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Hibiki Ichiue

Research Project on Central Bank Communication
702 Faculty of Economics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5841-5595 E-mail: watlab@e.u-tokyo.ac.jp
http://www.centralbank.e.u-tokyo.ac.jp/en/

The Bank of Japan's Stock Holdings and Long-term Returns*

Hibiki Ichiue†

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Abstract

The Bank of Japan (BoJ) purchased equity index exchange-traded funds (ETFs), including Nikkei 225 ETFs, for over a decade and has not sold any ETFs it purchased. On March 31, 2021, the BoJ's ETF holdings were more than 10% of the free float of the First Section of the Tokyo Stock Exchange. Primarily because the Nikkei index is price-weighted, the BoJ's indirect holdings as a percentage of the market capitalization vary widely among individual stocks. To identify the effects of the uneven demand shocks, this paper runs instrumental-variable cross-sectional regressions of cumulative returns between September 30, 2010, a few days before the first announcement of ETF purchases, and March 31, 2021, when the BoJ terminated Nikkei 225 ETF purchases. The results suggest that the price multiplier is around 6 to 9; a 1 percentage point higher BoJ share in a stock's market capitalization is associated with a roughly 6 to 9 percentage point higher return. The estimated multiplier is much higher than a typical estimate of 1 based on U.S. data. There is no evidence of a return reversal in the 9 months after Nikkei 225 ETF purchases ended. Various analyses, including monthly return regressions, support the analysis of cumulative returns and provide additional insights.

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† Faculty of Economics, Keio University; hichiue@keio.jp

1. Introduction

Many empirical studies find that demand for stocks influences stock prices. The literature often estimates the price multiplier, the percent change in the price of a particular stock when investors purchase 1% of the market capitalization of that stock. Gabaix and Koijen's (2022) survey suggests that a typical estimate of the price multiplier is about 1.[1] On the other hand, finance theory indicates that the impact of demand shocks on asset prices depends on the nature of demand. For instance, if demand shocks are expected to be more persistent, the impact is larger since asset prices reflect not only current but also expected demand. To contribute to this literature and the literature on unconventional monetary policy, this paper explores a unique natural experiment, the Bank of Japan's (BoJ's) persistent holdings of equity index exchange-traded funds (ETFs).

The BoJ made the first announcement of ETF purchases on October 5, 2010. The announcement stated that it would examine establishing a program to purchase financial assets, such as ETFs and government bonds, as part of its unconventional monetary policy. After completing preparations, the BoJ began purchasing ETFs in December 2010. It continued to do so for more than a decade while making numerous revisions to the size and composition of ETFs it purchased. At the end of March 2021, the market value of its holdings stood at 51.5 trillion yen. This is more than 7% of the market capitalization of issued stocks and more than 10% of the free-float market capitalization of the First Section of the Tokyo Stock Exchange (TSE), Japan's main stock market at the time.[2]

Most ETFs held by the BoJ are benchmarked to one of the two major indexes, the Tokyo Stock Price Index (TOPIX) and the Nikkei 225 index. The TOPIX is a free float-

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[1] As discussed by Gabaix and Koijen (2022), there are several different definitions of price multiplier. This paper focuses on the micro multiplier, which is defined as the price multiplier when controlling for movements in the aggregate market. This definition is discussed in detail in Appendix B in the online appendix.

[2] According to the Flow of Funds Accounts, the market capitalization of all listed stocks in Japan was 808 trillion yen on March 31, 2021. Meanwhile, the number of stocks listed on the First Section of the TSE exceeded 2,000, and the total market value of all issued stocks was 723 trillion yen (89.4% of all listed stocks in Japan) on that day. The First Section of the TSE no longer exists since, in April 2022, the TSE reorganized the old market segments, including the First Section, into the new market segments.

adjusted market capitalization-weighted index representing essentially all stocks listed on the First Section of the TSE. On the other hand, the Nikkei index is basically a simple average of the prices per share of only 225 stocks selected by a newspaper company. Therefore, the BoJ's holdings of Nikkei 225 ETFs produce variation in the amount of individual stocks indirectly held by the BoJ via ETFs as a percentage of their market capitalization. Meanwhile, the Nikkei 225 index rose more steeply than the TOPIX after the start of ETF purchases. Against this backdrop, there was concern that the BoJ's ETF purchases greatly distorted stock prices. To address such concern, the BoJ terminated its purchases of Nikkei 225 ETFs at the end of March 2021. The BoJ, however, has not sold any of the ETFs it purchased and, therefore, still holds a large amount of Nikkei 225 ETFs.

To estimate the effects of central bank asset purchases on financial markets, the literature typically conducts event studies. One issue with this approach is that it relies on the assumption that market participants form expectations of future purchases, which are reflected in prices, in a short period immediately after an announcement by the central bank, while at other times, those expectations remain unchanged. This assumption is questionable for the BoJ's ETF purchases, particularly after the BOJ moved to open-ended ETF purchases when it introduced Quantitative and Qualitative Monetary Easing (QQE) to achieve its price stability target of 2% inflation in April 2013. Given that the BoJ made many revisions to the ETF purchase policy while continuing to fail to meet its 2% target, it is plausible that market participants, closely following inflation and other information, updated their expectations regarding the size, composition, and duration of ETF purchases at every opportunity.

To identify the effects of the BoJ's ETF holdings, this paper exploits the cross-sectional variation in the amount of BoJ holdings as a percentage of market capitalization. Specifically, the baseline analysis runs instrumental-variable cross-sectional regressions of stock-level raw or abnormal returns between September 30, 2010, a few days before the first announcement of ETF purchases, and March 31, 2021, on the share of BoJ holdings in the market capitalization on March 31, 2021. Key to the analysis is the use of returns to the time after the BoJ ended its purchases of Nikkei 225 ETFs. While stock prices should have reflected market expectations of the BoJ's future purchases before the end of Nikkei 225 ETF purchases, there have been no such expectations since then. Therefore, the method used in this paper makes it possible to identify the effects of BoJ holdings on stock returns without being seriously contaminated by unobservable expectations.

Figure 1 plots the log excess total returns of individual stocks against the BoJ holding ratio, which is defined as BoJ holdings as a percentage of a measure of free float. The details of data construction are provided in Sections 4 and 5. The black circles represent stocks included in the Nikkei index on March 31, 2021, while the grey circles represent those not. The figure clearly shows that Nikkei 225 members play a dominant role in the variation of the BoJ holding ratio. When focusing on the Nikkei index members, there appears to be a clear positive relationship, suggesting that a higher BoJ holding ratio is associated with a higher return. This paper investigates the causal relationship between them.

The results show that the effects of BoJ holdings are very large. The baseline regressions suggest that the price multiplier is around 6; a stock's return is about 6 percentage points higher for each 1 percentage point increase in the BoJ share in the free float. The multiplier is estimated to be around 8 to 9 when BoJ holdings are normalized by shares outstanding, as in many studies on U.S. data. The estimated multiplier is much higher than typical estimates in the literature. Moreover, there is no evidence of a return reversal in the 9 months since the BoJ terminated purchases of Nikkei 225 ETFs. Various analyses, including Fama-Macbeth (1973) regressions based on monthly returns, support the results of the baseline analysis and provide additional insights. This study also investigates investment demand from non-BoJ investors and finds that such demand is unlikely to contaminate the identification. The large effects of BoJ holdings may be attributed to the semi-permanent nature of BoJ holdings, which is in line with finance theory that suggests that more persistent demand shocks have larger effects.

The rest of this paper is organized as follows. Section 2 reviews the literature. Section 3 provides an overview of the BoJ's ETF purchases. Section 4 estimates the BoJ's holdings of individual stocks. Section 5 discusses the baseline regression model and presents the results. Section 6 shows alternative regression results and discusses various issues. Section 7 concludes this paper. The online appendix contains supplemental tables and figures, details, a theoretical model, and additional analysis.

2. Literature Review

The literature on central bank asset purchases distinguishes between flow and stock effects (D'Amico and King, 2013). Flow effects are defined as the response of prices to ongoing purchasing operations. On the one hand, flow effects may simply reflect short-run liquidity effects. On the other hand, flow effects may understate the overall effect of central bank asset purchases: for instance, if, as a result of the announcement of an asset purchase policy, market prices already incorporate the expected impact of the purchases, the market response to the actual purchases may be weak. Since policymakers are interested in the persistent overall effects of central bank asset purchases, the literature often focuses on stock effects, which can be defined as persistent changes in asset prices resulting from changes in actual and expected central bank holdings. This paper also estimates the stock effects of the BoJ's ETF holdings.

The literature typically conducts event studies to estimate stock effects of central bank asset purchases (Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2011; Joyce et al., 2012, among others). However, event studies may fail to capture the true effect, for example, if market participants expected the policy changes to some extent prior to the event windows, if the possibility of additional easing in the future is factored in at the time of the policy announcements, or if event studies ignore important events, such as speeches by central bank officials.[3] To address this sort of critique, D'Amico and King (2013) employ cross-sectional regressions of security-level cumulative returns in estimating the stock effects of Treasury purchases by the Federal Reserve. This paper applies their method to the BoJ's ETF purchases.

Many studies on the BoJ's ETF purchases investigate the flow effects (Matsuki et al., 2015; Shirota, 2018; Harada and Okimoto, 2021; Charoenwong et al., 2021; Fukuda and Tanaka, 2022; Fukui and Yagasaki, 2022; Hattori and Yoshida, 2023; among others). On the other hand, only a few papers examine the stock effects of the BoJ's ETF purchases, and

[3] For critics and discussions of event studies, see Wright (2011), Ramey (2016), Greenwood et al. (2018), Neuhierl and Weber (2019), Cieslak et al. (2019), Bauer and Swanson (2023), and Haddad et al. (2023), among others.

these rely on event studies on a small number of events. Barbon and Gianinazzi (2019) conduct an event study focusing on BoJ announcements in October 2014 and July 2016. Katagiri et al.'s (2022a) event study examines the effect of the March 2021 Monetary Policy Meeting. The literature generally finds that the ETF purchase policy had a positive impact on stock prices.

To identify the stock effects, this paper exploits the fact that the BoJ's holdings reflect the weights of the Nikkei 225 index. The use of the uneven demand shocks resulting from the weights of the Nikkei 225 for identification is not new. For instance, Charoenwong et al. (2021) and Barbon and Gianinazzi (2019) take advantage of the skewed BoJ purchases to identify flow and stock effects, respectively. Similarly, Greenwood (2005) exploits the skewed weighting system of the Nikkei 225 index to examine the impact of the redefinition of the Nikkei index in April 2000.

The vast literature, beginning with Shleifer (1986) and Harris and Gurel (1986), examines the impact of demand shocks on stock returns or estimates the price multiplier, often focusing on short-term price changes when firms are added to stock indexes in the U.S. Gabaix and Koijen's survey (2022) suggests that a typical price multiplier is about 1. Several studies report higher multipliers, ranging between 2 and 5 (Chang et al., 2015; Greenwood et al., 2023). The multiplier obtained in this study is even higher than these estimates; it is around 8 to 9 when demand shocks are normalized by shares outstanding, following many studies on U.S. data. To the best of the author's knowledge, only Barbon and Gianinazzi (2019) estimate the price multiplier of the stock effects of the BoJ's ETF purchases. Again, the estimate in this paper is much higher than theirs of around 1. This comparison suggests that it may be difficult to fully capture the stock effects of the BoJ's policy using event studies, on which Barbon and Gianinazzi (2019) rely.

3. Background

This section overviews the BoJ's ETF purchases. For more details, see Table A1 in the online appendix, which summarizes the BoJ's key announcements. The BoJ made the first announcement of ETF purchases on October 5, 2010, which took market participants by surprise. After completing preparations, the BoJ began purchasing ETFs in December 2010. Since then, the BoJ has revised its ETF purchase policy many times.

The ETF purchases started as a temporary measure that was supposed to be terminated by around the end of 2011, with a maximum outstanding amount of ETFs of only around 0.45 trillion yen. The BoJ, however, repeatedly increased the maximum amount and extended the termination date. In April 2013, the BoJ introduced QQE to achieve the price stability target of 2% inflation at the earliest possible time, with a time frame of about 2 years. Upon introducing QQE, the BoJ moved to open-ended ETF purchases at an annual pace of increase in the amount outstanding of 1 trillion yen. The BoJ subsequently increased the pace of purchases several times as it continued to fail to meet its 2% inflation target.

Figure 2 shows the 4-quarter moving sums of flows from the BoJ into investment funds, which represent the BoJ's ETF purchases, and flows from investment funds into listed stocks. The figure shows that the BoJ accelerated the pace of ETF purchases until 2016. It then continued purchasing ETFs in the range of around 5 to 7 trillion yen per year, with its target of increasing the amount outstanding at a pace of about 6 trillion yen per year. In March 2021, however, it announced that it would eliminate the 6-trillion-yen target from April. As a result, it purchased only 0.28 trillion yen from April to December 2021. Figure 2 also indicates that the flows from the BoJ into investment funds largely matched those from investment funds into listed stocks, although short-term deviations were often observed. The total flows from the fourth quarter of 2010 to the fourth quarter of 2021 are very close (37.0 trillion yen and 35.6 trillion yen, respectively). This suggests that the BoJ has been the dominant end investor in equity funds.

The BoJ initially purchased only ETFs that track the TOPIX or the Nikkei 225 index. In 2014, it added ETFs that track the JPX-Nikkei 400 index, a newly established index. Meanwhile, until September 2016, the BoJ had set the maximum purchases of individual ETFs to roughly proportionate to their market capitalization. Subsequently, the BoJ revised the ETF purchase program several times to increase the allocation weight to TOPIX ETFs amid criticism that the purchases of Nikkei 225 ETFs distort the market. For instance, from October 2016 to early August 2018, while half of its investment was allocated to ETFs linked to any of the three indexes as before, most of the remaining investment was allocated to

TOPIX ETFs only. Finally, in March 2021, the BoJ decided to purchase only TOPIX ETFs from April onward.

In addition to the main program of ETF purchases, the BoJ established a supplementary program to support firms proactively investing in physical and human capital in 2016. However, purchases under this program were much smaller than under the main program, and most of the funds were allocated to JPX-Nikkei 400 ETFs. This program effectively ended in March 2021.[4]

The BoJ has also directly traded listed stocks under a different program. Specifically, from November 2002 to September 2004 and from February 2009 to April 2010, the BoJ purchased stocks of around 2.4 trillion yen from commercial banks to encourage them to reduce stock holdings, with the aim of promoting financial stability. The BoJ slowly sold these stocks on stock exchanges from October 2007 to October 2008 and since April 2016 so as not to significantly affect stock prices. Partly because no information about the composition of these direct trades is available, examining their impact is beyond the scope of this study. However, given that total net sales from the fourth quarter of 2010 to the first quarter of 2021 were only 1.7 trillion yen according to the Flow of Funds Accounts and that these sales should have been expected to some extent from the experience of previous sales, the direct trades likely had a much smaller impact on stock returns than ETF purchases during this period.

[4] Under the supplementary program, the BoJ purchased ETFs tracking indexes that meet the criteria set by the BoJ as indexes composed of firms proactively investing in physical and human capital, or JPX-Nikkei 400 ETFs. However, the total annual purchases were only 0.3 trillion yen. Moreover, according to the author's estimate, the BoJ held less than 0.15 trillion yen of ETFs other than JPX-Nikkei 400 ETFs at the end of March 2021 under this program. The reason is the limited amount of ETFs issued that met the BoJ's criteria and the BoJ's rule that, in principle, such ETFs could only be purchased up to half of their market capitalization. In March 2021, the BoJ decided that from April, it would not purchase JPX-Nikkei 400 ETFs under this program. This decision, in effect, spelled the termination of the supplementary program.

4. The BoJ's Indirect Stock Holdings

This section estimates the amount of individual stocks indirectly held by the BoJ. The estimation method is essentially the same as that in previous studies, although the approach differs in several respects, and this paper extends the estimation until the end of 2021. The estimation is carried out in three steps, which are outlined below. See Appendix A in the online appendix for more details. A list of the data used in this paper is provided in Table A2.

