Analysis of Japanese Stock Market Turbulence in Early August 2024

Executive Summary

This paper presents a detailed analysis of the sharp swings that occurred in the Japanese stock market on August 5, 2024. With the use of granular order/transaction level data of the Nikkei 225 Futures, the FSA has developed several indicators to evaluate market supply, demand and liquidity conditions, including dominance by buyers/sellers, concentration by specific entities in transactions, price impact per contract amount and liquidity around the best quote.

Closely following the year-to-date (until early August) and August 5 intraday movements of these indicators, the followings were suggested. On a daily basis from mid-July to early August, excessive imbalances were not observed but the market liquidity was markedly declining, making prices more susceptible to fluctuations. Furthermore, on an intraday basis focusing on August 5, market liquidity subsided rapidly toward the afternoon session. At these hours, take orders were found to be concentrated on the seller side. Combined, they may have caused rapid market turbulence.

The use of granular data has provided a new insight into the background and mechanism of the market turbulence on August 5, 2024, compared to previous literature that has been based mainly on the views of market participants or macro-level aggregated statistics. This is a novelty of this paper. On the other hand, there is one important caveat. The analysis is obliged to focus on the Japanese stock market. While other domestic and overseas markets, including bond, foreign exchange and derivatives, should be ideally analyzed all together given their close interconnectedness, it was not possible due predominantly to the lack of data availability.

Evaluating the impact of market fluctuations on financial stability is an important issue on the regulatory agenda. The FSA will continue to analyze the mechanism of sharp market turbulence and its impact on financial stability by enhancing analytical capabilities and expanding the scope of its analyses.

Summary of list of indicators for supply, demand and market liquidity

Indicator	Overview
Aggressive Buy Volume Ratio	Imbalance between supply and demand (i.e., whether buyers dominate or not)
Aggressive Buy Volume HHI **Aggressive Sell Volume HHI** (collectively referred to as Buy/Sell)	Degree of concentration of execution amounts of take orders by buying/selling entities (i.e., to what extent transactions by specific entities were concentrated)
Range of scale up HHI **Range of scale down HHI** (collectively referred to as up/down)	Concentration of price fluctuations by buying/selling entities (i.e., to what extent price increases/decreases were concentrated in transactions by specific entities)
Buy Price Impact Ratio **Sell Price Impact Ratio** (collectively referred to as Buy/Sell)	Likelihood of price movements due to buy/sell orders (i.e., the extent to which prices moved per contract amount)
Number of quotations indicated within five ticks around the best quote price for each transaction	Liquidity around the best quote (i.e., whether there were a lot of orders around the best quote prices)

I. Introduction

The Nikkei 225 has been solid since the beginning of 2024, and on February 22, it reached a record high for the first time in 34 years. After surpassing the 40,000 yen for the first time in March and undergoing a subsequent correction phase, the Nikkei 225 started to rise again in late June and reached a new record high on July 11 (closing at 42,224.02 yen). It then returned to the vicinity of 38,000, followed by a sharp drop on August 5, closing down 12.40%, the second largest loss rate on record (-4,451.28 yen, the largest loss amount on record)[1].

To maintain well-stabilized market functions, it is important to analyze the mechanism of such rapid market turbulence and assess risks to the financial system. This paper presents a detailed analysis of the sharp swings that occurred in the Japanese stock market on August 5, 2024.

Various views have been presented about the sharp market turbulence on August 5. For example, some market participants have pointed out that investors who had become increasingly risk averse unwound their long positions on Japanese stocks that had been accumulated since the beginning of the year, given the combination of weak economic indicators in the United States (U.S.) and heightened geopolitical tensions in late July when monetary policy decisions were announced in Japan and the U.S. Others have pointed out that the Japanese market, which is the first major market with high liquidity to open, was highly responsive to risk events that had occurred over the end of the previous week. In addition, it has been pointed out that from mid-July, speculators' short positions on the Japanese yen reflecting the gap between Japanese and U.S. interest rates were rapidly unwound, leading to the yen appreciation.

Since stock markets and various domestic and overseas markets (e.g., bond markets, foreign exchange markets, and derivatives markets) are intricately linked, ideally such intermarket connectedness needs to be also considered in evaluating the Japanese stock markets. However, it was not possible as the relevant data are not available in a complete, trustworthy manner. Therefore, this paper focuses on the Japanese stock market, for which comprehensive granular order/transaction

[1] Subsequently, the stock price index has been on a recovery trend. Some market participants have pointed out that risk averse sentiments have subsided after the release of stronger-than-expected U.S. economic data, with softened concerns against the U.S. economic conditions. Others have pointed out that mid-term positive views on the Japanese market have been unchanged as corporate governance reforms are progressing.

level data are available.

In this paper, a detailed analysis of trends in supply, demand and market liquidity of the Nikkei 225 Futures around August 5, 2024, has been conducted with the use of order/transaction details data[2] provided by the Osaka Exchange, Inc. Section II introduces new indicators created to gauge market supply, demand and liquidity conditions, and its subsection 1 examines the changes in these indicators from the beginning of 2024 to early August 2024 on a daily basis, and subsection 2 delves deeply into the August 5 intraday movements more closely. Section III concludes with a few takeaways.

To date, various discussions and analyses have been made mainly based on interviews with market participants or macroeconomic and financial statistics. Building on this existing literature, this paper analyzes the relationship between sharp market turbulence and market conditions by using individual order/transaction details data. By taking advantage of such granular data, this analysis introduces a novel approach in which it has developed indicators to evaluate supply, demand and liquidity by expanding existing indicators.

