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The Bank of Japan's equity purchases and stock illiquidity[☆]

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A B S T R A C T

Using the large-scale index-linked exchange-traded fund (ETF) purchase program of the Bank of Japan (BOJ), we examine the role of unconventional equity-based monetary policies in the market liquidity of the underlying securities. Using a large sample of Japanese stocks, we document a significant increase in stock illiquidity when a firm's ownership by the BOJ increases. Intensified ETF arbitrage activities partially mediate such effect. The increased illiquidity is concentrated among small and young firms and those whose shares are likely subject to strong buying pressure. Finally, BOJ ownership increases comovement in liquidity and reduces informational efficiency.

1. Introduction

As monetary policy becomes more constrained, central banks around the world use quantitative easing as a key unconventional policy tool. In late 2010, the Bank of Japan (BOJ) announced its quantitative and qualitative easing (QQE) policy and its key component, a large-scale asset purchase program. While asset purchase programs typically operate through the debt market (e.g., central banks buying government bonds), the BOJ is the first central bank to engage in large-scale equity purchases, setting out to increase its domestic equity holding through buying index-linked exchange-traded funds (ETFs).

Unprecedented and substantial in terms of both length and scale,[1] the BOJ's ETF purchase program has attracted growing research interest that has mainly focused on its stock price implications. For instance, Barbon and Gianinazzi (2019) present theoretical and empirical evidence that changes to the supply of securities due to the BOJ's interventions have led to increases in stock prices. Charoenwong et al. (2021) find that BOJ purchases cause significant increases in valuation and share issuance, but not in corporate investment. Harada and Okimoto (2021) find increased afternoon returns of Nikkei 225 constituent stocks when the BOJ purchases

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[1] At the end of December 2019, the BOJ bought approximately ¥28.3 trillion, or USD$269.6 billion, worth of equity in the Nikkei 225 Stock Average Index (Nikkei 225), the Tokyo Stock Price Index (TOPIX), and the Japan Exchange Group-Nikkei 400 Index (JPX400), which constituted 4.2% of the market capitalization of the entire Tokyo Stock Exchange. The BOJ thus became one of the top 10 largest shareholders for more than 40% of the listed companies in Japan (Tomita, 2018).

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ETFs. Despite this growing evidence, researchers have yet to explore whether and how the BOJ's interventions and associated expansion into ETF assets may distort the trading of and illiquidity of the underlying securities, both of which are important for the effectiveness of the QQE policy and market efficiency. In this paper, we address both of these issues.

The relation between the BOJ's ETF purchases and stock illiquidity is ambiguous. On the one hand, market illiquidity may decrease following the BOJ's intervention. One can view the BOJ as a committed buyer insensitive to asset prices (Christensen and Gillan, 2022). Its purchases offer an ongoing source of demand for illiquid stocks, especially during times of market disruption, stresses, or freezes, encouraging market makers to make market more actively and investors to take larger positions in the stocks they purchase. The result may be higher prices and increased trading volumes (Gagnon et al., 2011). On the other hand, considering that the BOJ is a buy-and-hold investor that does not sell over a prolonged period, its large-scale ETF purchases would substantially reduce the supply of firm shares available to the public, as well as the number of potential sellers in the market, creating a lock-up of shares in ETFs, leading to longer inventory hold periods, higher market making costs, and reduced trading, especially for stocks that are illiquid or in short supply (Kandrac, 2018; Barbon and Gianinazzi, 2019).

A unique feature of the BOJ's policy is that equity is acquired via ETF purchases. It is well known that the demand for ETFs can affect the underlying securities, because ETFs and their baskets are tied by arbitrage through the creation and redemption process (Ben-David et al., 2018; Brown et al., 2021).[2] In a nutshell, when the market prices of ETFs deviate from those of their basket of underlying securities, authorized participants (APs) will simultaneously take up opposite positions in the ETFs and the underlying securities to arbitrage such mispricing away.[3] Such mechanical arbitrage trading leads to an increase in correlated trading and demand for liquidity for the underlying securities that are linked with one another due to common ETF ownership (Agarwal et al., 2018).

In our context, the massive expansion of assets under ETFs due to the BOJ policy implies that the magnitude and intensity of ETF arbitrage activities likely increase in proportion to each other. Together, the more correlated demand for liquidity due to increased ETF arbitrage activities, along with the reduced supply of shares for a wide range of stocks due to the equity holdup in ETFs purchased by the BOJ, suggests that orders become more imbalanced and that market makers may face more severe inventory problems. Both of these phenomena reduce liquidity, especially for stocks that are already illiquid (Chordia et al., 2002). Fig. 1 provides a graphical summary of our theoretical predictions.

To test our hypothesis that the BOJ's equity purchases increase stock illiquidity, we estimate firm-level BOJ ownership using data on the quarterly holdings of index ETFs and the aggregate amount of ETF purchases by the BOJ. Illiquidity is measured by a stock's average daily Amihud (2002) illiquidity ratio and the extent of its volume-related daily return reversals (Pástor and Stambaugh, 2003). Using a sample of 3083 Japanese listed firms from 2010:Q1 to 2019:Q4, we document a positive and statistically significant relation between firm-level BOJ ownership and stock illiquidity. Hence, the BOJ's ETF purchases impede the liquidity of their underlying stocks.

To reinforce a causal interpretation, we perform two additional difference-in-differences (DiD) tests that apply matching techniques to improve covariate balance. In the first test, we analyze how the illiquidity of the constituent firms of the Nikkei 225 evolves over time relative to matched control firms outside of the Nikkei 225. In the second test, since only stocks listed in the first section of the Tokyo Stock Exchange (TSE) are tracked by index ETFs and thus are subject to BOJ ownership, we identify firms that have migrated from the second to the first section and examine whether subsequent increases in the BOJ ownership of these firms increase stock illiquidity relative to matched control firms listed in the second or third (Mothers) sections. The evidence from both tests supports our baseline results.

To gauge the extent to which increased ETF arbitrage drives our results, we follow Agarwal et al. (2018) and construct four proxies of ETF arbitrage activities. The first two proxies capture the amount of mispricing in ETFs that needs to be arbitraged away, and the other two capture the extent of their net share creation and redemption. Using the first principal component of the four, both a mediation test and a two-stage analysis show that BOJ ownership increases ETF arbitrage activities and the associated increases in arbitrage raise stock illiquidity. Increased ETF arbitrage activities *partially* account for the increase in stock illiquidity.

Next, we explore the heterogeneity in the effect of BOJ ownership on stock illiquidity. As expected, the positive effect in question is more pronounced among illiquid firms, characterized by a small size, a young age, and low institutional ownership. To the extent that the BOJ's purchases lead to the lock-up of shares in ETFs, the increased illiquidity may be concentrated among stocks facing strong (weak) buying (selling) pressure, where an adequate supply of shares is most pertinent. In line with this view, our results are stronger for firms with higher (lower) levels of margin trading of long (short) positions and those likely to be more undervalued.

Finally, we explore whether the BOJ's policy has further implications for comovement and informational efficiency. First, consistent with increased correlated trading, we find that BOJ ownership increases liquidity comovement. Yet, we find little evidence that BOJ ownership increases the comovement of returns. Second, although firms with greater BOJ ownership have more firm-specific return variation, BOJ ownership is associated with greater price delays and larger deviations from a random walk, together suggestive

[2] In the ETF primary market, ETF shares are created and redeemed only through APs. To purchase a large block of ETF shares, a market maker/ end investor must request it of an AP and deliver either cash, securities, or a mixture of cash and securities to the AP. In return, the AP delivers a basket of securities to the ETF, receives ETF shares from it, and hands the ETF shares to the market maker/end investor, a process known as the creation process. In a completely opposite process, known as the redemption mechanism, the AP requests from the ETF an exchange of ETF shares for an equivalent amount of securities. The two processes allow the ETF shares to be freely traded in the secondary market.

[3] If the trading price of an ETF is above (below) the value of its underlying securities, that is, trading at a premium (discount), APs short-sell the ETF shares (the underlying securities) while simultaneously buying the underlying securities (ETF shares). At the end of the trading day, the APs unwind their short-sold positions by delivering the underlying securities (ETF shares) to the ETF in exchange for ETF shares (underlying securities).

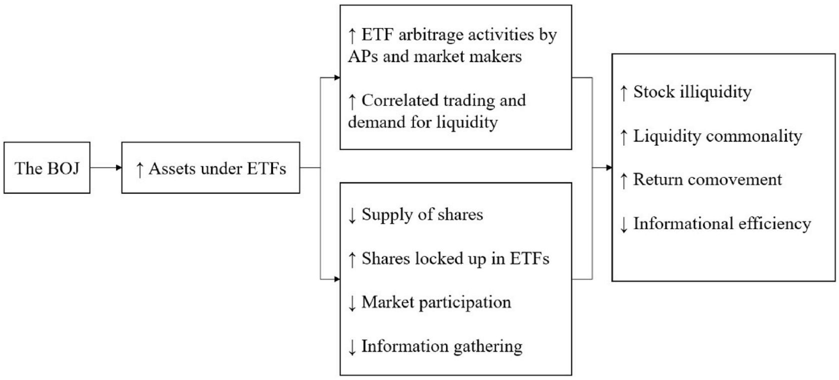


Fig. 1. Theoretical predictions.

of more pricing noise and lower informational efficiency. Finally, firms with greater BOJ ownership have current stock returns that are less reflective of future firm earnings. Together, our evidence suggests BOJ ownership has a negative effect on informational efficiency.

Our paper contributes to several strands of literature. First, we contribute to a growing body of research on quantitative easing, which examines mainly the impact and effectiveness of large-scale purchase programs of government debt securities (e.g., Eser and Schwaab, 2016; De Pooter et al., 2018; Ferdinandusse et al., 2020; Christensen and Gillan, 2022). Our study on the BOJ's equity purchases differs from most of these studies in several ways. First, since debt securities are often traded in over-the-counter markets and the search for potential investors is likely more costly, they are more illiquid than equity securities and accessible mostly by more sophisticated investors. Our inquiry into stock illiquidity is thus relevant to a broader range of investors. Second, because equity acquired by the BOJ is through ETF purchases, arbitrage trading by ETFs' APs and market makers may reinforce the policy's impact on illiquidity. Third, our findings of increased illiquidity in domestic equity have implications for firms and managers, because stock illiquidity determines various firm attributes and decision making, such as the quality of the information environment (Chordia et al., 2009), earnings management (Huang et al., 2017), and innovative activities (Fang et al., 2014).

Second, we add to the growing finance literature on whether and how ETFs may affect their underlying securities (e.g., Israeli et al., 2017; Ben-David et al., 2018; Glosten et al., 2021). Research documents a significant impact of ETF trading on stock liquidity (Hamm, 2014; Israeli et al., 2017) and the commonality of liquidity (Agarwal et al., 2018) of their constituent securities. Complementing these recent works, our findings suggest that increased ETF arbitrage activities play a partial role in explaining the documented increase in illiquidity after the BOJ's unconventional monetary intervention.

A contemporaneous paper by Chen et al. (2019) examines the impact of the BOJ's ETF equity purchases on stock liquidity, documenting a similarly positive relation between BOJ ownership and the market illiquidity of the underlying securities. While their findings are consistent with the information friction channel, we find supportive evidence that increased ETF arbitrage activities partially mediate the positive relation in question. We offer further evidence that the BOJ's policy increases liquidity and return commonality and reduces informational efficiency.

Finally, although liquidity is an important attribute, the implications of greater market illiquidity are nuanced and depend on the types of market participants. For instance, in the context of the BOJ's purchases, a greater price impact would mean that the purchases are more costly due to a higher premium paid by the BOJ when buying, but also that prices can be pushed farther upward when policy-induced price pressure arises. The latter phenomenon appears to be consistent with the BOJ's objective of fighting deflation. On the contrary, increased trading costs and lowered market participation have an adverse impact on information acquisition and market efficiency, both of which affect the risk and costs of trading for investors (Amihud and Mendelson, 2008) and corporate decisions (e.g., Chen et al., 2007).

The remainder of this study is organized as follows. Section 2 provides an overview of the BOJ's economic activities and policies. Section 3 explains our data and sample selection processes and provides descriptive statistics. Section 4 reports and discusses our empirical results. Section 5 concludes.

2. Institutional background

To overcome the long-time low-inflation environment since 1998, the BOJ implemented various monetary policies, such as purchasing government bonds, commercial papers, and other types of securities during the 2000s; however, their impact was limited. On December 28, 2010, the BOJ declared a new monetary policy that included the purchase of ETF shares. The BOJ does not, however, directly purchase ETFs; rather, it requires several trust banks to purchase them.

At first, the maximum purchase amount was ¥450 billion (about USD 5.6 billion), which was only 0.16% of the market capitalization of the TSE. Under this new program, the BOJ purchased ¥14.2 billion (about USD 177 million) of ETFs on December 15, 2010 for the first time. The BOJ gradually increased the program by increasing the maximum amount to ¥900 billion (about USD 11.25 billion) on March 14, 2011, and then to ¥1.4 trillion (about USD 17.5 billion) on August 4, 2011, followed by ¥1.5 trillion (about USD 18.75 billion) on April 27, 2012, and finally reaching ¥2.1 trillion (about USD 26.25 billion) on October 30, 2012.

In particular, the size of the program was expanded under Haruhiko Kuroda, who became governor on March 20, 2013. Kuroda started a so-called QQE policy to achieve the goal of a 2.0% annual inflation rate. Under the QQE, on April 4, 2013, Kuroda declared an increase in the annual budget of the ETF purchase program to ¥1 trillion (about USD 10.2 billion) every year, which gradually increased to ¥3 trillion (about USD 27.7 billion) on October 31, 2014, ¥3.3 trillion (about USD 29.2 billion) on March 15, 2016, and then ¥6 trillion (about USD 57.6 billion) on July 29, 2016.[4] The BOJ does not disclose when it makes its purchases, but it discloses the results of the program, reporting on its website the volume after the stock market closes if it purchases ETFs. While the exact dates of its purchases are not reported, practitioners have pointed out that the BOJ makes purchases if the market index drops in the morning session, as empirically observed by Harada and Okimoto (2021).

The massive expansion of the program is not negligible. At the end of 2019, the total volume of ETFs the BOJ purchased was about ¥30 trillion (about USD 275 billion), about 4.6% of the market capitalization of the first section of the TSE. Furthermore, because of a rule of the Nikkei 225, the BOJ indirectly owns more than 15% of several companies.

At the beginning of the program, BOJ bought two types of ETFs: those linked with the Nikkei 225 and TOPIX. Similar to the Dow Jones Industrial Average, the Nikkei 225 is a price-weighted stock index composed of 225 stocks chosen by the Nikkei Corporation from firms listed in the first section of the TSE. The price-weighted policy weights high-priced stocks higher. TOPIX is the market value-weighted stock index composed of all stocks listed on the first section of the TSE. At the start of the program, 1670 stocks were listed in the first section. At the end of 2019, 2160 were listed.

