Bank of Japan's ETF Purchase Program and Equity Risk Premium: A CAPM Interpretation *

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Abstract

This paper investigates the effects of the Bank of Japan's (BOJ) exchange-traded fund (ETF) purchase program on equity risk premia. We first construct a unique panel dataset for the amount of individual stock that the BOJ has indirectly purchased in the program. Then, the empirical analysis reveals that: (i) the BOJ's ETF purchases instantaneously support stock prices on the days of purchases, and (ii) the positive effects on stock prices, combined with the countercyclical nature of the BOJ's purchases, have affected the market beta and coskewness of Japanese stocks, leading to an economically significant decline in risk premia.

Keywords: Large-scale asset purchases (LSAP), ETF purchase program, Capital asset pricing model (CAPM), Bank of Japan

JEL Classification codes: E58, G12, G14

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"The Bank of Japan had an indirect influence. By making purchases of ETFs when stock prices go down, the BOJ gives a sense of peace of mind to investors."
— Financial Times, December 9, 2016

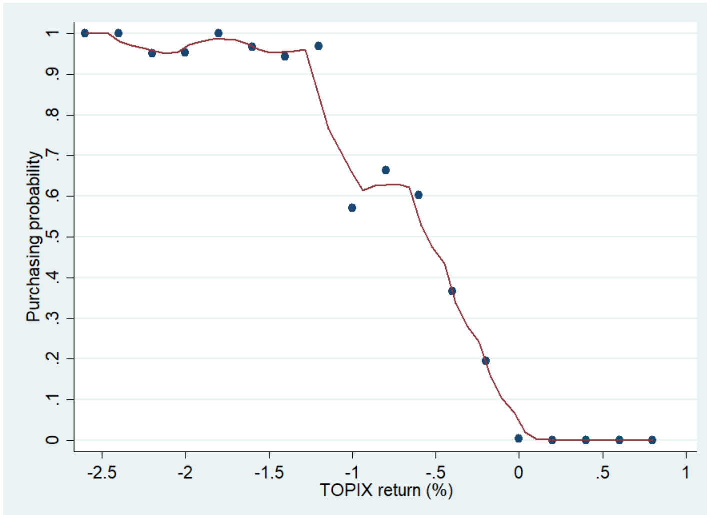
1 Introduction

The Bank of Japan (BOJ) undertook an unprecedented strategy of purchasing exchange tradable funds (ETFs) as part of its asset purchasing program. From the onset of the program in December 2010, the total amount of ETFs purchased by the BOJ has continued to increase and reached about 35 trillion yen, or 5% of the total market value of all listed stocks in Japan. The BOJ officially stated that the objective of the ETF purchase program was to lower the equity risk premia of Japanese stocks, and market participants largely share the view that the BOJ's ETF purchase program has somewhat supported Japanese stock prices.[1] However, from an analytical and empirical point of view, it is still underexplored whether and why the BOJ's ETF purchase program has had persistent effects on equity risk premia.

In this paper, we investigate the effects of the BOJ's ETF purchase program on equity risk premia, with a particular focus on the countercyclical nature of the BOJ's purchasing strategy. In the ETF purchase program, the BOJ does not randomly purchase ETFs, but instead only purchases ETFs when the stock market faces negative price pressure. Figure 1 shows the probability that the BOJ purchases ETFs (y-axis), given the return on Japanese stocks (TOPIX) in the morning session (x-axis). While the BOJ does not publicly announce its policy rule for ETF purchases, the figure clearly shows that the more significantly stock prices decline, the more likely is the BOJ to make purchases of ETFs. Considering the BOJ's countercyclical and systematic policy rule for ETF purchases, we hypothesize that the program possibly changes the risk profile of Japanese stocks by weakening the correlation between Japanese stock returns and returns (and volatility) on the global market portfolio, thus reducing a systematic risk and risk premia of Japanese stocks. While the BOJ

[1]For instance, the BOJ's governor Kuroda stated in a speech that the ETF purchases "aim at exerting positive effects on economic activity and prices by lowering risk premia in the markets." (Kuroda, 2021)

Figure 1: Probability of ETF Purchases under the Program



Note: The dots indicate the probability that the BOJ purchases a positive amount of ETFs under the purchasing program, given the TOPIX return in the morning session of the day. The x-axis indicates the TOPIX return. The probability is calculated based on data of the ETF purchasing program from December 2010 to December 2019.

probably decides whether it purchases ETFs by considering price changes in Japanese stock markets rather than global stock markets, Japanese stock markets follow the movements in global stock markets on the previous day. Therefore, from global investors' viewpoint, Japanese stocks might be a good hedge against the global market portfolio because the BOJ's countercyclical ETF purchases provide a type of the central bank "put option."

In common with other systematic policies, however, the BOJ's systematic rule for ETF purchases makes it challenging to identify the policy effects. Namely, given that the BOJ's ETF purchases are associated with declines in stock prices, positive policy effects on stock prices, if any, are hard to be identified only by time-series variations in ETF purchases and stock prices. Hence, to deal with this endogeneity problem, we construct a unique panel dataset of the amount of individual stock that the BOJ indirectly purchased through the ETF purchase program. As discussed in Section 2 in more detail, even though the BOJ does not purchase individual stocks, but only index-tracking ETFs, the amount of BOJ's (indirect) purchases shows substantial cross-sectional variation across individual stocks because of the difference in their weights in the ETFs. Furthermore, because the BOJ has frequently changed the purchasing shares across ETFs, the degree of cross-sectional variations across individual stocks has also changed over time, which helps us identify the policy effects as treatment effects in the panel data.

Our empirical analysis using the above panel dataset indicates that the BOJ's countercyclical ETF purchase program has changed the risk profile of Japanese stocks, thus leading to an economically significant decline in their equity risk premia. In our empirical analysis, we first estimate the market beta, downside beta, and coskewness of individual Japanese stocks in four-year windows and then examine by a panel regression analysis whether the BOJ's purchases affect changes in those measures of systematic risk between the windows. Our estimation results show that the stocks more heavily purchased in the BOJ's ETF purchase program are associated with more significant declines in the systematic risk measures, which suggests that the BOJ's ETF purchases have decreased the systematic risk of Japanese stocks. Furthermore, the size of the decline in risk premia is economically significant: According to a back-of-the-envelope calculation based on the security market line, the decline in the market beta caused by the BOJ's ETF purchase program has reduced the equity risk premia of Japanese stocks by around 1.0 percentage point on aggregate, which boosted Japanese stock prices (TOPIX) by 10–13% at the peak.

This study is based on the extensive literature on cross-sectional stock returns. In particular, we calculate the market beta of Japanese stocks using the global CAPM framework pioneered by Solnik (1974).[2] In addition, as relevant measures of systematic risk, we focus on downside beta proposed by Ang et al. (2006) and coskewness proposed by Harvey and Siddique (2000). Also, from a policy perspective, this study contributes to the literature on the central bank's asset purchase program. While most previous studies mainly examine the instantaneous effects of the bond- or asset-backed security purchase programs by an event study (e.g., D'Amico and King, 2013; Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2011), this paper analyzes the persistent effects of the ETF purchase program in Japan based on a standard finance theory, mainly focusing on its countercyclical nature and its effects on risk premia. In that sense, this study is also related to the literature on the central bank's countercyclical policy reacting to the stock market (i.e., the central bank put). For example, Cieslak and Vissing-Jorgensen (2021) investigates

[2] See also Stulz (1999) for advantages of the global CAPM compared with a standard local CAPM.

whether and why the Fed reacts to the stock market, and Miller et al. (2002) and Drechsler et al. (2018) examine the effects of the "Fed put" in the U.S. from the standpoint of crisis prevention and liquidity premia, respectively. This study shed some new and direct light on the effects of the "central bank put" by examining the BOJ's direct intervention to the stock market rather than accommodative interest rate policy in response to stock market downturns. Finally, this study contributes to the empirical literature on the effects of the BOJ's ETF purchase program (e.g., Shirota, 2018; Charoenwong et al., 2021; Katagiri et al., 2022; Maeda et al., 2022). Among others, Adachi et al. (2021) identify the policy effects on equity risk premia by using daily data for option-implied risk premia of the Japanese stock index. Our study complements such previous studies using high-frequency data in the sense that we utilize cross-sectional variation rather than time-series variation. In terms of an identification strategy, Barbon and Gianinazzi (2019) and Harada and Okimoto (2021) are particularly close to this paper because they also utilize cross-sectional variations due to the inclusion of Nikkei 225 ETFs in the BOJ's purchases.[3] Those studies examine whether the BOJ's purchases affect stock prices through the instantaneous flow effects or the portfolio balance channel; however, they do not focus on the possibility that the countercyclical BOJ's ETF purchases lower the equity risk premium by changing the covariance structure.

The remainder of the paper proceeds as follows. Section 2 describes our panel dataset and conducts a regression analysis to examine the BOJ's policy rule and the flow effects of ETF purchases. Section 3 presents the empirical analysis of the effects of the BOJ's ETF purchases on systematic risk measures. Section 4 estimates a cross section of stock returns in the Japanese stock market and derives some policy implications. Section 5 provides concluding remarks.

[3]The identification strategy to utilize the cross-sectional variation due to the price-weighted construction of Nikkei 225 is initially pioneered by Greenwood (2005). He uses this identification strategy to examine the effects of demand shocks in general based on a model with limits-to-arbitrage.

2 BOJ's ETF Purchasing Rule and the Flow Effects

This paper investigates the hypothesis that the instantaneous positive effects of the BOJ's ETF purchases on stock prices, combined with the countercyclical nature of the BOJ's purchases, have helped reducing the market beta of Japanese stocks. However, before examining our hypothesis, we should empirically check whether the following two fundamental prerequisites for this specific channel of the BOJ's ETF purchases are effective. First, we should show that the BOJ's ETF purchase strategy is countercyclical to lean against the wind in stock markets. The countercyclical nature of ETF purchases is a prerequisite to a lower market beta because, otherwise, they are not expected to lower the correlation with market returns. For instance, if the BOJ purchases ETFs randomly or follows a time-dependent policy rule (e.g., once a month on a prescheduled day), these purchases are not expected to affect the correlation with market returns.