In the first step, the BoJ's daily purchases of each ETF are estimated. The BoJ has published daily data on total ETF purchases for each of the main and supplementary programs. Using the data, the amount of daily purchases of each ETF is estimated based on several assumptions. For instance, when the BoJ set the maximum purchases of individual ETFs to be roughly in proportion to their market capitalization, it is assumed that the BoJ purchased ETFs exactly in proportion to their market capitalization on the previous day. In the second step, the BoJ's holdings of each ETF are estimated generally by cumulating returns and flows. Finally, in the third step, the BoJ's indirect holdings of individual stocks are calculated using the following equation:

$$BoJ_{n,t} = BoJ_t^{TPX} \cdot w_{n,t}^{TPX} + BoJ_t^{N225} \cdot w_{n,t}^{N22} + BoJ_t^{JN400} \cdot w_{n,t}^{JN400} \quad (1)$$

where $BoJ_{n,t}$ is the BoJ's holdings of stock n on day t. BoJ_t^{TPX}, BoJ_t^{N225}, and BoJ_t^{JN400} are the BoJ's holdings of ETFs that track the TOPIX, the Nikkei 225, and the JPX-Nikkei 400, respectively. These are calculated by aggregating the BoJ's holdings of individual ETFs estimated in the second step. w_n^{TPX} is the weight of stock n in the TOPIX, etc. Section 6.2 estimates the BoJ's holdings using alternative assumptions and checks the robustness of results.

The estimation result indicates that the BoJ's exposures to the TOPIX, the Nikkei 225, and the JPX-Nikkei 400 on March 31, 2021, were around 32 trillion yen, 17 trillion yen, and 3 trillion yen, respectively, as shown in Figure A2. The exposures have remained more or less flat since then, reflecting the limited BoJ purchases.

Due to data availability, most analyses in the remainder of this paper focus on stocks listed on the First Section of the TSE, which essentially correspond to stocks included in the TOPIX. While the BoJ has indirectly held several stocks not listed on the First Section of the

TSE, because these stocks were included in the JPX-Nikkei 400, the amount held has been negligible. For instance, on March 31, 2021, the BoJ held 51.5 trillion yen of ETFs in total, but holdings of non-TOPIX members accounted for only 636 million yen (0.124%).

Table 1 lists the top 10 firms in terms of the estimated BoJ holdings as a percentage of TSE-defined free float on March 31, 2021. The free-float market capitalization is basically proportional to the TOPIX weight because the TSE uses the free float to determine the TOPIX weights. As shown in column (1), the ratio of BoJ holdings to free float is greater than 100% for Fast Retailing. This seemingly odd result is likely because the TSE excludes BoJ holdings from its definition of free float, as will be discussed in the next section. Meanwhile, column (2) shows the ratio of a stock’s weight in the Nikkei 225 index to the weight in the TOPIX, which is called the "index weight ratio" in this paper. For example, the weight of Fast Retailing in the Nikkei 225 index (of more than 10% on March 31, 2021) is 25.1 times greater than that in the TOPIX (0.43%).

Looking at columns (1) and (2) together, a clear pattern emerges: the higher the ratio of BoJ holdings to free float, the higher the index weight ratio. This pattern is generally observed even for firms ranked 11th and below and can be explained as follows. Since the TOPIX is a free float adjusted weighted index, the BoJ’s holdings of TOPIX ETFs have essentially no effect on the variation in the BoJ’s holdings relative to free float. In addition, the BoJ’s holdings of JPX-Nikkei 400 ETFs play a limited role in the variation because the BoJ held only around 3 trillion yen of JPX-Nikkei 400 ETFs, and like the TOPIX, the weight of the JPX-Nikkei 400 index is basically proportional to the free float market capitalization. Therefore, the holdings of Nikkei 225 ETFs essentially determine the variation, and the ratio of BoJ holdings to free float and the index weight ratio, which measures the extent to which the weight of the Nikkei 225 index is skewed relative to the weight of the TOPIX or the free-float market capitalization, are highly correlated.

Meanwhile, column (3) indicates that the BoJ held 1.96 trillion yen of Fast Retailing shares, the second largest holding after SoftBank Group. Note that although the BoJ held 2.07 trillion yen of SoftBank Group shares, the firm is not listed in Table 1 since its free-float market capitalization was much larger than that of Fast Retailing. Furthermore, since two of the top 10 firms in terms of free-float market capitalization, Keyence, and Nintendo, were not included in the Nikkei 225 index, the ratio of BoJ holdings to free float for these firms is only around 8%.[5]

5. Baseline Analysis

This section discusses the baseline cross-sectional regression model and results. Specifically, Section 5.1 describes the baseline model. Section 5.2 presents the regression results. Finally, Section 5.3 evaluates the magnitude of the price multiplier estimated in this paper in comparison with those in the literature. See Appendix C for details on the data construction of variables used in this and the next sections, such as abnormal returns and control variables.

5.1. The baseline regression model

The baseline regression model in this paper is inspired by D'Amico and King (2013), who estimate the flow and stock effects of the Federal Reserve's Treasury purchases in 2009 using security-level data. To estimate the stock effects, they run a cross-sectional regression of cumulative total returns on Treasury securities between March 17 and October 30, 2009 (the day before the first announcement of the purchase program and the last day of purchases) on the amount of securities that were purchased by the Federal Reserve over the life of the program relative to the amount outstanding. The key idea of their identification strategy is using the returns to the last day of purchases. Before the end of the program, it was uncertain which securities the Fed would purchase, so security prices should have reflected market expectations about the Fed's future purchases. However, expectations regarding future purchases do not matter after the purchase program's conclusion. Therefore, this method allows them to identify the stock effects without being seriously contaminated by unobservable expectations.

In the baseline analysis of this paper, cumulative log excess returns of individual stocks between September 30, 2010, and March 31, 2021, are regressed on BoJ holdings as a

[5] Large firms are not necessarily included in the Nikkei 225 index since firms included in the index are selected taking the balance in the number of firms across sectors into account.

percentage of a measure of free float on March 31, 2021. Excess returns are calculated using the uncollateralized overnight call rate, a major interbank rate. September 30, 2010, is 3 business days before the BoJ's first announcement of ETF purchases on October 5, 2010. March 31, 2021, is the date on which the BoJ terminated its purchases of Nikkei 225 ETFs. These dates are selected partly because of the superior data availability at the end of a quarter. The most important reason is that future purchases of Nikkei 225 ETFs were not expected by market participants on these dates. Although the BoJ continued to purchase TOPIX ETFs even after March 31, 2021, the purchases of TOPIX ETFs are unlikely to have had a severe distorting impact on returns since the TOPIX weight is essentially proportional to the free-float market capitalization. In addition, from April 2021, the BoJ dramatically reduced its purchases of ETFs, including those tracking the TOPIX, as mentioned earlier.[6]

Since the BoJ was not expected to purchase ETFs on September 30, 2010, BoJ holdings on March 31, 2021, can be regarded as a demand shock between September 30, 2010, and March 31, 2021. In the literature on the impact of demand shocks on stock prices, demand shocks are usually calculated by dividing by a measure of the supply of stocks. Studies using U.S. data typically employ shares outstanding (i.e., shares issued minus treasury stocks) as the measure of supply. In contrast, the analysis here employs free float for two reasons. The first reason is data availability in Japan. Daily data on a stock's free-float market capitalization are easily obtained if the stock is included in the TOPIX. On the other hand, no daily data of shares outstanding are publicly available. The second reason is that free float may better represent the supply of stocks than shares outstanding. In fact, this is the reason why the TOPIX and the S&P 500 index adopted float-adjusted weightings around 2005. The U.S. literature, which has a long history, uses shares outstanding at least partly

[6] Another consideration in the date selection is market stress. Since central bank asset purchases are likely to have a particularly large impact at times of market stress, when arbitragers tend to be risk averse, as discussed in Appendix B, choosing such dates may seriously affect the estimation results. In fact, D'Amico and King (2013) warn that their results may not be extrapolated to periods of relatively low market stress since the Federal Reserve's Treasury purchases were announced and implemented in the immediate aftermath of the financial crisis. The results of this study are likely to capture the effects in a low-stress environment. This is because the BoJ began purchasing ETFs in an effort to achieve price stability rather than financial stability, and stock market volatility, a widely used indicator of stress, was not particularly high on these dates, as shown in Figure A1 in the online appendix.

because free float data were not readily available. Indeed, Wurgler and Zhuravskaya (2002) state that they do not use the free float because they are unaware of an electronic source for insider holdings.

However, it is necessary to be careful when using the TSE-defined free float. Harada (2021) argues that although the TSE has not disclosed whether it excludes BoJ holdings from its definition of free float, it is likely to do so. See Appendix D for evidence to support her argument. Based on this evidence, the free float is adjusted by adding BoJ holdings back, and the BoJ holding ratio is defined as the ratio of BoJ holdings to the adjusted free float.

Most regressions in this paper focus on non-financial stocks. The baseline regressions use data of stocks listed on the TSE's First Section for which price observations were available for all business days from September 30, 2005, to March 31, 2021.[7] Data for the period before September 30, 2010, are used to calculate some of the control variables. In addition, since free float data are readily available for TOPIX members, the analysis is restricted to stocks that were TOPIX members on March 31, 2021. Further, one stock is excluded since some of the data for the control variables are not available. This leaves a total of 1,158 stocks that are included in the sample.

As discussed in Section 1, Figure 1 plots the log excess total returns against the BoJ holding ratio. The figure clearly shows that Nikkei 225 members, which are represented by the black circles, play the dominant role in the variation of the BoJ holding ratio. There is one notable outlier toward the right of the figure. This is Fast Retailing, whose BoJ holding ratio slightly exceeds 50%, in line with the BoJ holdings to unadjusted free float ratio of 104.8% shown in Table 1. In all regressions in this paper, all variables are winsorized at the 1 and 99% levels to address such outliers. The positive relationship across the Nikkei index members suggests that a higher BoJ holding ratio is associated with a higher return. On the other hand, looking at non-Nikkei index members, which are represented by the grey circles, all circles generally fall on two vertical lines that are close to each other at BoJ holding ratios

[7] Since price observations are not available for October 1, 2020, due to the failure of the TSE's equity trading system, this paper treats this day as a holiday.

of around 6.9% and 7.6%. While stocks that are not included in the JPX-Nikkei 400 index are on the left line, most stocks that are included are on the right line.

This paper shows most regression results for both the full sample and the subsample of Nikkei 225 members. The reason is that the behavior of Nikkei 225 members and non-members may be different. For example, Nikkei 225 members may be overvalued and have lower ex-post returns than non-Nikkei 225 stocks because they receive more attention from investors. The subsample regression focuses on stocks that were members of the Nikkei index on September 30, 2010, instead of March 31, 2021, to address potential endogeneity arising from the effect of returns on the selection of stocks included in the Nikkei index. The subsample consists of 177 firms, of which 169 were still included in the Nikkei index on March 31, 2021.

The baseline regression model takes the following form:

$$R_n = \gamma Q_n + \rho' X_n + \epsilon_n \tag{2}$$

where R_n is the raw or abnormal log excess total return between September 30, 2010, and March 31, 2021, on stock n, Q_n represents the BoJ holding ratio on March 31, 2021, and X_n is a vector of control variables, including a constant. Abnormal returns are computed using a 1-, 3-, 4-, 5-, or 6-factor model estimated using monthly returns from October 2010 to March 2021.[8]

For the estimation, two-stage least squares is used. D'Amico and King (2013) also use two-stage least squares to address potential endogeneity that can occur if the Federal Reserve deliberately purchased underpriced securities. Since the BoJ purchased stocks indirectly through ETFs and followed preannounced rules in selecting the ETFs it purchased, there appears to have been little leeway for the BoJ to favor specific stocks. However, endogeneity may still be present if, for example, better firm fundamentals lead to both a higher return and a higher probability that the stock will be added to or remain in the Nikkei

[8] This paper runs regressions for individual stocks rather than portfolios. The reason is that, as shown analytically and empirically by Ang et al. (2020), using portfolios discards substantial information about cross-sectional variation. However, Appendix E examines portfolio returns and arrives at results that support those of the baseline estimation.

index. To address such potential endogeneity, a stock's index weight ratio (i.e., the ratio of the Nikkei 225 weight to the TOPIX weight) on September 30, 2010, is used to instrument the BoJ holding ratio. This instrument is chosen mainly because Table 1 suggests a high correlation between the index weight ratio and the ratio of BoJ holdings to free float on March 31, 2021. Since the index weight ratio is highly persistent, the ratio on September 30, 2010, is also highly correlated with the BoJ holding ratio more than 10 years ahead, as will be shown later.[9]

The control variables include a constant and at least six variables: beta, firm size, the book-to-market ratio, profitability, asset growth, and lagged returns. The first five variables are the firm characteristics of interest in Fama and French's (2015) 5-factor model. The lagged returns are used to control for mean reversion since mean reversion is often observed for long-term returns in the literature (e.g., Bondt and Thaler 1985). The full-sample regression also includes a dummy variable for Nikkei 225 members on September 30, 2010, to control for possible differences in the behavior of Nikkei 225 members and non-members. All control variables are calculated using data up to September 30, 2010. Further, following the convention beginning with Fama and French (1993), a gap of at least 6 months is left between the end of the accounting period and the return to ensure that the accounting variables are known before the return.

In sum, in the first stage of the two-stage least squares regressions, the BoJ holding ratio on March 31, 2021, is regressed on the index weight ratio and the controls. In the second stage, the return between September 30, 2010, and March 31, 2021, is regressed on the fitted value of the BoJ holding ratio and the controls. See Table A3 in the online appendix for summary statistics for variables used in the baseline regressions. Moreover, standard errors are clustered at the industry level based on the TSE's 33-industry classification. Although it is rare, firms' industry classification can change. To address this issue, the classification on September 30, 2010, is used.

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[9] Note that when the price of a given stock rises, both the TOPIX and Nikkei 225 weights increase, resulting in only a small change in the index weight ratio.

Finally, it is worth noting potential estimation biases. One concern is the possibility that the exogeneity of the instrumental variable fails. Stocks with a high index weight ratio may have been overvalued on September 30, 2010, possibly due to demand from index investors. In this case, such stocks may have yielded relatively low returns between the end of September 2010 and the end of March 2021. If so, the instrumental variable would be negatively correlated with the residual, leading to an underestimation of the effect of the BoJ's ETF holdings. Another concern is that if investors other than the BoJ increased their exposure to the Nikkei 225 index during this period, the regression may overstate the impact of BoJ holdings. Sections 6.3 and 6.4 investigate these possibilities and find that the baseline regression results are unlikely to be seriously biased for such reasons.

5.2. Baseline results

This subsection presents the results of the baseline two-stage least squares regressions. Columns (1) and (2) of Table 2 report the results of the first-stage regressions for the full sample and the Nikkei-225-member subsample, respectively. The coefficient on the index weight ratio is significantly positive for both samples. The t-statistics are 11.1 and 19.7, respectively. Kleibergen and Paap's (2006) F-statistics are 123.8 and 387.2, which are much higher than the conventional critical value of 10. Overall, the results show that the index weight ratio is informative in predicting the BoJ holding ratio more than 10 years ahead and is relevant as an instrumental variable. The coefficient on firm size is also significantly positive for both samples. This is possibly because firm size is a good predictor of whether a stock will remain in or be added to the Nikkei 225 index. In fact, the average size of firms included in the index on September 30, 2010, but not on March 31, 2021, is smaller than that of firms that remained in the index and that of newly added firms.

The second-stage regression results for the full sample presented in Table 3 suggest that BoJ holdings have a significantly positive impact on returns. The result for the raw return is reported in column (1), while the results for the abnormal returns are reported in columns (2) to (6). The coefficients on the BoJ holding ratio are positive and significant, with a t-statistic ranging from around 4 to 5. The size of the coefficients ranges from 5.21 to 6.74. Considering that the standard error is slightly higher than 1 in all regressions, it is concluded that the coefficient is around 6. This suggests that a 1 percentage point higher share of BoJ holdings in a stock's free float is associated with a roughly 6 percentage point higher return. In other words, the price multiplier is around 6. Many coefficients on the control variables are significant and have a high t-statistic. The coefficients on the Nikkei 225-member dummy are negative and significant. This is likely because Nikkei 225 members tend to be overvalued, resulting in low ex-post returns. The signs of the other highly significant coefficients are also in line with what one would expect.[10]

Panel A in Table 4 summarizes the results of the baseline regressions for 12 combinations of six types of returns (raw and abnormal returns) and two different samples (the full sample and the Nikkei 225-member subsample). To save space, the table only shows the coefficient estimates for the BoJ holding ratio and the corresponding t-statistics. The results for the full sample are precisely the same as those reported in Table 3. The results for the subsample show that the coefficients on the BoJ holding ratio are again around 6, and the t-statistics are around 4 to 6 and higher than those for the full sample.

This study also runs ordinary least squares (OLS) regressions to see whether the endogeneity is serious. That is, the raw or abnormal returns are regressed on the BoJ holding ratio and the control variables without instrumenting the BoJ holding ratio. Panel B in Table 4 reports the coefficient estimates for the BoJ holding ratio and the corresponding t-statistics for the same 12 combinations of returns and samples as Panel A. The coefficients are slightly higher than the baseline estimates for the full sample but somewhat smaller for the subsample. However, all coefficients are not significantly different from 6. These results suggest that the endogeneity is not severe.