Because of the differences in the composition between the Nikkei 225 (price weighted) and TOPIX (value weighted), firms with high stock prices are heavily weighted under the Nikkei 225. For example, Fast Retailing's weight in the Nikkei 225 was 9.90%, whereas it was 0.5% in TOPIX as of the end of December 2019. By contrast, the weight of Toyota Motors, the largest listed company in Japan, in the Nikkei 225 is only 1.19%.[5] When the BOJ started the program, the budget allocation between the Nikkei 225 and TOPIX ETFs was determined by the market value of each ETF. The aggregated market value of TOPIX-linked ETFs was almost equal, at ¥1.138 trillion (about USD 28.1 billion), to that of the Nikkei 225-linked ETFs, at ¥1.045 trillion (about USD 25.6 billion). This allocation policy makes the impact on the indirect ownership by the BOJ uneven. The BOJ's indirect level of ownership of high-priced stocks on the Nikkei 225 is higher than that for low-priced stocks. To mitigate the uneven impact, the BOJ changed its policy on July 31, 2018.

In addition to the Nikkei 225 and TOPIX, the BOJ also purchased ETFs tracking the JPX400 index (JPX400) in November 2014. The JPX400 was created by the TSE and the Nikkei in January 2014. The index comprises 400 firms chosen by the Nikkei based on various measurements, such as operating performance and market capitalization. However, the menu of JPX400 ETFs in the BOJ's ETF purchasing program is small. It was only 5% until July 2016, and 2% afterward. The small size is due to the fact that the menu of the program is determined by the ETFs' assets under management. The JPX400 was a new index, and therefore the number of ETFs tracking it was small.

3. Data and sample selection

3.1. Data sources

Our sample is constructed using several databases. To estimate the proportion of a firm's shares owned by the BOJ, we collect the monthly fund-holding data of all Japanese ETFs tracking the Nikkei 225, TOPIX, and JPX400 from the Refinitiv Eikon database. Such data include the names of the ETFs, their underlying indexes, and the percentage ownership in each of their invested stocks. We also collect the daily amount of purchases by the BOJ of ETFs tracking the three composite market indexes.

To estimate stock illiquidity, we download the daily stock prices, holding period returns, and trading volume data for all listed Japanese firms from the Nikkei Financial Quest database. Quarterly accounting data are collected from the Nikkei Financial Quest database, and information on annual dividends per share is obtained from the Nikkei Economic Electronic Databank System (NEEDS) Corporate Governance Evaluation Systems (CGES) database. To analyze ETF arbitrage activities, we obtain the daily closing prices and total number of shares outstanding of Japanese ETFs from the NEEDS database. Moreover, we download data on the weekly balances of margin trading (for both buying and selling) from Japan Securities Finance Co., Ltd. and annual data on firm ownership structure from the NEEDS CGES database.

After excluding financial firms and observations with missing data, our final sample consists of 87,785 firm-quarter observations and 3083 unique Japanese firms over the period from 2010:Q1 to 2019:Q4 (40 quarters in total).[6]

3.2. Measuring BOJ ownership

The BOJ discloses two aspects of its ETF purchases. First, the BOJ announces its basic policy, annual budget, and asset allocations (between types of ETFs) of the ETF purchase program through its policy documents. For instance, the policy committee of the BOJ decided the allocation of its annual budget for ETF purchases was ¥5.7 trillion (about USD 51.3 billion) in total, ¥4.2 trillion (about USD 37.8 billion) of which would go to the ETFs tracking TOPIX only, with the remaining ¥1.5 trillion (about USD 13.5 billion) going

[4] See https://www.BOJ.or.jp/announcements/release_2016/rel160921c.pdf.

[5] In addition to the weight of market capital, the TOPIX is constructed based on the percentage of floating shares. Hence, the weights of two firms with the same market capitalization in the First Section of the TSE differ by their percentages of floating shares.

[6] We end our sample in 2019:Q4, since that was the last year before the BOJ began its ETF lending program in 2020.

to ETFs tracking TOPIX, the Nikkei 225, and JPX400 from August 2018.[7] Second, the BOJ provides information of its daily operations in ETF purchases on its website.[8] The specifics of the purchases are not mentioned, nor are the weights for each type of ETF; only the total amount of daily ETF purchases is provided. For instance, the website reported that on January 17, 2018, the BOJ purchased a total of ¥74.7 billion (about USD 673.0 million) worth of ETFs.

To estimate the BOJ's ownership at the firm level, we assume that the BOJ allocates the purchases of ETFs tracking the Nikkei 225, TOPIX, and JPX400 according to the total market capitalization between the three types of ETFs. For instance, since fewer ETFs are tracking the JPX400 (as a group) than the other types, we expect the BOJ's purchases in the former would be smaller, in proportion with their market value. Using these estimated weights, the daily ETF purchases are assigned to the three types of ETFs. For each type of ETF, we aggregate the BOJ's daily purchases within a quarter to obtain the total monetary amount owned by the BOJ, represented in Japanese yen.

Next, using the quarterly holding data of all ETFs, we estimate for each firm the total amount of a firm's shares owned by each of the three types of ETFs. Combining both sets of data, a firm's indirect ownership by the BOJ is computed as follows:

$$BOJ\ ownership_{it} = \sum_{j}^{3}\left[\left(\frac{¥\ owned\ by\ ETF_j}{ME}\right)_{it} \times \left(\frac{¥\ owned\ by\ BOJ}{ME}\right)_{jt}\right] = \sum_{j}^{3}\left[\%\ ETF_j\ ownership_{\ it} \times \%\ BOJ\ ownership\ in\ ETF_{j\ t}\right] \quad (1)$$

where i denotes the firm and t is the year-quarter; j is the type of index ETF, ranging from one to three according to the three types of index ETFs tracking the Nikkei 225, TOPIX, and JPX400, respectively; $(¥\ owned\ by\ ETF_j)_{it}$ is the total monetary amount owned by all index ETFs[9] that track the jth index in firm i in year-quarter t; ME_{it} is the total market capitalization of firm i in year-quarter t; $(¥\ owned\ by\ BOJ)_{jt}$ is the total monetary amount owned by the BOJ in all index ETFs that track the jth index; and ME_{jt} is the total market capitalization of all index ETFs that track the jth index in year-quarter t (summing the market capitalization across all jth ETFs).

Hence, a firm's ownership by the BOJ via jth-type ETFs is computed as the proportion of its shares owned by all jth-type ETFs ($\%\ ETF_j\ ownership_{it}$) multiplied by the proportion of the total market value of the group of jth-type ETFs owned by the BOJ ($\%\ BOJ\ ownership\ in\ ETF_{j\ t}$); a firm's total ownership by the BOJ is thus computed by summing its BOJ ownership across the three types of ETFs.

Fig. 2 illustrates the intuition behind our measure. Suppose, in a given year-quarter t, there are only two ETFs ($ETF\ 1_{j=1}$ and $ETF\ 2_{j=1}$) of type $j = 1$. The market capitalization values of the two ETFs are ¥1,000 and ¥3,000, respectively, summing to a total of ¥4,000. We also know from the BOJ disclosure that 10% of the jth ETFs (i.e., ¥4,000 × 0.1 = ¥400) is owned by the BOJ. Both ETFs invest in three companies; our company of interest is Company A, which has a market capitalization of ¥10,000. ETF 1 and ETF 2 each own 40% of Company A, that is, ¥400 and ¥1,200 in Company A, respectively, summing to ¥1,600 in total (i.e., 16% of the firm's market capitalization). Hence, the BOJ's approximate[10] indirect ownership amounts in company A via the two ETFs are ¥400 × 10% = ¥40 and ¥1,200 × 10% = ¥120, respectively. In other words, ¥160, or 1.6% of Company A's market capitalization, is owned by the BOJ via ETFs of type $j = 1$; to compute the total BOJ ownership in the firm, the same calculation can be applied to the other two types of ETFs, then summing the ownership measures across the three types.

An alternative approach that has been used in prior studies (e.g., Chen et al., 2019; Charoenwong et al., 2021) is to compute a flow measure of BOJ purchases. This involves first computing the percentage weight of a firm the BOJ purchases in a year-quarter, as follows:

$$w_{it} = w_{it}^{N225} \times w_{BOJ\ t}^{N225} + w_{it}^{TOPIX} \times w_{BOJ\ t}^{TOPIX} + w_{it}^{JPX400} \times w_{BOJ\ t}^{JPX400} \quad (2)$$

where w_{it}^{N225}, w_{it}^{TOPIX}, and w_{it}^{JPX400} are the percentage (either price or market) weights of stock i in TOPIX, the Nikkei 225, and JPX400 at the end of year-quarter t and $w_{BOJ\ t}^{N225}$, $w_{BOJ\ t}^{TOPIX}$, and $w_{BOJ\ t}^{JPX400}$ are the three market indexes' percentage weights (averaged within a quarter) in the BOJ's purchase menu for year-quarter t, with menu weights manually collected from public disclosures by the BOJ, news articles, analyst reports, and other public sources. The firm-level weight (w_{it}) is then multiplied by the total amount of ETF purchases made by the BOJ in the given year-quarter to obtain the total amount of firm shares purchased by the BOJ. This amount is scaled by the firm's market capitalization. The flow measure of BOJ purchases is positively correlated (with a coefficient of 0.81; not tabulated) with our BOJ ownership measure. In subsequent robustness tests, we replicate our results using the alternative flow measure.

3.3. Sources of variation in the BOJ ownership of firms

Variations in BOJ ownership are likely to be plausibly exogenous to firms' stock illiquidity and other firm characteristics for two reasons. First, as pointed out by Charoenwong et al. (2021), the BOJ purchases ETFs tracking the three market indexes in pre-determined portions and each of the three market indexes has different inclusion criteria and weighting schemes. Firms moving in and out of the three indexes thus give rise to cross-sectional and time series variation in BOJ ownership. The highly irregular nature of such

[7] https://www.boj.or.jp/en/announcements/release_2018/rel180731h.pdf.

[8] The BOJ website can be accessed via https://www3.BOJ.or.jp/market/en/menu_etf.htm.

[9] That is, all index ETFs in Japan offered by different companies that track the same index.

[10] It is an approximate estimate, 1) because of the assumptions made regarding the allocation weights between the three types of ETFs discussed earlier and 2) the precise weights of the BOJ's purchases in each of the j ETFs are not known (i.e., the relative proportions of BOJ purchases in ETF 1 and ETF 2 are not known and are assumed to be equal in our computation).

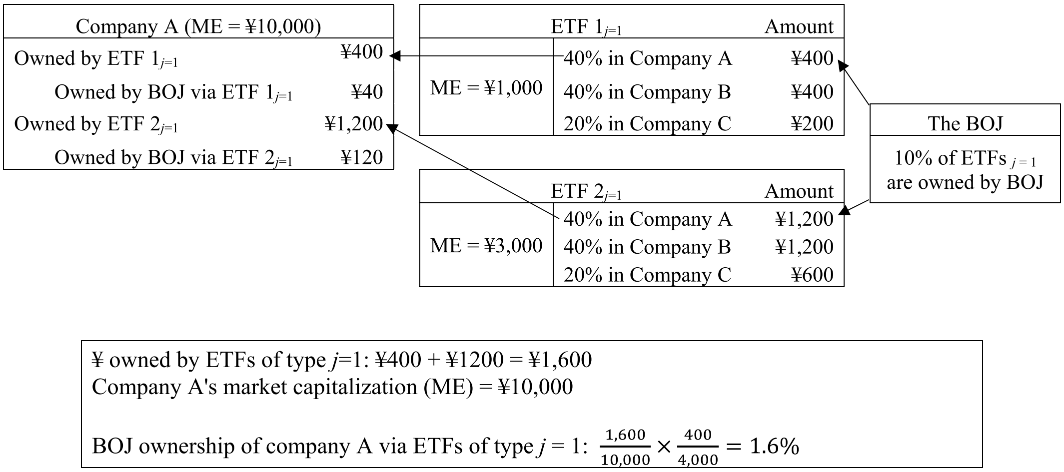


Fig. 2. Example of how the BOJ's firm-level ownership is calculated.

index inclusion/exclusion, along with the predetermined nature of the ETF purchase program suggests that the cross-sectional distribution of BOJ ownership is likely to be uncorrelated with firm characteristics pertaining to illiquidity and cannot be altered in response to changes in such characteristics, thereby mitigating endogeneity concerns.

Second, as pointed out by Chen et al. (2019), there is a source of plausibly exogenous variation in the BOJ ownership of firms that is driven by a bias due to the price-weighting scheme of the Nikkei 225. According to Chen et al. the BOJ ownership of a firm can be theoretically decomposed as follows:

$$\begin{aligned}
&BOJ\ ownership_{it} = \frac{BOJ\ investment_{it}}{ME_{it}} \\
&= \frac{¥\ BOJ\ holdings\ via\ N225_{it}}{ME_{it}} + \frac{¥\ BOJ\ holdings\ via\ TOPIX_{it}}{ME_{it}} + \frac{¥\ BOJ\ holdings\ via\ JPX400_{it}}{ME_{it}} \\
&= \frac{¥\ Total\ investment\ in\ N225_t}{Total\ N225\ ME_t} \times \frac{N225\ weight_{it}}{N225\ Value\ Weight_{it}} + \frac{¥\ Total\ investment\ in\ TOPIX_t}{Total\ TOPIX\ ME_t} \\
&\times \frac{TOPIX\ weight_{it}}{TOPIX\ weight_{it}} + \frac{¥\ Total\ investment\ in\ JPX400_t}{Total\ JPX400\ ME_t} \times \frac{JPX400\ weight_{it}}{JPX400\ weight_{it}} \\
&= \%\ BOJ\ holdings\ in\ N225_t \times Bias_{it} + \%\ BOJ\ holdings\ in\ TOPIX_t + \\
&\%\ BOJ\ holdings\ in\ JPX400_t
\end{aligned} \tag{3}$$

The decomposition shows that the cross-sectional distribution of firm-level BOJ ownership is driven by the proportion of BOJ ownership in the Nikkei 225, multiplied by a bias term arising due to its price-weighting scheme and the proportions of BOJ ownership in TOPIX and JPX400. The bias term in the first component gives rise to near-randomized variation in BOJ ownership in the cross-section, because it changes when stocks move in and out of the index (the bias term equals zero for firms outside of the Nikkei 225, by construction) and when prices change over time. The second and third components only exhibit time series variation; in other words, a firm's BOJ ownership via TOPIX and JPX400 is simply the BOJ's percentage ownership in the respective index. However, the latter two components also offer plausibly exogenous variation for identification, because the BOJ has modified the purchase programs over time and the speed of changes for *% BOJ holdings in TOPIX*$_t$ and *% BOJ holdings in JPX400*$_t$ therefore differs across programs.