Figure 1: Nikkei 225 index movements

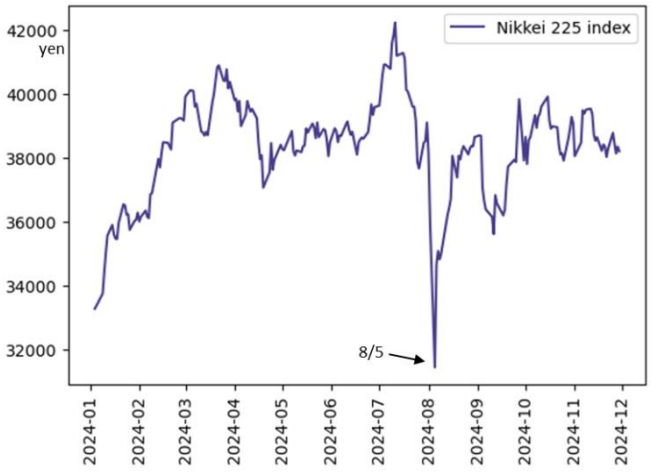
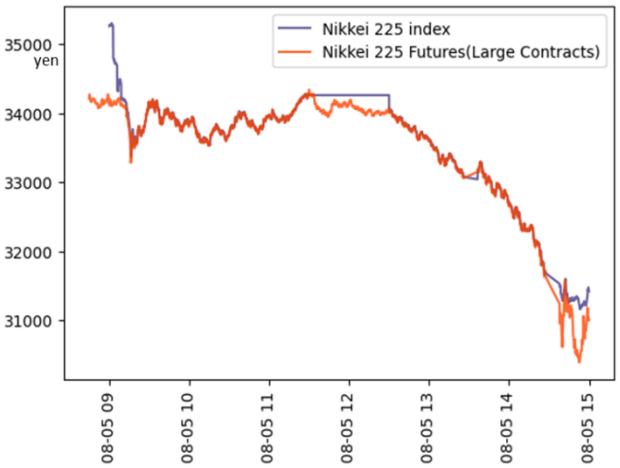


Figure 2: Nikkei 225 and Nikkei 225 Futures price movements on August 5, 2024



[2] The order/transaction details data include record categories such as new order, change order, cancelled order, and executed order, as well as trading category, price, number of orders, order quantity, order conditions, ordering party (including strategies in the case of HFTs), and time stamps. In this analysis, only auction transactions are included, while combination transactions are excluded.

II. Supply-Demand and Market Liquidity Indicators

In this section, five indicators summarized in Figure 3 have been calculated on a daily basis[3] in order to examine trends in supply, demand and liquidity conditions in the Nikkei 225 Futures market from the beginning of 2024 to August 5.

Throughout the analysis period, i.e., from January 4, 2024 to August 7, 2024, high-speed traders ("HFTs"), securities brokerage accounts, securities brokerage proprietary accounts and online securities firms accounted for 70.0%, 18.3%, 1.94% and 9.6% of the whole trading volume, respectively. By contrast, on August 5, the ratio for HFTs, securities brokerage accounts, securities brokerage proprietary accounts and online securities firms was 64.6%, 24.5%, 2.9% and 7.8%, respectively, showing a decrease in HFTs and an increase in the securities brokerage proprietary accounts.

Figure 3: List of indicators for supply/demand and market liquidity

Indicator	Overview
Aggressive Buy Volume Ratio	Imbalance between supply and demand (i.e., whether buyers dominate or not)
Aggressive Buy Volume HHI **Aggressive Sell Volume HHI** (collectively referred to as Buy/Sell)	Degree of concentration of execution amounts of take orders by buying/selling entities (i.e., to what extent transactions by specific entities were concentrated)
Range of scale up HHI **Range of scale down HHI** (collectively referred to as up/down)	Concentration of price fluctuations by buying/selling entities (i.e., to what extent price increases/decreases were concentrated in transactions by specific entities)
Buy Price Impact Ratio **Sell Price Impact Ratio** (collectively referred to as Buy/Sell)	Likelihood of price movements due to buy/sell orders (i.e., the extent to which prices moved per contract amount)
Number of quotations indicated within five ticks around the best quote price for each transaction	Liquidity around the best quote (i.e., whether there were a lot of orders around the best quote prices)

[3] In this paper, a combination of a day session and a night session is defined as one trading day (for example, a day session on August 5 and a night session on August 5 are defined as August 5).

1. Trends until August 5, 2024

First, the performance of the Nikkei 225 Futures up to August 5, 2024, was examined particularly from the perspective of "take orders." Take orders consist of market orders and limit orders that can be executed immediately. Take orders demand the liquidity of the market, which has been supplied by the "make orders". Take orders by sellers (buyers) lead to price decrease (increase). By comparing the amount executed by the take order on the buyer's side with the amount executed by the take order on the seller's side, it could be possible to assess the imbalance between supply and demand, i.e., whether the buyer is dominant or otherwise.

In order to evaluate this, the indicator "Aggressive Buy Volume Ratio" is calculated as follows. If the buyer's take order and the seller's take order are balanced, the indicator will become 0.5. If the buyer's (seller's) take order is more dominant, the indicator approaches 1 (0). Indicators in this section is calculated on a daily basis (the same applies to subsequent indicators).

$$Aggressive\ Buy\ Volume\ Ratio \coloneqq \frac{Total\ Aggressive\ Buy\ Volume\ by\ all\ buyers\ throughout\ the\ period}{Total\ volume\ of\ all\ take\ orders\ throughout\ the\ period (Total\ Aggressive\ (Buy/Sell)\ Volume)} \ldots (1)$$

$$\begin{pmatrix} Aggressive\ Buy\ Volume = The\ amount\ committed\ on\ the\ buyer's\ take\ order \\ Aggressive\ Sell\ Volume = The\ amount\ committed\ on\ the\ seller's\ take\ order \end{pmatrix}$$

Figure 4 shows the trend of the Aggressive Buy Volume Ratio since the beginning of the year. The ratio was 0.494 on August 5 compared to the YTD average of 0.497. No evidence is confirmed to mention that the massive take orders have disrupted the supply-demand balance on August 5.