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[10] The coefficient on beta is negative but insignificant for the raw return, while it is negative and significant for the abnormal returns. The former result is somewhat consistent with Black et al. (1972), Fama and French (1992), Baker et al. (2011), and Frazzini and Pedersen (2014), who find that the beta estimated from time-series regressions has a weak or even negative cross-sectional correlation with stock returns, contrary to the prediction of the Capital Asset Pricing Model (CAPM). The negative and significant coefficient on the beta for abnormal returns is also inconsistent with the CAPM, which predicts no correlation between beta and abnormal returns, but consistent with Frazzini and Pedersen (2014), who theoretically and empirically show that a high beta is associated with a low alpha.

5.3. Evaluating the magnitude of the estimated price multiplier

This subsection evaluates the magnitude of the price multiplier estimated in this paper mainly by comparing it with the estimates of preceding studies. As mentioned above, many studies using U.S. data employ shares outstanding instead of free float to normalize demand shocks. Therefore, to make the result in this paper comparable to those in the U.S. studies, the baseline regressions are rerun after BoJ holdings are normalized by estimated shares outstanding. See Appendix C for the method of estimating shares outstanding.

Recall that the index weight ratio (i.e., the Nikkei 225 weight-to-TOPIX weight ratio) on September 30, 2010, was used as the instrumental variable in the baseline regressions. This ratio is basically proportional to the ratio of the Nikkei 225 weight to the free-float market capitalization since the TOPIX weights are determined based on the free-float market capitalization. On the other hand, in line with the alternative normalization of BoJ holdings, here, the ratio of the Nikkei 225 weight to the market capitalization of shares outstanding on September 30, 2010, is used as the instrumental variable.

Panel C in Table 4 presents the coefficient estimates for normalized BoJ holdings and the corresponding t-statistics for the 12 combinations of six types of returns and two different samples used in the baseline analysis. As in the baseline results, the coefficient on normalized BoJ holdings is significantly positive in all 12 cases. The t-statistic is around 4 to 5, although slightly lower than in the baseline. The estimated value of the coefficient is about 8 to 9, which is higher than in the baseline regressions reported in Panel A. This is not surprising. Given that the TSE-defined free float excludes not only BoJ holdings and treasury stocks but also other stocks, such as those held by board members, the estimated market capitalization of shares outstanding exceeds the sum of BoJ holdings and the TSE-defined free-float market capitalization for all stocks in the sample. Thus, the dispersion of the ratio of BoJ holdings to shares outstanding is lower than that of the BoJ holding ratio, so a higher multiplier is needed to explain the dispersion of returns.

The estimated price multiplier (around 8 to 9) is much higher than a typical multiplier of about 1 in the literature. The high multiplier may be because the BoJ is expected to hold stocks through ETFs for an extended period, as suggested by the theory in Appendix B. In fact, the BoJ has not sold any of the ETFs it purchased for more than a decade.[11] Furthermore, on March 31, 2021, Japan still appeared to be caught in a prolonged low-inflation trap, many believed that the amount held by the BoJ was too big to sell without a significant impact on stock prices, and the BoJ claimed that it was not yet at the stage of considering the timing and strategy for terminating its ETF purchases.[12] Because of these factors, market participants may have expected the BoJ's holdings to be semipermanent.

Next, let us compare the results obtained here with those in the literature on the impact of the BoJ's ETF purchases. As mentioned, only a few studies examine the stock effects of ETF purchases. Among them, only Barbon and Gianinazzi (2019) estimate the price multiplier. They conduct an event study, focusing on two BoJ announcements: one on October 31, 2014, and one on July 29, 2016. They then find that the price multiplier is only around 1, much lower than the estimate obtained in this study. There are several possible reasons for the large difference. The event study by Barbon and Gianinazzi (2019) may underestimate the true effect, possibly because at previous announcements, such as on April 4, 2013, when QQE was introduced, market prices may, to some extent, have reflected the value of state-contingent actions to do more if the situation worsens.[13] On the other hand, the estimate in the present study may overstate the effect if other factors caused the greater increase in prices of stocks with a higher index weight ratio. This could be the case if non-BoJ investors increased their exposure to the Nikkei 225 index during the period of interest.

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[11] The BoJ terminated ETF purchases in March 2024. However, it has not expressed any plans to sell the ETFs it purchased.

[12] On March 23, 2021, then Governor Kuroda of the BoJ stated in the House of Councillors: "[S]ince it is expected to take some time to achieve the 2% price stability target, the Bank does not intend to stop purchasing ETFs or dispose of ETFs for the time being. [...] I do not believe that we are at the stage of considering the timing of the exit from monetary easing, including the current ETF purchases, or the specific measures to be taken in such a case." The original quote in Japanese is available here:

https://kokkai.ndl.go.jp/#/detail?minId=120415261X01620210325&current=1.

[13] Haddad et al. (2023) point out that the value of state-contingent actions is consistent with previous empirical evidence that earlier-stage announcements of central bank asset purchases in the US and Europe have large effects on asset prices, but later-stage announcements have little to no impact (Meaning and Zhu, 2011).

However, an analysis of investment flows from non-BoJ investors in Section 6.4 suggests that this is not the case.

Finally, to get a sense of the magnitude of the impact, the effects of BoJ holdings on relative returns are briefly examined. Since the baseline analysis suggests that the micro multiplier is around 6 when BoJ holdings are normalized by free float, the impact on the relative returns between two stocks can be approximated by multiplying the difference in the BoJ holding ratio between them by 6. As shown in Figure 1, even after excluding Fast Retailing as an outlier, there is a large variation in the BoJ holding ratio with a range of 23.6 percentage points from 6.9% to 30.5%. Multiplying this range by 6 gives 141.5 percentage points, which can be interpreted as the difference in log cumulative returns generated by the BoJ's ETF holdings. Since this is the 10.5-year return difference, the annualized difference is 13.5 percentage points.

6. Additional Analysis

This section shows alternative regression results and discusses various issues. Section 6.1 investigates the persistence of the impact of BoJ holdings by examining returns after the BoJ terminated its purchases of Nikkei 225 ETFs on March 31, 2021. Section 6.2 examines the weights of individual stocks held by ETFs and checks the robustness to using alternative assumptions to estimate BoJ holdings. Section 6.3 exploits long-term data before the BoJ's first announcement of ETF purchases and runs alternative regressions, including Fama-Macbeth (1973) regressions. Finally, Section 6.4 explores investment demand from non-BoJ investors to see whether such demand contaminates the identification in this paper.

6.1. Ex-post returns

This subsection examines returns after the BoJ stopped purchasing Nikkei 225 ETFs at the end of March 2021. To this end, an extended sample through the end of December 2021 (December 30, 2021), i.e., 9 months after the end of March 2021, is used. This exercise is also important as a robustness check of the baseline results. The reason is that the cumulative returns from September 30, 2010, to March 31, 2021, may have been pushed upward by short-term liquidity effects since the BoJ purchased ETFs frequently until the end of March 2021. In contrast, from April to December 2021, the BoJ purchased ETFs only on April 21, June 21, September 29, and October 1. In particular, since the BoJ did not buy ETFs for around 3 months up to December 30, 2021, liquidity effects can be ignored when examining the cumulative returns up to this day. Furthermore, if the effects of the BoJ's holdings are overestimated due to liquidity effects in the baseline analysis, a return reversal is expected to be observed after the termination of Nikkei 225 ETF purchases.

Two types of regressions are used for this analysis. First, the baseline regressions are modified using returns from September 30, 2010, to the end of December 2021. In line with this modification, the BoJ holding ratio is calculated from BoJ holdings and free float on December 30, 2021. To estimate abnormal returns, the factor models are re-estimated using the extended sample. The full sample and the subsample include 1,151 and 176 stocks, respectively. These samples cover stocks for which prices are available for all business days from September 30, 2005, to December 30, 2021, and that were included in the TOPIX on December 30, 2021. If returns were reversed after the termination of Nikkei 225 ETF purchases, the estimated coefficient on the BoJ holding ratio should be lower than in the baseline estimation.

Panel D in Table 4 reports the results. Again, the coefficient on the BoJ holding ratio is positive and significant in all 12 regressions. The size of the coefficient estimates is somewhat higher than in the baseline regressions, while the difference is within the standard error of the regressions. Therefore, these alternative regression results do not provide any evidence for return reversals.

The second type of regression examines returns from March 31, 2021. Specifically, the 9-month return from March 31 to December 30, 2021, is regressed on the BoJ holding ratio on March 31, 2021, and the controls. If the upward impact of BoJ holdings on returns reversed after the BoJ terminated its purchases of Nikkei 225 ETFs, the coefficient on the BoJ holding ratio should be negative. Abnormal returns are calculated by accumulating the sum of alpha and the residual from April to December 2021 after estimating the factor models using monthly return data from October 2010 to December 2021. The controls are calculated as in the baseline regressions, although data up to March 31, 2021, instead of September 30, 2010, are used. As in the baseline analysis, all variables are winsorized at the

1 and 99% levels. Standard errors are clustered at the industry level using the industry classification on March 31, 2021. The sample covers stocks for which prices are available for all business days from September 30, 2010, to December 30, 2021, and that were included in the TOPIX on March 31, 2021. The subsample consists of the Nikkei 225 members on March 31, 2021. As a result, the full sample consists of 1,304 stocks, while the subsample comprises 186 stocks.

The regression results are presented in Table 5 and provide no evidence of a return reversal after the termination of Nikkei 225 ETF purchases. The coefficient on the BoJ holding ratio is insignificant in all 12 estimations. Overall, the results in this subsection suggest that the effect of BoJ holdings did not diminish for at least 9 months after the termination of purchases of Nikkei 225 ETFs.

6.2. ETF weights vs. index weights

In Section 4, BoJ holdings were estimated based on several assumptions. For instance, it is assumed that the weights of individual stocks in the indexes are a good approximation of those in index ETFs. In practice, however, index ETFs do not perfectly replicate the benchmark index, for example, due to transaction costs, potentially leading to estimation bias.

To check the robustness of the baseline results, BoJ holdings here are estimated based on alternative assumptions, using data on the weights of individual stocks held by ETFs. Unfortunately, these data cannot be obtained for three ETFs eligible for BoJ purchases. However, the total market value of these ETFs is only 35.0 billion yen, much smaller than the total market value of all eligible ETFs of 56.5 trillion yen, on March 31, 2021.[14] Since the BoJ's annual accounting reports that its total holdings of ETFs were 51.5 trillion yen on that day, the BoJ holding share of eligible ETFs reached 91.2%. This overwhelming share indicates that these ETFs have been issued primarily to meet demand from the BoJ. This fact

[14] For ETFs tracking indexes composed of firms that proactively invest in physical and human capital, only half of the market capitalization is counted since the BoJ, in principle, purchased only up to half of the market value of these ETFs under the special rule of the supplementary program. That said, since the market value of these ETFs is small relative to that of many other eligible ETFs, how they are treated in the calculation does not make much difference to the result.

suggests that the weights of individual stocks indirectly held by the BoJ are well approximated by the weights of stocks held by all eligible ETFs. Thus, the weights in the BoJ's holdings are estimated by taking the weighted average of the weights in the ETFs based on the market values of the ETFs. The estimated weights are then multiplied by the BoJ's total holdings of ETFs to estimate the BoJ's indirect holdings of individual stocks.

Next, the difference between the BoJ holding ratio estimated in Section 4 based on index weights and that estimated here based on ETF weights is calculated. Figure 3 shows this difference against the adjusted free-float market capitalization (i.e., the TSE-defined free-float market capitalization plus BoJ holdings) on March 31, 2021, for 1,158 stocks covered in the baseline analysis. The figure reveals that the two estimated BoJ holding ratios substantially deviate from each other only for a few stocks, indicating that the estimated BoJ holdings used in the baseline analysis are largely robust. The large deviations are concentrated in relatively small-cap stocks, likely in part because fund managers are aware that tracking errors in such stocks have little impact on the overall index tracking performance. When a stock is held by index funds far out of proportion to its market capitalization, its price is likely distorted. Although this problem can arise for all index funds, it may be more severe for index ETFs held dominantly by the BoJ since the impact of BoJ holdings is estimated to be very large.

To check whether the baseline results are robust to using BoJ holdings estimated from ETF weights instead of index weights, regressions are estimated for the same 12 combinations of returns and samples as in the baseline. The results are presented in Panel E of Table 4, which shows that the coefficient estimate for the BoJ holding ratio is significantly different from zero with a t-statistic of around 5, and the size of the coefficients is not significantly different from 6 for all 12 regressions, indicating that the baseline results are robust.

6.3. Information in the index weight ratio

The baseline regressions use the index weight ratio on September 30, 2010, to instrument the BoJ holding ratio on March 31, 2021. The instrumental-variable regressions assume that the index weight ratio contains information beyond the control variables to predict the returns between September 30, 2010, and March 31, 2021, only through the BoJ holding ratio. If this assumption holds, the index weight ratio should be able to predict future returns only after the BoJ made the first announcement of ETF purchases. This subsection checks this prediction by running two types of regressions.

The first type is a slightly modified version of the baseline regressions. In the baseline, raw or abnormal returns between September 30, 2010, and March 31, 2021, are regressed on the BoJ holding ratio on March 31, 2021, and the control variables while using the index weight ratio on September 30, 2010, to instrument the BoJ holding ratio. In the modified version, the returns are simply regressed on the index weight ratio and the controls. The coefficient estimates for the index weight ratio using the same 12 combinations of returns and samples as above are presented in Panel A of Table 6. The coefficient is positive and significant, with a t-statistic of around 4 to 5 in all 12 cases. This result suggests that the index weight ratio had information of more-than-10-year future returns beyond the control variables.

Meanwhile, Panel B reports the results when regressing the returns between September 30, 2000, and September 30, 2010 (i.e., essentially 10 years until the BoJ's first announcement of ETF purchases) on the index weight ratio on September 30, 2000, and the control variables. The controls are the same as those in the baseline regressions, except that they are calculated using data up to September 30, 2000. The regressions using the pre-announcement data can be interpreted as a placebo test. In Panel B, the coefficient on the index weight ratio is insignificant in 11 of the 12 estimations. The coefficient is positive and significant (with a t-statistic of 2.14) only in the full sample regression for the 6-factor model. Since this is the only significant result among the 12 regressions and the t-statistic is not very large, this result is likely due to chance. Overall, the results suggest that a higher index weight ratio clearly predicted a higher return only after the BoJ's first announcement of ETF purchases, supporting the assumption of the baseline regressions.

The second type of regression is the Fama-MacBeth (1973) regression. Specifically, using monthly data, the raw log excess total return in a month is regressed on the index weight ratio at the end of the previous month and the control variables. The controls are calculated using data up to the previous month. While the controls are essentially the same as those used in the baseline regressions, there is one notable difference. The baseline regressions use the 3-year lagged return as a control variable to capture mean reversion since it examines the determinants of long-term returns. On the other hand, since the Fama-MacBeth regressions examine the determinants of monthly returns, the past 11-month return lagged by 1 month is used to capture the momentum effect. The regressions are run for the full sample and the subsample of firms that were Nikkei 225 members at the end of the previous month. All variables are winsorized each month at the 1 and 99% levels. Following the convention of Fama-MacBeth regressions, the coefficients are obtained by taking the average of the coefficients estimated in the cross-sectional regression for each month to correct for cross-sectional correlation.

To start with, this regression is run for two observation periods. The first period corresponds to the baseline period and includes monthly returns from October 2010 through March 2021. Since, on average, market participants must have revised their expectations of BoJ holdings of Nikkei 225 ETFs upward from the time before the BoJ's first announcement of ETF purchases, the average returns of stocks with a higher index weight ratio are expected to be higher during this period. Therefore, the coefficient on the index weight ratio is expected to be positive when using the sample during the baseline period. The second period corresponds to the 10 years just before the baseline period and includes returns from October 2000 through September 2010. The regression for this pre-baseline period represents another placebo test to examine whether the index weight ratio could predict returns only after the BoJ made the first announcement of ETF purchases.

The results for the baseline observation period for the full sample and the Nikkei-225-member subsample are reported in columns (1) and (2) of Table 7, respectively. The coefficient on the index weight ratio is positive and significant for both samples. The t-statistics are 2.64 for the full sample and 3.00 for the subsample. On the other hand, columns (3) and (4) report the results for the period before the BoJ's first announcement of ETF purchases and show that the coefficient on the index weight ratio is insignificant for both samples. These results suggest that a stock with a higher index weight ratio earned a higher return only after the first announcement of ETF purchases, again supporting the assumption underlying the baseline regression.