3.4. Measuring stock illiquidity

We construct two measures of stock illiquidity. Our first measure follows that of Amihud (2002) and computes stock illiquidity as the average ratio of the daily absolute return to the (monetary) trading volume on that day over a calendar quarter, as follows:

$$Amihud's\ ILLIQ_{it} = \frac{1}{D_{it}} \times \frac{|R_{itd}|}{P_{itd}VO_{itd}} \times 10^2 \tag{4}$$

where i denotes the firm's stock and d is the day within year-quarter t; D_{it} is the number of available trading days within year-quarter t; $|R_{itd}|$ is the absolute daily returns of stock i on day d in year-quarter t; and P_{itd} and VO_{itd} are, respectively, the stock price and share volume (in millions of shares) traded of stock i on day d in year-quarter t, with the measure multiplied by 100 for a more convenient interpretation. According to Amihud (2002), the illiquidity measure in equation (4) captures the average impact of the order flow on prices, that is, the discount sellers concede and the premium buyers pay when executing a market order, due to adverse selection costs and inventory risk. The price impact increases with illiquidity.

As equation (4) shows, Amihud's illiquidity measure consists of two components: the numerator and the denominator. Since the BOJ's ETF purchases have been shown to significantly raise the stock prices of the ETFs' underlying securities (Barbon and Gianinazzi, 2019), a relationship may exist between BOJ ownership and the numerator component (i.e., the absolute return), without clear implications for stock liquidity. To address this issue, in a subsequent robustness analysis, we disregard the numerator and perform an additional test that analyzes the relationship between BOJ ownership and the denominator of the illiquidity ratio, that is, the average daily turnover volume over a quarter.

Our second measure follows Pástor and Stambaugh (2003) and captures the extent of volume-related return reversals of Japanese stocks. Specifically, we estimate the following daily return regression for each stock in each year-quarter:

$$r^e_{itd+1} = a_{it} + \theta_{it} r_{itd} + \lambda_{it} sign\left(r^e_{itd}\right) v_{itd} + \varepsilon_{itd+1} \tag{5}$$

where i denotes the stock, t is the year-quarter, and d is the trading day; r^e_{itd} is computed as $r_{itd} - r_{mtd}$, with r_{mtd} the daily return of the Japanese market index on day d; and v_{itd} is the monetary volume (in Japanese yen) for stock i on day d in year-quarter t. A firm's stock liquidity is captured by the estimated coefficient λ_{it}, which is our second dependent variable of interest (*Pástor's* λ). According to Pástor and Stambaugh (2003), the estimated λ_{it} is expected to be negative in general, and a larger absolute magnitude suggests greater illiquidity. The rationale is that a higher trading volume signed by the stock return in excess of the market should be followed by a greater return reversal in the future to the extent that the stock is illiquid. For ease of interpretation, we multiply the estimated λ by 100,000.

Although the BOJ's total amount of ETF purchases are preannounced, the actual days of the purchases are not. The BOJ's purchases exhibit some degree of negative autocorrelation. Specifically, in an attempt to offer a stimulus, the BOJ often bought ETFs in the afternoon following a morning section (of the stock market) with low or negative returns.[11] Since Pástor and Stambaugh's (2003) illiquidity measure is based on return reversals, if a poor market return the day before is followed by a poor return in the morning section the next day and if the BOJ then decided to place a ETF purchase order, such a measure would be overestimated, because it is more susceptible to the BOJ's intervention.[12] In other words, a reversal in returns can arise on the day of and on the day(s) after the BOJ's purchase. To avoid capturing the effect of increased susceptibility to the BOJ's policy, when estimating equation (5), we exclude the observations on day d if the BOJ made ETF purchases on either day d or d – 1.,[13,14] Hence, our illiquidity measure, *Pástor's* λ, captures the volume-related return reversals of non-intervention days and is less likely to be driven by the mechanical reversal induced by the BOJ's interventions.

In a similar vein, when estimating Amihud's illiquidity measure of equation (4), we exclude all observations on days the BOJ purchased ETFs, because both the stock returns and trading on those days do not reflect normal market conditions but are, rather, driven by the immediate price pressure of the BOJ's interventions.[15] We require a minimum of 10 available daily observations for the estimation of both measures.

3.5. Descriptive statistics

Panel A of Table 1 provides a breakdown of our sample by year, showing the number of firm observations, the number of firms with and without (one-quarter-lagged) BOJ ownership, and the average level (one-quarter-lagged) of BOJ ownership among firms with at least some (one-quarter-lagged) BOJ ownership.

On average, our sample has about 2,195 firms per year. Consistent with the BOJ's implementation of the ETF purchase program in December 2010, our sample begins to have nonzero BOJ ownership from 2011:Q1 onward.[16] The number of firms with BOJ ownership increases sharply in 2012:Q2 and continues to rise steadily over the rest of the sample period. Among the firm-years where *BOJ ownership* is nonzero, the mean of *BOJ ownership* is 1.22% in the full sample, and its yearly means increase steadily and reach 3% at the end of 2019.

Panel B of Table 1 provides a sample breakdown following the Nikkei industry classification (32 industries in total). Our sample covers a wide range of industries. The top five industries with the most and least amounts of coverage, respectively, are services (20.9%), electric and electronic equipment (9.1%), wholesale trade (8.9%), machinery (7.8%), retail trade (7.6%), air transportation (0.2%), mining (0.3%), fish and marine products (0.3%), gas utilities (0.4%), and petroleum (0.4%). Among firms with nonzero *BOJ*

[11] According to Harada and Okimoto (2021), the time series average daily return for an average Japanese stock on non-intervention days is 0.16%, whereas that on intervention days is −0.34 over the sample period from April 2013 to October 2017.

[12] We thank an anonymous reviewer for pointing this out.

[13] In an untabulated robustness check, we instead exclude day d observations if the BOJ made ETF purchases that day and find that all our results and conclusions hold.

[14] Between December 15, 2010 and December 30, 2019, there are 2,215 days, of which there are 597 days with BOJ interventions. Excluding observations on day d if the BOJ made ETF purchases on day d, d – 1, or further lagged days would introduce further gaps to the data, adding more noise to the estimation of equation (5), and reducing our final sample size (since we need the data to be available for two consecutive days for the estimation). We thus choose the window [d, d – 1] of BOJ interventions, assuming implicitly that most of the effect on prices due to the BOJ purchases occurred on the event day [for empirical support, see Charoenwong et al. (2021) and Harada and Okimoto (2021)].

[15] Our results are intact if, instead, we do not exclude any daily observations on the days of BOJ interventions in our estimation of equations (4) and (5).

[16] It is because one-quarter-lagged levels of BOJ ownership are used to explain firm illiquidity in the current quarter.

Table 1

Descriptive statistics. Panel A reports the sample distribution by year-quarter. The total number of observations, firm-quarter observations with and without ownership by the BOJ, and the average proportion of the BOJ's firm ownership stakes are reported. Panel B reports the sample breakdown by industry. The number of observations, the number of unique firms, and the average proportion of the BOJ's firm ownership stakes (among firms with nonzero BOJ ownership) are reported.

Panel A: Sample distribution by year-quarter

Date	Obs.		*BOJ ownership*		Average *BOJ ownership* (%)
		%	0	>0	
2010:Q1	1,895	2.2	1,895	0	0.00
2010:Q2	1,927	2.2	1,927	0	0.00
2010:Q3	1,899	2.2	1,899	0	0.00
2010:Q4	1,881	2.1	1,881	0	0.00
2011:Q1	1,881	2.1	1,700	181	0.00
2011:Q2	1,894	2.2	1,700	194	0.02
2011:Q3	1,925	2.2	1,730	195	0.04
2011:Q4	1,891	2.2	1,696	195	0.06
2012:Q1	1,893	2.2	1,698	195	0.07
2012:Q2	1,941	2.2	741	1,200	0.02
2012:Q3	1,935	2.2	571	1,364	0.02
2012:Q4	1,950	2.2	534	1,416	0.19
2013:Q1	1,971	2.2	584	1,387	0.20
2013:Q2	1,991	2.3	550	1,441	0.32
2013:Q3	1,728	2.0	273	1,455	0.36
2013:Q4	1,739	2.0	277	1,462	0.41
2014:Q1	1,805	2.1	326	1,479	0.44
2014:Q2	2,122	2.4	581	1,541	0.46
2014:Q3	2,203	2.5	638	1,565	0.47
2014:Q4	2,213	2.5	636	1,577	0.52
2015:Q1	2,250	2.6	642	1,608	0.58
2015:Q2	2,272	2.6	630	1,642	0.64
2015:Q3	2,307	2.6	642	1,665	0.72
2015:Q4	2,333	2.7	650	1,683	0.77
2016:Q1	2,373	2.7	670	1,703	0.84
2016:Q2	2,353	2.7	629	1,724	0.89
2016:Q3	2,391	2.7	648	1,743	0.98
2016:Q4	2,411	2.7	645	1,766	1.14
2017:Q1	2,427	2.8	638	1,789	1.30
2017:Q2	2,458	2.8	650	1,808	1.48
2017:Q3	2,514	2.9	689	1,825	1.62
2017:Q4	2,553	2.9	708	1,845	1.81
2018:Q1	2,608	3.0	749	1,859	1.94
2018:Q2	2,644	3.0	762	1,882	2.11
2018:Q3	2,708	3.1	802	1,906	2.26
2018:Q4	2,723	3.1	808	1,915	2.35
2019:Q1	2,728	3.1	795	1,933	2.62
2019:Q2	2,677	3.0	732	1,945	2.69
2019:Q3	2,675	3.0	722	1,953	2.84
2019:Q4	1,696	1.9	458	1,238	3.02
Total	87,785	100.0	35,506	52,279	1.22

Panel B: Industry distribution

Nikkei Industry Classification	Obs.	%	Unique firms	%	*Average BOJ ownership*
Foods	3,347	3.8	109	3.5%	1.35
Textile Products	1,363	1.6	41	1.3%	1.15
Pulp & Paper	534	0.6	17	0.6%	1.33
Chemicals	6,072	6.9	191	6.2%	1.33
Drugs	1,877	2.1	62	2.0%	1.36
Petroleum	379	0.4	11	0.4%	1.26
Rubber Products	561	0.6	20	0.6%	1.26
Stone, Clay & Glass Products	1,437	1.6	47	1.5%	1.54
Iron & Steel	1,441	1.6	41	1.3%	1.14
Nonferrous Metal & Metal Products	3,456	3.9	115	3.7%	1.48
Machinery	6,817	7.8	212	6.9%	1.36
Electric & Electronic Equipment	7,958	9.1	241	7.8%	1.59
Shipbuilding & Repairing	153	0.2	5	0.2%	1.73
Motor Vehicles & Auto Parts	2,468	2.8	70	2.3%	1.14
Transportation Equipment	408	0.5	11	0.4%	0.92
Precision Equipment	1,502	1.7	49	1.6%	1.60
Other Manufacturing	2,677	3.0	88	2.9%	1.08

(*continued on next page*)

Table 1 (*continued*)

Panel B: Industry distribution

Nikkei Industry Classification	Obs.	%	Unique firms	%	*Average BOJ ownership*
Fish & Marine Products	286	0.3	11	0.4%	2.01
Mining	282	0.3	8	0.3%	0.95
Construction	4,481	5.1	146	4.7%	1.12
Wholesale Trade	7,826	8.9	278	9.0%	0.98
Retail Trade	6,645	7.6	232	7.5%	1.04
Real Estate	2,601	3.0	109	3.5%	1.11
Railroad Transportation	936	1.1	26	0.8%	1.53
Trucking	832	0.9	29	0.9%	1.08
Sea Transportation	384	0.4	11	0.4%	1.24
Air Transportation	156	0.2	5	0.2%	1.18
Warehousing & Harbor Transportation	890	1.0	28	0.9%	1.21
Communication Services	894	1.0	30	1.0%	1.29
Electric Utilities	465	0.5	13	0.4%	1.18
Gas Utilities	336	0.4	9	0.3%	1.20
Services	18,321	20.9	818	26.5%	1.00
Total	87,785	100.0	3,083	100.0%	1.22

ownership, the average *BOJ ownership* value is the highest among firms operating in the fish and marine products industry, and the lowest among those in the transportation equipment industry.

4. Empirical results

4.1. The BOJ's policy and stock illiquidity

To examine the link between the BOJ's ETF purchases and firms' stock illiquidity, we estimate the following baseline panel regression model:

$$Stock\ illiquidity_{it} = \beta_0 + \beta_1\ BOJ\ ownership_{it\text{-}1} + \boldsymbol{X_{it\text{-}1}}\Psi + Firm\ fixed\ effects\ (FE) + Industry{\times}year\text{-}quarter\ FE + \varepsilon_{it} \tag{6}$$

where i is the firm and t is the year-quarter, *Stock illiquidity*$_{it}$ is either Amihud's illiquidity measure or the volume-related return reversal measure of Pástor and Stambaugh (2003), and *BOJ ownership*$_{it\text{-}1}$ is the proportion of a firm's shares owned by the BOJ, estimated following the procedures explained in Section 3.2.

The vector $\boldsymbol{X_{it\text{-}1}}$ contains one-quarter-lagged firm control variables. Specifically, we control for the natural logarithm of market capitalization (ln*(ME)*) and the natural logarithm of firm age (ln*(AGE)*) and expect larger and more established firms to have a smaller price impact and less illiquidity. We include the market-to-book equity ratio (*MB*), financial leverage (*LEV*), a dummy for dividend-paying firm-quarters (*Dividend dummy*), and a dummy for firms with negative earnings (*Loss dummy*) to account for the effects of financial distress, financial constraints, and growth opportunities on stock illiquidity (Banerjee et al., 2007; Amihud and Mendelson, 2008). Since liquidity and asset prices are closely related (Amihud, 2002) and the BOJ's ETF purchases have been shown to drive short-term changes in stock prices (Barbon and Gianinazzi, 2019), we control for lagged quarterly stock returns (*RET*) in all regressions. Moreover, we control for the natural logarithm of the turnover ratio (ln*(TURN)*), computed as the total number of shares traded over the previous quarter, deflated by the end-of-quarter number of shares outstanding, in light of prior evidence that it predicts liquidity (Barinov, 2014). Finally, increases in stock return volatilities raise the likelihood of liquidity providers trading with informed traders, thereby increasing the adverse selection and inventory risk and reducing asset liquidity (Stoll, 1978, 2000; Ho and Stoll, 1981). We thus control for the natural logarithm of daily return volatilities estimated over the past quarter (ln*(VOL)*). The definitions of the variables are in Table A1 in the Appendix.

Table 2 reports the summary statistics for our main variables. The full sample mean (median) of *BOJ ownership* is 0.72% (0.18%), which is comparable to that previous reported (e.g., Chen et al., 2019).

Since firm fixed effects are included, our model relies only on the within-firm variation in *BOJ ownership* and stock illiquidity to identify the relation in question. Industry-year-quarter interacted fixed effects are included to account for any industry-specific time trends, allowing us to compare firms within the same industry. The variable *Industry* is defined following the Nikkei industry classification (32 industries in total). Standard errors are double-clustered at the firm and year-quarter levels.