The second indicator is "Aggressive (Buy/Sell) Volume HHI[4]" which measures the degree of concentration of market shares by trading entities, i.e., to what extent specific trading entities, such as large investors, are influencing the market by placing large take orders. The calculation method is as follows. When a particular trading entity has a large share (high monopoly) in the market, the HHI approaches 1. On the other hand, when there is little concentration, the HHI approaches 0.

[4] The Herfindahl-Hirschman Index (HHI) is a measure of market share concentration. In this paper, we use the HHI as an index to measure concentration of trading activities in the Nikkei 225 Futures market.

$$Aggressive\ (Buy/Sell)\ Volume\ HHI$$

$$:= \sum_{i=1}^{n} \left(\frac{Aggressive\ (Buy/Sell)\ Volume\ of\ trader\ i\ throughout\ the\ period}{Total\ Aggressive\ (Buy/Sell)\ Volume\ throughout\ the\ period} \right)^2 \quad \ldots (2)$$

Figure 5 shows the YTD performance of the Aggressive (Buy/Sell) Volume HHI. The Aggressive Buy (Sell) Volume HHI was 0.072 (0.075) on August 5, compared to the YTD average of 0.091 (0.089), suggesting that there was no particular sharp rise on August 5. Thus, it could not be confirmed that orders were concentrated on take orders by specific trading entities compared to normal times.

Figure 4: Aggressive Buy Volume Ratio

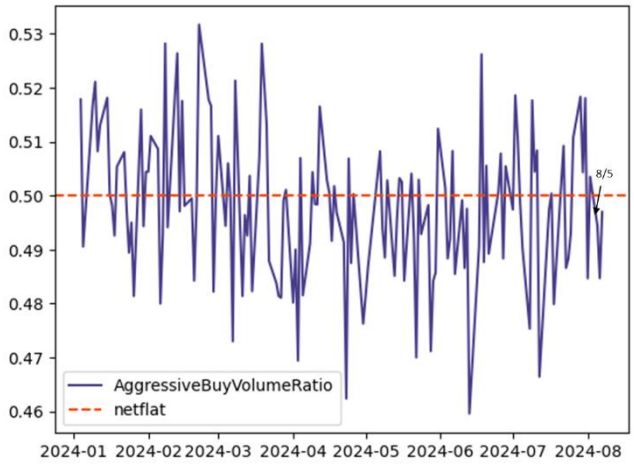
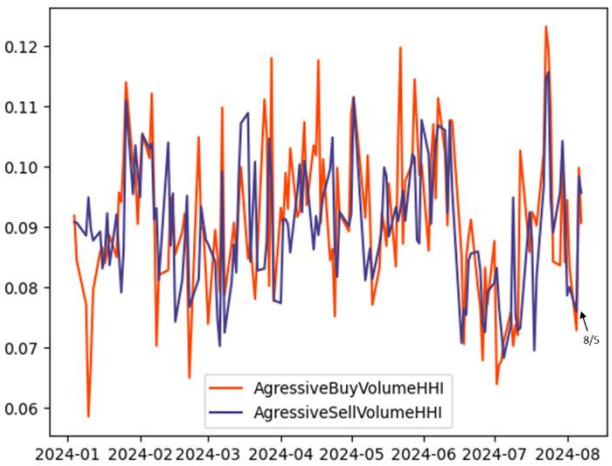


Figure 5: Aggressive (Buy/Sell) Volume HHI



Third, from the viewpoint of examining price fluctuations by certain trading entities, the degree to which each trading entity has affected the range of price movements[5] (see BOX 1) of contract prices has been calculated by using an indicator "Range of scale up/down HHI". Range of scale up/down HHI is given as the equation (3).

[5] "Range of scale up (down)" is the cumulative total of price movements when each trading entity sells (buys) and lowers (rises) prices. For more detail, see Ohyama et al. (2021) and BOX1.
https://www.fsa.go.jp/frtc/english/seika/srhonbun/20210707_Characterization_of_high_speed_tradingEN.pdf

$$Range\ of\ scale\ (up/down)\ HHI$$

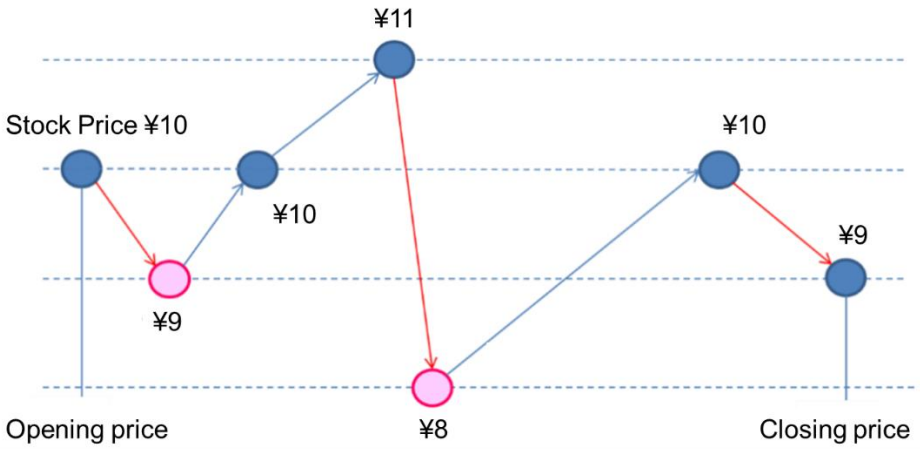
$$:= \sum_{i=1}^{n} \left(\frac{Range\ of\ scale\ (up/down)\ by\ trading\ entity\ i\ throughout\ the\ period}{Total\ range\ of\ scale\ (up/down)\ throughout\ the\ period} \right)^2 \quad \ldots (3)$$

If the share of this degree of impact is dispersed (HHI becomes close to 0), the impact of a specific trading entity on price fluctuations is relatively small, and if it is concentrated (HHI becomes close to 1), the impact of transactions of a specific trading entity on price fluctuations is relatively large.

