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The impact of Bank of Japan's exchange-traded fund purchases☆

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ABSTRACT

The Bank of Japan (BOJ) enhanced its large-scale asset purchases in October 2010 by purchasing equity exchange-traded funds (ETFs). This study is the first to demonstrate that the BOJ provides downside protection for stock prices through the countercyclical purchase of ETFs. The BOJ responds to a large negative stock return during the overnight and morning periods, and submits purchase orders during lunchtime. Using the BOJ's March 2020 announcement of doubling the annual purchase amount during the COVID-19 pandemic, this study also finds that the announcement effect is small and temporary. In contrast, the flow effect of the actual purchases is significant and increases. The BOJ's countercyclical ETF purchase prevents equity risk premia from rising during an economic downturn.

1. Introduction

The Bank of Japan (BOJ) started purchasing equity exchange-traded funds (ETFs) and real estate investment trust (REIT) shares in October 2010 as part of its Large-Scale Asset Purchase (LSAP) program to augment its zero-interest-rate policy starting in 1999 and bond-LSAP starting in 2001, that substantially preceded other central banks' programs (Krishnamurthy and Vissing-Jorgensen, 2013). The BOJ enhanced the equity purchase program under the quantitative and qualitative monetary easing (QQE) regime and now holds equity ETFs corresponding to 5 % of the total market capitalization on the Tokyo Stock Exchange, in addition to 3 % of all REIT shares (Fig. 1). Despite the deviation from the standard monetary policy in which asset prices do not play a central role (Bernanke and Gertler, 2001), the BOJ's equity purchase programs aim to decrease risk premia for various financial assets by attracting more funds into the financial markets and stabilizing the economy (Shirakawa, 2010).

Shortly after the outbreak of the coronavirus disease (COVID-19), credit and stock markets experienced a significant negative shock (Delis et al., 2021; Liu et al., 2021). The BOJ unveiled an emergency plan at the policy meeting on March 16, 2020, to mitigate the adverse economic condition. It decided to double its annual ETF purchasing target to JPY 12 trillion (approximately 109 billion USD) to expand its monetary stimulus. After this meeting, the BOJ increased the size of each operation from 70 billion yen (0.6 billion USD) worth of ETFs to 200 billion yen (1.8 billion USD) and purchased more than one trillion yen of ETFs in March and April. Stock market data during the COVID-19 pandemic allow us to analyze the effectiveness of the BOJ's unconventional ETF purchases in response to an unanticipated adverse shock to asset prices and economic activities.

Our study is the first to provide evidence that the BOJ's program mitigates an increase in risk premia after an unanticipated adverse shock to asset prices—analogous to the concept of "Fed Put"—instead of actively raising stock prices. Our objective is to document the detailed pattern of the BOJ's ETF purchases and assess whether it has the intended effect on stock prices. We contribute to future monetary policy discussions by analyzing the BOJ's unique experimental program, especially during an unforeseen crisis, such as the COVID-19 pandemic. Overall, we find that the BOJ's equity ETF purchase program provides downside protection to equity investors through countercyclical interventions. Specifically, the BOJ purchases ETFs on days when the cumulative TOPIX returns during the overnight and morning periods are significantly negative. On the day of the BOJ's intervention, ETF trade volume increased only at the opening of the afternoon market,

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suggesting that the BOJ submits purchase orders during lunchtime. The effect of the BOJ's purchases on lunchtime returns is positive and steadily increases during the sample period. Our study demonstrates that the BOJ's purchases have an immediate flow effect on stock prices when counterfactual returns are negative without the BOJ's intervention, a result not found by Barbon and Gianinazzi (2019) or Charoenwong et al. (2021). Overall, the BOJ's downside protection in the stock market prevents the equity cost of capital from increasing, and potentially improves risk-sharing among agents with limited participation in segmented markets (Peng and Zervou, 2022).

Furthermore, unlike Barbon and Gianinazzi (2019), who studied the initial phase of the ETF program, we found only a minor and short-term effect of an announcement on the expansion of the ETF purchase program during the COVID-19 pandemic. Instead, the BOJ's actual purchase of ETFs had a significant impact on stock prices during the COVID-19 pandemic. Thus, the main channel through which the BOJ's ETF purchase program affects stock prices has changed from a portfolio-rebalancing channel to a scarcity channel. This program shares a common feature with the BOJ's other unconventional policy measures, such as yield curve control, which achieves low long-term bond yields by providing downside protection to bond prices through an endogenous intervention rule (Hattori and Yoshida (forthcoming). Although it is beyond the scope of our study to identify a long-term causal relationship between the ETF program and equity cost of capital, the commitment to provide downside protection may be an effective tool during crises for a central bank to reduce investors' concerns (e.g., Galariotis et al., 2018; Lutz, 2015).

Policy measures that directly intervene in equity markets are rare. Without direct intervention, monetary policy affects a wide range of capital markets, such as corporate bond markets (Guidolin et al., 2017; Nozawa and Qiu, 2021, forthcoming), bank lending (Kapoor and Peia, 2021), bond collaterals (Avouyi-Dovi and Idier, 2012), foreign bond markets (Neely, 2015), foreign exchange (Claus et al., 2018; Ferrari et al., 2021), gold (Claus et al., 2018), and equities and REITs (Claus et al., 2018; Jansen and Zervou, 2017; Kholodilin et al., 2009; Henseler and Rapp, 2018). Several studies analyze the BOJ's equity purchases and find price effects stemming from the BOJ's equity demand (Barbon and Gianinazzi, 2019; Charoenwong et al., 2021). These studies use pre-pandemic data and find that the BOJ's equity purchases significantly affect share prices. However, they do not consider whether counterfactual returns without the BOJ's purchases are positive or negative.[1] In contrast, our study clearly demonstrates that returns would have been significantly negative without the BOJ's purchasing.[2]

Our study makes three contributions to the literature. First, we document the BOJ's countercyclical purchase behavior using intraday stock-price data. The BOJ purchases ETFs after observing large negative returns on the Tokyo Stock Exchange during the overnight and morning periods, and prevents further price declines during lunchtime and afternoon periods. In other words, we demonstrate that a counterfactual return is negative without the BOJ's endogenous intervention. Fig. 2 visually demonstrates that the BOJ's purchases are more intense when the TOPIX price decreases. We formally test this observation by estimating linear probability models and a Cox hazard model for the BOJ's purchase decisions. The probability of ETF purchases is 99 % when the overnight-to-morning return is below the first decile, but approximately 0 % when it is above the median. The BOJ continues operations while returns are negative and stops when returns become positive.

In the literature on LSAPs (e.g., D'Amico et al., 2012; Krishnamurthy and Vissing-Jorgensen, 2011, 2013), LSAPs take effect (1) through future short-term rate policies (the expectations/signaling channel), (2) by reducing bonds available to private investors (the scarcity channel), (3) by reducing aggregate exposure to duration risks (the duration-risk channel), (4) by reducing aggregate exposure to prepayment risks (the prepayment-risk channel), and (5) by reducing the under-diversification premium (the capital constraint channel). These channels do not require the central bank to time the market. Thus, major central banks make

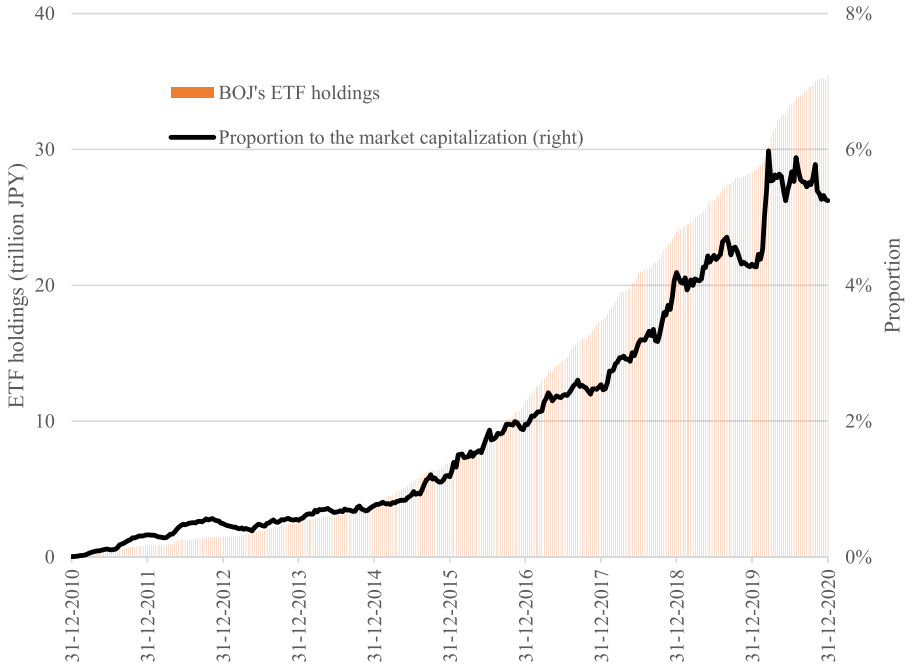

Fig. 1. The BOJ's ETF holdings. This figure depicts the amount of the Bank of Japan's exchange-traded fund (ETF) holdings (bold line) and the ratio of the BOJ's holdings to the market capitalization of the Tokyo Stock Exchange (thin bars).

