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Tetsuo Kurosaki*
tetsuo.kurosaki@boj.or.jp

Yusuke Kumano*
yuusuke.kumano@boj.or.jp

Kota Okabe*
kouta.okabe@boj.or.jp

Teppei Nagano*
teppei.nagano@boj.or.jp

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Bank of Japan
2-1-1 Nihonbashi-Hongokucho, Chuo-ku, Tokyo 103-0021, Japan

* Financial Markets Department

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Liquidity in JGB Markets: An Evaluation from Transaction Data*

Tetsuo Kurosaki,† Yusuke Kumano,‡ Kota Okabe,§ Teppei Nagano**

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Abstract

There is no single, widely-accepted definition of "market liquidity" even though the expression "market liquidity is high/low" is frequently used, and measuring market liquidity is not easy. Recognizing these challenges, this paper formulates a set of new liquidity indicators using transaction data of the markets related to Japanese government bonds (JGBs), including futures, cash, and special collateral (SC) repo, thereby examining market liquidity from various angles. Traditional liquidity indicators of the JGB futures market such as the bid-ask spread and the daily price range to transaction volume ratio suggest that liquidity in the JGB market has not declined significantly, even after the expansion of quantitative and qualitative monetary easing (QQE) in October 2014. However, the indicators newly formulated in this paper -- the volume of limit orders at the best-ask price, the impact of a unit volume of transactions on the market price in the JGB futures market, the divergence in quotes offered by dealers in the JGB cash market, and the lending fee of JGBs in the SC repo market -- all suggest that liquidity in the JGB market has been declining since fall 2014. While this may be a temporary phenomenon following the rapid decline in the long-term yield observed after the expansion of QQE as well as the short- and medium-term yields turning negative, it may also reflect other factors such as the massive purchases of JGBs by the Bank of Japan, structural changes in the markets, and regulatory changes. These findings underscore the need to monitor liquidity in the JGB market continuously and from many sides, using various indicators. In addition, it is important to enhance dialogue with market participants, thereby carefully monitoring the market's view on liquidity, which does not show up in the aforementioned indicators.

Keywords: JGB market; market liquidity; transaction data; SC repo
JEL Classification: C32, G12, G14

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† Financial Markets Department (E-mail: tetsuo.kurosaki@boj.or.jp)
‡ Financial Markets Department (E-mail: yuusuke.kumano@boj.or.jp)
§ Financial Markets Department (E-mail: kouta.okabe@boj.or.jp)
** Financial Markets Department (E-mail: teppei.nagano@boj.or.jp)

1. Introduction

1.1 Challenge of defining and measuring market liquidity

The expression "market liquidity is high/low" is occasionally used in various markets although not necessarily in the same context. In general, a liquid market is often defined as one in which market participants are able to smoothly buy and sell their intended amount at a price close to the market mid price. At times, it is defined as one in which purchases and sales by each market participant have little impact on the market price. Some directly link increased volatility to a decline in market liquidity. In this regard, the Bank for International Settlements (BIS, 2014) has presented its definition as follows: "the ability to rapidly execute large financial transactions with a limited price impact."

Measurement of market liquidity is not simple, since, as mentioned above, market liquidity itself is defined in various ways. For instance, when observed volatility increases, it is not easy to identify whether the increase is due to a decline in market liquidity or whether it is just reflecting other factors, such as unexpected economic indicators.

1.2 Growing attention to market liquidity

On the other hand, market liquidity, especially that for the bond market, has been attracting growing attention both at home and abroad for the following three reasons.[1]

One reason is the purchase of government bonds by major central banks of advanced countries, including the Bank of Japan. The Bank has been purchasing massive amounts of JGBs from the market since the introduction of QQE in April 2013, and has increased the pace of its purchases since the expansion of QQE in October 2014. Other central banks of major advanced countries have also embarked on the purchase of government bonds as part of monetary easing. It is inevitable that these unconventional monetary policies will affect the liquidity in the government bond market, since they are intended to exert downward pressure on yields through affecting the supply and demand of government bonds. Such adverse effects are already being observed both at home and abroad.

[1] In addition to the BIS (2014) mentioned above, the IMF (2014) and others have elaborated on the current situation of the liquidity in the global bond market.

The second reason is the various financial regulations enforced after the Lehman Crisis in 2008. It has occasionally been pointed out that some of these financial regulations could actually rather hinder the traditional market-makers' inventory holding and price discovery, and thus reduce market liquidity.

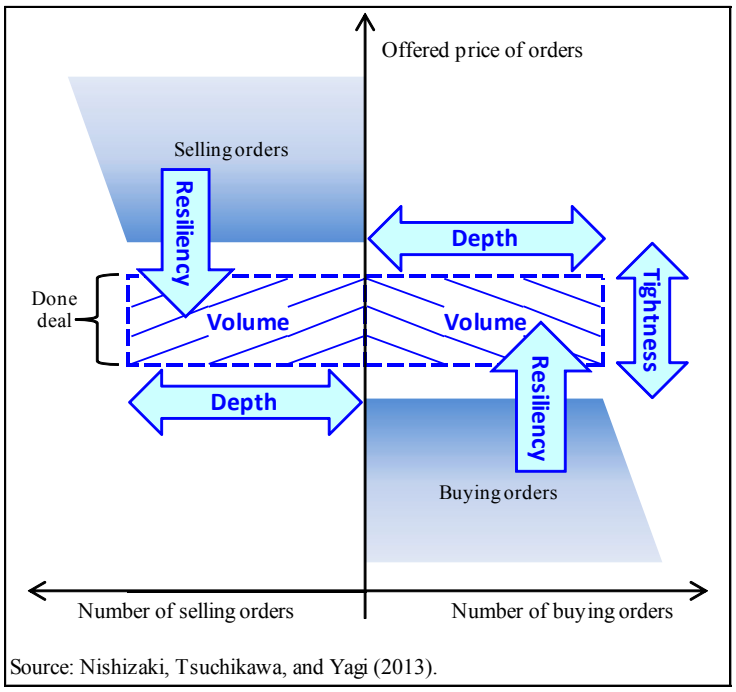
The third reason is the structural change in the bond market, owing partly to the aforementioned financial regulations. In the bond market, the presence of hedge funds, which often employ high-frequency trading (HFT) strategies, has recently been increasing. Some of these players have been reported to cancel the quote once volatility increases and their algorithmic trading struggles to respond. Liquidity in the bond market is then affected by the rapid disappearance of quotes.

1.3 Framework for analysis

In light of the growing attention to liquidity in the bond market, we examine liquidity in JGB markets since the Bank's introduction of QQE -- especially that since the expansion of QQE at the end of October 2014 -- from various angles using new analytical methods, while recognizing the challenges of defining as well as measuring market liquidity.

Classic studies on market liquidity, such as those by Kyle (1985), propose evaluating market liquidity using a number of concepts including (1) "tightness," the spread between the selling price and the buying price, (2) "depth," and (3) "resiliency." In addition to these, Fleming (2003) and *Domestic Open Market Operations* issued by the Federal Reserve Bank of New York (FRBNY, 2014) also focus on (4) "volume," that is, the turnover and trade size of each transaction. These four evaluation concepts can be plotted on a chart as follows.

Four Concepts of Evaluating Market Liquidity



Source: Nishizaki, Tsuchikawa, and Yagi (2013).

In a preceding study on liquidity in JGB markets, Nishizaki, Tsuchikawa, and Yagi (2013) analyzed the phase after the introduction of QQE, and evaluated market liquidity using various indicators. In addition, at a workshop hosted by the Center for Advanced Financial Technology (established within the Bank of Japan's Financial System and Bank Examination Department) in 2014, market participants pointed out the importance of using diverse indicators (Center for Advanced Financial Technology, 2014). The Bank of Japan's Financial Markets Department also analyzed liquidity in JGB markets after the Lehman Crisis using the concept of price distortion (Financial Markets Department, 2009).

Following these preceding studies, we expand the existing framework for analyzing market liquidity mainly in the following two directions.

First, we attempt to create indicators related to liquidity in JGB markets by focusing on not only the JGB futures market but also a wide range of markets, including the JGB cash market and the SC repo market (special collateral repo: a repo transaction in which a particular security is specified as the only acceptable collateral). While previous studies focused on JGB futures due mainly to data restrictions in analyzing other markets, it would be beneficial to grasp liquidity from as wide a perspective as possible

given the aforementioned difficulties in defining and measuring market liquidity.[2] Moreover, with the major central banks of advanced countries purchasing government bonds in the cash market as part of monetary easing, it is especially important to grasp liquidity in the cash market under the current monetary policy environment.

Second, following the latest studies in the United States and Europe, we use individual transaction data when available in creating liquidity indicators.[3] Considering the large amount of transactions conducted in the JGB market each day, only monitoring the aggregated data at a daily frequency entails the risk of overlooking a decline in liquidity at a certain point of time during the day. This risk can be mitigated by obtaining information from individual transaction data in the JGB futures market, rather than limiting to fixed-time data within a day (such as closing price) or daily aggregated transaction data. In addition, only looking at the aggregated data and on-the-run bonds in the JGB cash and SC repo markets where transactions are conducted for each of the few hundred issues could overlook a decline in the liquidity of a certain issue. Using individual transaction data will also alleviate this risk.

The structure of this paper is as follows.

The next section, Section 2, presents a set of liquidity indicators in the JGB futures market corresponding to tightness, volume, depth, and resiliency created from high-frequency tick data. Section 3 presents an indicator representing depth in the dealer-to-client transaction market, after summarizing the transaction development of the JGB cash market. Section 4 presents developments in the SC repo rates after examining the correlation between JGBs and JGB futures. Section 5 briefly evaluates liquidity in the JGB market after fall 2014 and elaborates on issues that warrant future attention, based on the analysis made from Section 2 to 4.

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[2] Higo et al. (1999) also comprehensively analyzed the microstructure of the JGB market, although the scale of the JGB market is different from what it is now. We do not explicitly take up issues related to the yen interest rate swap market, and the analysis of the inter-dealer JGB cash market is limited (this theme is elaborated by Tanemura et al., 2003). Expanding the analysis to these areas is left for future research.

[3] Recent studies on liquidity in the U.S. Treasury market, such as those by Mizrach and Neely (2006) and Fleming et al. (2014), use the transaction data of electronic trading platforms for U.S. fixed income markets (BrokerTec, eSpeed). Studies analyzing the euro-area government bond market conducted by Cheung et al. (2005) and Pelizzon et al. (2013) also use electronic trading platform (MTS) data.

