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Skewed Interest Rate Expectations and Effects of Central Banks' Market Operations: Empirical Findings Using Granular Transaction Data*

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Abstract

Using trade repository data on transaction records of Japanese yen-denominated overnight index swap, we estimate individual market participants' expectations on future interest rates and document their time-variant distribution with its higher order moments. By leveraging this novel information, we implement quantitative exercises to verify the state-dependent effects of the Bank of Japan (BoJ)'s outright purchase of Japanese Government Bonds (JGBs) on the JGB yields conditional on the moments of this expectation distribution. We find that the BoJ's fixed-rate purchase operation resulted in a larger reduction of the JGB yields when the expectation distribution on future interest rates was skewed more positively. This empirical result implies the usefulness of the estimated expectation distribution for central banks to conduct market operations effectively.

Keywords: *Interest rate expectations, skewness, granular data, trade repository, overnight index swap, market operation*
JEL classification: E43, E58, G15, G20.

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1. Introduction

Since around the 2000s, central banks in many advanced countries have implemented government bond purchases as a part of their unconventional monetary policy. This market operation is remarkable in its size. For example, the amount of Japanese Government Bonds (JGBs) purchased by the Bank of Japan (BoJ) during 2023 was 113 trillion Japanese Yen (JPY), which was almost equivalent to the net issuance amount for the same period.[1] Against this backdrop, extant literatures study the impact of central banks' government bond purchases and report their effects in lowering the bond yields (e.g., D'Amico and King, 2013; Krishnamurthy and Vissing-Jorgensen, 2011; Nakazawa and Osada, 2024). Furthermore, recent papers show some evidence about the heterogeneity in the effects of monetary policy conditional on economic agents' beliefs. To illustrate, Bauer et al. (2022) indicate that the impact of FOMC announcements on financial markets weakens when the variance of investors' expectations on future interest rates becomes larger. Therefore, understanding the state-dependent effects of market operations conditional on economic agents' beliefs is critical for central banks to effectively achieve policy targets.

In the present paper, we examine the state-dependent effects of the BoJ's market operations in affecting the JGB yields conditional on the heterogeneity in market participants' expectations. Specifically, we develop a novel estimate of individual market participants' expectations on future interest rates by leveraging the granular data of over-the-counter (OTC) derivative transactions, and estimate the effects of the BoJ's market operations which may depend on these expectations. To this end, first, we use trade repository data on transaction records of JPY-denominated overnight index swap (OIS) and estimate the market participants' expectation distribution on future interest rates at each point in time. Subsequently, we compute the first to fourth order moments of the estimated expectation distribution and verify the effects of the BoJ's market operations conditional on these moments. Particularly, we pay attention to the fixed-rate purchase operation, which purchases an unlimited amount of JGBs at a specific target level, among the BoJ's diverse market operations, because little work has been devoted to examining its effects despite the extensive use by the BoJ under the Yield Curve Control (YCC).

Our empirical methodology consists of two steps. First, using the transaction records of JPY-denominated OIS from January 2022 to September 2024, we implement a high-dimensional

[1] The net issuance amount is the amount of issuance subtracting the redemption.

panel estimation, which assigns the dummy variables to individual market participants as well as time stamps, to extract each participant's time-variant expectations on future interest rates. Namely, we regress the prices of OIS, which are a predetermined fixed rate paid by OIS buyers to receive a floating rate, on these multiple dummy variables. Given that the sum of estimated fixed effects is idiosyncratic for each participant and time period, we interpret it as the individual market participant's expectation on future interest rates for the specific time interval. Second, we draw the distribution of these interest rate expectations and compute the first to fourth order moments (i.e. mean, variance, skewness and kurtosis).[2] We use this novel information from January 2022 to March 2024 to examine how the marginal impact of the BoJ's fixed-rate purchase operation on the JGB yields depends on the moments of market participants' expectation distribution.

Our focus is the third order moment of the expectation distribution (i.e. skewness). We conjecture that the BoJ's fixed-rate purchase operation causes a larger reduction in the JGB yields under the higher third order moment of the distribution (i.e. more positively skewed). This hypothesis is contrastive to the prior research which focuses on the second order moment as a determinant of the effects of monetary policy (Falck et al. 2021; Bauer et al. 2022; Barbera et al. 2023). The intuition of our conjecture is as follows. Suppose, for given first and second order moments, the third order moment becomes higher. This indicates that there are a small number of participants predicting extremely higher interest rates in the future while the majority are expecting relatively lower interest rates. Under this condition, the fixed-rate purchase operation can induce the participants with extremely high interest rate expectations above the fixed-rate purchase operation's target yield to revise down their expectations.

Our unique empirical findings are threefold. First, the expectation distribution on future interest rates evolved over time, which allows us to compute the first to fourth order moments. Such a distribution accounted for the heterogeneity in market participants' expectations on

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[2] There are some other data for the market expectation on future interest rates. For example, data vendors such as Bloomberg provide World Interest Rate Probabilities (WIRP), which is the implied forecast for policy rates computed from market prices of OIS contracts. Researchers can also obtain the implied probability distribution on future interest rates computed from option prices of interest rate swaps (swaption premium), as in Yoneyama et al. (2024). Compared to these data, our granular data have the following characteristics. First, although WIRP indicates a representative value on the market expectation, our granular data provides individual market participants' expectations, enabling us to calculate their distribution with its higher order moments. Second, while the implied probability distribution computed from swaptions is mainly based on the transaction motives of "the insurance for a rainy day," our granular data, which employ interest rate swaps, reflect more general transaction motives among market participants.

future interest rates. Second, regarding the fixed-rate purchase operation, its impact on the JGB yields became smaller (i.e. interest rates declined less) when the variance of the expectation distribution was larger (i.e. the higher second order moment). This finding supports the results reported in the extant studies such as Bauer et al. (2022). Third, the impact of fixed-rate purchase operation became larger (i.e. interest rates declined more) when the distribution of market participants' expectations was more positively skewed (i.e. the higher third order moment). Positive skewness means that the majority of market participants predict interest rates to stay low while a small group of participants expect extremely high interest rates. Our empirical results suggest that the BoJ's fixed-rate purchase operation effectively induced investors with extremely high interest rate expectations to moderate their views, resulting in a larger decline in the JGB yields.[3]

Our contribution is to extend the prior research studying the impact of the second order moment of the expectation distribution among market participants by comprehensively taking into account higher order moments of the distribution. This implication is quite informative for policymakers to design their market operations. Central banks could be better informed by measuring the distribution of market participants' expectations on future interest rates and could adjust their market operations to achieve policy targets effectively.

The rest of this paper is organized as follows. In section 2, we go over the related studies. After presenting our empirical strategy and data in section 3 and 4, we report our empirical results in section 5. In section 6, we present an anecdotal episode of the BoJ's market operations to obtain some implications from empirical results. We add robustness checks in section 7. Section 8 concludes.

[3] Given our second and third empirical findings, we conjecture that the impact of fixed-rate purchase operation may not be sufficiently powerful to change the views of market participants when their expectations are extremely variant (i.e. the higher second order moment), but that it may be strong enough to alter a small group of market participants expecting extremely high interest rates when the rest majority are expecting lower interest rates (i.e. the higher third order moment). We may be able to add some hypothesis for this conjecture. When the variance of expectation distribution is large, the central bank's messages may not be a dominant factor for market participants in forming their expectations because they pay less attention to the central bank, which weakens the effects of the fixed-rate purchase operation. However, when the skewness of expectation distribution is large, the consistent and strong messages from the central bank behind the fixed-rate purchase operation may alter a small group of market participants expecting extremely high interest rates, which amplifies the effects of this operation. We leave the theoretical rationalization behind this conjecture to a future research agenda, as the present paper is tailored to be empirical.

2. Related Literature

This paper is related to the literature on the state-dependent effects of monetary policy conditional on the heterogeneous expectations held by firms, households or market participants and to the research on how economic agents receive the information from central banks. For example, Falck et al. (2021) examine how the disagreement about inflation expectations affects the transmission of monetary policy. They show that, contrary to the economic intuition, inflation can actually rise in response to monetary tightening shocks when the variation of inflation expectation is large. They conjecture that, under the higher dispersion on the firms' outlooks on economic developments, the central bank's decision of raising the interest rate can serve as a signal of increasing demand of the economy and can lead firms to raise prices. Similarly, Barbera et al. (2023) analyze how the impact of monetary policy is state-dependent on the disagreement of trend and cyclical inflation. They find that when the degree of disagreement on cyclical inflation is high, monetary tightening shocks tend to raise price levels instead of lowering them.

In the same context, Bauer et al. (2022) focus on financial markets and examine how the uncertainty in future policy rates determine the effects of monetary policy. Specifically, they develop an uncertainty index extracted from the prices of Eurodollar futures and options. Then, using monetary policy shocks constructed from Eurodollar futures, they empirically examine how the responses of asset prices to FOMC announcements depend on this uncertainty measure. Their results suggest that the asset prices show weaker responses to monetary policy shocks when such an uncertainty measure is high. They conjecture that, in the presence of interest rate uncertainty, market participants can gain only less precise information from the central bank's messages and pays less attention to them, which leads to a more muted reaction of asset prices in response to monetary policy shocks. Similarly, Bundick et al. (2021) and De Pooter et al. (2021) extract measures of interest rate uncertainty from derivative transactions to examine its impact on monetary policy effects. These papers indicate that the effects of monetary policy are state-dependent on the dispersion of economic agents' beliefs.

In the present paper, we follow this strand of literature that have reported the mixed results on the state-dependent effects of monetary policy. As a unique feature, we compute a novel measure of expectation distribution on future interest rates among market participants and use it to examine how the multiple moments of this expectation distribution affect the effects of central banks' market operations. Our paper deviates from Bauer et al. (2022) in that while they consider only the first and second order moments, we employ multiple higher order moments (i.e., first to fourth order moments) to capture the complex market environments potentially affecting the effects of central banks' market operations. In this sense, our paper is closely related to Dong et al. (2024), who focus on the variance and skewness in household inflation expectations, while we study market participants' expectations on future interest rates.

This paper also relates to prior research leveraging the trade repository data. Since the Global Financial Crisis, various countries have introduced trade repository systems to accumulate detailed data on OTC derivative transactions and started to utilize them for research to understand the financial market. For example, Cenedese et al. (2020), using highly granular data on interest rate swap transactions in the UK, quantify the existence of significant price differences between centrally and non-centrally cleared transactions (i.e. OTC premium). They attribute such OTC premium to differences in the bargaining power of dealers and customers and to various valuation adjustments. Miyakawa et al. (2023) also examine whether OTC premium exists, including the period when international financial regulations of OTC derivative transactions sufficiently progressed. They measure OTC premium using trade repository data on interest rate swap transactions in Japan from April 2013 to October 2021. We follow this strand of literatures and broaden the scope of analysis to the effects of central banks' market operations.

3. Empirical Strategy

Our empirical analysis consists of the following two steps. First, we estimate the evolution of market participants' expectations on future interest rates. Specifically, using the transaction records of JPY-denominated OIS, we conduct a high-dimensional panel estimation regressing the OIS prices with the dummy variables for individual market participants and time stamps. Since the OIS prices are predetermined fixed rates paid by OIS buyers to receive Tokyo Over Night Average (TONA) rate during the contracted period, the sum of estimated fixed effects accounts for the average fixed rate which each buyer (seller) agrees to pay (receive) in exchange of receiving (paying) the future floating rate. Therefore, we can interpret the sum of estimated fixed effects as the individual market participants' interest rate expectations from the effective day over the contracted period, and thus we can draw their time-variant expectation distribution. Second, we conduct a panel regression to test how the distribution of market participants' expectations on future interest rates can affect the impact of the BoJ's market operations on the concurrent JGB yields. To this end, we compute the first to fourth order moments of the time-variant expectation distribution and regress the JGB yields with these moments and the variables capturing the BoJ's market operations. The aim of this study is to gain insights of the state-dependent effects of the BoJ's market operations.

In extracting the market participants' expectations from OIS transactions, we conduct two types of specifications with respect to the frequency of estimations. In subsection 3.1, we extract expectations on a monthly basis, where we use full sample observations and capture the time-series variation by month dummies so that we can obtain relatively stable estimation results. In subsection 3.2, we extract expectations on a daily basis, where we restrict each regression window to two weeks and repeatedly run the regression by shifting the window day by day. This enables us to expand the frequency of estimated expectations from monthly to daily so that we can estimate the state-dependent effects of daily market operations at the expense of estimation stability due to fewer observations in the regressions.

