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Abstract

This study examines the effects of the Bank of Japan's (BOJ) large-scale equity purchases on the Nikkei 225 during the coronavirus (COVID-19) pandemic in 2020. Although the BOJ started equity purchases in 2010, the purchased amount reached unprecedented levels when the COVID-19 pandemic broke out. These large-scale purchases provide a natural experiment to examine how effective the central bank's equity purchases were in the crisis. Unlike previous studies, we investigate the equity purchase effects allowing for endogeneity. We first derive the BOJ's intra-day reaction function by estimating probit models. From this reaction function, we then calculate the BOJ's unexpected and expected equity purchases and examine their effects on the Nikkei 225 returns in the Tokyo Stock Exchange's afternoon session. We find that the BOJ's unexpected large-scale purchases had large positive instantaneous impacts on intra-day returns during the pandemic. However, the large positive impacts arose because most of the purchases came as big surprises to the markets. We argue that the policy would be effective only if the BOJ continues to surprise the market.

JEL code: E58, G12, G01, H12

Key words: large-scale equity purchases, the Bank of Japan, the coronavirus pandemic

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1. Introduction

After the outbreak of the coronavirus (COVID-19) pandemic, the global economy faced the worst economic crisis since the Great Depression. The pandemic led to price slumps in stock markets around the world in March 2020. The Tokyo Stock Exchange (TSE) was not an exception. The Nikkei 225, the premier Japanese stock index, fell by almost 25% from mid-February to early April 2020. In facing the crisis, the central banks of advanced economies adopted various unorthodox policies to stabilize the markets. However, only the Bank of Japan (BOJ) carried out large-scale equity purchases in the crisis. To the extent that the market mechanism functioned well, central bank equity purchases may not have additional benefits for the economy, given an appropriate inflationary response (Bernanke and Gertler, 2001). However, large-scale equity purchases of the central bank might help to stabilize the economy when asset prices have fallen dramatically in the crisis.

This study examines the effects of the BOJ's large-scale equity purchases on the Nikkei 225 when the COVID-19 pandemic broke out in 2020. Figure 1 provides a preliminary evaluation of the Nikkei 225 and NY Dow from February to April 2020. After normalizing the value to 100 in February 14, 2020, the two lines in the figure depict the daily Nikkei 225 and NY Dow data, respectively. The bar graph depicts the BOJ's daily equity purchase amounts. Throughout this period, the Nikkei 225 remained highly correlated with the NY Dow. However, the Nikkei 225 outperformed the NY Dow in late February—when the BOJ accelerated its purchase pace—and in the latter half of March—when the BOJ doubled its annual purchase pace. This outperformance continued until early April, when the BOJ decelerated its purchase pace. This implies that the BOJ's large-scale equity purchases had positive but temporary effects on the Nikkei 225 in the crisis. In the following analysis, we explore whether this implication is valid even for formal tests examining the effects of the BOJ's unexpected and expected equity purchases on the Nikkei 225.

The BOJ carried out equity purchases under the exchange-traded funds (ETFs) purchasing program. This program was launched in October 2010 as part of the BOJ's large-scale asset

purchases (LSAPs).[1] ETFs are managed to track the premier stock price indicators in Japan, such as the Nikkei 225 and Tokyo Stock Price Index (TOPIX). Table 1 summarizes the timeline of the program. The BOJ expanded its annual ETF purchases quantitatively and qualitatively several times. In particular, it almost doubled the pace of its annual purchase from about 3.3 trillion to about 6 trillion yen in July 2016. However, following the market crash, the BOJ accelerated its purchase pace in late February 2020, raising the upper limit of its annual pace to about 12 trillion yen on March 16, 2020. If the BOJ's equity purchases decreased the risk premiums of various financial assets, they would have attracted more funds into the financial markets and stabilized the economy. These unprecedented large-scale purchases provide a natural experiment to examine how effective the central bank's equity purchases were in the crisis.

Table 2 reports the BOJ's ETF purchase frequency and average per purchase amount for four subsample periods from December 2010 to July 2020. We split the Kuroda regime into three subsamples based on major policy changes and the COVID-19 advent. We find that the daily purchases, which were less frequent when Shirakawa was the BOJ governor, became more frequent from April 4, 2013, when Kuroda introduced quantitative and qualitative easing (QQE).[2] The amount per purchase increased substantially when the BOJ almost doubled its annual purchase pace to about 6 trillion yen in July 2016. However, after the COVID-19 outbreak in 2020, the frequency was over 35% and the average daily purchase exceeded 100 billion yen before tapering ETF purchases in summer of 2020. In the following analysis, we explore whether large-scale purchases had different impacts on the Nikkei 225 after the COVID-19 outbreak in 2020.

Numerous studies in the literature explore the central bank's LSAP effects on asset prices (e.g., Barbon and Gianinazzi, 2019; D'Amico et al., 2012; Henseler and Rapp, 2018; Jansen and Zervou, 2017; Kholodilin et al., 2009; Krishnamurthy and Vissing-Jorgensen, 2011). Studies also estimated the BOJ's ETF purchase effects on daily stock price returns before the COVID-19

[1] See Koeda (2019) and Shioji (2019) for the effects of other LSAP types in Japan.

[2] See Fukuda (2015) for the initial market responses to QQE.

outbreak (e.g., Barbon and Gianinazzi, 2019; Charoenwong et al., 2019; Harada and Okimoto, 2019; Adachi, Hiraki, and Kitamura, 2021). These studies treated the BOJ's purchases as exogenous shocks to the market. However, market analysts have suggested that the BOJ had purchased ETFs during the lunch break of the TSE when the Japanese stock prices have fallen substantially in the morning session. Hattori and Yoshida (2020) confirm the endogeneity in BOJ's purchases by estimating a linear probability and Cox hazard models. Thus, the BOJ's estimated purchase effects may suffer from endogenous biases if the BOJ's endogeneity is not controlled for.

In the following analysis, we investigate the impacts of the BOJ's equity purchases on the Nikkei 225, allowing for the endogeneity of the BOJ's purchases. We first explore the BOJ's intra-day reaction functions using probit model estimations. We find that the BOJ changed its purchase amount and frequency over time but kept its reaction function stable throughout the sample period. From this reaction function, we estimate the BOJ's unexpected and expected ETF purchases and examine their effects on the Nikkei 225 returns in the afternoon session of the TSE. The BOJ's unexpected large-scale purchases show large positive instantaneous impacts on intra-day returns during the pandemic. However, the large positive impacts arose because most of the purchases came as big surprises to the markets. The BOJ's expected purchases show no significant impact on intra-day returns. We argue that the surprise policy would be effective only if the BOJ continues to surprise the market.