Table 3 reports the estimation results of equation (6). Columns (1) to (3) report the results for *Amihud's ILLIQ*. All independent variables are standardized to have a zero mean and unit standard deviation. The firm controls discussed above are included in all the models. In column (1), where industry and year-quarter fixed effects are controlled for, we find that *BOJ ownership* enters the model positively and significantly (at the 1% level). We next apply firm effects and give the results in column (2); the positive coefficient estimate increases and remains significant. Column (3) presents the results of our most stringent specification, with firm and industry-year-quarter interacted fixed effects; the results continue to hold. In terms of economic magnitude, a one standard deviation increase in *BOJ ownership* is associated with a 7.2 percentage point increase in *Amihud's ILLIQ*, which corresponds to 13.6% of its sample standard deviation of 0.53.

Columns (4) to (6) of Table 3 report the results for *Pástor's* λ and yield similar conclusions. Specifically, as column (6) shows, we

Table 2
Summary statistics. This table reports summary statistics for our main variables. All variables come from a sample that consists of 87,785 firm-year-quarter observations from 3,077 unique firms listed on Japanese exchanges over the period from 2010:Q1 to 2019:Q4. Variable definitions are in Table A1 in the Appendix.

	Mean	Std. Dev.	25%	Median	75%
BOJ ownership	0.724%	1.367%	0.000%	0.182%	0.936%
Amihud's ILLIQ	0.193	0.530	0.005	0.028	0.114
Pástor's λ	−3.525	41.215	−4.860	−0.102	1.852
ME	151,885	406,853	10,128	25,618	87,614
MB	1.306	1.046	0.831	0.991	1.313
RET	0.031	0.174	−0.072	0.013	0.110
TURN	0.279	0.450	0.059	0.146	0.300
VOL	0.169	0.085	0.111	0.151	0.205
AGE	54.252	26.255	34.000	58.000	71.000
LEV	0.458	0.196	0.303	0.456	0.609
Dividend dummy	0.851	0.356	1.000	1.000	1.000
Loss dummy	0.120	0.325	0.000	0.000	0.000
ETF mispricing (average)	30.552	45.302	0.000	16.323	38.746
ETF mispricing (sd)	41.557	86.901	0.000	13.347	35.366
ETF net share creation & redemption (average)	2.459	9.465	0.000	0.062	0.306
ETF net share creation & redemption (sd)	7.455	28.353	0.000	0.187	0.975
ETF arbitrage index	0.004	1.388	−0.549	−0.336	0.005
R^2_{LIQ}	0.065	0.058	0.023	0.048	0.090
Ψ_{LIQ}	−3.102	1.137	−3.757	−2.983	−2.318
$\beta_{MKT}{}^{M1}$	0.821	0.501	0.453	0.801	1.141
$R^2_{MKT}{}^{M1}$	0.237	0.193	0.071	0.194	0.367
$SYNCH^{M1}$	−2.328	2.104	−3.205	−1.854	−0.914
$IVOL^{M1}$	0.142	0.078	0.090	0.122	0.169
DELAY	0.347	0.287	0.113	0.250	0.529
Variance ratio	0.253	0.181	0.107	0.222	0.365
$\beta_{MKT}{}^{M2}$	0.896	0.797	0.390	0.834	1.331
$R^2_{MKT}{}^{M2}$	0.309	0.184	0.159	0.276	0.434
$SYNCH^{M2}$	−0.975	1.012	−1.663	−0.965	−0.267
$IVOL^{M2}$	0.137	0.074	0.088	0.118	0.163

find that the coefficient estimate for *BOJ ownership* is −0.879, significant at the 5% level. A one standard deviation increase in *BOJ ownership* is associated with a decrease in *Pástor's λ* of 0.879, corresponding to 2.1% of its sample deviation of 41.22.

Overall, our evidence supports our hypothesis that the BOJ's purchases of ETFs significantly increase stock illiquidity.

4.2. Robustness tests

We present the results of several robustness tests in Table 4. To save space, only the estimates for the variable of interest are reported.

To ascertain that our results are not driven by increases in stock prices due to the BOJ's intervention itself, in the regression for row (1) of Table 4, we exclude the numerator of *Amihud's ILLIQ* (i.e., the absolute return) and replace the dependent variable of the baseline model with the denominator, computed as the natural logarithm of the average daily turnover volume, in millions, over all trading days with no BOJ interventions within a quarter. We find that *BOJ ownership* is associated with a significantly lower daily turnover volume, consistent with higher illiquidity. A one standard deviation increase in *BOJ ownership* reduces the daily turnover volume by 10.1%.

As discussed above, one of the main sources of plausibly exogenous variation in the BOJ's ownership of firms arises due to the price-weighting scheme of the Nikkei 225. In the regression for row (2) of Table 4, we replace *BOJ ownership* with the proportion of shares owned by the BOJ via the Nikkei 225 (*BOJ ownership* via *N225*) in our baseline model estimation. The results show that the coefficient estimates for *BOJ ownership* via *N225* are positive and highly significant in both stock illiquidity models, thus complementing our baseline evidence.

In row (3), we check whether our results are sensitive to the sample period analyzed. Removing observations before 2013, when the BOJ's ETF purchases were less prevalent, does not affect our results. In the regression for row (4), we double-cluster the standard errors at the industry and year-quarter levels. The results continue to hold.

In row (5) of Table 4, we present the regression results that use the alternative flow measure of BOJ purchases, following Charoenwong et al. (2021), and find that our results are similar for both measures of illiquidity. Finally, to mitigate further concerns that the index weights of individual stocks are endogenous to their illiquidity, we hold the index weights of each stock (for the three market indexes) fixed using their 2010:Q4 values and analogously compute the flow measure of BOJ purchases. As row (6) shows, our results remain qualitatively similar despite being weaker for *Pástor's λ*.

Table 3

BOJ ownership and stock illiquidity. This table reports the results from regression examining the relation between the BOJ's stock ownership and stock illiquidity. The dependent variables are *Amihud's ILLIQ* and *Pástor's λ*. The independent variable of interest is the proportion of the BOJ's stock ownership (*BOJ Ownership*). One-quarter-lagged firm controls include the natural logarithm of market capitalization (ln(*ME*)), the market-to-book equity ratio (*MB*), quarterly stock returns (*RET*), the natural logarithm of the turnover ratio (ln(*TURN*)), the natural logarithm of daily stock return volatilities (ln(*VOL*)), the natural logarithm of firm age (ln(*AGE*)), financial leverage (*LEV*), a dividend-paying dummy (*Dividend dummy*), and an earnings loss dummy (*Loss dummy*). The detailed definitions of the variables are presented in Table A.1 in the Appendix. All independent variables (except if they are dummy variables) are standardized to have a zero mean and unit standard deviation. The *t*-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	Amihud's ILLIQ			*Pástor's λ*		
	(1)	(2)	(3)	(4)	(5)	(6)
BOJ ownership	0.062***	0.074***	0.072***	−0.597**	−0.896**	−0.879**
	(5.000)	(6.938)	(6.847)	(-2.128)	(-2.118)	(-2.172)
ln*(ME)*	−0.133***	−0.138***	−0.137***	2.871***	3.292***	3.317***
	(-11.967)	(-4.768)	(-4.500)	(6.140)	(3.265)	(3.033)
MB	0.006	0.031***	0.034***	−0.206	−1.161***	−1.052***
	(1.366)	(4.049)	(4.461)	(-1.371)	(-3.667)	(-3.745)
RET	0.001	0.003	0.003	0.390**	0.477**	0.404**
	(0.219)	(0.910)	(0.886)	(2.077)	(2.512)	(2.035)
ln*(TURN)*	−0.279***	−0.267***	−0.268***	2.651***	1.860***	1.840***
	(-10.518)	(-10.402)	(-10.451)	(5.145)	(3.344)	(3.252)
ln*(VOL)*	0.135***	0.101***	0.100***	−0.351	−0.156	−0.053
	(8.401)	(8.019)	(7.979)	(-0.899)	(-0.343)	(-0.118)
ln*(AGE)*	−0.008	0.056	0.083*	0.145	−0.487	0.113
	(-1.490)	(1.397)	(1.944)	(0.937)	(-0.320)	(0.065)
LEV	0.015***	−0.005	−0.001	−0.009	−0.446	−0.286
	(3.001)	(-0.442)	(-0.097)	(-0.048)	(-0.734)	(-0.441)
Dividend dummy	−0.061***	−0.038**	−0.038**	0.613	1.006	1.165
	(-3.716)	(-2.219)	(-2.233)	(0.898)	(0.953)	(1.114)
Loss dummy	0.037***	0.033***	0.033***	−1.417**	−1.122*	−0.871
	(3.354)	(3.674)	(3.745)	(-2.346)	(-1.813)	(-1.373)
Industry FE	Yes			Yes		
Year–quarter FE	Yes	Yes		Yes	Yes	
Firm FE		Yes	Yes		Yes	Yes
Industry × year-quarter FE			Yes			Yes
Observations	87,785	87,785	87,785	87,785	87,785	87,785
Adj. R^2	0.349	0.600	0.603	0.015	0.043	0.042

Table 4

Robustness tests. This table reports the robustness test results. The model specifications of the robustness tests follow those in the models reported in columns (3) and (6) of Table 3, unless stated otherwise. In the regression for row (1), the dependent variable is the natural logarithm of the average daily number of shares traded (in a quarter, in millions). In the regression for row (2), we replace BOJ ownership with a firm's *BOJ ownership* via the ETFs tracking the Nikkei 225. Row (3) excludes observations prior to 2013. In row (4), we double-cluster standard errors at the industry and time levels. Row (5) reports results using the alternative flow measure of BOJ purchases. Row (6) reports results using the alternative flow measure of BOJ purchases where the index weights of each stock are held fixed (using *2010Q4* values). For brevity, we report only the estimates for the BOJ's stock ownership (*BOJ ownership*). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

		Alternative measure			*Amihud's ILLIQ*			*Pástor's λ*		
Row	Description	Coef.	Obs.	Adj. R^2	Coef.	Obs.	Adj. R^2	Coef.	Obs.	Adj. R^2
(1)	Decomposed *Amihud's ILLIQ*: ln(*VO)*	−0.106***	87,785	0.858						
		(-5.015)								
(2)	BOJ ownership via N225 only				0.024***	87,785	0.598	−0.249*	87,785	0.042
					(6.525)			(-1.792)		
(3)	Sample beginning in 2013				0.020**	64,873	0.655	−1.245*	64,873	0.062
					(2.136)			(-1.793)		
(4)	Double-clustered standard errors at the industry and year-quarter levels.				0.072***	87,785	0.603	−0.879**	87,785	0.042
					(5.797)			(-2.296)		
(5)	Alternative flow measure of *BOJ ownership*				0.080***	87,785	0.604	−1.271**	87,785	0.043
					(4.433)			(-2.608)		
(6)	Alternative flow measure of *BOJ ownership* (holding weights fixed at 2010:Q4)				0.045***	87,785	0.600	−0.417	87,785	0.042
					(3.902)			(-1.294)		

4.3. Matched DiD tests

While some of the plausibly exogenous variation in *BOJ ownership* is useful for identifying the relationship in question in our baseline tests, a concern is that the treatment and control firms may differ substantially from each other in a number of aspects, thereby violating the covariate balance condition needed for causal inference (Atanasov and Black, 2016). Hence, to reinforce a causal interpretation, we perform two additional sets of DiD tests using propensity score matching (PSM) techniques to improve covariate balance.

4.3.1. Matched DiD test 1: Nikkei 225 index membership

Since the price-weighting scheme of the Nikkei 225 offers plausibly exogenous variation in the BOJ ownership of firms, our first set of DiD tests analyzes how the Nikkei 225 constituent firms' stock illiquidity evolves over time relative to firms not listed in the Nikkei 225. We present a version of the DiD tests estimated on the full unmatched sample and another version estimated on a matched sample using PSM techniques.

At the end of 2010:Q4, which is the last year-quarter before the BOJ started purchasing ETFs, we match each constituent firm of the Nikkei 225 with control firms not listed in the Nikkei 225, using PSM techniques. Specifically, at the end of 2010:Q4, we estimate a logistic regression modeling the incidence of Nikkei 225 membership as a function of the full set of firm controls. Using the estimated propensity scores, we apply a radius approach to match each of the treatment firms with control firms, requiring that the latter have propensity scores within a radius of 0.025.[17] Since the number of treatment firms in our setting is relatively small (225 firms), the radius approach allows us to use additional control firms when the matches are good, thereby reducing the variance of the estimates. After the matching procedure, we apply the assigned weights of the matched firms to the rest of the sample and perform the DiD analysis on the matched sample using these weights.

Panel A of Table 5 reports the estimation results of the logistic regressions estimated on the sample before and after matching (with weights computed based on the radius approach) in 2010:Q4. Our results show that the matching successfully eliminated the differences in the set of firm observable characteristics, as shown by their nonsignificant estimates, the nonsignificant chi-squared statistics, and the small pseudo-R-squared values.

We next estimate the following DiD models on the unmatched and matched samples, respectively:

$$\begin{aligned}\text{Stock illiquidity}_{\text{it}} &= \beta_0 + \beta_1\%\ \text{BOJ ownership in ETF}_{\text{N225}}\ t + \beta_2\ \text{N225 dummy}_{\text{it}} + \beta_3\%\ \text{BOJ ownership in ETF}_{\text{N225}}\ t \\ &\times \text{N225 dummy}_{\text{it}} + \delta\text{X}_{\text{it}-1} + \text{Firm FE} + \text{Industry} \times \text{year} - \text{quarter FE} + \varepsilon_{\text{it}}\end{aligned} \tag{7a}$$

$$\begin{aligned}Stock\ illiquidity^{it} &= \beta_0 + \beta_1\%\ BOJ\ ownership\ in\ ETF_{N225\ t} + \beta_2\ N225\ dummy^{2010:Q4_i} + \beta_3\%\ BOJ\ ownership\ in\ ETF_{N225\ t} \\ &\times N225\ dummy^{2010:Q4_i} + \delta X_{it-1} + Firm\ FE + Industry \times year - quarter\ FE + \varepsilon_{it}\end{aligned} \tag{7b}$$

where *% BOJ ownership in* ETF_{N225_t} is the proportion of the market capitalization in the ETFs tracking the Nikkei 225 owned by the BOJ in year-quarter *t*. In equation (7a), ***N225 dummy***$_{it}$ is a dummy that equals one for firms listed in the Nikkei 225 in year-quarter *t*, and zero otherwise; in equation (7b), ***N225 dummy***$_{2010:Q4_i}$ is a time-invariant dummy that equals one for firms listed in the Nikkei 225 in 2010:Q4, and zero otherwise. The baseline firm controls and fixed effects are included. The estimated β_3 is a DiD estimate that captures how stock illiquidity is driven by changes in *BOJ ownership* of the Nikkei 225 constituent firms (or the treatment firms in equation (7b)) relative to firms outside of the Nikkei 225 (matched control firms in 2010:Q4).