Next, 5-year rolling Fama-Macbeth regressions are estimated up to the 5-year sample ending in December 2021. Figure 4 shows the coefficient estimates and the 95% confidence intervals for the index weight ratio. Panels A and B in this figure depict the results for the full sample and the subsample, respectively. In both panels, the coefficient is positive and significant only from the 5-year sample ending in February 2016 (i.e., starting in March 2011). This result suggests that stocks with a high index weight ratio benefited only after the BoJ made the first announcement in October 2010.

The coefficient is negative and significant for short periods in the early part of the sample in Panel B. This result suggests that stocks with a high index weight ratio were somewhat overvalued, possibly due to demand from index investors, generating relatively low ex-post returns on average. If this is the case, the baseline regressions may understate the effect of the BoJ's ETF holdings. The evidence is weak, however. The coefficient is insignificant in the early part of the sample in Panel A. Furthermore, recall that the first type of regression provides somewhat contradictory evidence; the coefficient on the index weight ratio is positive and significant in one of the 12 estimations for the samples before the BoJ's first announcement of ETF purchases. Therefore, this paper only keeps the possibility of underestimation in mind.

In both panels, the coefficient is relatively high from the 5-year sample ending in mid-2018 to early 2021. This suggests that between mid-2013 and early 2021, stocks with a high index weight ratio benefited the most. During this period, the BoJ dramatically changed its policy of ETF purchases. In April 2013, with the introduction of QQE, the BoJ moved to open-ended purchases at an annual pace of increase in the amount outstanding of 1 trillion yen. In October 2014, the BoJ tripled the annual pace from 1 trillion yen to 3 trillion yen; in July 2016, it further doubled to 6 trillion yen. Finally, in March 2020, in light of the outbreak of the COVID-19 pandemic, it announced that it would actively purchase ETFs so that the amounts outstanding would increase at an annual pace with an upper limit of about 12 trillion yen. These policy changes were somewhat predictable and did not fully surprise market participants at the announcements, partly because the BoJ continued to fail to meet its 2% inflation target, leading market participants to predict additional easing. However, Figure 4 suggests that market participants revised their expectations regarding the size and duration of Nikkei 225 ETF purchases upward on average during this period.

Interestingly, the coefficient estimates sharply decrease from the sample ending in February 2021 onward. This decrease is likely related to the BoJ's announcement immediately after the Monetary Policy Meeting (MPM) on March 19, 2021, that it would purchase only TOPIX ETFs from April. In fact, Katagiri et al. (2022b) document that on that day, the Nikkei 225 index dropped by around 3%, although the TOPIX slightly rose. However, the figure suggests that the stock market began to reflect the policy change somewhat earlier than March 2021. This is likely due to information revealed by the BoJ. Indeed, on the day of its December 2020 MPM, the BoJ announced that it would conduct an assessment for further effective and sustainable monetary easing and would make its findings public, likely at the March 2021 MPM. Subsequently, BoJ officials spoke publicly on the side effects of ETF purchases. For instance, in his speech in February 2021, board member Nakamura stated that it was "necessary to bear in mind that large-scale purchases and prolonged holding of assets—not limited to ETFs—could affect market functioning."[15] This episode also illustrates how the policy effect is difficult to capture by event studies focusing on MPM dates.

6.4. Demand from other investors

This subsection explores investment demand from non-BoJ investors to see whether such demand contaminates the identification in this paper. This exercise is important since the impact of BoJ holdings could be overstated by the baseline regressions if demand from other investors for portfolios tracking the Nikkei index also increased.

A candidate of such investors is Nikkei 225 index funds other than ETFs held by the BoJ. This is unlikely, however, since Figure 2 suggests that the BoJ has been the dominant end investor in equity funds. To further check this possibility, data on the total flows into publicly offered Nikkei 225 index funds are used. Figure 5 compares the 12-month moving sum of the total flows with that of BoJ purchases of Nikkei 225 ETFs estimated in Section 4

[15] Nakamura, Toyoaki. 2021. "Economic Activity, Prices, and Monetary Policy in Japan." Speech at a Meeting with Local Leaders in Kochi (via webcast). February 10, 2021:

https://www.boj.or.jp/en/about/press/koen_2021/ko210215a.htm.

in terms of the value on March 31, 2021.[16] The figure shows that these two are broadly similar. The total flows and BoJ purchases from December 2010 to March 2021 amount to 13.7 trillion yen and 16.2 trillion yen, respectively. This suggests that non-BoJ investors sold 2.5 trillion yen of Nikkei 225 index funds, possibly because they regarded the index as overvalued due to BoJ holdings. Overall, there is no evidence that the approach in this paper overestimates the effect of BoJ holdings due to other investors' investments in Nikkei 225 index funds.

Another possibility is that institutional investors invested in portfolios that track the Nikkei index without purchasing index funds. To see this possibility, the analysis here first examines flows from different types of investors to domestic listed stocks, using the Flow of Funds Accounts data. Table 8 summarizes cumulative flows into domestic listed stocks when the BoJ purchased Nikkei 225 ETFs (i.e., from the fourth quarter of 2010 to the first quarter of 2021) by sector. Column (1) presents simple sums of quarterly flows during this period. On the other hand, column (2) reports cumulative flows adjusted to be measured in terms of the value on March 31, 2021.[17] This table shows that adjusted cumulative flows are larger in absolute value than simple cumulative flows for all sectors. Both cumulative flows, however, present very similar results concerning the relative importance of the sectors. The result indicates that securities investment trusts, foreign investors ("overseas" in the terminology of

[16] The total flows are "sales minus repurchases and redemptions" published by the Investment Trusts Association, Japan. Unfortunately, monthly data are available only from August 2012, while annual data are available from 2010. Therefore, monthly data from January 2010 to July 2012 are constructed by dividing the flows in 2010 and 2011 by 12 and the flows from January to July 2012 by 7. To calculate the value on March 31, 2021, monthly flows are divided by the corresponding monthly average prices of the Nikkei 225 index relative to the price on March 31, 2021.

[17] The adjusted cumulative flows are estimated as follows. First, for every quarter, the return is estimated by subtracting the flow in the quarter from the change in the stock between the beginning and end of the quarter and then dividing it by the stock at the beginning of the quarter. Next, the estimated returns from the fourth quarter of 2010 through the first quarter of 2021 and the stock at the end of the third quarter of 2010 are used to calculate the counterfactual stock on March 31, 2021, in the absence of flows. Finally, the counterfactual stock is subtracted from the actual stock to obtain the adjusted cumulative flows.

the Flow of Funds Accounts), and public pensions purchased large amounts of listed stocks, while households, deposit corporations, private pension funds, and insurers sold them.[18]

The following will focus on the three sectors that purchased large amounts of domestic listed stocks. First, the cumulative flows from securities investment trusts are essentially due to flows from the BoJ via ETFs. In fact, simple and adjusted cumulative flows from securities investment trusts (34.2 trillion yen and 52.0 trillion yen) are almost identical to those from the BoJ to investment trust beneficiary certificates (36.5 trillion yen and 51.4 trillion yen).[19]

Second, the large flows from public pension funds were mainly due to the reform of the Government Pension Investment Fund (GPIF), the world's largest institutional investor. On October 31, 2014, the GPIF announced a new asset mix, raising its target allocation to domestic equities from 12% to 25%. However, the GPIF is unlikely to have increased its exposure to the Nikkei index since its benchmark for domestic stocks is the TOPIX (including dividends), a popular benchmark among pension funds.[20]

Finally, foreign investors' exposures are examined using annual data on the shareholding ratios of foreign corporations, etc. Since most listed firms report ownership data at the end of March, the exposures are estimated at the end of March in 2010 and 2021, the

[18] The simple and adjusted cumulative flows from the central bank (-1.7 trillion yen and -2.3 trillion yen, respectively) represent sales of stocks that were purchased by the BoJ from commercial banks to promote financial stability from November 2002 to September 2004 and from February 2009 to April 2010.

[19] Note that the adjusted cumulative flows from the BoJ to investment trust beneficiary certificates are very close to the BoJ's ETF holdings of 51.5 trillion yen at the end of March 2021. This makes sense since the BoJ's holdings at a given point in time must be identical to the sum of the previous flows in terms of the value at that point in time. The small difference may be due to estimation errors in the adjusted cumulative flows as a result of using quarterly flow data when it would be ideal to use higher-frequency flow data.

[20] On March 31, 2021, public pensions held 61.4 trillion yen of domestic listed stocks, according to the Flow of Funds Accounts. On the same day, the GPIF held domestic equities of 47.2 trillion yen, according to its disclosures. While the GPIF's definition of domestic equities includes investment trust beneficiary certificates and alternative assets, such as private equity and real estate, listed stocks likely account for the majority of the GPIF's portfolio. This is because, for instance, according to the Flow of Funds Accounts, public pensions, including the GPIF, held only 0.165 trillion yen in investment trust beneficiary certificates.

latest end of March before the first announcement of ETF purchases and the termination date of Nikkei 225 ETF purchases. To estimate the exposures, foreign investors' holdings (in trillion yen) of individual stocks listed on the TSE First Section are regressed on the weights of the TOPIX, Nikkei 225, and JPX-Nikkei 400. The coefficient on an index weight can be interpreted as the exposure to the index in trillion yen.

Columns (1) and (2) of Table 9 show the results when only firms with financial years ending in March 2010 and 2021, respectively, are included in the sample. The results suggest that foreign investors' exposure to the TOPIX increased from 88 trillion yen to 228 trillion yen. This indicates a 2.6-fold increase in the exposure, mainly due to the TOPIX nearly doubling over the same period. The exposure to the Nikkei index was 6.20 trillion yen in 2010. However, the exposure was only 1.37 trillion yen in 2021, and this estimate is not statistically different from zero. This result suggests that foreign investors actually reduced their exposure to the Nikkei index from 2010 to 2021. Columns (3) and (4) check the robustness by using the sample of all stocks in the TSE First Section and assuming that the percentage of individual stocks held by foreign investors remained unchanged until the following March for firms that closed their books before March. Now, the exposure to the Nikkei index is statistically significant for 2021. However, the results suggest that the exposure in 2021 remained roughly the same as in 2010, about 6 trillion yen, despite a 2.6-fold rise in the Nikkei index. Overall, the regression analysis suggests that foreign investors are unlikely to have increased their exposure to the Nikkei index between 2010 and 2021.[21]

In sum, this subsection finds no evidence that demand from non-BoJ investors for portfolios tracking the Nikkei index increased during the period of interest. This result suggests that investment demand from non-BoJ investors is unlikely to contaminate the identification in this paper.

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[21] Note that the constant term is statistically significant at -0.01 in all columns. This indicates that foreign investors' holdings of each stock are, on average, 0.01 trillion yen less than predicted by the index weights. This amount is negligible for large-cap stocks but not for small-cap stocks, suggesting that small-cap stocks represent a lower percentage of foreign investors' portfolios than expected from the index weights. This may be because foreign investors are aware that small-cap stocks are less important to tracking performance.

7. Conclusion

This paper examines the effects of the BoJ's ETF holdings on long-term stock returns. The analysis shows that the effects are very large. The baseline regression results suggest that the price multiplier is around 6. It is about 8 to 9 when BoJ holdings are normalized by shares outstanding, as in many studies on the impact of demand shocks on stock returns in the U.S. The estimated multiplier is much higher than typical estimates in the literature. There is no evidence of a return reversal in the 9 months after the BoJ terminated purchases of Nikkei 225 ETFs.

The BoJ revised its ETF purchase policy to be essentially market-neutral on a flow basis by terminating the purchases of Nikkei 225 ETFs at the end of March 2021. Furthermore, it ended all ETF purchases in March 2024. However, it still holds a large amount of Nikkei 225 ETFs and has not expressed any plans to sell the ETFs it purchased. The results obtained in this paper suggest that the BoJ's holdings of Nikkei 225 ETFs have large effects on stock prices even after the end of the purchases.

This study also highlights problems arising from stock indexes. Most importantly, the analysis in this paper suggests that major price-weighted indexes, such as the Nikkei 225 index, can seriously distort the financial market and that such problems can be greatly amplified by large-scale unconventional policies, such as the BoJ's ETF purchases. This implies that when planning a new policy, careful assessment of existing market distortions is needed.

The literature provides a wide range of estimates of the price multiplier. The large estimated impact of the BoJ's persistent ETF holdings may imply that the multiplier is higher when demand shocks originate from investors expected to hold assets for a longer period. However, this study on one type of demand shock is insufficient to identify the determinants of the multiplier. Therefore, the determinants remain an important issue for future research.

Another important avenue of future work is to examine the impacts of such demand shocks on firm behavior and the macroeconomy. Gabaix and Koijen (2022) argue that the macro multiplier, the price multiplier without controlling for movements in the aggregate market, is needed to assess the impact of a demand shock on the aggregate market. They also find that the macro multiplier is much higher than the micro multiplier. If this is the case, the high micro multiplier estimated in this paper may suggest that the BoJ's ETF holdings have had a huge impact on the aggregate stock market and, thus, the macroeconomy. On the other hand, this policy may also adversely affect the macroeconomy, for example, through distortions in resource allocation and weakened corporate governance. There is still much room to study the complicated channels for the effects of such large, uneven, and persistent demand shocks.

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Table 1. Top 10 Firms in Terms of BoJ Holdings to Free Float

Ranking	Firm name	(1) BoJ holdings to free float (%)	(2) Nikkei 225 weight to TOPIX weight (multiple)	(3) BoJ holdings (trill. yen)
1	Fast Retailing Co Ltd	104.8	25.1	1.96
2	Konami Group Corp	44.0	9.3	0.17
3	Advantest Corp	42.5	8.9	0.49
4	Taiyo Yuden Co Ltd	36.9	7.4	0.14
5	Hitachi Construction Machinery Co Ltd	35.5	7.1	0.09
6	COMSYS Holdings Corp	34.7	6.9	0.09
7	TDK Corp	34.6	6.8	0.41
8	Matsui Securities Co Ltd	33.8	6.8	0.02
9	NTT Data Corp	32.6	6.3	0.24
10	Trend Micro Inc/Japan	32.5	6.3	0.15

Note: The table shows the top 10 firms in terms of the ratio of estimated Bank of Japan (BoJ) holdings to the Tokyo Stock Exchange-defined free float on March 31, 2021. Columns (1), (2), and (3) show the ratio of BoJ holdings to the free float (in %), the ratio of the Nikkei 225 weight to the TOPIX weight (in terms of multiples), and the outstanding amount of BoJ holdings (trillion yen), respectively.

Table 2. Baseline First-stage Regressions

	(1) Full sample	(2) Subsample
Index weight ratio	0.0191**	0.0181**
	(11.13)	(19.68)
Beta	0.0007	-0.0061
	(0.56)	(-0.89)
Firm size	0.0033**	0.0065**
	(4.70)	(2.87)
Book to market ratio	-0.0019	-0.0096
	(-1.75)	(-1.12)
Profitability	-0.0048	-0.0202
	(-0.70)	(-1.21)
Asset growth	-0.0069	-0.0058
	(-1.26)	(-0.22)
Lagged returns	-0.0038	-0.0084
	(-1.94)	(-0.91)
Nikkei 225 member	-0.0041	
	(-1.17)	
Observations	1,158	177
R-squared	0.772	0.780

Note: The table reports the results of the first-stage regressions of the baseline analysis. The dependent variable is the BoJ holding ratio, which is defined as the ratio of BoJ holdings to a measure of free float on March 31, 2021. The independent variables are calculated using data up to September 30, 2010. "Index weight ratio" is the ratio of the Nikkei 225 weight to the TOPIX weight. "Beta," "Firm size," "Book to market ratio," "Profitability," and "Asset growth" are the firm characteristics of interest in Fama and French's (2015) 5-factor model. "Lagged returns" is the 3-year return to August 31, 2010. "Nikkei 225 member" takes 1 if the stock was included in the Nikkei 225 index on September 30, 2010, and 0 otherwise. Column (1) reports the full-sample results, while column (2) reports the results for the subsample of Nikkei 225 members on September 30, 2010. A constant term is included in the regressions, but the coefficient estimates are suppressed. t-statistics are shown in parentheses. ** denotes statistical significance at the 1% level. Standard errors are clustered at the industry level.