2. Liquidity Indicators in the JGB Futures Market

This section presents liquidity indicators using detailed transaction data, i.e., tick data, for JGB futures listed on the Osaka Exchange. Specifically, it aims to construct a set of indicators regarding market liquidity by looking at (1) quotation and volume of the bid-ask data with a 1-minute frequency (limit order) and (2) price and volume of transaction data (market order) from tick data provided by Nikkei NEEDS.[4] These constructed indicators show that levels have shifted significantly since 2012, suggesting that some kind of structural change is affecting the continuity of the data. This section therefore focuses on the development of various liquidity indicators after 2012, while the appendix looks at these from a long-term perspective.

2.1 Tightness and volume of JGB futures

The bid-ask spread -- used as an indicator to track tightness in JGB futures -- is defined as the difference between the highest quoted bid price by buyers (best-bid price) and the lowest quoted offer price by sellers (best-ask price). When the bid-ask spread is large, it is typically more difficult for traders to execute transactions around their intended prices and they face higher trading costs.

After the Bank's expansion of QQE at the end of October 2014, long-term JGB yields declined rapidly toward the middle of January 2015, and subsequently rallied sharply toward the middle of February. During the same period, the implied volatility of JGB futures clearly picked up from very low levels by historical standards (Chart 1). Observing these fluctuations in long-term yields since fall 2014, some market participants hold the view that market liquidity has been declining.

However, the bid-ask spreads for JGB futures have been at tight levels even after the expansion of QQE at the end of October 2014 (Chart 2). Looking at the histogram of the bid-ask spreads with a 1-minute frequency, the bid-ask spread is 1 JPY sen -- the minimum trading unit equivalent to 1/100 yen -- during most of the regular trading sessions even on December 10, 2014, the date on which the spread (average of the widest 10 percent) widened the most after fall 2014. The fact that the bid-ask spread is

[4] Data of 10-year JGB futures of the most actively traded month during the Regular Sessions are used. Data during the Night Session and those of mini 10-year JGB futures are excluded. In this paper, data until the end of 2014 are obtained from Nikkei NEEDS, while some were extended from January 2015 using Bloomberg.

tight suggests that market participants do not find it difficult to trade JGB futures at the intended price; indeed, its daily transaction volume has maintained an adequate level even since fall 2014. The fact that trade size per transaction has remained large unlike when QQE was introduced in April 2013 suggests that there are no major difficulties regarding the execution of large-volume transactions (Chart 3).

There are several possible hypotheses for the difference between the view of some market participants that market liquidity is declining and what the traditional indicators such as the bid-ask spread indicate. One is that the change in market liquidity may be occurring in a way difficult to capture by using traditional indicators. For example, even if the bid-ask spread is superficially tight, it would be difficult for traders to rapidly execute large financial transactions with a limited price impact if there are few limit orders at the best-ask (-bid) prices. In order to grasp market liquidity in line with the view of market participants, it is necessary to monitor not only indicators associated with price such as the bid-ask spread but also indicators associated with quantity, such as the volume of limit orders that can be executed at that price.

2.2 Depth of JGB futures market

As an indicator to monitor quantity, market participants often refer to the depth of the market at the time of the transaction. The volume of limit orders at the best-ask (-bid) price at a certain time is often used to indicate the depth of the JGB futures market. When there is enough depth in the market with orders centering around the best-bid (-ask) prices, traders are able to execute large-volume transactions with a small impact on prices.

Nishizaki, Tsuchikawa, and Yagi (2013) proposed measuring the depth of the market by plotting the median of the volume of limit orders at the best-ask price within each business day. The market depth indicators based on this method show that market depth declined in spring 2013, then briefly recovered, and has been on a clear declining trend since fall 2014 (Chart 4).[5] Looking at the histogram of intraday data in detail, the period of time when the volume of limit orders at the best-ask price is around 10 to 30, which is deemed very few by recent standards, has been long since the beginning of February 2015. These developments since fall 2014 are consistent with the views of some market participants that the market depth has been decreasing since the expansion

[5] The chart only shows the volume of limit orders at the best-ask price, but on the whole, the volume of limit orders at the best-bid price has also been developing similarly to that of the best-ask price.

of QQE at the end of October 2014.

As mentioned above, market depth measured from the volume of limit orders at the best-ask price may contain relevant information, but one has to be careful that it may not fully capture the dynamic relationship between limit orders and market orders. For example, even when the volume of limit orders seems to be increasing, if an event can easily trigger its sharp decline and the speed of recovery is slow, market participants' view of market liquidity will be unchanged or may even be that it is declining. Looking at developments in the volume of limit orders at the best-ask price for the JGB futures market from a somewhat longer-term perspective, while its level has been rising on average, the range of fluctuation has been increasing from around 2012. In addition, from around the same time, the effect of market orders on market depth has been increasing on average, and the degree of such effect has been volatile as well (see the appendix for details). In particular, the volume of limit orders at the best-ask price declined temporarily after the introduction of QQE, recovered thereafter and reached extremely high levels in the first half of 2014, but then declined sharply. Such fluctuation of the market depth indicator may reflect the following behavior of market participants: some investors, who were offering huge amounts of quotes while yield volatility was becoming very small in the first half of 2014, withdrew their quotes rapidly when the volatility increased again.

For this reason, having a lot of limit orders under low volatility in yields does not necessarily mean that market liquidity is high. It is necessary to interpret indicators regarding market depth collectively with those regarding market resiliency.

2.3 Resiliency of JGB futures market

The daily price range to transaction volume ratio, which can be calculated from daily data, has been traditionally used to grasp resiliency in the JGB futures market.[6] This ratio is defined as the daily price range, that is, the difference between the highest and lowest transaction prices of the day divided by the transaction volume in the day. Roughly speaking, this indicator shows the price movement per transaction during the day. When the market is resilient, even if the volume of limit orders at the best-ask (-bid) price temporarily decreases following transactions, it will smoothly revert to the "equilibrium level," resulting in a small price change. In other words, roughly speaking,

[6] For example, Sarr and Lybek (2002) presented the price range to turnover ratio (and related indicators) as a convenient liquidity indicator.

the more resilient the market, the lower the daily price range to transaction volume ratio.

While this ratio calculated from daily data is a convenient indicator, it has its limits. For example, even when the difference between the highest and lowest transaction prices during the day is small, resulting in a low ratio, there may be cases where market participants have difficulties executing transactions, such as where intraday price movement is volatile, moving frequently between the highest and lowest transaction prices.

In order to measure market resiliency, which cannot be obtained from the daily price range to transaction volume ratio, a "price impact" indicator can be calculated as the impact that a unit volume of transactions has on the price by using tick data instead of daily data. Several methods have been proposed to estimate price impact: (1) a generalization of a liquidity measure by Amihud (2002) (such as summing up the intraday absolute price change at a 5-minute frequency and then dividing the sum by the transaction volume) and (2) the methods of Kyle (1985) and Fleming (2003) who estimated the model accounting for the relationship between price change and transaction volume. As shown in the following model based on Fleming (2003), this section calculates the price impact of a unit volume of transactions in the JGB futures market with a Kalman Filter by positing the hypothesis that price impact β will follow a random walk and then by smoothing the developments in price impact (Chart 5).[7]

$$\Delta p_t = \beta_t q_t + \varepsilon_t, \quad \varepsilon_t \sim \text{i.i.d.} N(0, \sigma_\epsilon^2)$$

$$\beta_t = \beta_{t-1} + \delta_t, \quad \delta_t \sim \text{i.i.d.} N(0, \sigma_\delta^2)$$

Δp_t : 5-minute price change of futures price (bid-ask midpoint basis)
q_t : 5-minute net transaction volume of futures
(buyer-initiated transactions less seller-initiated transactions)

Note: Buyer-initiated (seller-initiated) transactions are those executed at the ask (bid) price immediately before the transaction. t is the indicator at a 5-minute frequency. The sample size is 133,767.

[7] Regarding the calculation of price impact, (1) estimations of a linear regression model using OLS per 5-day data set, as Fleming (2003) did in his study, and (2) estimations of a VAR model per 5-day data set (see the appendix for details) were made, but the results were basically in line with the results of this section.

Looking at developments in the price impact (β), its instability has increased since spring 2013 when QQE was introduced. Since fall 2014, the price impact has heightened even though the daily price range to transaction volume ratio has remained at low levels.[8]

This suggests that in the JGB futures market, indicators of market depth and resiliency had been declining before the volatility increased in the middle of January 2015, while its degree has been small compared to that of spring 2013.

3. Liquidity Indicators in the JGB Cash Market

This section presents liquidity indicators of the JGB cash market. Specifically, it analyzes the transaction volume of the JGB cash market for both inter-dealer transactions and dealer-to-client transactions. Then it focuses on dealer-to-client transactions, and measures market depth using transaction data of a dealer-to-client electronic trading platform.

3.1 Volume of JGBs

JGB cash transactions can be mainly divided into (1) inter-dealer transactions, (2) dealer-to-client transactions, and (3) other transactions such as auctions for primary issuance held by the Ministry of Finance and purchases by the Bank of Japan.

Of these, the inter-dealer transaction volume, according to *Government Bond Trading Volume by Type of Investors* released by the Japan Securities Dealers Association, decreased temporarily in spring 2013, but then tended to increase until falling sharply in January 2015. The inter-dealer transaction volume via Japan Bond Trading also increased significantly, especially in that of on-the-run bonds after fall 2014 (Chart 7).

On the other hand, the development of dealer-to-client transactions observed through the aforementioned statistics released by the Japan Securities Dealers Association has been sluggish in both transaction volume and turnover ratio (transaction volume divided

[8] This suggests that the intraday price change was large compared to the daily closing price-based price change. In fact, compared to historical volatility, which is an indicator for the latter, realized volatility, which is an indicator for the former (calculated by summing up the square of the price change per transaction during the day) has remained fairly high (Chart 6).

by outstanding amount), and has decreased rather considerably since fall 2014.[9] In addition to the decrease in transaction volume by city banks, which is a highly volatile component, that of investors such as insurance companies is remarkable (Chart 8).

3.2 Depth of JGB Cash Market

This section formulates indicators other than transaction volume, regarding the dealer-to-client market in which transaction volumes have tended to be sluggish.