Second, we should show that the BOJ's ETF purchases have instantaneous and positive effects on stock prices. Those instantaneous "flow effects" on stock prices are also a prerequisite for lowering the market beta because, otherwise, the BOJ's ETF purchases do not have any power to change the correlation with market returns and thus do not work as a put option. While the market beta depends on expected correlation rather than realized correlation, the effective flow effects of the BOJ's purchases are necessary for the BOJ's announcement to change the expectation of market participants in stock markets. In other words, if market participants do not believe that the BOJ's ETF purchases have flow effects that are large enough to change the correlation with market returns, the risk perception of investors—risk premium—should also not change.

In the rest of this section, first, we empirically show the countercyclical nature of the BOJ's ETF purchases. Then, we estimate the flow effects of the BOJ's ETF purchases. To deal with the endogeneity problem in estimating the flow effects, we construct a unique panel dataset for the amount of individual stock that the BOJ indirectly purchased through its ETF purchase program. Note that our estimation of the BOJ's countercyclical ETF purchasing rule just follows what has been widely shared among market participants and that the significant flow effects of the BOJ's ETF purchases echo what other previous empirical studies found; therefore, the empirical results in Section 2 per se have few additional contributions to the literature. Hence, while those empirical results are essential to make this paper self-contained, readers who are only interested in the main contribution of this study can skip the rest of Section 2 and go to Section 3.

2.1 Countercyclical Policy Rule for ETF Purchases

This subsection estimates the BOJ's policy rule for ETF purchases to show their countercyclical nature. To do so, we focus on the belief of market participants that the BOJ purchases ETFs in the afternoon session after having observed the daily momentum in the morning session. More specifically, we investigate whether the BOJ's policy rule depends on stock price changes in the morning session in Japan. That is, the aggregate amount of the BOJ's ETF purchase on date t, which is denoted by ETF_t, is assumed to be a function of price changes of TOPIX in the morning session, R_t^M. This assumption is natural and consistent with market participants' view, but ETF_t is expected to be highly nonlinear with respect to R_t^M because the BOJ makes purchases of ETFs infrequently, about five or six times per month. Hence, we estimate the policy rule for ETF_t by the following two-step approach. First, we estimate the probability that the BOJ purchases ETFs, $Pr(ETF_t > 0)$. Then, we estimate the policy rule for the purchase amount conditional on the positive amount of purchase, $\mathbf{E}_t[ETF_t|ETF_t > 0]$.

First, we estimate the probability that an ETF purchase takes place. Define a dummy variable D_t that equals one if the BOJ makes an ETF purchase,

$$D_t \equiv \mathbf{I}[ETF_t > 0],$$

where $\mathbf{I}[\cdot]$ is an indicator function.[4] Then, using the dummy variable, we estimate the following probit model

$$Pr\left(D_t = 1|R_t^M, X_t\right) = \Phi\left(\gamma_0 + \gamma_1 R_t^M + \gamma_2 X_t + \varepsilon_t\right), \tag{1}$$

[4]Data on daily BOJ ETF purchases are available on their website at `https://www3.boj.or.jp/market/en/menu_etf.htm`.

Table 1: BOJ's ETF Purchase Program

Announcement Date	Total size	Purchased ETFs and their share.
(1) 10/28/2010	The maximum outstanding amount to be purchased is about **0.45 tril. yen**	ETFs tracking the **Tokyo Stock Price Index (TOPIX)** and **Nikkei 225 Stock Average** are purchased so that the bank's purchase would roughly be proportionate to the total market value of that ETF issued. (2010/11/5)
(2) 3/14/2011	The "maximum" amount is increased to about **0.9 tril. yen**	Unchanged
(3) 8/4/2011	Up to about **1.4 tril. yen**	Unchanged
(4) 4/27/2012	Up to about **1.6 tril. yen**	Unchanged
(5) 10/30/2012	Up to **2.1 tril. yen**	Unchanged
(6) 4/4/2013	**At an annual pace of 1 tril. yen**.	Introduction of the "Quantitative and Qualitative Monetary Easing"
(7) 10/31/2014	**3.0 tril. yen/year**	Unchanged
(8) 11/19/2014	Unchanged	**JPX400** ETFs are included. (The decision was made on 10/31/2014)
(9) 3/15/2016 (4/1/2016)	**3.3 tril. yen/year**	Of which 0.3 tril. yen/year for purchasing ETFs composed of stocks issued by firms that are proactively investing in physical and human capital.
(10) 7/29/2016	**6.0 tril. yen/year**	Unchanged
(11) 9/21/2016	Unchanged	**3.0 tril. yen/year** for TOPIX, Nikkei 225, and JPX400 (proportional to the market value of that ETF); **2.7 tril. yen/year** for TOPIX; **0.3 tril. yen/year** for ETFs to support corporate investment
(12) 7/31/2018 (8/6/2018)	Unchanged	**1.5 tril. yen/year** for TOPIX, Nikkei 225, and JPX400 ETFs; **4.2 tril. yen/year** for TOPIX ETFs; **0.3 tril. yen/year** for ETFs to support corporate investment
(13) 3/16/2020	**12 tril. yen/year** as a temporary measure for COVID-19	Unchanged
(14) 3/19/2021	**12 tril. yen/year** even after COVID-19 subsidies	The Bank only purchases ETFs tracking TOPIX.

Note: Based on a decision on 10/28/2010, the BOJ started purchasing ETFs on 12/5/2010. The date in parenthesis indicates the starting date of the policy change.

Table 2: The BOJ's Intervention and Stock Prices

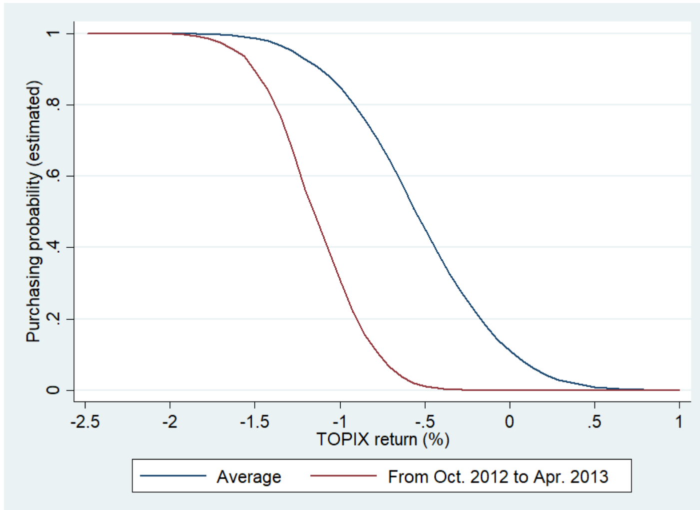
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Intervention dummy (D_t)			Purchasing amount (ETF_t)			
Model	Probit	IV Probit	Probit	OLS		Heckit	
Ind. var.	Morning		FTSE	Morning	FTSE	Morning	FTSE
$\Delta Morning_t$	-0.501***	-0.495***		0.304		0.884	
	(0.0292)	(0.0401)		(1.121)		(1.421)	
$\Delta FTSE_{t-1}$			-0.240***		-2.214		-10.37
			(0.0189)		(1.390)		(8.001)
Policy regime dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2215	2215	2215	591	591	2225	2225

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Columns (1) to (3) in the table indicate the marginal effect of each variable on the probability of the implementation of the ETF purchases when TOPIX returns in the morning session ($\Delta Morning$) or in FTSE All-World index equal zero. Column (2) indicates the IV probit estimation result when the FTSE All-World index returns are used as an instrumental variable for the TOPIX returns in the morning session while Columns (3) shows the result with FTSE All-World index returns as a direct dependent variable. Columns (4) to (7) show the estimation result for the regressions using daily purchases by the BOJ as a dependent variable. Columns (4) and (5) shows the OLS results using samples on days when the BOJ purchased ETFs. Columns (6) and (7) are based on the Heckit model. The first-stage regression is not reported in the table because the results are quantitatively similar to the results shown in columns (1) and (3). The sample period covers from Dec. 2010 to Dec. 2019.

where $\Phi(\cdot)$ is the cumulative distribution function of a normal distribution. Here, X_t is a vector of control variables, including dummy variables for each policy regime. As shown in Table 1, the BOJ has made not a few policy changes to its ETF purchase program in terms of the total amount of purchases, as well as the purchase share across ETFs. Hence, we classify the BOJ's ETF purchase program by December 2019 into 12 policy regimes based on the BOJ's announcements listed in Table 1 and construct 11 dummy variables, $d_{1,t}, ..., d_{11,t}$, that equal one when time t is included in the corresponding policy regime.

Table 2 presents the estimation result for the probit model. Column (1) of the table shows that γ_1 in equation (1) is negative and statistically significant, which implies that the more significantly stock prices decline in the morning session, the more likely is the BOJ to purchase ETFs. That is, the BOJ's ETF purchases are countercyclical with respect to stock

Figure 2: Estimated ETF Purchase Probability



Note: The blue line shows the fitted value using the probit model without policy change dummies based on the data from December 2010 to December 2019. The red line shows the fitted value based on the probit model when the policy regime dummy for the period from Oct. 2012 to Apr. 2013 (period [5] in Table 1) equals one.

prices. This estimation result, however, could be distorted if market participants purchase stocks in the morning session in expectation of the BOJ's ETF purchase in the afternoon session for some reason. To deal with the possibility of this endogeneity problem, we also estimate a probit model in which we use changes in the FTSE All-World index for the previous day as an instrumental variable (IV). The IV probit estimation (column 2 in Table 2) shows that the sensitivity to changes in the stock price index γ_1 is almost the same as in the probit model in column (1), implying that the baseline estimation in column (1) is robust to this endogeneity problem. Column (3) shows the estimation result with the FTSE All-World index returns for the previous day as an independent variable instead of an IV, which confirms that the BOJ's purchases were counter-cyclical to global stock markets.

