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The Impact of Quantitative and Qualitative Easing and Yield Curve Control on the Functioning of the Japanese Government Bond Market

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The Impact of Quantitative and Qualitative Easing and Yield Curve Control on the Functioning of the Japanese Government Bond Market*

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Abstract

This paper examines the impact of the Bank of Japan (BOJ)'s Quantitative and Qualitative Easing (QQE) and Yield Curve Control (YCC) on the functioning of the Japanese government bond (JGB) market using panel data for JGB issues. The main results can be summarized in the following three points. First, regarding the impact on transaction volume in the JGB market, JGB purchases by the BOJ (i.e. increase in flow) increase transaction volume on average, while the BOJ's increased holdings of JGBs (i.e. increase in stock) and its conduct of continuous fixed-rate purchase operations decrease transaction volume. However, if the BOJ conducts JGB purchases when its share of JGB holdings exceeds a certain threshold, transaction volume will decrease. Second, regarding the impact on bid-ask spreads in the JGB market, while JGB purchases by the BOJ reduce these spreads, the increase in the share of JGBs held by the BOJ will lead to a nonlinear widening of the spreads. Third, regarding the impact on the shape of the yield curve, an increase in the BOJ's holdings of certain JGB issues and its conduct of continuous fixed-rate purchase operations will lead to a downward distortion in the yield curve.

JEL classification numbers: C23, D4, D53, E58, G12
Key words: QQE, YCC, JGB market, market functioning, market liquidity

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1. Introduction

The Bank of Japan (BOJ)'s large-scale monetary easing policies of the past decade or so, such as Quantitative and Qualitative Easing (QQE), which was introduced in April 2013, and Yield Curve Control (YCC) under the framework of QQE with YCC, which was introduced in September 2016, had the effect of boosting the economy and pushing up prices by lowering real interest rates.[1,2] However, it has been suggested that under QQE and YCC, the functioning of the Japanese government bond (JGB) market diminished as the BOJ increased its holdings of JGBs and its influence over market interest rates. In fact, according to the findings of the BOJ's Special Survey of the Bond Market Survey (November 2023), bond market participants assessed that the functioning of the bond market had declined considerably since the introduction of QQE (Figure 1).

Against this backdrop, this paper empirically analyzed the impact of QQE and YCC on the functioning of the JGB market. To conduct this analysis, we first need to set some analyzable quantitative indicators for the somewhat abstract concept of "market functioning." Many metrics exist for measuring market functioning, but here we focus on two types: liquidity indicators (such as the bid-ask spread) and relative price indicators (such as the deviation from the spline interpolation of the yield curve).[3] Specifically, we used three indicators as market function metrics: transaction volume and the bid-ask spread as liquidity indicators and yield curve distortion for the relative price indicator. For these indicators, we used panel data for JGB issues to perform a regression analysis on the impact of the BOJ's monetary easing policies.

The results of the panel data analysis confirmed the following three points. First, from the analysis using transaction volume as the dependent variable, we found that JGB purchases by

[1] At its March 2024 Monetary Policy Meeting, the BOJ decided to shift to the monetary policy framework in which the primary policy tool would be to guide the short-term interest rates under the price stability target of 2%, in the belief that its large-scale monetary easing had fulfilled its role.

[2] The effects of monetary policy and developments in economic activity and prices after the introduction of QQE were analyzed and assessed in "Comprehensive Assessment: Developments in Economic Activity and Prices as well as Policy Effects since the Introduction of Quantitative and Qualitative Monetary Easing (QQE)" (2016) and "Assessment for Further Effective and Sustainable Monetary Easing" (2021). The Review of Monetary Policy from a Broad Perspective, which is now in progress, also includes analytical results.

[3] Lorie Logan, president of the Federal Reserve Bank of Dallas, states that to measure whether a market is functioning requires not just looking at one indicator, but using several different metrics in a comprehensive way (Logan, 2020). She suggests dividing these indicators into liquidity metrics and relative price metrics, as we do in this paper.

the BOJ (i.e. increase in flow) increased transaction volume on average, while an increase in the share of JGBs held by the BOJ (i.e. increase in stock) and its conduct of continuous fixed-rate purchase operations caused transaction volume to decline. However, it was found that transaction volume tended to decline if JGB purchases were made when the BOJ's holdings of JGBs exceeded a certain threshold. Second, from the analysis using the bid-ask spread as the dependent variable, we confirmed that while BOJ purchases of JGBs reduced bid-ask spreads, an increase in the proportion of JGBs held by the BOJ caused a nonlinear widening of bid-ask spreads. Third, from the analysis using the distortion of the yield curve as the dependent variable, we found that an increase in the BOJ's holdings of some JGB issues and its conduct of continuous fixed-rate purchase operations caused a downward distortion of the yield curve.

The remainder of this paper is organized as follows. Section 2 discusses its relationship with the existing literature. Section 3 reviews the developments in the functioning of the JGB market. Section 4 describes the estimation methodology and data for analyzing the impact of the BOJ's monetary policies of QQE and YCC on the functioning of the JGB market. Section 5 gives the results of an empirical analysis using panel data for JGB issues. Section 6 presents our conclusion.

2. Relationship with existing literature

Although a fair amount of research has been done both in Japan and overseas on the impact of government bond purchases by central banks and the impact of monetary policy on market functioning, there has been little consensus among their conclusions.

First, among the prior studies of periods when traditional monetary policies were being implemented, Harvey and Huang (2002) and Andersson (2010) pointed out that the Fed's open market operations led to increased volatility in government bond prices.[4] For Japan as well, Inoue (1999) reported that the BOJ's open market operations caused transaction volume in the JGB market to increase and the volatility of JGB prices to go up.[5] Meanwhile,

[4] Harvey and Huang (2002) analyzed the period from 1982 to 1988, while Andersson (2010) looked at the period from 1999 to 2006.

[5] Iwatsubo and Taishi (2018) described the mechanism whereby central bank purchases of government bonds increase the volatility in the government bond market as follows. In a situation where the central bank possesses some special (private) information about government bond prices, market participants watching the open market

Pasquariello *et al.* (2020) asserted that from 2001 to 2007, the Fed's open market operations caused bid-ask spreads to narrow and market liquidity to improve.[6]

Among prior overseas studies of periods when unconventional monetary policies were being implemented on a broad scale, there are no definitive assessments of the impact that central bank government bond purchases or monetary policies have on market functioning. Kandrac and Schlusche (2013) reported being unable to find any evidence that the Fed's Large Scale Asset Purchases (LSAP) reduced market liquidity. In addition, De Pooter *et al.* (2018) argued that the Securities Market Programme (SMP) of the European Central Bank (ECB) reduced government bond liquidity premiums in the Eurozone peripheral countries and improved market functioning. In contrast, Schlepper *et al.* (2020) asserted that the ECB's Public Sector Purchase Programme (PSPP) had the negative effect of reducing the depth of the German government bond market. Additionally, Finlay *et al.* (2023) reported that under the Reserve Bank of Australia's Yield Target, government bond purchases had an adverse effect on market liquidity, as they reduced the volume of government bonds circulating in the market and caused bid-ask spreads to widen.

Of the research on the unconventional monetary policies implemented by the BOJ, Iwatsubo and Taishi (2018) reported that since the introduction of QQE, liquidity in the JGB market improved when the BOJ increased the frequency of its JGB purchases, reduced the amount it purchased each time, and reduced the variability of the amounts purchased per day. In addition, according to Pelizzon *et al.* (2018), BOJ purchases of JGBs have both positive and negative effects on market liquidity, the former being called the *spotlight effect* and the latter being called the *scarcity effect*. The spotlight effect occurs when the BOJ purchases a

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operations will think that these open market operations are using some special information that is not yet reflected in the market prices. As a result, trading in the market becomes cautious, and the volatility of the government bond market increases with rising uncertainty over future prices anticipated by market participants. Bhattacharya and Weller (1997) and Chari (2007) also pointed out that in the foreign exchange market, the same type of mechanism occurs through foreign exchange intervention by the currency authorities.

[6] Regarding the background to such improvements in market liquidity, Pasquariello *et al.* (2020) commented that the transparency of monetary policy improved after former Fed Chair Alan Greenspan started announcing what the Federal Open Market Committee (FOMC) had decided and the Fed's monetary policy stance at a press conference following a FOMC meeting, and that there was no additional information regarding the Fed's monetary policy stance in the open market operations themselves. When open market operations possess no additional information, market participants who are watching the open market operations view them as "noise trades" and start to engage in more arbitrage trading, which lowers the volatility of the government bond market because it reduces the uncertainty over future prices anticipated by market participants (Iwatsubo and Taishi, 2018).

certain bond issue and it becomes easier for market participants to sell JGBs from that issue, leading to an increase in inter-dealer transactions and improved market liquidity. On the other hand, the scarcity effect occurs when the BOJ's JGB purchases cause the volume of JGBs circulating in the market to decline, leading to a reduction in transaction volume and less market liquidity. Furthermore, Han and Seneviratne (2018) noted that the impact of the BOJ's JGB purchases on market liquidity changes depending on the level of the BOJ's holdings of JGBs.