Table 3. Baseline Second-stage Regressions for the Full Sample

	(1) Raw	(2) 1 factor	(3) 3 factors	(4) 4 factors	(5) 5 factors	(6) 6 factors
BoJ holding ratio	5.73**	5.95**	6.40**	6.74**	5.21**	5.54**
	(4.98)	(4.19)	(4.70)	(4.82)	(3.83)	(3.89)
Beta	-0.22	-0.78**	-0.62**	-0.68**	-0.57**	-0.65**
	(-1.83)	(-5.59)	(-4.92)	(-5.23)	(-4.59)	(-4.77)
Firm size	0.02	0.01	0.09*	0.09*	0.05	0.05
	(0.67)	(0.22)	(2.47)	(2.55)	(1.51)	(1.36)
Book to market ratio	0.14	0.20*	0.30**	0.31**	0.34**	0.38**
	(1.64)	(2.09)	(3.12)	(3.20)	(3.35)	(3.68)
Profitability	1.42**	1.73**	1.80**	1.88**	1.88**	2.04**
	(3.97)	(4.74)	(5.43)	(5.37)	(5.15)	(5.01)
Asset growth	-0.77*	-1.20**	-1.17**	-1.21**	-1.31**	-1.36**
	(-2.58)	(-3.08)	(-3.07)	(-3.23)	(-3.15)	(-3.25)
Lagged returns	-0.19*	0.01	0.02	0.03	0.01	0.03
	(-2.37)	(0.18)	(0.22)	(0.39)	(0.11)	(0.52)
Nikkei 225 member	-0.37**	-0.38**	-0.35**	-0.36**	-0.31**	-0.33**
	(-4.99)	(-4.07)	(-4.10)	(-4.25)	(-3.46)	(-3.72)

Note: The table presents the results of the second-stage regressions of the baseline analysis for the full sample. Column (1) reports the results when using the raw return between September 30, 2010, and March 31, 2021, as the dependent variable, while columns (2) to (6) report the results when using the abnormal returns computed based on the 1-, 3-, 4-, 5-, and 6-factor models, respectively. “BoJ holdings ratio” is the ratio of BoJ holdings to a measure of free float on March 31, 2021. This ratio is instrumented by the index weight ratio, which is defined as the ratio of the Nikkei 225 weight to the TOPIX weight on September 30, 2010. The other independent variables are calculated using data up to September 30, 2010. “Beta,” “Firm size,” “Book to market ratio,” “Profitability,” and “Asset growth” are the firm characteristics of interest in Fama and French’s (2015) 5-factor model. “Lagged return” is the 3-year return to August 31, 2010. “Nikkei 225 member” takes 1 if the stock is included in the Nikkei 225 index on September 30, 2010, and 0 otherwise. A constant term is included in the regressions, but the coefficient estimates are suppressed. t-statistics are reported in parentheses. ** and * denote statistical significance at the 1 and 5% levels, respectively. Standard errors are clustered at the industry level. The number of observations is 1,158 for all regressions.

Table 4. Price Multipliers for Alternative Regressions

	(1) Raw	(2) 1 factor	(3) 3 factors	(4) 4 factors	(5) 5 factors	(6) 6 factors
Panel A: Baseline IV regressions						
Full sample	5.73**	5.95**	6.40**	6.74**	5.21**	5.54**
	(4.98)	(4.19)	(4.70)	(4.82)	(3.83)	(3.89)
Subsample	5.56**	6.03**	5.89**	6.26**	4.94**	5.27**
	(5.90)	(5.24)	(5.29)	(5.58)	(4.20)	(4.23)
Panel B: OLS regresssions						
Full sample	6.76**	6.72**	6.48**	6.88**	5.49**	5.93**
	(7.01)	(6.04)	(5.97)	(6.14)	(5.20)	(5.31)
Subsample	5.47**	5.91**	5.57**	5.91**	4.71**	5.07**
	(5.62)	(4.97)	(4.93)	(5.04)	(4.08)	(4.01)
Panel C: Normalizing BoJ holdings by shares outstanding						
Full sample	7.69**	8.22**	8.90**	9.38**	7.30**	7.76**
	(4.77)	(4.10)	(4.62)	(4.73)	(3.76)	(3.83)
Subsample	7.84**	8.82**	8.79**	9.39**	7.39**	8.01**
	(5.29)	(4.84)	(4.88)	(5.12)	(3.95)	(4.10)
Panel D: Using returns to December 30, 2021						
Full sample	6.22**	6.38**	6.79**	6.97**	5.27**	5.67**
	(5.39)	(4.16)	(4.31)	(4.39)	(3.33)	(3.44)
Subsample	5.94**	6.89**	6.80**	7.00**	5.62**	5.91**
	(5.88)	(4.93)	(4.58)	(4.69)	(3.68)	(3.76)
Panel E: Using the weights of individual stocks in ETFs						
Full sample	5.42**	5.63**	6.05**	6.38**	4.93**	5.24**
	(4.95)	(4.17)	(4.67)	(4.79)	(3.80)	(3.87)
Subsample	5.25**	5.70**	5.57**	5.91**	4.67**	4.98**
	(5.86)	(5.20)	(5.25)	(5.54)	(4.18)	(4.21)

Note: The table presents the coefficient estimate on normalized BoJ holdings for cross-sectional regressions for the full sample and the subsample of Nikkei 225 members on September 30, 2010. Column (1) reports the results when using the raw return as the dependent variable, while columns (2) to (6) report the results when using the abnormal returns computed based on the 1-, 3-, 4-, 5-, and 6-factor models, respectively. Panel A summarizes the results of the baseline instrumental-variable regressions, in which returns between September 30, 2010, and March 31, 2021, are used, and BoJ holdings are estimated from index weights and normalized by a measure of free float. Panel B reports the ordinary least squares (OLS) regression results. Panel C reports the results when BoJ holdings are normalized by shares outstanding. Panel D reports the results when returns to the end of December 2021 are used. Panel E reports the results when BoJ holdings are estimated from the weights of individual stocks in ETFs. The number of observations for the full sample and the subsample are 1,151 and 176 in Panel D and 1,158 and 177 in the other panels. t-statistics are reported in parentheses. ** denotes statistical significance at the 1% level. Standard errors are clustered at the industry level.

Table 5. Regressions of Ex-post Returns

	(1)	(2)	(3)	(4)	(5)	(6)
	Raw	1 factor	3 factors	4 factors	5 factors	6 factors
Full sample	-0.15	-0.16	-0.17	-0.28	-0.27	-0.32
	(-0.55)	(-0.58)	(-0.61)	(-0.96)	(-0.96)	(-1.09)
Subsample	0.02	0.03	0.03	0.02	-0.03	-0.03
	(0.06)	(0.07)	(0.07)	(0.04)	(-0.08)	(-0.06)

Note: The table presents the results of regressing returns from March 31, 2021, to December 30, 2021, on the BoJ holding ratio, which is defined as the ratio of BoJ holdings to a measure of free float, on March 31, 2021, and control variables. The table only shows the coefficients on the BoJ holding ratio. Column (1) reports the results for the raw return, while columns (2) to (6) report those for the abnormal returns computed using the 1-, 3-, 4-, 5-, and 6-factor models, respectively. The number of observations for the full sample and the subsample are 1,304 and 186, respectively. t-statistics are reported in parentheses. Standard errors are clustered at the industry level.

Table 6. OLS Regressions of Cumulative Returns on the Index Weight Ratio

	(1)	(2)	(3)	(4)	(5)	(6)
	Raw	1 factor	3 factors	4 factors	5 factors	6 factors
Panel A: Baseline sample (September 30, 2010, to March 31, 2021)						
Full sample	0.1095**	0.1138**	0.1224**	0.1290**	0.0997**	0.1059**
	(4.53)	(3.91)	(4.60)	(4.78)	(3.72)	(3.85)
Subsample	0.1005**	0.1090**	0.1065**	0.1131**	0.0892**	0.0953**
	(5.68)	(4.97)	(5.09)	(5.45)	(4.08)	(4.20)
Panel B: Alernative sample (September 30, 2000, to September 30, 2010)						
Full sample	-0.0050	0.0035	0.0049	0.0121	0.0360	0.0404*
	(-0.30)	(0.20)	(0.28)	(0.63)	(1.98)	(2.14)
Subsample	-0.0499	-0.0409	-0.0402	-0.0332	-0.0084	-0.0059
	(-1.91)	(-1.42)	(-1.40)	(-1.10)	(-0.24)	(-0.17)

Note: The table presents the estimated coefficients on the index weight ratio, which is defined as the ratio of the Nikkei 225 weight to the TOPIX weight, when regressing the return on the index weight ratio and controls. Column (1) reports the results for the raw return, while columns (2) to (6) report those for the abnormal returns computed using the 1-, 3-, 4-, 5-, and 6-factor models, respectively. Panel A uses the return between September 30, 2010, and March 31, 2021, and independent variables computed from data up to September 30, 2010. Panel B uses the return between September 30, 2000, and September 30, 2010, and independent variables computed from data up to September 30, 2000. The number of observations for the full sample and the subsample are 1,158 and 177 in Panel A, and 742 and 166 in Panel B. t-statistics are reported in parentheses. ** denotes statistical significance at the 1% level. Standard errors are clustered at the industry level.

Table 7. Fama-MacBeth Regressions

	(1)	(2)	(3)	(4)
	Oct. 2010-Mar. 2021		Oct. 2000-Sep. 2010	
	Full sample	Subsample	Full sample	Subsample
Index weight ratio	0.00108**	0.00124**	-0.00032	-0.00101
	(2.64)	(3.00)	(-0.66)	(-1.82)
Beta	-0.00370	-0.00439	-0.01062	-0.00511
	(-0.91)	(-0.70)	(-1.81)	(-0.78)
Firm size	0.00012	0.00053	-0.00043	-0.00226
	(0.20)	(0.69)	(-0.45)	(-1.42)
Book to market ratio	0.00118	0.00301	0.00468**	0.00319
	(1.06)	(1.48)	(4.05)	(1.04)
Profitability	0.01237**	0.01536*	0.00429	-0.00097
	(3.64)	(2.05)	(1.00)	(-0.11)
Asset growth	0.00130	-0.00626	-0.00679*	0.00606
	(0.42)	(-0.87)	(-2.12)	(0.76)
Lagged returns	-0.02272	0.00342	-0.04882	-0.08680
	(-0.53)	(0.06)	(-1.41)	(-1.75)
Nikkei 225 member	-0.00244		0.00418	
	(-1.31)		(1.61)	
Observations	198,977	24,575	129,688	20,819
Number of months	126	126	120	120
R-squared	0.088	0.160	0.115	0.198

Note: The table presents the results of Fama-MacBeth (1973) regressions of the return in a month on independent variables calculated using data up to the end of the previous month. Columns (1) and (2) report the results when using monthly returns from October 2010 to March 2021, while columns (3) and (4) report those when using returns from October 2000 to September 2010. Columns (1) and (3) report the full-sample results, while columns (2) and (4) report the results for the subsample of stocks that were included in the Nikkei 225 index at the end of the previous month. "Index weight ratio" is the ratio of the Nikkei 225 weight to the TOPIX weight. "Beta," "Firm size," "Book to market ratio," "Profitability," and "Asset growth" are the firm characteristics of interest in Fama and French's (2015) 5-factor model. "Lagged return" is the 11-month past return lagged 1-month. "Nikkei 225 member" takes 1 if the stock is included in the Nikkei 225 index at the end of the previous month and 0 otherwise. A constant term is included in the regressions, but the coefficient estimates are suppressed. t-statistics are reported in parentheses. ** and * denote statistical significance at the 1 and 5% levels, respectively.

Table 8. Cumulative Flows to Domestic Listed Stocks by Investor Type

	(1) Simple (trill. yen)	(2) Adjusted (trill. yen)
Securities investment trusts	34.2	52.0
Overseas	17.0	36.2
Public pensions	13.9	23.0
Financial dealers and brokers	1.9	3.2
Central and local government	0.0	0.0
Other financial institutions	-0.6	-1.0
Central bank	-1.7	-2.3
Other domestic nonfinancial sector	-5.1	-9.9
Insurance	-8.6	-13.6
Private pension funds	-10.0	-21.0
Depository corporations	-10.8	-22.7
Households	-28.0	-42.4

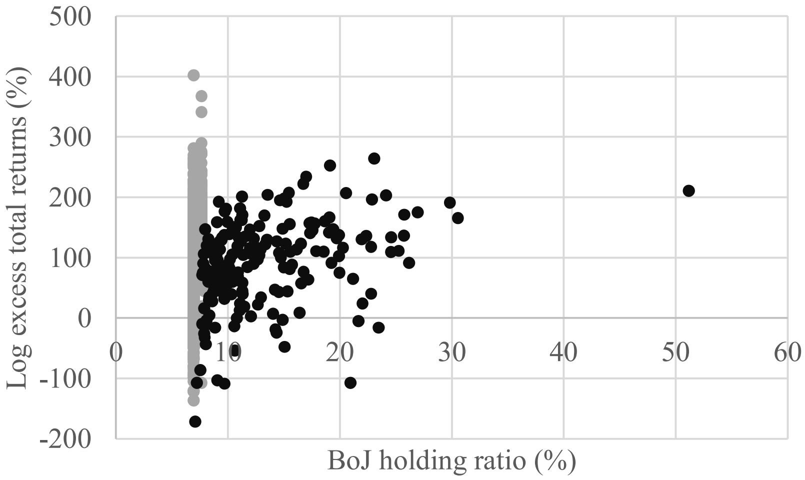
Note: The table presents cumulative flows to domestic listed shares (in trillion yen) by sector between the fourth quarter of 2010 and the first quarter of 2021. The original data are from the Flow of Funds Accounts. Columns (1) and (2) report simple and adjusted cumulative flows, respectively. Adjusted cumulative flows are cumulative flows in terms of the value on March 31, 2021, which are estimated as follows. First, for every quarter, the return is calculated by subtracting the flow during the quarter from the change in the stock between the beginning and end of the quarter and then dividing it by the stock at the beginning of the quarter. Next, the estimated returns and the stock at the end of the third quarter of 2010 are used to calculate the counterfactual stock on March 31, 2021, in the absence of flows between the fourth quarter of 2010 and the first quarter of 2021. Finally, the counterfactual stock is subtracted from the actual stock to obtain the adjusted cumulative flows. Most sector names are those used in the Flow of Funds Accounts. However, “Central and local governments” is the sum of “Central government” and “Local governments.” “Other financial institutions” is calculated by subtracting “Securities investment trusts,” “Financial dealers and brokers,” “Central bank,” “Insurance,” “Private pension funds,” and “Depository corporations” from “Financial institutions.” “Other domestic nonfinancial sector” is calculated by subtracting “Public pensions,” “Central and local governments,” and “Households” from “Domestic nonfinancial sector.” The adjusted cumulative flows are estimated after quarterly flows and stocks are calculated for all of these sectors.

Table 9. Estimated Exposures of Foreign Investors to Indexes

	(1)	(2)	(3)	(4)
	Only March-end firms		Full sample	
	March-10	March-21	March-10	March-21
TOPIX	87.66**	228.15**	88.67**	218.90**
	(74.47)	(48.70)	(83.47)	(36.53)
Nikkei 225	6.20**	1.37	6.05**	6.39**
	(6.47)	(1.03)	(7.64)	(5.12)
JPX-Nikkei 400		4.34		13.23*
		(0.94)		(2.27)
Constant	-0.01*	-0.01**	-0.01*	-0.01*
	(-2.08)	(-2.79)	(-2.49)	(-2.24)
Observations	1,115	1,448	1,381	2,119
R-squared	0.879	0.927	0.881	0.852

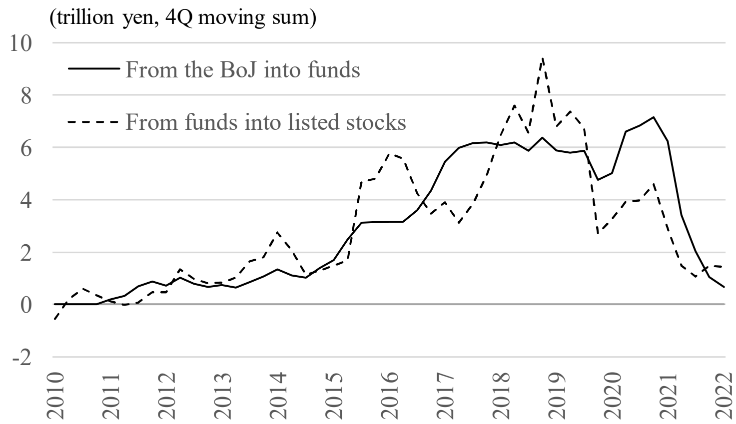
Note: The table shows foreign investors' estimated exposures (in trillion yen) to the Tokyo Stock Price Index (TOPIX), the Nikkei 225, and the JPX-Nikkei 400. The estimated exposures are obtained by regressing foreign investors' holdings of individual stocks (in trillion yen) on a constant and the weights of the three indexes at the end of March of each year. t-statistics are reported in parentheses. ** and * denote statistical significance at the 1 and 5% levels, respectively. Columns (1) and (2) report the results when using only firms that closed their book in March, while columns (3) and (4) report the results for the full sample using the latest ownership data up to March. Columns (1) and (3) report the results at the end of March 2010, while columns (2) and (4) report the results at the end of March 2021.