The remainder of this paper is organized as follows. Sections 2 and 3 derive the unexpected and expected BOJ's ETF purchases for probit model estimation. Section 4 investigates the purchase effects on the Nikkei 225 in the afternoon session of the TSE. Sections 5 and 6 explore the robustness by including extra control variables and by estimating tobit models, respectively. Section 7 examines the purchase effects on the Nikkei 225 for different time zones in the TSE's afternoon. Section 8 summarizes our results and discusses their implications.

2. Timing of the BOJ's equity purchases

In its ETFs purchasing program, the BOJ does not announce equity purchases on a day-to-day basis. However, among professionals, it is known to purchase ETFs during the lunch break of the TSE when the Japanese stock prices have fallen substantially in the morning session. Thus, the BOJ's daily purchase timing can be partly predicted around midday.

Table 3 summarizes the average growth rates of Japanese stock prices for four subsamples in the morning session of the TSE on days when the BOJ purchased and did not purchase ETFs respectively. For growth rate in the morning session on date *t*, it reports the average growth rates of the Nikkei 225 and TOPIX from 3 p.m. on date *t*-1 to 11:30 a.m. on date *t*. Both the Nikkei 225 and TOPIX show a negative growth rate for all subsamples when the BOJ purchased ETFs and a positive growth rate when the BOJ did not purchase EFTs. These results indicate that the BOJ decides to purchase ETFs when the Japanese stock prices have fallen substantially in the morning session of the TSE.

To predict the probability of the BOJ's daily purchases from the stock prices in the morning session, we estimate probit models, with the dependent variable y_t taking the value 1 when the BOJ purchased ETFs, and 0 otherwise. We assume that the random latent variable y^*_t is determined as

$$(1) \quad y^*_t = constant + a_1 \Delta S^1_t/S^1_t + a_2 \Delta S^2_t/S^2_t + \sum_{j=1}^{n} b_j x_t^j + \varepsilon_t,$$

where $\varepsilon_t \sim N(0, 1)$. We then view the dependent variable y_t as an indicator, for which $y_t = 1$ when $y^*_t > 0$, and 0 otherwise.

In equation (1), the explanatory variables are the intra-day stock price changes (i.e., $\Delta S^1_t/S^1_t$ and $\Delta S^2_t/S^2_t$) and several control variables x_t^j (j = 1, 2, …, n). For the intra-day stock price changes on date *t*, we use the TOPIX growth rate (i.e., log difference) from 3 p.m. on date *t*-1 to

9 a.m. on date t for $\Delta S^1_t/S^1_t$, and that from 9 a.m. to 11:30 a.m. on date t for $\Delta S^2_t/S^2_t$. For the control variables x_t^j (j = 1, 2, …, n), we include several policy dummies, each of which takes the value 1 after the BOJ announced an increase in annual amount of ETF purchases, and 0 otherwise. To check for robustness, we include the daily changes in the NY Dow on date t-1 and intra-day changes in the Nikkei 225 on date t as extra control variables. For intra-day changes of the Nikkei 225, we use the growth rate from 9:15 a.m. to 10 a.m. and from 10 a.m. to 11:30 a.m. on date t.[3]

Since the BOJ's monetary policy became more aggressive in QQE, we estimate the model separately for two subsamples, the Shirakawa regime (December 1, 2010, to March 19, 2013) and the Kuroda regime (March 20, 2013, to July 31, 2020). We include four policy change dummies (i.e., dummies 01, 02, 03, and 04) in the Shirakawa regime and four policy change dummies (i.e., dummies 11, 12, 13, and 14) in the Kuroda regime as explanatory variables.[4]

Table 4 reports the estimation results of the alternative specifications in the two regimes. The Shirakawa regime policy dummies are significantly negative. This indicates that the policy change decreased the BOJ's purchase probability when Shirakawa was the governor. In contrast, dummies 11 and 13 in the Kuroda regime are significantly positive. This indicates that some policy changes increased the BOJ's probability of purchases in QQE.

The most noteworthy result is that the changes in the TOPIX are always significantly negative in all cases. This confirms the view that the BOJ purchases ETFs when the Japanese stock prices have fallen substantially in the morning session of the TSE. The estimated coefficients are, however, smaller in the Kuroda regime than in the Shirakawa regime. The BOJ's purchase

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[3] We use the growth rate from 9:15a.m. because some stock trades do not complete when the TSE opens at 9a.m.

[4] Each policy change dummy takes the value 1 in each policy regime and 0 otherwise. Each policy regime is from March 15, 2011, to August 4, 2011, for "dummy 01"; from August 5, 2011, to April 27, 2012, for "dummy 02"; from April 30, 2012, to October 30, 2012, for "dummy 03"; from October 31, 2012, to March 19, 2013, for "dummy 04"; from November 3, 2014, to December 18, 2015, for "dummy 11"; from December 21, 2015, to July 29, 2016, for "dummy 12"; from August 1, 2016, to March 16, 2020, for "dummy 13"; and from March 17, 2020, to July 31, 2020, for "dummy 14."

decision is more sensitive to decline of the TOPIX in the Shirakawa regime than in the Kuroda regime. In contrast, the intra-day changes in the Nikkei 225 are significantly negative only in the Kuroda regime. Thus, while the BOJ's purchase decision is based only on changes of the TOPIX in the Shirakawa regime, it might have been based on changes of the TOPIX as well as other stock price changes in the Kuroda regime.

3. The BOJ's expected ETF purchases

In the previous section, probit models showed that the BOJ has a tendency to purchase ETFs when the Japanese stock prices have fall substantially in the morning session of the TSE. This implies that probit model estimations can predict the BOJ's purchase probability from the intra-day stock prices before the lunch break of the TSE. This section calculates the BOJ's expected daily ETF purchases based on the predicted probability.

To estimate the expected purchases on a day-to-day basis, we use our probit model estimation results obtained in the previous section with or without extra control variables.[5] From the estimated parameters in the Shirakawa and Kuroda regimes, we first derive the BOJ's predicted purchase probability, and use it to calculate the BOJ's expected purchases as follows:

(2) Expected daily purchase = the predicted probability × purchase amount

In the ETF purchasing program, the amount per purchase has been highly stable over time on a day-to-day basis unless the BOJ changed its policy regime. Even when the BOJ changed its policy regime, it remained highly predictable because the BOJ had announced its purchase amount on a year-to-year basis. We thus use the latest positive purchase amount for "purchase

[5] The extra control variables are the daily change in the NY Dow and intra-day changes in the Nikkei 225.

amount" in equation (2). This is equal to the new purchase amount when the BOJ purchases ETFs and the latest positive purchase amount when the BOJ does not purchase ETFs.