BOX 1: Range of Scale Up/Down

For example, as shown in Figure 6 below, if a certain entity lowers the stock price twice during the period (colored in pink) as a result of its sell orders, the range of scale down for the entity is calculated as (10 - 9) + (11 - 8) = 4 yen.

Figure 6: Image of Range of scale up/down by a certain entity



Source: "Characterization of High-Speed Trading" by Atsuyuki OHYAMA, Yoshitaka FUKUYAMA, Shintaro OKUDE, and Kenta SUZUKI.

Figure 7 shows the trend of Range of scale (up/down) HHI since the beginning of the year. Although extreme values were not observed from the latter half of July to the beginning of August, it was at a level slightly higher than normal, indicating that the market environment was slightly more prone to

price movements due to orders from specific trading entities. The Range of scale up (down) HHI was 0.096 (0.105) on August 5, compared to the YTD average of 0.086 (0.087).

Fourth, to assess the likelihood of price fluctuations arising from supply-demand imbalances, "Buy/Sell Price Impact Ratio" is introduced by calculating the ratio between the Range of scale (up/down) and the Aggressive (Buy/Sell) Volume, as shown in equation (4). It is considered that the larger the ratio of the Range of scale (up/down) to the Aggressive (Buy/Sell) Volume, the more likely for price fluctuations to occur due to liquidity demands from take orders, and that prices will be more likely to respond to imbalances in the supply-demand balance.

Specifically, for each of long and short positions, (Buy/Sell) Price Impact Ratio is obtained by dividing the sum of all trading entities of the Range of scale (up/down) by the aforementioned Aggressive (Buy/Sell) Volume as follows:

$$(Buy/Sell)\ Price\ Impact\ Ratio := \frac{Total\ Range\ of\ scale\ (up/down)\ by\ trading\ entities\ throughout\ the\ period}{Total\ Aggressive\ (Buy/Sell)\ Volume\ by\ all\ trading\ entities\ throughout\ the\ period} \ldots (4)$$

The (Buy/Sell) Price Impact Ratio has been on a rising trend since mid-July and skyrocketing toward early August, suggesting that the market was prone to large price fluctuations against a small imbalance between supply and demand. The Buy (Sell) Price Impact Ratio was 4.29×10^{-8} (4.34×10^{-8}) on August 5, compared to YTD average of 1.21×10^{-8} (1.20×10^{-8}).

Figure 7: Range of Scale (up/down) HHI

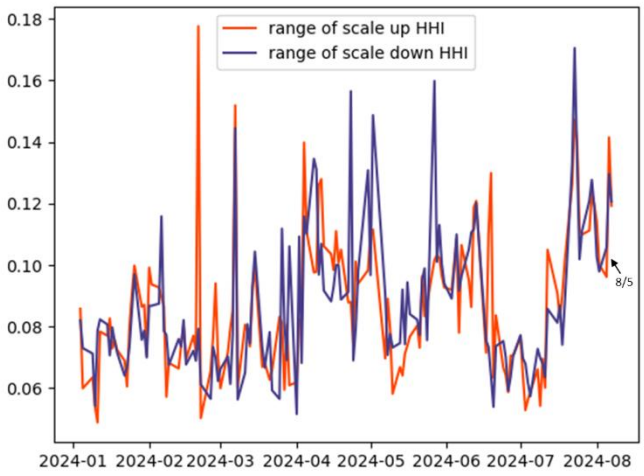
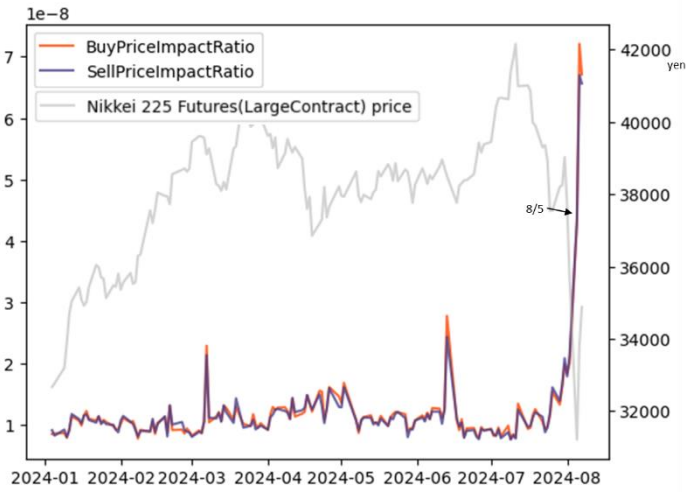


Figure 8: (Buy/Sell) Price impact ratio



Finally, the thickness of limit orders placed around the best quote price on the order book was examined. In general, price fluctuations are considered to be less likely to occur if many limit orders are placed near the best quote, as thick orders absorb the price fluctuations caused by liquidity demand from take orders, and vice versa.

Specifically, the time-weighted average order volume within the five ticks from the best quote[6] is observed for each transaction (see BOX 2).

Figure 9 shows the order volume placed within the five ticks from the best quotes. It can be confirmed that the depth of orders has been on a decreasing trend since mid-July and declined sharply toward early August. The order volume placed within the five ticks from the best quotes on the long (short) side was 79.55 (71.80) units on August 5, compared to the YTD average of 322.20 (322.28) units.

Figure 10 shows the ratio of order volume placed by HFTs within the five ticks from the best quotes. On August 5, the ratio was not at a prominent level compared to the YTD movement, but dropped from the most recent level on August 2. On the long (short) side, the ratio was 0.738 (0.797) on August 5 compared to the YTD average of 0.785 (0.783).