Note that equation (7a) closely resembles the model specification in a contemporaneous study by Harada and Okimoto (2021); this unmatched DiD test thus enhances the robustness of our results to an alternative model specification. Equation (7b) improves the robustness beyond the unmatched DiD tests by further improving the covariate balance.

Columns (1) and (3) In Panel B of Table 5 report the estimation results for equation (7a) on the full unmatched sample and columns (2) and (4) report them for equation (7b) on the matched sample. Columns (1) and (3) show that BOJ ownership significantly (at the 10% or better) increases stock illiquidity among the Nikkei 225 constituent firms relative to firms outside of the index. In columns (2) and (4), which report the matched DiD results, we again find that stock illiquidity increases significantly (at the 10% or better) for the treatment firms relative to the matched control firms when BOJ ownership increases. The evidence supports our baseline results reported in Table 3.

4.3.2. Matched DiD test 2: firms migrating from the second to the first section

We present a second set of matched DiD tests with alternatively defined treatment and control groups. The TSE consists of three sections: the first and second sections include large and mid-sized companies, respectively; the third section, referred to as the Mothers section, includes only high-growth startup companies. Only stocks listed in the first section of the TSE are tracked by index ETFs and thus are subject to BOJ ownership via index ETF purchases. We identify the events of firms moving from the second to the first section and examine whether the subsequent increases in the BOJ ownership of these firms affect stock illiquidity relative to matched control firms listed in the second or Mothers sections. Note that firms that have recently migrated to the first section likely have characteristics that have yet to differ considerably from those listed in lower section(s), thereby allowing us to find better firm matches.

[17] A similar radius approach in matching has been applied by Guo and Masulis (2015), who use a radius of 0.15.

Table 5

Matched DiD test 1: Nikkei 225 index membership. This table reports the results for the matched DiD tests based on a firm's Nikkei 225 index membership in 2010:Q4. Panel A reports the results of logistic regressions (in 2010:Q4) using a firm's Nikkei 225 index membership dummy (*N225 dummy2010:Q4*) as the dependent variable for the pre- and post-matched samples. Panel B reports the DiD test results estimated on the unmatched full sample (columns (1) and (3)) and the matched sample (columns (2) and (4)). The variable *N225 dummy* is a dummy that equals one for a firm listed in the Nikkei 225 in a given year-quarter, and zero otherwise. The variable *N225 dummy2010:Q4* is a dummy that equals one for a firm listed in the Nikkei 225 in 2010:Q4, and zero otherwise; it is time invariant by construction. The variable *% BOJ ownership in ETFN225* is the proportion of market capitalization of all BOJ-owned ETFs tracking the Nikkei 225. The dependent variables are *Amihud's ILLIQ and Pástor's λ*. Firm controls and fixed effects identical to those in the baseline models are included. The *t*-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Diagnostics tests, logistic regression estimation (2010Q4)

	N225 dummy	
	Pre-matched sample	*Post-matched sample*
	(1)	(2)
ln*(ME)*	3.069***	0.381
	(14.056)	(1.167)
MB	−1.072*	−0.105
	(-1.921)	(-0.256)
RET	−0.071	−0.132
	(-0.369)	(-0.423)
ln*(TURN)*	1.577***	0.069
	(6.888)	(0.209)
ln*(VOL)*	0.070	0.345
	(0.279)	(1.119)
ln*(AGE)*	0.383**	0.328
	(2.168)	(1.516)
LEV	0.645***	−0.090
	(4.635)	(-0.444)
Dividend dummy	−0.629	0.555
	(-0.862)	(0.714)
Loss dummy	0.224	0.305
	(0.378)	(0.471)
Observations	1,881	1,865
Pseudo-R^2	0.668	0.033
Chi-squared	252.34***	6.68

Panel B: Matched DiD tests

	Amihud's ILLIQ		*Pástor's λ*	
	Unmatched	*Matched*	*Unmatched*	*Matched*
	(1)	(2)	(3)	(4)
% of N225 owned by BOJ	−0.309	−0.065	37.987	5.503*
	(-0.617)	(-1.120)	(1.319)	(1.688)
N225 dummy	−0.108***		1.212	
	(-2.984)		(1.298)	
% of N225 owned by BOJ × N225 dummy	0.254***		−2.469*	
	(5.685)		(-1.728)	
% of N225 owned by BOJ × N225 dummy$_{2010:Q4}$		0.023***		−0.210*
		(6.746)		(-1.999)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry × year-quarter FE	Yes	Yes	Yes	Yes
Observations	87,785	69,885	87,785	69,885
Adj. R^2	0.599	0.475	0.042	0.018

During our sample period, we identify 184 events of stocks moving from the second to the first section of the TSE. In each year-quarter with at least one event, we apply PSM techniques, estimate a logistic regression modeling the incidence of the event as a function of pre-event firm controls, and match each of the moving firms with a control firm (i.e., one to one) that is listed in the second or Mothers sections and has the closest estimated propensity scores.[18] We retain the 12 quarters before and after the event for the matched analysis (requiring at least four quarters of available observations before and after the event). The observations of the matched pairs in each year-quarter are then stacked in a panel; the event quarter is dropped.

Panel A of Table 6 reports the average firm characteristics for the treatment and matched control groups at the beginning of the event year-quarter. The differences in all the firm covariates are small and statistically nonsignificant (using two-sample *t*-tests), suggesting that the matching has been successful in removing observable differences between the two groups.

In Panel B of Table 6, we provide the results of an estimation of the baseline model specification on the matched sample. As column

[18] The matching procedure requires that the absolute difference in propensity scores not exceed 1%.

Table 6
Matched DiD test 2: Migrating from the second to the first section. This table reports the results from matched DiD tests based on 184 events in which a stock moved from the second to the first section in the TSE. Panel A reports the average pre-event firm characteristics for the treated and matched control groups and their respective two-sample t-test results. Panel B reports the results from our baseline stock illiquidity tests estimated on the matched sample. Firm controls and the set of fixed effects identical to those in the baseline tests are included. The t-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: t-tests at the beginning of the event quarter

	Treatment (N = 184)	Control	Treatment – Control	p-value
ln(*ME*)	−0.552	−0.536	−0.016	0.782
MB	0.130	0.105	0.025	0.804
RET	0.196	0.253	−0.057	0.610
ln(*TURN*)	−0.165	−0.170	0.006	0.955
ln(*VOL*)	−0.139	−0.173	0.034	0.775
ln(*AGE*)	−0.325	−0.275	−0.051	0.581
LEV	−0.005	−0.010	0.005	0.962
Dividend dummy	0.941	0.951	−0.011	0.647
Loss dummy	0.016	0.011	0.005	0.654

Panel B: Baseline tests estimated on the matched sample

	Amihud's ILLIQ	*Pástor's λ*
	(1)	(2)
BOJ ownership	0.121**	−5.276
	(2.697)	(-1.521)
Firm controls	Yes	Yes
Firm FE	Yes	Yes
Industry × year-quarter FE	Yes	Yes
Observations	6,909	6,909
Adj. R^2	0.573	0.083

(1) shows, *BOJ ownership* significantly (at the 5% level) increases *Amihud's ILLIQ*. Yet, in column (2) with *Pástor's λ* as the dependent variable, the estimate on *BOJ ownership* has the correct sign but is nonsignificant. The evidence thus provides some support for our hypothesis that the BOJ's equity purchases increase stock illiquidity and reinforces a causal interpretation of our findings.

4.4. ETF arbitrage channel

Our results thus far show that the BOJ's purchases of index ETFs significantly increase stock illiquidity, and our results survive a number of robustness analyses and alternative estimation approaches and specifications. In this subsection, we examine the role played by ETF arbitrage activities in driving the relation in question.

4.4.1. Measuring ETF arbitrage activities

To capture the extent of ETF arbitrage activities, we follow Agarwal et al. (2018) and construct four empirical proxies for such activities, capturing two aspects of ETF arbitrage. The first aspect is the degree of ETF mispricing, that is, the deviation between the ETF and the underlying basket prices. As pointed out by Ben-David et al. (2018), such a deviation represents the profitability of ETF arbitrage strategies, and greater mispricing thus attracts more arbitrageurs to engage in arbitrage activities. For each of the index ETFs, we calculate the extent of its mispricing as the absolute value of the daily difference between its end-of-the-day price and its end-of-the-day net asset value (NAV). We then average the daily mispricing measure over all non-BOJ intervention trading days in a calendar quarter, assign it to each of the investee firms according to the ETF's percentage ownership in the firms, and then aggregate the measure across the ETFs. Hence, the firm-level ETF mispricing measure can be written as

$$ETF\ mispricing\ (average)_{it} = \sum_{j=1}^{J}\left[w_{jt-1} \times \frac{1}{D}\sum_{d=1}^{D}\left|\frac{PRC_{jd} - NAV_{jd}}{PRC_{jd}}\right|\right] \tag{8}$$

where i is the firm, j is the ETF, and d is the trading day in year-quarter t; D is the total number of trading days in year-quarter t; PRC_{jd} (NAV_{jd}) is the end-of-the-day price (NAV) of ETF j on day d; and w_{jt-1} is the ownership percentage of ETF j in firm i at the end of year-quarter t – 1.

However, as pointed out by Agarwal et al. (2018) and Ben-David et al. (2018), the level of ETF mispricing may be driven by limits of arbitrage, as opposed to the extent of arbitrage activities. Following Agarwal et al. (2018), we construct an alternative measure of ETF mispricing by first calculating the standard deviation (over all non-BOJ intervention trading days in a calendar quarter) of the absolute daily deviation between the ETF's end-of-the-day price and its end-of-the-day NAV and then similarly weight-average the standard deviation-based measure to arrive at a firm-level measure, which we denote as *ETF mispricing (sd)*. Both ETF mispricing measures are multiplied by 100,000 for ease of interpretation.

The second aspect is the ETFs' net share creation and redemption activities, captured by the daily percentage changes in the numbers of ETF shares. Similar to the mispricing measures, we construct two versions of the net share creation and redemption measure, one using averages and the other using standard deviations, using all non-BOJ intervention trading days in a calendar quarter. Specifically, the firm-level ETF net creation and redemption measure (the measure based on averages) is computed as follows:

$$ETF\ net\ share\ creation\ \&\ redemption\ (average)_{it} = \sum_{j=1}^{J}\left[w_{jt-1} \times \frac{1}{D}\sum_{d=1}^{D}\left|\frac{SHRSOUT_{jd} - SHRSOUT_{jd-1}}{SHRSOUT_{jd-1}}\right|\right] \quad (9)$$

where $SHRSOUT_{jd}$ is the number of shares outstanding of ETF j at the end of day d, and *ETF net share creation & redemption (sd)*$_{it}$ is similarly constructed, except that the standard deviation of the daily absolute percentage changes in outstanding ETF shares is used and then weight-averaged at the firm level.

We obtain a composite measure of ETF arbitrage activities (*ETF arbitrage index*) by taking the first principal component of the above four empirical proxies. As pointed out by Tetlock (2007), this approach avoids the need to make a subjective judgment regarding the relative importance of the four proxies. Following Tetlock, we perform the principal component analysis in each year-quarter using current information, thus avoiding any potential look-ahead bias if we use information in the future. Untabulated analysis results show that the full-sample pairwise correlation between the *ETF arbitrage index* and the four empirical proxies ranges from 0.44 to 0.81.[19]

4.4.2. Mediation tests for ETF arbitrage

To the extent that the BOJ purchases may affect stock illiquidity partly via its induced changes to the extent of ETF arbitrage activities, ETF arbitrage may play a (partial or complete) mediating role. In other words, our analysis attempts to quantify the extent to which the resulting changes in ETF arbitrage activities due to increases in BOJ ownership can explain the increase in stock illiquidity documented in our baseline tests. To this end, we follow prior studies (e.g., Baron and Kenny, 1986) and perform a four-step procedure and a series of Sobel tests to examine the mediation relationship.

Panel A of Table 7 depicts how ETF arbitrage may mediate the relationship between BOJ ownership and stock illiquidity; Panel B provides a more detailed description of the mediation testing procedures. Specifically, we first gauge the total effect by showing how the causal variable, BOJ ownership, is associated with the outcome variable, stock illiquidity (i.e., Amihud's ILLIQ and Pástor's λ), Path C. We then establish that the causal variable (BOJ ownership) is significantly associated with the mediating variable (i.e., ETF arbitrage index), Path A. Finally, to evaluate Path B, we estimate baseline regressions regressing stock illiquidity on BOJ ownership and ETF arbitrage index simultaneously. In the Path B analysis, if BOJ ownership is nonsignificant while ETF arbitrage index is significant in explaining stock illiquidity, the mediation effect can be viewed as complete. Otherwise, if BOJ ownership and ETF arbitrage index are both significant in explaining stock illiquidity, the mediation effect would be partial.

We perform formal tests of the mediation effect of ETF arbitrage activities following Sobel (1982). Specifically, the Sobel test statistics are computed as follows:

$$Sobel\ Test = \frac{\alpha_a \alpha_b}{\sqrt{\alpha_b^2 \delta_a^2 + \alpha_a^2 \delta_b^2}} \quad (10)$$

where α_a and δ_a are the estimated coefficient and standard error for *BOJ ownership* in the Path A analysis, and α_b and δ_b are the estimated coefficient and standard error for *ETF arbitrage index* in the Path B analysis.

Panel C of Table 7 reports the estimation results for the Path A analysis for the ETF arbitrage mediating variable. The results consistently show that *BOJ ownership* is positively and significantly associated with *ETF arbitrage index*. Panel D reports the results for the Path B analysis that includes both *BOJ ownership* and *ETF arbitrage index* in the model. Across the two illiquidity models, we find that the coefficient for *BOJ ownership* reduces in magnitude when the ETF arbitrage index is controlled for. Moreover, the coefficient estimates on *ETF arbitrage index* are positive in both illiquidity models and it is significant in the Amihud's illiquidity model at the 1% level but insignificant for the other model. This evidence points to a nontrivial mediating effect of ETF arbitrage. More importantly, the results from the Sobel tests in Panel E show that the mediating effect of ETF arbitrage is significant (at the 1% level) in the Amihud's illiquidity model but is nonsignificant in the Pástor and Stambaugh's illiquidity model. Our evidence lends some support to the view that BOJ purchases intensify ETF arbitrage activities, which partially explains the increase in stock illiquidity we document.