We calculate the unexpected ETF purchase amount by subtracting the expected amount from the realized amount in each regime. Depending on whether equation (1) is with or without extra control variables, we obtain two sets of daily data on the expected and unexpected ETF purchase amounts. Using the probit model with extra control variables, Figure 2 depicts the expected and unexpected ETF purchase amounts from December 2010 to July 2020. The expected amount was small in the Shirakawa regime, but the amount in the Kuroda regime became large, especially after July 2016 when the BOJ almost doubled its annual purchase pace. The unexpected amount showed little fluctuation in the Shirakawa regime, but it became more volatile in the Kuroda regime, especially after July 2016. After the COVID-19 outbreak, the expected amount increased, but only moderately for most of the period. In contrast, the unexpected amount became much more volatile in 2020. Thus, a substantial part of large-scale ETF purchases after the COVID-19 outbreak came as unexpected shocks for the market participants.

Before the COVID-19 outbreak, the BOJ did not purchase ETFs when the TOPIX showed a rise in the morning session except on December 8, 2014. This indicates that the BOJ's purchase probability was negligible when the TOPIX showed a rise in the morning session before the COVID-19 outbreak. In contrast, the BOJ purchased ETFs on March 2 and 19, 2020, although the TOPIX showed a substantial rise in the morning session.[6] In particular, the BOJ increased its daily purchase amount from 70.3 to 100.2 billion yen on March 2, 2020, and from 120.4 to 200.4 billion yen on March 19, 2020. These highly unexpected shocks in ETF purchases could have had very different impacts on the Nikkei 225 in the afternoon session of the TSE.

[6] The TOPIX in the morning session increased from the Tokyo close on the previous day by 1.11% on March 2, 2020, and by 1.47% on March 19, 2020.

4. The unexpected and expected BOJ purchase effects

In this section, we examine the BOJ's unexpected and expected ETF purchases effects on the Japanese stock prices, particularly after the COVID-19 outbreak in 2020. Since the BOJ decides its ETF purchases during the lunch break, we investigate the BOJ purchase effects on stock prices in the afternoon session of the TSE.

In the following estimation, we use the change (i.e., log difference) in the Nikkei 225 from 11:30 p.m. to 3 p.m. as the dependent variable.[7] We chose the Nikkei 225 because it is the premier representative of the stock price index of Japanese companies. The explanatory variables are the BOJ's unexpected and expected ETF purchase amounts.[8] To the extent of market efficiency, only the unexpected amounts will have a significant impact on stock prices. We estimate the GARCH(1,1) model as follows:

$$(3a) \quad \Delta s_t/s_t = \text{constant} + \alpha\, Unexpected_t + \beta\, Expected_t,$$

$$(3b) \quad \sigma_t^2 = \gamma_0 + \gamma_1 u_{t-1}^2 + \delta \sigma_{t-1}^2,$$

where $\Delta s_t/s_t$ is the Nikkei 225 growth rate (i.e., log difference) from 11:30 a.m. to 3 p.m on date t. $Unexpected_t$ and $Expected_t$ are the unexpected and expected ETF purchase amounts on date t, respectively. u_t is the disturbance term of equation (3a), and σ_t^2 is its time-dependent variance.

We estimate the above GARCH(1,1) model for four alternative subsamples: the Shirakawa regime and three subsamples in the Kuroda regime. The subsample period in the Shirakawa regime is from September 1, 2011, to March 19, 2013.[9] The three subsamples periods in the

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[7] The TSE is temporarily closed from 11:30a.m. to 12:30p.m. Thus, the Nikkei 225 at 11:30a.m. is considered to be its initial price of the afternoon session which does not reflect any information during the lunch break.

[8] The amount of BOJ purchases takes a positive value when the BOJ purchased ETFs and 0 otherwise. However, the unexpected amount takes either a positive or a negative value depending on the BOJ's purchase decision, whereas the expected amount always takes a positive value.

[9] The BOJ started to purchase ETFs in December 2010 in the Shirakawa regime. However, we

Kuroda regime are from March 20, 2013, to July 29, 2016; from August 1, 2016, to December 30, 2019; and from January 6, 2020, to July 31, 2020. The last subsample period in the Kuroda regime is after the COVID-19 outbreak, of which we have a special interest.

Depending on whether the probit model is with or without extra control variables, we have two sets of $Unexpected_t$ and $Expected_t$. Table 5 reports the estimation results for the four alternative subsamples using the set of $Unexpected_t$ and $Expected_t$. The coefficient of the unexpected amount is positive for all subsamples, and statistically significant except in the Shirakawa regime. Although it is relatively large for the first subsample in the Kuroda regime, it has a similar positive value for the other subsamples. This implies that larger unexpected purchases result in larger impacts on stock prices in the afternoon session.

In contrast, the coefficient of the expected amount is not statistically significant for any subsample. This is consistent with the efficient market hypothesis that expected changes have no significant impact on stock prices because their effects are already reflected in the market. Expected shocks might mitigate the stock price changes in a morning session, but have no further impact in the afternoon session.

This suggests that the BOJ's large-scale equity purchases after the COVID-19 outbreak had a large positive impact on Japanese stock prices because they were implemented in unprecedented ways. These unprecedented purchases might have been useful to mitigate the dramatic declines in stock prices following the crisis. However, large impacts do not necessarily mean that large-scale equity purchases have persistent positive effects on stock prices. This is because such impacts would disappear when the market participants update their expectations and forecast the BOJ's purchases accurately. Even large-scale purchases would have a significant impact on stock prices only if the BOJ continued to surprise the market participants.

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started our subsample period from September 1, 2011, in order to exclude the market participants' learning period to study the BOJ's purchasing rule. The subsample also excluded the market turbulence period after the Great East Japan earthquake and the Fukushima Daiichi nuclear disaster.

5. Estimation with lag dependent variables and global shocks

In the previous section, we estimated the GARCH model without any control variables in equation (3a). This section explores the robustness of our results with lag dependent variables and global shocks as control variables in equation (3a). The lag dependent variables included in the analysis are the Nikkei 225 growth rates from 11:30 a.m. to 3 p.m. on date t-1, from 3 p.m. on date t-1 to 9 a.m. on date t, and from 9 a.m. to 11:30 a.m. on date t. The global shocks are the growth rates of the NY Dow on date t-1 and those of volatility index (VIX) (created by the Chicago Board Options Exchange) on date t-1.