[1] Harada and Okimoto (2021) conducts difference in differences since the BOJ tends to purchase ETF under negative return of stock market but they do not explicit investigate the ETF purchase behavior by the BOJ.

[2] Hattori and Yoshida (2022) also demonstrate negative counterfactual returns related to the BOJ's purchase of real estate investment trusts.

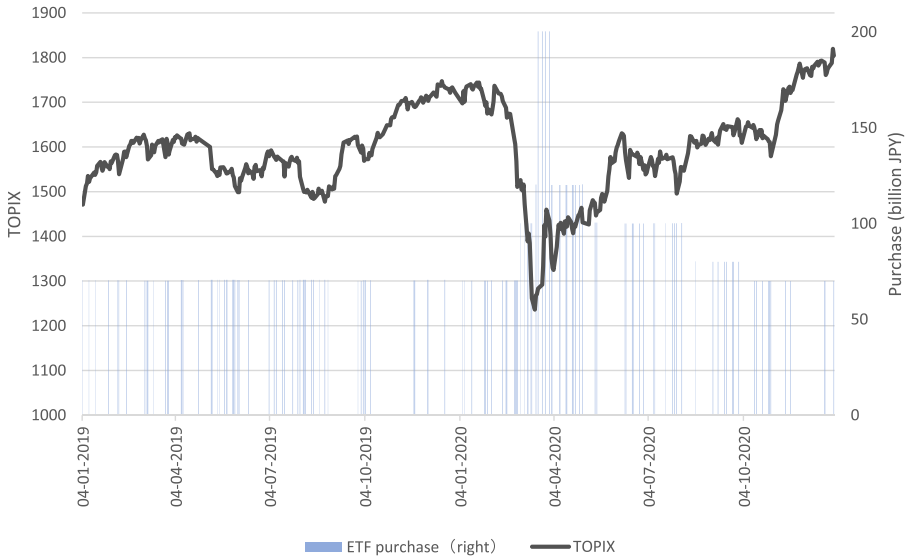

Fig. 2. TOPIX and the BOJ's ETF purchase. This figure depicts TOPIX (bold line) and the amount of the Bank of Japan's purchase of exchange-traded funds (ETFs) (thin bars) for 2019 and 2020.

advance announcements regarding their bond purchase schedules.[3] In sharp contrast, the BOJ's ETF purchases are contingent on daily stock returns. The BOJ's countercyclical purchase behavior is consistent with its objective of decreasing equity risk premia because the BOJ intervenes in the market precisely when risk premia increase. Thus, our study extends the literature on LSAP channels by documenting how the BOJ directly impacts equity risk premia when its interest-rate policy is ineffective.

Second, we demonstrate that the specific channel through which the BOJ's operations affect stock prices changes over time. In response to the severe effects of the COVID-19 pandemic on stock prices in Japan (Gormsen and Koijen, 2020; and Narayan et al., 2020), the BOJ announced to enhance its ETF program in March 2020. The BOJ created a cross-sectional variation in stock demand (or, equivalently, variation in shares available for private investors) when it purchased both Nikkei-225 ETFs and TOPIX ETFs because Nikkei 225 is a subset of TOPIX. Using Barbon and Gianinazzi (2019) measure of the BOJ's extra demand for each stock, we estimate both the announcement effect (through the portfolio-rebalancing channel) and the flow effect before and after this announcement (through the scarcity channel). Our finding that the BOJ submits its purchase orders before the opening of the afternoon market allows us to identify the flow effect of the BOJ's purchases on stock prices using intraday data. By using the same measure consistently for both effects, we contrast announcement and flow effects. The immediate announcement effect through the portfolio rebalancing channel is small and temporary; the price effect reverts to zero within ten days. In addition, investors may have anticipated this announcement to some extent because a positive effect on the price was observed three days before the announcement. However, the flow effect of ETF purchases is large and statistically significant. This result is in stark contrast to the results of Barbon and Gianinazzi (2019), who found a significant announcement effect and a minor flow effect in 2014 and 2016.

Third, we find that the flow effect of the BOJ's purchases increased during the COVID-19 pandemic. It is an empirical question whether the effect of monetary policy is amplified during a crisis (D'Amico and King, 2013). The effect of ETF purchases on lunchtime returns significantly increased during the COVID-19 pandemic, and the positive return drift in the afternoon market decreased. Additionally, stock market volatility decreased consistently with repeated countercyclical interventions. Although causality is unclear for a long period due to other factors, Nikkei 225's outperformance over TOPIX during the COVID-19 pandemic does not contradict the BOJ's larger allocation of funds to Nikkei 225 stocks.

The remainder of this paper is organized as follows. Section 2 outlines the BOJ's ETF purchases. Section 3 discusses the BOJ's ETF purchase behavior. Section 4 presents the empirical results for ETF purchases on stock returns during the COVID-19 pandemic. Finally, Section 5 concludes the paper.

2. The BOJ's ETF purchase program

The BOJ began buying ETFs in 2010. Central banks have rarely purchased equity, with only a few exceptions. The BOJ bought individual stocks held by banks from November 2002 to September 2004, and from February 2009 to April 2010. The Hong Kong government purchased shares of the 33 stocks that constituted the Hang Seng Index during the Asian financial crisis in August 1998 (Su et al., 2002).

To purchase ETFs, the BOJ established an asset purchase program to buy ETFs when Masaaki Shirakawa was its governor, starting from December 15, 2010. The BOJ first set an upper limit on purchase (0.45 trillion yen) but increased the limit several times while Governor Shirakawa managed the bank. In March 2013, Haruhiko Kurokawa became the BOJ governor. QQE was implemented in April 2013. For "qualitative" easing, the BOJ started purchasing ETFs to double the amount of ETF holdings in two years and increase the balance of ETF holdings by 1 trillion yen per year. Under QQE, the purchase limit has been raised several times to strengthen this policy (Table 1). For example, the annual purchase amount subsequently increased to approximately 3 trillion yen in October 2014 and to approximately 6 trillion yen in July 2016. The BOJ's policy is characterized by the fact that it sets an upper limit on the amount of money it will buy. This policy is interpreted as an open-ended policy under which the BOJ does not specify its end.

After these increases, the annual purchase limit increased to 6 trillion yen in July 2016. At the end of 2019, the BOJ's ETF holdings corresponded to approximately 5 % of the total market capitalization on the Tokyo Stock Exchange (Fig. 1). The BOJ's share of the equity ETF market increased to approximately 70 % by late March 2019. In March 2020, the BOJ temporarily increased its limit to 12 trillion yen per year to

[3] Although the Federal Reserve announces its bond-purchase schedule, there still are small "flow effects" in purchased sectors on purchased days, possibly owing to liquidity constraints (D'Amico and King, 2013). Nevertheless, the Federal Reserve does not time the market in its LSAP.

Table 1
The timeline of the ETF purchase by the BOJ.

October 2010	Established Asset Purchase Program for asset purchases. The maximum outstanding amount for ETF to be purchased (0.45 trillion yen)
March 2011	Increased the maximum amount of the Asset Purchase Program by about 0.45 trillion to about 0.9 trillion yen in total
August 2011	Increased the maximum of the Asset Purchase Program by about 0.5 trillion to about 1.4 trillion yen in total
April 2012	Increased the maximum of the Asset Purchase Program by about 0.2 trillion to about 1.6 trillion yen in total
October 2012	Increased the maximum outstanding amount of ETF by 0.5 trillion yen to a balance of 2.1 trillion yen
April 2013	As a "Qualitative" policy, the BOJ started purchasing ETF so that their amounts outstanding will increase at annual paces of about 1 trillion yen.
October 2014	Increase the purchase amount to three times (Purchased ETF so that their amounts outstanding will increase at annual paces of about 3 trillion yen per year)
December 2015	Establish a new program for purchases of exchange-traded funds (ETFs) to support firms' investment in physical and human capital
July 2016	Purchase to double the balance of holdings (at a pace equivalent to about 6 trillion yen per year).
July 2018	With a view to lowering risk premia of asset prices in an appropriate manner, the Bank may increase or decrease the amount of purchases depending on market conditions.
March 2020	Purchase ETFs for the time being so that their amounts outstanding will increase at annual paces with the upper limit of about 12 trillion yen.

Source: BOJ

mitigate the negative economic impact of the COVID-19 pandemic.

The BOJ initially purchased only ETFs tracking TOPIX and Nikkei 225, but included ETFs tracking JPX-Nikkei 400 in December 2014. In December 2015, the BOJ launched a new program to purchase 1.2 billion yen of ETFs daily that tracked companies that were proactively making investments in physical and human capital. The BOJ announces an annual budget each year and reports daily purchase amounts.

2.1. Purchasing rules

Under QQE, the BOJ does not purchase individual or specific equities, only ETFs. One reason for this is to avoid the direct consequences of voting rights. Voting rights are exercised only by investment trust management companies that have accepted stewardship codes. As an ETF investor, the BOJ gives up voting rights.

When purchasing ETFs, the BOJ sets up a trust agreement with a trust bank, and the trust bank purchases ETFs from the market on its behalf. Specifically, the BOJ places an order for ETFs with the trust bank and the trust bank places an order for ETFs with investment banks. Since the ETFs purchased by the BOJ are managed as trust assets by the trust bank, the BOJ's name does not appear in the shareholder registries of individual companies.