Based on the baseline estimation result (column 1 in Table 2), Figure 2 shows the estimated probability that the BOJ purchases ETFs (y-axis), given the TOPIX returns in the morning session (x-axis). The figure indicates that the probability of ETF purchases is very sensitive and nonlinear to stock returns in the morning session. More specifically, the figure implies that the threshold for ETF purchases (i.e., the point where the probability of ETF purchases exceeds 50%) has been, on average, around a -0.5% decline in TOPIX in the morning session (the blue line), which is broadly consistent with the view shared among market participants.[5] The figure also shows that the thresholds to purchase ETFs are different across policy regimes. For instance, before the new governor Kuroda revised the ETF purchase program in 2013, the threshold was much lower and around -1.2% (the red line).[6]

Next, we estimate the policy rule for the amount of purchases conditional on a positive amount of purchases. Specifically, we estimate

$$ETF_t = \psi_0 + \psi_1 R_t^M + \psi_2 X_t + u_t \tag{2}$$

using data conditional on $D_t = 1$ (i.e., $ETF_t > 0$). Here, X_t includes the same dummy variables for policy regimes used for estimating equation (1). The estimation results for the policy rule (column 4 in Table 2) shows that ψ_1 is not statistically significant, which implies that once the BOJ decides to purchase ETFs, the amount of each purchase is determined independently of stock market situations. In addition, even if we use the FTSE All-World index in the previous day instead of the TOPIX morning session return, the coefficient on the return was not significantly different from zero. However, these estimation results for ψ_1 may suffer from sample selection bias. In other words, when we use data only for $D_t = 1$, it is known that ψ_1 would be biased toward zero if there exists a common unobserved factor influencing both $Pr(D_t = 1)$ and $\mathbf{E}_t[ETF_t|D_t = 1]$, i.e., $Corr(\varepsilon_t, u_t) \neq 0$. To deal with the possibility of sample selection bias, we estimate the policy rule (2) using the Heckit model following the literature on sample selection bias. In the estimation result for Heckit (columns 6 and 7 in Table 2), ψ_1 is not statistically significant as in the OLS estimations in column (4) and (5), which implies that the estimation result for ψ_1 is robust to the sample selection bias.

We conclude that the BOJ's ETF purchase program has been conducted as a counter-

[5] For example, an article in Financial Times (March 23, 2021) reports that "*Although it is not an explicit rule, the central bank has tended to step in whenever the Topix index has lost more than 0.5% in the morning session, analysts at Nomura wrote in a February 19 research note.*"

[6] Including the past cumulative returns (from $t-j$ to $t-1$, $j = 1, ..., 20$) on the TOPIX index as independent variables does not change the effect of the morning session return although the past returns, especially $t-1$, are statistically significant (The result is not reported). We should note that the estimated impacts of the past returns are economically marginal.

cyclical policy to lean against the wind in stock markets. More precisely, the estimation results reveal that: (i) whether the BOJ purchases ETFs is highly countercyclical with respect to stock prices in the morning session, and (ii) the amount of each purchase given intervention is determined independently of stock market situations. In common with other conventional monetary policies, the BOJ's systematic and countercyclical rule for ETF purchases makes it challenging to identify the policy effects because of the endogeneity problem. In the following subsection, we discuss how to address this endogeneity problem by constructing a unique panel dataset for the amount of individual stock that the BOJ has indirectly purchased under the program.

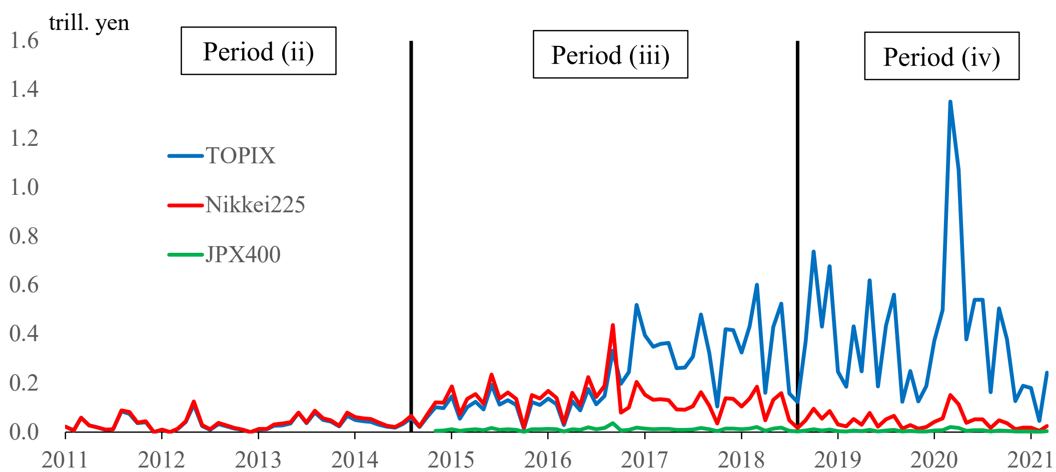
2.2 Panel Dataset for BOJ's (Indirect) Purchases of Individual Stock

As discussed in the previous subsection, the BOJ's systematic and countercyclical ETF purchasing rule makes it difficult to identify the policy effects. More specifically, given that the BOJ's ETF purchases are associated with a decline in stock prices, the positive policy effects on stock prices, if any, are difficult to identify only by time-series variations in ETF purchases and stock prices. Hence, to deal with this endogeneity problem, we construct a unique panel dataset for the amount of individual stock that the BOJ has indirectly purchased through the ETF purchasing program. By doing so, we can exploit cross-sectional variations across individual stocks that arise from their different weights in each ETF and the policy changes for the purchase shares across ETFs.

More specifically, as a first step, we construct time-series data for the BOJ's ETF purchases by ETF type: those tracking returns of (i) TOPIX, (ii) Nikkei 225, and (iii) JPX400.[7] While the BOJ does not publicly announce which ETFs it purchases in each intervention, we calculate it from the BOJ's announced strategy in Table 1 and the market value of each type of ETF. The Appendix explains our methodology of computation. Figure 3 shows the developments in the purchases of ETFs that track TOPIX, Nikkei 225, and JPX400, respectively. The figure indicates that the BOJ has occasionally changed the total amount

[7] Other than ETFs that track the returns of the three major stock price indices, the BOJ purchases ETFs to support firms that invest in human and physical capital. Nonetheless, we exclude those ETFs from our analysis because the weights of the individual stocks in those ETFs are not easy to obtain, and the purchase amounts of those ETFs is small.

Figure 3: Purchasing Amount by ETF Type



Note: The figure shows the developments in the estimated ETF purchases that track TOPIX, Nikkei 225, and JPX400, respectively, on a monthly basis. Periods (ii), (iii), and (iv) correspond to the four-year time windows in the CAPM analysis in Section 3. See Appendix for more details on how to estimate the purchase amounts.

of purchases, as well as the purchase shares, across ETFs, in line with the policy changes listed in Table 1. As discussed later, we will exploit those policy changes regarding each ETF's purchase amount to identify the policy effects.

In the next step, given these time-series data, we construct a panel dataset for ETF_{it}, the BOJ's (indirect) purchases of stock i at time t relative to its market value, Mkt_{it}, as follows:

$$ETF_{it} = \frac{w^T_{it} ETF^T_t + w^N_{it} ETF^N_t + w^J_{it} ETF^J_t}{Mkt_{it}} \tag{3}$$

where ETF^T_t, ETF^N_t, and ETF^J_t derived in the first step are the BOJ's purchases of ETFs tracking TOPIX, Nikkei 225, and JPX400, and w^T_{it}, w^N_{it}, and w^J_{it} are stock i's weight in TOPIX, Nikkei 225, and JPX400 respectively.

While the BOJ purchases only ETFs, and not individual stocks, the BOJ's (indirect) purchases, ETF_{it}, potentially show some cross-sectional variation across individual stocks because of their different weights in ETFs. To understand what drives the cross-sectional variation across individual stocks, we transform ETF_{it} in equation (3) to

$$ETF_{it} = \frac{ETF_t^T}{Mkt_t} + \frac{w_{it}^N}{w_{it}^T} \cdot \frac{ETF_t^N}{Mkt_t}.$$

Here, we use the fact that the weight in TOPIX is approximated by $w_{it}^T = Mkt_{it}/Mkt_t$ where $Mkt_t = \sum_i Mkt_{it}$ because TOPIX is a market value-weighted index that covers all stocks listed in the first section of the Tokyo Stock Exchange (TSE). Furthermore, we hereafter ignore the purchase of JPX400 ETFs just for simplicity because the amount of JPX400 ETF purchases is relatively small, as shown in Figure 3. Given that the first term, ETF_t^T/Mkt_t, is the same across individual stocks, all the cross-sectional variation is driven by the second term. Hence, time-series changes in the cross-sectional variation for ETF_{it} are approximated by

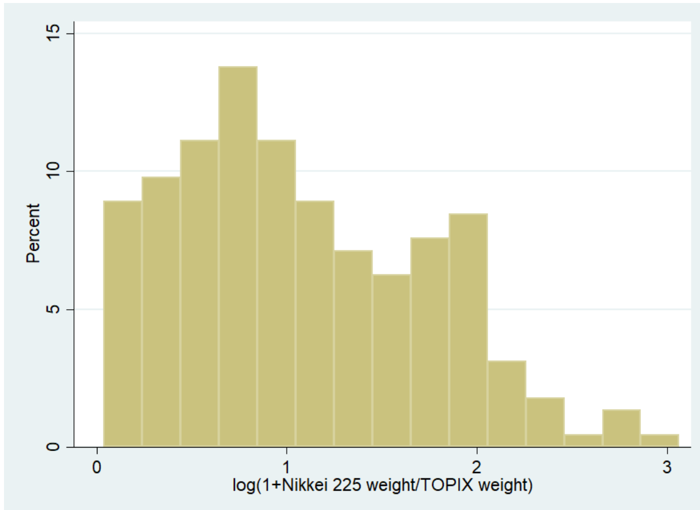
$$\Delta\left(\frac{w_{it}^N}{w_{it}^T}\right) \cdot \frac{ETF_t^N}{Mkt_t} + \frac{w_{it}^N}{w_{it}^T} \cdot \Delta\left(\frac{ETF_t^N}{Mkt_t}\right), \tag{4}$$

where the first term represents changes in stock i's weight in Nikkei 225 relative to the weight in TOPIX, while the second term represents the effects of the BOJ's policy changes regarding the purchase amount of Nikkei 225 ETFs. Note that while the BOJ's policy change itself (i.e., ΔETF_t^N) is an aggregate change, it possibly has different effects among individual stocks because of the difference in their weights in Nikkei 225 relative to that in TOPIX, w_{it}^N/w_{it}^T, thus generating sizable cross-sectional variation in ETF_{it}.