Figure 9: Order volume within five ticks around the best quote

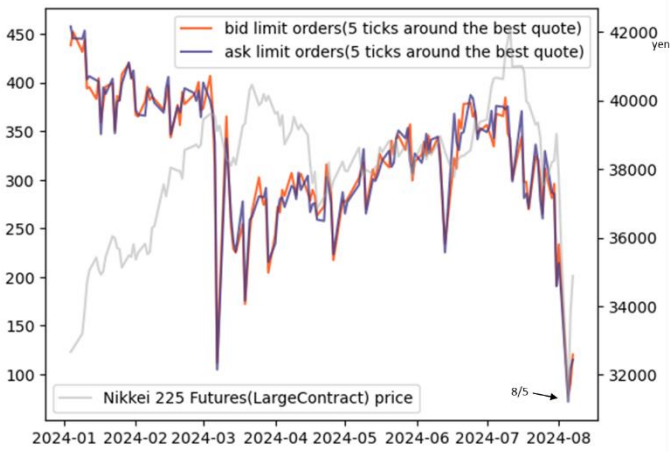
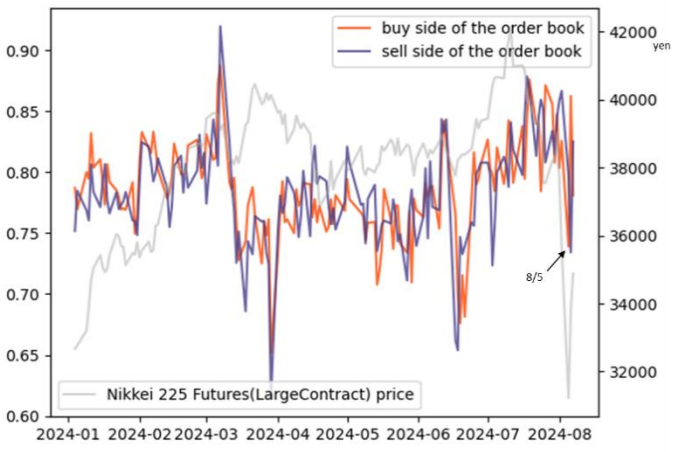


Figure 10: Ratio of order volume placed by HFT within five ticks around the best quote



[6] For more detail, see FSA Analytical Notes (2024.7) vol.2. https://www.fsa.go.jp/en/about/fsaanalyticalnotes/20241121/02.pdf

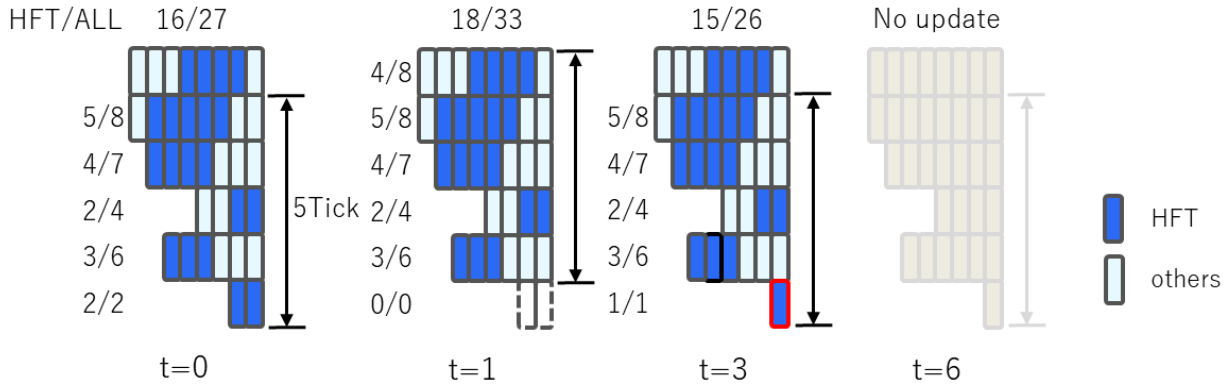
BOX 2: Calculation of the ratio of order volume placed by HFTs within the five ticks from the best quotes (the ratio of liquidity provision by HFTs)

The "time-weighted average of the order volume within 5 ticks of the best quote" is used as an indicator of market liquidity. The liquidity provision ratio by HFT, $R_{j,[t_s,t_e)}$, is defined as follows, where t_s and t_e denotes the time interval subject to the measurement and j is buy or sell side of the order book.

$$R_{j,[t_s,t_e)} := \frac{the\ avarage\ of\ \boldsymbol{HFT}\ order\ volume\ per\ time\ within\ 5\ ticks\ from\ best\ quote}{the\ avarage\ of\ \boldsymbol{ALL}\ order\ volume\ per\ time\ within\ 5\ ticks\ from\ best\ quote}$$

As shown in the definition formula, $R_{j,[t_s,t_e)}$ takes the value ranging between 0 and 1, and the larger $R_{j,[t_s,t_e)}$ indicates the higher liquidity provision by HFT. Figure 1 shows an example of the calculation of $R_{j,[t_s,t_e)}$. In this case, the liquidity provision ratio by HFT in the time interval t=0 to t=6 for sell side of the order book, $R_{sell,[0,6)}$, become 0.57.

Figure 11: Example of liquidity supply ratio $R_{j,[t_s,t_e)}$ calculation



$$\boldsymbol{R_{sell,[0,6)}} = \frac{the\ avarage\ of\ \boldsymbol{HFT}\ order\ volume\ per\ time\ within\ 5\ ticks\ from\ best\ quote}{the\ avarage\ of\ \boldsymbol{ALL}\ order\ volume\ per\ time\ within\ 5\ ticks\ from\ best\ quote}$$

$$= \frac{\frac{16\times 1 + 18\times 2 + 15\times 3}{1+2+3}}{\frac{27\times 1 + 33\times 2 + 26\times 3}{1+2+3}}$$

$$= 0.57$$

Calculation R in t∈ [0,6) when the sell board is updated at t=0,1,3

Source: FSA, "Analysis of Impact of High-speed Trading Activity on Market Liquidity and Magnitude of Market Fluctuations," FSA Analytical Notes (2024.7) vol. 2.