The BOJ has not disclosed its purchase rules and does not provide an advance notice about a specific date and amount, unlike regular Japanese government bond (JGB) auctions (Hattori, 2020; Hattori and Takahashi, 2022). The purchase amount is released later through its website. Table 2 shows how the BOJ changed ETF purchase rules. The BOJ allocated funds to ETFs based on market capitalization. Thus, it allocated more funds to Nikkei 225 ETFs until October 2016 because of their popularity. The BOJ increased the allocation to ETFs by tracking TOPIX over time because the number of TOPIX ETFs increased. In May 2020, the BOJ changed its fund allocation rule by excluding BOJ holdings from market capitalization calculations to correct the disproportionate shares of BOJ holdings.

2.2. ETF purchases during the COVID-19 pandemic

During the COVID-19 pandemic, the BOJ expanded its monetary stimulus to mitigate the global recession, in line with other major central banks. At the monetary policy meeting on March 16, 2020, the BOJ decided to double its annual purchasing target to JPY 12 trillion. It also launched a new program to facilitate corporate financing for companies hit by the pandemic by expanding the purchase of commercial paper. After this meeting, each ETF purchase operation was increased to JPY 200 billion.

Table 2
The weight of the BOJ's ETF purchase.

Period	Rule	Weight (%)		
		TOPIX	Nikkei225	JPX 400
12/15/2010–12/1/2014	Purchasing ETFs tracking TOPIX and Nikkei 225 based on the market capitalization of each ETF	46.8	53.2	-
12/2/2014–10/2/2016	Purchasing ETFs tracking TOPIX, Nikkei 225, and JPX 400 based on the market capitalization of each ETF	43.8	53	3.3
10/3/2016–8/5/2018	Purchasing 2.7 trillion ETFs tracking TOPIX and 3 trillion ETFs tracking TOPIX, Nikkei 225, and JPX 400 based on the market capitalization of each ETF	57.2	37.5	5.3
8/6/2018–4/30/2020	Purchasing 4.2 trillion ETFs traking TOPIX and 1.5 trillion ETFs tracking TOPIX, Nikkei 225, and JPX 400 based on the market capitalization of each ETF	66.5	28	5.5
5/1/2020–	Purchasing ETFs tracking TOPIX using 75 % of the fund and ETFs tracking TOPIX, Nikkei 225, and JPX 400 using 25 % of the fund, based on the non-BOJ portion of the ETF market capitalization	68	26.3	5.6

Note: This table shows the Bank of Japan's rule of purchasing exchange-traded funds (ETFs) and the allocation weights estimated by Samigawa and Nakano (2020).

Fig. 2 shows the BOJ's purchases and TOPIX during the COVID pandemic. The BOJ purchased 200 billion yen in ETFs in March in response to a sharp drop in TOPIX. In March and April 2020, it purchased more than one trillion yen in ETFs. On March 16, 2020, it spent 66.5 % on TOPIX, 28 % on Nikkei 225 %, and 5.5 % on JPX 400. Stock prices have been on an upward trend since April, and the BOJ has reduced its ETF purchases from 120 billion yen to 70 billion yen. It also reduced the frequency of its purchases from 11 days in March 2020 to only two days in November and three days in December.

The BOJ also modified its purchasing rules during this period. From May 2020, it switched its ETF purchases to a "balance in circulation" basis. In the past, the BOJ purchased ETFs in proportion to the market capitalization of each stock; however, it switched to purchasing ETFs based on the number of ETFs in circulation, excluding those held by the BOJ.

2.3. Features of Japanese stock exchanges

A unique feature of Japan's stock market is its lunch break. The Tokyo Stock Exchange is closed between 11:30 and 12:30, whereas neither the New York Stock Exchange nor the London Stock Exchange has a lunch break. If the BOJ submits a buy order during lunchtime, this is reflected in the opening price of the afternoon market. Thus, we treated lunchtime as a separate subperiod in our study.

The Tokyo Stock Exchange consists of five stock markets: the First Section, the Second Section, Mothers, JASDAQ, and the TOKYO PRO Market. The First and Second sections are the main stock markets that

list large- and medium-sized companies, whereas the Mothers, JASDAQ, and TOKYO PRO markets typically list startup companies that do not meet the stringent standards for the First and Second sections. The BOJ purchases ETFs listed in the First Section.

The ETFs that the BOJ purchases on the Tokyo Stock Exchange mainly track TOPIX and Nikkei 225, both of which make up the First Section stocks. Although the First Section is one of the world's largest and most liquid markets, the BOJ's purchase amount is sufficiently large to affect the stock market. The average daily trading volume of the First Section was 2809.1 billion yen (approximately 26.49 billion USD) between April 2020 and March 2021, whereas the average daily trading value of ETFs was 280.9 billion yen (2.65 USD) during the same period. As shown in Fig. 2, the amount of each purchase by the BOJ was between JPY 70 and 100 billion during that period. Thus, the share of the BOJ's purchases is approximately 25–36 % of the ETF market and 2–4 % of the First Section.

3. ETF purchase behavior

3.1. TOPIX intraday returns

A challenge in analyzing the BOJ's ETF purchase behavior is that it does not reveal exactly at what time it purchased ETFs. Thus, we first analyze the correlations between ETF purchases and intraday stock returns to infer the timing of the BOJ's purchases. We obtained the date and amount of daily ETF purchases from the BOJ's website. We use TOPIX to compute stock index returns from December 2010 to December 2020 by dividing each trading day into four subperiods: the overnight period (from 15:00 on the previous trading day to 09:00 on the next trading day), the morning market (from 09:00–11:30), lunchtime (from 11:30–12:30), and the afternoon market (from 12:30–15:00).

We first estimate a linear probability model of the BOJ's ETF purchase decisions for each subperiod $i = \{overnight(N), morning(A), lunchtime(L), afternoon(P)\}$:

$$\mathbb{I}_t = \alpha_1^i + \sum_{d=\{1,\ldots,5,7,\ldots,10\}} \beta_1^{i,d} \mathbb{r}_t^{i,d} + \varepsilon_{1,t}^i, \tag{1}$$

where $\mathbb{I}_t$ denotes a dummy variable for an ETF purchase on date t, and $\mathbb{r}_t^{i,d}$ denotes a dummy variable for decile-group d of a subperiod-i return on date t. We use the sixth-decile group as the reference group. We also construct decile dummies $\mathbb{r}_t^{i,d}$ for a combined subperiod of *overnight* and *morning*. Tables A1 and A2 show the descriptive statistics for TOPIX returns and the ETF purchase dummy variable, respectively. The BOJ purchased ETFs 668 times during the sample period of 2458 business days (approximately 30 %).

Coefficient $\beta_1^{i,d}$ represents the incremental probability of the BOJ's purchase when a subperiod return is in the dth-decile group instead of the sixth-decile group. This coefficient does not necessarily suggest a causal relationship, because the BOJ can submit an order anytime between 09:00 and 15:00. However, the regression coefficient $\beta_1^{N,d}$surely represents the causal effect of overnight returns on the BOJ's purchase probability, regardless of purchase timing. Thus, a larger coefficient $\beta_1^{N,d}$ suggests that the BOJ is more likely to purchase ETFs in response to overnight returns in the dth-decile group. In contrast, the coefficient of morning returns may or may not represent a causal relationship. If, for example, the BOJ submits a purchase order after a morning market closes (during lunchtime), the coefficient of morning returns will also represent causal effects. In this case, the estimated coefficients of the morning return decile groups are similar to those of the overnight return decile groups. However, the coefficients of lunchtime and afternoon returns represent reverse causality in this case if these returns are determined after the BOJ submits orders.

Table 3 and Fig. 3 present the predicted purchase probabilities based on the linear probability model specified in Eq. (1).[4] For overnight and morning returns (columns (1) and (2) of Table 3 and panels A and B of Fig. 3), the purchase probability monotonically decreases in the return decile groups. The purchase probabilities are 85.0 %, 58.1 %, and 48.4 % for the first, second, and third decile groups for overnight returns, respectively. Similarly, for morning returns, the purchase probabilities are 73.2 %, 46.3 %, and 32.5 % for the first, second, and third decile groups, respectively.[5] In contrast, the BOJ is unlikely to purchase ETFs when overnight and morning returns are high. For example, the estimated probability for the 10th decile group is 0.8 % for overnight returns and 3.7 % for morning returns. Table A3 presents the results of the formal pairwise F-tests of equal probabilities. For most combinations of overnight and morning returns (panels A and B), probabilities are significantly different from each other. In particular, the high purchase probability for the first decile group is significantly different from that for the second or higher decile groups.

As the descriptive statistics in Table A1 show, returns are negative in the low-decile groups below the fifth group. For example, the average overnight and morning returns in the first decile group are −2.27% and −1.37%, respectively. In Appendix B, we estimate the difference in the effect of returns on purchase probabilities between the negative and positive return ranges. In the positive range for overnight returns, a one-percentage-point lower return is associated with a 15.7 % higher purchase probability. However, in the negative range, a one percentage point lower return is associated with a 50.6 % higher purchase probability. Thus, the BOJ's high probability of purchase is associated with negative overnight and morning TOPIX returns.