3.1 Monthly Distribution of Market Participants' Expectations on Future Interest Rates

To explain how we estimate the evolution of market participants' expectations on future interest rates, we use the following illustrative specification of a panel estimation based on the equation (1) for the OIS transaction at each maturity m:

$$\begin{aligned} FixedRate_{t,s,b,i} = {} & \alpha + YYYYMM_t^T \cdot \beta + Seller_s^T \cdot \gamma + Buyer_b^T \cdot \delta \\ & + YYYYMM_t^T \cdot \zeta \cdot Seller_s + YYYYMM_t^T \cdot \eta \cdot Buyer_b \\ & + \theta \cdot \log\left(NotionalAmount_{t,s,b,i}\right) + \varepsilon_{t,s,b,i}. \end{aligned} \tag{1}$$

Here, $FixedRate_{t,s,b,i}$ indicates the fixed interest rate of the OIS transaction between seller s and buyer b on the trade date t whose transaction number is i. $YYYYMM_t^T$ indicates the year and month to which the trade date t of each OIS transaction belongs. $Seller_s$ and $Buyer_b$ indicate the seller and buyer of each OIS transaction. In OIS transactions, the seller refers to the party that receives the fixed interest rate and pays the floating interest rate (TONA), while the buyer is the party that receives TONA and pays the fixed interest rate. $NotionalAmount_{t,s,b,i}$ is the notional amount of OIS transaction, and we include its logarithmic value as a control variable. $\varepsilon_{t,s,b,i}$ is the error term, and $\alpha, \beta, \gamma, \delta, \zeta, \eta, \theta$ denote the coefficients to be estimated.

This empirical model explains what causes the fluctuations in fixed interest rates of OIS transactions between seller s and buyer b. As a premise, the fixed rate of OIS reflects the expected path of future interest rates agreed between seller s and buyer b at the trade date t. If all market participants have the same tendency to view future interest rates over the whole sample period, we measure it by the constant term α. If all market participants have the same tendency to view future interest rates at time t, possibly caused by market-wide events, we measure it by $YYYYMM_t^T \cdot \beta$. If seller s has a tendency to view future interest rates over the whole sample period, we measure it by $Seller_s^T \cdot \gamma$. Similarly, if buyer b has a tendency to view future interest rates over the whole sample period, we measure it by $Buyer_b^T \cdot \delta$. If the fixed rate varies due to the change in seller s's idiosyncratic views at time t, we measure it by $YYYYMM_t^T \cdot \zeta \cdot Seller_s$. Likewise, if the fixed rate changes due to the change in buyer b's idiosyncratic views at time t, we measure it by $YYYYMM_t^T \cdot \eta \cdot Buyer_b$. Based on these interpretations, $(\hat{\alpha} + YYYYMM_t^T \cdot \hat{\beta} + Seller_s^T \cdot \hat{\gamma} + YYYYMM_t^T \cdot \hat{\zeta} \cdot Seller_s)$ is assumed to capture the expectation of future interest rates for the seller s at time t, and $(\hat{\alpha} + YYYYMM_t^T \cdot \hat{\beta} + Buyer_b^T \cdot \hat{\delta} + YYYYMM_t^T \cdot \hat{\eta} \cdot Buyer_b)$ is the expectation of future interest rates for the buyer b at time t.[4]

In this way, we can compute an individual market participant' expectation on future interest rates at each point of time by either $(\hat{\alpha} + YYYYMM_t^T \cdot \hat{\beta} + Seller_s^T \cdot \hat{\gamma} + YYYYMM_t^T \cdot \hat{\zeta} \cdot Seller_s)$ or $(\hat{\alpha} + YYYYMM_t^T \cdot \hat{\beta} + Buyer_b^T \cdot \hat{\delta} + YYYYMM_t^T \cdot \hat{\eta} \cdot Buyer_b)$. Therefore, by aggregating these expectations, we can construct the time-variant expectation distribution of market participants on future interest rates. Subsequently, we can compute the first to fourth order moments of the expectation distribution (i.e. mean, variance, skewness and kurtosis) as the variables capturing how market participants expect future interest rates.

3.2 Verifying the State-Dependent Effects of the BoJ's JGB Purchases Conditional on the Expectation Distribution

In this subsection, we explain the empirical method of verifying the state-dependent effects of the BoJ's market operations conditional on the market participants' expectation distribution. Because the BoJ's market operations are observed on a daily basis, we need to compute the market participants' expectations day by day. As the method described in subsection 3.1 is

[4] Amiti and Weinstein (2018) employ a similar empirical specification to decompose the changes in the loan amounts into firms' credit shocks and lenders' supply shocks.

estimated monthly, we employ the market participants' expectations measured over a rolling two-week window shifting day by day in this exercise.

3.2.1 Two-Week Distribution of Market Participants' Expectations on Future Interest Rates

First, we estimate the equation (2) for a given two-week period.[5] Specifically, we estimate the distribution of market participants' expectations corresponding to a given two-week period:

$$\begin{aligned} FixedRate_{t,s,b,i} &= \alpha + Seller_s^T \cdot \beta + Buyer_b^T \cdot \gamma \\ &\quad + \delta \cdot \log\left(NotionalAmount_{t,s,b,i}\right) + \varepsilon_{t,s,b,i}, \end{aligned} \tag{2}$$

where the definitions of the variables is the same as in equation (1). After estimating these parameters, we add up $\hat{\alpha} + Seller_s^T \cdot \hat{\beta}$ $(\hat{\alpha} + Buyer_b^T \cdot \hat{\gamma})$ for each OIS seller (each OIS buyer) in order to obtain individual sellers' (buyers') expectations on interest rates as of a respective two-week window. Repeating this estimation process while rolling the two-week window on a daily basis, we can obtain the evolution of expectations on future interest rates day by day.[6] Finally, by aggregating sellers' and buyers' expectations, we draw the daily distribution of market participants' expectations on future interest rates. Based on this estimated expectation distribution, we compute the first to fourth order moments (i.e. mean, variance, skewness and kurtosis) on a daily basis.

3.2.2 Estimating the Effects of the BoJ's JGB Purchase Conditional on the Expectation Distribution

Second, based on the daily information on the distribution of market participants' expectations on future interest rates described in subsection 3.2.1, we implement the following high-dimensional panel estimation (3):[7]

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[5] If we change the rolling window to one-week, the time interval is so short that we cannot estimate the distribution of market participants' expectations sufficiently. If we change the rolling window to three-week or four-week, the estimation results of market participants' expectations do not change considerably.

[6] In equation (1), the estimation period is the whole sample period and the time-variant fluctuations are captured by the time dummy $YYYYMM$. In contrast, in equation (2), the time-variant fluctuations are captured by the repetitions of the two-week window estimation. Although the computational approach is different, the basic idea of estimating market participants' expectations is identical between these two specifications.

[7] Since the 10-year JGB rate was sometimes capped by the upper limit of the YCC, a nonlinear estimation such as Tobit model can be an alternative estimation method. However, the nonlinear estimation may be difficult to be applied in our exercise due to the multiple changes of the target range of YCC as decided in the Monetary Policy

$$JGBRate_{t,m} = \alpha + X_{t,m}^T \cdot \beta + Y_{t,m}^T \cdot \gamma + X_{t,m}^T \cdot \delta \cdot Y_{t,m}^T + FE_{t,m} + \varepsilon_{t,m}. \quad (3)$$

Here, $JGBRate_{t,m}$ denotes the JGB yield of maturity m observed at the end of date t. $X_{t,m}$ indicates the daily series of the mean, variance, skewness and kurtosis of the distribution of market participants' expectations on future interest rates for maturity m computed in subsection 3.2.1. $Y_{t,m}$ denotes the variables concerning the BoJ's market operations for maturity m. Specifically, for each maturity m at date t, $Y_{t,m}$ includes the daily series of (i) the logarithm of the offered values of scheduled and unscheduled outright purchase operations by competitive auction method, (ii) the dummy variables concerning whether there is a bid for the fixed-rate purchase operation ($FRP\ Dummy$), and (iii) the yield deviation between the interest rate levels for the fixed-rate purchase operation and the average of market participants' expectation distribution on future interest rates ($FRP\ Intensity$).[8] $FE_{t,m}$ indicates the date and maturity fixed effects.

Through this maturity-level panel estimation, we aim to empirically examine how the distribution of market participants' expectations on future interest rates determines the effects of the BoJ's JGB purchases. Particularly, the cross term ($X_{t,m}^T \cdot \delta \cdot Y_{t,m}^T$) indicates the state-dependent effects of the BoJ's market operations conditional on the moments of the expectation distribution.[9] It is noteworthy that, since the market participants' interest rate expectations on a specific day may be influenced by the concurrent JGB yields as well as market operations on that day, we employ one-day lag structure to ensure the exogeneity of market participants' expectations against the price formation of JGBs. Specifically, we treat the estimated interest rate expectations for the specific two-week window as representing the expectations just before the market opens on the next day of the end of the two-week window.[10]

Meetings (MPM) in December 2022, July 2023 and October 2023.

[8] As $FRP\ Intensity$ matters only when a fixed-rate purchase operation is conducted on a specific day (i.e. $FRP\ Dummy = 1$), $FRP\ Intensity$ appears as the cross-term $FRP\ Dummy \cdot FRP\ Intensity$.

[9] Following Bauer et al. (2022), we empirically analyze the state-dependent effects of market operations conditional on market participants' expectation distribution. Bauer et al. (2022) assume the distribution of market participants' expectation as representing the uncertainty of monetary policy by extracting the daily change of expectations around FOMC announcements. In contrast, because our estimation window for the expectation is two-week, which is longer than Bauer et al. (2022), the interest rate expectation distribution in our paper may be driven by various factors, such as the monetary policy announcements and the releases of economic indicators. Unraveling the mechanism behind the formation of market participants' expectation is an interesting research topic, but it is beyond the scope of this paper to disentangle all the complex factors behind market participants' expectation formation. In this paper, we take market participants' expectations as given and we focus on the impact they have on the effects of market operations.

[10] When examining the impact of market operations on day T, we use the interest rate expectations estimated for

Our focus is the effects of the fixed-rate purchase operation because little work has been devoted to examining the effects of this operation, which purchases an unlimited amount of JGBs at a specific target yield.[11] Because our dependent variable $JGBRate_{t,m}$ is the JGB yields observed at the end of the day, it reflects not only the target yield of the fixed-rate purchase operation but also the market participants' behaviors after experiencing this operation, the latter of which is what we aim to capture as the impact of the fixed-rate purchase operation. However, from the identification perspective, we need to take into account the fact that, in the fixed-rate purchase operation, the target yield is predetermined and announced. This means that market participants can foresee whether or not the BoJ will purchase the JGBs under the fixed-rate purchase operation by simply looking at the concurrent JGB yields. This endogenous association between the JGB yields and the variable capturing the fixed-rate purchase operation ($FRP\ Dummy$) makes it difficult to interpret the estimated coefficient associated with $FRP\ Dummy$ as causal. In short, the JGB purchase under the fixed-rate purchase operation might simply coincide with a higher JGB yield.

This discussion suggests that, instead of $FRP\ Dummy$, we need to construct another explanatory variable for identifying the causal relation directing from the fixed-rate purchase operation to the JGB yields. For this purpose, we employ $FRP\ Intensity$, which accounts for the distance between the target yield for the fixed-rate purchase operation and the average of the distribution of market participants' expectations on future interest rates.[12] Our identification assumption is that each market participant may partially know the counterparty's interest rate expectation through individual transactions but cannot observe the entire distribution of the

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the period between $T-14$ and $T-1$.

[11] The fixed-rate purchase operation is unique in its asymmetry between above and below the target yield. This operation purchases an unlimited amount of JGBs when the JGB yields are equal to or above the target yield, while it remains inactive when the yields stay below the target, including the case resulting from this operation itself. The BoJ decided to introduce "fixed-rate purchase operations for consecutive days," in which the BoJ purchases "a necessary amount of JGBs without setting an upper limit" on March 19, 2021. Then, the BoJ clarified this policy on April 28, 2022 that the BoJ would "offer to purchase 10-year JGBs at 0.25 percent every business days through fixed-rate purchase operations, unless it is highly likely that no bids will be submitted." As a reference, we present the chronological developments in the BoJ's fixed-rate purchase operation in Table A1.