As 80 to 90 percent of the dealer-to-client JGB transactions consist of over-the-counter transactions, it is difficult to obtain transaction data. We therefore construct liquidity indicators using transaction data from the Yensai electronic trading platform (hereafter Yensai), where a wide range of issues are traded though the platform does not necessarily have a high market share.[10]

In Yensai, a maximum of five dealers designated by the client offer quotes against the client's request with issue and trade size indicated. Therefore, it is not possible to create an indicator similar to that of JGB futures, where each market participant offers bid and ask amounts (Chart 9).

While there are few preceding studies which pick up liquidity indicators related to dealer-to-client transactions of government bonds both in domestic and overseas markets, this section constructs the best-worst quote spread as a liquidity indicator following Kakuma (2012), a preceding study using Yensai transaction data.[11] The best-worst quote spread is calculated by taking the spread between the best and the worst quotes offered by dealers against each request of the clients.[12] This spread is close to the measure of market depth, in the sense that a tight best-worst quote spread

[9] Investors categorized as "others" in *Government Bond Trading Volume by Type of Investors* (Government entities, Japan Post Bank, Bank of Japan, etc.) are excluded from clients.

[10] In Yensai, 14 major securities companies from home and abroad take part in the dealer side (as of November 2014). On the client side, the main users are asset management firms and trust banks. These firms use Yensai to make fairly small transactions of JGBs with a wide range of residual maturities. Therefore, while Yensai's volume-based market share for dealer-to-client transactions is about 10 percent, the number of transactions is at an adequate amount, and thus transaction data of Yensai for each residual maturity is regarded as statistically reliable. The analysis in this section was made by requesting Yensai.com, the operating organization of Yensai, to process and collect data.

[11] A study by Musto, Nini and Schwarz (2014), which is one of the few exceptions, uses the dealer-to-client electronic transaction platform called Tradeweb to analyze distortion in on-the-run U.S. Treasury Bond prices.

[12] Only transactions which had quote offers from five dealers are counted.

means that there are many dealers who are able to make transactions at a price level equal to or close to the best quote.

The best-worst quote spread narrowed temporarily after widening in spring 2013, but has been widening again since fall 2014 (Chart 10(1)). The widening of best-worst quote spreads in spring 2013 and in the period since fall 2014 is more prominent in the tail of their distribution as evidenced in the increased probability of the spread being 1 bps or wider (Chart 10(2)(3)). This suggests that since fall 2014, the difference in depth is widening among issues, i.e., the possible increase in issues for which a large-volume transaction is difficult due to factors such as tightness in the supply and demand of JGBs.

Looking at these best-worst quote spreads by residual maturity, those in the short- and medium-term have been widening from an early period (Chart 11). One reason for this may be due to the yields for the short- and medium-term decreasing to near-zero from an early period, and some issues having negative yields in fall 2014, resulting in market participants dismissing JGB transactions for that maturity. In addition, the spread for the long- and super-long-term has also been widening since November 2014, prior to the rise in volatility of long-term yields after entering 2015.

4. Relationship between JGB Cash and Futures Markets and SC Repo Markets

This section examines whether the current environment allows dealers to engage smoothly in market-making activities for JGBs, which is considered important in measuring JGB market liquidity, from the following two points.

The first is the correlation between JGBs and JGB futures. When the relationship between the two becomes unstable, market-making capacity decreases as it would become more difficult to hedge interest rate risk which derives from JGB cash positions by using JGB futures.

The second point is the development in the SC repo market. Market participants of JGBs, such as dealers, frequently take a short position in order to engage in market-making and arbitrage transactions. The specific issues needed to cover the short position are often borrowed from the SC repo market. The SC repo rate indicates the

costs for borrowing a particular security, and the scarcer the issue becomes, the larger the negative value becomes. If the negative value of the SC repo rate increases largely, there is a possibility of market participants having difficulties taking a short position, which affects the transactions in the JGB market.

4.1 Relationship between JGBs and JGB Futures

Looking at the link between the prices of 10-year JGBs and JGB futures, the correlation coefficient of the daily change in yields has been relatively high even since fall 2014, and the relationship of yields of JGB futures rising (falling) when yields of JGBs rise (fall) seems to be maintained. The correlation coefficient has actually been increasing after entering 2015, amid temporarily increasing volatility in yields. The intraday yields are also moving together as a whole, and the function of the JGB futures market as a hedge against interest rate risk seems to be broadly maintained (Chart 12).

At the same time, however, since the beginning of 2014, the negative value of the implied repo rate for the JGB futures' cheapest-to-deliver bond has been widening, albeit with fluctuations (Chart 13).[13] In other words, as the availability of JGBs decreases, they appear to be becoming more overvalued than before, when compared with JGB futures. If this trend strengthens, the arbitrage relationship between JGBs and JGB futures via the SC repo market may weaken. It is therefore necessary to carefully monitor how the correlation between the two changes, especially at the timing of calendar rollover.

4.2 SC Repo Market

Theoretically, the SC repo rate per issue is defined as the risk-free interest rate -- for which we simply use the general collateral (GC) repo rate, a rate for repo transaction where securities to be used as collateral are not specified -- minus the lending fee which reflects the scarcity of each issue. The difference between the GC and SC repo rates (GC-SC spread), which shows the lending fee added on to each issue, is affected by the

[13] The final settlement of JGB futures is made by delivering the JGB. Sellers of JGB futures contracts are granted options regarding deliverable JGB issues, and the issue among the deliverable pool which is the most beneficial for the seller is called the cheapest-to-deliver bond. If there is no arbitrage opportunity between the cheapest-to-deliver bonds and futures, there would not be any profit from such a transaction as (1) making orders to buy futures and selling the cheap-to-deliver bonds (borrowed from the SC repo market) today and (2) receiving the JGB on the day of the settlement (closing the short position with the received bond). A SC repo rate that fulfills this no-arbitrage condition is called the implied repo rate.

issue's supply and demand, i.e., the issuance volume and the size of market participants' short positions. Developments in the SC repo rate affect the yields of JGBs as well (Duffie, 1996). Using data for individual issues, D'Amico et al. (2014) showed that the large-scale purchases by the Federal Reserve Board significantly affected the SC repo rate of the Treasury market.

In Japan's SC repo market, similar to the aforementioned dealer-to-client JGBs market, over-the-counter trading accounts for a high proportion and it is therefore difficult to obtain transaction data. This section uses the SC repo rate (S/N) per issue from the SC Repo Electronic Platform offered by JBond Totan Securities (hereafter JBOND). Although the market share of JBOND is about 10 percent of the entire overnight SC repo transactions, 70 to 90 issues are traded each business day. Thus, JBOND holds a certain amount of information regarding the difference in SC repo rates among the issues.

Developments of the GC-SC spread (average for all the traded issues) after 2013 using JBOND reveal that the spread has been widening albeit with fluctuations such as those from term-end effects, since around the beginning of 2014 (Chart 14).[14] The data also reaffirms that dispersions in the GC-SC spread among issues are expanding after entering the second half of 2014. This indicates that issues with larger lending fees due to tightness in supply and demand are gradually increasing.

5. Conclusion

We constructed and examined a wide range of indicators to grasp the liquidity of the JGB market using transaction data from a number of markets such as JGB futures, JGB cash, and SC repo. A tentative appraisal of the liquidity in the JGB market after the expansion of QQE in October 2014 obtained from the analysis is summarized below.

First, in the JGB futures market, the bid-ask spread has been tight and transaction volume as well as trade size per transaction has been maintained during the period since fall 2014. On the other hand, market depth observed from the volume of limit orders at

[14] The Tokyo repo rate (T/N) is used for the GC repo rate. The SC repo rate is S/N as stated above, and thus the GC-SC spread is calculated by synchronizing the settlement date (i.e., by using the GC repo rate of the business day following the day the SC repo transaction is made).

the best-ask price has been slightly decreasing since fall 2014. Moreover, the market resiliency, which is represented by the speed with which the decreased volume of limit orders at the best-ask price reverts to the "equilibrium level," or the ability to make a transaction without resulting in a large price change, may have been edging lower.

Second, in the JGB cash market, while the inter-dealer transaction volume has remained at an adequate level even since fall 2014, the dealer-to-client transaction volume has been sluggish. Looking at the detailed information of dealer-to-client transactions, the market liquidity may have been decreasing for some issues as the discrepancy in quotes is becoming large.

Third, the correlation between JGBs and JGB futures is at a high level and the function of JGB futures to hedge interest rate risk seems to be maintained. However, JGBs appear to be slightly overvalued compared to JGB futures. In the SC repo market, issues with a somewhat high lending fee have been increasing since the second half of 2014, which suggests increasing scarcity of certain issues.

Judging from these indicators as a whole, currently there is no large problem in the execution of transactions in the JGB market and the hedging of positions. It can therefore be assumed that market liquidity in the JGB market is not decreasing significantly. However, a careful examination of the new indicators formulated from individual transaction data in this paper reveals that several indicators suggest market liquidity has been declining since fall 2014.

It is difficult to clarify the reason for the decline in market liquidity since fall 2014, as suggested by the newly constructed indicators. The increase in the Bank of Japan's JGB purchases may be affecting the market liquidity in some way by directly tightening the supply and demand of JGBs. On the other hand, it is also possible that the rapid decline in long-term yields and the turn of short- and medium-term yields to negative rates which occurred at that time has reduced market liquidity as shown in the above indicators, through domestic investors' temporary holding-off on trading.

If the latter factor is dominant, market liquidity could recover depending on future developments in long-term yields. On the other hand, if the former factor or a more structural factor is the prime factor, the depth and resiliency of the JGB market may not recover to the original level. For example, some foreign securities companies have

recently been reducing their transactions within the JGB market, and their share of the long-term JGB auctions is declining (Chart 15). However, this may be due to factors other than monetary policy and developments in long-term yields, such as global financial regulations and the downgrading of Japan's sovereign rating.

Based on the above observations, it is worth monitoring liquidity in the JGB market continuously and from many sides, using the various indicators newly constructed in this paper as well as the *Bond Market Survey*.[15] Moreover, as market liquidity could also be influenced by unquantifiable factors such as market participants' behavior in the JGB market, it is important to carefully monitor the market's view toward liquidity, through establishment of the "Bond Market Group" recently set up by the Financial Markets Department of the Bank of Japan and communication with market participants through daily market intelligence activities.

[15] The Financial Markets Department of the Bank of Japan newly introduced a "Bond Market Survey" in February 2015, with eligible institutions for outright sales and purchases of JGBs as respondents. The results are released on the Bank's web site.

Appendix. Liquidity Indicators in the JGB Futures Market from a Long-term Perspective

Looking at the liquidity indicators presented in Section 2 from time-series since the mid 2000s, every indicator shows that levels have shifted significantly since 2012 (Appendix Chart 1).