However, for lunchtime and afternoon returns (columns (3) and (4) of Table 3 and panels C and D of Fig. 3), purchase probabilities generally increase in return deciles. The estimated probability for the 10th decile group is 39.2 % for lunchtime returns and 37.1 % for afternoon returns. The average return in the 10th decile is significantly positive for intraday returns (0.33 % for lunchtime returns and 0.92 % for afternoon returns). This positive association between purchase probabilities and positive returns is likely to indicate reverse causality; the BOJ submits a purchase order after observing a morning return and increases stock prices at the beginning of or during the afternoon market. We further demonstrate that the BOJ is likely to submit purchase orders during lunchtime in later sections.

3.2. Changes during the COVID-19 pandemic

In March and April 2020, the BOJ intensively purchased ETFs when TOPIX showed a significant downward trend at the outset of the COVID-19 pandemic (Fig. 2). The BOJ paused purchases as TOPIX recovered in May but started buying ETFs again in June when TOPIX became stagnant. From November, the TOPIX recovery was significant, and the BOJ did not provide a large amount.

To see the consistency of the BOJ's purchase behavior before and during COVID-19, we estimate the following simple linear probability model:

$$\mathbb{I}_t = \alpha_3 + \sum_i \sum_j \beta_3^{ij} r_t^i \mathbb{P}^j + \varepsilon_{3,t}, \tag{2}$$

where r_t^i denotes the TOPIX returns during subperiod i: overnight period (N), morning market (A), lunchtime (L), and afternoon market (P). $\mathbb{P}^j$

[4] In Appendix C, we also present the result of a probit model, which is consistent with the result shown in Fig. 3.

[5] Following Horrace and Oaxaca (2006), we confirm the prediction falls between 0 and 1. Fig. A1 depicts the predicted probabilities.

Table 3
Predicted Probability of ETF Purchase.

Decile Groups	Overnight (1)	Morning (2)	Lunchtime (3)	Afternoon (4)	Overnight and Morning (5)	Daily (6)
1st	0.850	0.732	0.321	0.313	0.992	0.821
	(0.025)	(0.029)	(0.033)	(0.032)	(0.006)	(0.025)
2nd	0.581	0.463	0.240	0.256	0.715	0.589
	(0.038)	(0.035)	(0.029)	(0.031)	(0.049)	(0.038)
3rd	0.484	0.325	0.236	0.183	0.561	0.402
	(0.037)	(0.033)	(0.03)	(0.023)	(0.046)	(0.040)
4th	0.253	0.244	0.268	0.248	0.294	0.306
	(0.028)	(0.026)	(0.028)	(0.032)	(0.042)	(0.034)
5th	0.183	0.257	0.216	0.176	0.134	0.224
	(0.026)	(0.029)	(0.027)	(0.028)	(0.027)	(0.029)
6th	0.171	0.244	0.199	0.252	0.004	0.183
	(0.027)	(0.031)	(0.027)	(0.028)	(0.004)	(0.027)
7th	0.098	0.150	0.211	0.317	0.004	0.086
	(0.02)	-0.025	(0.026)	(0.03)	(0.004)	(0.018)
8th	0.057	0.126	0.293	0.293	0.000	0.069
	(0.016)	(0.023)	(0.03)	(0.032)	(0.000)	(0.016)
9th	0.033	0.138	0.341	0.309	0.004	0.020
	(0.011)	(0.022)	(0.034)	(0.034)	(0.004)	(0.012)
10th	0.008	0.037	0.392	0.371	0.004	0.012
	(0.006)	(0.012)	(0.034)	(0.034)	(0.004)	(0.007)
Observations	2,457	2,458	2,458	2,458	2,457	2,457
F-statistic	141.93	70.47	3.79	5.06	5741.72	124.68

Note: This table shows the predicted probability of the Bank of Japan's exchange-traded fund purchase corresponding to 10 decile groups of subperiod TOPIX returns (overnight, morning, lunchtime, afternoon, and overnight and morning combined). The first decile represents the lowest (negative) return, whereas the tenth decile represents the highest return. The linear probability model is specified in Eq. (1). The sample period is December 15, 2010 to December 31, 2020. Newey-West standard errors are shown in parentheses.

denotes a dummy variable for the four BOJ regimes: the initial phase of the ETF program (December 15, 2010–March 30, 2013), *QQE* before yield curve control (April 1, 2013–October 2, 2016), yield curve control (*YCC*, October 3, 2016–February 28, 2020), and *COVID-19* (March 1, 2020–December 31, 2020).

Table 4 shows the estimation results. The estimated coefficients of overnight and morning returns are consistently negative throughout the four monetary policy regimes. Furthermore, based on the interaction terms of *QQE*, *YCC*, and *COVID-19*, the negative relationship between overnight returns and ETF purchases became stronger. The coefficients of the lunchtime and afternoon returns remain positive. In particular, the coefficient of lunchtime returns increases during *COVID-19*.

3.3. Starting and stopping behavior

An issue with a linear probability model is that it does not distinguish the first purchase from subsequent daily purchases in a consecutive purchase operation. To analyze the BOJ's decision conditional on a sequence of past decisions, we estimate the Cox (1972) hazard model by allowing for a time-dependent covariate vector $\boldsymbol{X}(t)$ (e.g., Dirick et al., 2019):

$$\lambda(t|\boldsymbol{X}(t)) = \lambda_0(t)\exp\left(\sum_i \beta_2^i r_t^i + \gamma_2^i r_{t-1}^i\right), \tag{3}$$

where $\lambda(t|\boldsymbol{X})$ denotes the hazard function that represents an instantaneous rate of failure conditional on survival up to trading day t, $\lambda_0(t)$ denotes an unspecified baseline hazard function, and r_t^i denotes a subperiod-i TOPIX return on trading day t. We analyze both starting and stopping decisions by defining failure events based on the start and discontinuation of consecutive purchases, respectively. A negative coefficient β_2^i indicates that a lower return is associated with a larger conditional probability of starting or stopping decisions depending on the definition of failure events.

Table 5 presents the estimated coefficients for the Cox conditional hazard model. The reported coefficients represent the natural logarithm of the hazard ratio for a one-percentage-point higher return. In columns (1) and (2), the coefficients of the overnight and morning returns are negative and statistically significant. Thus, after a period of inaction, the BOJ is more likely to start purchasing ETFs when negative overnight and morning returns are observed. The coefficients of lunchtime returns are positive and significant, implying that the BOJ's first purchase impacts stock prices after the morning market. For stopping decisions (columns (3) and (4)), the coefficients of overnight and morning returns are positive and significant. Thus, after consecutive daily purchases, the BOJ is more likely to stop purchasing ETFs when the overnight and morning returns are positive. The non-significant coefficients of lunchtime and afternoon returns in the stopping case confirm our inference that the BOJ's decision is unaffected by returns after the morning market.

Table A4 additionally demonstrates the BOJ's starting and stopping decisions by summarizing the average TOPIX returns before and during its consecutive purchase operations. The first row shows 406 single-day purchase operations. The mean TOPIX daily return is −0.0110% on the previous day of single-day operations but becomes positive (0.0059%) when the BOJ stops purchasing. Similarly, the second through fourth rows show that the BOJ continues purchase operations while TOPIX returns are consecutively negative but stops purchases when returns become positive.

3.4. Combined overnight and morning returns

Given that the BOJ's purchases are significantly associated with both overnight and morning returns, we further analyze combined (cumulative) returns during the overnight and morning periods (the return from 15:00 on the previous day to 11:30). In particular, we pay particular attention to cases when an overnight return and the subsequent morning return have the opposite signs. For example, what will be the BOJ's action when a negative overnight return is followed by a positive morning return, but the cumulative return is negative?

The results are presented in Table 6. We estimate the mean purchase frequency α^i from the estimation equation $\mathbb{I}_t = \alpha^i + \varepsilon_t^i$ for subsample i with different combinations of overnight and morning returns. Columns (1) and (2) show the mean purchase frequency when the cumulative return during the overnight and morning periods is positive. Regardless of return combinations, the purchase frequency is less than 1 %. In other words, the BOJ does not purchase ETFs as long as the overnight-to-