[12] Because $FRP\ Intensity$ is the distance between the interest rate level for the fixed-rate purchase operation and the average of market participants' interest rate expectation distribution, this variable captures the intensity of the fixed-rate purchase operation against the concurrent market yields. We assume the fixed-rate purchase operation as having the following two interlinked channels on the JGB yields. First, the fixed-rate purchase operation has a direct impact on the demand-supply balance of the JGB market because the BoJ serves as a large-sized buyer who purchases an unlimited amount of JGBs at the target yield. We call this as "volume effect." Second, the fixed-rate purchase operation can serve as a signal of strong commitment of the monetary policy stance, which may alter market participants' interest rate expectations. We call this as "signaling effect." We aim to capture both of these interlinked effects of the fixed-rate purchase operation by $FRP\ Intensity$.

interest rate expectations. As far as the market participants cannot learn, at least directly, the distance between the target yield and the average of interest rate expectations, $FRP\ \ Intensity$ serves as the variable capturing the intensity of the market operations, which are quasi-exogenous against the concurrent JGB yields from market participants' viewpoints.[13, 14]

In addition, to further ensure the exogeneity of $FRP\ \ Intensity$ against the JGB yields, we use the distribution of market participants' expectations over one day prior to the timing of each operation. With this one-day lag structure, $FRP\ \ Intensity$ can affect the JGB yields on day T, but the reverse relation is considered relatively weak. Thus, we can interpret the coefficient of $FRP\ \ Intensity$ as capturing the causal relation from $FRP\ \ Intensity$ to the JGB yields. Given these considerations, we focus on the coefficient of $FRP\ \ Intensity$ as a measure of the effects of the BoJ's fixed-rate purchase operation and examine its state-dependency on the moments of expectation distribution by $X_{t,m}^{T} \cdot \delta \cdot FRP\ \ Intensity$.[15]

4. Data

We use trade repository data from Japan's Financial Services Agency (FSA), which covers almost entire universe of OTC derivative transactions. After the Global Financial Crisis, it was decided at the G20 Pittsburgh Summit that OTC derivative contracts should be reported to trade repository. Since then, various countries have introduced trade repository systems to record OTC derivative transactions. In Japan, FSA has collected the trade repository data since 2013.[16] Among them, we use the JPY-denominated OIS transaction data from January 1, 2022 to September 30, 2024 as the trade date.

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[13] While each participant's expectation is private information, market participants can learn their counterparties' interest rate expectations through repeated transactions. The hub participants, who are called as market makers, may have information advantages relative to peer participants.

[14] In equation (3), we include both the mean of the market participants' expectations in $X_{t,m}$ and $FRP\ \ Intensity$ in $Y_{t,m}$. The latter variable is the distance between the target yield for the fixed-rate purchase operation and the average of the market participants' expectation distribution. These two variables are not necessarily multi-collinear because the fixed-rate purchase operation's target yields have variations over the sample period.

[15] The estimated coefficient on $FRP\ \ Intensity$ in equation (3) is the sensitivity of JGB yields with respect to the interest rate expectation deviating above the target yield of the fixed-rate purchase operation.

[16] FSA asks all financial instruments clearing organizations, foreign financial instruments clearing organizations, financial instruments business operators, and registered financial institutions to report their OTC derivative transactions. Financial instruments business operators and registered financial institutions include business operators that conduct Type I Financial Instruments Business, all banks, Shoko Chukin Bank, Development Bank of Japan, the members of the Federation of Shinkin Banks operating nationwide, Norinchukin Bank, and insurance companies.

We deal with misreporting or missing variables by following the prior research.[17] In the first step of data cleaning, we exclude the transaction records missing any of the variables used in our regression; the identifiers of sellers and buyers, notional amounts, fixed rates and maturities.[18] Second, to exclude misreporting, we also drop the records whose OIS fixed rates deviate from Bloomberg's OIS rate (benchmark) by more than 90 basis points in absolute values, in a similar manner as Cenedese et al. (2020). After these data cleaning, we are left with 235,582 records of transactions for our sample period.

Regarding the estimation equation (1), we use our full sample between January 2022 and September 2024. In estimating equation (2) and (3), we use the data from January 1, 2022 to March 18, 2024. This is because we focus on examining the effects of fixed-rate purchase operation, and the BoJ announced the termination of YCC on March 2024 MPM (i.e. in the daytime on March 19, 2024).[19]

Table 1 shows the summary statistics of our data. The counts of transactions and market participants are relatively larger for 5-, 10-, and 20-year maturities. The average notional amounts are larger for shorter maturities, while the average fixed interest rates tend to be higher for longer maturities.

5. Empirical Results

5.1 Monthly Distribution of Market Participants' Expectations on Future Interest Rates

In this subsection, we report interest rate expectations obtained from the estimation model (1) as described in subsection 3.1. Here, we focus on the results of 2- and 10-year maturities for an illustrative purpose, because 2-year OIS fixed rate is considered to represent the expected path of monetary policy for the coming few years and 10-year OIS fixed rate is closely related to the BoJ's YCC.[20]

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[17] We note that the result can be subject to the revision of raw data and the change in the data cleaning process.

[18] The maturity is calculated as the difference between the contract's start day and end day. For simplicity, we round the maturity days divided by 365 days to calculate the maturity year as an integer.

[19] At its March 18-19, 2024 MPM, the BoJ decided to make a shift to the monetary policy framework in which the primary policy tool is guiding the short-term interest rates, considering that Quantitative and Qualitative Monetary Easing (QQE) with YCC and the negative interest rate policy had fulfilled its role. As we focus on examining the fixed-rate purchase operation mainly employed under YCC, we exclude the second day of March 2024 MPM and the days onwards.

[20] While we only report the results of 2- and 10-year maturities in this paper, the results of other maturities can be

Figure 1 represents the monthly boxplots of the estimated interest rate expectations by equation (1) from January 2022 to September 2024.[21] The upper panel illustrates the market participants' expectations on future interest rates for 2-year maturity and the lower panel indicates those for 10-year maturity. In this boxplot, the box extends from the first quartile (25%) to the third quartile (75%) of the estimated expectation distribution, with a horizontal line at its median. The whisker extends from the end of the box to the farthest data point lying within 1.5 times the inter-quartile range of the box. Green dots out of the whiskers show outliers of the expectation distribution.

Overall, there was a gradual upward trend in the interest rate expectations during our sample period from January 2022 to September 2024, reflecting the rise in foreign interest rates and domestic inflation expectations.[22] This observation confirms our empirical methodology extracting the market participants' interest rate expectations relatively well because the results are broadly consistent with other survey results on market participants. A closer look at the diagrams tells us that there emerged a group of outliers, especially those who had relatively higher interest expectations, particularly in 2-year maturity, from the second half of 2022 to the beginning of 2024, implying the positive skewness of the estimated interest rate expectation distribution.

Figure 2 describes the computed first to fourth order moments of the monthly expectation distribution depicted in Figure 1. The first order moment (i.e. mean) shows the gradual increase for both 2-year and 10-year maturities. The second order moment (i.e. variance) indicates that the variance of the expectation distribution of 2-year strikingly increased for the second half of 2022 to the end of 2023, whereas the variance of 10-year remained relatively stable, with some fluctuations after the modification of YCC, such as December 2022, July 2023 and October 2023 MPMs. The third order moment (i.e. skewness) evolved almost constantly above zero for 2-year, meaning that the market participants' expectation distribution for the coming two years entailed the rightly fat tail, i.e. a small group of market participants expected extremely higher

obtained from authors upon request.

[21] As presented in equation (2), we extract market participants' expectations on future interest rates as a seller and a buyer separately. As OIS sellers (buyers) receive (pay) the fixed rate in exchange of paying (receiving) the future floating rate, market participants may have different expectations depending on whether they transact as sellers or buyers. Thus, we treat one entity's expectations as a seller and a buyer as distinct in calculating the distribution.

[22] The trend of market participants' inflation expectations observed through inflation-indexed bonds was rising over the sample period.

interest rates while the majority of market participants predicted relatively lower interest rates. The third order moment for 10-year also hovered above zero, with some month dipping below zero. Finally, the fourth order moment (i.e. kurtosis) spiked several times for 10-year. These observations show the dramatic changes in market participants' expectation distribution during our sample period and motivate us to investigate the state-dependent effects of the BoJ's market operations conditional on the moments of this expectation distribution.

5.2 Market Participants' Expectations and the Effects of Market Operations

Using the rolling window estimation presented in equation (2), we compute the market participants' expectation distribution on future interest rates over a given two-week period, and calculate the first to fourth order moments of this distribution. Then, we use the daily changes in the expectation distribution to verify the state-dependent effects of the BoJ's JGB purchases, especially the fixed-rate purchase operation.

We now show our main results. Based on equation (3), Table 2 displays how the impact of the BoJ's market operations on the JGB yields are state-dependent conditional on the moments of the expectation distribution on future interest rates among market participants.[23] We perform the estimation in equation (3) with some variations in how we include the higher order moments of the expectation distribution: Column (1) incorporates the mean and variance, column (2) considers the mean, variance and skewness, and column (3) covers all the four moments (mean, variance, skewness and kurtosis).

Our main variable of interest is $FRP\ \ Intensity$. Table 2 shows the estimated coefficients of $FRP\ \ Dummy \cdot FRP\ \ Intensity$ are negative in a statistically significant manner for all specifications. This means that the JGB yields would be pushed down more significantly when $FRP\ \ Intensity$ is larger. The fixed-rate purchase operation purchasing an unlimited amount of JGBs at the target yield becomes more powerful when the average of the interest rate expectations is relatively higher than this target yield, which is consistent with intuition.

Next, the coefficients of $FRP\ \ Dummy \cdot FRP\ \ Intensity \cdot Variance$ are positive in a statistically significant way in column (2) and (3). This implies that the effects of the BoJ's

[23] We report the estimated coefficients of our main interest for an illustrative purpose, though the independent variables in equation (3) include other variables than ones related to the fixed-rate purchase operation, such as the logarithm of offered values of scheduled and unscheduled outright purchase operations by competitive auction method.

fixed-rate purchase operation are attenuated when the variance of market participants' expectations is higher. This result is consistent with Bauer et al. (2022) who show that the effect of monetary policy on asset prices weakens when investors' outlooks on future interest rates are highly uncertain.

We additionally consider the skewness in column (2) and (3). Here, the estimated coefficients of $FRP\ Dummy \cdot FRP\ Intensity \cdot Skewness$ are negative in a statistically significant way, indicating that the effects of the fixed-rate purchase operation are amplified when the degree of skewness in the expectation distribution is larger (i.e., the expectation distribution is more rightly skewed). If the degree of skewness increases by 1 standard deviation while all other variables are kept at the historical average, the effects of the operation in the case of column (2) are amplified by -0.077.[24] As the coefficient of $FRP\ Dummy \cdot FRP\ Intensity$ is -0.124, the total effects are enlarged by approximately 60%. Therefore, the information contained in the skewness of the distribution is quantitatively significant. This outcome remains unchanged when we additionally control for the kurtosis in column (3).[25]

In summary, the effects of the fixed-rate purchase operation on the JGB yields became smaller (i.e., interest rate declined less) when the variance of market participants' expectation distribution was larger (i.e. higher second order moment), as consistent with the prior research. Our unique finding by considering multiple higher order moments is that the impact of the fixed-rate purchase operation became larger (i.e., interest rates declined more) when the expectation distribution was rightly skewed (i.e. higher third order moment).

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[24] Note that the dependent variable, the moment variables, and the variables accounting for the scheduled and unscheduled outright purchase operations of JGBs by competitive auction method are standardized during the sample period.

[25] As we discussed in subsection 3.2, $FRP\ Intensity$ in Table 2 is expected to capture both "volume effect" and "signaling effect" of the fixed-rate purchase operation. Behind this premise, we assume the underlying transmission channel such that $FRP\ Intensity$ exerts "volume effect" indirectly via the amount of JGB purchase under the fixed-rate purchase operation while it exerts "signaling effect" directly on the JGB yields. In Table A2, we present a provisional estimation result which aims to disentangle these two effects. Here, we incorporate both $FRP\ Intensity$ and the amount of JGB purchase under the fixed-rate purchase operation ($FRP\ Amount$) as explanatory variables. Then, we can consider the coefficient of $FRP\ Amount$ as "volume effect," and that of $FRP\ Intensity$ as "signaling effect," because $FRP\ Intensity$ is now the residualized component after removing "volume effect" through $FRP\ Amount$. The result shows that the coefficients of $FRP\ Amount$ and $FRP\ Intensity$ in Table A2 are broadly consistent with the main result in Table 2, indicating that both "volume effect" and "signaling effect" are important components of the fixed-rate purchase operation.