Meanwhile, the BOJ has also been analyzing the liquidity and market functioning of the JGB market (Nishizaki *et al.*, 2013; Kurosaki *et al.*, 2014; Kinugasa and Nagano, 2017; Sakiyama and Kobayashi, 2018; Kobayashi *et al.*, 2019; Genma and Inamura, 2019). Some of these papers proposed new monitoring indicators for measuring the liquidity of the JGB market in a more multifaceted manner. These liquidity indicators are now being posted on the BOJ's website about once per quarter.[7]

The present paper is based on this strand of prior studies. However, we also include in the scope of our analysis several key issues that were not addressed in prior research. First of all, while most prior research focused on the liquidity metric such as the bid-ask spread, we use the relative price metric of yield curve distortion as well as the liquidity metrics of transaction volume and the bid-ask spread in the analysis. This enables a broader examination of how the BOJ's monetary easing policy affected the market's functioning. Second, as for the impact of unconventional monetary policy, we analyze not only that of QQE, which was based on large-scale JGB purchases, but also that of fixed-rate purchase operations that were conducted in order to accomplish the long-term interest rate target of YCC. This allows us to form a clearer picture for our assessment of the BOJ's monetary easing policy, which is thought to have reduced the market's functioning. Third, our panel data analysis used data through June 2023, so the analysis includes the samples of increased volatility in international financial markets due to the outbreak of COVID-19 or the interest rate hikes by overseas central banks since 2022. As we review in Section 3, pronounced deteriorations of market functioning, such as the widening of bid-ask spreads and distortion of the yield curve, were observed in this

[7] https://www.boj.or.jp/en/paym/bond/index.htm#p02

period. Thus, having this period as part of our analysis enables us to conduct a more comprehensive assessment of how QQE and YCC affected market functioning.[8]

3. Developments in JGB market functioning

In this section, we use liquidity indicators and relative price indicators to review the functioning of the JGB market.

First, Figure 2 shows the results of a survey on the major causes of price changes identified by bond market participants when trading. From the late 1990s to the early 2000s, bond market participants focused on "Economic situation" and "Supply/demand for bonds" when they were trading, but after around 2013, when QQE was introduced, they started to pay attention to "Monetary policy" when trading. Then, from 2016, when YCC began, until around 2021, market participants' expectations for 10-year interest rates three months forward started to trend generally within the YCC range of fluctuation (Figure 3). Starting from around 2022, overseas interest rates rose and expectations for domestic inflation increased. This further increased bond market participants' focus on monetary policy and also led market participants to expect that interest rates would go above the YCC range of fluctuation.

Against this backdrop, transaction volumes in the JGB cash market declined with fluctuation following the introduction of QQE (Figure 4 (1)). For some time after the introduction of YCC, the bid-ask spread improved as market participants' expectations for interest rates trended to be within the YCC range of fluctuation, but then it widened significantly starting in 2022 (Figure 4 (2)). Also, from early 2022 to early 2023, pronounced distortions in the yield curve were seen in the JGB cash market. Figure 5 shows the deviation between the yield curve smoothed with spline interpolation and the actual market yield (for on-the-run 10-year bonds), showing that a major distortion in the yield curve occurred in 2022.[9]

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[8] At its July 2023 Monetary Policy Meeting, the BOJ decided to conduct YCC with greater flexibility, partly in order to reduce the risk of affecting bond market functioning in light of future upside and downside risks, and no further bidding for fixed-rate purchase operations took place subsequently. As this paper focuses on examining the negative effects of QQE and YCC on market functioning (which are side effects of the monetary easing policy), we have not included the period after July 2023 in our analysis.

[9] Figure 5 uses a cubic spline, but approximately the same results can be obtained with a spline that uses the Nelson-Siegel model or a spline that uses locally weighted scatterplot smoothing (LOWESS). Furthermore, in calculating the yield curve distortion, we could use a spline that a priori excludes issues thought to generate price

In this way, the JGB market's liquidity indicators deteriorated with the introduction of QQE. Then, from the start of YCC until around 2021, some of the liquidity indicators such as the bid-ask spread improved, as market participants' expectations for interest rates moved basically in tandem with the YCC range of fluctuation. However, from around 2022, overseas interest rates began rising and expectations of domestic inflation increased, so liquidity indicators deteriorated overall as market participants' expectations for interest rates deviated from the YCC range of fluctuation, and yield curve distortion became pronounced.

4. Framework and data for the empirical analysis

This section presents the framework for our empirical analysis and describes the data used.

As stated previously, various metrics exist for measuring the degree of the JGB market's functioning, but this paper focuses on two types: liquidity indicators (e.g. the bid-ask spread) and relative price indicators (e.g. the deviation from the spline of the yield curve). Specifically, we use three indicators as our metrics for the degree of market functioning: transaction volume and the bid-ask spread as liquidity indicators and yield curve distortion as the relative price indicator. In addition, we performed regression analyses using these indicators as dependent variables and issue-by-issue panel data for cash market JGBs (2-, 5-, 10-, 20-, 30-, and 40-year bonds) in order to examine the impact of QQE and YCC on the functioning of the JGB market (Figure 6 shows the developments of the dependent variables in the following analysis).

4-1. Estimation model using transaction volume as the dependent variable

Let us first use the following equation for the estimation model with transaction volume as the dependent variable. We call this estimation model Model (1).

$$Trad_{i,t} = c + \alpha \cdot Pur_{i,t} + \beta \cdot Hol_{i,t-1} + \gamma \cdot YCC_{i,t} + Control + \mu_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

premiums for individual bond issues (such as on-the-run 10-year bonds). However, to keep from being arbitrary, we have not made any such adjustments in this paper.

Here, the dependent variable $Trad_{i,t}$ is the transaction volume of issue i at time t divided by the outstanding issuance amount.[10] As for the independent variables, $Pur_{i,t}$ is the percentage of JGB purchases by the BOJ, that is, the amount of JGB purchases by the BOJ (which is a flow variable) divided by the outstanding issuance amount. $Hol_{i,t}$ is the percentage of JGBs held by the BOJ, that is, the balance of JGBs held by the BOJ (which is a stock variable) divided by the outstanding issuance amount. $YCC_{i,t}$ is the YCC range of fluctuation upper bound dummy, which takes 1 if, (i) the issue i could be purchased through the BOJ's continuous fixed-rate purchase operations at time t (or in other words, it is subject to the operations), AND (ii) the difference between the yield on the issue i and the interest rate level for continuous fixed-rate operations is within 3 basis points at time t. $Control$ denotes the control variables, specifically, the on-the-run issue dummy (which is 1 when the issue i is a new issue), the first off-the-run issue dummy (which is 1 when it is the first seasoned issue), and the cheapest dummy (which is 1 when it is the cheapest-to-deliver bond for JGB future contracts). Additionally, μ_i is the individual issue fixed effect and μ_t is the time period fixed effect.

The second term ($Pur_{i,t}$) and third term ($Hol_{i,t-1}$) on the right-hand side of equation (1) try to capture the impact of QQE, which is based on the large-scale JGB purchases. As mentioned above, according to Pelizzon *et al.* (2018), BOJ purchases of JGBs can have both a positive effect (spotlight effect) and negative effect (scarcity effect) on market liquidity. In the spotlight effect, when the BOJ purchases a certain JGB issue, it becomes easier for market participants to sell that issue, so inter-dealer transactions increase and market liquidity improves. This effect can be captured by $Pur_{i,t}$, the share of JGB purchases. In the case of the scarcity effect, when the BOJ purchases JGBs, the volume of bonds circulating in the market declines, which reduces transaction volume and causes market liquidity to deteriorate. This effect can be captured by $Hol_{i,t-1}$, the share of JGBs held by the BOJ. $Hol_{i,t-1}$ is lagged by one period in order to avoid overlap with the effect of the current period's share of JGB purchases ($Pur_{i,t}$).

The fourth term ($YCC_{i,t}$) tries to capture the impact of continuous fixed-rate purchase operations conducted so that the YCC's long-term interest rate target can be met. Continuous

[10] Figure 6 (1) shows the chronological development of the average of all issues for the transaction volume of issue *i* at time *t* divided by the outstanding issuance amount ($Trad_{i,t}$).

fixed-rate purchases are operations for limitless purchases of JGBs of a certain maturity over a certain time period at an interest rate designated by the BOJ in order to prevent large interest rate increases.[11] If the yield on issues subject to continuous fixed-rate purchase operations approaches the interest rate level for continuous fixed-rate operations, market participants are cognizant of possible conducts of the continuous fixed-rate operations while they trade. Specifically, when the yield on issues subject to continuous fixed-rate purchase operations is approaching the interest rate level for continuous fixed-rate operations, trading may ease off due to expectations that the continuous fixed-rate purchase operations will take place and the yield on that issue will hit the interest rate level for continuous fixed-rate purchase operations, and that the resulting price change will be restricted.[12] $YCC_{i,t}$ is a dummy variable for assessing these impacts of continuous fixed-rate purchase operations. It takes 1 when the yield on the issue i subject to continuous fixed-rate purchase operations is within 3 basis points of the interest rate level for continuous fixed-rate purchase operations, and 0 otherwise.