Figures 12 and 13 are scatter plots of the Price Impact Ratio defined in equation (4) and the number of limit orders quoted within the five ticks from the best quote. It is observed that both are negatively correlated. This is consistent with the "depth" concept in the definition of market liquidity, i.e., the thinner the market is, the less the amount of money that can be traded without moving the price is. This could be considered as one of the pieces of evidence that the Price Impact Ratio indicator is valid. With this relationship in mind, on August 5, both indicators were at unusual levels compared to other days of the year, suggesting that prices were extremely prone to move due to a decline in market liquidity.

Figure 12: Scatter plot of Buy Price Impact Ratio and ask limit order volume around the best quote

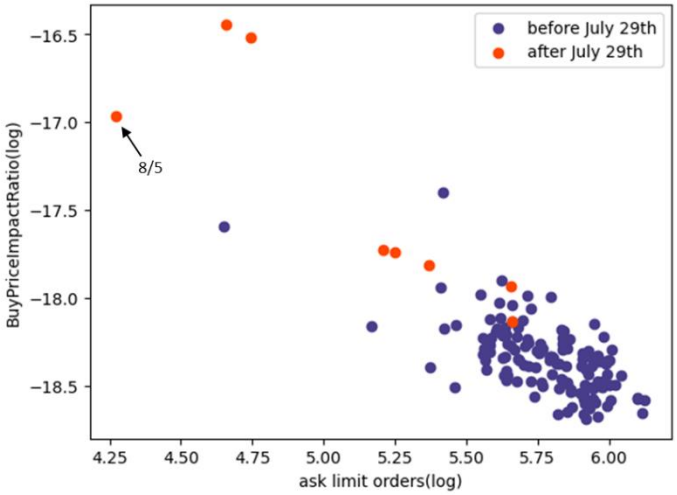
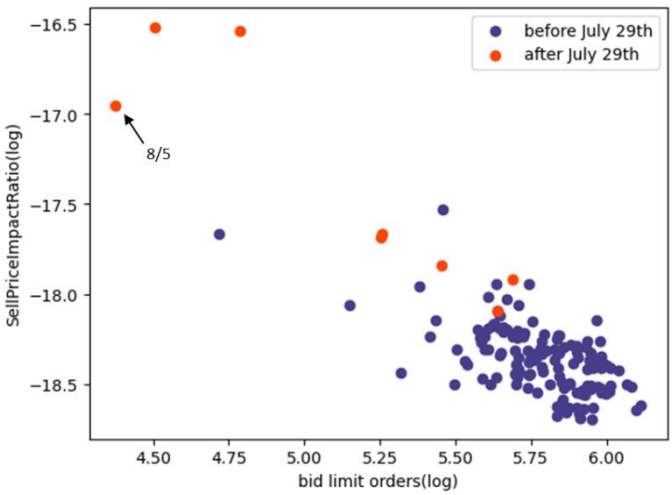


Figure 13: Scatter plot of Sell Price Impact Ratio and bid limit order volume around the best quote



2. Intraday movements on August 5

In this subsection, August 5 intraday movements of the five indicators introduced in the previous subsection are examined as a deep-dive analysis to grasp the background of the rapid market turbulence. For each indicator in this subsection, calculations are made for a one-minute period. In addition, in Figures 14-19, indicators calculated every minute are leveled using a 10-minute moving average (MA) for the purpose of making it easier to understand the trends of the indicators.

Figure 14 shows the intraday movements of (1) Aggressive Buy Volume Ratio, which is the ratio of the amount of money contracted in the take order on the buyer side to that on buyer and seller sides

in total. It is observed that the take order was biased toward sellers (the ratio is close to 0) from around the lunch break in the cash equity market (11:30 to 12:30) to around 14:00, where a sharp fall occurred.

Figure 15 shows the intraday movements of (2) Aggressive (Buy/Sell) Volume HHI, which shows the degree of concentration of the share of the amount of money executed by buyers / sellers on take orders (the degree of market share). It indicates that the HHI on sellers' side peaked after the lunch break in the cash equity market, suggesting a high degree of concentration. However, there was a downward trend toward around 14:00, and no tendency was observed for specific sellers to occupy the market share by a large number of take orders.

Figure 14[7]: Aggressive Buy Volume Ratio over the course of the day on August 5

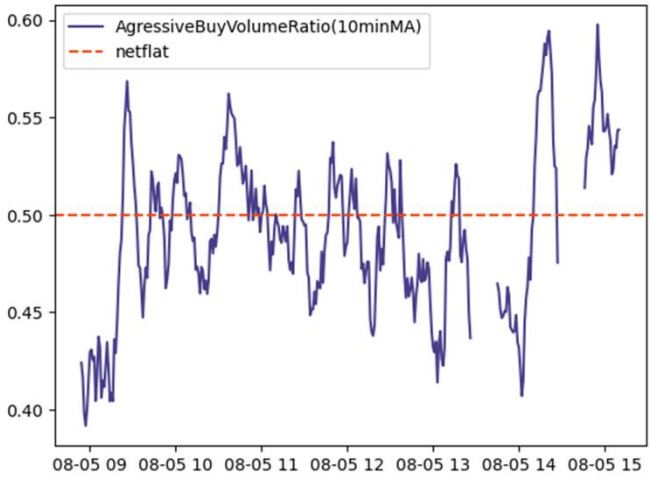


Figure 15: Aggressive (Buy/Sell) Volume HHI over the course of the day on August 5