On the ratios of the weights in Nikkei 225 relative to those in TOPIX, w_{it}^N/w_{it}^T, there exist substantial differences in w_{it}^N/w_{it}^T among individual stocks for the following two reasons. First, Nikkei 225 covers only 225 stocks listed in the first section of TSE. Therefore, large gaps in w_{it}^N/w_{it}^T exist between stocks included in Nikkei 225 (i.e., those with $w_{it}^N > 0$) and those included only in TOPIX (i.e., those with $w_{it}^N = 0$). Second, Nikkei 225 is a price-weighted equity index rather than a market value-weighted index; therefore, w_{it}^N/w_{it}^T varies even among stocks included in Nikkei 225. To see the variation in the data, we define the Nikkei-TOPIX ratios, $Nikkei\_TPX_{it}$, as

$$Nikkei\_TPX_{it} = \log\left(1 + \frac{w_{it}^N}{w_{it}^T}\right) \tag{5}$$

Figure 4: Relative Weights in Nikkei 225 and TOPIX



Note: The figure shows a histogram of the average weight in Nikkei 225 relative to that in TOPIX for stocks included in Nikkei 225 in December 15, 2010 (the first day of the BOJ's ETF purchase). Note that the relative weights for stocks that are not included in Nikkei 225 are zero and not shown in the figure.

and show the histogram only for stocks included in Nikkei 225 in Figure 4.[8] The figure indicates that $Nikkei\_TPX_{it}$ shows substantial cross-sectional variation across individual stocks, suggesting that the BOJ's ETF purchase program should have a different size of impact even among stocks included in Nikkei 225.

Thanks to the substantial differences in w^N_{it}/w^T_{it} among individual stocks, the BOJ's policy changes regarding the purchasing amount of Nikkei 225 ETFs induce changes in the cross-sectional variations in ETF_{it}. Those variations due to the BOJ's policy change help identify the policy effects as treatment effects in a panel regression analysis of the flow effects in the following subsection, as well as the effects on the market beta in Section 3. In particular, as discussed later, we carefully construct the four-year time windows for our CAPM analysis so as to exploit the cross-sectional variation caused by the policy changes.

[8]We define the Nikkei–TOPIX ratios as $\log\left(1 + w^N_{it}/w^T_{it}\right)$ rather than w^N_{it}/w^T_{it} to mitigate the effects of outliers. Note, however, that these two ratios are monotone mappings of each other and that previous studies including Greenwood (2005) use a similar transformation.

2.3 Flow Effects of BOJ's ETF Purchases

This subsection investigates whether the BOJ's ETF purchases affect the daily returns of Japanese stocks on the day of purchase (i.e., the instantaneous flow effects). Those instantaneous "flow effects" on stock prices are also a prerequisite for lowering the market beta because, otherwise, the BOJ's ETF purchases do not have any power to change the correlation with market returns. As described in the previous subsection, we exploit the cross-sectional variation in the BOJ's (indirect) purchases of individual stocks and their time-series fluctuations because of the policy shifts to identify the policy effects. Specifically, we estimate:

$$r_{it} = FE_i + T_t + \theta_1 ETF_{it} + \theta_2 X_{it} + \varepsilon_{it} \tag{6}$$

where r_{it} is the daily total return of stock i on day t, and ETF_{it} is the BOJ's purchases of stock i on day t divided by the market value of stock i at t. We also include a time-invariant fixed effect for stock i and time dummies, FE_i and T_t, as well as a vector of control variables X_{it}. The parameter of interest is θ_1, which is expected to be positive because of the instantaneous flow effects on stock prices.

Given the countercyclical nature of the BOJ's ETF purchases established in Section 2.1, the policy effect θ_1 may not be identifiable by a full-sample estimation. To see why, the individual stock returns ε_{it} in equation (6) are decomposed as $\varepsilon_{it} \equiv \tilde{\varepsilon}_{it} + \chi_i R_t^M$, where $\tilde{\varepsilon}_{it}$ is an idiosyncratic shock to stock i's returns, satisfying $\mathbf{E}[\tilde{\varepsilon_{it}}] = 0$. Here, R_t^M can be correlated with ε_{it} because it systematically affects ε_{it} when $\chi_i \neq 0$. Typically, high-beta (low-beta) stocks tend to be associated with high (low) χ_i. Note that the systematic effects of R_t^M may not be controlled for by time dummies because χ_i can be different across individual stocks. At the same time, the BOJ purchases ETFs only when the stock returns in the morning session R_t^M are substantially negative; therefore, the relative amount of purchases across individual stocks ETF_{it} can be correlated with R_t^M as well. Hence, ETF_{it} and ε_{it} are also possibly correlated along with fluctuations in R_t^M, thus leading to a biased estimator of θ_1.

To deal with this potential endogeneity problem, we estimate the flow effects in equa-

Table 3: Effect of the BOJ's ETF Purchases on Daily Stock Returns

	(1)	(2)	(3)
	r_{it}	r_{it}	r_{it}
ETF	35.98***	52.98***	58.68***
	(0.631)	(1.127)	(1.217)
Nikkei_TPX			-0.509***
			(0.0223)
Individual Stock Fixed Effect	YES	YES	YES
Time Fixed Effect	No	YES	YES
N	1251307	1251307	1250501

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The table reports the estimation results for the flow effect model of equation (6) based on samples on days when the BOJ purchased the ETF funds.

tion (6) by focusing only on the dates when the BOJ purchases ETFs.[9] It is important to note the following two points to understand our identification strategy. First, the BOJ does not adjust the purchase share across individual stocks in response to their contemporaneous stock prices, given that: (i) the BOJ does not purchase individual stocks but only ETFs, and (ii) the purchase share across ETFs under the program is preannounced. Hence, we can assume that the (relative) amount of BOJ's purchases of individual stocks ETF_{it} is not influenced by any idiosyncratic shocks to the relative returns of individual stocks, i.e., $Corr(ETF_{it}, \tilde{\varepsilon}_{it}) = 0$. Second, as shown in Section 2.1, the total amount of purchases given intervention $\mathbf{E}_t[ETF_t|D_t = 1]$ is independent of stock returns in the morning session R_t^M. As the purchase shares across ETFs are preannounced, we can assume that $\mathbf{E}_t[ETF_{it}|D_t = 1]$ is also independent of aggregate stock returns, i.e., $Corr(ETF_{it}, R_t^M|D_t = 1) = 0$. Hence, by combining these two assumptions, i.e., $Corr(ETF_{it}, \tilde{\varepsilon}_{it}) = 0$ and $Corr(ETF_{it}, R_t^M|D_t = 1) = 0$, we can assume that ETF_{it} given intervention is uncorrelated with ε_{it}, i.e., $Corr(ETF_{it}, \varepsilon_{it}|D_t = 1) = 0$, suggesting that θ_1 in equation (6) is properly identified as the flow effects by focusing only on the dates when the BOJ purchases ETFs.

Table 3 shows the estimation results for the flow effects of the BOJ's ETF purchases. In

[9]The identification strategy is similar to that in Harada and Okimoto (2021)

line with previous studies mentioned in the Introduction, the table indicates that the BOJ's ETF purchase program has instantaneous "flow effects" at least on the day of purchase. More specifically, the baseline estimation in column (1) indicates that a one-basis-point increase in the BOJ's ETF purchases relative to market values raises the daily stock return by around 0.5 percentage points.[10] Given that the average daily purchases of individual stocks is about 0.6 basis points of issued stock, the average impact of the ETF purchases on stock prices is about 0.3 percentage points. The estimation result is almost unchanged even with time dummies (column 2 in Table 3). As described in Section 2.2, however, the amount of BOJ purchases is relatively larger for stocks with higher weights in the Nikkei 225 index. Hence, the significant θ_1 in columns (1) and (2) may capture some effects of higher weights in Nikkei 225 rather than the BOJ's ETF purchases. To deal with the possibility of spurious correlations, we include the Nikkei–TOPIX ratios defined in equation (5) as a control variable, but the main result is almost unchanged (column 3 in Table 3).

In sum, Table 3 implies that the BOJ's ETF purchase program has instantaneous flow effects. However, given that this program aims to support economic activity by lowering equity risk premia, a more relevant policy question is whether it can persistently lower equity risk premia in addition to instantaneously supporting daily returns. As emphasized by Bernanke (2020) in the context of the bond purchasing program, the persistence of policy effects is always an issue for any asset purchase program. That is, given the monetary policy objective, any central bank's asset purchase programs for government bonds, mortgage-backed security (MBS), and ETFs are expected to have persistent effects on asset prices rather than instantaneous and temporary effects. In the following section, we address this policy question by examining our hypothesis based on the effects on the market beta.

[10]The estimated impact is comparable to one estimated by previous literature. For example, Charoenwong et al. (2021) find that the BOJ's indirect stock purchase of one basis point of the market value increases the stock price by 1.7 percentage points (Table IV of Charoenwong et al. (2021)).

3 BOJ's ETF Purchases and Systematic Risk

This section examines the hypothesis that the BOJ's ETF purchase program has decreased equity risk premia of Japanese stocks by lowering their systematic risk. Section 2 shows that: (i) the BOJ purchases ETFs when stock prices decline significantly (i.e., countercyclical ETF purchases), and (ii) the BOJ's purchase of ETFs mitigates the decline in stock prices at least on the day of purchase (i.e., instantaneous flow effects). These two empirical results imply that the BOJ's ETF purchase program possibly weakens the correlation between the returns of Japanese stocks and the returns (and volatility) of the global market portfolio by leaning against the wind in stock markets, thus lowering systematic risks for Japanese stocks. While the BOJ decides whether it purchases ETFs by looking at the price changes in Japanese stock markets in the morning session rather than global stock markets, Japanese stock markets basically follow the trend in global stock markets on the previous day. Therefore, from the global equity investors' viewpoint, Japanese stocks could be a good hedge against the global market portfolio because of the BOJ's countercyclical ETF purchases.

To investigate the relationship between the BOJ's ETF purchase program and the systematic risk for Japanese stocks, we examine the effects of BOJ's ETF purchases on the following three measures of systematic risk, namely: (1) market beta, (2) downside/upside beta, and (3) coskewness. In the rest of this section, we estimate the systematic risk for Japanese stocks by period for each measure of systematic risk. Then, we examine the effects of the BOJ's ETF purchases on changes in systematic risk measures in each period using a panel regression analysis.