One concern with regard to the lag dependent variables in equation (3a) is that the growth rate from 9 a.m. to 11:30 a.m. is highly correlated with $Expected_t$. Since the expected ETF purchase amount increases when the Japanese stock prices fall in the morning session of the TSE, the growth rate from 9 a.m. to 11:30 a.m. can capture some of the expected ETF purchase shocks whose inclusion may bias the estimated coefficient of $Expected_t$. However, lag dependent variables have little correlation with $Unexpected_t$, and including the growth rate from 9 a.m. to 11:30 a.m. is less likely to bias the estimated coefficient of $Unexpected_t$.

Table 6 summarizes the growth rate correlations of the Nikkei from 9 a.m. to 11:30 a.m. with $Expected_t$ and $Unexpected_t$ respectively. The growth rate shows a significant negative correlation with $Expected_t$: around -36% in the Shirakawa regime and close to -40% in the Kuroda regime. In contrast, the growth rate had no significant correlation with $Unexpected_t$ in either regime.

Table 7 reports the estimation results with the control variables for the same subsamples used in the previous section. Neither the unexpected nor the expected amounts remained statistically significant in the Shirakawa regime. In contrast, the coefficient of the unexpected amount remained significantly positive and that of the expected amount remained insignificant for all subsamples in the Kuroda regime. The estimation results in the Kuroda regime are still consistent

with the efficient market hypothesis, where only unexpected shocks have significant impacts on stock prices. They confirm the view that the BOJ's large-scale equity purchases had positive impacts on stock prices after the COVID-19 outbreak because the BOJ's purchases were unanticipated.

6. Estimation based on tobit models

In the previous sections, we investigated the effects of unexpected and expected ETF purchases on Japanese stock prices. The analysis used probit models to derive the expected BOJ purchase amounts. The analysis was based on the assumption that market participants would know the BOJ's purchase amounts in each policy regime. However, we should explore the robustness of our results even when the market participants do not know when or what amount the BOJ would purchase. To explore the robustness, this section estimates tobit models to derive the BOJ's expected purchase amounts.

In the tobit models, the dependent variable y_t is equal to the BOJ's ETF purchase amount when it is positive and 0 otherwise. As with the probit models, the latent variable y^*_t is expressed by equation (1) with or without extra control variables (i.e., the NY Dow daily and Nikkei 225 intra-day changes). However, unlike with the probit models, the estimated tobit models can predict the amount of BOJ's purchases directly.

Table 8 reports the tobit model estimation results. They are essentially the same as those of the probit models. The policy dummies are negative, but most of them are not significant in the Shirakawa regime. However, dummies 11, 13, and 14 are significantly positive in the Kuroda regime, indicating that most of the policy changes increased the BOJ's purchases in QQE. More importantly, the changes in the TOPIX were always significantly negative. As with the probit models, tobit models reveal that the BOJ purchases ETFs when the Japanese stock prices have fallen substantially in the morning session of the TSE.

The estimated tobit models derive the BOJ's expected daily purchase amounts. We can calculate the unexpected ETF purchase amount by subtracting the expected amount from the realized amount. The expected and unexpected amounts are more volatile than those in the previous section because of the uncertainty on when and what amount the BOJ would purchase. Using the new sets of the BOJ's unexpected and expected purchase amounts, we estimate equations (3a) and (3b) for the four subsample periods. The explanatory variables are the unexpected and expected ETF purchase amounts derived by the tobit models.

Table 9 reports the estimation results for the four alternative subsamples. As in the previous sections, the estimated coefficients in the Shirakawa regime are not statistically significant. In contrast, those in the Kuroda regime are essentially the same as in the previous sections. The coefficient of the unexpected amount is positive at a marginal significance level for the first subsample. However, it is positive at the 2% significant level for the other two subsamples. Unlike in the previous sections, the coefficient of the expected amount took a significant negative value for the third subsample. However, it was less significant for the other two subsamples. Laying aside the negative impacts of the expected purchases for the third subsample, the results in the Kuroda regime are still consistent with the efficient market hypothesis that only unexpected shocks have significant impacts on stock prices. Even with the tobit models, we can conclude that the BOJ's large-scale equity purchases have positive impacts on stock prices because the BOJ's purchases are unanticipated.

7. The BOJ's purchase effects on price changes for different time zones

This section explores the effects of BOJ's purchases on stock prices for different time zones. In the previous sections, we investigated the effects of BOJ's purchases on stock prices from 11:30 a.m. to 3 p.m. However, to the extent of market efficiency, the stock prices would respond to news instantaneously. We therefore need to consider the impacts using data from different time zones

with higher frequency.

In the analysis, we examine the impacts on the Nikkei 225 growth rate (i.e., log difference) from 11:30 a.m. (i.e., morning close) to 12:45 p.m., from 12:45 p.m. to 2 p.m., and from 2 p.m. to 3 p.m. (i.e., afternoon close). If the stock prices are instantaneously adjusted in the first 15 minutes of the afternoon session, we would observe significant effects only from 11:30 a.m. to 12:45 p.m.[10] However, in case of some delayed adjustments, we would observe significant effects even from 12:45 p.m. to 2 p.m. and from 2 p.m. to 3 p.m.

By replacing the dependent variable with the price changes for a different time zone, we can estimate the GARCH(1,1) model and explore the effects of unexpected and expected ETF purchases on the Nikkei 225. Except for the dependent variable, the explanatory variables are the same as those in section 4. Table 10 summarizes the estimation results for each dependent variable. Since most of the estimated coefficients in the Shirakawa regime are insignificant, the table reports the estimation results for the three subsamples in the Kuroda regime.

When using the data from 11:30 a.m. to 12:45 p.m., the unexpected amount has a significantly positive impact for all subsamples. However, unlike in the previous sections, its coefficient takes the largest value for the last subsample. This indicates that the unexpectedly large amount of ETF purchases in the Kuroda regime increased the stock prices instantaneously, with impacts becoming larger after the COVID-19 outbreak. In contrast, the expected amount shows no significant impacts for the last subsample, and takes a negative coefficient value for the other two subsamples. The negative signs might reflect some learning process of the BOJ's ETF purchases for the first and second subsamples.