In particular, the volume of limit orders at the best-ask price -- which is an indicator of market depth -- shows the growing tendency to decline rapidly under distressed market conditions since around 2012, while the level has greatly increased under tranquil market conditions. Given that variance of the indicators has varied over time, it is not appropriate to compare directly the volume of limit orders at the best-ask price between the mid 2000s and the present. Also, it is likely that the market liquidity described by the indicators has deviated from the view of market participants since 2012.

To clarify this issue, this appendix discusses the resiliency of the volume of limit orders at the best-ask (-bid) price based on the structural VAR model with five lags for a vector of endogenous variables that consist of (1) volume of limit orders at the best-ask (-bid) price, (2) seller-initiated (buyer-initiated) transaction volume (market orders) and (3) price change, following Fleming, Mizrach and Nguyen (2014). Specifically, the model is described by

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & \alpha_{3,2} & 1 & 0 & 0 \\ \alpha_{4,1} & 0 & 0 & 1 & 0 \\ \alpha_{5,1} & \alpha_{5,2} & \alpha_{5,3} & \alpha_{5,4} & 1 \end{pmatrix} \begin{pmatrix} La_t \\ Lb_t \\ QS_t \\ QB_t \\ \Delta p_t \end{pmatrix} = \sum_{j=1}^{5} B_j \begin{pmatrix} La_{t-j} \\ Lb_{t-j} \\ QS_{t-j} \\ QB_{t-j} \\ \Delta p_{t-j} \end{pmatrix} + \varepsilon_t$$

$La_t(Lb_t)$: volume of limit orders at the best-ask (-bid) price at the beginning of time *t*

$QS_t(QB_t)$: 1-minute seller-initiated (buyer-initiated) transaction volume between time *t* and *t* + 1

Δp_t : 1-minute price change between time *t* and *t* + 1 (bid-ask midpoint basis)

The above VAR model is iteratively estimated by pooling data of every five business days. The model is structured as follows. First of all, limit orders are offered.

Subsequently, market orders are conducted by consuming the limit orders. Consequently, the price level changes. For parsimony, it is assumed that the seller-initiated (buyer-initiated) transaction volume is not correlated with the volume of limit orders at the best-ask (-bid) price simultaneously.

When a seller-initiated (buyer-initiated) transaction is done in the market, the volume of limit orders at the best-ask (-bid) price will decline at least temporarily. However, if the market is highly resilient, such decline will be temporary and the volume will recover quickly.

Appendix Chart 2 (1) illustrates the impacts of a 1-unit seller-initiated (buyer-initiated) transaction on the volume of limit orders at the best-ask (-bid) price over one hour in terms of cumulative impulse responses. Before 2012, the cumulative impulse responses remained approximately zero in general. This means that even if the transaction had caused a temporary decline in the volume of limit orders at the best-ask (-bid) price, the decline would have recovered quickly. By contrast, after 2012, one can occasionally observe situations in which the cumulative impulse responses become clearly negative, even if the volume of limit orders at the best-ask (-bid) price was superficially increasing as at the end of 2013 and summer 2014. Under these situations, even if the market depth is high on average, after the transaction it will recover only slowly, and thus there is a gap between the indicator of market depth, i.e., volume of limit orders at the best-ask (-bid) price, and market participants' view toward market liquidity.

In addition, looking at the cumulative impulse responses of the volume of limit orders at the best-ask (-bid) price to a negative 1-unit shock to itself, one would expect the decline in the volume of limit orders at the best-ask (-bid) price to last longer once it actually declines, after 2012 (Appendix Chart 2 (2)).

These calculations based on the simple VAR model suggest that the resiliency in the JGB futures market has been declining since 2012, in terms of the speed of recovery of market depth. Given that the resiliency is different, it is not appropriate to compare directly the volume of limit orders at the best-ask price between the mid 2000s and the present.

From the above observations, it is difficult to evaluate market liquidity with the limited available set of indicators. Appropriate levels of individual liquidity indicators

significantly depend on market regulation and structure, and behavioral changes among market participants. For evaluating market liquidity properly, it is indispensable to keep monitoring the market trend and assess liquidity indicators from various aspects, without relying on specific indicators.

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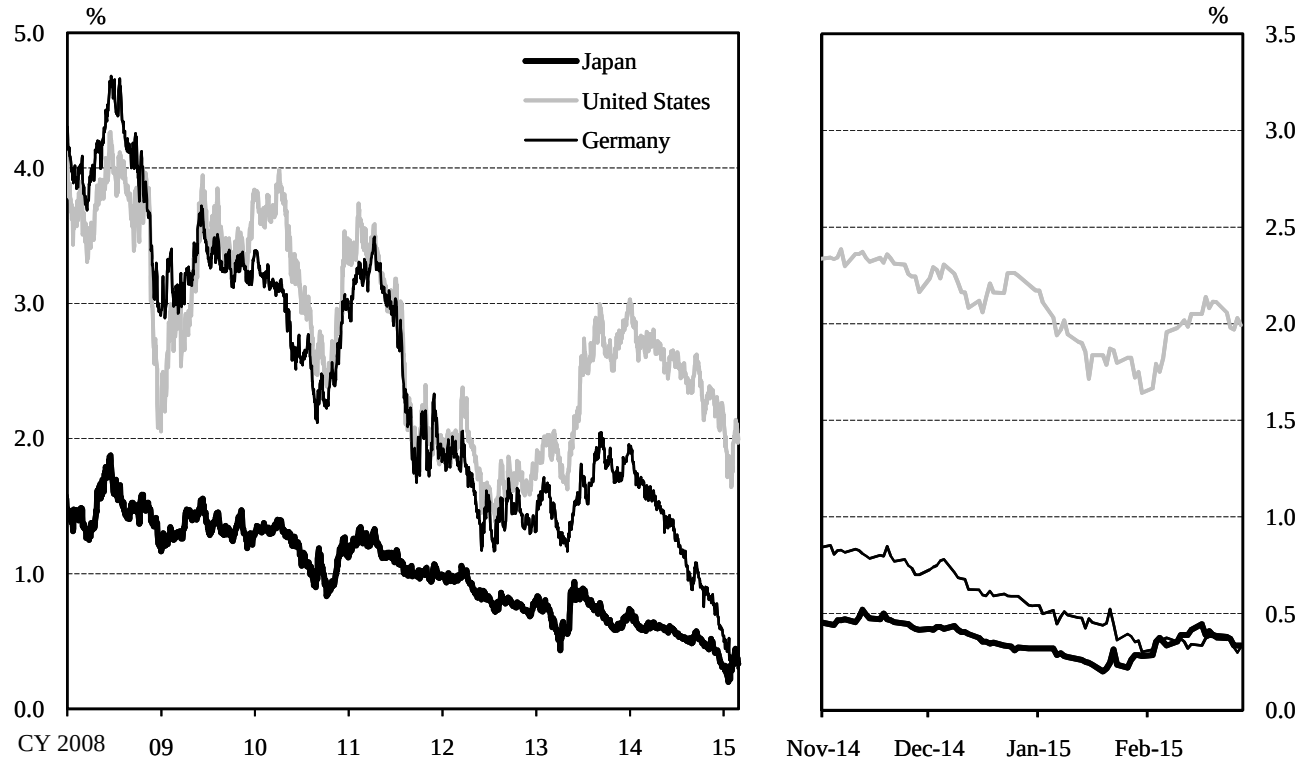
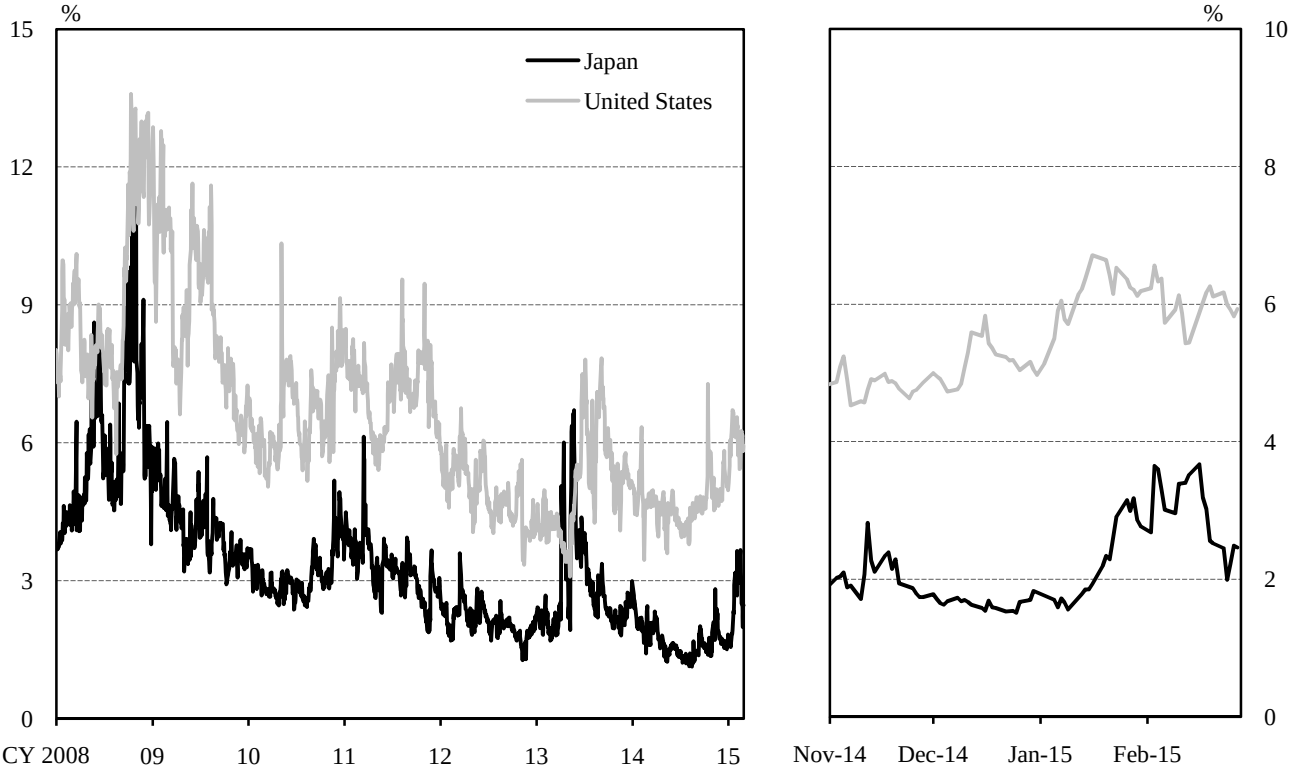
(Chart 1)