In addition to Equation (1), we use Equation (2) below, which takes into account the possibility that the coefficient of the share of JGB purchases by the BOJ ($Pur_{i,t}$) changes with the level of the share of JGBs held by the BOJ ($Hol_{i,t-1}$). This estimation model, which we call Model (2), is a more flexible model in which the impact of the share of JGBs purchased by the BOJ ($Pur_{i,t}$) on transaction volume ($Trad_{i,t}$) can vary as the share of JGBs held by the BOJ ($Hol_{i,t-1}$) changes. Note that the coefficient θ in Equation (2) is the coefficient for the cross term of the share of JGBs purchased by the BOJ ($Pur_{i,t}$) and the share of JGBs held by the BOJ ($Hol_{i,t-1}$).

$$Trad_{i,t} = c + \left(\alpha + \theta \cdot Hol_{i,t-1}\right) \cdot Pur_{i,t} + \beta \cdot Hol_{i,t-1} + \gamma \cdot YCC_{i,t} + Control + \mu_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

[11] The decision to conduct continuous fixed-rate purchase operations was made at the March 2021 Monetary Policy Meeting. Later, the April 2022 Monetary Policy Meeting specified that these fixed-rate purchase operations would take place every business day, unless it is highly likely that no bids will be submitted, at a yield of 0.25% for 10-year JGBs. Then, the December 2022 Monetary Policy Meeting revised the operation so that they would be conducted continuously at a yield of 0.5% for 10-year JGBs. The YCC range of fluctuation upper bound dummy ($YCC_{i,t}$) is constructed for the period after April 2022, when the interest rate levels for continuous fixed-rate operations were clarified.

[12] According to Kobayashi *et al.* (2019), a positive correlation exists between market volatility and liquidity metrics such as transaction volume. The mechanism here is that when market volatility increases, the price change expands, which leads to increased trading by stimulating inter-dealer price hedging transactions and short-term trading.

4-2. Estimation model using the bid-ask spread as the dependent variable

Next, we consider the following equation as an estimation model that uses the bid-ask spread as the dependent variable.

$$BAS_{i,t} = c + \alpha \cdot DPur_{i,t} + \beta_1 \cdot Hol_{i,t-1} + \gamma \cdot YCC_{i,t} + Control + \mu_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

Here, the dependent variable $BAS_{i,t}$ is the bid-ask spread of issue i at time t, and the independent variable $DPur_{i,t}$ is a dummy for JGB purchases by the BOJ (which is 1 when the BOJ has conducted JGB purchases).[13] The other variables are the same as in Model (1), where transaction volume was the dependent variable.

In addition to the estimation model of Equation (3), we run a model that takes into account the possible nonlinearity of the scarcity effect by adding the square of the share of JGBs held by the BOJ ($Hol_{i,t-1}$), as in Equation (4) below. In this estimation model, the impact of the share of JGBs held by the BOJ ($Hol_{i,t-1}$) on the bid-ask spread ($BAS_{i,t}$) is captured by the combined value of the linear effect's elasticity β_1 and the nonlinear squared term's elasticity β_2. This equation allows us to explore the possibility that the scarcity effect can change nonlinearly depending on the BOJ's share of JGB holdings.

$$BAS_{i,t} = c + \alpha \cdot DPur_{i,t} + \beta_1 \cdot Hol_{i,t-1} + \beta_2 \cdot Hol_{i,t-1}^2 + \gamma \cdot YCC_{i,t} + Control + \mu_i + \mu_t + \varepsilon_{i,t} \quad (4)$$

4-3. Estimation model using yield curve distortion as the dependent variable

Finally, we consider the following equation as an estimation model in which the distortion of the yield curve is the dependent variable.

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[13] In the estimation model where the bid-ask spread is the dependent variable, if we use the share of JGBs purchased by the BOJ ($Pur_{i,t}$) as the variable for capturing the spotlight effect, we verify that its coefficient is not significant. Because the bid-ask spread cannot be 0 or less, this result may be caused by the fact that the effect of reducing the bid-ask spread may be limited when the spreads are already small even if the BOJ purchases large volumes of JGBs. For this reason, in the estimation model where the bid-ask spread is the dependent variable, we use a dummy that is 1 when the BOJ has conducted JGB purchases ($DPur_{i,t}$) as the variable for capturing the spotlight effect.

$$Dist_{i,t} = c + \alpha \cdot Hol_{i,t} + \beta_1 \cdot FRO_{i,t} + \beta_2 \cdot FROC_{i,t} + Control + \mu_i + \mu_t + \varepsilon_{i,t} \quad (5)$$

Here, the dependent variable $Dist_{i,t}$ represents the distortion of the yield curve for issue *i* at time *t*. This yield curve distortion is measured as the deviation of the actual yields from the yield curve in which the yield on each issue has been smoothed with a spline. For example, looking at the distortions in the case of the yield for on-the-run10-year JGB issues (Figure 6 (3)), in 2022, although the entire yield curve was under upward pressure, continuous fixed-rate purchase operations held down increases in the 10-year interest rate so that the deviation becomes significantly negative. In such a situation where the actual yield is markedly lower than the yield on the spline-smoothed yield curve, it can be said that there is a downward distortion in the yield curve. The independent variable $Hol_{i,t}$ is the share of JGBs held by the BOJ, $FRO_{i,t}$ is the fixed-rate purchase operations dummy (which is 1 when the bid for fixed-rate purchase operations have been submitted), and $FROC_{i,t}$ is the continuous fixed-rate purchase operations dummy (which is 1 when the bid for continuous fixed-rate purchase operations have been submitted).[14, 15] $Control$ denotes the control variables, which include the SLF utilization dummy (which is 1 when the Securities Lending Facility (SLF) is used), the on-the-run issue dummy, the first off-the-run issue dummy, and the cheapest issue dummy.

[14] As indicated by Sudo and Tanaka (2021), because the impact of JGB purchases by the BOJ on interest rates is considered to be more important in terms of the stock effect than the flow effect, in Model (5) we omit the flow variable of JGB purchases by the BOJ. Instead of this, for the share of JGBs held by the BOJ, which is a stock variable, we add the value of the flow during the current period ($Hol_{i,t}$).

[15] The fixed-rate purchase operations dummy and the continuous fixed-rate purchase operations dummy used in Model (5) indicate the actual occurrence or non-occurrence of purchases through these operations, which differs from the YCC range of fluctuation upper bound dummy used in Models (1) through (4). The YCC range of fluctuation upper bound dummy not only indicates whether an actual operation was conducted, but also captures any increased expectations of market participants regarding the conduct of continuous fixed-rate purchase operations. On this point, for the shape of the yield curve, actual purchases through these operations should have a greater impact than market participants' increased expectations regarding the conduct of these operations, because actual purchases also directly affect the balance of supply and demand for JGBs in the relevant maturity. In fact, we did not obtain any statistically significant coefficient on the YCC range of fluctuation upper bound dummy when we added it to Model (5). Therefore, for Model (5), we used the fixed-rate purchase operations dummy and the continuous fixed-rate purchase operations dummy, which indicates whether purchase operations were actually conducted or not.

4-4. The data

This subsection describes the data used in the estimations. In all estimation models, Models (1) through (5), we used issue-by-issue panel data for cash JGBs (2-, 5-, 10-, 20-, 30-, and 40-year bonds) (the horizontal divisions are individual bonds and the time divisions are months).

First, in Models (1) and (2), transaction volume ($Trad_{i,t}$) is inter-dealer transaction volume (monthly average) divided by outstanding issuance amount (at month-end). Because the transaction volume is among dealers, there is no way that purchases by the BOJ will directly increase transaction volume ($Trad_{i,t}$). The sample period is from January 2012 to June 2023, and the frequency of observations is monthly. The share of JGB purchases by the BOJ ($Pur_{i,t}$) is the amount of JGB purchases by the BOJ (calculated from the difference in the BOJ's holdings of JGBs at month-end) divided by outstanding issuance amount (at month-end). Also, the share of JGBs held by the BOJ ($Hol_{i,t}$) is the BOJ's holdings of JGBs (at month-end) divided by outstanding issuance amount (at month-end). The YCC range of fluctuation upper bound dummy ($YCC_{i,t}$) is 1 when the difference between the monthly average yield on the issues subject to continuous fixed-rate purchase operations and the interest rate levels for continuous fixed-rate purchase operations is within 3 basis points. The on-the-run issue dummy is 1 when the relevant issue is a new issue, the first off-the-run issue dummy is 1 when the relevant issue is a first seasoned issue, and the cheapest issue dummy is 1 when the relevant issue is the cheapest-to-deliver bond for JGB futures contracts.

In Models (3) and (4), the bid-ask spread ($BAS_{i,t}$) is the bid-ask spread for inter-dealer transaction. The sample period is from October 2015 to June 2023, and observation values per second are converted to monthly averages. The dummy for JGB purchases by the BOJ ($DPur_{i,t}$) is 1 when so ascertained from the difference from the prior month's JGB holdings by the BOJ. The other variables are the same as in Models (1) and (2).

In Model (5), the yield curve distortion ($Dist_{i,t}$) is calculated from the yield curve smoothed by a spline (using a cubic spline) and the actual yields on each issue of JGBs, the result being a deviation of the actual yield on each issue from the splined yield curve. The sample period is from January 2008 to June 2023, and daily observation values are converted to monthly averages. Also, the fixed-rate purchase operations dummy ($FRO_{i,t}$) is 1 when the bid for fixed-rate purchase operations is submitted, the continuous fixed-rate purchase

operations dummy ($FROC_{i,t}$) is 1 when the bid for continuous fixed-rate purchase operations is submitted, and the SLF utilization dummy is 1 when the SLF is used. The other variables are the same as in Models (1) through (4).