6. Who Drives the Skewness?

In the previous section, we document how the effects of fixed-rate purchase operation is state-dependent on the second and third order moments of interest rate expectation distribution. Our unique finding compared with extant literatures is that the impact of the BoJ's fixed-rate purchase operation is magnified when the distribution of interest rate expectations is positively skewed. We might wonder whether and to what extent (if any) this empirical result fits the episode associated with the phenomenon so-called "YCC attack," which was observed during our sample period. During the "YCC attack," foreign investors speculatively attacked YCC by massively short-selling specific JGB issues based on their beliefs that the BoJ would tighten its monetary policy as other central banks in advanced countries did (see, for example, Shiratsuka 2024).

First, Figure 3 and 4 depict the monthly histograms of the interest rate expectations for 2-year and 10-year maturities, respectively. Here, we classify market participants into "domestic" and "foreign" entities, and then overlay the densities of the two groups' interest rate expectations. In identifying the domestic and foreign status of each market participant, we check their names from our trade repository data and classify it as "foreign" when a participant's headquarter is located overseas. The estimated interest rate expectations classified as foreign entities occasionally showed a longer right-tail relative to domestic entities, which resulted in the higher skewness of the entire distribution. Thus, we can confirm that the large positive skewness was mainly driven by foreign market participants.

Next, in order to quantitatively evaluate the skewed expectations by foreign market participants, we compute several quantiles from the monthly expectation distributions for the domestic and foreign entities respectively, and subtract the former from the latter. Through this exercise, we can compare the difference at a specific quantile between the domestic and foreign distributions, and see which entity group has higher interest rate expectations. The panels in Figure 5 (2-year) and 6 (10-year) depict the time-varying differences of foreign entities' expectations relative to domestic entities' expectations at the specific quantiles (namely, 10%, 25%, 50%, 75% and 90% quantiles), and we also compute the differences in the standard deviations. There was little difference in the 50% quantile and lower quantiles between foreign and domestic investors' expectations, especially for 2-year. In contrast, foreign entities had clearly higher interest rate expectations relative to domestic ones specifically for the higher quantiles (75% and 90% quantiles). This result suggests that only a selected group of foreign investors exhibited extremely higher expectations on future interest rates, while the median- or lower-quantile groups of foreign and domestic entities shared the similar expectations.[26] We consider that identifying who drives the tails of the expectation distribution could be useful for central banks to effectively implement market operations and communicate with the market.

Finally, we examine whether the BoJ's market operations alter the expectations of market participants with extremely high interest rates. Figure 7 shows the transition probability between the quartile groups in the interest rate expectations. Precisely speaking, we divide each market participant's expectations into four quartile groups for each month. Then, we calculate the transition probability between five states, namely four quartile groups and a state with no transaction in a given month. The figures tell us that those whose expectations were situated in the 0-25%, 25-50%, 50-75% quartile groups of the distribution were less likely to switch to the 75-100% quartile in the next month. In contrast, the market participants whose interest rate expectations were located in the highest quartile (75-100%) of the distribution in the current month were more likely to stay in the same highest quartile in the next month. At the same time, we should note that more than a half of market participants in the highest quartile did not remain in the same highest quartile group, given that the average probability of staying at the highest quartile is 0.44 for 2-year and 0.37 for 10-year maturity. This implies that the interest rate expectations for the majority of investors declined partly due to the BoJ's fixed-rate purchase operation, although a group of market participants with higher interest rate expectations, for example, foreign investors as shown in Figure 3 and 4, tend to maintain such expectations.[27]

We consider that the fixed-rate purchase operations can induce the market participants with extremely high interest rate expectations to revise down their expectations through the following two interlinked channels. First, the fixed-rate purchase operation is assumed to have a direct impact on the demand-supply balance of the JGB market. The BoJ serves as a large-sized buyer who purchases an unlimited amount of JGBs at the target yield. This makes the investment strategy to bet on short selling of JGBs less profitable, especially for investors who

[26] There may be some hypotheses regarding why some foreign investors expect higher interest rates than domestic ones. (i) Foreign investors may have more bullish outlooks on the economy (e.g. higher inflation expectations), simply associating the Japanese outlooks with the overseas economic developments. (ii) Foreign investors may have different expectations on the central bank's policy reaction functions, even when both foreign and domestic investors share similar economic outlooks (specifically, foreign investors may expect the central bank to respond more aggressively to a rising inflation rate).

[27] We should note that confounding factors other than the BoJ's fixed-rate purchase operation may also play a role in causing this phenomenon, such as the fluctuations in foreign interest rates.

have higher interest rate expectations relative to the target yield of fixed-rate purchase operation, which forces them to exit out of the short-selling. Second, the fixed-rate purchase operation can serve as a signal of strong commitment of the monetary policy stance. This can alter investors' interest rate expectations such that they become more consistent with the central bank's policy stance. Looking back the period of "YCC attack," some foreign market participants, who initially had bullish outlooks on the Japanese inflation and expected the BoJ to raise interest rates simply because they associated the Japanese economy with the US and European economies, seemed to revise down their expectations gradually as the Japanese inflation dynamics behaved differently from the US and European ones. Figure 7 provides some evidence on how foreign market participants, facing the fixed-rate purchase operation, changed their interest rate expectations over the period of "YCC attack."

7. Robustness Checks

In this section, we report our robustness checks in estimating equation (3). Table 3 illustrates the results when the dependent variable is the first difference in the JGB yields. The estimated coefficients of $FRP\ Dummy \cdot FRP\ Intensity$ are negative and statistically significant in column (2) and (3). In addition, the coefficients of $FRP\ Dummy \cdot FRP\ Intensity \cdot Variance$ are positive and statistically significant when we control the interaction terms with higher order moments in column (2) and (3). The estimated coefficient of $FRP\ Dummy \cdot FRP\ Intensity \cdot Skew$ness is negative and statistically significant in column (3), showing that the effects of fixed-rate purchase operations is amplified when the skewness of the expectation distribution is larger (i.e. the distribution is more rightly skewed). These results confirm our finding in section 5.

Table 4 restricts our sample to 10-year maturity to examine whether the estimated impact of fixed-rate purchase operation in Table 2 is driven by the main target maturity (10-year) of fixed-rate purchase operation.[28] As is consistent with Table 2, column (2) and (3) in Table 4 show that the coefficients for our main variable of interest, $FRP\ dummy \cdot FRP\ Intensity \cdot Skewness$, are negative and statistically significant. This confirms that the BoJ's fixed-rate purchase operation resulted in a larger reduction of the JGB yields when the expectation distribution was more rightly skewed.

[28] We drop maturity fixed effects since we only use 10-year maturity for Table 4 and 5.

Table 5 restricts our sample to 10-year maturity and include the moment information of interest rate expectations extracted from 2-year as well as from 10-year. Column (3) in Table 5 shows that both of the coefficients of $FRP\ \ dummy \cdot FRP\ \ Intensity \cdot Skewness(2y)$ and $FRP\ \ dummy \cdot FRP\ \ Intensity \cdot Skewness(10\text{y})$ are negative and statistically significant, with a slightly higher magnitude of the latter coefficient. This confirms our main result too.

8. Conclusion

In this paper, we develop a novel estimate of the distribution of market participants' expectations on future interest rates by using trade repository data. We also leverage this information to examine whether the effects of the BoJ's fixed-rate purchase operation is state-dependent on the moments of this distribution. Our empirical findings are threefold. First, the estimated expectation distribution on future interest rates displayed the time-variant heterogeneity in market participants' expectations. Second, regarding the fixed-rate purchase operation, its impact on the JGB yields became smaller when the variance of the expectation distribution was larger. Third, the effect of the fixed-rate purchase operation is amplified when the distribution of the interest rate expectations is more positively skewed. These findings are useful for central banks to execute effective market operations, simultaneously indicating the benefit of using the granular data to capture the financial market accurately.

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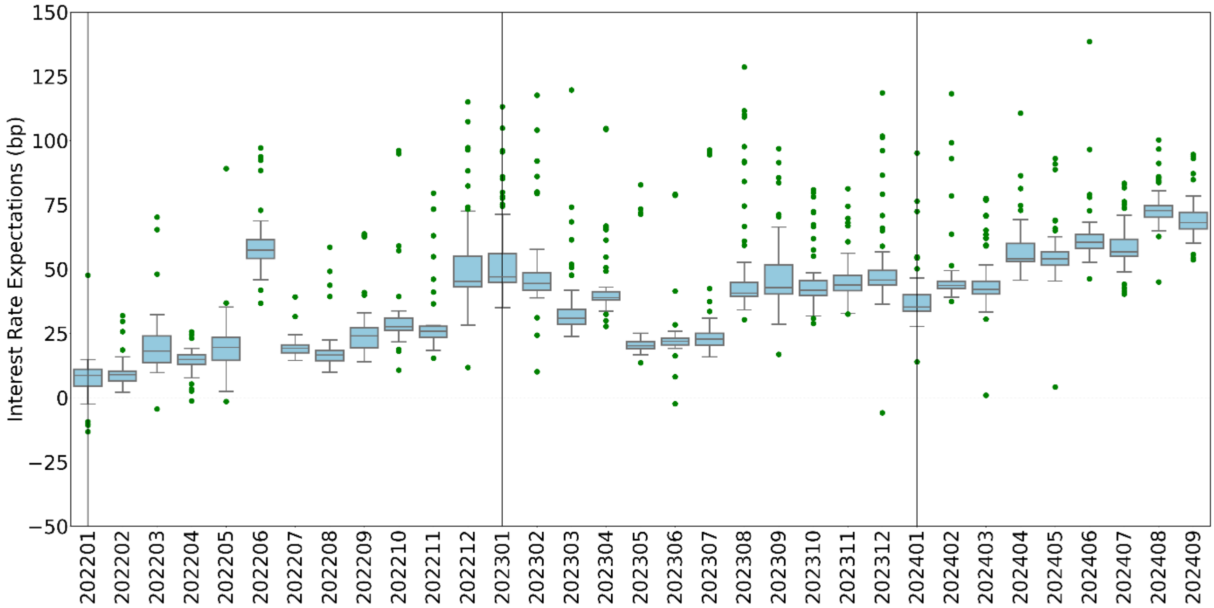
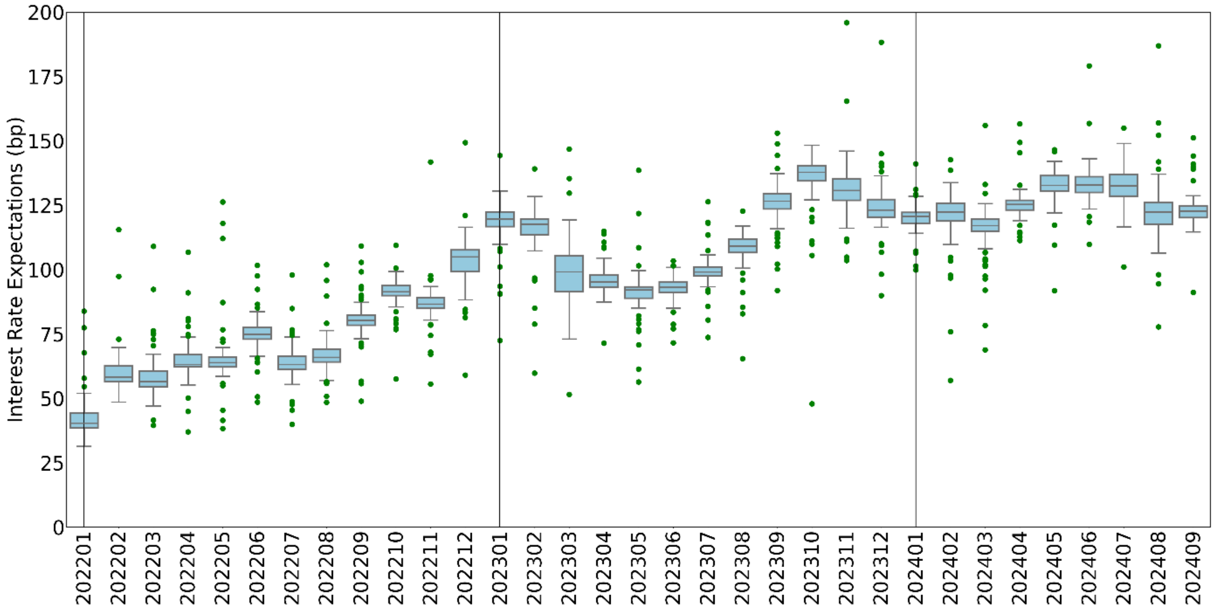
Figure 1. Boxplots of the estimated interest rate expectations (upper panel: 2-year, lower panel: 10-year)