Long-term Interest Rates

(1) 10-year Government Bond Yields



(2) Implied Volatilities of Government Bond Futures

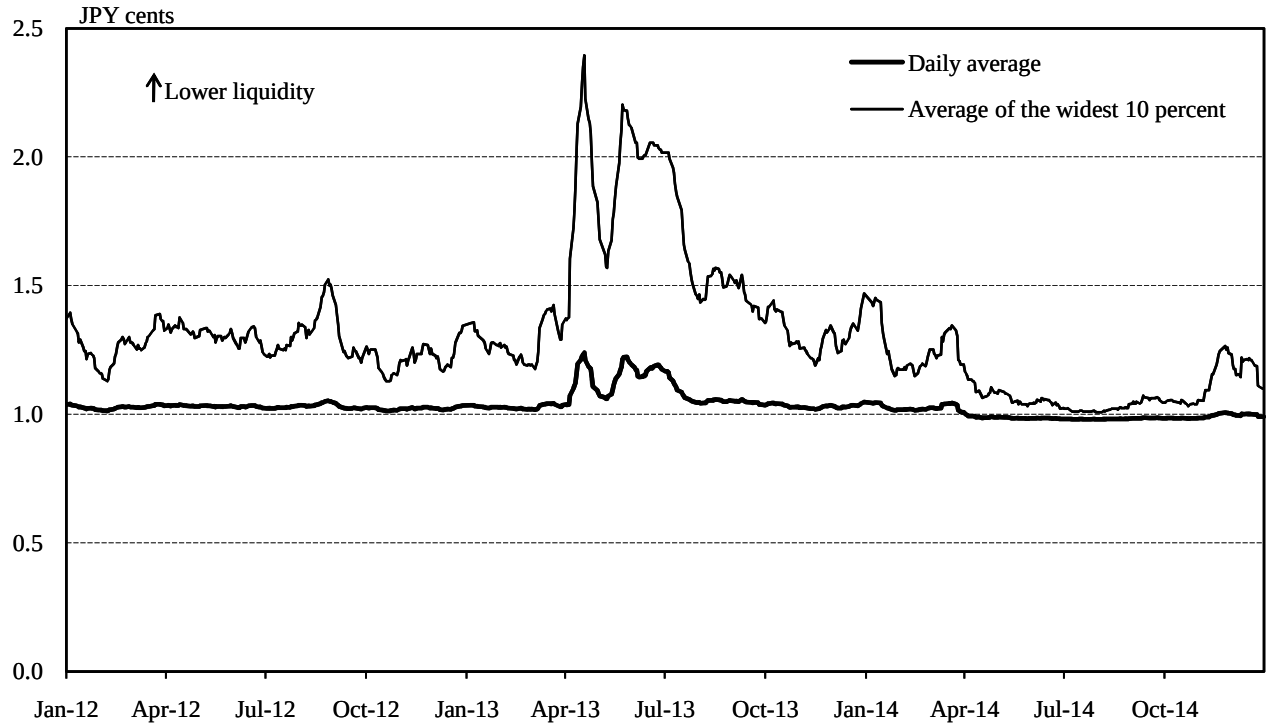


Note: The latest data are as of end-February 2015.
Source: Bloomberg.

(Chart 2)

Liquidity Indicators in the JGB Futures Market: Bid-ask Spreads (Tightness)

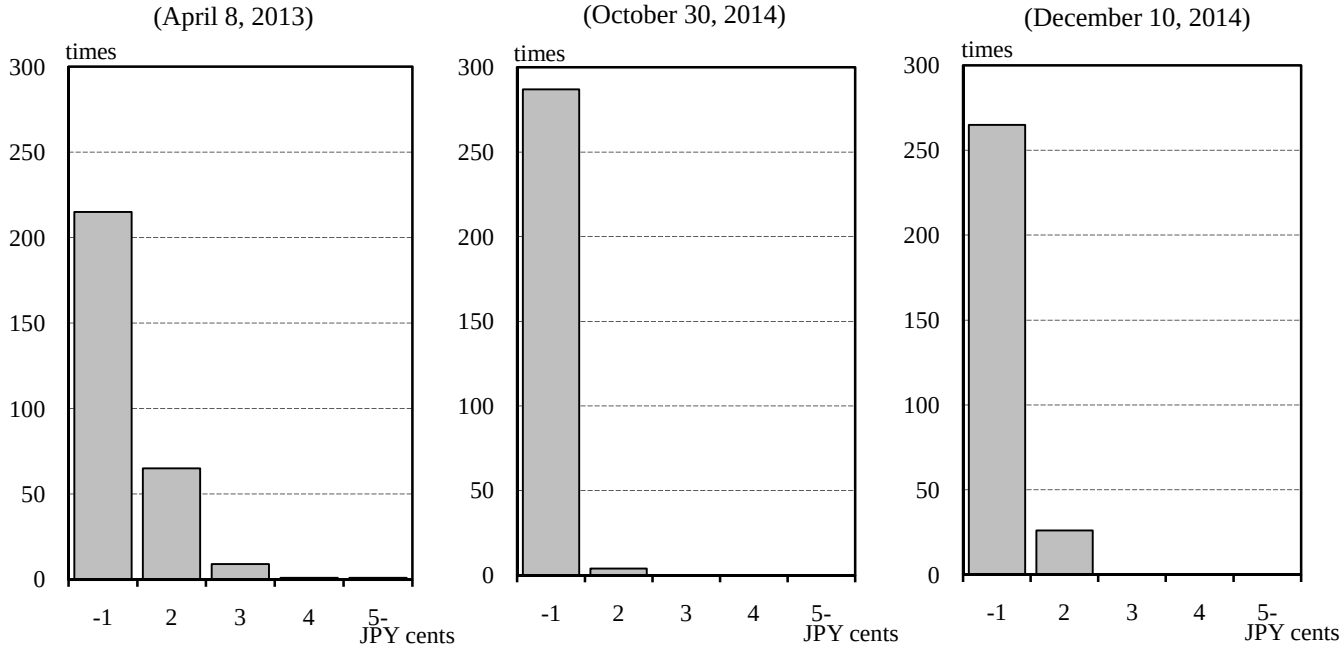
(1) Bid-ask Spreads (Daily Average and Average of the Widest 10 percent)



Notes: 1. The latest data are as of end-December 2014.

2. "Daily average" is the average of the bid-ask spread data with a 1-minute frequency within each business day. "Average of the widest 10 percent" is the average of the widest 10 percent of that data. A 10-day backward moving average is then applied to both time-series.

(2) Histogram of the Bid-ask Spreads



Notes: 1. Figures are calculated by summing up the appearance frequency of the bid-ask spread with a 1-minute frequency within each business day.

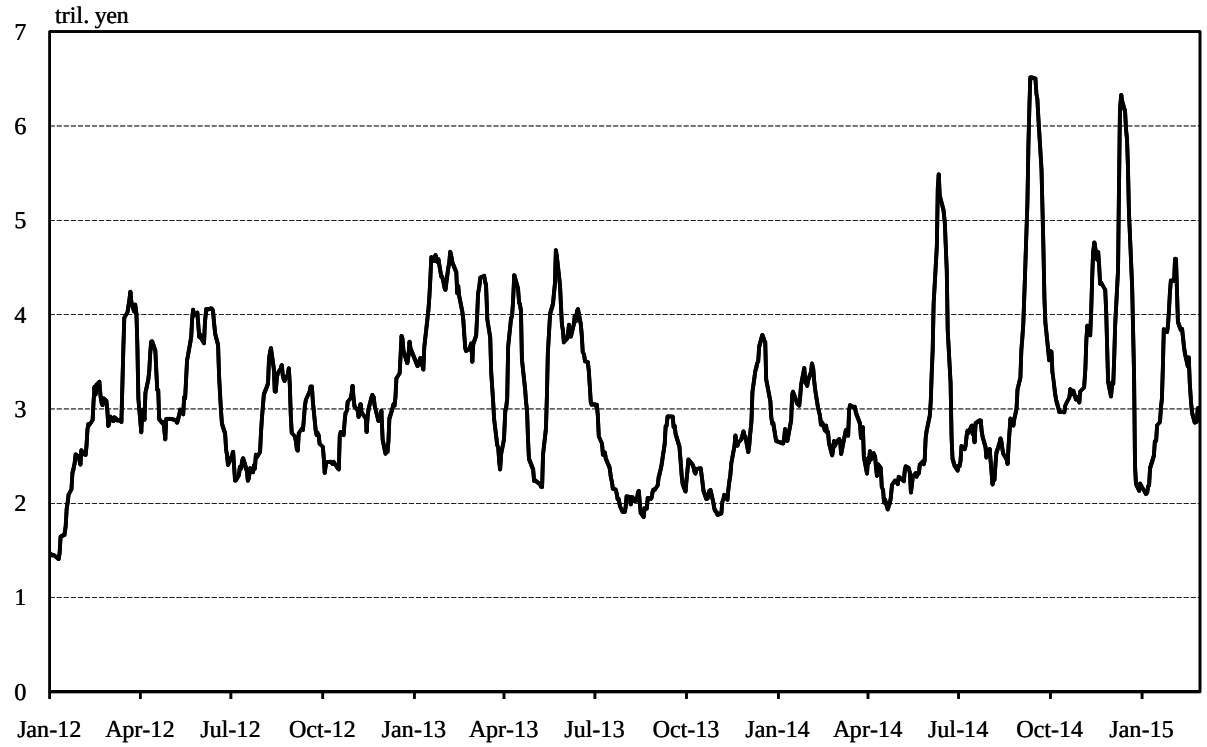
2. December 10, 2014 is the day on which "average of the widest 10 percent" is the largest during the October-December quarter of 2014.

Source: Nikkei NEEDS.