5. Estimation results

5-1. Estimation results when transaction volume is the dependent variable

Figure 7 (1) shows the regression results for Models (1) and (2), in which transaction volume is the dependent variable. In Model (1), the coefficient of the share of JGBs purchased by the BOJ ($Pur_{i,t}$) is positive and statistically significant at the 1% level. This indicates that transaction volume increases when the BOJ purchases JGBs, and hence confirms that there is a spotlight effect. Meanwhile, the coefficient of the share of JGBs held by the BOJ ($Hol_{i,t-1}$) is negative and statistically significant at the 1% level, and we can confirm the existence of a scarcity effect that reduces transaction volume when the share of JGBs held by the BOJ increases. In addition, the coefficient of the YCC range of fluctuation upper bound dummy ($YCC_{i,t}$) is negative and statistically significant at the 1% level, and we observe that when continuous fixed-rate purchase operations are conducted or market participants are aware of possible conducts of the operations, the price change of JGB issues that will be subject to continuous fixed-rate purchase operations are expected to become limited in the future, and as a result, transaction volume declines.

To consider the implications of the results of Model (1), we examine the situation in which the BOJ purchases 1% of the outstanding issuance amount of JGBs at time t_0. In this case, noting that the estimated parameters are $\alpha = 0.0065$ and $\beta = -0.0026$, at time t_0, the spotlight effect will cause transaction volume (as a percentage of total issuance) to increase by $+0.0065$ $\left(= +0.0065 \times 1(\%)\right)$. At this point, the scarcity effect has not yet appeared. In the following period, t_1, the spotlight effect goes away, and transaction volume declines by -0.0026 $\left(= -0.0026 \times 1(\%)\right)$ due to the scarcity effect from the JGB holdings that were purchased in the previous period. Because JGBs purchased by the BOJ are generally held to maturity, the scarcity effect occurs at time t_2 and subsequent periods as well, so that transaction volume declines -0.0026 each period until the bonds mature. In other words, while the spotlight effect is transient, the scarcity effect continues until maturity.

Looking at the estimation results of Model (2), where the spotlight effect can change depending on the share of JGBs held by the BOJ ($Hol_{i,t-1}$), the coefficient for the cross term of the share of JGBs purchased by the BOJ ($Pur_{i,t}$) and the share of JGBs held by the BOJ ($Hol_{i,t-1}$) is negative and statistically significant at the 1% level. The coefficients of the share of JGBs purchased by the BOJ ($Pur_{i,t}$), the share of JGBs held by the BOJ ($Hol_{i,t-1}$), and the YCC range of fluctuation upper bound dummy ($YCC_{i,t}$) are almost the same as those in Model (1). Based on these results, Figure 7 (2) shows how the spotlight effect ($\alpha + \theta \cdot Hol_{i,t-1}$) changes depending on the level of the share of JGBs held by the BOJ ($Hol_{i,t-1}$). We see that the spotlight effect is positive until the share of JGBs held by the BOJ ($Hol_{i,t-1}$) reaches around 70%, but once the share of JGBs held by the BOJ ($Hol_{i,t-1}$) exceeds around 70%, the spotlight effect becomes negative.

The spotlight effect makes it easier for market participants to sell the specific JGB issue that the BOJ is purchasing, and it stimulates inter-dealer transactions. The above results suggest that when the share of a certain JGB issue held by the BOJ reaches a certain level, market participants will realize that inter-dealer market liquidity has decreased, there will be no inducement to trade outside of auctions conducted through BOJ operations, and a negative spotlight effect will occur (i.e., transaction volume will decline). In addition, in light of the above results, it can be said that if the share of JGB held by the BOJ exceeds a certain level, a negative signaling effect can occur with respect to the market liquidity in the future, and this could work to constrain JGB transactions.

5-2. Estimation results when the bid-ask spread is the dependent variable

Figure 8 (1) shows the regression results for Models (3) and (4), in which the bid-ask spread is the dependent variable. In Model (3), the coefficient of the dummy for JGB purchases by the BOJ ($DPur_{i,t}$) is negative and statistically significant at the 1% level. This indicates that the bid-ask spread tightens when the BOJ purchases JGBs, and confirms again that there is a spotlight effect. Meanwhile, the coefficient of the share of JGBs held by the BOJ ($Hol_{i,t-1}$) is positive and statistically significant at the 1% level, and a scarcity effect is again confirmed whereby the bid-ask spread widens when the share of JGBs held by the BOJ increases. Additionally, the coefficient of the YCC range of fluctuation upper bound dummy ($YCC_{i,t}$) is negative and statistically significant at the 1% level. However, we think that this result only reflects the following rather mechanical movement: When continuous fixed-rate

purchase operations are conducted or market participants become aware of possible conducts of these operations, market participants expect the price changes of the issues subject to continuous fixed-rate purchase operations to be limited in the future, resulting in tightening of bid-ask spreads.

To consider the implications of the results of Model (3), as we did for Model (1), we examine the situation in which the BOJ purchases 1% of the outstanding issuance amount of JGBs at time t_0. In this case, noting that the estimated parameters are $\alpha = -0.0337$ and $\beta_1 = 0.0062$, the spotlight effect causes the bid-ask spread to tighten by -0.0337 $(= -0.0337 \times 1)$. At this point, the scarcity effect has not yet appeared. In the following period, t_1, the spotlight effect goes away, and the bid-ask spread widens by $+0.0062$ $\left(= +0.0062 \times 1(\%)\right)$ due to the scarcity effect from the JGB holdings that were purchased in the previous period. Because JGBs purchased by the BOJ are generally held to maturity, the scarcity effect occurs in time t_2 and subsequent periods, so that the bid-ask spread continues to widen $+0.0062$ each period until the bonds mature. It should be noted that the spotlight effect is transient, whereas the scarcity effect continues until maturity. Taking into account such differences in the persistence of these effects, we calculated the impact of the BOJ's JGB purchases (a spotlight effect) and JGB holdings (a scarcity effect) on the bid-ask spread of on-the-run 10-year JGBs during the sample period, and found it to average about +0.2 basis points.[16]

When we look at the regression results for Model (4), which takes into account the possible nonlinearity of the scarcity effect, we find that the coefficient β_1 of the share of JGBs held by the BOJ ($Hol_{i,t-1}$) is negative and statistically significant at the 1% level, and the coefficient of its square β_2 is positive and also statistically significant at the 1% level. Figure 8 (2) shows the scarcity effect when the simple term and squared term for the share of JGBs held by the BOJ ($Hol_{i,t-1}$) are combined. Here, the bid-ask spread does not fluctuate much until the share of JGBs held by the BOJ reaches about 40%, but as it exceeds 50% and continues to grow, the bid-ask spread tends to widen in a nonlinear fashion.

[16] The average bid-ask spread for on-the-run 10-year JGBs during the sample period (shown in Figure 6 (2)) was about 0.7 bps.

5-3. Estimation results when yield curve distortion is the dependent variable

Finally, Figure 9 (1) shows the regression results for Model (5), in which yield curve distortion is the dependent variable. The coefficient of the share of JGBs held by the BOJ ($Hol_{i,t-1}$) is negative and statistically significant at the 1% level. This indicates that, if the share of a certain issue of JGBs held by the BOJ increases, the interest rate on that issue declines, causing a downward distortion in the yield curve.[17] Additionally, we see that the coefficient of the continuous fixed-rate purchase operations dummy ($FROC_{i,t}$) is also negative and statistically significant at the 1% level. This implies that the yield curve experienced a downward distortion due to the strong pressure that the continuous fixed-rate purchase operations exert on rising interest rates.

Figure 9 (2), which is based on the estimation results of Model (5), divides the sample period into three intervals—start of QQE (from April 2013 to September 2016), start of YCC (from October 2016 to December 2021), and from 2022 on (from January 2022 to June 2023)—and shows the causes of the yield curve distortions for on-the-run 10-year JGBs in each period.[18] In the case of the period from 2022 on, when the yield curve experienced a downward distortion, the results show that the conducts of continuous fixed-rate purchase operations significantly contributed to the downward distortion.

5-4. Robustness check

This section reports results of robustness check on the empirical results of the previous sections regarding the sample periods and the calculation methods of the yield curve distortion.

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[17] The direction of the impact of central bank purchases of government bonds on yield curve distortion is not clear *a priori*. A central bank's purchase of a certain issue of government bonds reduces the volume of government bonds circulating in the market (supply), and this can cause a downward distortion of the yield curve. At the same time, however, because reduced volume of government bonds circulating in the market (supply) may increase the liquidity premium, demand for that issue can decrease, and an upward distortion of the yield curve can take place. Nevertheless, our analytical results suggest that the yield curve experiences a downward distortion when the BOJ purchases JGBs and its holdings increase.

[18] In calculating the historical decomposition shown in Figure 9 (2), we used the coefficients of the estimation results from the whole sample (the results in Figure 9 (1)), and the subsample averages of the independent variables.