4.4.3. Further evidence of a mediating relationship using a two-stage approach

To offer further evidence of the mediating role of ETF arbitrage, we formulate an alternative, two-stage approach. In the first stage, we regress the *ETF arbitrage index* on *BOJ ownership*, and in the second stage, we regress the stock illiquidity measures on the channel variable "predicted" from the first stage, that is, on the variation in *ETF arbitrage index* explained by *BOJ ownership*. The control variables and fixed effects identical to those in the baseline models are included in both stages. Note that this two-stage approach is akin to an instrumental variable approach, except that *BOJ ownership* is not treated as the instrument for the ETF arbitrage variables, since BOJ ownership may affect stock illiquidity through channels other than changes in ETF arbitrage activities.[20]

Panel A of Table 8 reports the first-stage estimation results. As expected, we find that *BOJ ownership* is positively and significantly

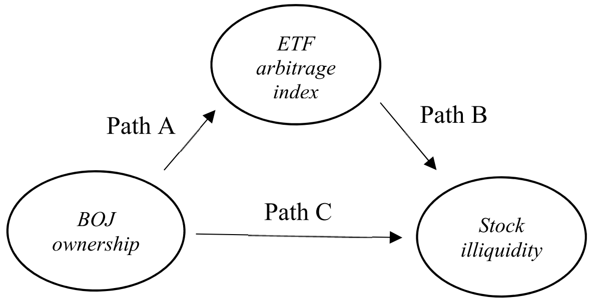
[19] These statistics are available from the authors upon request.

[20] For a similar two-stage approach in testing economic channels, see, for example, Liang and Renneboog (2017, Section V).

Table 7

Mediation tests for ETF arbitrage. This table reports the results of our tests examining whether ETF arbitrage activities mediate the relation between BOJ ownership and stock illiquidity. Panel A presents a graph showing the three paths (Paths A, B, and C) of the mediating relation in question. Panel B provides a description of our mediation test procedures and the formula for the Sobel test. Panels C and D report the regression results for Paths A and B, respectively. Panel E reports the coefficients and standard errors of interest from the Path A and B regressions for both Amihud's ILLIQ and Pástor's λ. The variable ETF arbitrage index is the first principal component of the four variables capturing ETF arbitrage activities: ETF mispricing (average), ETF mispricing (sd), ETF net share creation & redemption (average), and ETF net share creation & redemption (sd). The t-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses.*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Graph for the mediation relation



Panel B: Steps for the mediation tests

Step	Description
1	Path A: Regress *ETF arbitrage index* (mediator) on *BOJ ownership* (following the baseline model specification); take the coefficient and standard errors for *BOJ ownership* (α_a, δ_a)
2	Path B: Regress stock illiquidity on *BOJ ownership* and the mediator (following the baseline model specification); take the coefficient and standard errors for the mediator (α_b, δ_b).

$$\text{Sobel test} = \frac{\alpha_a\alpha_b}{\sqrt{\alpha_b^2\delta_a^2 + \alpha_a^2\delta_b^2}}$$

Panel C: ETF arbitrage activities and BOJ ownership (Path A)

	ETF arbitrage index (1)
BOJ ownership	0.189***
	(5.564)
Firm controls	Yes
Firm FE	Yes
Industry × year-quarter FE	Yes
Observations	87,785
Adj. R^2	0.937

Panel D: Controlling for ETF arbitrage activities (Path B)

	Amihud's ILLIQ		*Pástor's λ*	
	(1)	(2)	(3)	(4)
BOJ ownership	0.072***	0.055***	−0.879**	−0.776**
	(6.847)	(6.472)	(-2.172)	(-2.050)
ETF arbitrage index		0.088***		−0.544
		(4.590)		(-1.124)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry × year-quarter FE	Yes	Yes	Yes	Yes
Observations	87,785	87,785	87,785	87,785
Adj. R^2	0.603	0.607	0.042	0.042

Panel E: Sobel tests

Outcome	*Amihud's ILLIQ*		*Pástor's λ*	
Path	A	B	A	B
Coefficient	0.189	0.088	0.189	−0.544
Standard error	0.034	0.019	0.034	0.484
Sobel test	3.558***		−1.101	
p-value	[0.000]		[0.271]	

Table 8
The ETF arbitrage channel: Evidence from a two-stage estimation. In this table, we examine whether BOJ ownership affects stock illiquidity via its effect on ETF arbitrage activities using a two-stage approach. In the first stage (Panel A), we regress BOJ ownership on the firm-level ETF arbitrage index (ETF arbitrage index); in the second stage (Panel B), we regress stock illiquidity on the predicted channel variable from the first stage, i.e., ETF arbitrage index that is explained by BOJ ownership. The dependent variables are Amihud's ILLIQ and Pástor's λ. Firm controls and fixed effects identical to those of the baseline models are included. The t-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: First-stage results

	ETF arbitrage index
	(1)
BOJ ownership	0.189***
	(5.564)
Firm controls	Yes
Firm FE	Yes
Industry × year-quarter FE	Yes
Observations	87,755
F-Statistics of excluded instrument	30.96***

Panel B: Second-stage results

	Amihud's ILLIQ	*Pástor's λ*
	(1)	(2)
ETF arbitrage index	0.379***	−4.649**
	(5.031)	(-2.151)
ln*(ME)*	−0.214***	4.263***
	(-6.005)	(3.734)
MB	0.040***	−1.119***
	(4.731)	(-4.037)
RET	0.006*	0.363*
	(1.804)	(1.847)
ln*(TURN)*	−0.266***	1.816***
	(-10.850)	(3.235)
ln*(VOL)*	0.099***	−0.043
	(8.482)	(-0.097)
ln*(AGE)*	0.056	0.437
	(1.314)	(0.260)
LEV	0.007	−0.381
	(0.529)	(-0.574)
Dividend dummy	−0.038**	1.174
	(-2.335)	(1.129)
Loss dummy	0.031***	−0.846
	(3.235)	(-1.322)
Firm FE	Yes	Yes
Industry × year-quarter FE	Yes	Yes
Observations	87,755	87,755

associated with the *ETF arbitrage index*. In Panel B, where the second-stage results are reported, we find that the predicted *ETF arbitrage index* is significantly (at the 5% level or better) associated with higher stock illiquidity (both *Amihud's ILLIQ* and *Pástor's λ*). Overall, the evidence lends further support to the partial mediating role of increased ETF arbitrage activities in explaining the increase in stock illiquidity. Note, however, our mediation analysis thus far is not conclusive, since other channels potentially explaining the link between BOJ ownership and stock illiquidity may be at work.

4.5. Cross-sectional heterogeneity tests

To the extent that the BOJ, as a committed buyer, increases the number of shares locked up by ETFs and thus reduces the supply of stocks for trading and thus stock liquidity, two further predictions can be made regarding how the relationship between *BOJ ownership* and stock illiquidity may vary in the cross-section.

First, we expect the increases in stock illiquidity due to BOJ ownership to be concentrated among firms whose shares are typically illiquid. Two firm characteristics associated with asset illiquidity are considered: market capitalization (*ME*) and age (*Age*). Smaller and younger stocks are less likely to be listed in major exchanges, receive less media, market, and analyst attention, and thus face greater limits to arbitrage, trading costs, and market frictions. Firm size and age are thus associated with higher illiquidity (Stoll and Whaley, 1983; Baker and Wurgler, 2006). The variables *Small* and *Young* are dummy variables equal to one for firms with below-median *ME* and *Age* values, respectively, and zero otherwise.

Second, if a reduction in the supply of shares for trading is the underlying driver of our results, the positive effect of the BOJ's ETF purchases on stock illiquidity is likely to be more pronounced among firms that experience a strong buy pressure, where a decline in the supply of shares would reduce the extent to which buy orders are filled to a greater degree, thereby widening the price impact and increasing illiquidity; on the contrary, the effect of BOJ ownership on stock illiquidity would be weak among firms experiencing a strong selling pressure, since the supply likely outweighs the demand for shares.

To capture the extent of the buying and selling pressure firms experience, we download firm-level data on the weekly outstanding balance of margin trading for both long and short positions from the Japan Securities Finance Co., Ltd., average these weekly amounts

Table 9

BOJ ownership and stock illiquidity: Cross-sectional heterogeneity. In this table, we examine the cross-sectional heterogeneity in the association between BOJ ownership and stock illiquidity. The dependent variables are *Amihud's ILLIQ* (Panel A) and *Pástor's λ* (Panel B). The variable *Small (Young)* is a dummy equal to one for firms with below-median market capitalization (firm age), and zero otherwise; *Margin trading (selling) – high* [*Margin trading (buying) – high*] is a dummy equal to one for firms whose average weekly outstanding balance of the number of shares lent for short selling [leverage buying] (in the previous quarter, scaled by the number of shares outstanding at the end of the last quarter) is above the sample median, and zero otherwise; *Undervalued* is a dummy equal to one for firms whose lagged quarterly stock returns (*RET*) and market-to-book equity ratio (*MB*) are both below their respective sample medians, and zero otherwise; and *Institutional ownership – high* (*Small investors – high*) is a dummy equal to one for firms whose proportion ownership by institutional investors (small investors) is above the sample median, and zero otherwise. In each model, we control for the baseline firm controls and fixed effects, all interacted with the dividing variables; their estimates are suppressed for brevity. All independent variables (except if they are dummy variables) are standardized to have a zero mean and unit standard deviation. The *t*-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: *Amihud's ILLIQ*

	Amihud's ILLIQ						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
BOJ ownership	0.008***	0.050***	0.141***	0.055***	0.058***	0.242***	0.055***
	(5.071)	(5.412)	(5.131)	(6.608)	(6.460)	(4.424)	(6.435)
BOJ ownership × Small	0.199***						
	(3.989)						
BOJ ownership × Young		0.041**					
		(2.567)					
BOJ ownership × Margin trading (selling) – high			−0.130***				
			(-4.884)				
BOJ ownership × Margin trading (buying) – high				0.027*			
				(1.994)			
BOJ ownership × Undervalued					0.065***		
					(3.941)		
BOJ ownership × Institutional ownership – high						−0.227***	
						(-4.211)	
BOJ ownership × Small investors – high							0.037**
							(2.253)
Firm controls (interacting with the dividing variable)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87,785	87,785	87,785	87,785	87,785	87,785	87,785
Adj. R^2	0.666	0.618	0.669	0.658	0.625	0.655	0.631

Panel B: *Pástor's λ*

	Pástor's λ						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
BOJ ownership	−0.132	−0.640	−2.038*	−0.920*	−0.572*	−3.155	−0.978***
	(-1.193)	(-1.523)	(-1.694)	(-1.803)	(-1.765)	(-1.577)	(-3.227)
BOJ ownership × Small	−2.280*						
	(-1.709)						
BOJ ownership × Young		−0.631					
		(-1.172)					
BOJ ownership × Margin trading (selling) – high			1.863*				
			(1.745)				
BOJ ownership × Margin trading (buying) – high				0.189			
				(0.347)			
BOJ ownership × Undervalued					−1.702**		
					(-2.027)		
BOJ ownership × Institutional ownership – high						2.916	
						(1.453)	
BOJ ownership × Small investors – high							−0.036
							(-0.044)
Firm controls (interacting with the dividing variable)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87,785	87,785	87,785	87,785	87,785	87,785	87,785
Adj. R^2	0.044	0.045	0.037	0.059	0.069	0.044	0.047

within a quarter, and deflate the average balance by the end-of-quarter number of shares outstanding. We then classify firms subject to strong selling and buying pressure as those with above-median margin trading of short and long positions in the previous quarter, respectively, and construct two dummy variables: *Margin trading (selling) – high* and *Margin trading (buying) – high*. Moreover, our second measure of buying pressure is a dummy variable, *Undervalued*, which is equal to one for firms with a below-median lagged quarterly stock return, *RET*, and a below-median lagged market-to-book equity ratio, *MB*, and is zero otherwise. Such firms are likely to be undervalued and to have experienced stock underperformance over the past quarter, and, hence, they would be appealing to fundamental buyers looking to exploit such fundamental arbitrage opportunities.

Table 9 reports the results for tests interacting the above-defined dummy variables with *BOJ* ownership in the baseline model. Panels A and B report the results for *Amihud's ILLIQ* and *Pástor's* λ, respectively. As shown in Panel A, the results in columns (1) to (5) are consistent with our conjecture. The positive effect of *BOJ ownership* on *Amihud's ILLIQ* is significantly more pronounced among firms that are smaller and younger, have less (more) margin trading of short (long) positions, and are likely to be undervalued.

Finally, we examine whether the effect in question varies in the cross-section according to the level of share ownership by institutions and small investors using data from the NEEDS CGES database. Since firms with greater levels of ownership by institutional investors or lower levels of ownership by small investors likely have more informed trading and less illiquidity (Grullon et al., 2004; Agarwal, 2007), we expect the effect of *BOJ ownership* on illiquidity to be weaker. Accordingly, we construct dummy variables equal to one for firms with above-median levels of institutional ownership and ownership by small investors and interact them with *BOJ ownership* in the baseline model. The results in columns (6) and (7) are in line with our conjecture.

The results reported in Panel B exhibit very similar patterns (except for the margin trading of long positions), but they in general have weaker statistical significance, possibly because *Pástor's* λ is estimated from regressions and thus is subject to more measurement errors.

4.6. Further implications of the BOJ's policy

In this subsection, we extend beyond examining the level of illiquidity and study the implications of BOJ ownership for the degree of comovement in stock liquidity and returns. We then perform additional analysis to understand whether the BOJ's policy is associated with better or worse information efficiency.

4.6.1. The BOJ's policy and comovement in liquidity and stock returns

As discussed previously, the demand for ETFs is transmitted to their underlying securities via the arbitrage activities undertaken by arbitrageurs trading in opposite positions in the ETFs and the underlying securities. Due to such nonfundamental shocks, firms held by ETFs would experience higher correlated trading and thus demand liquidity for their securities. Hence, their liquidity and return may comove more than is warranted by common exposure to fundamentals, implying that ETF ownership is positively related to both liquidity commonality and return comovement (Agarwal et al., 2018; Da and Shive, 2018). Such excessive comovement created by ETF arbitrage activities is consistent with the demand-based explanation for liquidity commonality in which correlated trading by certain investors may lead to greater commonality (Chordia et al., 2000; Hasbrouck and Seppi, 2001) and with prior studies showing that nonfundamental factors, such as market friction or sentiment, can lead to return comovement (Barberis et al., 2005).

Following Karolyi et al. (2012), we measure the commonality in the stock liquidity for Japanese firms using the following procedures. First, in the spirit of Amihud's illiquidity measure, the liquidity of stock *i* on day *d* within year-quarter *t* is defined as follows

$$LIQ_{itd} = -\,log\left(1 + \frac{|R_{itd}|}{P_{itd}VO_{itd}}\right) \tag{11}$$

We then run the following filtering regression for each firm *i* in each year-quarter *t* to remove any first-order serial correlations and day-of-the-week effects in daily liquidity:

$$LIQ_{itd} = \alpha_{it}\, LIQ_{itd-1} + \sum_{\tau=1}^{5} \beta_{it\tau} D_\tau + \omega_{itd} \tag{12}$$

where $D_\tau(\tau = 1, \ldots, 5)$ represents the day-of-the-week dummies. The residual (ω_{itd}) from equation (12) represents the innovations in daily liquidity. To measure the degree of comovement in stock liquidity, we estimate the R-squared (R^2_{LIQ})[21] value from the following regression, estimated for each stock in each year-quarter (requiring a minimum of 10 available daily observations for the estimation):

$$\widehat{\omega}_{itd} = \alpha_{it} + \sum_{j=-1}^{1} \beta_{itj} \widehat{MLIQ}_{td+j} + \varepsilon_{itd} \tag{13}$$

where $MLIQ_{td+j}$ is the aggregate market liquidity innovation, computed as the market value–weighted average of the liquidity residuals of all stocks on day *d*. We include the one-day-leading and one-day-lagging *MLIQ* in the model. As Table 2 shows, the mean (median) of the estimated liquidity R-squared is 0.065 (0.048).