(Chart 3)

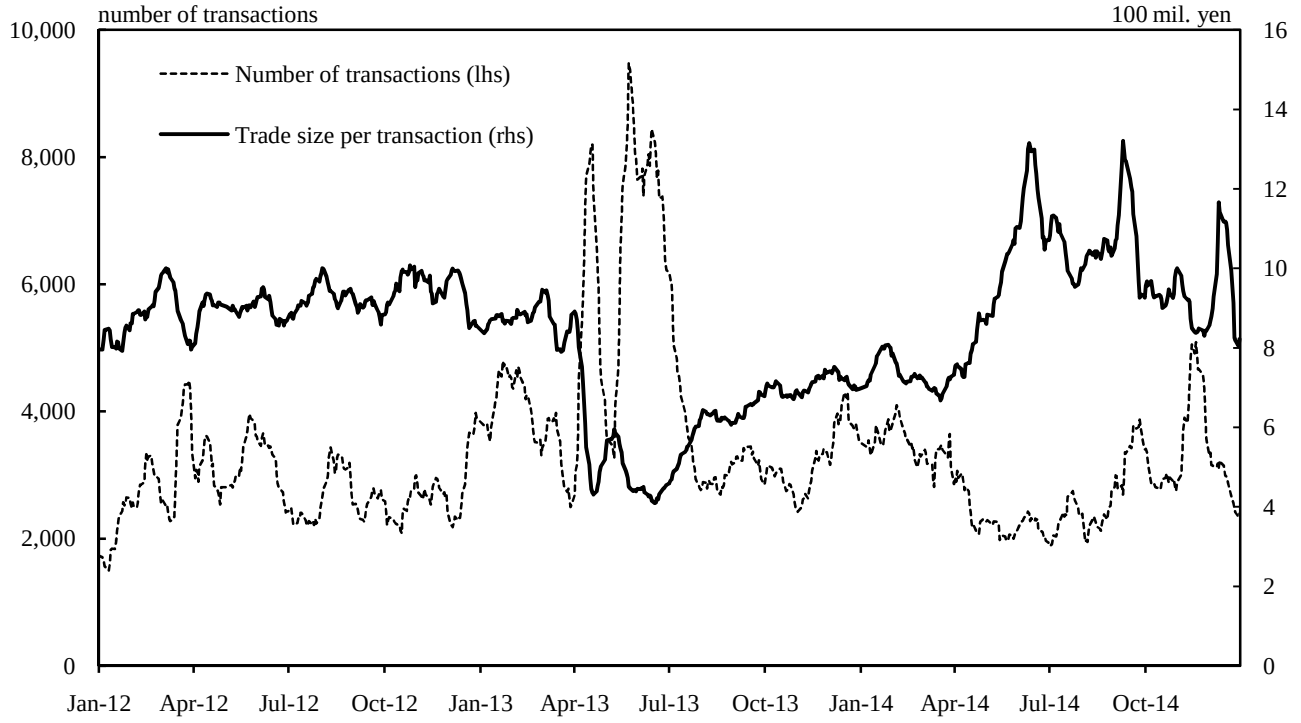
Liquidity Indicators in the JGB Futures Market: Transaction Volume and Trade Size (Volume)

(1) Transaction Volume of JGB Futures



Note: 10-day backward moving average. The latest data are as of end-February 2015.
Source: Bloomberg.

(2) Number of Transactions and Trade Size per Transaction

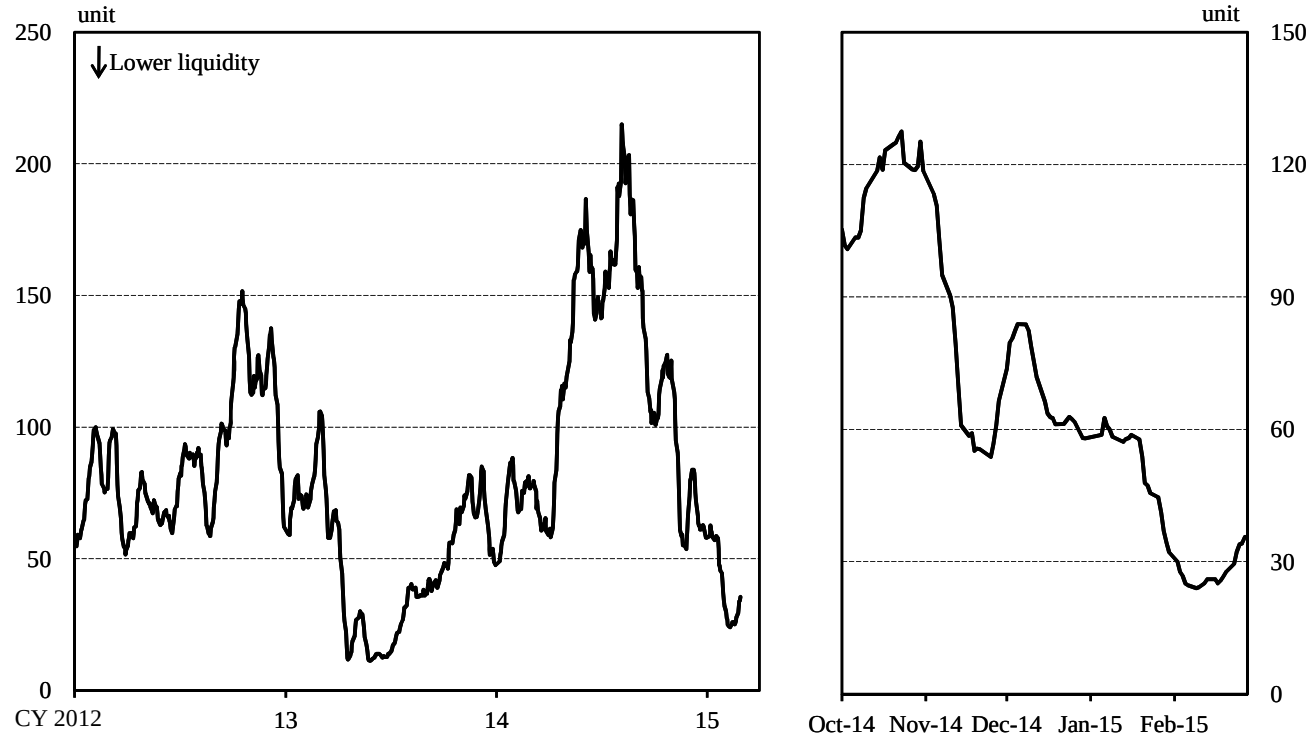


Note: 10-day backward moving average. The latest data are as of end-December 2014.
Source: Nikkei NEEDS.

(Chart 4)

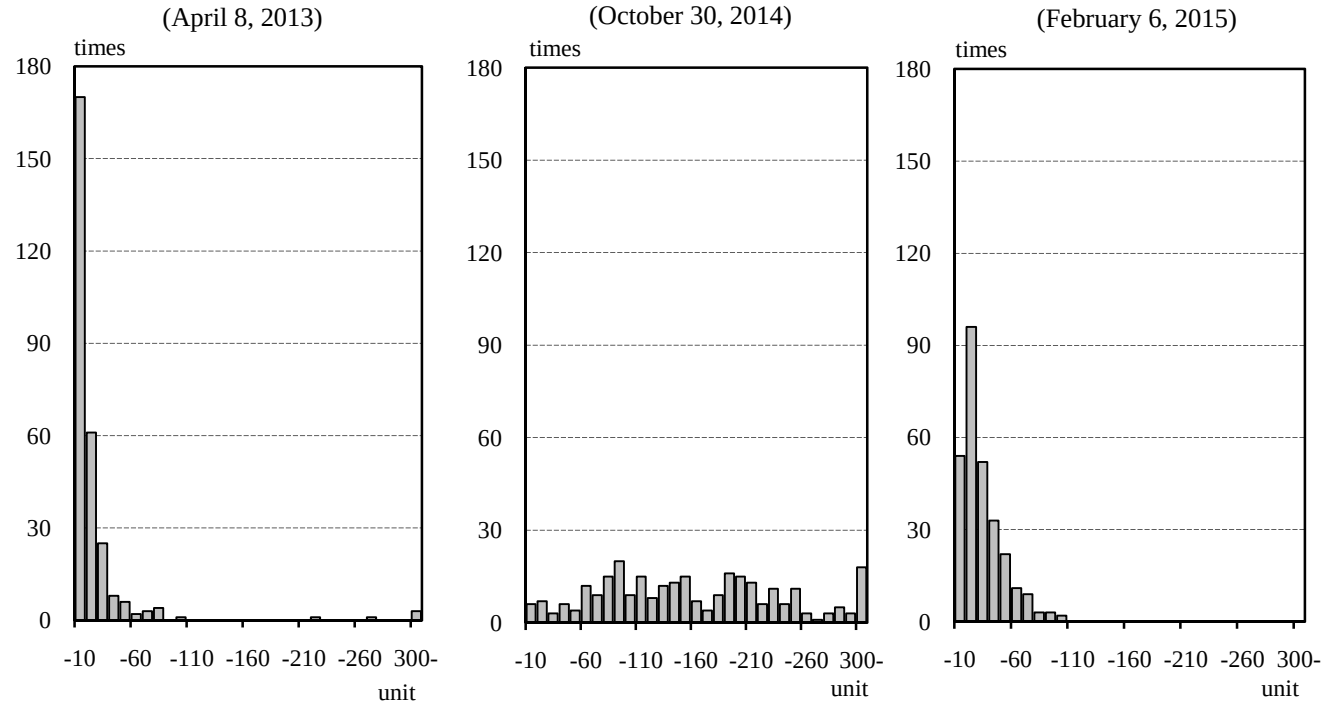
Liquidity Indicators in the JGB Futures Market: Volume of Limit Orders at the Best-ask Price (Depth)

(1) Volume of Limit Orders at the Best-ask Price (Daily Median)



Note: Figures are calculated by taking the median of the volume of limit orders at the best-ask price with a 1-minute frequency within each business day, and then applying a 10-day backward moving average. The latest data are as of end-February 2015.