First, as we saw in Section 3, because the functioning of the JGB market deteriorated significantly from 2022 on, the samples from 2022 on may heavily influence the empirical results. If this is true, then the impact of QQE and YCC discussed in the previous sections should be interpreted for the limited period from 2022 on. Figure 10 shows the estimation results for samples through December 2021 for Models (1) through (5). Looking at the estimated coefficients and their significance levels, one can see that the subsample results have few significant differences from the full sample results (Figures 7 to 9). This means that the impact of QQE and YCC on the JGB market's functioning discussed above extends over the entire sample period.

Second, the computation of the yield curve distortion in Model (5) uses a cubic spline to smooth the yield curve. As other methods can be used to smooth the yield curve (e.g., a spline that uses the Nelson-Siegel model or a spline that uses LOWESS), the choice of the smoothing method may affect the results of the empirical analysis. Figure 11 shows the estimation results of Model (5) with the yield curve distortion calculated using the yield curve smoothed by the Nelson-Siegel model and LOWESS. The coefficients for the share of BOJ holdings ($Hol_{i,t}$) and the continuous fixed-rate purchase operations dummy ($FROC_{i,t}$) are negative and statistically significant. This is the same as in the case where the cubic spline was used (Figure 9), and consistent with our discussion in the previous sections.

6. Conclusion

The present paper reviewed the developments in the functioning of the JGB market and examined the impact of the QQE and YCC policies of the BOJ on the JGB market's functioning. Specifically, we conducted an empirical analysis of how QQE and YCC affected the JGB market's transaction volume, bid-ask spreads, and yield curve distortion using panel data for JGB issues. The analysis yielded the following three key findings. First, according to the results of the analysis where transaction volume is the dependent variable, JGB purchases by the BOJ increase transaction volume on average, while the BOJ's increased share of JGB holdings and its conduct of continuous fixed-rate purchase operations decrease transaction volume. However, if the BOJ conducts JGB purchases when its share of JGB holdings exceeds a certain threshold, transaction volume will decrease. Second, the results where the bid-ask spread is the dependent variable shows that, while JGB purchases by the BOJ reduce the bid-ask spreads, the increase in the share of the BOJ's holdings of JGBs will lead to a

nonlinear widening of the spreads. Third, the results where the yield curve distortion is the dependent variable shows that an increase in the BOJ's share of a certain issue of JGB holdings and continuous fixed-rate purchase operations will lead to a downward distortion in the yield curve.

At its Monetary Policy Meeting in March 2024, the BOJ decided to shift to a monetary policy framework in which the primary policy tool is to guide the short-term interest rates under the price stability target of 2%, in the belief that its large-scale monetary easing had fulfilled its role. Nonetheless, as the results of our empirical analysis show, among the effects of the large-scale monetary easing on the functioning of the JGB market, the effect of the share of JGBs held by the BOJ (which is a stock effect) will continue to remain. Furthermore, as the BOJ continues purchasing long-term JGBs, if the developments of the financial markets shift, the functioning of the JGB market can experience other new changes. In light of this point, the functioning of the JGB market should continue to be monitored closely.

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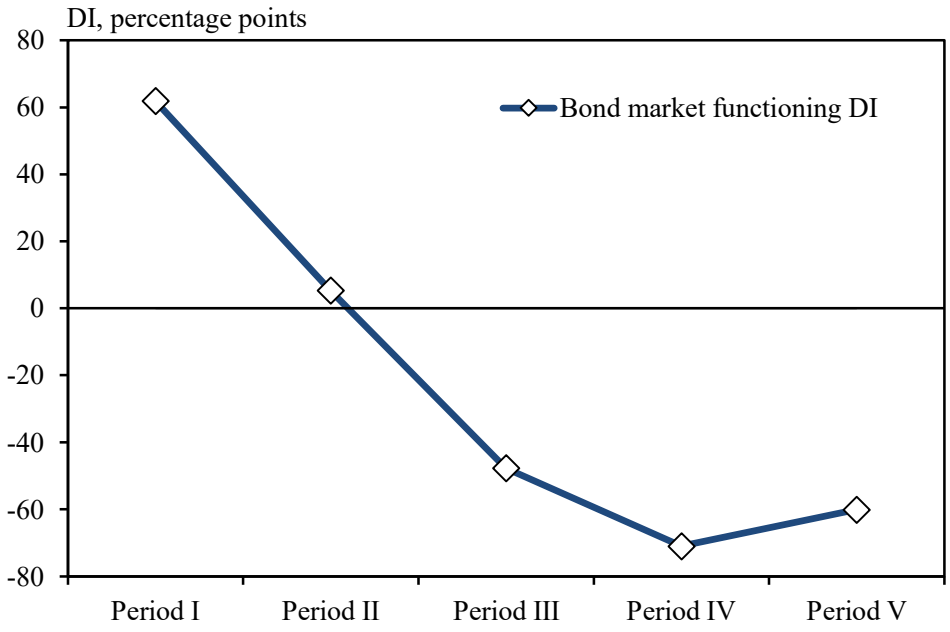
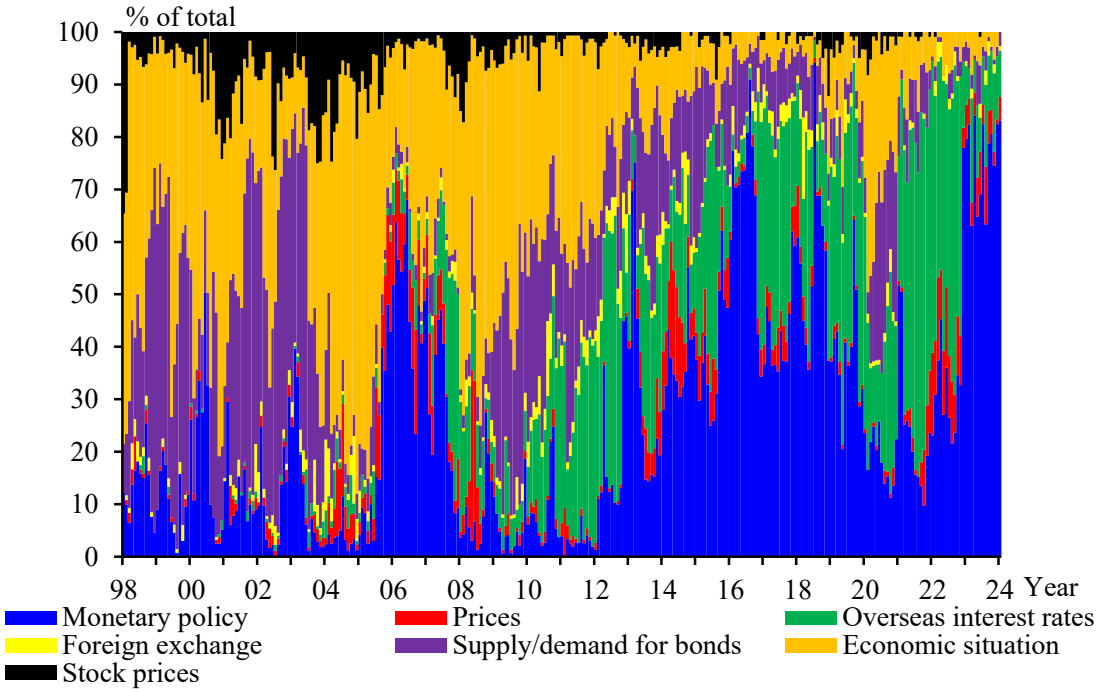
Figure 1. Comparison of bond market functioning by period



Note: Based on the Bond Market Survey, Results of Special Survey (November 2023).
Period I: before the introduction of QQE (from late 1990s to April 2013)
Period II: after the introduction of QQE (from April 2013 to January 2016)
Period III: after the introduction of the negative interest rate policy (from January 2016 to September 2016)
Period IV: after the introduction of YCC (from September 2016 to December 2021)
Period V: from 2022 on

Source: BOJ.

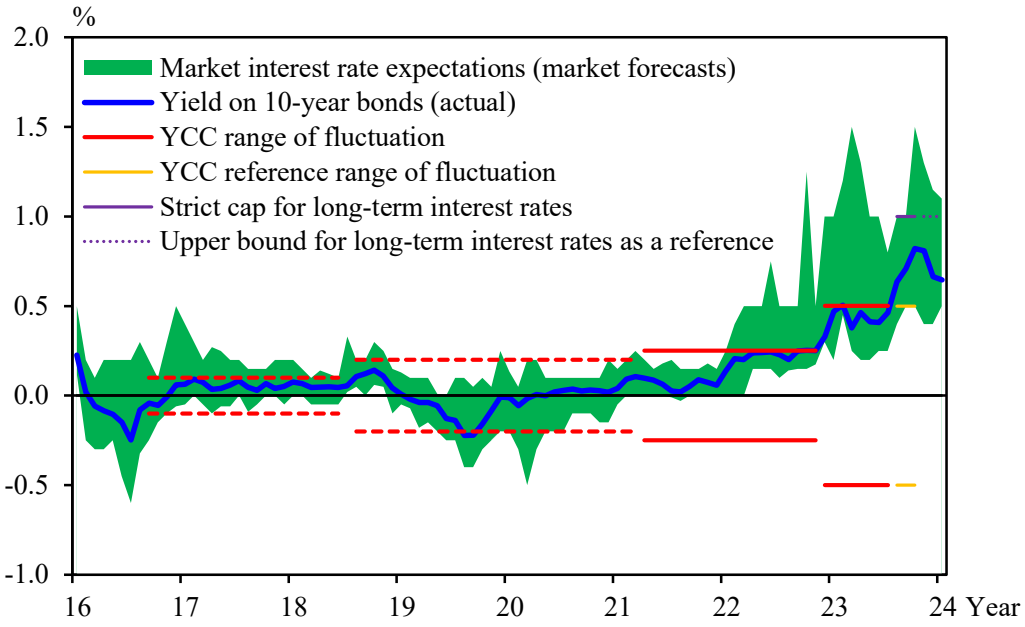
Figure 2. Major causes of price changes identified by bond market participants



Note: Survey subjects were banks, brokerage firms, institutional investors, and other market participants.