When using the data from 12:45 p.m. to 2 p.m., the unexpected amount still has a significant positive impact for the first and second subsamples, but no significant impact for the third subsample. This implies that unexpected ETF purchases had persistent positive impacts before,

[10] Because of the lunch break from 11:30a.m. to 12:30p.m, the Nikkei 225 at 11:30a.m. is considered to be its initial price of the afternoon session.

but not after the COVID-19 outbreak. The larger the ETF purchase, the more easily can the market participants infer the purchase. Unexpected purchases are not likely to have significant impacts from 12:45 p.m. to 2 p.m. for the last subsample because market participants can infer large-scale purchases in the first 15 minutes of the afternoon session. In contrast, the expected amount shows no significant impact for the first and second subsamples, but has a significantly negative impact for the third subsample. If unexpected large-scale purchases continue, market participants may have excessive expectations on purchase amounts in the following periods. The negative impacts of expected purchases for the last subsample might be attributed to such excessive expectations.

With the data from 2 p.m. to 3 p.m., the unexpected amount showed no significant positive impact for any subsample period. This implies that unexpected purchases have no positive impacts after the first 1.5 hours of the afternoon session. Since 1.5 hours is a sufficiently long period for market participants to identify the BOJ's ETF purchases, unexpected ETF purchases are not likely to have positive impacts even for the first and second subsamples. However, the expected amount showed different effects depending on the subsamples. They were insignificant for the first subsample, significantly positive for the second subsample, and significantly negative for the third subsample. These inconsistent results might have risen because several exogenous shocks which were independent of the BOJ's ETF purchases had occurred in late afternoons.

8. Concluding remarks

This study examined how the BOJ's large-scale equity purchases affected the Nikkei 225 when the COVID-19 pandemic broke out in 2020. We found that the unexpected purchases had large positive impacts on intraday returns but the unexpected purchases did not. The estimation results suggest that the large impacts arose because most of the purchases came as big surprises to the markets. Thus, large-scale equity purchases increased the stock prices only when the purchasing exceeded the expected value.

Table 11 summarizes the average Nikkei 225 growth rates from 11:30 a.m. (i.e., morning close) to 12:45 p.m. for the three subsamples in the Kuroda regime. In calculating the growth rates, the day following the Brexit referendum on June 23, 2016, and the day following the US presidential election on November 8, 2016, are excluded from the samples as outliers.[11] A comparison of the impacts with and without the BOJ purchases shows that the average growth rate was positive on days when the BOJ purchased ETFs and negative on days when the BOJ did not purchase ETFs. The contrasting features are most conspicuous when the COVID-19 pandemic caused serious market turbulence in 2020. The last subsample showed that the Nikkei 225 increased by more than 10% on days when the BOJ purchased ETFs and declining by more than 10% on days when the BOJ did not purchase ETFs. Thus, during the COVID-19 pandemic, stock prices in the afternoon session rose dramatically when the BOJ purchased equities and declined substantially when the BOJ did not purchase equities.

To the extent that the unexpected large-scale purchases continued, the BOJ's purchases will have positive impacts. However, the larger the unexpected purchases, the more excessively would the market participants expect future purchases. Once the market participants have excessive expectations, even large-scale purchases would have negative impacts on the stock prices, unless the amount is within the expectations. Under these circumstances, the surprise policy would not be effective unless the BOJ continues to surprise the market.

[11] For the Brexit referendum and the US presidential election, critical information on the voting results was revealed around the lunch time in Tokyo.

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Table 1. Timeline of ETF purchase program

Announcement Date	Key Features
October 28, 2010	Intention to purchase about 450 billion yen of ETFs announced (conditional on obtaining authorization)
November 5, 2010	Principal terms and conditions announced: ETFs to track TOPIX and Nikkei 225
March 14, 2011	Total intended amount doubles to about 900 billion (conditional on obtaining authorization)
August 4, 2011	Total intended amount of ETF purchases increased to about 1.4 trillion (conditional on authorization)
April 27, 2012	Total intended amount of ETF purchases increased to about 1.6 trillion (conditional on authorization)
October 30, 2012	Total intended amount increased to about 2.1 trillion (conditional on obtaining authorization)
January 22, 2013	Introduction of the "open-ended asset purchasing method", a method without setting any termination date.
April 4, 2013	Introduction of the "Quantitative and Qualitative Monetary Easing (QQE)".
	Overall cap abandoned, intention to purchase about 1 trillion yen of ETFs annually announced
October 31, 2014	Annual ETF purchases tripled to about 3 trillion yen; JPX Nikkei 400 added to the list of indexes
December 18, 2015	Supplementary measures for QQE: annual purchases of 300 billion ETFs to support firms' investment in physical and human capital; Annual ETF purchases increased to about 3.3 trillion yen.
July 29, 2016	Annual ETF purchases tripled to about 6 trillion yen (almost double the previous pace).
July 31, 2018	Flexibility in the amount of purchases allowed depending on market conditions. The amount of ETFs to track TOPIX increased.
December 19, 2019	Introduction of the ETF Lending Facility
March 16, 2020	Enhancement of monetary easing in light of the impact of the outbreak of the COVID-19.
	For the time being, the amounts outstanding of ETFs will increase at annual paces with the upper limit
	of about 12 trillion yen.

Table 2. Frequency of purchases and average amount per purchase

sub-sample periods	purchase frequency	average amount per purchase	BOJ governor
December 1, 2010 - March 19, 2013	12.0%	22.7 billion yen	Shirakawa
March 20, 2013 - July 29, 2016	32.6%	26.8 billion yen	Kuroda
August 1, 2016 - December 30, 2019	31.0%	71.2 billion yen	Kuroda
January 6, 2020 - July 31, 2020	36.4%	104.6 billion yen	Kuroda

Table 3. Stock price growth rates in the morning session

unit: %

	days of ETF purchases		days of no purchase	
	Nikkei225	TOPIX	Nikkei225	TOPIX
December 1, 2010 - March 19, 2013	-1.67	-1.67	0.28	0.27
March 20, 2013 - July 29, 2016	-1.10	-1.11	0.57	0.55
August 1, 2016 - December 30, 2019	-0.83	-0.81	0.43	0.39
January 6, 2020 - July 31, 2020	-1.45	-1.33	0.90	0.68