(2) Histogram of Volume of Limit Orders at the Best-ask Price

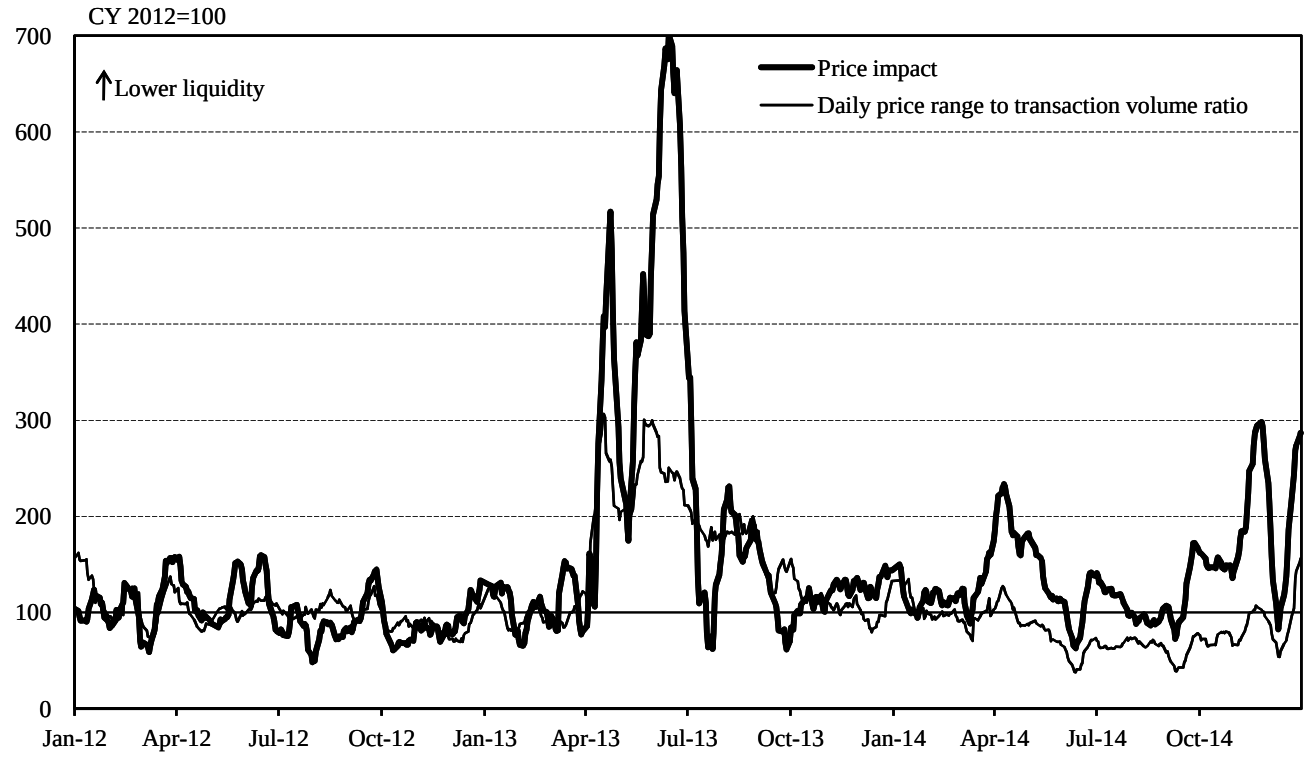


Note: Figures are calculated by summing up the appearance frequency of the volume of limit orders at the best-ask price with a 1-minute frequency within each business day.

Sources: Bloomberg; Nikkei NEEDS.

(Chart 5)

Liquidity Indicators in the JGB Futures Market: Price Impact (Resiliency)

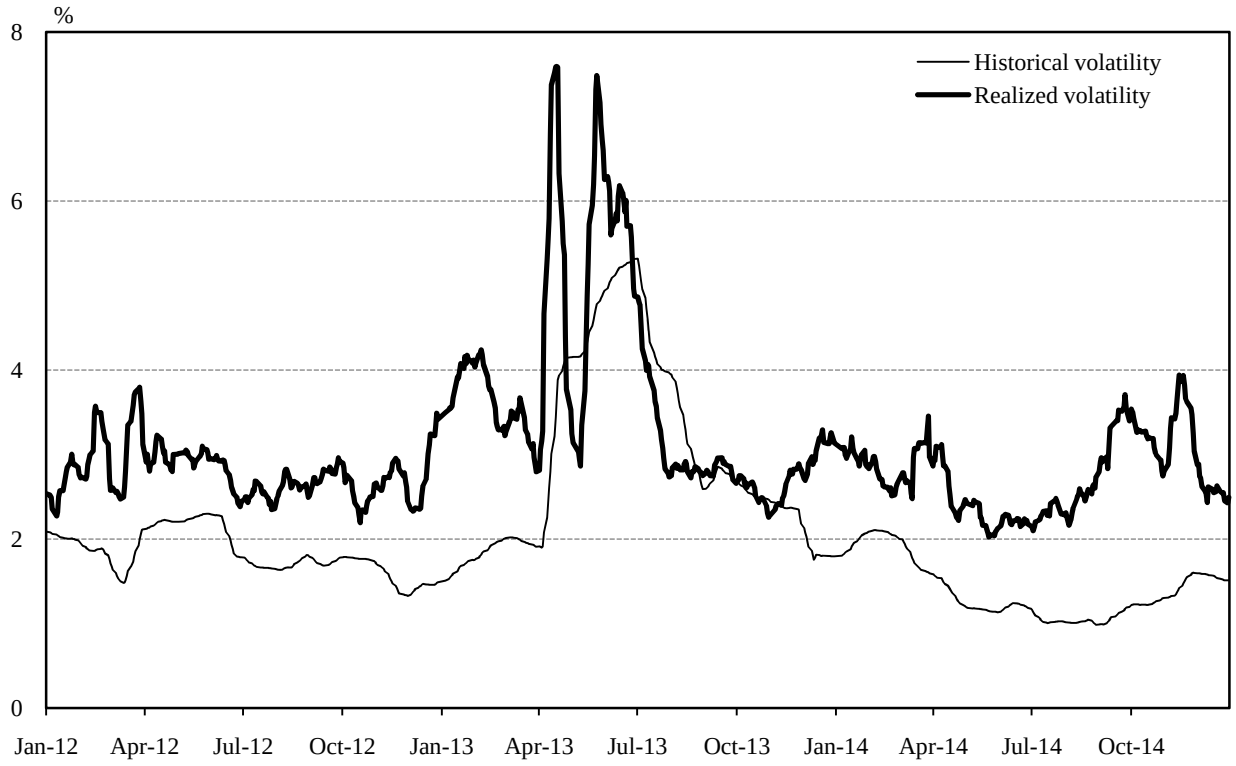


Note: "Price impact" is calculated by taking the average of each business day. A 10-day backward moving average is then applied to both time-series. The latest data are as of end-December 2014.

Sources: Bloomberg; Nikkei NEEDS.

(Chart 6)

Historical Volatility and Realized Volatility of JGB Futures



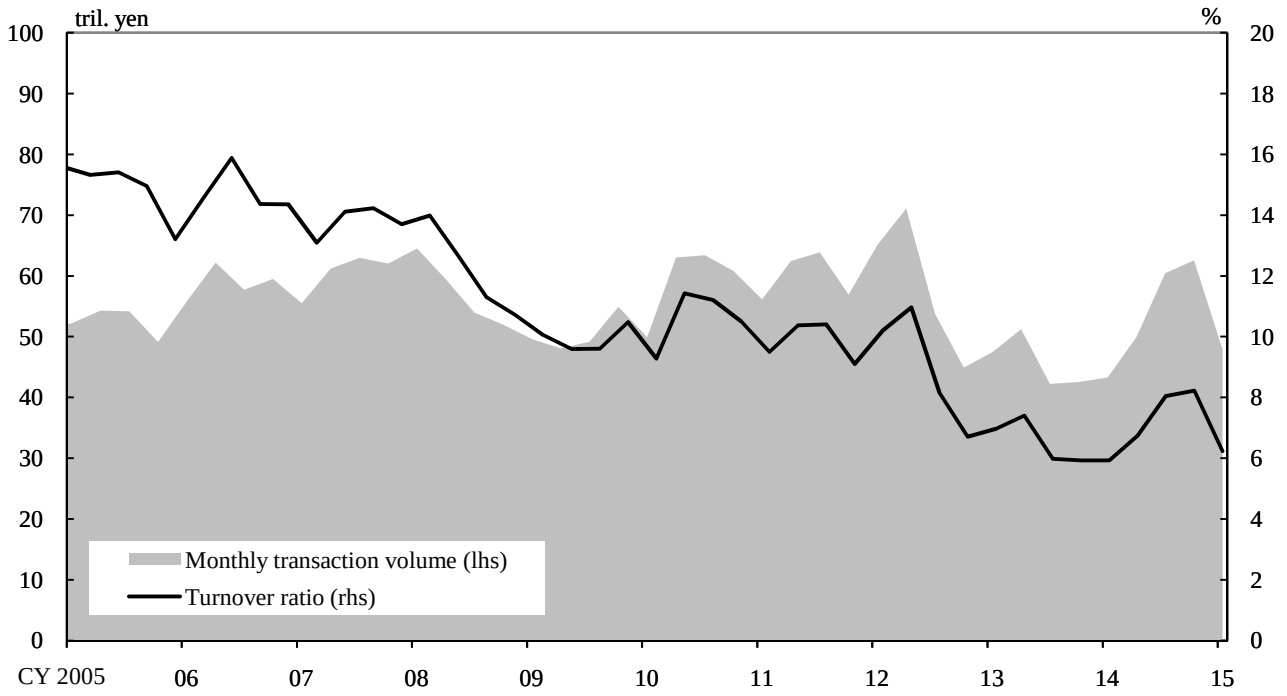
Note: Historical volatilities are calculated with a 60 business-day rolling window. A 10-day backward moving average is then applied to both time-series. The latest data are as of end-December 2014.

Sources: Bloomberg; Nikkei NEEDS.