Source: QUICK, "QUICK Monthly Survey (Bonds)."

Figure 3. Long-term interest rates after the introduction of YCC

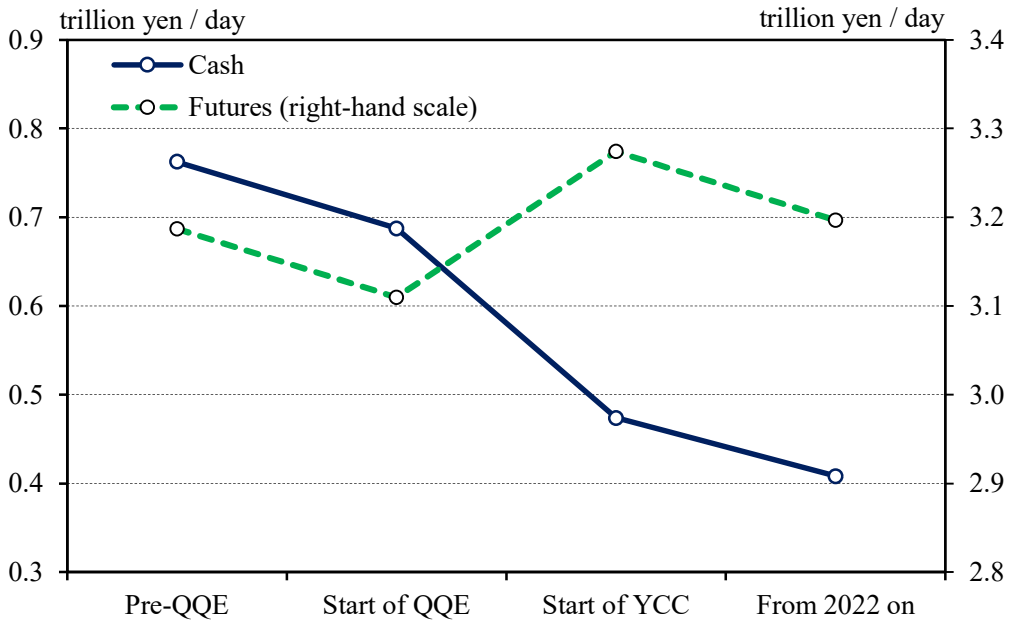


Note: Survey subjects were banks, brokerage firms, institutional investors and other market participants. “Market interest rate expectations (market forecasts)” is the expected range for the yield of on-the-run 10-year JGBs three months forward. Until March 2021, “YCC range of fluctuation” is based on the views of market participants and fixed-rate purchase operations at the time. From September 2016 through July 2018, the range is set to be ±0.1%, and from August 2018 to March 2021, it is set to be ±0.2%.

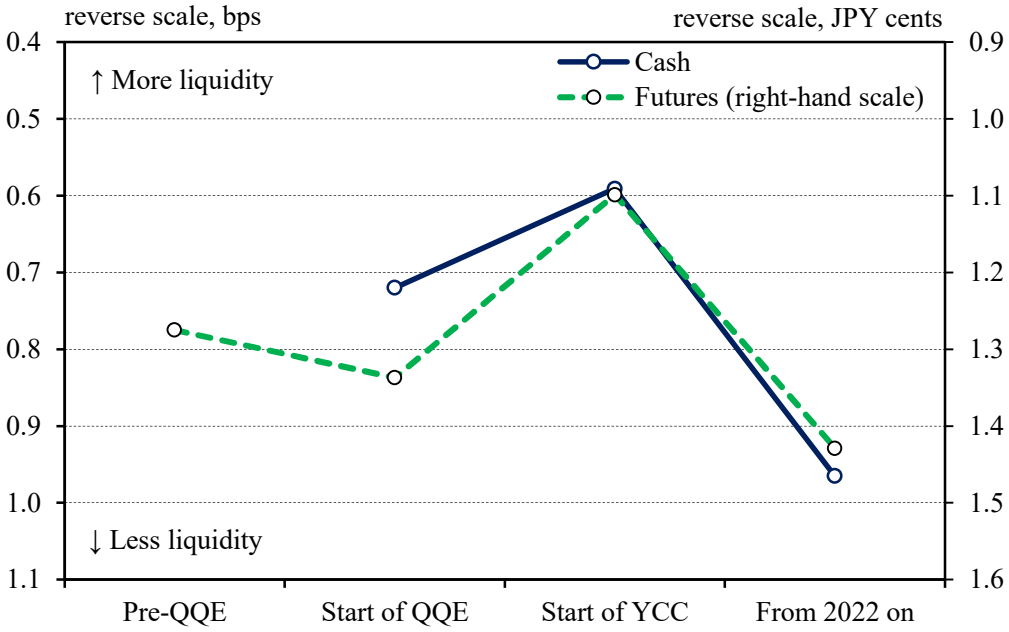
Sources: QUICK, "QUICK Monthly Survey (Bonds)"; Bloomberg.

Figure 4. JGB market transaction volumes and bid-ask spreads

(1) Transaction volumes



(2) Bid-ask spread

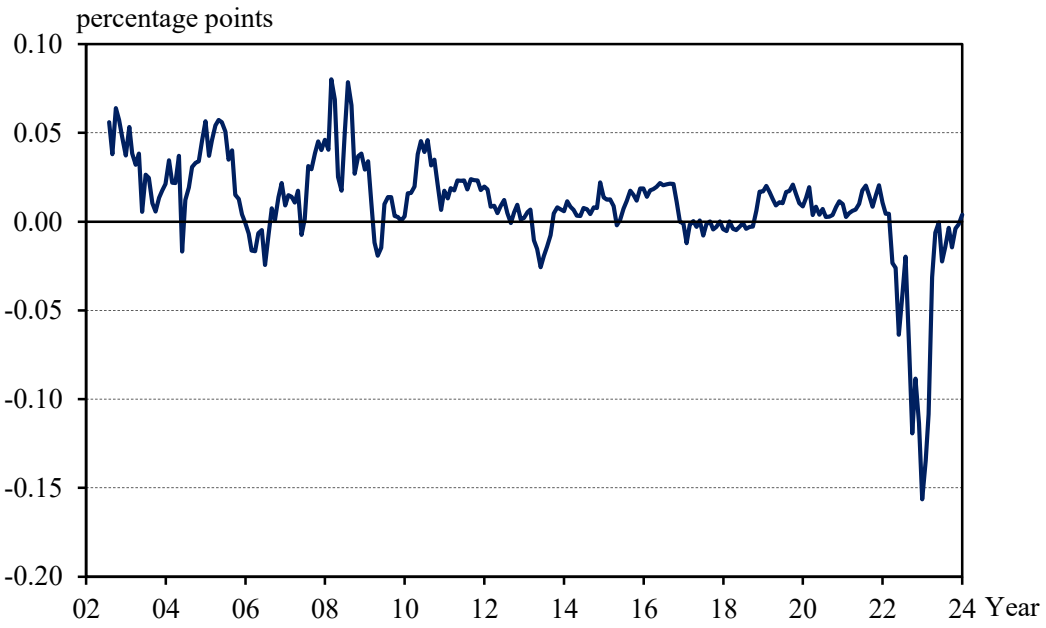


Notes: 1. Figures are period averages (Pre-QQE: from January 2012 to March 2013; Start of QQE: from April 2013 to September 2016; Start of YCC: from October 2016 to December 2021; From 2022 on: from January 2022 to January 2024; the same applies hereinafter).

2. For the cash market in (1), total daily transaction volume (inter-dealer transactions) for 2-, 5-, 10-, 20-, 30-, and 40-year bonds. For the cash market in (2), the average bid-ask spread within a 1-second frequency for on-the-run 10-year bonds (inter-dealer transactions). For the futures market in (2), the average for the widest 10 percent of the bid-ask spread within a 1-minute frequency (the average of the widest 10%).

Sources: QUICK; Japan Bond Trading; Osaka Stock Exchange, Inc.; Nikkei Inc., "Nikkei NEEDS."