Figure 1. Total Returns against the BoJ Holding Ratio



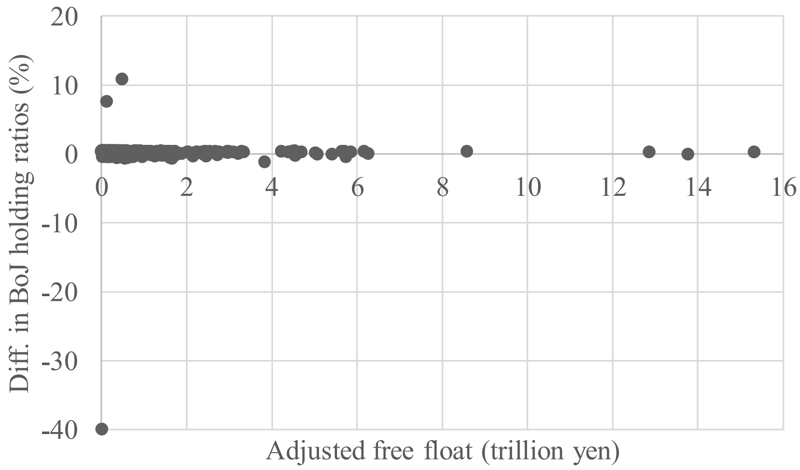
Note: The figure shows the log excess total return between September 30, 2010, and March 31, 2021 (in %) against the BoJ holding ratio (the ratio of Bank of Japan holdings to a measure of free float) on March 31, 2021 (in %). The black circles represent Nikkei 225 members on March 31, 2021, while the grey circles represent other stocks.

Figure 2. Flows from the BoJ to Funds and from Funds to Domestic Listed Stocks



Note: The figure shows 4-quarter moving sums of flows from the Bank of Japan (BoJ) into investment funds (solid line) and from investment funds into domestic listed stocks (broken line) from the first quarter of 2010 to the first quarter of 2022. The former and latter flows are those from the "Central bank" into "Investment trust beneficiary certificates" and from "Security investment trusts" into "Listed shares," respectively, in the Flow of Funds Accounts.

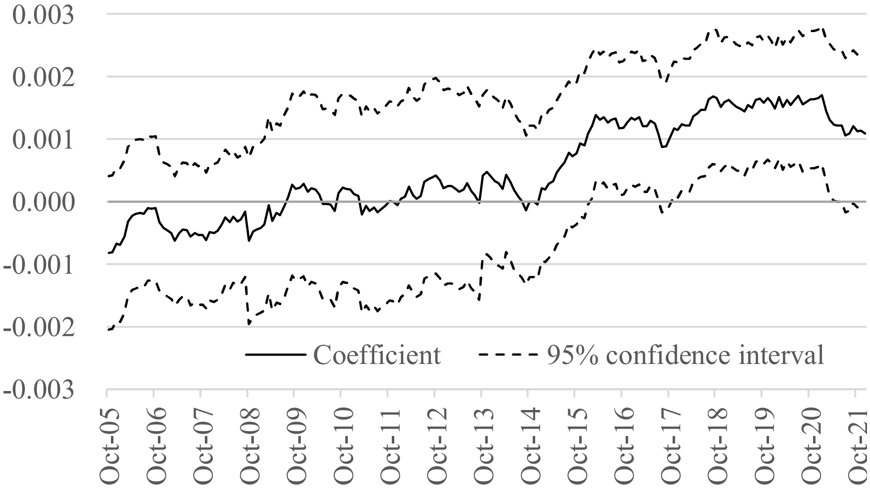
Figure 3. ETF Weights versus Index Weights



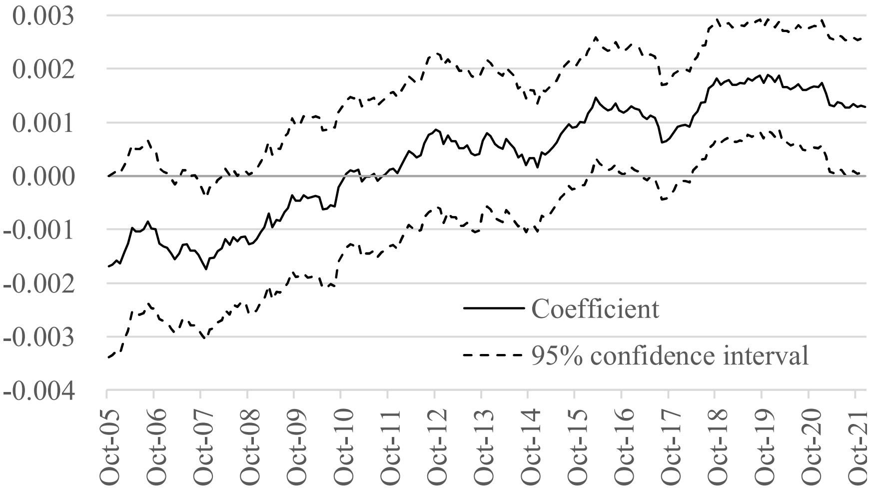
Note: The figure plots the difference between the Bank of Japan holding ratio estimated based on ETF weights and that estimated based on index weights (in %) on the vertical axis against the adjusted free float (i.e., the Tokyo Stock Exchange-defined free-float market capitalization plus BoJ holdings in trillion yen) on the horizontal axis.

Figure 4. Rolling Fama-MacBeth Regressions

A. Full sample

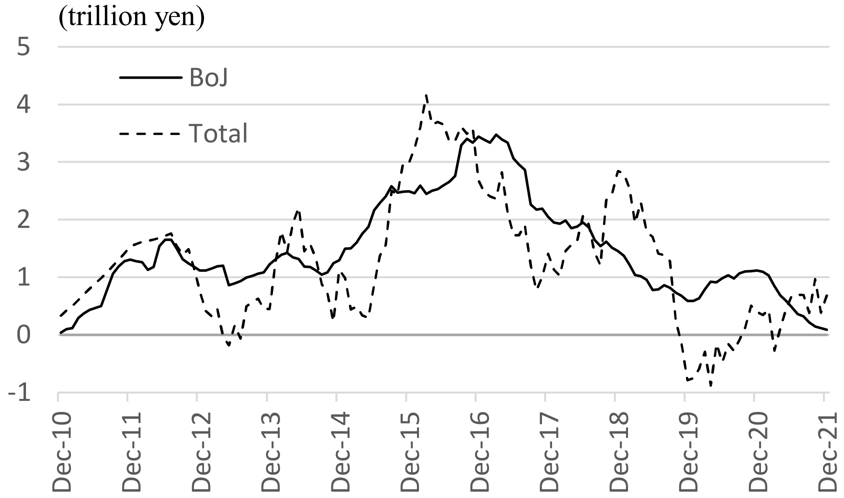


B. Subsample



Note: Panels A and B show the coefficient (solid line) and 95% confidence interval (broken lines) of the index weight ratio (the Nikkei 225 weight to the TOPIX weight) for 5-year rolling Fama-MacBeth (1973) regressions for the full sample and the subsample of Nikkei 225 members at the end of the previous month, respectively. The monthly log excess total return in a month is regressed on independent variables calculated using data up to the end of the previous month. The observation period is from the 5-year sample ending in October 2005 to December 2021.

Figure 5. BoJ Purchases of Nikkei 225 ETFs and Total Flows to Nikkei Index Funds



Note: The figure shows the 12-month moving sums of Bank of Japan purchases of Nikkei 225 ETFs (solid line) and total flows into Nikkei 225 index funds (broken line) in terms of the value on March 31, 2021, for the period from December 2010 to December 2021. The value on March 31, 2021, is calculated using the Nikkei 225 index price on March 31, 2021, and its monthly averages.

Online Appendix for
“The Bank of Japan’s Stock Holdings and Long-term Returns”[1]

Hibiki Ichiue[2]

February 2024

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[1] This research was supported by the Yu-cho Foundation (Grant-in-Aid for Research, 2023).

[2] Faculty of Economics, Keio University; hichiue@keio.jp

A. The BoJ's Indirect Stock Holdings in More Detail

Section 4 estimates the Bank of Japan's (BoJ's) indirect holdings of individual stocks in three steps. This appendix discusses the first two steps and the estimation results in more detail.

In the first step, the BoJ's daily purchases of each exchange-traded fund (ETF) are estimated. The BoJ has published daily data on total ETF purchases for each of the main and supplementary programs. Using these data, the amount of daily purchases of each ETF is estimated based on several assumptions. For instance, when the BoJ set the maximum purchases of individual ETFs to be roughly in proportion to their market capitalization under the main program, it is assumed that the BoJ purchased ETFs exactly in proportion to their market capitalization on the previous day. Data on the market capitalization of ETFs are from Nikkei NEEDS. The data cover all 27 equity index ETFs that track the Tokyo Stock Price Index (TOPIX), the Nikkei 225, or the JPX-Nikkei 400. Note that leveraged and inverse ETFs were not eligible for the ETF purchase programs. From May 2020 to March 2021, as the BoJ became the dominant investor in the ETF market, it allocated about 25% of the funds for the main program to ETFs tracking either of the three indexes, taking the amount outstanding in circulation (i.e., the market capitalization excluding BoJ holdings) into account, while about 75% was allocated to investment in TOPIX ETFs only. During this period, it is assumed that the BoJ allocated exactly 25% of its investment to ETFs tracking either of the three indexes in proportion to the market value minus its holdings on the previous day and 75% to TOPIX ETFs only. As for the supplementary program, it is assumed that the BoJ purchased only JPX-Nikkei 400 ETFs since most of the funds for this program were allocated to those ETFs.

In the second step, the BoJ's holdings of each ETF are estimated. To this end, returns and flows are cumulated as follows:

$$h_{j,t} = h_{j,t-1}(1 + r_{j,t}) + f_{j,t}$$

where $h_{j,t}$ represents the BoJ's holdings of ETF j at the end of day t, $r_{j,t}$ is the day t daily rate of return of the index tracked by ETF j, and $f_{j,t}$ is the amount of BoJ purchases of ETF j on day t estimated in the first step. The cumulation starts from the day before the first ETF purchase when BoJ holdings were equal to zero.

Moreover, the BoJ's accounting data on the market value of its total ETF holdings are used to adjust for the estimated holdings. The BoJ makes data on the market value of its holdings at the end of March and September each year, going back several years, available on its website.[3] However, older data appear to be removed as new data are released. Therefore, the analysis here uses data from 2015 through 2021 since data for the period before 2015 were unavailable on the website. Further, data for March are used since data for September are only an approximation based on March prices. The estimated BoJ holdings of each ETF are adjusted by the same adjustment rate so that the sum of the adjusted BoJ holdings is equal to the BoJ's accounting data for each end of March from 2015. The adjustment rate is then linearly interpolated for all days from April 1, 2015, to March 30, 2021, and a constant rate of adjustment is assumed up to the end of March 2015 and from the end of March 2021. Although the adjustment rate is time-varying, it varies in a narrow range, between 1 and 2%, as shown in Table A4. The unadjusted estimates understate the BoJ's ETF holdings, likely in part because, in the estimation, it is assumed that the BoJ purchased ETFs at the closing price. In contrast, in practice, it likely purchased ETFs at a lower price due to its de facto rule of purchasing ETFs in the afternoon on days when stock prices fell sharply in the morning.

Note that although the BoJ's holdings are estimated in the second step, these are needed in the first step since from May 2020 to March 2021, it is assumed that the BoJ allocated 25% of the funds for the main program to ETFs tracking either of the three indexes in proportion to the market capitalization minus its holdings on the previous day. Therefore, in the first step, the BoJ's purchases are initially estimated based on the assumption that the BoJ's holdings are zero. Next, the estimated purchases are used to estimate the BoJ's holdings in the second step. Furthermore, the estimated holdings are used to estimate purchases in the first step. These estimations are iteratively carried out ten times, which is sufficient for achieving convergence.

Figure A2 shows the daily estimates of BoJ holdings by index from 2010 to 2021. The figure indicates that the BoJ's exposures to the TOPIX, the Nikkei 225, and the JPX-Nikkei 400

[3] The data are available in the financial statements here:

https://www.boj.or.jp/en/about/account/index.htm.

on March 31, 2021, were around 32 trillion yen, 17 trillion yen, and 3 trillion yen, respectively. The exposures had remained more or less flat since then, reflecting the limited BoJ purchases. On the other hand, Figure A3 shows the estimated share of the BoJ in the eligible ETFs by index. This figure shows that the BoJ's share ranged from 80% to 100% for all three indexes in 2021, suggesting that the BoJ became the dominant investor in the ETF market.

B. Theory

This appendix employs a simple theory to help interpret the regression results. The model builds on De Long et al. (1990), Hong and Stein (1999), and Greenwood (2005). The model has T periods ($t = 0, 1, \dots, T$), N stocks ($n = 1, 2, \dots, N$), and two types of investors (the central bank and arbitragers). Stocks are in zero net supply. The risk-free rate is normalized to zero. Arbitragers maximize a mean-variance utility function with risk aversion coefficient γ (> 0).

In period 0, neither the central bank nor arbitragers hold any stock. In period 1, the central bank purchases h_n (> 0) shares of stock n by surprise and credibly commits that it will hold $\rho^{t-1}h_n$ shares of stock n in period t ($\leq T - 1$). Here, $\rho \in [0,1]$ represents the persistence of the central bank's holdings after period 1. Period 1 corresponds to around 10.5 years from before the first announcement of the BoJ's ETF purchases to the time after the end of Nikkei 225 ETF purchases. As mentioned in Section 3, the BOJ made many adjustments to the ETF purchase policy during this period. However, this simple model setting is adequate to consider the effects of BoJ holdings on cumulative returns during this period. Furthermore, the model ignores the BoJ's purchases of TOPIX ETFs after the end of Nikkei 225 ETF purchases, partly because the amount of purchases has been limited since then.

In period T, when investors consume all their wealth, stock n is liquidated and pays a risky dividend per share equal to

$$\bar{\theta}_n + \sum_{t=1}^{T} \theta_{n,t}$$

where

$$\theta_{n,t} = \beta_n Z_t + \epsilon_{n,t}.$$

Here, $Z_t \sim i.i.d.N(0, \sigma_Z^2)$ is a common shock, $\epsilon_{n,t} \sim i.i.d.N(0, \sigma_n^2)$ is an idiosyncratic shock, and β_n (> 0) is a factor loading. Z_t, $\epsilon_{n,t}$, and thus $\theta_{n,t}$ become public in period t. $\bar{\theta}_n + \sum_{s=1}^{t} \theta_{n,s}$ can be interpreted as the fundamental value of stock n according to the information revealed up to period t. Without loss of generality, $\bar{\theta}_n$ is set to 1 for all n.