Table 4. Probit model estimation results

	Shirakawa regime		Kuroda regime	
	A	B	A	B
constant term	-3.830	-3.946	-1.417	-1.458
	(-5.74)***	(-5.71)***	(-11.77)***	(-11.81)***
$\Delta S^1/S^1$	-5.216	-5.456	-3.327	-3.455
	(-7.05)***	(-6.90)***	(-20.52)***	(-20.12)***
$\Delta S^2/S^2$	-5.205	-6.075	-3.186	-2.915
	(-6.41)***	(-5.39)***	(-19.08)***	(-14.38)***
dummy 1	-1.875	-2.181	0.433	0.434
	(-2.75)***	(-2.92)***	(2.65)***	(2.63)***
dummy 2	-1.605	-1.659	-0.228	-0.239
	(-2.70)***	(-2.73)***	(-0.99)	(-1.02)
dummy 3	-1.731	-1.874	0.288	0.307
	(-2.81)***	(-2.95)***	(2.23)**	(2.34)**
dummy 4	-1.854	-1.786	0.213	0.214
	(-2.52)**	(-2.34)**	(0.95)	(0.94)
$\Delta Nikkei^1/Nikkei^1$		1.110		-0.609
		(0.97)		(-2.77)***
$\Delta Nikkei^2/Nikkei^2$		1.127		-0.479
		(1.26)		(-2.40)**
$\Delta DOW/DOW$		-0.210		0.077
		(-1.15)		(1.44)
number of observations	600	600	1923	1923
McFadden R-squared	0.837	0.844	0.630	0.635

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

Table 5. GARCH(1, 1) model estimation

		Shirakawa regime		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B	A	B
	constant term	-0.003	-0.004	-0.069	-0.069	-0.012	-0.015	0.030	0.024
		(-0.14)	(-0.15)	(-2.44)**	(-2.46)**	(-0.71)	(-0.88)	(0.65)	(0.53)
(3a)	*unexpected pur.*	0.179	0.208	0.873	0.846	0.452	0.436	0.373	0.355
		(0.21)	(0.23)	(2.48)**	(2.45)**	(6.13)***	(5.88)***	(3.67)***	(3.56)***
	expected pur.	-0.511	-0.502	-0.002	0.009	0.015	0.036	-0.108	-0.084
		(-1.26)	(-1.26)	(-0.01)	(0.05)	(0.31)	(0.74)	(-1.18)	(-0.95)
	Constant term	0.077	0.077	0.040	0.040	0.026	0.024	0.012	0.011
		(2.49)**	(2.47)**	(4.81)***	(4.82)***	(6.47)***	(6.33)***	(1.61)	(1.54)
(3b)	u_{t-1}^2	0.202	0.200	0.245	0.244	0.137	0.127	0.397	0.402
		(2.75)***	(2.75)***	(10.58)***	(10.62)***	(5.77)***	(5.70)***	(3.70)***	(3.66)***
	σ_{t-1}^2	0.477	0.479	0.762	0.762	0.719	0.741	0.670	0.674
		(2.82)***	(2.83)***	(33.27)***	(33.59)***	(17.53)***	(19.15)***	(9.82)***	(9.97)***
number of observations		404	404	878	878	892	892	153	153

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

Table 6. Correlation of *Unexpected*$_t$ and *Expected*$_t$ with the Nikkei225 in the morning

	Expected amount		Unexpected amount	
	A	B	A	B
Whole sample	-36.7%	-36.5%	-2.5%	-2.9%
Shirakawa	-35.8%	-36.8%	-1.0%	0.2%
Kuroda	-39.6%	-39.3%	-2.7%	-3.2%

Table 7. Estimation with control variables

		Shirakawa regime		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B	A	B
	constant term	-0.044	-0.042	-0.072	-0.073	-0.008	-0.012	0.027	0.017
		(-1.73)*	(-1.66)*	(-2.28)**	(-2.29)**	(-0.43)	(-0.68)	(0.47)	(0.30)
(3a)	*unexpected pur.*	-0.274	-0.144	0.889	0.871	0.408	0.393	0.312	0.289
		(-0.29)	(-0.14)	(2.54)**	(2.55)**	(6.94)***	(6.69)***	(2.55)**	(2.44)**
	expected pur.	0.586	0.516	7.46E-02	0.0843	0.006	0.032	-0.146	-0.114
		(1.12)	(1.05)	(0.33)	(0.38)	(0.09)	(0.45)	(-0.97)	(-0.74)
	$\Delta NikkeiA$(-1)	-0.028	-0.029	-0.151	-0.152	-0.052	-0.054	-0.038	-0.041
		(-0.48)	(-0.49)	(-3.86)***	(-3.87)***	(-1.41)	(-1.46)	(-0.30)	(-0.33)
	$\Delta NikkeiN$	0.101	0.100	0.014	0.015	0.014	0.021	-0.059	-0.052
		(2.67)***	(2.64)***	(0.32)	(0.33)	(0.48)	(0.72)	(-1.06)	(-0.94)
	$\Delta NikkeiM$	0.185	0.180	0.056	0.057	0.100	0.104	0.067	0.075
		(3.25)***	(3.21)***	(1.80)*	(1.81)*	(5.71)***	(5.85)***	(1.73)*	(1.90)*
	ΔDOW(-1)	0.022	0.022	-0.034	-0.034	-0.113	-0.114	0.036	0.036
		(0.55)	(0.54)	(-0.55)	(-0.53)	(-4.86)***	(-4.95)***	(0.95)	(0.94)
	ΔVIX(-1)	0.004	0.004	-0.002	-0.002	-0.005	-0.005	0.004	0.004
		(0.73)	(0.75)	(-0.29)	(-0.28)	(-2.80)***	(-2.82)***	(0.69)	(0.67)
	Constant term	0.091	0.090	0.035	0.035	0.027	0.027	0.010	0.010
		(2.37)**	(2.42)**	(4.24)***	(4.24)***	(5.60)***	(5.60)***	(1.51)	(1.51)
(3b)	u_{t-1}^2	0.221	0.226	0.258	0.258	0.353	0.357	0.428	0.433
		(2.61)***	(2.65)***	(9.56)***	(9.55)***	(7.89)***	(8.00)***	(3.43)***	(3.41)***
	σ_{t-1}^2	0.385	0.384	0.761	0.762	0.569	0.568	0.649	0.649
		(1.86)*	(1.89)*	(29.57)***	(29.73)***	(12.34)***	(12.41)***	(8.43)***	(8.38)***
number of observations		404	404	878	878	892	892	153	153

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

3) Δ*NikkeiA*(-1), Δ*NikkeiN*, and Δ*NikkeiM* are the Nikkei 225 growth rates from 11:30 a.m. to 3 p.m. on date t-1, from 3 p.m. on date t-1 to 9 a.m. on date t, and from 9 a.m. to 11:30 a.m. on date t, respectively. Δ*DOW*(-1) and Δ*VIX*(-1) are the NY Dow and VIX growth rates on date t-1, respectively.