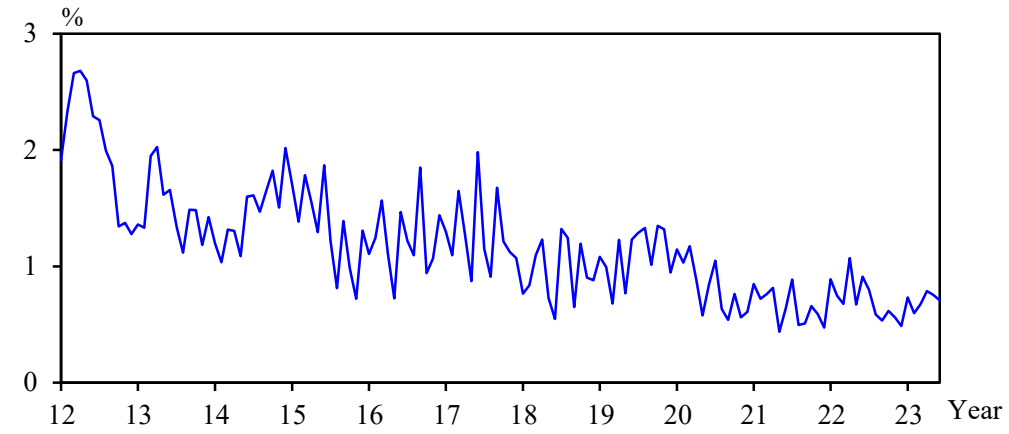
Figure 5. Yield curve distortion (for on-the-run 10-year bonds)



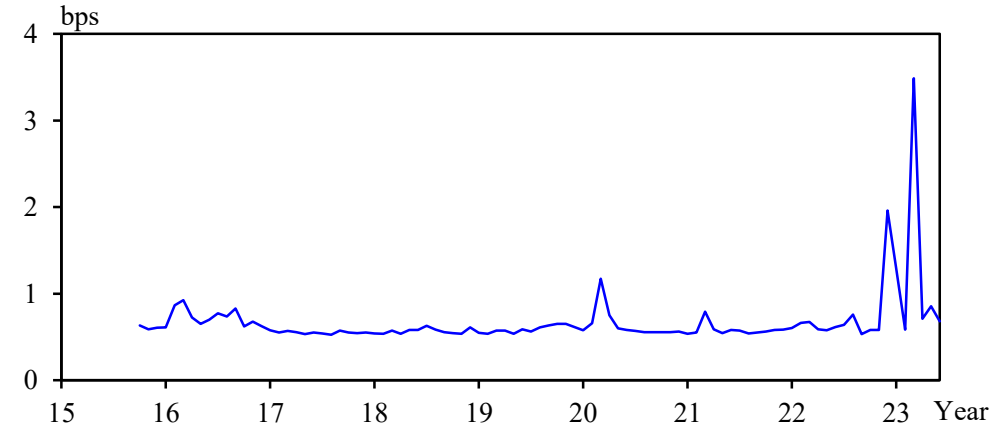
Note: The differential between the yield curve estimated by using a cubic spline interpolation for the yield curve for each individual issue and the actual yield curve for each individual issue.
Source: Japan Securities Dealers Association.

Figure 6. Developments in dependent variables in the panel regression analysis

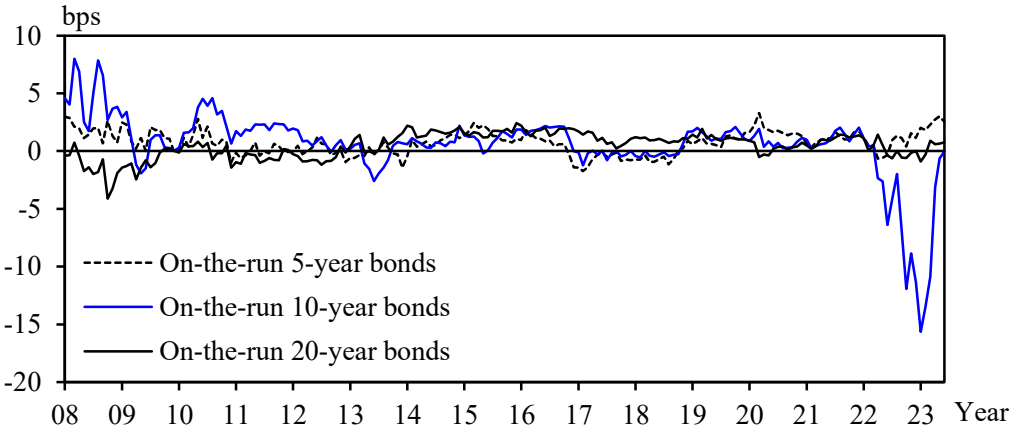
(1) Transaction volume / outstanding issuance amount (average for all issues)



(2) Bid-ask spread (for on-the-run 10-year bonds)



(3) Yield curve distortion



Note: (1) is inter-dealer transactions (monthly average value) divided by the outstanding issuance amount (at month-end). These are simple averages for all individual issues. (2) is the monthly average of the bid-ask spread within a 1-second frequency for inter-dealer transactions. (3) is the deviation from the cubic spline of the yield curve for each individual issue.

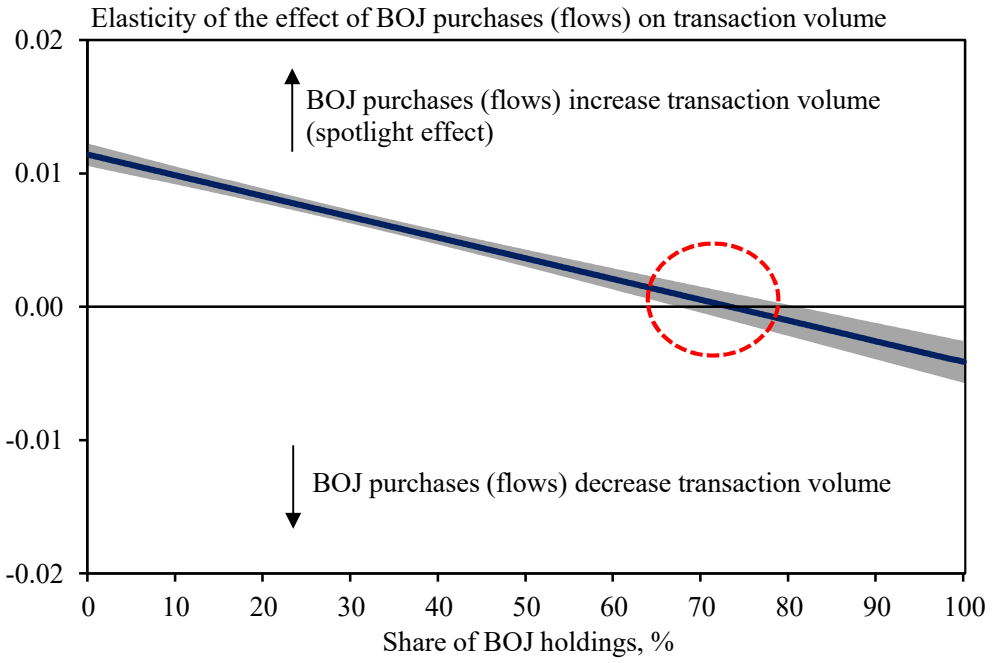
Sources: QUICK; Japan Bond Trading; Japan Securities Dealers Association.

Figure 7. Estimation results for the impact on transaction volume

(1) Estimation results

	Model (1)	Model (2)
Share of BOJ purchases (%)	0.0065 ***	0.0114 ***
Share of BOJ holdings (%)	-0.0026 ***	-0.0024 ***
Share of BOJ purchases (%) x share of BOJ holdings (%)	—	-0.0002 ***
YCC range of fluctuation upper bound dummy	-0.2517 ***	-0.1978 ***
On-the-run issue dummy	0.9640 ***	0.9622 ***
First off-the-run issue dummy	0.2571 ***	0.2576 ***
Cheapest issue dummy	0.0710 ***	0.0704 ***
Individual issue fixed effect	Yes	Yes
Time period fixed effect	Yes	Yes
Adjusted R-squared	0.51	0.52
Sample size	41,313	41,313
Estimation period	From January 2012 to June 2023	

(2) Relation between the spotlight effect and the share of BOJ holdings (Model 2)



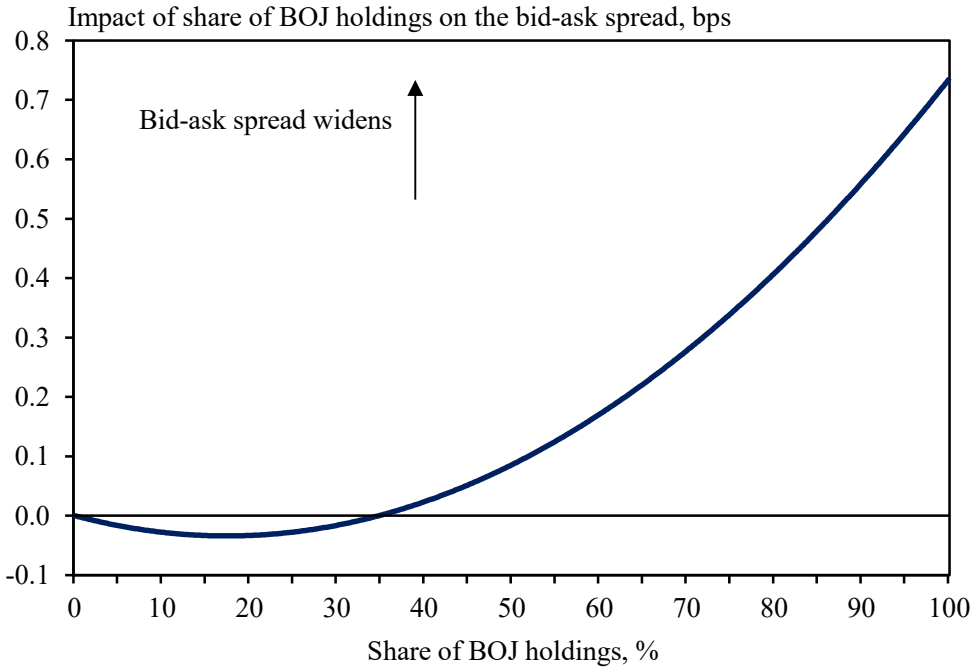
Note: In (1), the share of BOJ purchases is the percentage of the amount purchased by the BOJ over the outstanding issuance amount. The amount purchased by the BOJ is the difference of the amount held by the BOJ. The share of BOJ holdings is lagged by one period to avoid overlap with BOJ purchases in the current period. The YCC range of fluctuation upper bound dummy becomes 1 when the monthly average interest rate for issues subject to continuous fixed-rate purchase operations is within 3 bps of the interest rate levels for continuous fixed-rate purchase operations. The on-the-run issue dummy is 1 when it is a new issue, the first off-the-run issue dummy is 1 when it is a first seasoned issue, and the cheapest issue dummy is 1 when it is the cheapest-to-deliver issue. The estimations use panel data for each issue. In (1), *** denotes significance at the 1% level. (2) was computed based on Model (2). The shaded area denotes the 99% confidence interval.