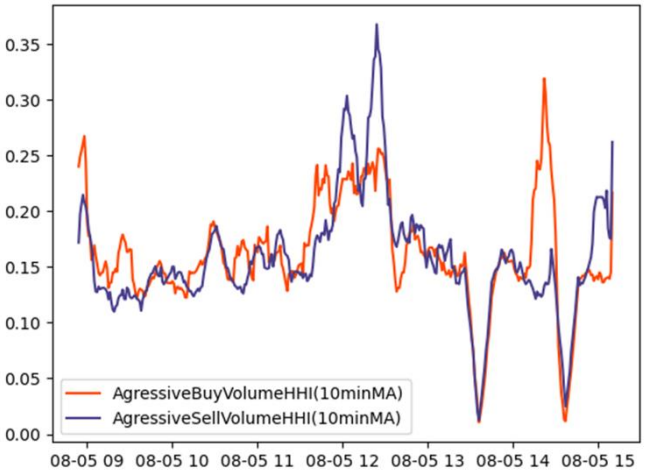


Figure 16 shows the intraday movements of (3) Range of scale (up/down) HHI, which shows the concentration rate of entities that have had an impact on the range of buy prices and sell prices. The indicator also peaked after the lunch break in the cash equity market, but it declined through the afternoon session of the cash equity market thereafter (hereinafter, the afternoon session refers to that of the cash equity market). It could not be confirmed that specific trading entities tended to occupy a share of price turbulence in the afternoon session when prices plummeted.

[7] The impact of the circuit breakers that were activated at 13:26 and 14:27 are presented in the disconnected part of the graph. The same for Figures 14-17.

Figure 17 shows the intraday movements of (4) (Buy/Sell) Price Impact Ratio, which shows price fluctuations per contract amount of take orders. The ratio rose rapidly toward the afternoon session, suggesting that the market environment was prone to large price fluctuations against a small supply-demand imbalance.

Figure 16: Range of scale (up/down) HHI over the course of the day on August 5

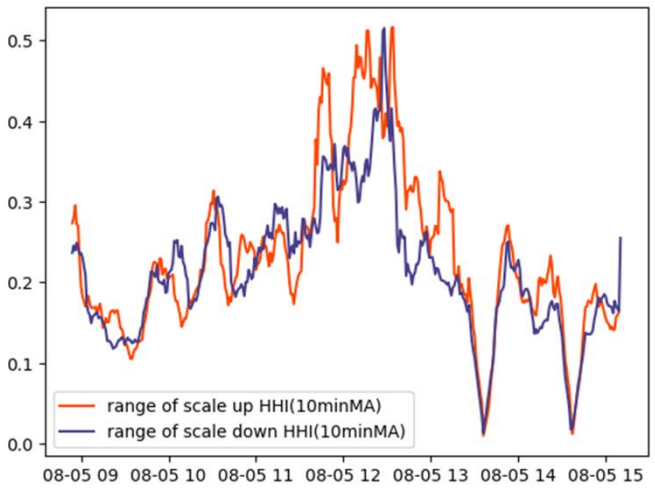
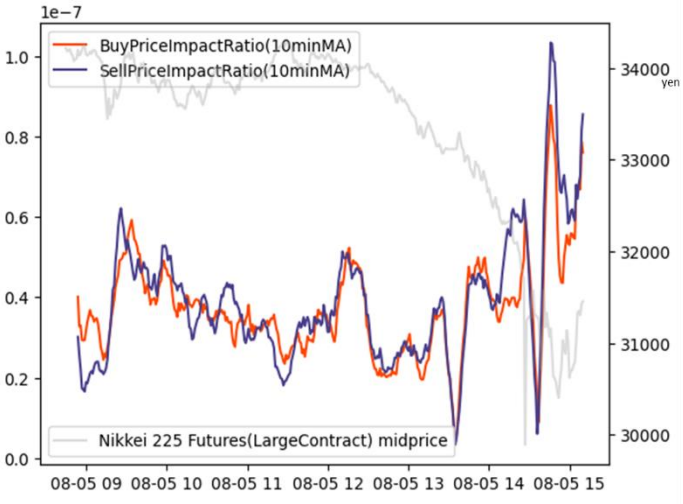


Figure 17: (Buy/Sell) Price Impact Ratio over the course of the day on August 5



As shown in Figure 18, the order volume placed within the five ticks from the best quotes tended to decrease toward the afternoon session, which suggested a decline in market liquidity. In addition, as shown in Figure 19, the ratio of order volume placed by HFTs within the five ticks from the best quotes also tended to decrease toward the afternoon session, confirming that liquidity provision by HFTs was restrained at that time.

Figure 18: The order volume placed within the five ticks from the best quotes on August 5

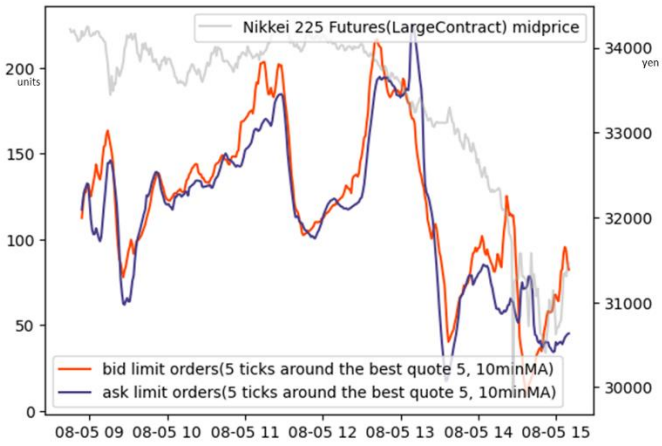
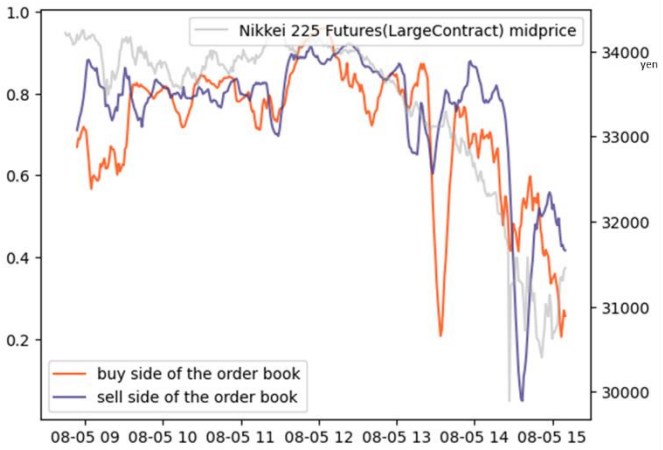