Panel A: 2-year



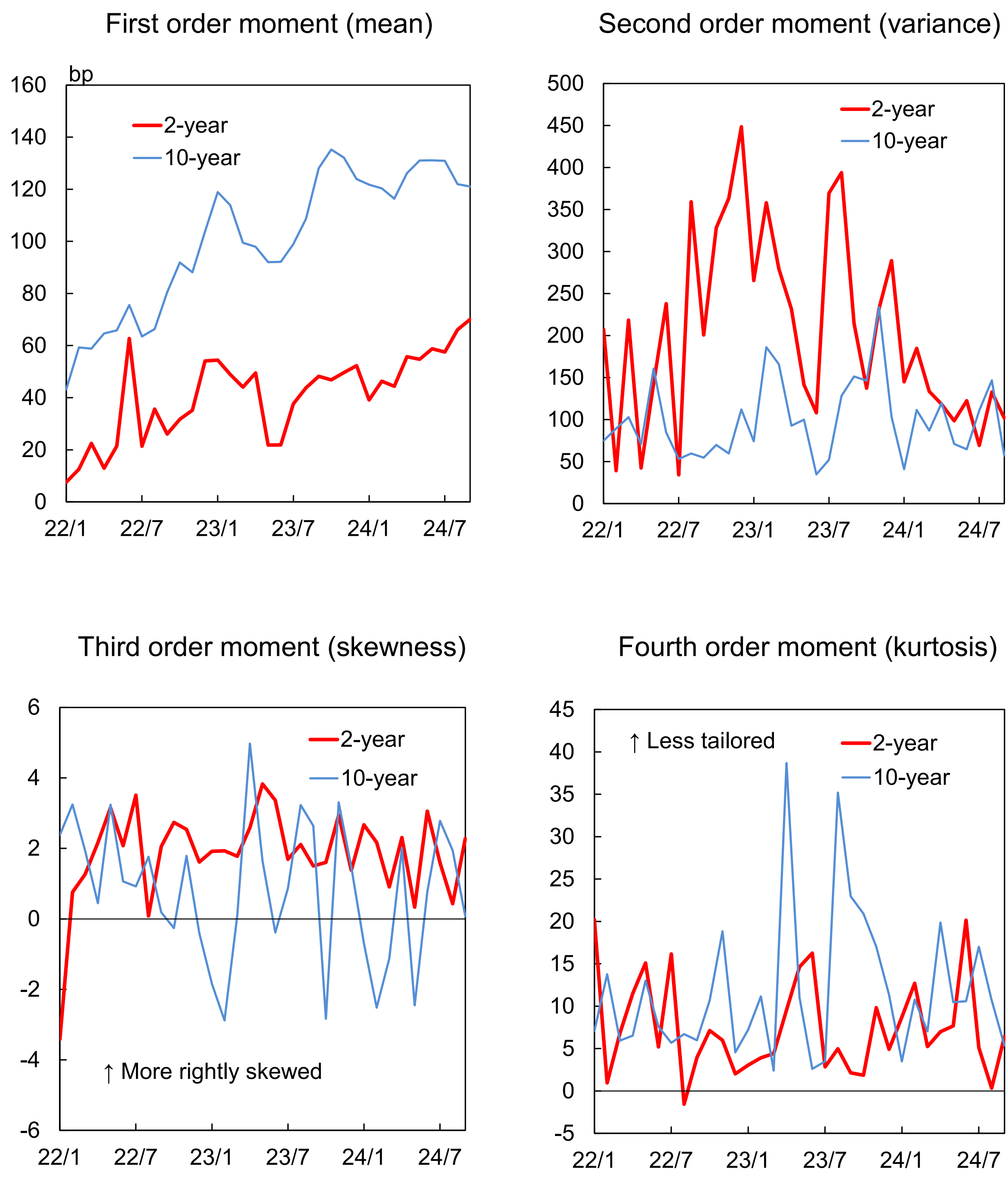
Panel B: 10-year



Note: The interest rate expectations are estimaed by equation (1). The box extends from the first quartile (25%) to the third quartile (75%) of the estimaed interest rate expectations, with a horizontal line at its median. The whisker extends from the end of the box to the farthest data point lying within 1.5 times the inter-quartile range from the box. Green dots out of the whiskers show outliers of the estimated interest rate expectations.

Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 2: First to fourth order moments of the distribution on the estimated interest rate expectations



Note: Latest data as of September, 2024.
Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 3. Distribution of the interest rate expectations by nationality (2-year)

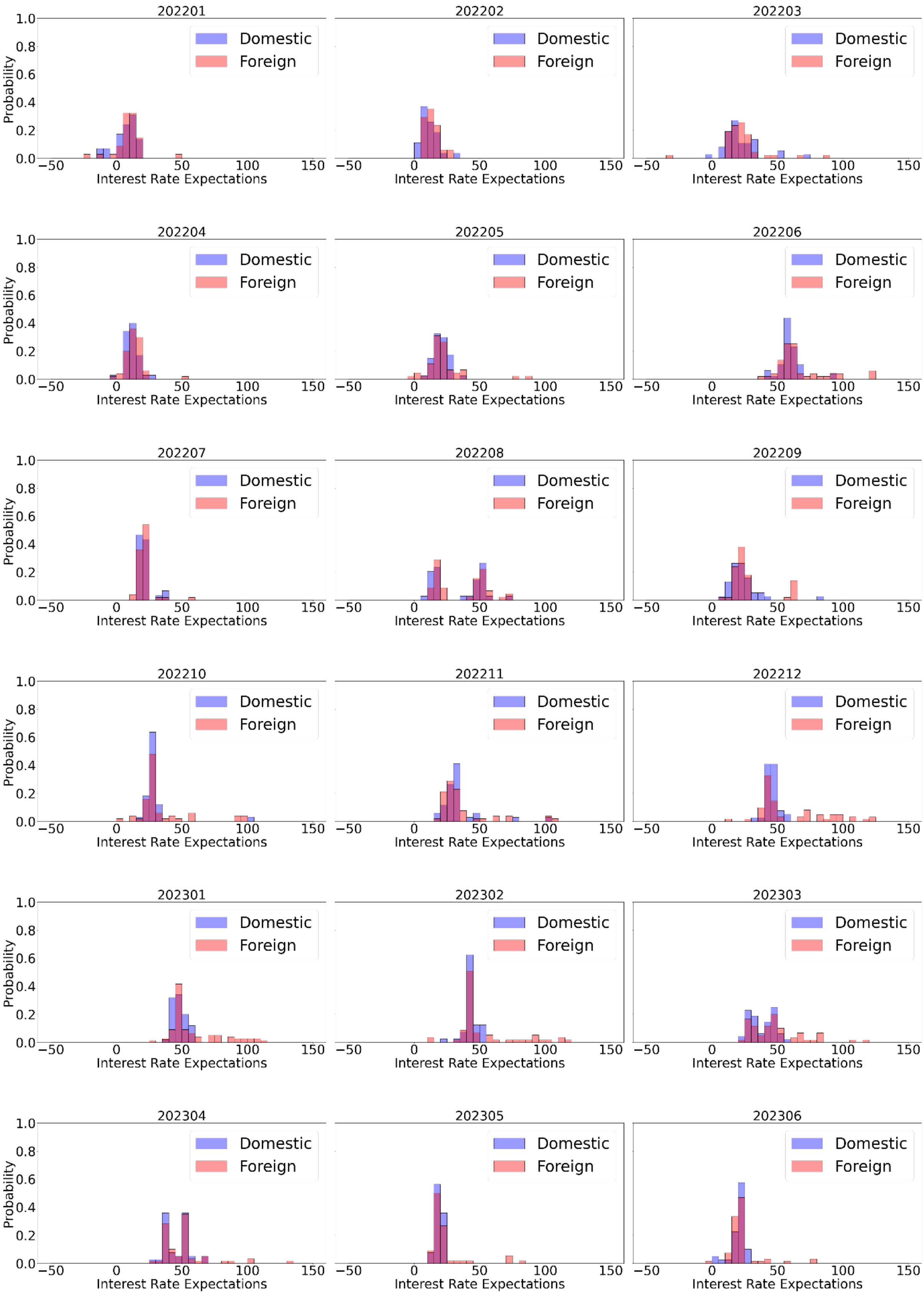


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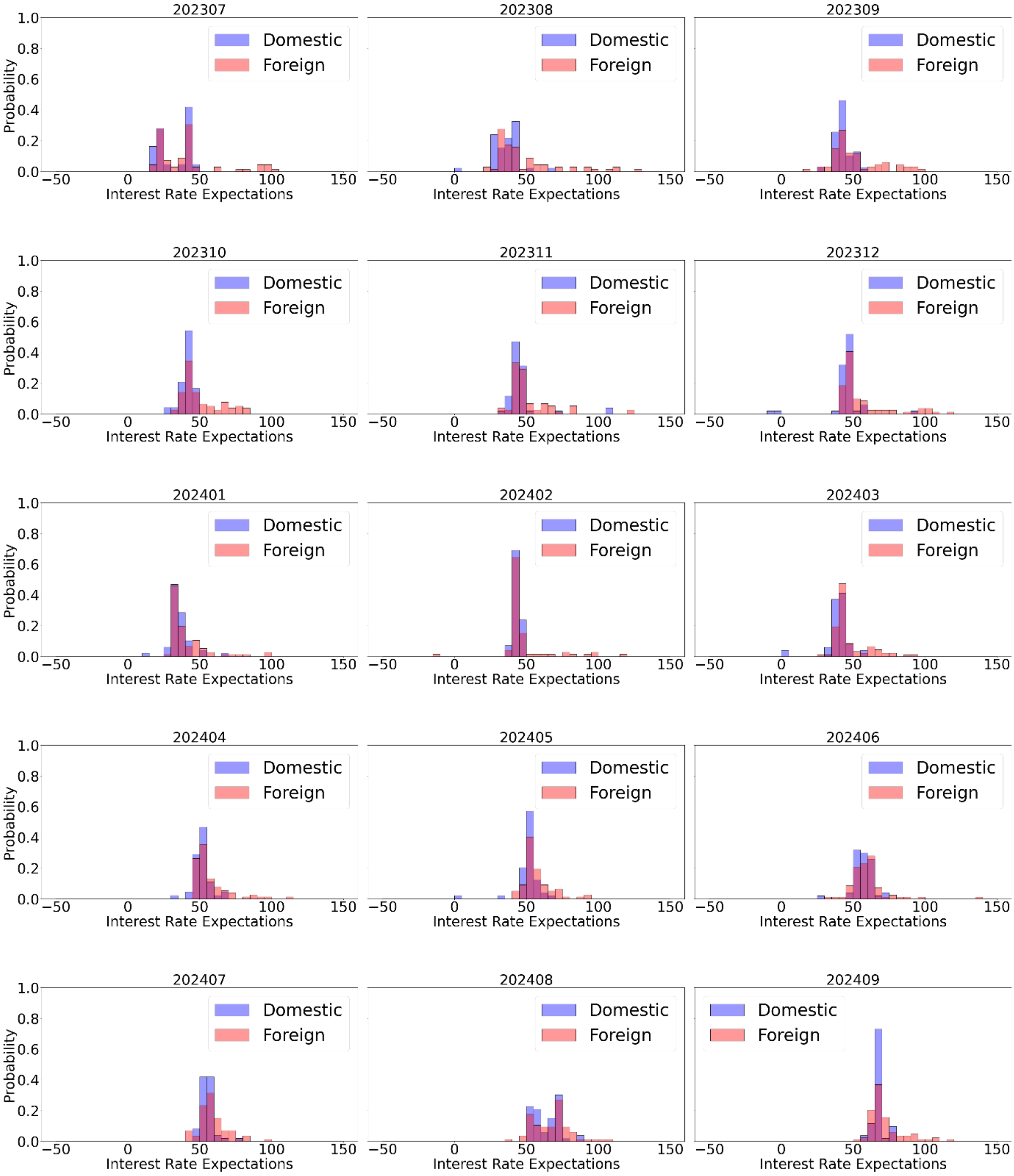
Figure 3. Distribution of the interest rate expectations by nationality (2-year) (continued)



Note: Each panel corresponds to the probability density distribution of the estimated interest rate expectations for domestic and foreign entities. The probability density distribution is calculated separately for domestic and foreign entities. Two distributions are overlayed for the purpose of comparison.

Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 4. Distribution of the interest rate expectations by nationality (10-year)

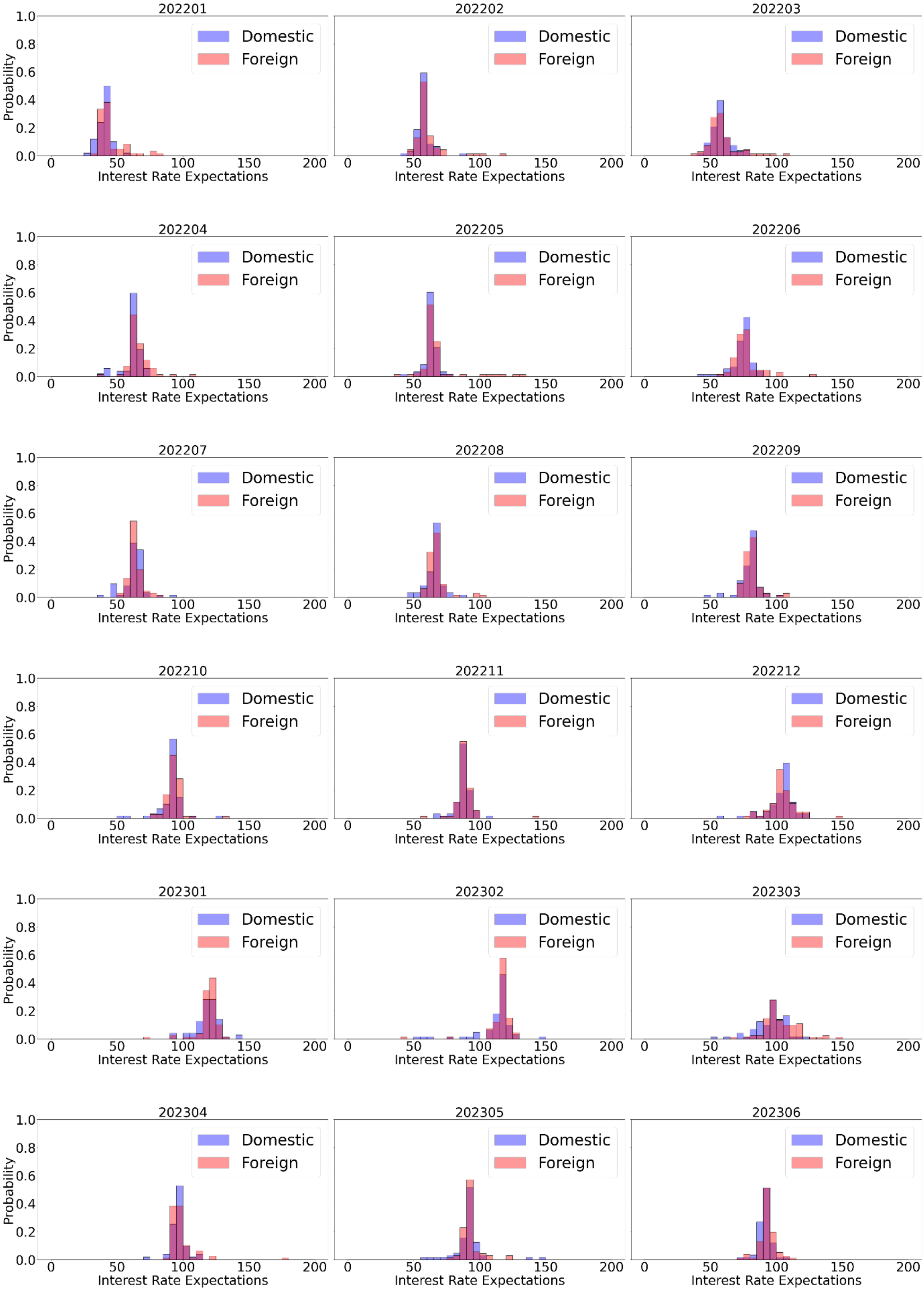


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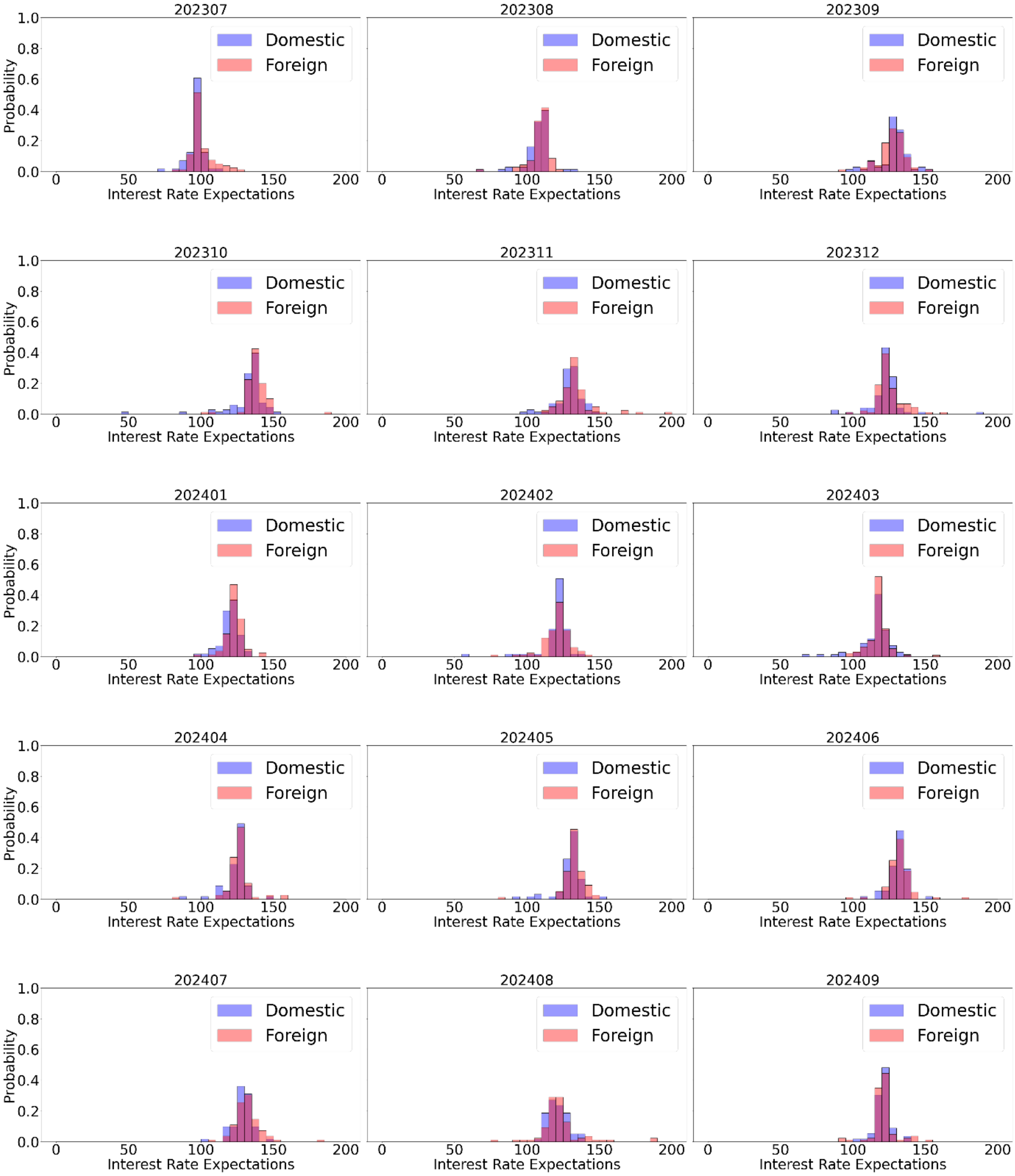
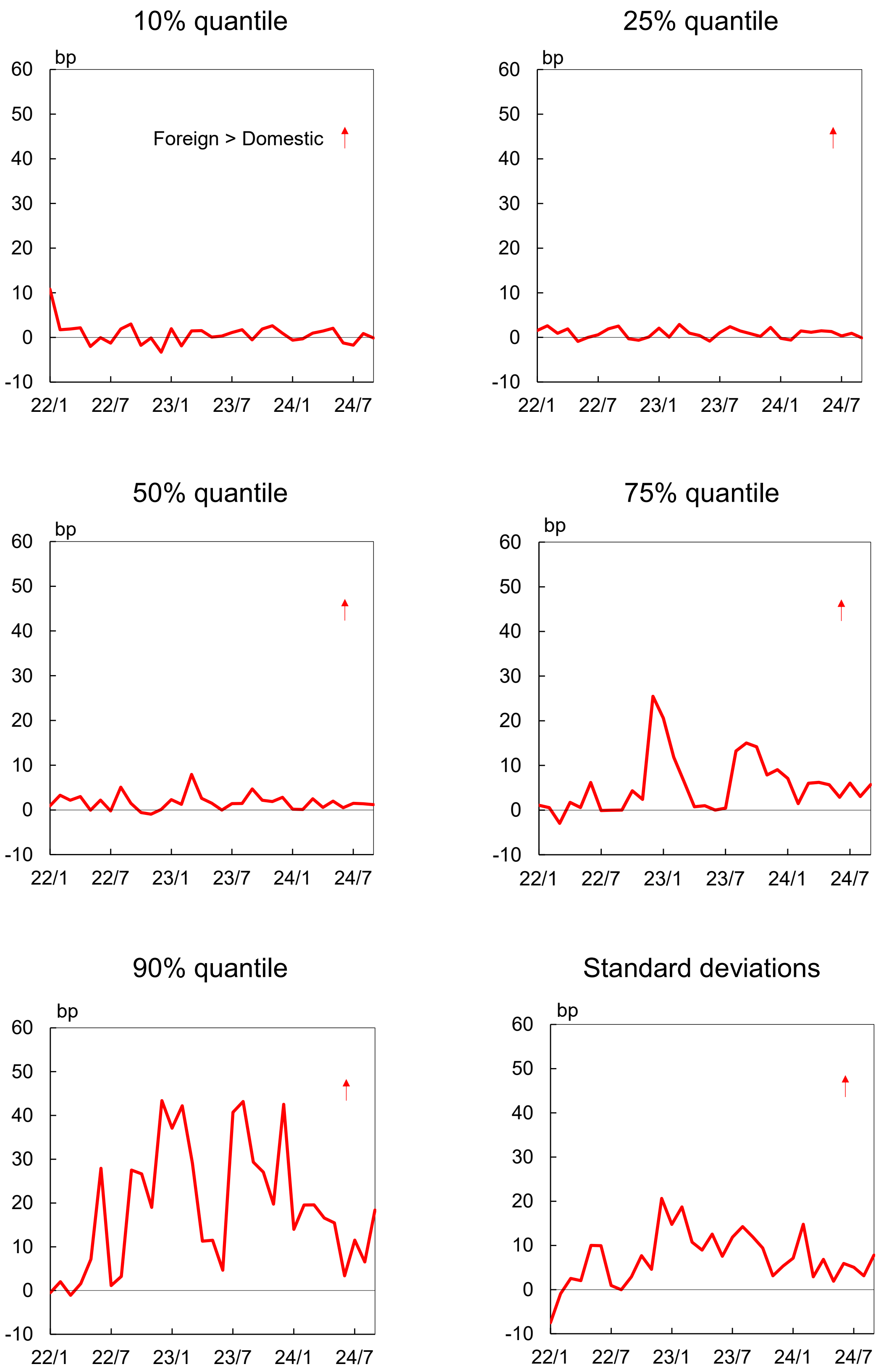
Figure 4. Distribution of the interest rate expectations by nationality (10-year) (continued)