Figure 8. Estimation results for the impact on the bid-ask spread

(1) Estimation results

	Model (3)	Model (4)
BOJ purchases dummy	-0.0337 ***	-0.0291 ***
Share of BOJ holdings (%)	0.0062 ***	-0.0039 **
Share of BOJ holdings (%), squared	—	0.0001 ***
YCC range of fluctuation upper bound dummy	-0.5613 ***	-0.4909 ***
On-the-run issue dummy	0.0737 **	0.0806 **
First off-the-run issue dummy	0.0173	0.0286
Cheapest issue dummy	-0.0131	-0.0189
Individual issue fixed effect	Yes	Yes
Time period fixed effect	Yes	Yes
Adjusted R-squared	0.05	0.05
Sample size	19,350	19,350
Estimation period	From October 2015 to June 2023	

(2) Impact of share of BOJ holdings (Model 4)



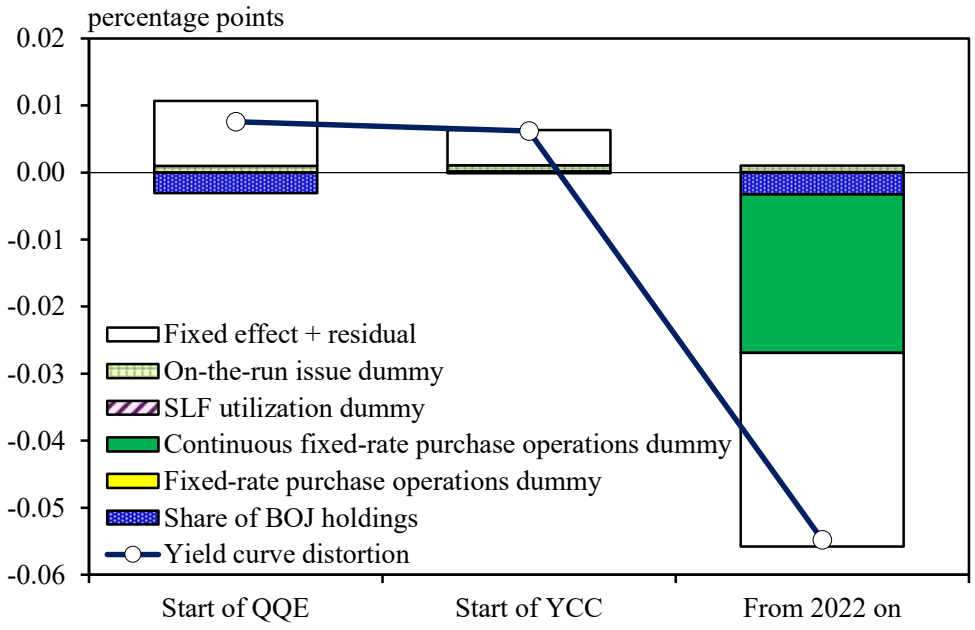
Note: In (1), the BOJ purchase dummy is for purchases by the BOJ. BOJ purchases are calculated from the changes in the amount of BOJ holdings. The share of BOJ holdings is lagged by one period to avoid overlap with BOJ purchases in the current period. The YCC range of fluctuation upper bound dummy becomes 1 when the monthly average interest rate for issues subject to continuous fixed-rate purchase operations is within 3 bps of the interest rate level for continuous fixed-rate purchase operations. The estimations use panel data for each issue. In (1), *** denotes significance at the 1% level, and ** denotes significance at the 5% level. (2) was computed based on Model (4).

Figure 9. Estimation results for the impact on yield curve distortion

(1) Estimation results

	Model (5)
Share of BOJ holdings (%)	-0.0002 ***
Continuous fixed-rate purchase operations dummy	-0.0033 ***
Fixed-rate purchase operations dummy	0.0001
SLF utilization dummy	-0.0425
On-the-run issue dummy	0.0009
First off-the-run issue dummy	0.0018 *
Cheapest issue dummy	-0.0170 ***
Individual issue fixed effect	Yes
Time period fixed effect	Yes
Adjusted R-squared	0.02
Sample size	50,254
Estimation period	From January 2008 to June 2023

(2) Breakdown of factors in the changes (on-the-run 10-year bonds)



Note: In (1), the fixed-rate purchase operations dummy is 1 when a bid was submitted for fixed-rate purchase operations. The continuous fixed-rate purchase operation dummy is 1 when a bid was submitted for continuous fixed-rate purchase operations (implementation of this operation began in March 2022). The SLF utilization dummy is 1 when the Securities Lending Facility is used. The estimations use panel data for each issue. In (1), *** denotes significance at the 1% level, and * denotes significance at the 10% level. In (2), the share of BOJ holdings is computed using the share of the BOJ's holdings of on-the-run 10-year bonds less the simple average of the share of the BOJ's holdings of all JGB issues (the deviation from the average) at each point of time.

Figure 10. Estimation results (subsamples)

(1) Dependent variable is transaction volume

	Model (1)	Model (2)
Share of BOJ purchases (%)	0.0067 ***	0.0122 ***
Share of BOJ holdings (%)	-0.0032 ***	-0.0030 ***
Share of BOJ purchases (%) x share of BOJ holdings (%)	–	-0.0002 ***
YCC range of fluctuation upper bound dummy	–	–
On-the-run issue dummy	1.0205 ***	1.0216 ***
First off-the-run issue dummy	0.2727 ***	0.2751 ***
Cheapest issue dummy	0.0610 ***	0.0595 ***
Individual issue fixed effect	Yes	Yes
Time period fixed effect	Yes	Yes
Adjusted R-squared	0.51	0.51
Sample size	35,954	35,954
Estimation period	From January 2012 to December 2021	

(2) Dependent variable is bid-ask spread

	Model (3)	Model (4)
BOJ purchase dummy	-0.0383 ***	-0.0338 ***
Share of BOJ holdings (%)	0.0096 ***	-0.0050 **
Share of BOJ holdings (%), squared	–	0.0002 ***
YCC range of fluctuation upper bound dummy	–	–
On-the-run issue dummy	0.1503 ***	0.1713 ***
First off-the-run issue dummy	0.0537	0.0765 **
Cheapest issue dummy	-0.0468	-0.0511
Individual issue fixed effect	Yes	Yes
Time period fixed effect	Yes	Yes
Adjusted R-squared	0.04	0.04
Sample size	15,763	15,763
Estimation period	From October 2015 to December 2021	

(3) Dependent variable is yield curve distortion

	Model (5)
Share of BOJ holdings (%)	-0.0002 ***
Continuous fixed-rate purchase operations dummy	–
Fixed-rate purchase operations dummy	-0.0013
SLF utilization dummy	-0.0005 **
On-the-run issue dummy	-0.0003
First off-the-run issue dummy	0.0023 ***
Cheapest issue dummy	-0.0189 ***
Individual issue fixed effect	Yes
Time period fixed effect	Yes
Adjusted R-squared	0.01
Sample size	45,325
Estimation period	From January 2008 to December 2021

Note: See Figures 7 to 9 for definitions of the variables. *** denotes significance at the 1% level, and ** denotes significance at the 5% level.

Figure 11. Estimation results (dependent variables are other indicators of yield curve distortion)

	Nelson-Siegel	LOWESS
Share of BOJ holdings (%)	-0.0008 ***	-0.0001 ***
Continuous fixed-rate purchase operations dummy	-0.0400 **	-0.0365 ***
Fixed-rate purchase operations dummy	-0.0149	-0.0043 ***
SLF utilization dummy	0.0020 ***	0.0000
On-the-run issue dummy	-0.0155 ***	-0.0006
First off-the-run issue dummy	-0.0120 ***	-0.0013 **
Cheapest issue dummy	-0.0253 ***	-0.0067 ***
Individual issue fixed effect	Yes	Yes
Time period fixed effect	Yes	Yes
Adjusted R-squared	0.02	0.06
Sample size	50,247	50,267
Estimation period	From January 2008 to June 2023	

Note: See Figure 9 for definitions of the variables. *** denotes significance at the 1% level, and ** denotes significance at the 5% level.