Figure 19: The ratio of order volume placed by HFTs within the five ticks from the best quotes on August 5



Figures 20 and 21 are scatter plots of the aforementioned Price Impact Ratio and the order volume placed within the five ticks from the best quotes. Similar to the daily relationship, it shows an inverse correlation (the thinner the order book, the less the order amount required for prices to move) intraday on August 5. In particular, from 12:30 onwards, it can be confirmed that most of the data points are located in the upper left area of the graph (i.e., the order book is thin and prices move easily). Based on the above, it can be inferred that one of the factors behind the rapid market movements was a decline in market liquidity, particularly in the afternoon session.

Figure 20: Scatter plot of "Buy Price Impact Ratio" and ask limit order volume on August 5

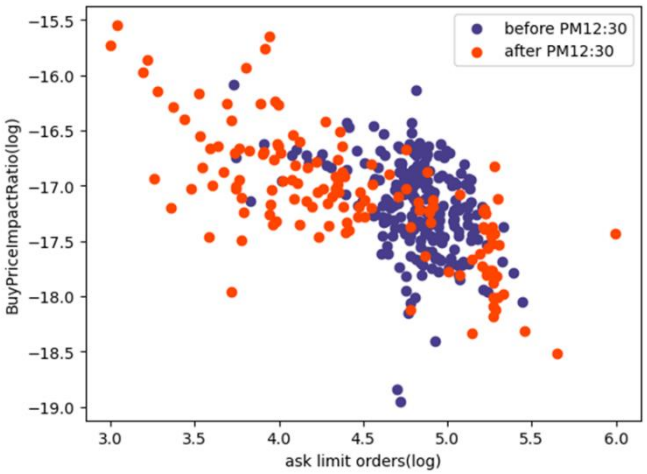
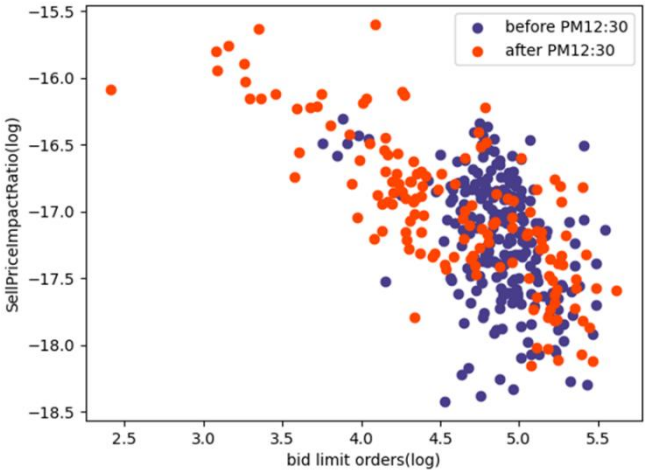


Figure 21: Scatter plot of Sell Price Impact Ratio and bid limit order volume on August 5



III. Conclusion

In this paper, trends in supply, demand and market liquidity conditions behind the sharp turbulence that occurred in the Japanese stock market on August 5, 2024, are analyzed using granular order/transaction details data of the Nikkei 225 Futures provided by the Osaka Exchange, Inc.

Looking at the year-to-date movements of the five developed indicators related to supply, demand and market liquidity, excessive imbalances in supply and demand (imbalances in take orders) dominated by sellers were not observed from mid-July to early August. On the other hand, it is suggested that market liquidity was declining at the time and prices were prone to fluctuations.

In addition, regarding the intraday movements on the day of August 5, several indicators confirmed that market liquidity had rapidly subsided toward the afternoon session and that price fluctuations were likely to occur in such an illiquid market environment. This suggests that the imbalance between supply and demand on the seller side was amplified by a shortage of market liquidity, which may be one of the factors of the rapid market turbulence.

August 5 recorded the largest daily trading volume since the beginning of the year for the central contract month of the Nikkei 225 Futures. Given that take orders were concentrated on the seller side in the afternoon session as confirmed by the movements of the Aggressive Buy Volume Ratio on August 5, one of the implications was that, amid a decline in market liquidity, a large amount of selling demand that occurred at a specific period caused a shortage of market liquidity provided by buyers, resulting in rapid market turbulence in which sell orders called other sell orders.

It should be noted that the supply-demand and market liquidity trends, which are the focuses of this analysis, are one aspect of the market. In reality, financial markets (e.g., bond, foreign exchange and derivatives) are intricately linked with each other, and there could be various explanations behind the market turbulence, including market correlations and fundamentals such as corporate earnings. They are not directly dealt with in this paper due predominantly to the lack of data.

Evaluating the impact of such market fluctuations on financial stability is an important issue on the regulatory agenda. The FSA will continue to improve its analytical capabilities and expand the scope of its analyses to better understand the mechanism of sharp market turbulence and assess their impacts on the financial system from various perspectives.