various statistical and quantitative analyses, such as an analysis of the impact of the huge number of registered HFT orders on prices, etc. These are future issues.

<sup>59</sup> Examples of cases in which algorithmic orders have been triggered include: (i) individual investors in Case 18 of the Administrative Monetary Penalties under the Financial Instruments and Exchange Act (June 2011); and (ii) Type I Financial Instruments Business Operators in Case 22 of the Administrative Monetary Penalties under the Financial Instruments and Exchange Act (August 2017). The publicly disclosed cases of inducing algorithmic orders are (i) by individual investors in Case 18 of the Administrative Monetary Penalties under the Financial Instruments and Exchange Act (June 2011), and (ii) by Type I Financial Instruments Business Operators in Case 22 of the Administrative Monetary Penalties under the Financial Instruments and Exchange Act - Unfair Trade Edition (August 2017).

<sup>60</sup> The publicly disclosed cases of the use of algorithms include: (i) corporate officers (individuals domiciled in foreign countries) in Case 16 of the Administrative Monetary Penalties - Unfair Trade Practices - under the Financial Instruments and Exchange Act, (August 2015); and (ii) limited companies established under the Hong Kong Act in Case 17 of the Administrative Monetary Penalties - Unfair Trade Practices - under the Financial Instruments and Exchange Act.

administrative disciplinary actions against HFTers. However, if HFTers are misusing their high frequency and high speed to manipulate the market, it may be possible to figure out through tracing past trading records, such as the extent to which each order in a large number of orders has affected the price, whether it is the execution of an algorithm designed to manipulate the market, and whether it is a malfunction. In addition, if concerns arise that ordinary investors may move away from the Japanese market due to the existence of HFTs, it may be necessary to analyze the unfairness among investors and measures to remedy such a sense of unfairness (such as speed bump).<sup>61</sup> For example, Glosten and Milgrom (1985) pointed out that the BBO spread is the result of adverse-selection caused by information asymmetry, and Biais et al. (2015) pointed out that increasing the speed of HFTs leads to higher information asymmetry and adverse-selection costs, leading to a widening of the BBO spread. These studies suggest that HFTs may reduce market liquidity, but further consideration is needed, including the concept of "quality of information" and "speed of information" (Huang and Yueshen (2018)).<sup>62</sup>

In this report, we examined whether registered HFTs encourage market fluctuations on the TSE (by limiting the subjects to stocks for spot trading). However, there is a possibility that the trading behavior of futures (stock price index), which are highly liquid and have a high correlation with spot trading, may have influenced market fluctuations (futures leading theory). Therefore, it is necessary to consider the trend of registered HFTs in combination with futures. In addition, it is natural to think that there are HFTers who have developed trading strategies focusing on spreads and market making on the two PTS markets (Japannext and Chi-x), dark pools, and other foreign exchanges. With regard to dark pools, which had been opaque so far, the applicable Cabinet Office Order and the updates to the "Comprehensive Guidelines for Supervision of Financial Instruments Business Operators, etc." took effect on September 1, 2020, thereby requiring record keeping and archiving of the trading information. Appropriate monitoring systems will be established for cross-market strategies while reviewing best execution policies.<sup>63</sup> For example, 林 (2017) pointed out that trading on the TSE tends to be executed about four milliseconds ahead of the two PTS markets. This suggests that as long as each market is linked with a small time lag and there is a gap in the bid price between markets (a feature that is not seen in the United States<sup>64</sup> and Europe), the opportunity for inter-market arbitrage strategies<sup>65</sup> will not disappear, whereas in the United States, it is pointed out that there is a possibility of malicious gaming<sup>66</sup> and preemptive trading. In any event, the perspective of market

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<sup>61</sup>In the empirical research of the regulation on transaction speed such as Speed Bump, there are some papers e.g. (Hu (2019)) stating that the introduction of Speed Bump leads to the reduction of spread, whereas others (Chen et al. (2017)) stating that it does not. Some papers including the paper published by (Khapko and Zoican (2020)) state that symmetric Speed Bump is not effective but asymmetric Speed Bump is effective. There is no consensus in the academic world.

<sup>62</sup>In this paper, no empirical analysis has been conducted in terms of investor fairness. One method of empirical research is to use actual bid-ask spread data to measure the impact of adverse selection on market trading (Easley et al. (1996), Easley et al. (2012), Andersen and Bondarenko (2014), and Aoyagi (2019)).

<sup>63</sup> Prescribed in Article 40-2 (1) of the FIEA.

<sup>64</sup>See Pachare and Rainer (2018).

<sup>65</sup> Specifically, there are various arbitrage strategies, such as quote matching.

<sup>66</sup>For details, see 杉原 (2011) .

fairness and protection of retail investors, etc. is important, as stated in the supplementary resolution<sup>67</sup> on May 16, 2017 (2017): "In order to ensure the protection of individual investors, etc., the government should consider, as appropriate, how to regulate investors in cooperation with the international community."

Three years have passed since the introduction of the registration system for HFTers under the amendments to the FIEA. The groundwork has been laid for further discussions in close cooperation with market players, including securities companies, exchanges (self-regulatory organizations), and experts. We will make use of our position as an authority capable of collecting information across exchanges, thereby appropriately disseminating information. We will work to accumulate further analysis for the avoidance of market fluctuations caused by doubts and speculation about HFT (improvement of market transparency), the suppression of investors who attempt to manipulate the market (suppression effect by monitoring signaling), and the enhancement of market structure (discovery of any distortions between markets or structural problems in the market).

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<sup>67</sup>Supplementary Resolution to the Bill for Partially Amending the Financial Instruments and Exchange Act, the 193rd Session of the National Diet. (the Committee on Financial Affairs of the House of Councillors) (May 16, 2017 (2017)) ([https://www.sangiin.go.jp/japanese/gianjoho/ketsugi/193/futai\\_ind.html](https://www.sangiin.go.jp/japanese/gianjoho/ketsugi/193/futai_ind.html), Viewed: May 31, 2021)

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