Table 8. Tobit model estimations

	Shirakawa regime		Kuroda regime	
	A	B	A	B
constant term	-0.325	-0.325	-0.582	-0.588
	(-5.62)***	(-5.77)***	(-13.75)***	(-13.88)***
$\Delta S^1/S^1$	-0.322	-0.357	-0.571	-0.612
	(-9.27)***	(-9.36)***	(-21.97)***	(-22.18)***
$\Delta S^2/S^2$	-0.131	-0.054	-0.386	-0.205
	(-5.32)***	(-1.83)*	(-15.16)***	(-5.25)***
dummy 1	-0.091	-0.107	0.236	0.235
	(-1.46)	(-1.75)*	(4.43)***	(4.43)***
dummy 2	-0.051	-0.065	0.017	0.012
	(-0.93)	(-1.23)	(0.26)	(0.18)
dummy 3	-0.012	-0.030	0.363	0.370
	(-0.20)	(-0.54)	(8.61)***	(8.80)***
dummy 4	-0.101	-0.131	0.647	0.655
	(-1.37)	(-1.79)*	(9.14)***	(9.34)***
$\Delta Nikkei^1/Nikkei^1$		-0.133		-0.325
		(-2.56)**		(-5.42)***
$\Delta Nikkei^2/Nikkei^2$		-0.238		-0.246
		(-3.11)***		(-4.77)***
$\Delta DOW/DOW$		-0.019		0.005
		(-1.36)		(0.36)
Error Distribution□	0.204	0.193	0.490	0.483
	(9.92)***	(10.01)***	(29.94)***	(30.00)***
number of observations	600	600	1923	1923

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

Table 9. Estimation based on tobit models

		Shirakawa regime		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B	A	B
	constant term	-0.005	-0.003	-0.085	-0.084	-0.013	-0.013	0.024	0.029
		(-0.21)	(-0.12)	(-3.11)***	(-3.08)***	(-0.86)	(-0.85)	(0.44)	(0.53)
(3a)	*unexpected pur.*	-0.306	-0.124	0.319	0.339	0.288	0.294	0.210	0.240
		(-0.71)	(-0.28)	(1.63)	(1.70)*	(6.79)***	(6.82)***	(2.46)**	(2.66)***
	expected pur.	-0.474	-0.662	0.262	0.258	-0.064	-0.061	-0.232	-0.244
		(-0.64)	(-0.97)	(1.65)*	(1.63)	(-1.43)	(-1.37)	(-2.02)**	(-2.08)**
	Constant term	0.076	0.076	0.041	0.042	0.035	0.035	0.017	0.016
		(2.42)**	(2.45)**	(4.73)***	(4.71)***	(6.75)***	(6.53)***	(1.67)*	(1.58)
(3b)	u_{t-1}^2	0.197	0.198	0.240	0.240	0.221	0.226	0.421	0.406
		(2.73)***	(2.73)***	(8.79)***	(9.00)***	(6.48)***	(6.46)***	(3.57)***	(3.43)***
	s_{t-1}^2	0.487	0.485	0.761	0.762	0.604	0.597	0.637	0.649
		(2.86)***	(2.86)***	(30.30)***	(30.55)***	(11.71)***	(11.21)***	(8.13)***	(8.46)*
number of observations		404	404	878	878	892	892	153	153

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

Table 10. Effects on the Nikkei 225 for different time zones

(1) The Nikkei 225 from morning, close to 12:45 p.m.

		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B
	constant term	0.016	0.016	0.002	0.001	0.011	0.007
		(0.97)	(0.97)	(0.21)	(0.13)	(0.28)	(0.17)
(3a)	*unexpected pur.*	0.271	0.259	0.265	0.261	0.330	0.315
		(1.82)*	(1.71)*	(5.55)***	(5.49)***	(3.85)***	(3.64)***
	expected pur.	-0.526	-0.536	-0.051	-0.045	0.019	0.030
		(-5.63)***	(-5.78)***	(-1.65)*	(-1.46)	(0.30)	(0.47)
	Constant term	0.012	0.012	0.010	0.010	0.007	0.007
		(6.04)***	(5.99)***	(2.43)**	(2.53)**	(2.17)**	(2.16)**
(3b)	u_{t-1}^2	0.311	0.319	0.035	0.038	0.163	0.161
		(8.19)***	(8.41)***	(2.18)**	(2.25)**	(2.12)**	(2.08)**
	σ_{t-1}^2	0.746	0.742	0.776	0.765	0.796	0.800
		(32.95)***	(33.44)***	(8.59)***	(8.44)***	(10.48)***	(10.63)***
number of observations		878	878	892	892	153	153

(2) Nikkei 225 from 12:45 p.m. to 2 p.m.

		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B
	constant term	-0.025	-0.026	0.007	0.007	0.044	0.044
		(-1.82)*	(-1.86)*	(0.92)	(0.89)	(1.28)	(1.33)
(3a)	*unexpected pur.*	0.39	0.379	0.136	0.136	0.027	0.030
		(2.26)**	(2.22)**	(3.98)***	(3.86)***	(0.33)	(0.39)
	expected pur.	5.36E-03	0.0104	0.008	0.010	-0.173	-0.173
		(0.05)	(0.11)	(0.36)	(0.45)	(-2.60)***	(-2.60)***
	Constant term	0.021	0.021	0.001	0.001	0.011	0.011
		(7.63)***	(7.66)***	(4.82)***	(4.85)***	(3.33)***	(3.24)***
(3b)	u_{t-1}^2	0.248	0.248	0.086	0.088	0.686	0.671
		(11.82)***	(11.78)***	(9.38)***	(9.35)***	(3.76)***	(3.77)***
	σ_{t-1}^2	0.686	0.686	0.892	0.890	0.487	0.494
		(30.86)***	(30.80)***	(81.23)***	(80.24)***	(5.77)***	(5.81)***
number of observations		878	878	892	892	153	153

Table 10. Effects on the Nikkei 225 for different time zones (continued)

(3) The Nikkei 225 from 2 p.m. to the afternoon close.