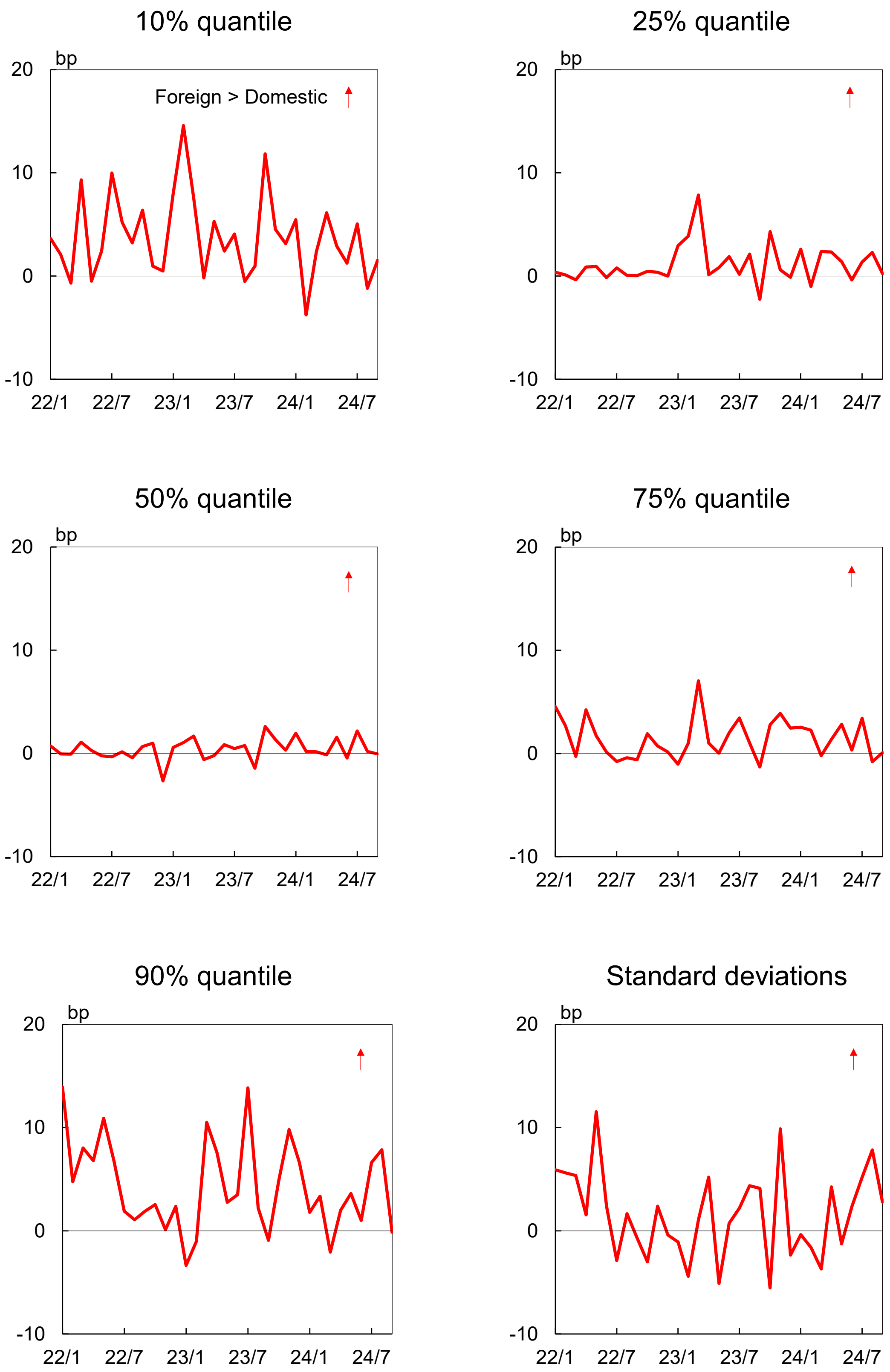
Note: The Note for Figure 3 applies.
Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 5: Differences in quantiles between domestic and foreign entities' interest rate expectations (2-year)



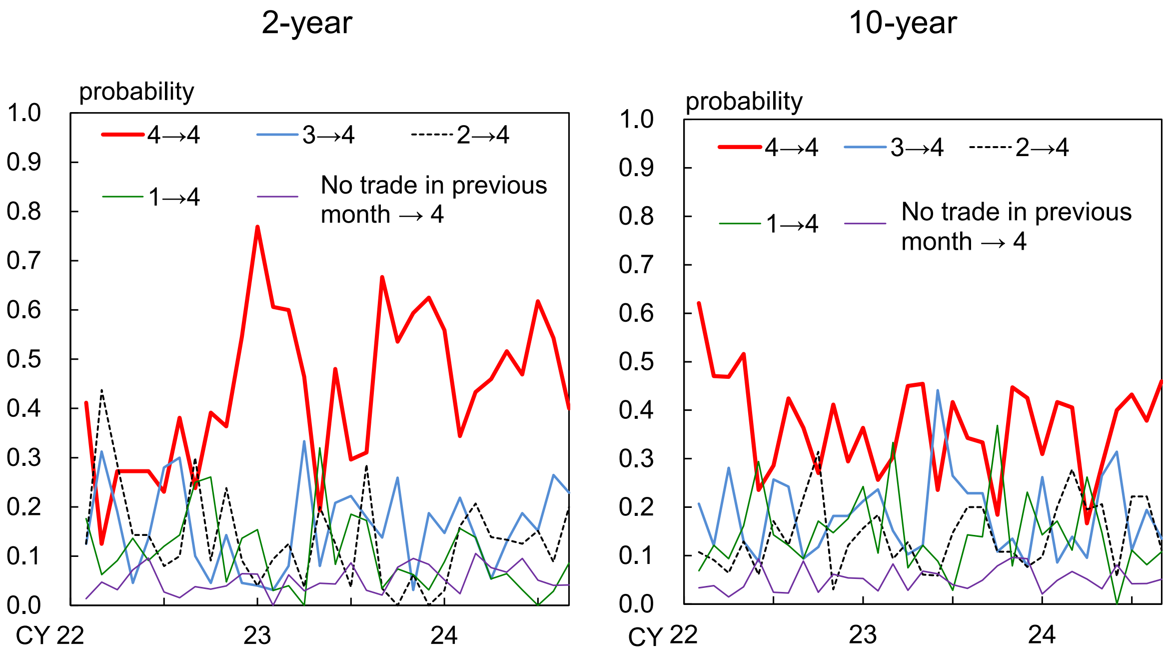
Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 6: Differences in quantiles between domestic and foreign entities' interest rate expectations (10-year)



Sources: Trade repository data; Bloomberg; Bank of Japan.

Figure 7: Transition probability between each quartile group of interest rate expectations



Note: Latest data as of September, 2024. We divide the estimated interest rate expectations into quartile groups. "1", "2", "3" and "4" in the figures denote the groups whose interest rate expectations lie within the range of 0-25%ile, 25-50%ile, 50-75%ile, 75-100%ile, respectively. Then, we calculate the transition probability between five states, namely four quartiles and a state with no transactions in a specific month.

Sources: Trade repository data; Bloomberg; Bank of Japan.

Table 1: Summary statistics of our data

	Count	Mean	Std	Min	25%ile	50%ile	75%ile	Max	N (Seller / Buyer)	
Panel A : 1Y										
Fixed Rate (bp)	11,699	8.2	15.7	-87.5	1.3	5.8	11.6	98.7	87	87
Notional Amount (billion yen)	11,699	38.2	44.4	0.0	12.5	25.0	50.0	767.0		
Panel B : 2Y										
Fixed Rate (bp)	19,883	18.9	16.7	-87.5	8.2	17.9	24.5	103.7	92	96
Notional Amount (billion yen)	19,883	21.9	32.2	0.0	8.3	12.5	24.8	902.5		
Panel C : 3Y										
Fixed Rate (bp)	11,408	23.1	14.6	-39.0	12.9	21.0	32.9	119.3	82	85
Notional Amount (billion yen)	11,408	13.6	17.2	0.0	5.0	10.0	16.5	410.0		
Panel D : 5Y										
Fixed Rate (bp)	38,843	36.5	18.1	-75.0	22.6	37.5	50.6	139.6	109	102
Notional Amount (billion yen)	38,843	9.1	15.9	0.0	3.0	5.0	10.0	500.0		
Panel E : 7Y										
Fixed Rate (bp)	24,679	49.5	21.1	-83.0	34.3	47.9	67.3	135.0	107	97
Notional Amount (billion yen)	24,679	8.2	12.5	0.0	2.2	5.0	10.0	284.1		
Panel F : 10Y										
Fixed Rate (bp)	71,731	63.9	25.1	-70.0	44.3	61.9	85.0	196.3	115	122
Notional Amount (billion yen)	71,731	6.6	20.8	0.0	1.5	2.6	5.0	834.0		
Panel G : 15Y										
Fixed Rate (bp)	10,740	85.6	32.5	0.0	62.9	83.1	110.1	227.0	81	82
Notional Amount (billion yen)	10,740	4.3	8.0	0.0	1.0	2.0	4.1	165.0		
Panel H : 20Y										
Fixed Rate (bp)	37,101	106.1	34.1	0.0	80.6	106.5	133.5	216.3	121	132
Notional Amount (billion yen)	37,101	2.8	6.2	0.0	1.0	1.4	2.5	180.0		
Panel I : 30Y										
Fixed Rate (bp)	9,498	115.0	29.1	10.5	96.6	115.3	136.6	200.0	87	98
Notional Amount (billion yen)	9,498	2.1	3.3	0.0	1.0	1.0	2.0	62.0		

Note: "N (seller/buyer)" denotes the number of swap sellers and buyers for each OIS maturity. The sample period is from January 1, 2022 to March 18, 2024.
Source: Trade repository data.

Table 2: Estimation results of fixed-rate purchase operation on the JGB yields, conditional on the market participants' interest rate expectations

	(1)		(2)		(3)	
FRP dummy	0.054		0.093		0.096	
	(0.157)		(0.159)		(0.164)	
FRP dummy * Mean	0.042		0.106		0.102	
	(0.059)		(0.065)		(0.074)	
FRP dummy * Variance	-0.159	***	-0.199	***	-0.211	***
	(0.059)		(0.063)		(0.061)	
FRP dummy * Skewness			0.094	***	0.087	**
			(0.027)		(0.034)	
FRP dummy * Kurtosis					0.023	
					(0.030)	
FRP dummy * FRP Intensity	-0.082	*	-0.124	**	-0.127	**
	(0.044)		(0.059)		(0.062)	
FRP dummy * FRP Intensity * Mean	0.046		0.006		0.003	
	(0.032)		(0.035)		(0.034)	
FRP dummy * FRP Intensity * Variance	0.085		0.133	**	0.151	***
	(0.064)		(0.055)		(0.041)	
FRP dummy * FRP Intensity * Skewness			-0.077	**	-0.080	*
			(0.035)		(0.043)	
FRP dummy * FRP Intensity * Kurtosis					0.012	
					(0.022)	
Date, Maturity FEs	YES		YES		YES	
Scheduled / Unscheduled CAM operations	YES		YES		YES	
Observations	5,093		5,093		5,093	

Note 1: The dependent variable is the daily JGB yields. We use the first to fourth order moments from the distribution of all swap market participants' estimated interest rate expectations. We report clusterd standard errors at the maturity level in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% confidence level, respectively.

Note 2: The table reports the estimation results in the equation (3). "FRP dummy" takes the value of 1 when the fixed-rate purchase operation is bid and 0 otherwise. "FRP Intensity" denotes the distance between the interest rate level for fixed-rate purchase operations and the average of the distribution of market participants' interest rate expectations. "Mean," "Variance," "Skewness" and "Kurtosis" represent the first to fourth moment of the distribution of market participants' interest rate expectations over the past 14 days, respectively. The estimation takes into account date and maturity fixed effects as well as the logarithm of the offered values of scheduled and unscheduled ouright purchase operations of JGBs by competitive auction method. All of the dependent variable, the moment variables, and the variables accounting for market operations are standardized during the sample period.

Sources: Trade repository data; Bloomberg; Bank of Japan

Table 3: Estimation results of fixed-rate purchase operations on first difference in the JGB yields, conditional on the market participants' interest rate expectations

	(1)		(2)		(3)	
FRP dummy	0.054	**	0.071	***	0.076	***
	(0.026)		(0.023)		(0.023)	
FRP dummy * Mean	-0.001		0.053		0.060	
	(0.030)		(0.034)		(0.037)	
FRP dummy * Variance	0.061		0.031		0.026	
	(0.039)		(0.040)		(0.038)	
FRP dummy * Skewness			0.039		0.039	
			(0.027)		(0.032)	
FRP dummy * Kurtosis					0.030	*
					(0.018)	
FRP dummy * FRP Intensity	-0.044		-0.072	*	-0.076	*
	(0.029)		(0.042)		(0.041)	
FRP dummy * FRP Intensity * Mean	0.009		-0.014		-0.020	
	(0.045)		(0.033)		(0.035)	
FRP dummy * FRP Intensity * Variance	0.067		0.091	**	0.099	**
	(0.046)		(0.046)		(0.039)	
FRP dummy * FRP Intensity * Skewness			-0.051		-0.060	*
			(0.036)		(0.033)	
FRP dummy * FRP Intensity * Kurtosis					-0.001	
					(0.018)	
Date, Maturity FEs	YES		YES		YES	
Scheduled / Unscheduled CAM operations	YES		YES		YES	
Observations	5,092		5,092		5,092	

Note: The dependent variable is the first difference in the daily JGB yields. We use the first to fourth order moments from the distribution of all swap market participants' estimated interest rate expectations. We report clusterd standard errors at the maturity level in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% confidence level, respectively. The Note 2 for Table 2 applies.
Sources: Trade repository data; Bloomberg; Bank of Japan

Table 4: Estimation results of fixed-rate purchase operations on the JGB yields (10-year), conditional on the market participants' interest rate expectations (10-year)

	(1)	(2)	(3)
FRP dummy	-0.229 ***	-0.138 ***	-0.130 ***
	(0.062)	(0.043)	(0.040)
FRP dummy * Mean	0.154 ***	0.277 ***	0.320 ***
	(0.043)	(0.034)	(0.035)
FRP dummy * Variance	0.128 ***	0.029	0.043
	(0.048)	(0.037)	(0.038)
FRP dummy * Skewness		0.479 ***	0.477 ***
		(0.037)	(0.034)
FRP dummy * Kurtosis			-0.155 ***
			(0.047)
FRP dummy * FRP Intensity	-0.525 ***	-0.578 ***	-0.575 ***
	(0.020)	(0.024)	(0.022)
FRP dummy * FRP Intensity * Mean	0.037 **	0.013	0.007
	(0.017)	(0.021)	(0.022)
FRP dummy * FRP Intensity * Variance	-0.028	-0.033	-0.032
	(0.031)	(0.028)	(0.026)
FRP dummy * FRP Intensity * Skewness		-0.078 ***	-0.086 ***
		(0.017)	(0.018)
FRP dummy * FRP Intensity * Kurtosis			0.028 ***
			(0.010)
Date, Maturity FEs	NO	NO	NO
Scheduled / Unscheduled CAM operations	YES	YES	YES
Observations	566	566	566

Note: The dependent variable is the daily JGB yields (10-year). We use the first to fourth order moments from the distribution of all swap market participants' estimated interest rate expectations (10-year). We report HAC standard errors at the maturity level in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% confidence level, respectively. The Note 2 for Table 2 applies.