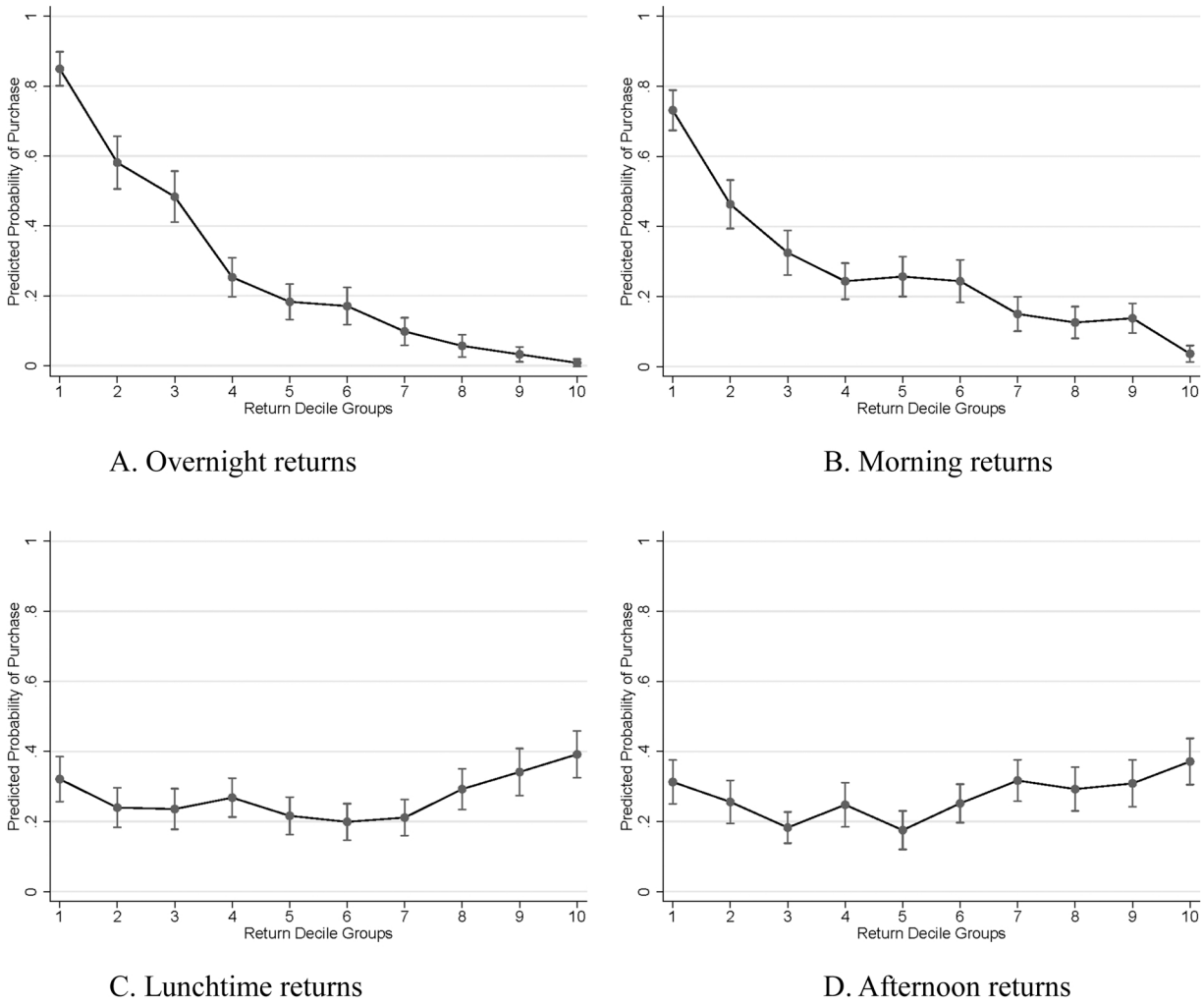

Fig. 3. Purchase probability by return decile groups. This figure depicts the predicted probability of the Bank of Japan's exchange-traded fund purchase corresponding to 10 decile groups of subperiod TOPIX returns (overnight, morning, lunchtime, and afternoon returns). The first decile represents the lowest (negative) return, whereas the tenth decile represents the highest return. The linear probability model is specified in Eq. (1). The sample period is December 15, 2010, to December 31, 2020. The 95 % confidence intervals are based on Newey-West standard errors.

morning cumulative return is positive, even if either an overnight return or a morning return is negative. In contrast, when an overnight-to-morning cumulative return is negative (columns (3) and (4)), the BOJ's purchase frequency is significantly different from zero, even if either an overnight return or a morning return is positive. The average frequencies were 0.373 and 0.465 for columns (3) and (4), respectively.

Table 3 (column (5)) and Fig. 4 show the predicted purchase probabilities for the return decile groups based on Eq. (1) when the subperiod is defined by both overnight and morning periods combined. The results demonstrate a clear contingency of ETF purchases on cumulative overnight and morning returns. The probability of purchase is 0.99 when the cumulative return is in the first decile. The probability monotonically and almost linearly decreases to 0.00 for the sixth return decile group. The purchase probability is constantly zero for the sixth to tenth deciles. This result strongly suggests that the BOJ's ETF purchase decision is based on the cumulative return during the overnight and morning periods.

3.5. Trading volume

If the BOJ observes a cumulative return for the overnight and morning periods and submits orders during lunchtime, the accumulated order during lunchtime will be larger on the day of the BOJ's operation. The accumulated orders will result in larger trading volume at the opening of the afternoon session. Bloomberg provides data on ETF trading volume at the opening and closing of morning and afternoon sessions. We regress the trading volume at each of these intraday points on the ETF purchase dummy to see if the trading volume is significantly larger only at the opening of the afternoon session on the day of operation. The estimation equation is as follows:

$$Volume_t^i = \alpha_4 + \beta_4^i \mathbb{I}_t + \varepsilon_t^i, \tag{4}$$

where $Volume_t^i$ denotes the trading volume at intraday point i, $i = \{morning\ opening, morning\ close, afternoon\ opening, afternoon\ close\}$. $\mathbb{I}_t$ denotes a dummy variable for an ETF purchase on date t. To construct $Volume_t^i$, we sum the trading volume of all ETFs that track the TOPIX listed on the Tokyo Stock Exchange.

Table 7 shows the estimation results. The trading volume is significantly larger on the day of the BOJ's operation, only at the opening of the afternoon session. At the opening of the afternoon session, the trading volume is 16,806 larger on the day of the BOJ's purchase (column (3)). However, for the opening and closing of the morning session, the coefficient of the ETF purchase dummy is positive but statistically indistinguishable from zero (columns (1) and (2)). There was also no significant increase in the volume at the close of the afternoon market. Thus, this result provides additional evidence that the BOJ submits purchase orders during lunchtime after observing the cumulative

Table 4
ETF Purchase and subperiod returns.

Dependent Variables	Coefficient	Standard Errors
Overnight return	−0.211***	(0.021)
Morning return	−0.177***	(0.030)
Lunchtime return	0.051	(0.051)
Afternoon return	0.051*	(0.026)
QQE (pre-YCC)	0.216***	(0.020)
YCC (pre-COVID)	0.182***	(0.020)
COVID-19	0.155***	(0.033)
QQE (pre-YCC)×overnight return	−0.083***	(0.029)
YCC (pre-COVID)×overnight return	−0.181***	(0.031)
COVID-19 ×overnight return	−0.089**	(0.040)
QQE (pre-YCC)×morning return	−0.086**	(0.043)
YCC (pre-COVID)×morning return	−0.097**	(0.049)
COVID-19 ×morning return	0.080	(0.055)
QQE (pre-YCC)×lunchtime return	0.033	(0.072)
YCC (pre-COVID)×lunchtime return	0.191	(0.122)
COVID-19 ×lunchtime return	0.280**	(0.123)
QQE (pre-YCC)×afternoon return	−0.013	(0.031)
YCC (pre-COVID)×afternoon return	0.125**	(0.062)
COVID-19 ×afternoon return	−0.031	(0.034)
Observations	2,457	
Adjusted R-squared	0.475	

This table presents the estimation results of the linear probability model specified by Eq. (2). The four policy regimes are the omitted initial phase of the exchange-traded fund program (December 15, 2010–March 30, 2013), quantitative and qualitative monetary easing before yield curve control (April 1, 2013–October 2, 2016), yield curve control (October 3, 2016–February 28, 2020), and COVID-19 (March 1, 2020–December 31, 2020). Newey-West standard errors are shown in parentheses.

Table 5
The Cox conditional hazard model.

	Starting Decisions		Stopping Decisions	
TOPIX Returns	(1)	(2)	(3)	(4)
Overnight (%)	−1.074***	−1.076***	0.519***	0.538***
	(0.067)	(0.068)	(0.064)	(0.065)
Morning (%)	−0.630***	−0.637***	0.358***	0.432***
	(0.069)	(0.072)	(0.066)	(0.075)
Lunchtime (%)	0.831***	0.878***	−0.093	−0.118
	(0.251)	(0.256)	(0.210)	(0.215)
Afternoon (%)	−0.005	−0.005	−0.096	−0.062
	(0.086)	(0.088)	(0.071)	(0.074)
Lagged Overnight		−0.046		0.038
		(0.080)		(0.077)
Lagged Morning		−0.099		0.086
		(0.094)		(0.076)
Lagged Lunchtime		0.019		0.316*
		(0.212)		(0.182)
Lagged Afternoon		0.044		−0.024
		(0.089)		(0.065)
Observations	1,790	1,789	666	666

Note: This table shows the estimated coefficients for the Cox conditional hazard model (Eq. (3)) for the decision to start a purchase (columns (1) and (2)) and to stop purchasing (columns (3) and (4)). The reported coefficients represent the natural logarithm of the hazard ratio for a one-basis-point higher return. Standard errors are shown in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

returns for the overnight and morning periods.

3.6. Volatility

The question is whether the BOJ responds to increased volatility or return levels. According to the preceding analysis, the BOJ purchases ETFs only when the cumulative returns for the overnight and morning periods are significantly negative. In other words, a bank's purchase does not depend on upward price changes. In fact, there are only five out

Table 6
The average frequency of ETF purchase by cumulative return.