		Kuroda regime I		Kuroda regime II		Kuroda regime III	
		A	B	A	B	A	B
	constant term	-0.023	-0.024	-0.022	-0.022	0.020	0.017
		(-1.14)	(-1.19)	(-2.83)***	(-2.91)***	(0.91)	(0.77)
(3a)	*unexpected pur.*	0.333	0.299	0.044	0.037	0.012	-0.015
		(1.48)	(1.35)	(1.12)	(0.97)	(0.10)	(-0.14)
	expected pur.	0.103	0.118	0.120	0.123	-0.118	-0.11
		(0.97)	(1.11)	(6.25)***	(6.37)***	(-2.96)***	(-2.70)***
	Constant term	0.026	0.026	0.001	0.001	0.002	0.002
		(4.94)***	(4.96)***	(5.12)***	(5.10)***	(1.02)	(1.02)
(3b)	u_{t-1}^2	0.151	0.152	0.096	0.096	0.332	0.331
		(5.05)***	(5.10)***	(9.45)***	(9.41)***	(4.18)***	(4.09)***
	σ_{t-1}^2	0.748	0.747	0.889	0.889	0.746	0.746
		(17.35)***	(17.42)***	(88.93)***	(87.97)***	(17.73)***	(17.32)***
number of observations		878	878	892	892	153	153

Notes: 1) z-statistics are in parenthesis.

2) ***: 1% significance level; **: 5% significance level; and *: 10% significance level.

Table 11. The Nikkei 225 growth rates from morning close to 12:45 p.m.

unit: %

	days of purchases	days of no purchase
March 20, 2013 - July 29, 2016	0.86%	-0.25%
August 1, 2016 - December 30, 2019	3.87%	-4.79%
January 6, 2020 - July 31, 2020	13.66%	-11.47%

Figure 1. The Nikkei 225 and NY Dow from February 2020 to April 2020

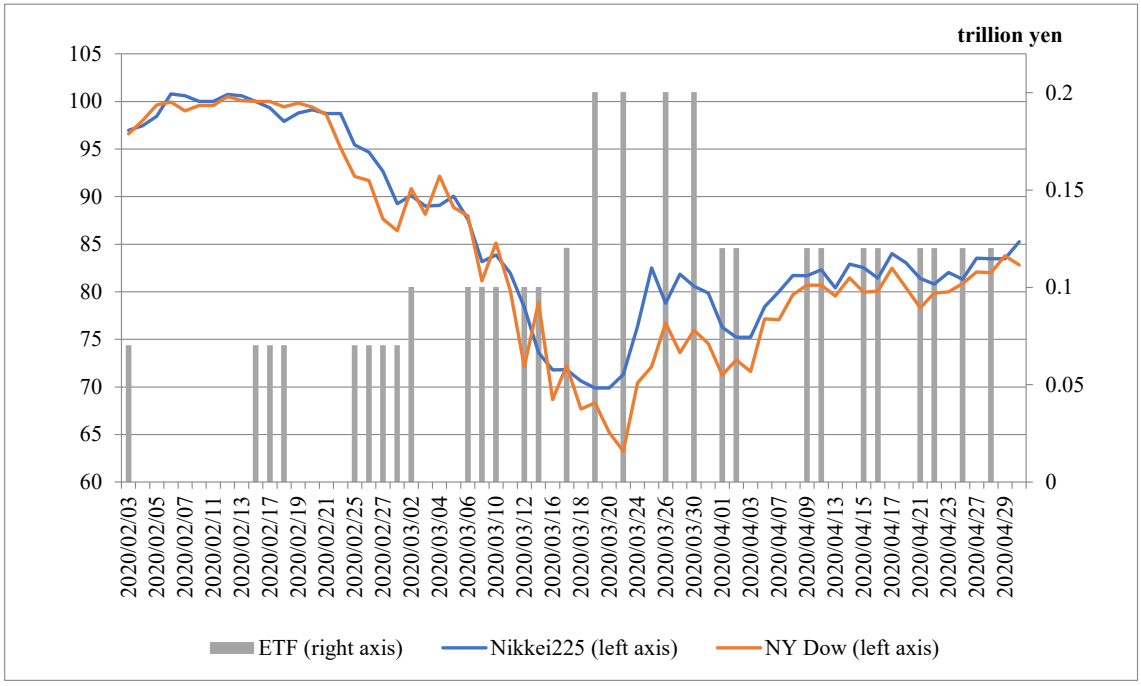
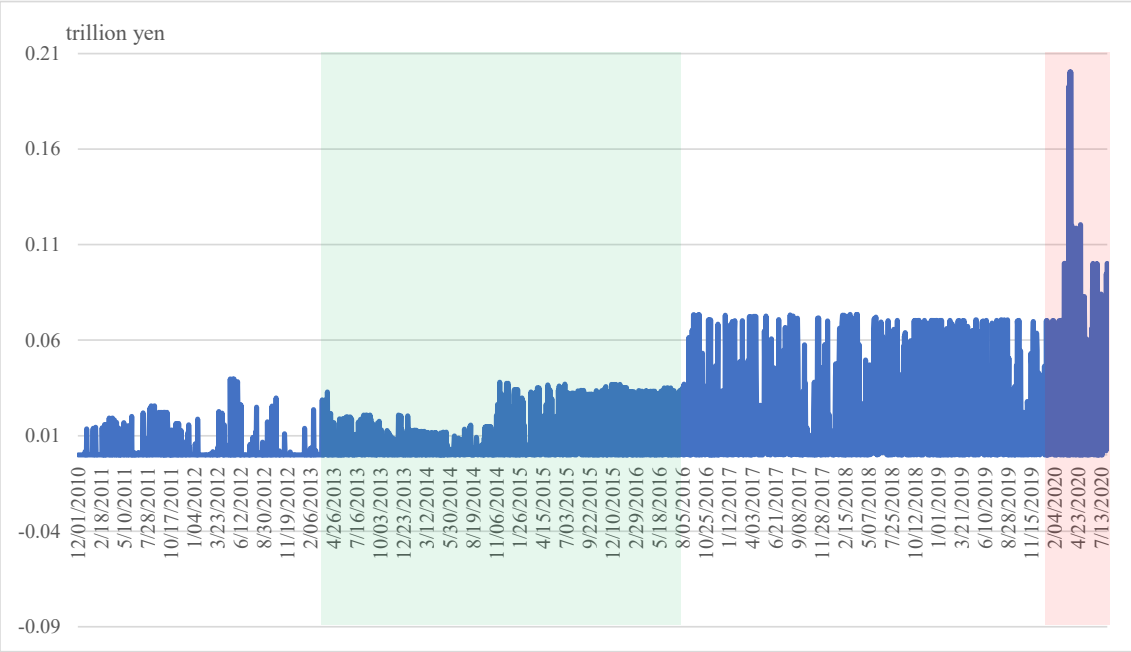


Figure 2. Expected and unexpected BOJ purchase amounts

(1) Expected amount



(2) Unexpected amount