3.1 Different Phases of the ETF Purchase Program

For the time window to estimate systematic risk, we use the following four equally divided four-year windows in our baseline estimation to capture the policy changes listed in Table 1: (i) Aug.2006–Jul.2010, (ii) Aug.2010–Jul.2014, (iii) Aug.2014–Jul.2018, and (iv) Aug.2018–Dec.2021. First, the BOJ started the ETF purchase program in December 2010, immediately after the beginning of period (ii); therefore, period (i) is unaffected by the BOJ's ETF

Table 4: Summary Statistics of the BOJ's Purchase Amounts

Variable	Mean	Std. Dev.	Min.	Max.	
ETF_BOJ					
(ii) Aug. 2010–Jul. 2014	0.42	0.58	0	5.83	1935
(iii) Aug. 2014–Jul. 2018	1.75	1.40	0	14.17	2143
(iv) Aug. 2018–Dec. 2021	1.78	0.64	0.05	3.74	2172
ΔETF_BOJ					
(i) → (ii)	0.46	0.59	0	5.85	1755
(ii) → (iii)	1.47	0.86	-0.31	8.52	1935
(iii) → (iv)	0.05	1.04	-10.85	2.14	2143

Note: ETF_BOJ indicates the cross-sectional average of the total purchased amount of each stock in each period shown as the ratio to its market value (measured as a percentage) and ΔETF_BOJ shows its change from the previous period. For details of the calculation, see Appendix.

purchase program, while period (ii) is affected by the introduction of the ETF purchase program. Then, in periods (ii) and (iii), the BOJ expanded the program substantially and changed the purchase amount and shares across ETFs. In particular, in October 2014, the BOJ announced that the annual purchase amount was being tripled by increasing its target to three trillion yen. As the BOJ purchases ETFs tracking Nikkei 225 in addition to those tracking TOPIX, the purchase amount of stocks with higher Nikkei–TOPIX ratios increased more substantially during those periods, thus generating significant changes in cross-sectional variation between windows (ii) and (iii). Finally, at the beginning of period (iv) in August 2018, the BOJ reduced the purchasing amount of ETFs that track Nikkei 225 by half, while keeping the total purchase amount unchanged. This policy change led to large decreases in the purchasing amount of stocks with higher Nikkei–TOPIX ratios.

Table 4 shows the summary statistics of the BOJ's ETF purchases by period. The table confirms the plausibility of our definition of the subsample periods. The purchasing amount by the BOJ increased from 0.4% of the market value at the beginning of the program in period (ii) to 1.7% in period (iii). In addition, the variation in the purchase amount across stocks increased from period (ii) to period (iii), i.e., from 0.6% to 1.4% of the market value, reflecting that the BOJ substantially increased the total purchase amount of ETFs, while maintaining the higher purchase weights on ETFs tracking the Nikkei 225 index. In period (iv), the heterogeneity in purchase amounts across individual stocks was substantially reduced because of the adjustment of the purchase method as mentioned above. As emphasized in Subsection 2.2, these policy shifts induced changes in the cross-sectional variation of the BOJ's indirect purchases across individual stocks, thus helping us identify the policy effects in a panel regression analysis.

3.2 Market Beta

As a primary measure of systematic risk, we examine the effects of the BOJ's ETF purchases on market beta with regard to the global stock index. This subsection first estimates a market beta of Japanese stocks based on the CAPM in each period discussed above. Then, we examine the effects of the BOJ's ETF purchases on the market beta by a panel regression, as well as a cross-sectional regression. Finally, as a robustness check, we estimate market betas by Fama–French multifactor models and examine the policy effects on the estimates.

3.2.1 Estimation of CAPM Market Beta

According to a standard CAPM, a market beta for individual Japanese stock i in period t, $Beta_{it}$, is estimated by:

$$\frac{R_{i\tau}}{\Delta FX_{\tau}} - R_{\tau}^{f} = \alpha_{it} + \hat{Beta}_{it} \times \left(R_{\tau}^{M} - R_{\tau}^{f}\right) + \varepsilon_{i\tau} \text{ where } \tau \in t. \tag{7}$$

We use the four periods, i.e., $t \in \{1, ..., 4\}$, as described in Subsection 3.1. $R_{i\tau}/\Delta FX_{\tau}$ is the weekly return of stock i on a US dollar basis for week τ included in period t, where $R_{i\tau}$ is the weekly return of stock i on a Japanese yen basis and ΔFX_{τ} is the weekly change in the yen–dollar exchange rate. As a proxy of the return of the market portfolio and a risk-free asset, R_{τ}^{M} and R_{τ}^{f}, the weekly return of the FTSE ALL-World Index and the six-month US treasury are used, respectively. α_{it} is a CAPM alpha of stock i in period t, which is estimated as a constant term in the regression.

Table 5 shows a summary of the estimated CAPM market betas in each period. Some remarks are in order. First, the table shows that the market betas of Japanese stocks have been driven by an aggregate shock in addition to idiosyncratic shocks. In particular, the table shows that the market betas of Japanese stocks have been increasing during the

Table 5: Summary of Beta Estimation

Period	Mean	Std. Dev.	Min.	Max.	N
(i) Aug.2006–Jul.2010	0.393	0.349	-1.875	4.23	2285
(ii) Aug.2010–Jul.2014	0.631	0.906	-6.464	29.112	2238
(iii) Aug.2014–Jul.2018	0.578	0.476	-14.377	3.086	2325
(iv) Aug.2018–Dec.2021	0.793	0.312	-0.532	2.433	2279
(i) → (ii)	0.199	0.251	-2.367	2.49	2113
(ii) → (iii)	-0.075	0.897	-28.581	6.785	2122
(iii) → (iv)	0.211	0.48	-2.081	15.388	2228

Note: The table shows the summary statistics of the estimated CAPM market betas for each individual stock based on equation (7) by using weekly stock returns for each sample period as defined in the first column of the table. The sixth to eighth rows indicate those for changes in the market beta from the previous period.

sample periods on average. As we hypothesize that the Japanese stocks' market betas should have *decreased* because of the BOJ's ETF purchase program, the increasing trend in market beta implies that it is difficult to identify the policy effects, if any, only using time series variations.[11] Second, the table shows substantial cross-sectional variation across individual stocks. In addition to the level of the market betas, there is substantial cross-sectional variation for *changes* in the market betas as well. For instance, from the first to the second window, the market betas increased by 0.199 on average, but the standard deviation of the changes in market betas is 0.251, implying that the market betas of individual stocks experienced large idiosyncratic shocks.[12]

3.2.2 Fixed Effect Estimation of Policy Effects on Market Beta

Using the estimated CAPM market beta of Japanese stocks, we first estimate the effects of the BOJ's ETF purchases on the market beta by a panel regression analysis. Specifically, we estimate:

$$Beta_{it} = FE_i + T_t + \phi_1 ETF_{it} + \phi_2 X_{it} + \varepsilon_{it}, \quad \text{where } t \in \{1, ..., 4\} \tag{8}$$

[11]The reason why the average market beta with respect to the global equity index increased during the sample periods is beyond the scope of this paper, but it might reflect an increase in the importance of the Japanese firms' foreign business through foreign direct investment.

[12]The fact that the market betas are time-varying is consistent with the previous empirical works in other countries. See, for instance, Jagannathan and Wang (1996).

where $Beta_{it}$ is the estimated market beta of stock i in period t, and ETF_{it} is the sum of the BOJ's purchases of stock i divided by the market value of stock i in period t. Note that the subscript t indicates the period for estimating the market beta. We also include a time-invariant fixed effect of stock i and the time dummy, FE_i and T_t, as well as a vector of control variables X_{it}. The time dummy T_t is expected to absorb all effects of macroeconomic and aggregate policy changes, including changes in the aggregate amount of ETF purchases and the potential confounding effects coming from other monetary policy changes. In the estimation, the coefficient of interest is ϕ_1, which measures the marginal effects of the BOJ's ETF purchases on the market betas.

Columns (1) and (2) in Table 6 show the results for the effects of the BOJ's ETF purchase program on the CAPM market betas. Column (1) shows the results without control variable X_{it} in the regression model (8), while column (2) shows those with X_{it} consisting of a) $NikkeiDummy_{it}$: dummy variable equal to one if stock i is included in Nikkei 225 at t, b) $log(P/Eratio_{it-1})$: log of forecast-base price-earnings ratio (PER) of i at $t-1$, c) $log(book\_to\_market_{it-1})$: log of book-to-market ratio of i at $t-1$, and d) $log(size_{it-1})$ is log of i's market value at $t-1$. Both of the estimated coefficients of ETF_{it} in columns (1) and (2) are around -0.04 and statistically significant, indicating that the BOJ's ETF purchase program had significant and negative effects on the market betas of Japanese stocks and that a one percentage point increase in the BOJ's ETF purchases relative to the market value decreased the market betas by around -0.04. As for the result in column (2), it should be noted that the coefficient on ETF_{it} is almost unchanged from column (1) even when the Nikkei dummy is included as a control variable. As discussed in Section 2, the significant estimate of ϕ_1 in column (1) may capture some effects that stem from higher relative weights in Nikkei 225 rather than the BOJ's ETF purchases, given that the amount of the BOJ's purchases is larger for stocks with higher weights in Nikkei 225. The Nikkei dummy is included in column (2) to examine the possibility of spurious correlation. The result indicates that the marginal impact of the BOJ's ETF purchases is almost unchanged even after controlling for the Nikkei dummy, as well as the PE ratios, book-to-market ratios, and firm size.