	(1)	(2)	(3)	(4)
Cumulative Return	Positive		Negative	
Overnight Return	Negative	Positive	Positive	Negative
Morning Return	Positive	Negative	Negative	Positive
ETF Purchase Frequency	0.0083	0.0074 *	0.3726 * **	0.4650 * **
	(0.0071)	(0.0043)	(0.0352)	(0.0318)
Observations	241	405	263	357

Note: This table shows the mean of the ETF purchase dummy variable for the subsamples with different combinations of overnight and morning TOPIX returns. Columns (1) and (2) show the results for subsamples with positive cumulative returns, which include a sample with negative overnight and positive morning returns (column (1)) and a sample with positive overnight and negative morning returns (column (2)). Similarly, columns (3) and (4) show the results for subsamples with negative cumulative returns, including a sample with positive overnight and negative morning returns (Column (3)) and a sample with negative overnight and positive morning returns (column (4)). Newey-West standard errors are shown in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

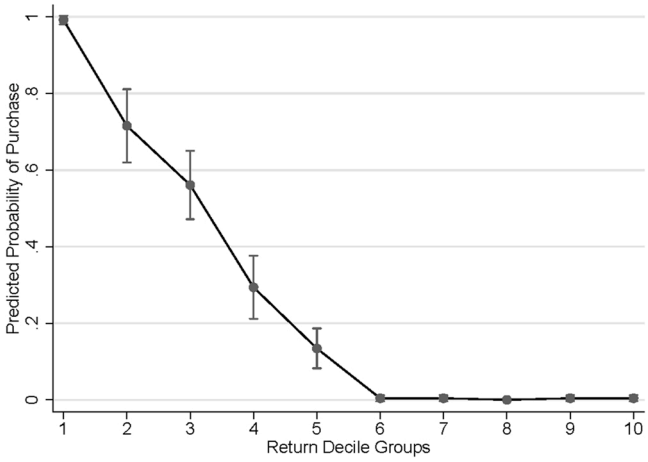

Fig. 4. Purchase probability by return decile groups. This figure depicts the predicted probability of the Bank of Japan's exchange-traded fund purchase corresponding to 10 decile groups of cumulative TOPIX returns during the overnight and morning periods. The first decile represents the lowest (negative) return, whereas the tenth decile represents the highest return. The linear probability model is specified in Eq. (1). The sample period is December 15, 2010 to December 31, 2020. The 95 % confidence intervals are based on Newey-West standard errors.

Table 7
Trading volume.

Dependent Variable: Trading Volume	Morning Session		Afternoon Session	
	Opening (1)	Close (2)	Opening (3)	Close (4)
ETF Purchase dummy	11,560	320	16,806**	2,838
	(16,711)	(995)	(7,880)	(5,754)
Cosntant	251,147	12,932	69,488	122,982
	(10,979)	(658)	(3,189)	(5,022)
Observations	2,459	2,459	2,459	2,459

Note: This table shows the estimation result of Eq. (4). We regress trade volume at four intraday points on a constant and an ETF purchase dummy. Four intraday points are the opening of morning session (column (1)), the close of morning session (Column (2)), the opening of afternoon session (column (3)), and the close of afternoon session (column (4)). For each intraday point, a regression is based on daily data from December 2010 to December 2020. Newey-West standard errors are shown in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

of 668 total purchases when the cumulative TOPIX returns are positive for the overnight and morning periods. Thus, the BOJ is likely to respond to return levels rather than volatility. We formally test this observation by estimating the following equation.

$$\mathbb{I}_t = \alpha_5 + \beta_5 \Delta IV_t^i + \gamma_5 \Delta IV_t^i \times Covid + \delta_5 r_t^i + \varepsilon_t^i, \quad (5)$$

where $\mathbb{I}_t$ is a dummy variable for the BOJ's ETF purchase on date t and ΔIV_t^i is the change in the Nikkei Stock Average Volatility Index for period $i = \{overnight, tradingday\}$. The overnight period is between 15:00 on the previous day and 09:00, and the trading-day period is between 09:00 and 15:00. We cannot use additional granular periods, as shown in Eq. (1), because the Tokyo Stock Exchange publishes IV data only for the beginning of the morning session and the end of the afternoon session. *Covid* denotes a dummy variable for the COVID-19 pandemic (March 1, 2020–December 30, 2020).

Table 8 shows the regression results. For both overnight (column (1)) and trading-day changes (column (2)), the coefficient of ΔIV_t^i is not statistically significant after controlling for the effect of TOPIX returns. The results remain unchanged during the COVID-19 pandemic. This result confirms our previous finding that the BOJ's ETF purchase decision is based on an asymmetric response to returns instead of volatility.

4. The effect of ETF program on stock returns

We estimate the effect of BOJ's ETF purchases on returns using the approach proposed by Barbon and Gianinazzi (2019). They extended Greenwood's (2005) theoretical framework to develop a model with multiple assets of finite supply and a representative agent with constant absolute risk aversion. The BOJ's asset purchases create an exogenous shock to the asset supply available to private investors (or, equivalently, a shock to total asset demand). They exploit the cross-sectional variation in a demand shock owing to the simultaneous purchase of different ETFs. Purchasing TOPIX ETFs creates asset demand for all stocks listed on the Tokyo Stock Exchange, based on market weights. In addition, the purchase of Nikkei 225 ETFs will create additional demand for the 225 stocks included in the index. Furthermore, because Nikkei 225 is not a current-value-weighted index, certain firms have disproportionately large weights in Nikkei 225. For example, *Fast Retailing* accounts for only 0.3 % of TOPIX and 11 % of Nikkei 225. Thus, the combination of different ETFs creates significant cross-sectional variation.

Barbon and Gianinazzi (2019) theoretically demonstrate that equity returns are linearly related to the BOJ's ETF purchase amount multiplied by the return variance-covariance matrix, both on the announcement day (an announcement effect through the portfolio rebalance channel) and the day of an actual intervention (a flow effect through the scarcity channel). Intuitively, a volatile stock should respond to the BOJ's intervention more than a stable stock. Following their model, we define the ETF purchase amount $u_i = Tw_{i,T} + Nw_{i,N}$ for stock i, where $w_{i,T}$ and $w_{i,N}$ are the weights of stock i in the TOPIX and Nikkei 225 indexes, respectively. T and N denote the BOJ's purchase amounts for TOPIX and Nikkei 225, respectively. Unlike Barbon and Gianinazzi (2019), who assume $T = N$, we use a 70 % allocation to the ETFs tracking TOPIX and a 30 % allocation to those tracking Nikkei 225 after the 2020 announcement, based on the weights calculated by Samigawa and Nakano (2020) (see Table 2). We further define $\pi \equiv \Sigma u$, where Σ is the variance-covariance matrix of asset returns.

Based on our analysis in Section 3, we use lunchtime returns to estimate the flow effect of the BOJ's ETF purchases. Specifically, we test two hypotheses.

Hypothesis 1. (Announcement effects): *Daily individual stock returns are positively related to π in the cross-section on the announcement day.*

Hypothesis 2. (Flow effects): *Lunchtime stock returns are positively related to π in the cross-section on the day of actual intervention.*

4.1. Announcement effects

We estimate the following equation by a cross-sectional regression at different horizons H:

$$r_i^H = \alpha_6 + \beta_6^H \pi_i + \gamma_6^H u_i + \delta_6^{H'} X_i + \varepsilon_{5,i}^H, \quad (6)$$

where r_i^H is the cumulative return of stock i over a horizon of H business days, $H = \{-10, -5, -3, -1, 1, 3, 5, 10, 30\}$ from the announcement on March 16, 2020. X_i denotes a vector of stock-level control variables composed of the natural logarithm of market capitalization, foreign exchange beta, market beta, illiquidity (Amihud measure), and industry-fixed effects.[6] Industry-fixed effects are particularly important in controlling for the heterogeneous effects of the COVID-19 pandemic on different industries.

Table 9 presents the estimation results for Eq. (6). Columns (5) through (9) show the post-announcement effects on the 1-, 3-, 5-, 10-, and 30-day returns, respectively. Our variable of interest, π_i, is positive and significant from 1 to 5 business days. Furthermore, there is a large additional effect of the covariance-unadjusted demand shock u on 1-day return (column (5)). Thus, we confirm the positive effects immediately after the announcement. However, unlike Barbon and Gianinazzi (2019), the announcement effect is short-term during the COVID-19 period. There is no significant effect on the 10-day and 30-day cumulative returns. Thus, the immediate positive effect is reversed within ten business days. The table also shows significantly positive coefficients for π_i up to three days prior to the announcement (columns (3) and (4)). This result suggests that investors anticipate the BOJ's purchases to some extent. As the severity of the COVID-19 pandemic became apparent in mid-February, stock prices plummeted by nearly 30 % by the time of the BOJ's announcement. In response to this global pandemic, major central banks had discussions prior to March 16 and announced coordinated action to enhance the provision of liquidity via the standing U.S. dollar liquidity swap line arrangements.[7] Thus, it is not surprising that investors speculated about the BOJ's expansion of ETF programs.

4.2. Flow effects

To estimate the flow effect of the BOJ's actual intervention, we use

Table 8
ETF purchase and volatility changes.

Dependent Variable: ETF purchase dummy	Overnight (1)	Trading Day (2)
ΔIV	−0.013	0.003
	(0.012)	(0.020)
$\Delta IV \times Covid$	0.004	0.014
	(0.016)	(0.026)
TOPIX return	−0.418***	−0.108***
	(0.029)	(0.031)
Constant	0.307***	0.300***
	(0.017)	(0.021)
Observations	840	840

Note: This table shows the estimation results of Eq. (5). Columns (1) and (2) show the effects of trade orders at the beginning and end of the morning market, respectively. Columns (3) and (4) show the effects of trade orders at the beginning and end of the afternoon market, respectively. Newey-West standard errors are shown in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

[6] We use a one-year sample to estimate the forex beta, the market beta, and the Amihud ratio. For industry fixed effects, we use Bloomberg's sector classification.