In period T, since the dividend is known for sure, the price of stock n equals the dividend as

$$P_{n,T} = 1 + \sum_{t=1}^{T} \theta_{n,t}.$$

In period $T-1$, the value of $\theta_{n,T} = \beta_n Z_T + \epsilon_{n,T}$ is unknown. Given arbitragers' choice of their demand for stock n, $D_{n,T-1}$, their profit in period T is

$$\sum_{n=1}^{N} (P_{n,T} - P_{n,T-1}) D_{n,T-1} = \sum_{n=1}^{N} \left(1 + \sum_{t=1}^{T-1} \theta_{n,t} + \beta_n Z_T + \epsilon_{n,T} - P_{n,T-1}\right) D_{n,T-1}.$$

Since $Z_t \sim i.i.d.N(0, \sigma_Z^2)$ and $\epsilon_{n,t} \sim i.i.d.N(0, \sigma_n^2)$, arbitragers maximize a mean-variance utility function,

$$\sum_{n=1}^{N} \left(1 + \sum_{t=1}^{T-1} \theta_{n,t} - P_{n,T-1}\right) D_{n,T-1} - \frac{\gamma}{2} \left[\sigma_Z^2 \left(\sum_{n=1}^{N} \beta_n D_{n,T-1}\right)^2 + \sum_{n=1}^{N} \sigma_n^2 D_{n,T-1}^2\right]$$

The first-order condition with respect to $D_{n,T-1}$ is

$$P_{n,T-1} = 1 + \sum_{t=1}^{T-1} \theta_{n,t} - \gamma\left(\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m D_{m,T-1} + \sigma_n^2 D_{n,T-1}\right).$$

Since stocks are in zero net supply, the market clearing condition for stock n is

$$D_{n,T-1} + \rho^{T-2} h_n = 0.$$

From the market clearing condition and the first-order condition,

$$P_{n,T-1} = 1 + \sum_{t=1}^{T-1} \theta_{n,t} + \gamma \rho^{T-2} (\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \sigma_n^2 h_n).$$

Given that arbitragers choose their demand $D_{n,T-2}$ in period $T-2$, their profit in period $T-1$ is

$$\sum_{n=1}^{N} (P_{n,T-1} - P_{n,T-2}) D_{n,T-2}$$
$$= \sum_{n=1}^{N} \left[1 + \sum_{t=1}^{T-1} \theta_{n,t} + \gamma \rho^{T-2} (\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \sigma_n^2 h_n) - P_{n,T-2}\right] D_{n,T-2}.$$

With similar calculations, the stock price is represented by

$$P_{n,T-2} = 1 + \sum_{t=1}^{T-2} \theta_{i,t} + \gamma(\rho^{T-3} + \rho^{T-2})(\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \sigma_n^2 h_n).$$

Repeating the same procedure, the stock price in period t is

$$P_{n,t} = 1 + \sum_{s=1}^{t} \theta_{n,s} + \gamma(\rho^{t-1} + \rho^{t} + \cdots + \rho^{T-2})(\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \sigma_n^2 h_n),$$

for $t \geq 1$. As in Hong and Stein (1999), the limiting case where T goes to infinity is considered. In this case, the stock price is represented as

$$P_{n,t} = 1 + \sum_{s=1}^{t} \theta_{n,s} + \frac{\gamma \rho^{t-1}}{1-\rho}(\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \sigma_n^2 h_n). \tag{A1}$$

In period 0, since arbitragers do not expect stock purchases by the central bank, they choose their demand $D_{n,0}$ to maximize

$$\sum_{n=1}^{N}(1 - P_{n,0})D_{i,0} - \frac{\gamma}{2}\left[\sigma_Z^2\left(\sum_{n=1}^{N} \beta_n D_{n,0}\right)^2 + \sum_{n=1}^{N} \sigma_n^2 D_{n,0}^2\right].$$

The first-order condition with respect to $D_{n,0}$ is

$$P_{n,0} = 1 - \gamma\left(\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m D_{m,0} + \sigma_n^2 D_{n,0}\right).$$

Since the central bank does not hold any stock in period 0, the market clearing condition is

$$D_{n,0} = 0$$

for all n. Substituting this into the first-order condition leads to

$$P_{n,0} = 1. \tag{A2}$$

This suggests that in period 0, stock prices are determined only by the fundamental value.

From equations (A1) and (A2), the return on stock n in period 1 is represented by

$$\frac{P_{n,1}}{P_{n,0}} - 1 = \beta_n Z_1 + \epsilon_{n,1} + \frac{\gamma}{1-\rho}\sigma_Z^2 \beta_n \sum_{m=1}^{N} \beta_m h_m + \frac{\gamma}{1-\rho}\sigma_n^2 h_n. \tag{A3}$$

The first and second terms on the right side of this equation correspond to the unexpected returns due to common and idiosyncratic shocks, respectively. The third and fourth terms correspond to the effects of the central bank's absorbing systematic and idiosyncratic risks. These terms increase as γ or ρ increases, suggesting that the effects of the central bank's holdings on the return in period 1 are larger as arbitragers are more risk averse or the central bank holdings are more persistent.

As discussed in Section 5, cross-sectional regressions in this paper generally regress the cumulative returns of individual stocks between September 30, 2010, and March 31, 2021, which corresponds to period 1 in this theory, on a measure of BoJ holdings. Most regressions use abnormal returns to control for the unexpected returns due to common shocks, which correspond to the first term on the right side of equation (A3). In addition, to control for factor loadings, the regressions include firm characteristics variables, such as market beta and firm size. Thus, the effect through absorbing systematic risk, which corresponds to the third term and is heterogeneous only due to factor loadings, is also controlled for. Note that while the simple theory has only one common shock, the regression analysis checks the robustness of results using 1-, 3-, 4-, 5-, and 6-factor models. The unexpected returns due to idiosyncratic shocks, which correspond to the second term, are accounted for as residuals in the empirical analysis. Therefore, the regressions are interpreted to capture the fourth term or the effect through absorbing idiosyncratic risk. In that sense, this paper estimates the micro multiplier, which is defined as the price multiplier when controlling for movements in the aggregate market. While the fourth term suggests that the impact of central bank holdings differs across stocks depending on the variance of idiosyncratic shocks, the regression analysis in this paper estimates an average impact.[4]

C. Data Construction for Regression Analysis

This appendix provides details on the data construction of variables used in the regression analysis.

The Tokyo Stock Exchange (TSE)-defined free float is calculated by multiplying the number of TSE-defined free float shares by the stock price.

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[4] As pointed out by Greenwood (2005), who also examines Japan's data using a model with constant relative risk aversion utility and normally distributed shocks to expected dividends, the return is associated with the demand shock expressed in yen rather than in the ratio relative to a measure of supply. On the other hand, the regression analysis in Section 5 and many other studies examines the relationship between returns and demand shocks normalized by a measure of supply. Although this inconsistency is acknowledged, the discussion here prefers the simple model setup.

Abnormal returns are computed using factor models that regress the monthly log excess total return on a constant and various factors. Specifically, different combinations of Fama and French's (2015) five factors, i.e., the market, small minus big (SMB), high minus low (HML), robust minus weak (RMW), and conservative minus aggressive (CMA), and Carhart's (1997) momentum factor (MOM) are used.[5] Models with 1, 3, 4, 5, and 6 factors are employed. The 1-factor model is the capital asset pricing model (CAPM), which includes only the market factor. The 3-factor model is Fama and French's (1993) 3-factor model, which consists of the market, SMB, and HML. The 4-factor model adds MOM to the 3-factor model. The 5-factor model adds RMW and CMA to the 3-factor model. The 6-factor model adds MOM to the 5-factor model. The factor models are estimated using data for the 126 months from October 2010 to March 2021. Cumulative abnormal returns are calculated by multiplying alpha by 126.

As for control variables, firm size is measured as the log of the market capitalization of shares outstanding on September 30, 2010. The book-to-market ratio, profitability, and asset growth are calculated from the latest annual accounting data up to March 2010. Note that in Japan, firms typically end their financial year in March. In fact, 941 out of the 1,158 firms in the baseline sample closed their books for the 2009 financial year in March 2010. Following the convention beginning with Fama and French (1993), a gap of at least six months is left between the end of the accounting period and the return to ensure that the accounting variables are known before the return. The annual accounting data are also used to estimate firm size as follows. First, the ratio of treasury stocks to issued stocks is calculated using accounting data. Next, one minus this ratio is multiplied by the market value of issued stocks on September 30, 2010, to estimate the shares outstanding. The implicit assumption here is that the latest treasury stocks-to-issued stocks ratio up to March 2010 approximates the ratio on September 30, 2010. Beta is estimated by calculating the volatilities of stock and market excess returns and the correlation between them separately, using daily returns for one year and overlapping three-day returns for five years, respectively, to

[5] The factor returns are obtained from Kenneth French's website. They are converted to continuously compounded returns and from dollars into yen. See "Fama/French Japanese 5 Factors" and "Japanese Momentum Factor (Mom)" here:

https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

September 30, 2010, following Frazzini and Pedersen (2014). Market excess returns are calculated from the TOPIX (including dividends). The book-to-market ratio is also logged. Profitability is measured in terms of the return on equity (ROE, i.e., firms' current earnings-to-book equity). While Fama and French (2015) use operating profits, here, current earnings are used, following Kubota and Takehara (2018), who argue that financial analysts in Japan widely use current earnings. The lagged returns are the 3-year returns up to the end of August 2010.

Section 5.3 normalizes BoJ holdings by the shares outstanding on March 31, 2021, which is estimated by multiplying one minus the latest ratio of treasury stocks to issued stocks up to March 2021 by the market capitalization of issued stocks on March 31, 2021. This subsection computes the instrumental variable using the market capitalization of shares outstanding on September 30, 2010, which is the same as the firm size variable used in the baseline regressions, except that the log is not taken here.

Section 6.1 runs regressions to examine returns from March 31, 2021, to December 30, 2021. To estimate abnormal returns, the factor models are re-estimated using the extended sample from October 2010 to December 2021. As control variables, firm size, the book-to-market ratio, profitability, and asset growth are calculated using the latest annual accounting data up to September 2020, following the convention of a 6-month gap between returns and accounting data.

Finally, Section 6.3 runs Fama-MacBeth (1973) regressions. Following the 6-month gap convention, and given that in Japan, the financial year of firms typically ends in March, the latest accounting data by March of year y are used for returns in October of year y through September of year $y+1$.

D. Issues Regarding Free Float

Harada (2021) argues that the TSE appears to exclude BoJ holdings from its definition of free float. According to its documents, the TSE, in principle, excludes stocks held by the top 10 largest shareholders, treasury stocks, and so forth.[6] The top 10 shareholders usually include

[6] The documents are available here (in Japanese only):

custodians who hold ETF's assets on behalf of the ETF issuers. Although the TSE can make exceptions, for example, when custodians manage stocks held by an unspecified large number of end investors, stocks held by the BoJ through ETFs do not satisfy the conditions for an exception. In support of her argument, Harada (2021) shows that the TSE-defined free float ratio (the ratio of the free float to shares issued) is much lower than the Bloomberg-defined free float ratio for the 15 stocks for which the BoJ share of the market capitalization appears to be high. This result suggests that BoJ holdings are excluded from the TSE-defined free float but not from the Bloomberg-defined free float.

To further support Harada's (2021) argument, 2,177 stocks listed on the first section of the TSE on March 31, 2021, are examined. Figure A4 plots the difference between the TSE- and Bloomberg-defined free float ratios against the ratio of BoJ holdings to the market capitalization of shares issued. There seems to be a negative correlation between them. In fact, regressing the difference in the free float ratio on the ratio of BoJ holdings to the market capitalization and a constant (after winsorizing both variables at the 1 and 99% levels) yields a significantly negative slope coefficient of -1.1731. Since the standard error is 0.0854, the hypothesis that the slope is -1 cannot be rejected at the 5% level, suggesting that the TSE-defined free float decreases to the extent that BoJ holdings increase.

Figure A4 and the associated regression result also imply a large discrepancy between the TSE and Bloomberg definitions. The adjusted R-squared is only 0.0798, which suggests that BoJ holdings are not a decisive driver of the discrepancy. The constant is -0.0695 and is highly significant, with a t-statistic of -16.7. This indicates that the TSE-defined ratio, on average, is around 7 percentage points lower than the Bloomberg-defined ratio after controlling for BoJ holdings.

To address this issue regarding the difference in the definition of free float, Table A5 shows the robustness of the baseline regression results to using the Bloomberg-defined free float to normalize BoJ holdings instead of using the BoJ holding ratio as the main independent variable.

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https://www.jpx.co.jp/markets/indices/line-up/files/cal2_1_FFW.pdf;

https://www.jpx.co.jp/equities/market-restructure/revisions-indices/nlsgeu000005mjg9-att/deta_j.pdf.

Like Table 4 in the main text, Table A5 reports only the coefficient estimates for the normalized BoJ holdings with the corresponding t-statistics for the 12 combinations of six types of returns and two types of samples. The t-statistics are around 4 to 5 in all 12 cases, although slightly lower than those in the baseline results summarized in Panel A of Table 4. The coefficient is larger than that in the baseline analysis. On the other hand, it is smaller than the coefficient reported in Panel C of Table 4 when BoJ holdings are normalized by shares outstanding. These results make sense. As shown above, the Bloomberg-defined free float ratio, on average, is higher than the TSE-defined ratio, even taking into account that the TSE-defined free float does not include BoJ holdings. On the other hand, for all 1,158 stocks in the regression sample, the Bloomberg-defined free float market capitalization is smaller than the market capitalization of shares outstanding, as expected, given that Bloomberg's definition of free float excludes more than treasury stocks. As a result, the multiplier estimate is between that obtained when the BoJ holding ratio is used and when BoJ holdings are normalized by the shares outstanding.

E. Portfolio analysis

The analysis in the main text uses data on individual stocks instead of grouping the stocks since using portfolios would discard substantial information about cross-sectional variation. However, to provide further support for the results of the analysis in the main text, this appendix examines the returns of portfolios.

The analysis in this appendix focuses on Nikkei 225 members. The portfolios are constructed at the end of each month using the index weight ratio (i.e., the Nikkei 225 weight-to-TOPIX weight ratio) since this ratio, as shown in Section 6.3, contains information about 1-month future returns. Raw and abnormal cumulative returns are calculated for the top 30%, middle 40%, and bottom 30% portfolios for two different observation periods used in Section 6.3: the baseline sample from October 2010 to March 2021 (126 months) and the alternative sample from October 2000 to September 2010 (120 months). The abnormal cumulative returns are calculated by multiplying alpha by 126 and 120 for these two samples. t-statistics for the raw return are obtained by regressing the return on a constant.

Panels A and B in Table A6 report the results for the baseline and alternative samples, respectively. When using the baseline sample, all columns in the table show that the return is highest for the top 30% and lowest for the bottom 30%, as expected. In contrast, this pattern cannot be seen when using the alternative sample. These results are at least qualitatively consistent with the individual stock-level analysis in the main text.

Table A1. Key BoJ Announcements

Date	Summary of announcements
October 5, 2010	As a temporary measure, the BoJ will examine establishing a program to purchase various financial assets, such as government securities and ETFs.
October 28, 2010	The maximum outstanding amount of ETFs will be about 0.45 trillion yen. The BoJ will purchase ETFs until around the end of 2011.
November 5, 2010	ETFs that track the TOPIX or the Nikkei 225 will be eligible. The maximum purchases of individual ETFs shall be set to be roughly proportionate to their market capitalization.
December 14, 2010	ETFs will be purchased from tomorrow, depending on market conditions.
March 14, 2011	The maximum outstanding amount will be increased to 0.9 trillion yen. The BoJ intends to complete the increased purchases by around the end of June 2012.
August 4, 2011	The maximum outstanding amount will be increased to 1.4 trillion yen. The BoJ intends to complete the increased purchases by around the end of 2012.
April 27, 2012	The maximum outstanding amount will be increased to 1.6 trillion yen. The BoJ intends to complete the increased purchases by around the end of 2013.
October 30, 2012	The maximum outstanding amount will be increased to 2.1 trillion yen.
April 4, 2013	The BoJ decided to introduce QQE, as part of which it will purchase ETFs so that the amount outstanding of its ETF holdings will increase by 1 trillion yen per year to achieve the price stability target of 2% inflation at the earliest possible time, with a time frame of about 2 years.
October 31, 2014	The amount outstanding of the BoJ's ETF holdings will increase by about 3 trillion yen annually.
November 19, 2014	ETFs that track the JPX-Nikkei 400 will also be eligible.
December 1, 2014	ETFs that track the JPX-Nikkei 400 shall be purchased from tomorrow.
December 18, 2015	The BoJ will establish a supplementary program under which it will purchase ETFs composed of stocks issued by firms proactively investing in physical and human capital. It will purchase such ETFs so that the amount outstanding will increase by around 0.3 trillion yen per year from April 2016.

Table A1. Key BoJ Announcements (continued)

Date	Summary of announcements
March 15, 2016	Under the supplementary program, the BoJ will purchase ETFs that track indexes deemed eligible according to the criteria set out by the BoJ, or JPX-Nikkei 400 ETFs. In principle, the BoJ will purchase ETFs other than JPX-Nikkei 400 ETFs up to half of their market value.
July 29, 2016	The amount outstanding will increase by about 6 trillion yen per year.
September 21, 2016	From October, 3 trillion yen per year will be used for ETFs that track either of the three indexes as before, and 2.7 trillion yen per year will be used exclusively for TOPIX ETFs under the main program.
July 29, 2018	From August 6, 1.5 trillion yen per year will be used for ETFs that track either of the three indexes, and 4.2 trillion yen per year will be used exclusively for TOPIX ETFs under the main program.
March 16, 2020	In light of the impact of COVID-19, the BoJ will actively purchase ETFs for the time being so that the amount outstanding will increase at an annual pace with an upper limit of about 12 trillion yen.
April 27, 2020	From May, the maximum purchases of individual ETFs will be set, taking into account the amount outstanding in circulation.
April 30, 2020	From May, about 25% of the funds for ETF purchases under the main program will be used for ETFs that track either of the three indices, and about 75% will be used exclusively for TOPIX ETFs.
December 18, 2020	The BoJ will conduct an assessment for further effective and sustainable monetary easing and will make public its findings, likely at the March MPM.
March 19, 2021	Under the main program, the BoJ will purchase ETFs as necessary and only TOPIX ETFs. Under the supplementary program, the BoJ will not purchase JPX-Nikkei 400 ETFs.
March 23, 2021	The decision on March 19, 2021, will be effective from April.