Table 6: Effects of the BOJ's ETF Purchases on Market Beta

	(1) Beta	(2) Beta	(3) Beta (2y)	(4) Beta (2y)	(5) Beta (6w)	(6) $Beta^{3f}$	(7) $Beta^{3f}$	(8) $Beta^{4f}$	(9) $Beta^{4f}$
ETF	-0.045***	-0.041***	-0.054***	-0.057***	-0.044***	-0.047***	-0.044***	-0.049***	-0.046***
	(0.004)	(0.004)	(0.010)	(0.009)	(0.007)	(0.005)	(0.005)	(0.004)	(0.004)
log(P/E ratio)		0.025***		0.038***	0.029***		0.037***		0.034***
		(0.006)		(0.006)	(0.006)		(0.007)		(0.007)
log(book-to-market)		-0.058***		-0.071***	-0.062***		-0.085***		-0.078***
		(0.013)		(0.017)	(0.012)		(0.014)		(0.014)
log(size)		0.002		0.046***	0.016		-0.020*		-0.025**
		(0.010)		(0.011)	(0.010)		(0.012)		(0.014)
NikkeiDummy		0.067*		0.052	0.017		0.091**		0.109***
		(0.037)		(0.048)	(0.032)		(0.040)		(0.035)
Individual stock FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	7859	6998	13995	12968	10991	7867	6933	7871	6946
R^2	0.398	0.412	0.233	0.370	0.218	0.137	0.163	0.170	0.185

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The table reports the estimation results for the fixed effect model (8) with market betas as dependent variables. Columns (1) and (2) show the results for the model with the CAPM market betas estimated by the equally divided four-year windows as a dependent variable, while columns (3) and (4) show the results for the equally divided two-year windows. Column (5) is based on six periods that are defined according to changes in the policy framework. Columns (6)/(7) and (8)/(9) show the results for the models with the market betas estimated by a Fama–French three-factor model and four-factor model, respectively. The P/E ratio, book-to-market ratio, and size are one-period lagged variables. NikkeiDummy is a dummy variable that equals one if the stock is included in the Nikkei 225 index. The top and bottom 1% of market betas are removed as outliers.

3.2.3 Robustness Check

As a robustness check, we consider the following two alternative cases: (i) different windows for estimating market betas, and (ii) market betas derived by Fama–French three- and four-factor models.

In the first robustness check, we construct the equally divided two-year windows as well as the windows based on the BOJ's policy changes, and use those windows for estimating market betas in place of the equally divided four-year windows used in the baseline estimation. Furthermore, to construct the windows so that each window matches a major policy change of the program, we use the following six windows: (i) Oct.28.2006–Oct.27.2010, (ii) Oct.28.2010–Oct.30.2014, (iii) Oct.31.2014–Sep.20.2016, (iv) Sep.21.2016–July.30.2018, (v) July.31.2018–Mar.15.2020, and (vi) Mar.16.2020–Dec.31.2021. As in an event study analysis, these six windows are divided by the major five policy changes in Table 1, specifically the policy changes (1), (7), (11), (12), and (13) in the table, to exploit the effects of those major policy changes. As a result, while the length of periods is no longer the same across the windows, they capture the effects of policy changes more precisely than the baseline.

In the second robustness check, we estimate the market betas by regressing $R_{i\tau}/\Delta FX_\tau$ in (7) on $R^M_\tau - R^f_\tau$ (market factor), SMB_τ (size factor), HML_τ (value factor), and MOM_τ (momentum factor, used only for four-factor model) for each window $t \in \{1, ..., 4\}$.[13] Then, letting $Beta^{3f}_{it}$ and $Beta^{4f}_{it}$ be the estimated market betas from the three- and four-factor models, respectively, we estimate the effects of the BOJ's ETF purchases on the market betas according to (8) in which $Beta^{3f}_{it}$ and $Beta^{4f}_{it}$ are dependent variables.

The estimation results for the first and second robustness checks are shown in columns (3) to (5) and columns (6) to (9) of Table 6, respectively. Both results ensure the robustness of our results. For the first robustness check in columns (3) to (5), the estimation results using market betas estimated by the two-year windows (columns 3 and 4) as well as those estimated by the six windows based on the BOJ's policy changes (column 5) give almost the same results as in the baseline, implying that our baseline estimation is robust

[13] All factors are in US dollars and for developed markets (market-value weighted-average of 23 developed countries). For more details, see Kenneth R. French's website at `https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`.

Table 7: Cross-Sectional Regression for the BOJ's ETF Purchases and Market Beta

	(1)	(2)	(3)	(4)	(5)	(6)
Sample Period	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)
ΔETF	-0.049***	-0.041***	-0.020***			
	(0.008)	(0.007)	(0.006)			
Nikkei_TPX				-0.055***	-0.059***	0.059***
				(0.011)	(0.015)	(0.017)
Constant	0.174***	0.048***	0.217***	0.195***	-0.029***	0.199***
	(0.008)	(0.011)	(0.006)	(0.005)	(0.006)	(0.006)
N	976	1749	1895	1828	2015	2179
R^2	0.027	0.021	0.006	0.013	0.008	0.006

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Columns (1) to (3) show the OLS estimates of the cross-sectional model of equation (9) with the time differences of ETF_BOJ from the previous period as dependent variables. Columns (4) to (6) show the estimation results with the level of the Nikkei–TOPIX ratio as the dependent variable.

to the way of constructing the windows for panel regression. For the second robustness check in columns (6) to (9), the estimation using market betas estimated by the three-factor model (columns 6 and 7) and four-factor model (columns 8 and 9) give almost the same coefficients of ETF_{it} as in the CAPM case.

3.2.4 Cross-Sectional Regression of Policy Effects

While the panel regression analysis indicates that the BOJ's ETF purchase program has significantly lowered the market betas, the magnitude of the effect could change over time. To take into account those time varying effects, we also run a cross-sectional regression analysis for time differences of the market betas. More precisely, we run the following cross-sectional regression for each period separately:

$$\Delta Beta_{it} = T_t + \phi_1 \Delta ETF_{it} + e_{it}, \quad \text{where } t \in \{2, 3, 4\}. \tag{9}$$

where $\Delta[\cdot]$ indicates the time difference from the previous period.

The estimation results in columns (1), (2), and (3) in Table 7 confirm the baseline estimation results. Namely, in all the estimation results for periods (ii), (iii), and (iv), ϕ_1

is statistically significant and negative, which implies that the BOJ's ETF purchases have significant effects on changes in the market betas in all periods. Nevertheless, the absolute magnitude of the impact decreased, from -0.047 in period (ii) to -0.020 in period (iv), which implies that the effect of the BOJ's ETF program has become somewhat smaller over time.

Next, in order to confirm that ϕ_1 in (9) captures the effects of the BOJ's ETF purchases, we regress changes in the market betas on the level of the Nikkei–TOPIX ratios (Nikkei_TPIX in Table 7) instead of ΔETF. As shown in columns (4), (5), and (6), the Nikkei–TOPIX ratios have negative and statistically significant effects on changes in the market betas in periods (ii) and (iii), while they have positive and statistically significant effects in period (iv). The switch of the sign can be interpreted as reflecting the BOJ's policy change regarding the purchase amount across ETF types. Specifically, when the BOJ started and expanded the ETF purchase program around the beginning of periods (ii) and (iii), respectively, the BOJ purchased a large amount of ETFs tracking Nikkei 225. Therefore, the BOJ's purchase amount was larger for stocks with higher Nikkei–TOPIX ratios, which is consistent with the estimation results in columns (4) and (5). Then, around the start of period (iv), the BOJ decreased the purchase amount of ETFs tracking Nikkei 225 by half. Those policy changes are expected to raise the market betas of stocks with higher Nikkei–TOPIX ratios, consistent with the estimation results in column (6).

3.3 Downside Beta

As the second systematic risk measure, we examine the effects on the downside and upside betas proposed by Ang et al. (2006). The downside (upside) beta is different from the regular market beta in that the downside (upside) beta is estimated only by samples of market returns lower (higher) than the average. Therefore, the downside (upside) beta is expected to capture the possibility that investors have an asymmetric preference for downside and upside systematic risks. Ang et al. (2006) shows that the downside beta is a relevant measure of systematic risk of realized stock returns, and recently Lettau et al. (2014) shows that it explains not only stock returns but also various asset returns. In our analysis, examining the policy effects on the downside and upside betas is important because the BOJ tends to purchase ETFs when the market return is negative. If this

Table 8: Effects of the BOJ's ETF Purchases on Downside and Upside Betas and Coskewness

	(1)	(2)	(3)	(4)	(5)	(6)
	β_{down}	β_{down}	β_{up}	β_{up}	CoSkew	CoSkew
ETF	-0.032***	-0.027***	-0.037***	-0.022***	0.001**	0.001**
	(0.007)	(0.007)	(0.007)	(0.006)	(0.001)	(0.001)
log(P/E ratio)		0.044***		-0.009		-0.003***
		(0.009)		(0.010)		(0.001)
log(book-to-market)		-0.054***		-0.035*		-0.001
		(0.019)		(0.018)		(0.001)
log(size)		-0.045***		0.005		0.004***
		(0.015)		(0.017)		(0.001)
NikkeiDummy		0.099*		0.035		-0.002
		(0.060)		(0.066)		(0.004)
Individual stock FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
N	7865	7004	7870	6977	7866	6999
R^2	0.223	0.246	0.369	0.440	0.063	0.081

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The table reports the estimation result for the fixed effect model (8) with downside/upside betas and coskewness as dependent variables. Columns (1) to (2) and (3) to (4) show the results for the models with the downside beta and upside beta as dependent variables, respectively. Columns (5) and (6) show the results for the models with coskewness as a dependent variable. The top and bottom 1% of market betas are removed as outliers. The P/E ratio, book-to-market ratio, and size are one-period lagged variables. NikkeiDummy is a dummy variable that equals one if the stock is included in the Nikkei 225 index.

asymmetric policy behavior induces different policy effects on the downside and upside betas, separately estimating the policy effects on them gives more precise policy effects.

Columns (1) to (4) in Table 8 show the estimation results of the panel regression analysis about the effects of the BOJ's ETF purchases on the upside and downside betas. The downside (upside) beta is estimated by equation (7) for the four periods, using only samples with market returns lower (higher) than the average. Then, the effects of the BOJ's ETF purchases are examined by a panel regression of equation (8). The table shows that the BOJ's ETF purchases significantly decreased both the upside and downside betas. More specifically, for the downside beta, columns (1) and (2) show that a one percentage point increase in the BOJ's ETF purchases relative to the market value decreased the downside beta by around -0.03, while it also decreased the upside beta by the same degree in general.[14] These results are consistent with those for the CAPM and multifactor market betas.