[7] See https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315c.htm.

Table 9
The announcement effect of BOJ's ETF program.

Horizon	(1) −10 days	(2) −5 days	(3) −3 days	(4) −1 day	(5) 1 day	(6) 3 days	(7) 5 days	(8) 10 days	(9) 30 days
π	0.048	0.025	0.046**	0.022*	0.131***	0.159***	0.108**	−0.073	0.071
	(0.031)	(0.025)	(0.018)	(0.012)	(0.017)	(0.035)	(0.052)	(0.051)	(0.067)
u	−2.689**	−3.770***	−3.489***	−1.790***	2.280***	0.312	−3.031	−1.003	2.550
	(1.092)	(1.111)	(0.850)	(0.543)	(0.443)	(1.385)	(2.433)	(2.103)	(2.067)
ln (Market Cap.)	0.657***	0.799***	0.750***	0.368***	−1.066***	−1.277***	−0.769**	−1.460***	−1.499***
	(0.151)	(0.126)	(0.091)	(0.061)	(0.074)	(0.207)	(0.324)	(0.379)	(0.434)
Foreign Exchange β	7.985***	7.675***	6.202***	6.585***	−2.326***	−0.367	0.219	−3.815***	−2.597*
	(0.966)	(0.859)	(0.842)	(0.361)	(0.369)	(0.812)	(1.082)	(1.199)	(1.516)
Market β	−22.789***	−18.679***	−17.293***	−9.938***	−10.204***	−15.453***	−14.142***	13.474***	2.350
	(2.893)	(2.389)	(1.801)	(1.106)	(1.524)	(3.256)	(4.871)	(4.725)	(5.966)
Amihud Measure	-0.008	-0.005	0.012	-0.027*	0.013	0.054	0.107	0.272**	0.374***
	(0.038)	(0.028)	(0.018)	(0.014)	(0.020)	(0.057)	(0.087)	(0.124)	(0.140)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,742	1,742	1,742	1,742	1,742	1,742	1,742	1,742	1,742
Adj. R-squared	0.465	0.521	0.538	0.539	0.331	0.197	0.185	0.235	0.235

Note: This table shows the estimation results of Eq. (5) to test the effect of the Bank of Japan's March 2020 announcement on stock returns at different horizons. Columns (1) through (4) show the pre-announcement effects for 10-, 5-, 3-, and 1-day returns, respectively, prior to the announcement date (March 16). Columns (5)–(9) show the post-announcement effects for 1-, 3-, 5-, 10-, and 30-day returns, respectively. u_{it} denotes the demand for each stock created by an ETF purchase operation and π_i denotes the covariance-adjusted stock demand. Robust standard errors are shown in parentheses. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % levels, respectively.

intraday data and focus on lunchtime returns. As demonstrated in the previous section, the BOJ submits purchase orders during lunchtime in response to a negative return by the close of the morning market. First, we estimate a linear model for lunchtime returns for each policy regime:

$$r_t^L = \alpha_7 + \sum_j \beta_7^j \mathbb{I}_t \mathbb{P}^j + \varepsilon_{7,t}. \tag{7}$$

Coefficient β_7^j represents the effect of the BOJ's purchase on lunchtime returns.

Fig. 5 depicts the estimated coefficient β_7^j on an ETF purchase dummy. The BOJ's ETF purchase program has a statistically significant positive effect on lunchtime returns since *QQE*. The effect increased over time, particularly during *COVID-19*. The lunchtime effect is 6 basis points (bps) before *COVID-19* but 16 bps during *COVID-19,* which is a 160 % increase. Based on pairwise F-tests for equality between β_7^{COVID} and β_7^j for other regimes, the lunchtime effect during *COVID-19* is statistically different from that during other regimes. The F statistic and p-value are 3.88 and 0.049 for $\beta_7^{COVID} = \beta_7^{YCC}$, 5.01 and 0.025 for $\beta_7^{COVID} = \beta_7^{QQE}$, and 6.63 and 0.010 for $\beta_7^{COVID} = \beta_7^{ETF}$, respectively. Thus, the flow effect of ETF purchase has been positive except for the initial phase prior to *QQE* and increasing over time.

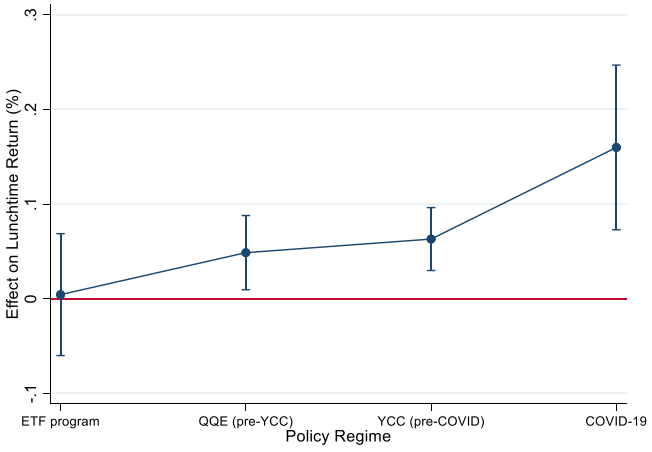

Fig. 5. The effect of ETF purchase on lunchtime returns before and after COVID-19. This figure depicts the effect of the BOJ's ETF purchase on the lunchtime TOPIX return for four policy regimes: the initial phase of the ETF program (December 15, 2010–March 30, 2013), QQE before yield curve control (April 1, 2013–October 2, 2016), yield curve control (October 3, 2016, to February 28, 2020), and COVID-19 (March 1, 2020–December 31, 2020). The 95 % confidence intervals are based on Newey-West standard errors.

Next, we estimate a flow effect through the scarcity channel by running a panel regression for return r_{it}^k on π_{it} and u_{it} for $k = \{lunchtime, afternoon\}$ while controlling for stock fixed effects η_i:

$$r_{it}^k = \alpha_8^k + \beta_8^k \pi_{it} + \gamma_8^k u_{it} + \delta_8^k \pi_{it} \times Covid + \phi_8^k u_{it} \times Covid + \eta_i + \varepsilon_{8,it}, \tag{8}$$

where u_{it} denotes a vector of demand for each stock created by each ETF purchase operation, π_i denotes the covariance-adjusted stock demand, *Covid* denotes a dummy variable for the COVID-19 pandemic (March 1, 2020–December 30, 2020), and $\varepsilon_{8,it}$ denotes the error term. To determine a vector of demand $u_{it} = T_t w_{it,T} + N_t w_{it,N}$ for each trading day, we use the daily index weights $w_{it,T}$ and $w_{it,N}$ as well as the BOJ's allocation weights as shown in Table 2. To estimate a change in the magnitude of flow effects, we include interaction terms between the demand shock variables and *Covid*. Stock fixed effects η_i implicitly control for time-invariant characteristics, including the market beta, forex beta, Amihud liquidity measure, and any industry effects. We estimate both unconditional and conditional versions of Eq. (8). The unconditional version includes all trading days with or without the BOJ's ETF purchase, whereas the conditional version is restricted to the days with the BOJ's purchases.

Table 10 shows the estimation result of Eq. (8). Column (1) and (2) show the result of unconditional estimation, in which u_{it} and π_{it} take a value of zero when there is no ETF purchase. For lunchtime returns, the coefficient of π is positive and significant (7.564 and 7.658) for both unconditional and conditional estimations (columns (1) and (3), respectively). Furthermore, the interaction between π and *Covid* is positive and statistically significant (0.994 and 0.952). Thus, the flow effect of ETF purchase is amplified during the COVID-19 pandemic. For afternoon returns, the coefficient of π_{it} is also positive and significant for both unconditional and conditional estimations (columns (2) and (4)). However, the interaction between π and *Covid* is significantly negative. Thus, during the COVID-19 period, the flow effect is larger on lunchtime returns than on afternoon returns. Overall, the BOJ's ETF purchase program mitigates stock price decline through timely purchases rather than the expectation about the total size of the program. Our result

Table 10
The flow effect of BOJ's ETF program.

	Unconditonal		Conditional	
	Lunchtime (1)	Afternoon (2)	Lunchtime (3)	Afternoon (4)
π	7.564***	25.00***	7.658***	25.87***
	(0.295)	(0.848)	(0.346)	(1.052)
$\pi \times Covid$	0.994***	−16.90***	0.952**	−17.24***
	(0.371)	(0.970)	(0.380)	(0.982)
u	2.056	32.27	−1.036	63.40*
	(3.374)	(24.70)	(3.584)	(33.06)
$u \times Covid$	−11.22	−66.48***	−9.895	−81.10***
	(9.324)	(11.92)	(9.524)	(14.98)
Constant	−0.0113***	−0.0139***	−0.00917***	−0.0306***
	(0.000833)	(0.00235)	(0.00149)	(0.00510)
Stock fixed effects	Yes	Yes	Yes	Yes
Observations	843,056	843,056	484,386	484,386
Adj R-squared	0.0103	0.0116	0.0107	0.0132

Note: This table shows the results of the panel regressions for lunchtime and afternoon returns (Eq. (7)). Unconditional estimation is based on all trading days with or without the BOJ's ETF purchase, whereas conditional estimation is based only on days when the amount of ETF purchase is positive. u_{it} denotes the demand for each stock created by an ETF purchase operation and π_i denotes the covariance-adjusted stock demand. Standard errors, clustered by stock tickers, are shown in parentheses. The pre-COVID period is from January 4, 2019 to February 28, 2020, and the COVID-19 period is March 1, 2020 to December 30, 2020.

shows marked contrast with the result by Barbon and Gianinazzi (2019) who find a limited flow effect. Unlike our study, they do not directly test the effect of a covariance-adjusted demand shock π. Instead, they use daily returns and estimate the effect of the unadjusted purchase amount accumulated for up to 10 days. Our better identification is based on our finding that the BOJ purchases ETFs during lunchtime. Thus, we use lunchtime returns to estimate an immediate flow effect through the scarcity channel.