[21] In untabulated robustness tests, we apply a logistic transformation to the liquidity R-squared measure and find qualitatively similar results. The results are available from the authors upon request.

Table 10
BOJ ownership, comovement, and informational efficiency. In this table, we examine the effect of the BOJ's stock ownership on liquidity and return comovement and informational efficiency. In column (1), the dependent variable is the liquidity-commonality measure, R^2_{LIQ}. In columns (2) to (4), the dependent variables are the market beta (β^{MKTM1}), R-squared values ($R^{2\ M1}$), and the natural logarithm of residual volatilities (ln($IVOL^{M1}$)) from the market model regression of equation (14). In columns (5) and (6), the dependent variables in the regression are the natural logarithm of price delay (ln(*Delay*)) and the price-variance ratio. In columns (7) to (9), the dependent variables in the regression are the sum of the betas on the current and lagged market factors (β^{M2}_{MKT}), R-squared values $R^{2\ M2}$), and the natural logarithm of residual volatilities (ln($IVOL^{M2}$)) from the expanded market model regression of equation (15). The independent variable of interest is a firm's proportion of shares owned by the BOJ (*BOJ ownership*). The firm controls are identical to those of the baseline models; their estimates are suppressed for brevity. All independent variables (except if they are dummy variables) are standardized to have a zero mean and unit standard deviation. Industry fixed effects are constructed using the Nikkei industry classification. The *t*-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

		$r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd}$,			Informational efficiency		$r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd}$		
	R^2_{LIQ}	β^{M1}_{MKT}	$R^{2\ M1}$	ln($IVOL^{M1}$)	ln(*Delay*)	*Variance ratio*	β^{M2}_{MKT}	$R^{2\ M2}$	ln($IVOL^{M2}$)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BOJ ownership	0.0025*	−0.004	−0.012**	0.014**	0.043*	0.0059***	0.010	−0.011**	0.014**
	(1.758)	(-0.284)	(-2.394)	(2.543)	(1.946)	(2.822)	(0.642)	(-2.380)	(2.504)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87,785	87,785	87,785	87,785	87,785	87,785	87,785	87,785	87,785
Adj. R^2	0.0772	0.538	0.611	0.606	0.459	0.0680	0.264	0.584	0.602

We follow Da and Shive (2018) and Glosten et al. (2021) to measure a firm's stock return comovement for each stock in a given year-quarter in a market model:

$$r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd} \tag{14}$$

where r_{itd} is the daily stock return for stock *i* on day *d* in year-quarter *t*, and r_{mtd} is the daily Japanese market index return on day *d* in year-quarter *t*. The extent of the stock return comovement is captured by the estimated β (${\beta_{MKT}}^{M1}$). The mean (median) ${\beta_{MKT}}^{M1}$ is 0.82 (0.80).

We next regress our measure of liquidity commonality, R^2_{LIQ}, on *BOJ ownership*, firm controls, and fixed effects. The results in column (1) of Table 10 show that BOJ ownership is associated with significantly (at the 10% level) higher comovement in stock liquidity. A one standard deviation increase in *BOJ ownership* increases the liquidity R-squared by 25 bps, corresponding to a 3.8% increase relative to the sample mean.

Column (2) of Table 10 reports the results from the baseline model with ${\beta_{MKT}}^{M1}$ as the dependent variable. The estimate is small (coefficient = −0.004) and statistically nonsignificant. Hence, the results thus far suggest the BOJ's policy has little effect on stock return comovement.

4.6.2. The BOJ's policy and informational efficiency

A natural follow-up question is whether the documented increase in stock illiquidity due to the BOJ's policy has any implications for the degree of information efficiency among Japanese stocks. According to Chordia et al. (2008), in the presence of limited risk-bearing capacity and inventory constraints, deviations of the mid quotes (of market makers) from fundamental values due to incoming price pressure would be quickly eliminated by arbitrage orders that are sufficiently large and timely. However, arbitrageurs are more inclined to submit such orders when the trading costs or illiquidity are low. Hence, increased stock illiquidity due to the BOJ's policy may impede the extent and efficacy of arbitrage activities in the secondary market, leading to lower informational efficiency.

In addition, increased illiquidity and the associated increases in trading costs and frictions would deter market participants from engaging in firm-specific information gathering and consequently result in less informativeness or more noise in the firm-specific component of stock prices (Grossman and Stiglitz, 1980; Admati, 1985). On the contrary, Glosten et al. (2021) argue that, when information arrives, ETF investors must assess what such information may imply for a larger number of securities, as opposed to for a single security in the case of trading individual stocks. Hence, ETF flows are associated with the timelier incorporation of market information into contemporaneous stock returns, suggestive of better informational efficiency.

However, the mechanism suggested by Glosten et al. (2021) might not apply to the BOJ's ETF purchases, because the BOJ is a single, committed buyer whose objective is quantitative easing rather than broadening the investor base of ETFs. Moreover, although the days of purchase are not determined in advance, the BOJ has bought ETFs over a prolonged period according to fixed, predetermined policy schedules. Accordingly, the increases in BOJ ownership might not improve or even impede the timeliness or amount of market information incorporated into stock prices.

As a first test, we examine the degree of return synchronicity among Japanese stocks using the estimated R-squared values ($R^{2\ M1}$)[22] from equation (14) (requiring at least 10 available daily observations). Previous studies (e.g., Morck et al., 2000) argue that firms with greater informational efficiency likely have stock prices that incorporate more variation in firm-specific factors and synchronize less with market factors (i.e., lower R-squared).

Column (3) of Table 10 shows that *BOJ ownership* is associated negatively and significantly (at the 5% level) with $R^{2\ M1}$, suggesting more firm-specific variation. We then apply an alternative measure of firm-specific variation, the natural logarithm of idiosyncratic volatilities ($\ln(IVOL^{M1})$), computed as the standard deviation of the residuals from equation (14). The results in column (4) similarly show that *BOJ ownership* is associated with significantly higher idiosyncratic volatilities.

However, the validity of return synchronicity in capturing the amount of market- or firm-specific information in stock returns and thus the degree of informational efficiency is debatable. As pointed out by Li et al. (2014), two strands of literature are in disagreement regarding what firm-specific return variation captures. On the one hand, studies (e.g., Morck et al., 2000; Jin and Myers, 2006) argue that greater firm-specific return variation reflects stock prices with more information and less noise. On the other hand, others (e.g., Campbell et al., 2001; Hou and Moskowitz, 2005; Bartram et al., 2012) argue that firm-specific return variation reflects pricing errors and is thus inversely related to informational efficiency. Li et al. (2014) empirically show that lower return synchronicity is associated with proxies of poorer information environment, such as greater price delays and higher illiquidity, consistent with more noise. In light of their evidence and our findings of increased illiquidity, we argue that our findings of reduced return synchronicity (due to *BOJ ownership*) reflect more noise than information, that is, a less informationally efficient market.

To offer more evidence for our conjecture, we construct two additional proxies for the firm information environment. The first is the degree of price delays, following Hou and Moskowitz (2005), which involves estimating an expanded market model for each stock in each year-quarter (requiring a minimum of 10 available daily observations for the estimation):

$$r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd} \tag{15}$$

where *j* ranges from one to five. The model in equation (15) augments the market model of equation (14) by including five daily lags for the market excess returns.[23] The extent of price delays is defined as follows:

$$Delay_{it} = \left(1 - \frac{R^{2\ M1}}{R^{2\ M2}}\right)_{it} \tag{16}$$

where $R^{2\ M1}$ and $R^{2\ M2}$ are the estimated R-squared values from equations (14) and (15), respectively. A high value in *Delay* suggests a longer price delay in response to market information, and thus lower informational efficiency. We take the natural logarithm of *Delay* due to high skewness.

Our second measure of informational efficiency is the price-variance ratio following Ben-David et al. (2018), which gauges the extent to which stock prices follow a random walk:

$$Variance\ ratio_{it} = \frac{Var\left(r_{itd}^{5-day}\right)}{\left[5 \times Var\left(r_{itd}^{1-day}\right)\right]} \tag{17}$$

where r_{itd}^{5-day} is the five-day return (over the days $d-5$ to d) for stock i on day d in year-quarter t, and r_{itd}^{1-day} is the one-day return on day d for stock i in year-quarter t. The rationale for this measure is that, if the prices of a stock follow a random walk, its variance should be constant and the returns should not be serially correlated; hence, the ratio of the five-day return variance to five times the variance of the one-day return should equal one. A deviation in the ratio from one rejects the random walk hypothesis, suggestive of market and price inefficiencies.

As shown in columns (5) and (6) of Table 10, *BOJ ownership* is positively and significantly (at the 10% level or better) associated with both $\ln(Delay)$ and *Variance ratio*. The evidence suggests that, for firms with higher levels of BOJ ownership, the timeliness of stock prices incorporating market information is significantly worse, and there is significant evidence of reduced market efficiency given a larger variance ratio. Our evidence thus favors the explanation that greater firm-specific return variation captures more noise in our findings.

Our results of a greater price delay suggest that equation (15), which includes both current and lagged market excess returns, likely better captures the dynamic nature of the market risk factor and is thus a more appropriate model for expected returns. For robustness,

[22] In untabulated robustness tests, we apply a logistic transformation to $R^{2\ M1}$. The results, which are qualitatively similar, are available from the authors upon request.

[23] Note that the estimation of equation (15) does not exclude trading days within a stock-quarter in which there is BOJ intervention. Such exclusion would introduce many gaps in the data and moderately reduce our sample size, given our model with five lagged market returns. For consistency, all the measures examined in Subsection 4.6 (including liquidity commonality, return comovement, return synchronicity, idiosyncratic volatilities, price delay, and variance ratios) follow the same approach, that is, without excluding those days with BOJ intervention. In untabulated analysis, we re-estimate all measures (except price delays) using only trading days without BOJ intervention and find that all our results remain similar in both magnitude and significance. These results are available from the authors upon request.

based on equation (15), we construct a new measure of return comovement (${\beta_{MKT}}^{M2}$) as the sum of the coefficients on current and lagged market excess returns. We also obtain the R-squared ($R^{2\ M2}$) and the natural logarithm of idiosyncratic volatilities (ln($IVOL^{M2}$)) from equation (15).

As shown in column (7) of Table 10, where ${\beta_{MKT}}^{M2}$ is the dependent variable, we similarly find that the coefficient estimate on *BOJ ownership* is positive but nonsignificant. In columns (8) and (9), the results for $R^{2\ M2}$ and ln($IVOL^{M2}$) remain similar to those based on their counterparts estimated from equation (14).

Overall, our evidence suggests that the BOJ's ETF purchases lead to greater ETF arbitrage activities and thus more strongly correlated trading and demand for the underlying securities, causing liquidity to comove more. Moreover, we find that informational efficiency declines, as revealed by greater delay in stock prices reflecting market information, a larger variance ratio, and more pricing noise.

4.6.3. *The BOJ's policy and future earnings response coefficients*

To offer more evidence on the negative role of *BOJ ownership* on informational efficiency, we adopt an alternative approach and examine the future earnings response coefficients. Specifically, we follow Israeli et al. (2017) and estimate the following quarterly return regression:

$$RET_{it} = \beta_0 + \sum_{k=-1}^{1} \beta_{2+k} EARN_{it+k} + \beta_4 BOJ\ ownership_{it-1} + \left(\sum_{k=-1}^{1} \beta_{6+k} EARN_{it+k}\right) \times BOJ\ ownership_{it-1} + \boldsymbol{X}_{it-1}\boldsymbol{\Psi} + \left(\sum_{k=-1}^{1} \delta_{3+k} EARN_{it+k}\right) \times \boldsymbol{X}_{it-1} + Industry \times Year - quarter\ FE + \varepsilon_{it} \tag{18}$$

where RET_{it} is firm i's quarterly stock return in quarter t; $EARN_{it}$ is firm i's seasonally adjusted earnings per share (EPS) in quarter t deflated by the stock price at the end of quarter t – 1, and $\boldsymbol{X}_{it\text{-}1}$ is a vector of one-quarter-lagged firm controls, including all baseline controls, quarterly stock returns in quarter $t+1$ (RET_{t+1}), earnings loss dummies for quarter t and $t+1$ (*Loss dummy*$_t$ and *Loss dummy*$_{t+1}$), earnings persistence (*EP*), and EPS volatilities (*EPS VOL*). Standard errors are double-clustered at the firm and year-quarter levels.

The coefficients of interest are those on the interaction terms between current and future earnings and *BOJ ownership*, that is, β_6 and β_7, which capture whether the extent of current stock returns in reflecting current and future firm earnings is affected by *BOJ ownership*; if *BOJ ownership* is associated with lower informational efficiency, we expect the estimated β_6 and/or β_7 to be negative and significant.

The estimation results for equation (18) are reported in Table 11. In column (1), as expected, the estimates on $EARN_{t\text{-}1}$, $EARN_t$, and $EARN_{t+1}$ are positive and significant at the 10% or better. Importantly, the estimate of the interaction between *BOJ ownership* and $EARN_{t+1}$ is −0.075, significant at the 5% level. The evidence suggests that firms with a higher *BOJ ownership* have current stock returns that are less reflective of future firm earnings, consistent with lower informational efficiency.

We follow Glosten et al. (2021) and decompose *EARN* into a systematic and firm-specific component. Specifically, we regress *EARN* on the size-weighted averages of *EARN* across all firms and across all firms in the same Nikkei industry, respectively. The fitted *EARN* values from the decomposition regression are the systematic component of *EARN* (*EARN_SYS*), whereas the regression residuals are the firm-specific component (*EARN_FIRM*). We then replace *EARN* with its two decomposed components in equation (18) and report the results (only the coefficients of interest, for brevity) in column (2) of Table 11.

Column (2) of Table 11 shows that the interaction of *BOJ ownership* with the systematic component of quarter t earnings and with the firm-specific components of future quarter $t+1$ earnings are negative and significant at the 10% level. This evidence confirms that the stock returns of firms with greater BOJ ownership are significantly less reflective of current systematic and future firm-specific earnings, consistent with lower informational efficiency.

5. Conclusion

The QQE program carried out by the BOJ is unprecedented in terms of its operation, scale, and impact. In this paper, we provide insight on the impact of this program on the underlying stock market. More precisely, we study the effect of the BOJ's ETF purchases on stock illiquidity.