3.4 Coskewness

As the third systematic risk measure, we examine the effects on coskewness proposed by Harvey and Siddique (2000). Coskewness is a systematic exposure to market volatility. More specifically, negative coskewness for a particular stock means that its return tends to be lower when the volatility of market returns is high. Harvey and Siddique (2000) shows that coskewness is a relevant measure of systematic risk to be compensated by higher returns, and recently Schneider et al. (2020) showed that coskewness can resolve the low-beta anomaly, i.e., low-beta stocks offer high risk-adjusted returns. In our analysis, examining the policy effects on coskewness is possibly important because the BOJ purchases ETFs only when the market return is *significantly* negative. As a significant decline in market returns is usually associated with high volatility of market returns, the BOJ's ETF purchases possibly influence the systematic relationship between Japanese stock returns and market volatility. Given that coskewness is a relevant measure of systematic risk that is not captured by a regular market beta, the policy effects on coskewness can induce additional policy effects on equity risk premia.

Following the empirical analysis in previous studies, the coskewness of stock i at time t, $CoSkew_{it}$, is estimated by:

$$\frac{R_{i\tau}}{\Delta FX_\tau} - R^f_\tau = \alpha_{it} + \hat{Beta}_{it} \times \left(R^M_\tau - R^f_\tau\right) + Co\hat{Skew}_{it} \times \left(R^M_\tau - R^f_\tau\right)^2 + \varepsilon_{i\tau} \text{ where } \tau \in t, \tag{10}$$

which implies that the coskewness captures an exposure to market volatility. Note that stocks with more negative coskewness are riskier ones because negative coskewness implies their returns are low during high-volatility periods. Using the estimated coskewness as a dependent variable, we estimate the policy effects of the BOJ's ETF purchases on

[14] Given the BOJ's asymmetric policy behavior, the significant effects on the upside beta are somewhat puzzling but possibly reflect the effects of return reversal. That is, as the BOJ's ETF purchases mitigate the price decline in a market downturn, the return reversal is also weak afterwards, thus lowering the upside beta as well.

coskewness by a panel regression analysis of equation (8).

Columns (5) to (6) in Table 8 show the estimation results of a panel regression analysis of the effects of the BOJ's ETF purchases on coskewness. The table shows that the BOJ's ETF purchases have statistically significant and positive effects on coskewness. This estimation result suggests that the ETF purchase program has contributed to making the negative influence of high market volatility on individual stock returns wane. The policy effects on coskewness should be distinguished from the effects on market beta identified in the previous subsections.

4 Policy Effects of BOJ's ETF Purchasing Program

This section quantifies the impact of the BOJ's ETF purchase program on the equity risk premia and stock prices of Japanese stocks. The previous section shows that the BOJ's ETF purchase program has significantly reduced systematic risks of Japanese stocks, measured by market beta, downside beta, and coskewness. In this section, we quantify how much the reduction in systematic risk measures affects the equity risk premia and stock prices of Japanese stocks. Specifically, first, we estimate the size of compensation for those systematic risks in the Japanese stock market, following traditional estimation analyses of the cross section of stock returns. Then, we conduct a back-of-the-envelope calculation for the policy effects of the BOJ's ETF purchase program on stock returns by feeding the estimated reduction in systematic risks into the estimation results of the cross section of stock returns.

4.1 Cross Section of Stock Returns

To quantify the relationship between excess returns and systematic risk exposures, we regress the realized average returns on the factor loadings of systematic risk measures. Following the previous literature, such as Ang et al. (2006), we control for the three key corporate characteristics identified as relevant variables for stock returns, namely, firm size, book-to-market ratios, and past returns. In addition, we include the time-invariant fixed effect and the time dummies to control for the market alpha and the realized macro factors, respectively. Finally, we exclude the top and bottom 1% of samples as outliers for all independent variables. In all the estimations, we use cluster-robust standard errors.

Table 9 shows the estimation results of the cross section of stock returns. Column 1 indicates that a high market beta is associated with high realized excess returns as predicted by the CAPM. In addition, the lagged corporate characteristics have statistically significant effects on excess returns. In line with the previous literature, small stocks and stocks with high book-to-market ratios offer high excess returns, i.e., the size and value effects. Furthermore, stocks with high past returns have low returns, i.e., return reversal. In column 2, we conduct the same exercise using a market beta estimated by the Fama–French three-factor model. The estimation results show that all the parameter estimates are almost the same as those in column 1, implying that our estimation results in column 1 are robust to changes in the estimation methodology of the market beta.

In column 3, we regress the realized excess returns on coskewness in addition to market beta. While the impact of the market beta on excess returns is almost unchanged from column 1, coskewness has negative and statistically significant effects on the realized excess returns. The negative coefficient implies that investors require additional compensation for stocks if their returns tend to be low in a high-volatility environment. Hence, consistent with previous studies using US data, such as Ang et al. (2006) and Schneider et al. (2020), coskewness represents an independent and additional exposure to systematic risk.

In column 4, we estimate the effects of the upside and downside betas separately. As in Ang et al. (2006), the estimation results indicate that both of them have statistically significant effects on excess returns and that stocks with a high downside (upside) beta are associated with high (low) excess returns. In column 5, we regress the realized excess returns on coskewness in addition to the upside and downside betas. In contrast to the estimation using a regular market beta in columns 1 and 3, coskewness does not significantly affect excess returns as an additional measure of systematic risk. This result is not surprising because market returns tend to be low during high-volatility periods. In fact, the correlation between coskewness and downside beta is high and more than 80% in our estimation, which implies that coskewness and downside beta possibly represent similar risk exposures and thus suffer from the multicollinearity problem. While Ang et al.

Table 9: Risk Factors and Stock Returns

	(1)	(2)	(3)	(4)	(5)
Beta	0.085***		0.080***		
	(0.021)		(0.021)		
Beta_3factor		0.082***			
		(0.019)			
CoSkew			-0.866***		-0.172
			(0.153)		(0.273)
β_{down}				0.089***	0.079***
				(0.014)	(0.023)
β_{up}				-0.041***	-0.033*
				(0.012)	(0.018)
log(book-to-market)	0.059***	0.061***	0.059***	0.059***	0.059***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
log(size)	-0.175***	-0.173***	-0.171***	-0.169***	-0.169***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
lagged stock return	-0.187***	-0.188***	-0.186***	-0.181***	-0.181***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Individual stock FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
N	6828	6828	6828	6828	6828
R^2	0.362	0.362	0.367	0.366	0.366

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The table shows the estimation results of panel regressions where the average weekly return of each stock is regressed on the estimated beta and risk factors using all sample periods.

(2006) emphasizes that the downside beta is an independent risk measure in the US stock market, even after controlling for coskewness, column 5 implies that this is not the case for the Japanese stock market.

In summary, the estimation results in Table 9 indicate that all three measures, namely, regular market beta, upside and downside beta, and coskewness, are relevant measures of systematic risk of Japanese stocks. In the following subsection, we quantify the policy effects of the BOJ's ETF purchases on excess returns and stock prices, based on the estimation results in Table 9 as well as those in Section 3.

4.2 Quantitative Impact on Risk Premia and Stock Prices

This subsection quantifies the policy effects of the BOJ's ETF purchases on excess returns and stock prices. Let ΔRP_{it} be the policy effects on the equity risk premia of stock i in time t, which are defined as the estimated decline in risk premia from those in the counterfactual case without the BOJ's ETF purchases. As the baseline estimates in column 2 of Table 6 indicate that the marginal effect of the BOJ's purchases on the market beta is $\phi = -0.041$, the estimated decline in the market beta of stock i caused by the BOJ's ETF purchases is calculated as $0.041 \times ETF_{it}$. Then, the decline in the market beta can be translated into the changes in risk premia of stock i by multiplying it by the coefficient on each risk exposure estimate in Table 9. As the table shows that the estimated impact of the market beta on excess returns is 0.085, we can calculate ΔRP_{it} by:

$$\Delta RP_{it} = 0.041 \times ETF_{it} \times 0.085.$$

Finally, changes in risk premia ΔRP_{it} can be transformed into changes in stock prices, $\Delta P_{it}/P_{it}$, by multiplying the price to earnings ratio (PER_{it}) under certain assumptions, [15]

$$\frac{\Delta P_{it}}{P_{it}} = -PER_{it} \times \Delta RP_{it}$$

[15] Based on the discounted dividend model, $P_{it} = D_{it}/r_{it}$, where D_{it} is a dividend payment and r_{it} is the discount rate of stock i. Hence, $dP_{it}/P_{it} = -(P_{it}/D_{it})\, dr_{it}$, implying that changes in the risk premium can be translated into the rate of changes in stock prices by multiplying the inverse of the dividend yield. In practice, the forecast-based PER is used as a proxy of the dividend yield here, given that the dividend yield is so volatile across stocks and over time.

Table 10: Effects of the ETF Program on Stock Returns

Stock index	TOPIX		Nikkei 225	
Period	ΔRP(%)	$\Delta P/P$ (%)	ΔRP(%)	$\Delta P/P$ (%)
One-factor beta				
(ii)	-0.16	3.61	-0.40	10.47
(iii)	-0.58	12.30	-1.15	30.36
(iv)	-0.43	11.05	-0.52	15.09
One-factor beta and coskewness				
(ii)	-0.20	4.53	-0.51	13.13
(iii)	-0.72	15.43	-1.44	38.08
(iv)	-0.54	13.86	-0.65	18.93

Note: The top and bottom panels show a back-of-the-envelope calculation for the reduction in risk premia and increase in stock prices based on the estimation results in column 2 of Table 6 and column 6 of 8, respectively. The impact of changes in the beta on risk premia is calculated using the estimation results in Table 9.

where ΔP_{it} represents the policy effects on stock prices of stock i at time t, which are defined by the gap from stock prices in the counterfactual case without the BOJ's ETF purchases. Once ΔRP_{it} and $\Delta P_{it}/P_{it}$ are calculated for individual stocks, we can compute the effects on stock price indices such as the TOPIX and the Nikkei 225 index by taking a weighted average using their share in each index.