4.3. Controlling for economic news release

A concern in the estimation of a flow effect is the confoundedness by a macroeconomic news release. Our estimations are not particularly prone to this issue because few government statistics are released during lunchtime. As Hashimoto and Ito (2010) point out, most important statistics, such as consumer price index (CPI) and gross domestic product (GDP), are released before the morning market opens. However, an exception is the statement of monetary policy meeting, which has no predetermined release time. Also, it is still possible that a news release before the morning market may create a continuing price drift during the lunchtime.

To check the robustness, we control for dummy variables representing the release of macroeconomic statistics and monetary policy meeting. Specifically, we construct dummy variables for the release of nominal GDP, CPI, BOJ Tankan, unemployment, and industrial production index, and the statement of monetary policy meeting. Table A6 shows that the estimated coefficients are almost identical to those in Table 10 after controlling for economic news release. However, the news release dummies have significant explanatory power and increase R-squared.

4.4. Counterfactual returns

We further focus on the sample of trading days with below-median returns during overnight and morning periods. As demonstrated in Section 3.4, the BOJ purchases ETFs when the cumulative overnight-to-morning return is below the median. Thus, this sample has a high propensity for the BOJ's intervention. To estimate the mean return with and without the BOJ's purchase, we run a regression $r_t^i = \alpha_{A5}^i + \beta_{A5}^i \mathbb{I}_t + \varepsilon_{A5,t}^i$, where the dependent variable r_t^i is returns during period $i = \{lunchtime, afternoon\}$, and $\mathbb{I}_t$ is a dummy variable for an ETF purchase on date t.

Table A5 shows the estimation results. Based on a constant, the mean lunchtime return without the BOJ's intervention is -0.035%, which is statistically different from zero. Thus, when the cumulative overnight-to-morning return is below the median, the subsequent lunchtime return tends to be negative, indicating intraday momentum return. In contrast, when the BOJ purchases ETFs, the mean lunchtime return is 0.048% higher and becomes positive. Similarly, the mean afternoon return is negative (-0.064%) without the BOJ's intervention but higher by 0.107% when there is an intervention. These negative constants can be interpreted as counterfactual returns without the BOJ's intervention. This counterfactual analysis provides additional support for the positive flow effect, although it is not based on a structural model. As there is no well-performing structural model to predict volatile intraday stock returns, our empirical analysis is a good alternative.

4.5. Discussion about stock prices during the COVID-19 period

Fig. 6 depicts the cumulative return to Nikkei 225, TOPIX, and Volatility Index Japan (VXJ)—a stock price volatility index—in 2020. VXJ is based on implied volatility based on the Nikkei 225 index options.[8] Although the estimated announcement effect is short-term and limited, both Nikkei 225 and TOPIX recovered sharply with a large amount of ETF purchases. Starting in mid-May, Nikkei 225 consistently outperformed TOPIX. The larger appreciation of Nikkei 225 than TOPIX is consistent with the BOJ's ETF program, which results in a greater purchase of Nikkei 225 stocks. The volatility index also consistently decreased after the BOJ's announcement. However, the causality is unclear for these long-term relationships because there are confounders that could cause larger stock price appreciation and stabilization of Nikkei 225. For example, the BOJ also provided other bold policy measures to decrease interest rates through yield curve control. Concurrently, the government significantly increased its spending to support households and businesses negatively affected by the pandemic. Furthermore, Nikkei 225 tends to include more large-cap stocks, which could be considered more resilient during crises.

Nevertheless, it is possible that the BOJ's announcement of a bolder ETF purchase program increased investor confidence by credibly providing downside protection. Notably, the BOJ did not need to intervene as frequently in the ETF market as the bank initially anticipated. The bank did not use all of the increased budgets for the ETF program. If the BOJ's ETF program works with credible commitment to provide downside support, it serves as an effective monetary policy tool. Indeed, the BOJ commits to providing downside protection in a market downturn consistently across the bond and stock markets. The BOJ provides downside protection in the JGB market as part of the yield curve control (Hattori and Yoshida (forthcoming)). The bank launched a fixed-price JGB purchase program, in which it commits to purchasing an unlimited amount of JGBs at a target yield. It has also made the timing of fixed-amount JGB auctions endogenous to market yield. Consequently, investors' expectations converged to the BOJ's target yield, and the bank did not need to conduct fixed-price purchase operations frequently. Identifying a long-term causal relationship between the BOJ's downside protection and cost of capital for both bonds and stocks may prove fruitful.

5. Conclusion

This study analyzes how the BOJ purchased ETFs as part of its

[8] The data are available at: http://www-mmds.sigmath.es.osaka-u.ac.jp/en/activity/vxj.php.

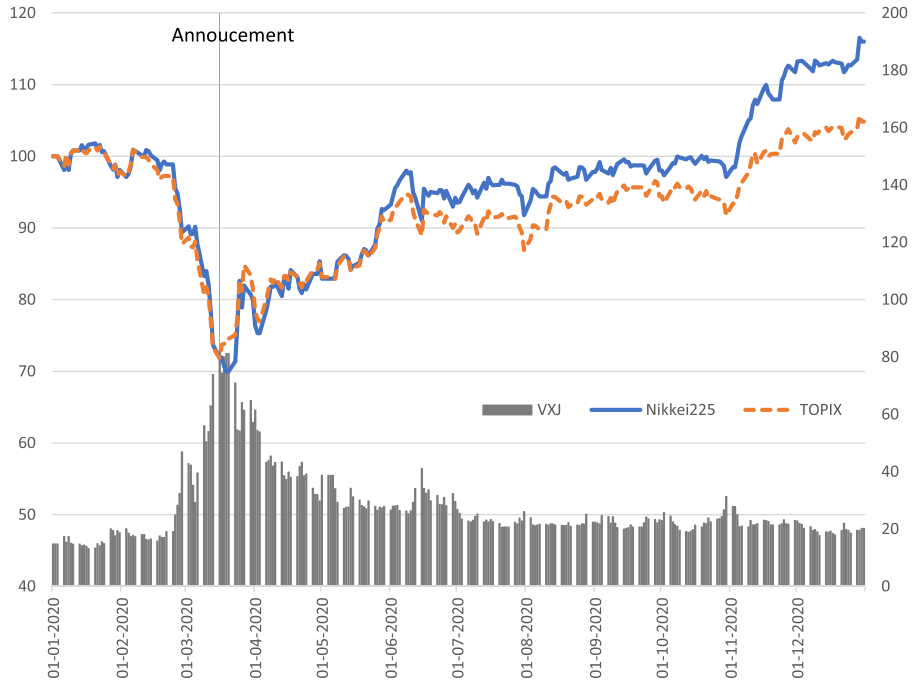

Fig. 6. TOPIX, Nikkei 225, and Stock Volatility Index. This figure depicts the time series of TOPIX, Nikkei 225, and VXJ for 2020. VXJ is a stock volatility index based on the Nikkei 225 index options. The vertical line for March 16, 2020, indicates the BOJ's announcement of an increase in ETF purchases.

unconventional monetary policy. We find clear evidence of a countercyclical intervention rule contingent on intraday stock returns. Although endogenizing the purchase timing to market prices is unconventional for monetary policy, it is consistent with the BOJ's objective of decreasing equity risk premia, particularly because the BOJ has exhausted other monetary policy instruments such as the policy rate, inflation targeting, and bond-LSAP. The BOJ enhanced its countercyclical equity purchases during the COVID-19 pandemic. Although the announcement of the enhanced purchase program did not have a large permanent effect on stock prices, actual purchases had a larger flow effect on stock prices during the COVID-19 pandemic than in the previous period. This finding suggests that a central bank can affect the equity cost of capital by providing downside protection to equity investors during crises.

Our study contributes to the discussion of monetary policy under a prolonged zero interest rate and a recessionary environment during the COVID-19 pandemic. Our study on the BOJ's countercyclical equity market intervention extends the literature on LSAPs because central banks rarely time the market or intervene directly in equity markets. Our study also emphasizes the dynamic nature of channels through which LSAPs affect stock prices. Thus, it implies that a major channel reported in early studies may not be persistent across different economic environments. Furthermore, our study presents a case in which the magnitude of policy impacts was amplified during an unforeseen economic crisis. Thus, our study suggests the importance of revisiting policy evaluations in an alternative economic environment.

Data availability

The authors do not have permission to share data.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfs.2023.101102.

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