Using a sample of 87,785 firm-quarter observations and 3083 unique Japanese firms from 2010:Q1 to 2019:Q4, we find that the BOJ's ownership of domestic equities increases firms' stock illiquidity. This finding survives a number of robustness analyses and alternative estimation approaches and specifications. We then perform a mediation analysis and a two-stage analysis, both showing that BOJ ownership increases ETF arbitrage activities and that the associated increases in arbitrage raise stock illiquidity. Increased ETF arbitrage activities partially account for the rises in stock illiquidity.

Further, we find that the increased illiquidity due to the BOJ's policy is more pronounced among illiquid firms, characterized by a small size, young age, and low levels of institutional ownership, and among firms subject to strong buying pressure. Finally, we document that the BOJ's ownership increases comovement in liquidity but not in returns, and it is associated with longer price delays and larger deviations from a random walk. Firms with greater BOJ ownership also have current stock returns that are less reflective of future firm earnings. Together, the evidence suggests that the BOJ's policy leads to greater pricing errors and lower informational efficiency.

Table 11
BOJ ownership and information efficiency: Earnings coefficient tests. In this table, we examine whether the BOJ's stock ownership affects the extent to which current stock returns reflect future firm earnings, i.e., the future earnings response coefficient. The dependent variable is quarterly stock returns (*RET*). The terms $EARN_{t-1}$, $EARN_t$, and $EARN_{t+1}$ are seasonally adjusted earnings deflated by the beginning-of-quarter stock price during quarters t – 1, *t*, and *t* + 1, respectively. $EARN\_SYS_t$ and $EARN\_FIRM_t$ are the systematic and firm-specific component of $EARN_t$. In addition to the baseline controls, we also include quarterly stock returns in quarter *t* + 1 (*RETt+1*), earnings loss dummies for quarter t and t + 1 (*Loss dummy*$_t$ *and Loss dummy*$_{t+1}$), earnings persistence (*EP*), and EPS volatilities (*EPS VOL*). All firm controls are interacted with the lagged, current, and future earnings variables; the estimates for the main and interaction effects of all the firm controls are suppressed for brevity. The variable *BOJ ownership* and all firm controls (except if they are dummy variables) are standardized to have a zero mean and unit standard deviation. The *t*-statistics based on double-clustered standard errors at the firm and year-quarter levels are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	RET	
	(1)	(2)
$EARN_{t-1}$	0.866***	
	(8.008)	
$EARN_t$	0.541***	
	(6.076)	
$EARN_{t+1}$	0.200*	
	(1.896)	
BOJ ownership	0.003	
	(1.596)	
BOJ ownership × $EARN_{t-1}$	−0.028	
	(-0.594)	
BOJ ownership × $EARN_t$	−0.030	
	(-0.789)	
BOJ ownership × $EARN_{t+1}$	**−0.075****	
	(-2.101)	
BOJ ownership × $EARN\_SYS_{t-1}$		0.366*
		(1.824)
BOJ ownership × $EARN\_SYS_t$		**−0.315***
		(-1.743)
BOJ ownership × $EARN\_SYS_{t-1}$		−0.047
		(-0.344)
BOJ ownership × $EARN\_FIRM_{t-1}$		−0.020
		(-0.446)
BOJ ownership × $EARN\_FIRM_t$		−0.030
		(-0.716)
BOJ ownership × $EARN\_FIRM_{t+1}$		**−0.053***
		(-1.734)
Firm controls (interacted with $EARN_{t-1}$, $EARN_t$, and $EARN_{t+1}$)	Yes	Yes
Industry × year-quarter FE	Yes	Yes
Observations	63,406	63,406
Adj. R^2	0.317	0.315

Recent studies document evidence suggesting that the BOJ's ETF purchase program may not be as effective as planned. For instance, some show that the program has failed to stimulate aggregate investment, has led to potential declines in corporate governance quality (Charoenwong et al., 2021), and has reduced market efficiency, investor participation, and the cost of equity capital (Chen et al., 2019). Our findings add new evidence to this growing body of studies by documenting the negative impact of the BOJ's policy on stock liquidity and informational efficiency.

Driven by concerns of market illiquidity (Eckett, 2019), in June 2020 the BOJ started an ETF lending program in which its ETF holdings could be temporarily lent to market makers and APs (Feng, 2021). While critics mention that the lending program has lacked investor interest, future research may leverage such an empirical setting and examine whether ETF lending affects stock illiquidity.

Finally, our findings that increased illiquidity and its commonality due to the BOJ's policy likely have implications for firm-level exposure to liquidity risk and thus asset prices. Future research could examine the extent to which the policy-induced price increases can be attributed to liquidity risk. The answers to such questions could have implications for the effectiveness of the BOJ's policy.

Data availability

The authors do not have permission to share data.

Appendix

Table A.1
Detailed definitions of the main variables.

Variable	Definition	Source
BOJ ownership	The proportion of a firm's shares owned by the Bank of Japan (BOJ).	BOJ Eikon Nikkei Quick
Amihud's ILLIQ	Amihud's (2002) illiquidity measure, computed as the average of the daily ratio of the absolute stock return to the monetary volume in each quarter, written as follows: $Amihud's\ ILLIQ_{it} = \frac{1}{D_{it}} \times \frac{\lvert R_{itd} \rvert}{P_{itd} VO_{itd}} \times 10^2$, where i denotes the firm's stock, d is the day within year-quarter t; D_{it} is the number of available trading days within year-quarter t; $\lvert R_{itd} \rvert$ is the absolute daily return of stock i on day d in year-quarter t, and P_{itd} and VO_{itd} are, respectively, the stock price and share volume (in millions of shares) traded of stock i on day d in year-quarter t; the measure is multiplied by 100 for more convenient interpretation. A higher value of *Amihud's ILLIQ* denotes greater stock illiquidity.	Nikkei Quick
Pástor's λ	Pástor and Stambaugh's (2003) liquidity measure, computed by estimating the following daily return regression for each stock in each year-quarter: $r^e_{itd+1} = \alpha_{it} + \theta_{it} r_{itd} + \lambda_{it} sign(r^e_{itd}) v_{itd} + \varepsilon_{itd+1}$, where i denotes a stock, t is a year-quarter, and d is a trading day; r^e_{itd} is computed as $r_{itd} - r_{mtd}$, with r_{mtd} the daily return of the Japanese market index of day d; v_{itd} is the monetary volume (in yen) for stock i on day d in year-quarter t; and *Pástor's* λ is the estimated coefficient, λ_{it}, from the regression. The daily returns of all trading days with BOJ intervention are excluded from the estimation. The estimated γ_{it} is expected to be negative in general, and a larger absolute magnitude suggests a lesser extent of stock liquidity (i.e., greater illiquidity). For ease of interpretation, we multiply the estimated λ by 100,000.	Nikkei Quick
R^2_{LIQ}	A measure of commonality in stock liquidity following Karolyi et al. (2012). First, we compute the logarithm of the negative of Amihud's daily ratio of the absolute stock return to the monetary volume for stock i on day d within year-quarter t, as follows: $LIQ_{itd} = -log\left(1 + \frac{\lvert R_{itd} \rvert}{P_{itd} VO_{itd}}\right)$. We then run the following filtering regression for firm i in each year-quarter t to remove any first-order serial correlations and day-of-the-week effects in daily liquidity: $LIQ_{itd} = \alpha_{it}\ LIQ_{itd-1} + \sum_{\tau=1}^{5} \beta_{it\tau} D_\tau + \omega_{itd}$, where $D_\tau (\tau = 1, \ldots, 5)$ represents the day-of-the-week dummies. The residual (ω_{itd}) represents the innovations in daily liquidity. To measure the degree of comovement in stock liquidity, we estimate the R-squared (R^2_{LIQ}) value from the following regression, estimated for each stock in each year-quarter: $\widehat{\omega}_{itd} = \alpha_{it} + \sum_{j=-1}^{1} \beta_{itj} \widehat{MLIQ}_{td+j} + \varepsilon_{itd}$, where $MLIQ_{td+j}$ is the aggregate market liquidity innovation, computed as the market value–weighted average of the liquidity residuals of all stocks on day d. We include the one-day-leading and one-day-lagging *MLIQ* in the model.	Nikkei Quick
${\beta_{MKT}}^{M1}$	Market beta, defined as the estimated coefficient on the daily Japanese market index returns from the market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd}$.	Nikkei Quick
$R^{2\ M1}$	The estimated R-squared value from the market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd}$.	Nikkei Quick
ln(*IVOL*^{M1})	Natural logarithm of quarterly idiosyncratic volatilities. Idiosyncratic volatilities are computed as the standard deviation of the residuals from the market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd}$, multiplied by the squared root of 63.	Nikkei Quick
${\beta_{MKT}}^{M2}$	Market beta, defined as the sum of the estimated coefficients on the current and lagged daily Japanese market index returns from the expanded market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd}$.	Nikkei Quick
$R^{2\ M2}$	The estimated R-squared ($R^{2\ M2}$) value from the expanded market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd}$.	Nikkei Quick
ln(*IVOL*^{M2})	Natural logarithm of quarterly idiosyncratic volatilities, computed analogously using the residuals from the expanded market model regression, $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd}$.	Nikkei Quick
ln(*Delay*)	Natural logarithm of a measure capturing the extent of the stock price delay, following Hou and Moskowitz (2005). Specifically, for each stock in each year-quarter, we estimate the R-squared ($R^{2\ M1}$ and $R^{2\ M2}$) values from two regressions: *M1:* $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + e_{itd}$, *M2:* $r_{itd} = \alpha_{it} + \beta_{it} r_{mtd} + \sum_{j=1}^{5} r_{mtd-j} + e_{itd}$, where i denotes the stock and d is the trading day in year-quarter t, r_{itd} is the daily stock return for stock i on day d in year-quarter t, r_{mtd} is the daily	Nikkei Quick

(*continued on next page*)

Table A.1 (*continued*)

Variable	Definition	Source
	Japanese market index return on day *d* in year-quarter *t*, and *j* ranges from one to five. The extent of the price delay over a five-day window is defined as follows: $DELAY_{it} = \left(1 - \frac{R^{2\ M1}}{R^{2\ M2}}\right)_{it}$. A high value of $DELAY_{it}$ suggests a longer price delay in response to market information.	
Variance ratio	The price–variance ratio following Ben-David et al. (2018), gauging the extent to which stock prices follow a random walk, computed as: $Variance\ ratio_{it} = \frac{Var(r_{itd}^{5-day})}{[5 \times Var(r_{itd}^{1-day})]}$, where r_{itd}^{5-day} is the five-day return (from day *d* – 5 to day *d*) for stock *i* on day *d* in year-quarter *t*, and r_{itd}^{1-day} is the one-day return on day *d* for stock *i* in year-quarter *t*. The rationale for this measure is that, if the prices of a stock follow a random walk, its variance should be constant and the returns are not serially correlated; hence, the ratio of the five-day return variance to five times the variance of the one-day return should equal one. A deviation in the ratio from one rejects the random walk hypothesis, suggestive of market and price inefficiencies.	Nikkei Quick
ln*(ME)*	Natural logarithm of market capitalization.	Nikkei Quick
MB	Market-to-book equity ratio.	Nikkei Financial Quest Nikkei Quick
RET	Quarterly stock returns.	Nikkei Quick
ln*(TURN)*	Natural logarithm of the stock turnover ratio. The turnover ratio is computed as the total trading volume (excluding the volume on trading days with BOJ intervention) over a quarter, divided by the total number of shares outstanding at the end of the quarter.	Nikkei Quick
ln*(VOL)*	Natural logarithm of quarterly stock return volatilities, computed as daily stock return volatilities over a given quarter (excluding daily stock returns on trading days with BOJ intervention), multiplied by the squared root of 63. The estimation requires at least 12 available daily return observations.	Nikkei Quick
ln*(AGE)*	Natural logarithm of firm age.	Nikkei Quick
LEV	Financial leverage, computed as total liabilities divided by total assets.	Nikkei Financial Quest
Dividend dummy	A dividend-paying dummy equal to one for firms whose dividend per share (DPS) is positive in a given quarter within a fiscal year, and zero otherwise. Firms often report the DPS in their last fiscal quarter.	Nikkei Financial Quest
Loss dummy	A dummy that equals one if earnings are negative, and zero otherwise.	Nikkei Financial Quest
ETF mispricing (average)	A firm's exposure to ETF mispricing, computed as the average of the daily absolute difference between the ETF's end-of-the-day price and its end-of-the-day NAV (i.e., the ETF's discount or premium) over a calendar quarter and then averaged at the stock level using the ETF's ownership for the stock as weights.	Investment Trusts Association, Japan Nikkei Quick
ETF mispricing (sd)	A firm's exposure to ETF mispricing, computed as the standard deviation of the daily absolute difference between the ETF's end-of-the-day price and its end-of-the-day NAV (i.e., the ETF's discount or premium) over a calendar quarter and then averaged at the stock level using the ETF's ownership for the stock as weights.	Investment Trusts Association, Japan Nikkei Quick
ETF net share creation & redemption (average)	A firm's exposure to ETF net share creation and redemption, computed as the average of the daily absolute net share creation and redemption over a calendar quarter and then averaged at the stock level using the ETF's ownership for the stock as weights.	Nikkei Quick
ETF net share creation & redemption (sd)	A firm's exposure to ETF net share creation and redemption, computed as the standard deviation of the daily absolute net share creation and redemption over a calendar quarter and then averaged at the stock level using the ETF's ownership for the stock as weights	Nikkei Quick
ETF arbitrage index	The first principal component of *ETF mispricing (average), ETF mispricing (sd)*, *ETF net share creation & redemption (average)*, and *ETF net share creation & redemption (sd)*. The principal component analysis is estimated in each year-quarter.	Nikkei Quick
$EARN_t$	Seasonally adjusted earnings during quarter *t* deflated by the beginning-of-quarter stock price, computed as (firm subscript *i* dropped for brevity): $EARN_t = \frac{EPS_t - EPS_{t-4}}{P_{t-1}}$, where EPS_t is a firm's earnings per share in quarter *t* and P_{t-1} is a firm's stock price in quarter *t* – 1.	Nikkei Quick
EARN_SYS (EARN_FIRM)	The systematic (firm-specific) component of *EARN*. To decompose *EARN,* we regress it on the size-weighted average $EARN_t$ for all firms and the size-weighted average $EARN_t$ for all firms in the same Nikkei industry; $EARN\_SYS_t$ ($EARN\_FIRM_t$) is the fitted value (residual) from the decomposition regression.	Nikkei Quick
EP	Earnings persistence, computed as the estimated coefficient on the lagged seasonally adjusted EPS (*UEPS*) in the following quarterly time-series regression, estimated for each firm over the previous 16 quarters (requiring a minimum of four quarters for the estimation; firm subscript *i* dropped for brevity): $UEPS_t = \beta_0 + \beta_1 UEPS_{t-1}$.	Nikkei Quick
EPS VOL	Earnings volatility, computed as the standard deviation of the EPS over the previous 16 quarters (requiring a minimum of four quarters for the estimation).	Nikkei Quick

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