Sources: Trade repository data; Bloomberg; Bank of Japan

Table 5: Estimation results of fixed-rate purchase operations on the JGB yields (10-year), conditional on the market participants' interest rate expectations (2-year and 10-year)

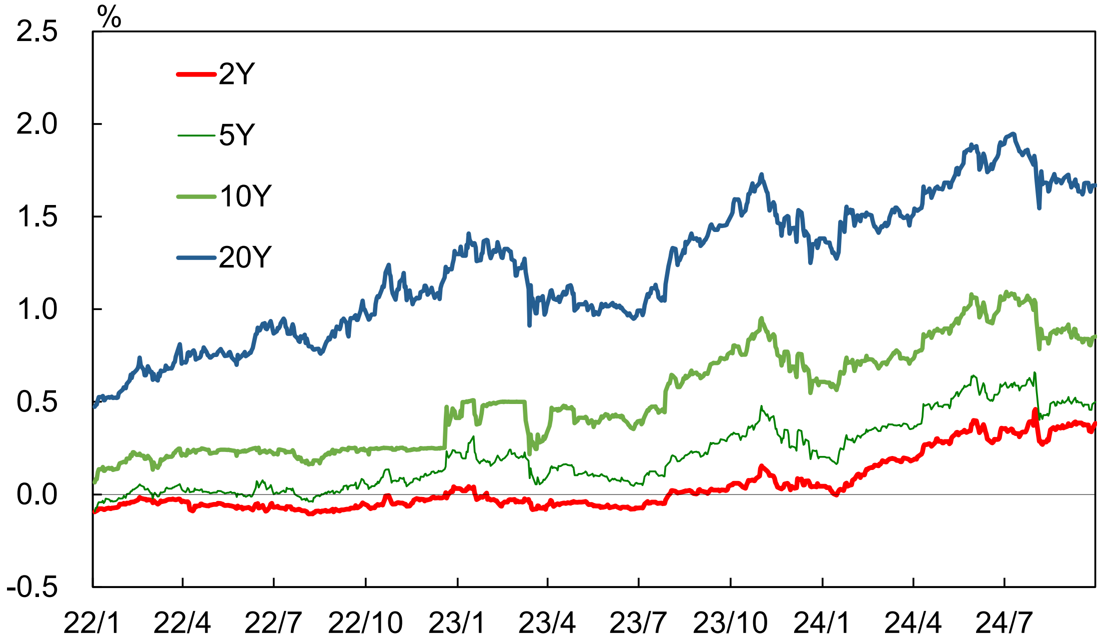
	(1)		(2)		(3)	
FRP dummy * FRP Intensity	-0.529	***	-0.583	***	-0.576	***
	(0.019)		(0.024)		(0.022)	
FRP dummy * FRP Intensity * Mean (2y)	-0.081	***	-0.067	***	-0.059	***
	(0.017)		(0.016)		(0.018)	
FRP dummy * FRP Intensity * Variance (2y)	0.063	***	0.048	**	0.050	*
	(0.022)		(0.021)		(0.026)	
FRP dummy * FRP Intensity * Skewness (2y)			-0.018		-0.064	***
			(0.014)		(0.020)	
FRP dummy * FRP Intensity * Kurtosis (2y)					0.071	**
					(0.029)	
FRP dummy * FRP Intensity * Mean (10y)	0.074	***	0.051	**	0.051	**
	(0.022)		(0.026)		(0.026)	
FRP dummy * FRP Intensity * Variance (10y)	-0.057	*	-0.056	**	-0.031	
	(0.030)		(0.027)		(0.027)	
FRP dummy * FRP Intensity * Skewness (10y)			-0.072	***	-0.097	***
			(0.014)		(0.017)	
FRP dummy * FRP Intensity * Kurtosis (10y)					0.005	
					(0.012)	
Date, Maturity FEs	NO		NO		NO	
Scheduled / Unscheduled CAM operations	YES		YES		YES	
Observations	566		566		566	

Note: The dependent variable is the daily JGB yields (10-year). We use the first to fourth order moments from the distribution of all swap market participants' estimated interest rate expectations (2-year and 10-year). We report HAC standard errors at the maturity level in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% confidence level, respectively. The Note 2 for Table 2 applies.

Sources: Trade repository data; Bloomberg; Bank of Japan

Appendix

Figure A1: Daily JGB rates by Maturity



Note: Latest data as of September 30, 2024.
Source: Bloomberg.

Table A1: Chronological developments relating to the fixed-rate purchase operation

MPM dates	MPM statements
September 21, 2016	The Bank will purchase Japanese government bonds (JGBs) so that 10-year JGB yields will remain more or less at the current level (around zero percent).
March 19, 2021	The Bank will make clear that the range of 10-year Japanese government bond (JGB) yield fluctuations would be between around plus and minus 0.25 percent from the target level. At the same time, it will introduce "fixed-rate purchase operations for consecutive days" as a powerful tool to set an upper limit on interest rates when necessary.
April 28, 2022	The Bank will offer to purchase 10-year JGBs at 0.25 percent every business day through fixed-rate purchase operations, unless it is highly likely that no bids will be submitted.
December 20, 2022	The Bank will expand the range of 10-year JGB yield fluctuations from the target level: from between around plus and minus 0.25 percentage points to between around plus and minus 0.5 percentage points. In order to encourage the formation of a yield curve that is consistent with the guideline for market operations, the Bank will make nimble responses for each maturity by increasing the amount of JGB purchases even more and conducting fixed-rate purchase operations.
July 28, 2023	The Bank will continue to allow 10-year JGB yields to fluctuate in the range of around plus and minus 0.5 percentage points from the target level, while it will conduct yield curve control with greater flexibility, regarding the upper and lower bounds of the range as references, not as rigid limits, in its market operations. The Bank will offer to purchase 10-year JGBs at 1.0 percent every business day through fixed-rate purchase operations, unless it is highly likely that no bids will be submitted.
October 31, 2023	The Bank will regard the upper bound of 1.0 percent for 10-year JGB yields as a reference in its market operations.
March 19, 2024	The Bank considers that the policy framework of Quantitative and Qualitative Monetary Easing (QQE) with Yield Curve Control and the negative interest rate policy to date have fulfilled their roles. With the price stability target of 2 percent, it will conduct monetary policy as appropriate, guiding the short-term interest rate as a primary policy tool.

Source: Bank of Japan.

Table A2: Estimation results of fixed-rate purchase operations on the JGB yields, when the effect of $FRP\ Intensity$ is decomposed into volume effect ($FRP\ \ Amount$) and signaling effect ($FRP\ \ Intensity$)

	(1)		(2)		(3)	
FRP dummy	0.073		0.098		0.107	
	(0.155)		(0.156)		(0.160)	
FRP dummy * Mean	0.037		0.080		0.088	
	(0.057)		(0.062)		(0.066)	
FRP dummy * Variance	-0.150	***	-0.182	***	-0.190	***
	(0.056)		(0.053)		(0.055)	
FRP dummy * Skewness			0.075	***	0.075	***
			(0.020)		(0.018)	
FRP dummy * Kurtosis					0.028	
					(0.032)	
FRP dummy * FRP Intensity	-0.061	*	-0.100	***	-0.102	**
	(0.035)		(0.037)		(0.041)	
FRP dummy * FRP Intensity * Mean	0.034		0.019		0.011	
	(0.040)		(0.036)		(0.035)	
FRP dummy * FRP Intensity * Variance	0.062		0.102	***	0.114	***
	(0.052)		(0.037)		(0.033)	
FRP dummy * FRP Intensity * Skewness			-0.059	**	-0.064	**
			(0.024)		(0.025)	
FRP dummy * FRP Intensity * Kurtosis					0.008	
					(0.015)	
FRP amount	-0.058	*	-0.050	**	-0.052	**
	(0.030)		(0.024)		(0.026)	
FRP amount * Mean	-0.055	*	-0.044		-0.042	
	(0.030)		(0.039)		(0.043)	
FRP amount * Variance	0.115	***	0.102	***	0.094	***
	(0.031)		(0.026)		(0.027)	
FRP amount * Skewness			0.024		0.033	
			(0.026)		(0.035)	
FRP amount * Kurtosis					-0.017	
					(0.024)	
Date, Maturity FEs	YES		YES		YES	
Scheduled / Unscheduled CAM operations	YES		YES		YES	
Observations	5,093		5,093		5,093	

Note: The dependent variable is the daily JGB yields. We use the first to fourth order moments from the distribution of all swap market participants' estimated interest rate expectations. We report clusterd standard errors at the maturity level in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% confidence level, respectively. "FRP amount" denotes the amount of JGB purchase under the fixed-rate purchase operation. The Note 2 for Table 2 applies.

Sources: Trade repository data; Bloomberg; Bank of Japan

Table A3: Summary statistics of each variable related to 2-year OIS transactions

	Count	Mean	Std	Min	25%ile	50%ile	75%ile	Max
Daily JGB rate (bp)	566	-1.7	6.5	-10.5	-6.3	-4.0	2.2	19.5
FRP dummy	566	0.0	0.1	0.0	0.0	0.0	0.0	1.0
FRP Intensity (bp)	566	0.4	4.3	0.0	0.0	0.0	0.0	59.4
Interest Rate Expectations' Mean	566	23.8	49.0	-148.7	6.1	21.4	51.7	211.2
Interest Rate Expectations' Variance	566	256.5	293.7	1.2	38.7	174.1	372.7	2817.3
Interest Rate Expectations' Skewness	566	1.7	1.6	-4.3	0.8	1.7	2.6	6.7
Interest Rate Expectations' Kurtosis	566	7.5	8.2	-1.6	1.7	4.8	10.7	46.1
Scheduled CAM Offer Amount (bil. yen)	566	81.8	172.5	0.0	0.0	0.0	0.0	625.0
Unscheduled CAM Offer Amount (bil. yen)	566	1.9	18.2	0.0	0.0	0.0	0.0	300.0

Table A4: Summary statistics of each variable related to 10-year OIS transactions

	Count	Mean	Std	Min	25%ile	50%ile	75%ile	Max
Daily JGB rate (bp)	566	42.3	21.1	13.2	23.9	39.9	60.8	95.2
FRP dummy	566	0.7	0.5	0.0	0.0	1.0	1.0	1.0
FRP Intensity (bp)	566	18.0	20.1	-22.1	0.0	19.1	34.7	68.2
Interest Rate Expectations' Mean	566	75.1	27.4	13.5	54.4	75.4	88.9	165.9
Interest Rate Expectations' Variance	566	69.8	42.0	12.4	41.6	57.4	85.6	275.2
Interest Rate Expectations' Skewness	566	0.3	2.4	-6.2	-1.5	0.4	2.0	5.9
Interest Rate Expectations' Kurtosis	566	11.1	8.2	-0.9	5.7	9.1	14.3	49.2
Scheduled CAM Offer Amount (bil. yen)	566	105.3	223.0	0.0	0.0	0.0	0.0	800.0
Unscheduled CAM Offer Amount (bil. yen)	566	14.5	75.5	0.0	0.0	0.0	0.0	700.0

Note: The sample period is from January 1, 2022 to March 18, 2024.
Sources: Trade repository data; Bloomberg; Bank of Japan.