Based on the baseline estimation using market beta as the sole measure of systematic risk, Table 10 quantifies the impact of the BOJ's ETF purchase program on the equity risk premia and stock prices of Japanese stocks for TOPIX and Nikkei 225 in each period. The table indicates that the BOJ's ETF purchase program has economically significant effects on risk premia and stock prices of Japanese stocks. In particular, during period (iii) in which the BOJ substantially increased their total amount of ETF purchases, the BOJ's ETF purchase program decreased the risk premia of TOPIX and Nikkei 225 by -0.58 and -1.15 percentage points and consequently increased TOPIX and Nikkei 225 index by 12.3 and 30.4 percentage points, respectively. The effects on Nikkei 225 were much larger than those on TOPIX, reflecting that the BOJ actively purchased ETFs tracking Nikkei 225. In the actual data, the increase in TOPIX and Nikkei 225 index from period (i) to (iv) was 41.5 and 96.9%, respectively, which implies that around one-fourth of the increase in stock prices during Abenomics can be accounted for by the effects of the BOJ's ETF purchase program.

While this estimation of policy effects in Table 10 is a reasonable starting point, it may underestimate the policy effects because the BOJ's ETF purchases possibly have effects on equity risk premia by affecting measures of systematic risks other than the market beta. In particular, column 3 in Table 9 identifies coskewness as an independent and additional risk exposure. Hence, in the lower part of Table 10, we take into account the possibility that the BOJ's ETF purchase program has policy effects on equity risk premia by influencing coskewness in addition to the market beta. Specifically, based on the estimation results in column 3 of Table 9, we calculate the policy effects by:

$$\Delta RP_{it} = 0.041 \times ETF_{it} \times 0.080 + (-0.001) \times ETF_{it} \times (-0.866).$$

The first and second parts in this equation represent the policy effects through lowering the market beta and coskewness, respectively. The lower part of Table 10 indicates that the policy effects are estimated to be around 20% larger than the baseline estimation, in which market beta is considered the sole risk exposure. Specifically, during period (iii) in which the BOJ substantially increased the total amount of ETF purchases, the BOJ's ETF purchase program decreased the risk premia of TOPIX and Nikkei 225 by -0.72 and -1.44 percentage points and consequently increased the TOPIX and the Nikkei 225 index by 15.4 and 38.1 percentage points, respectively. Hence, the BOJ's ETF purchase program, which counteracted stock price declines during the high-volatility periods, lowered equity premia by reducing the coskewness of Japanese stocks. In other words, if we ignore the policy channel to lower the equity risk premia through reducing coskewness, the policy effects are possibly underestimated.[16]

The quantitative results in Table 10 are informative but subject to the following caveats. First, the quantitative results in the table possibly overestimate the policy impact on

[16]When using the estimation results based on the downside and upside betas in column 4 of Table 9, the policy effects are still economically significant but smaller than the two baseline cases in Table 10 by around 30%. The small policy effects stem from the fact that the BOJ's ETF purchases lower the upside betas in addition to the downside betas and thus offset some of the policy effects through lowering the downside betas. As shown by Ang et al. (2006), however, the sign and size of the coefficient on the upside betas is not robust to including control variables, implying that the policy exercise based on the upside and downside betas may not be robust as well.

stock prices because the formula that we use to translate the changes in risk premia into those in stock prices presumes that the decline in risk premia is permanent. Hence, if market participants took the decline in risk premia caused by the BOJ's ETF purchases as temporary effects, the impact on stock prices would be smaller. Second, the quantitative results in the table may underestimate the policy effects because we quantify only those through a specific channel for lowering risk premia. In particular, the cumulative increase in ETFs on the BOJ's balance sheet may affect equity risk premia through some other channels, such as the "stock effects" of the bond purchase program on term premia.[17] Given those possibilities of under- and overestimating policy effects, the quantitative results in the table should be interpreted with some caution.

Finally, given the substantial effects of the BOJ's ETF purchase program through lowering the market betas and coskewness, our quantitative analysis has the following policy implications for the exit strategy of the BOJ's ETF purchase program. While the BOJ has not made any announcement about the exit strategy as of April 2022, it has decreased the frequency of ETF purchases since 2021 and purchased ETFs only when stock prices in the morning session declined more substantially. Considering that the policy effects depend on the effects on the correlation with market returns and volatility, such policy shifts can be interpreted as a way of reducing the purchase amount while minimizing the adverse effects on stock prices. Furthermore, our quantitative analysis implies that if the BOJ needs to sell ETFs purchased in the past, the adverse effects on stock prices can be minimized by selling ETFs periodically (or randomly) with an option not to sell them when stock prices decline or when stock price volatility increases. Having an option to stop selling ETFs in low-return or high-volatility periods is essential for reducing the correlation with the market portfolio, thus mitigating the possible rise in risk premia caused by the BOJ's ETF divestment.

[17]For details of the stock effects of the bond purchase program, see D'Amico and King (2013).

5 Conclusion

In this paper, we investigate the effects of the BOJ's ETF purchase program on equity risk premia. We construct a unique panel dataset for the amount of individual stock that the BOJ indirectly purchased in the program. The dataset shows significant cross-sectional and time-series variations across individual stocks because of their different weights in ETFs and the BOJ's policy changes regarding the purchasing share across ETFs. Utilizing the cross-sectional and time-series variations, our empirical analysis reveals that the BOJ's ETF purchases have decreased systematic risk for Japanese stocks, thus leading to an economically significant decline in risk premia.

Note that while this paper indicates the significant effects on equity risk premia, it does not endorse the BOJ's ETF purchase program as an efficient and desirable policy. To evaluate the efficiency and desirability of the ETF purchase program, it is necessary to assess the effects on economic activity and take into account the associated cost, including unintended distributional effects across businesses. Such an analysis from the optimal policy perspectives is an interesting future topic.

Appendix

This appendix explains the construction of the time-series dataset for the amount of the BOJ's ETF purchases by ETF type, i.e., (i) TOPIX tracking ETFs, (ii) Nikkei 225 tracking ETFs, and (iii) JPX400 tracking ETFs. In construction, two data sets are used. First, the total amount of ETF purchases by the BOJ is available from the BOJ's webpage on a daily basis.[18] Second, the total net assets of individual ETFs listed on Tokyo Stock Exchange are available at Japan Investment Trust Association.[19]

We must allocate a total daily amount of ETF purchases by the BOJ to (i) the amount of TOPIX tracking ETF purchases, (ii) that of Nikkei 225 tracking ETF purchases, and (iii) that of JPX400 tracking ETF purchases, following the BOJ's actual implementation as precisely as possible by using information that is publicly available.

[18] `https://www3.boj.or.jp/market/en/menu_etf.htm`

[19] `https://toushin-lib.fwg.ne.jp/FdsWeb/` (only Japanese page available)

Such an "allocation rule" is considered to vary over time in line with the policy changes by the BOJ. Specifically, we allocate daily ETF purchases by the above three different tracking types of ETF using the following rule (major changes from the previous rule shown in *italic*) for periods 1 to 5.

1. From December 15, 2010 to October 31, 2014: the total amount of daily BOJ purchases is proportionally allocated to (i) TOPIX tracking ETFs and (ii) Nikkei 225 tracking ETFs, according to total net assets of each type.

2. From November 19, 2014, to September 30, 2016: the total amount of daily BOJ purchases is proportionally allocated to (i) TOPIX tracking ETFs, (ii) Nikkei 225 tracking ETFs, *and (iii) JPX400 tracking ETFs,* according to the total net assets of each type.

3. From October 1, 2016, to August 5, 2018: *(I) Three trillion yen out of 5.7 trillion yen* of the total amount of daily BOJ purchases is proportionally allocated to (i) TOPIX tracking ETFs, (ii) Nikkei 225 tracking ETFs, and (iii) JPX400 tracking ETFs, according to the total net assets of each type. *(II) The remaining 2.7 trillion yen out of 5.7 trillion yen of the total amount is allocated to TOPIX tracking ETFs.*[20]

4. From August 6, 2018, to April 30, 2020: (I) *1.5* trillion yen out of 5.7 trillion yen of a total amount of daily BOJ purchases is proportionally allocated to (i) TOPIX tracking ETFs, (ii) Nikkei 225 tracking ETFs, and (iii) JPX400 tracking ETFs, according to the total net assets of each type. (II) The remaining *4.2* trillion yen out of 5.7 trillion yen of the total amount is allocated to TOPIX tracking ETFs.[21]

5. From May 1, 2020 to March 31, 2021: (I) *25%* of the total amount of daily BOJ purchases is proportionally allocated to (i) TOPIX tracking ETFs, (ii) Nikkei 225 tracking ETFs, and (iii) JPX400 tracking ETFs, according to *amounts outstanding in the circulation of each type*. (II) The remaining *75%* of the total amount is allocated to TOPIX tracking ETFs.

[20]This rule is based on BOJ's policy change made on September 21, 2016, which was effective from October 2016. https://www.boj.or.jp/en/announcements/release_2016/rel160921c.pdf

[21]This rule is based on BOJ's policy change made on July 31, 2018, which was effective from August 6, 2018. https://www.boj.or.jp/en/announcements/release_2018/rel180731h.pdf

6. From April 1, 2021 to the present:[22] All BOJ purchases are allocated to TOPIX tracking ETFs.[23]

To calculate the allocated amounts by ETF type for the period 5 (From May 1, 2020 to March 31, 2021), we need to have "*the amounts outstanding in the circulation of each type*"of (i), (ii), and (iii). Here we take a standard interpretation that the amount of ETFs in circulation of type j is obtained by subtracting the BOJ's holding of ETFs of type j from the total net amount of ETFs of type j. The BOJ's ETF holdings for type j (measured by market value) are calculated as follows. First, select the size of ETF purchases on the *first* day of the purchase program and compute the amount allocated to type j, following the rule discussed above. Note that the *first* day belongs to period 1 (From December 15, 2010 to October 31, 2014) , and at this point this amount is a flow variable. Second, compute the market value of the BOJ's ETF holdings allocated to type j on the *second* day of the purchase program in the same way as in the previous step. If no purchase is implemented, simply use a value of zero. Third, take the summation of (A) BOJ's ETF holdings of type j on the second day and (B) BOJ's ETF holdings of type j on the first day *multiplied by the associated index daily returns (rate of change in prices) on the second day*. Note that this amount is the BOJ's ETF holdings of type j on the second day, which is a stock variable. Finally, iterate the same steps from the third day onward.[24]

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[22] As of February 2022.

[23] The decision was made on March 23, 2021 and became effective from April 1, 2021. https://www.boj.or.jp/en/announcements/release_2021/rel210323d.pdf

[24] The returns of TOPIX, Nikkei 225, and JPX400 are from Bloomberg.

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