Table A2. List of Data

Data name	Source
Flow of Funds Accounts	BoJ
BoJ ETF purchases	BoJ
Market capitalization of ETFs	Nikkei NEEDS
Closing prices of indexes	Bloomberg
BoJ's total ETF holdings	BoJ
Weights of indexes	Bloomberg
Stock prices	Bloomberg
Number of TSE-defined free float shares	Bloomberg
Bloomberg-defined free float weights	Bloomberg
Total return indexes of individual stocks	Financial Data Solutions Inc.
Market capitalization of stocks (common equity)	Financial Data Solutions Inc.
Uncollateralized overnight call rate	BoJ
Fama-French-Carhart 6 factors	Kenneth French
Exchange rates (17:00 Japanese standard time)	BoJ
TOPIX (including dividends)	Bloomberg
Book values	Nikkei NEEDS
Current earnings	Nikkei NEEDS
Total assets	Nikkei NEEDS
Treasury stocks	Nikkei NEEDS
Weights of individual stocks in ETFs	Bloomberg
Total flows into publicly offered Nikkei 225 index funds	Investment Trusts Association, Japan
Shareholding ratios of foreign corporations, etc.	Nikkei NEEDS
Nikkei Stock Average Volatility Index	Bloomberg

Table A3. Summary Statistics

	(1) Mean	(2) Median	(3) Std. dev.	(4) Min	(5) Max	(6) 1%	(7) 99%
Raw return	0.938	0.916	0.716	-1.710	4.027	-1.028	2.646
Abnormal return (1 factor)	-0.101	-0.044	0.846	-3.593	2.786	-2.491	1.781
Abnormal return (3 factors)	-0.227	-0.163	0.801	-3.566	2.745	-2.550	1.483
Abnormal return (4 factors)	-0.275	-0.212	0.830	-3.564	2.619	-2.643	1.534
Abnormal return (5 factors)	-0.116	-0.061	0.780	-3.427	2.973	-2.409	1.619
Abnormal return (6 factors)	-0.153	-0.102	0.831	-3.687	2.794	-2.555	1.578
BoJ holding ratio	0.081	0.069	0.033	0.069	0.512	0.069	0.231
Index weight ratio	0.440	0.000	1.526	0.000	19.496	0.000	6.933
Beta	0.969	0.956	0.382	0.154	2.503	0.286	1.892
Firm size	24.474	24.240	1.585	21.183	29.872	21.731	28.583
Book-to-market ratio	0.073	0.106	0.538	-2.979	1.620	-1.418	1.281
Profitability	0.085	0.077	0.120	-0.514	1.415	-0.235	0.482
Asset growth	-0.001	0.001	0.097	-1.032	0.583	-0.280	0.266
Lagged returns	-0.495	-0.475	0.398	-2.811	1.151	-1.484	0.415
Nikkei 225 member dummy	0.153	0.000	0.360	0.000	1.000	0.000	1.000

Note: The table presents summary statistics of the variables used in the baseline regressions. Columns (1) to (7) show the mean, median, standard deviation, minimum, maximum, 1st percentile, and 99th percentile, respectively. The number of observations is 1,158 for all variables. "Raw return" is the log excess total return between September 30, 2010, and March 31, 2021. "Abnormal return" is the abnormal returns computed by an asset pricing model with 1, 3, 4, 5, or 6 factors. "BoJ holding ratio" is the ratio of BoJ holdings to a measure of free float on March 31, 2021. The other variables are calculated using data up to September 30, 2010. "Index weight ratio" is the ratio of the Nikkei 225 weight to the TOPIX weight. "Beta," "Firm size," "Book-to-market ratio," "Profitability," and "Asset growth" are the firm characteristics of interest in Fama and French's (2015) 5-factor model. "Lagged return" is the 3-year return to August 31, 2010. "Nikkei 225 member" takes one if the stock was included in the Nikkei 225 index on September 30, 2010, and 0 otherwise.

Table A4. Total Bank of Japan Holdings of ETFs

	2015	2016	2017	2018	2019	2020	2021
Adjusted holdings (trillion yen)	7.0	8.8	15.9	24.5	28.9	31.2	51.5
Pre-adjusted holdings (trillion yen)	6.9	8.6	15.7	24.2	28.5	30.6	50.7
Adjustment rate (%)	1.31	1.50	1.27	1.24	1.40	1.96	1.58

Note: "Adjusted holdings" refers to the total Bank of Japan (BoJ) holdings of ETFs on a market value basis based on the BoJ's accounting data. "Pre-adjusted holdings" are estimated from data other than the BoJ's accounting data. "Adjustment rate" is the percentage deviation of the adjusted holdings from the pre-adjusted holdings. These figures are reported for the end of March from 2015 to 2021.

Table A5. Price Multipliers when Normalizing BoJ holdings by Bloomberg Free Float

	(1) Raw	(2) 1 factor	(3) 3 factors	(4) 4 factors	(5) 5 factors	(6) 6 factors
Full sample	6.33**	6.61**	7.02**	7.42**	5.73**	6.15**
	(4.63)	(4.01)	(4.53)	(4.67)	(3.70)	(3.81)
Subsample	6.13**	6.64**	6.53**	6.95**	5.49**	5.93**
	(5.19)	(4.64)	(4.77)	(5.02)	(3.87)	(3.94)

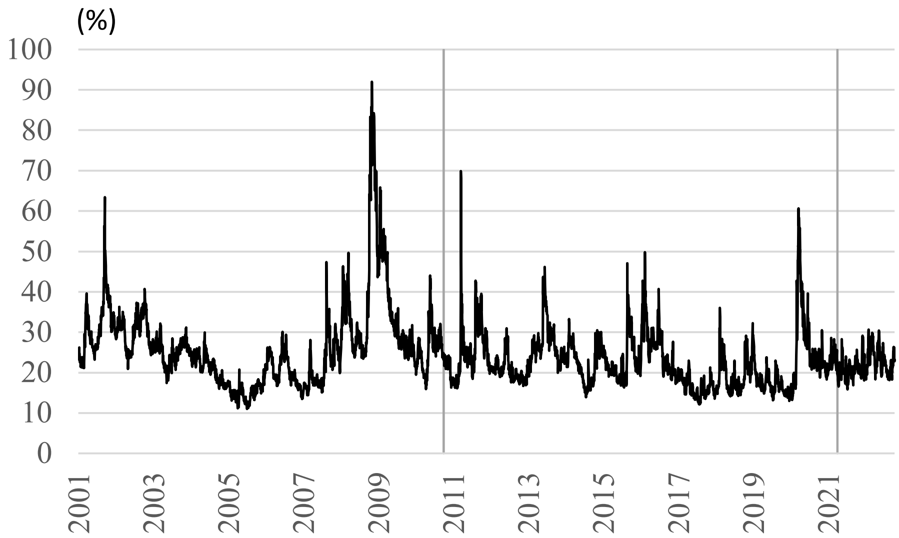
Note: The table presents – for the full sample and the subsample of Nikkei 225 members on September 30, 2010 – the estimated coefficients on normalized BoJ holdings when BoJ holdings are normalized by the Bloomberg-defined free float. The number of observations is 1,158 for the full sample and 177 for the subsample. Column (1) reports the results for the raw return, while columns (2) to (6) report those for the abnormal returns computed using the 1-, 3-, 4-, 5-, and 6-factor models, respectively. t-statistics are reported in parentheses. ** denotes statistical significance at the 1% level. Standard errors are clustered at the industry level.

Table A6. Portfolio Alpha

	(1) Raw	(2) 1 factor	(3) 3 factors	(4) 4 factors	(5) 5 factors	(6) 6 factors
Panel A: Baseline sample (October 2010 to March 2021)						
Top 30%	113.4	3.0	5.3	6.1	-3.2	-2.1
	(1.94)	(0.12)	(0.21)	(0.24)	(-0.13)	(-0.09)
Middle 40%	86.4	-23.6	-14.9	-14.3	-17.7	-18.6
	(1.59)	(-1.78)	(-1.18)	(-1.13)	(-1.43)	(-1.49)
Bottom 30%	56.4	-59.9**	-44.5**	-46.7**	-45.7**	-51.6**
	(0.96)	(-3.22)	(-2.68)	(-2.83)	(-2.74)	(-3.20)
Panel B: Alternative sample (October 2000 to September 2010)						
Top 30%	-86.9	-10.4	-7.4	-7.4	5.8	3.5
	(-1.10)	(-0.32)	(-0.23)	(-0.22)	(0.17)	(0.10)
Middle 40%	-55.2	6.3	-1.3	2.2	14.5	17.1
	(-0.90)	(0.32)	(-0.07)	(0.11)	(0.80)	(0.93)
Bottom 30%	-79.2	-12.6	-24.8	-34.0	-21.3	-28.1
	(-1.19)	(-0.55)	(-1.20)	(-1.66)	(-1.02)	(-1.36)

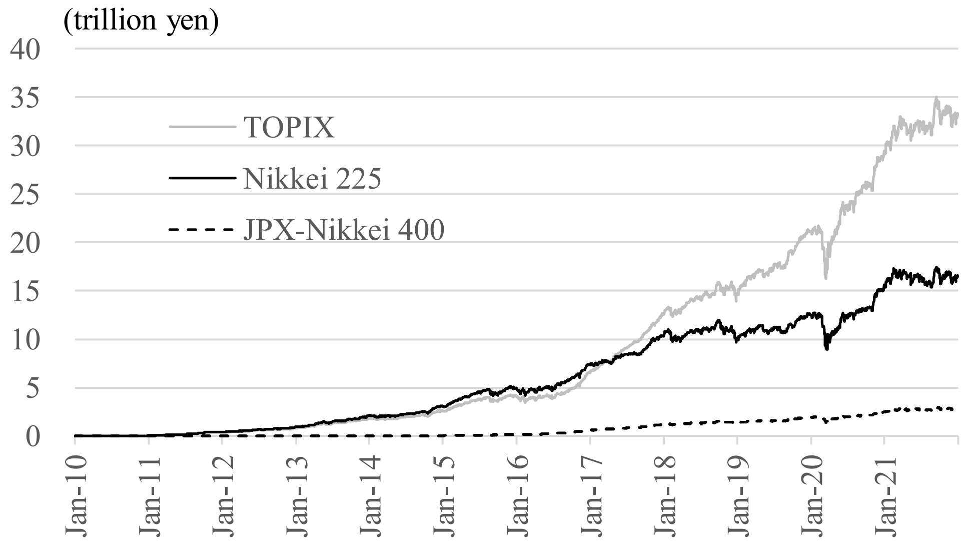
Note: This table reports the estimated cumulative returns (in %) of three portfolios of Nikkei 225 members. The portfolios are constructed at the end of each month using the index weight ratio (i.e., the Nikkei 225 weight-to-TOPIX weight ratio). The breakpoints are the 30th and 70th percentiles. Column (1) reports the raw cumulative return, while columns (2) to (6) report the abnormal returns computed using the 1-, 3-, 4-, 5-, and 6-factor models, respectively. Panel A presents the results for the sample from October 2010 to March 2021, while Panel B presents those for the sample from October 2000 to September 2010. Abnormal returns are calculated by multiplying alpha by 126 and 120 for these observation periods, respectively. t-statistics are reported in parentheses. t-statistics for the raw return are obtained by regressing the return on a constant. ** indicates statistical significance at the 1% level.

Figure A1. Volatility Index



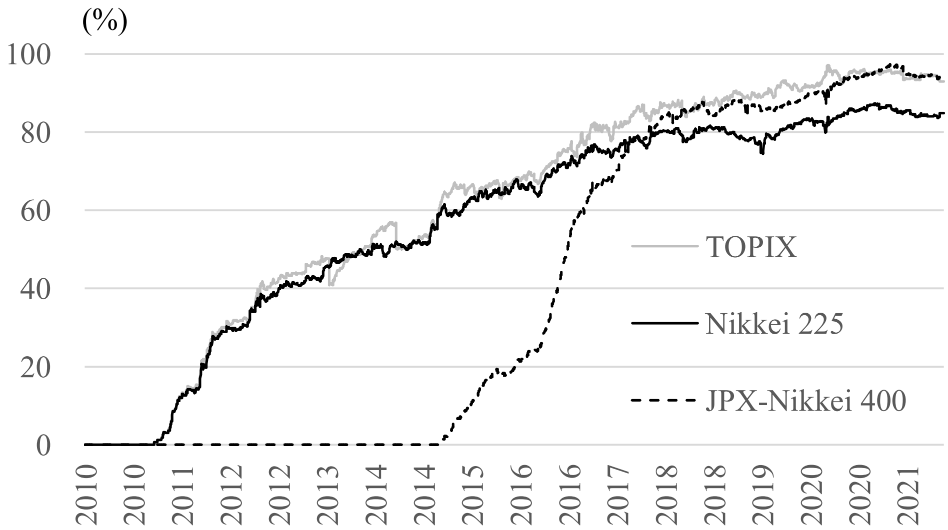
Note: The black line represents the Nikkei Stock Average Volatility Index (in %) from January 4, 2001, to December 30, 2021. The two vertical grey lines represent September 30, 2010, and March 31, 2021.

Figure A2. Estimated BoJ Holdings of ETFs by Index



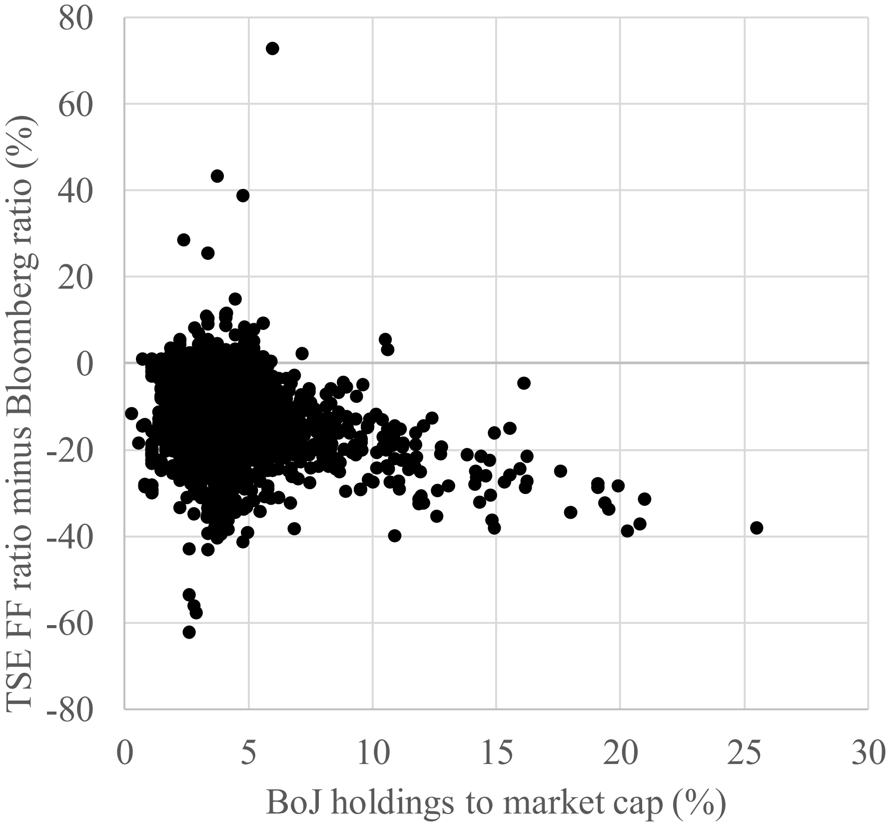
Note: The figure shows the estimated Bank of Japan holdings of ETFs that track the Tokyo Stock Price Index (TOPIX, broken line), the Nikkei 225 (black line), and the JPX-Nikkei 400 (grey line) from January 1, 2010, to December 31, 2021.

Figure A3. Estimated BoJ Share of ETFs by Index



Note: The figure shows the estimated share of the Bank of Japan holdings in the ETFs that were eligible for its ETF purchases from January 1, 2010, to December 31, 2021, by index: the Tokyo Stock Price Index (TOPIX, broken line), the Nikkei 225 (black line), and the JPX-Nikkei 400 (grey line).

Figure A4. BoJ Holdings and Difference in the Free Float Ratio



Note: The figure plots the difference between the Tokyo Stock Exchange- and Bloomberg-defined free float ratios against the ratio of Bank of Japan holdings to issued stocks on March 31, 2021, for all stocks listed on the First Section of the Tokyo Stock Exchange on March 31, 2021.