(Chart 7)

Liquidity Indicators in the JGB Cash Market: Inter-dealer Transaction Volume (Volume)

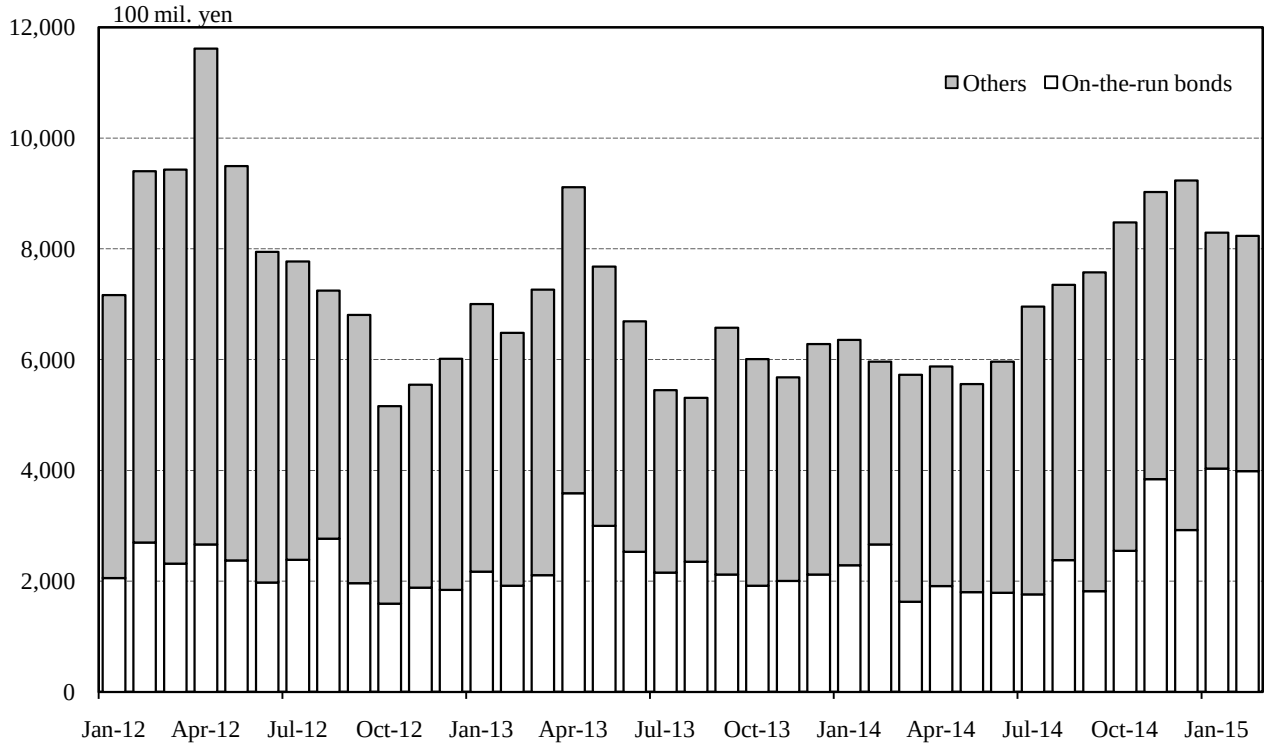
(1) Inter-dealer Monthly Transaction Volume



Notes: 1. The latest data are as of January 2015.
2. Treasury Discount Bills, etc. are excluded from transaction volume.
3. "Turnover ratio" is calculated by dividing the transaction volume by the outstanding amount.

Sources: Japan Securities Dealers Association; Ministry of Finance.

(2) Inter-dealer Daily Transaction Volume (via Japan Bond Trading)



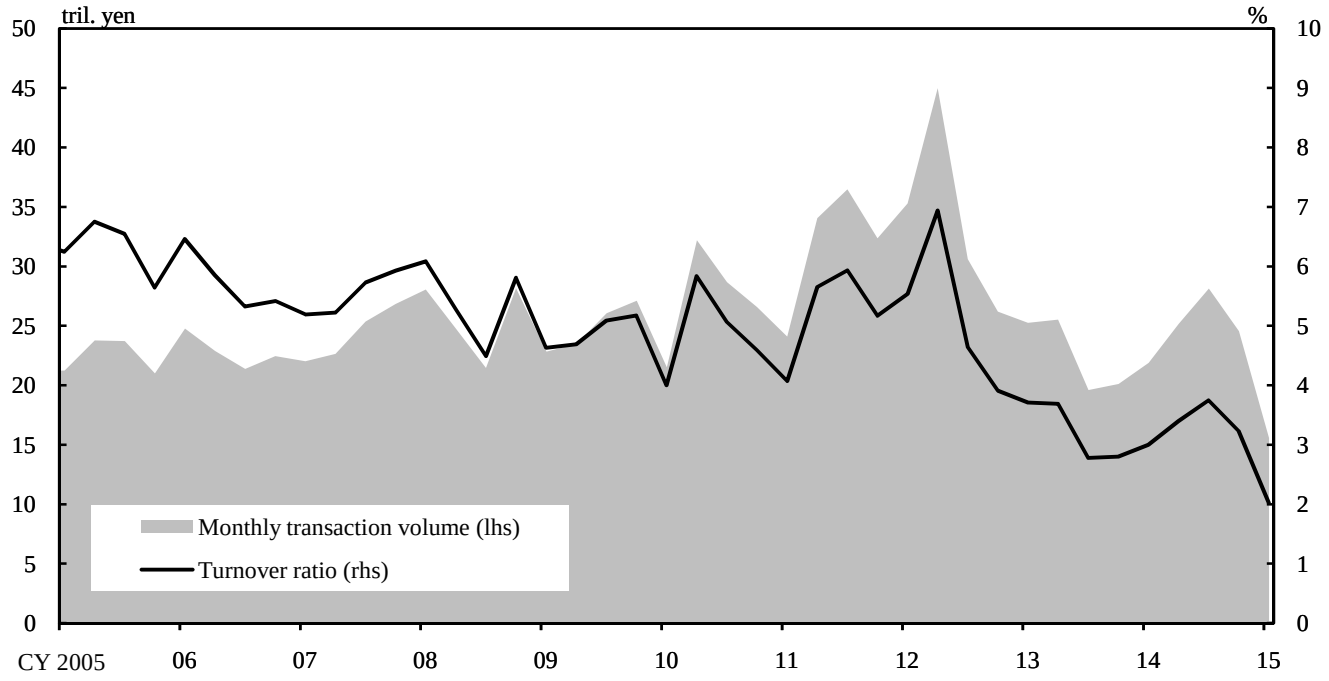
Note: Daily transaction volume of 2-year, 5-year, 10-year, 20-year, 30-year, and 40-year JGBs via Japan Bond Trading.
The latest data are as of February 2015.

Source: QUICK.

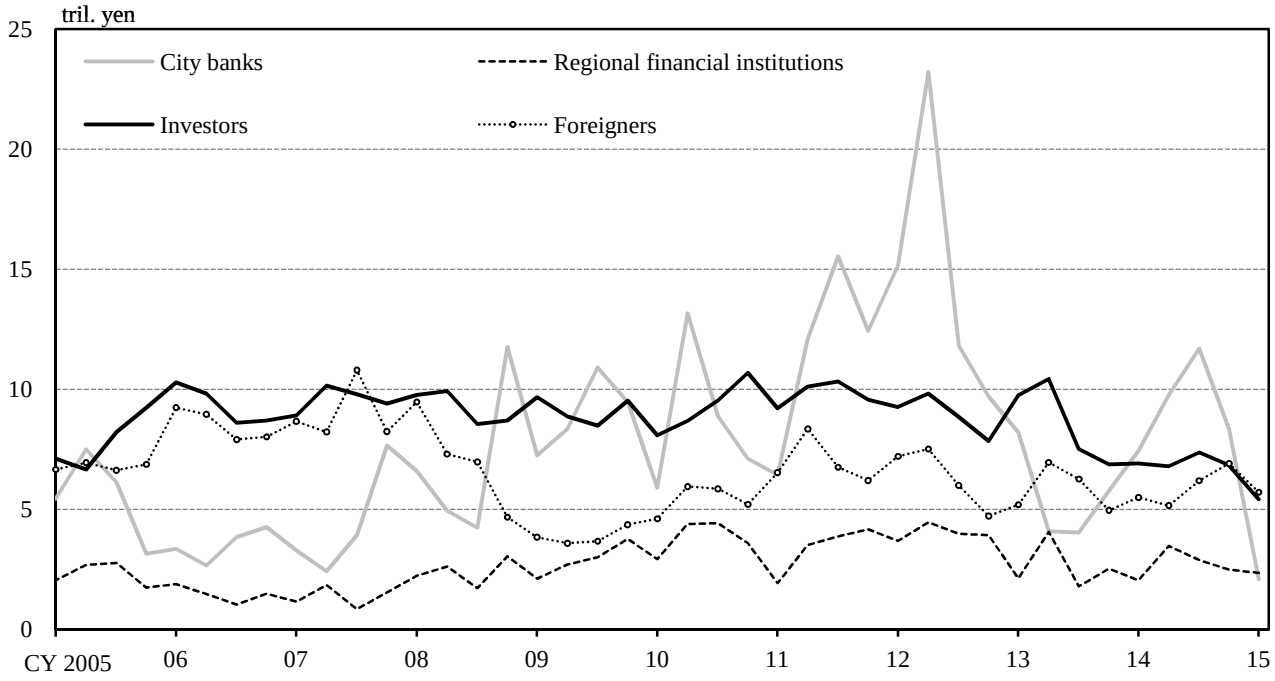
(Chart 8)

Liquidity Indicators in the JGB Cash Market: Dealer-to-client Transaction Volume (Volume)

(1) Dealer-to-client Monthly Transaction Volume (Gross Amount Purchased by Clients)



(2) Breakdown of Dealer-to-client Monthly Transaction Volume (Gross Amount Purchased by Clients)



Notes: 1. The latest data are as of January 2015.
2. Treasury Discount Bills, etc. are excluded from transaction volume.
3. "Turnover ratio" is calculated by dividing the transaction volume by the outstanding amount.
4. Government, Japan Post Bank, Japan Post Insurance, Bank of Japan, etc. are excluded from "clients."
5. "Investors" are agricultural, forestry and fishery financial institutions, insurance companies, investment trusts, national and local public officers mutual aid associations, and trust banks.

Sources: Japan Securities Dealers Association; Ministry of Finance.

(Chart 9)

Yensai's Electronic Trading Platform (Outline)

(1) Feature of Yensai's Electronic Trading Platform

JGB futures, etc.

Osaka Exchange

yen (price), unit (volume of orders)

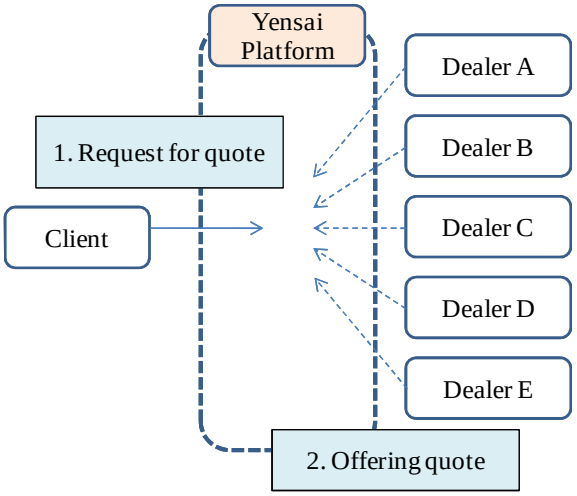
Selling limit orders		Price	Buying limit orders	
Accumulated orders	Orders		Orders	Accumulated orders
100	45	140.04-		
55	15	140.03		
40	30	140.02		
10	10	140.01		
0	0	140.00	0	0
		139.99	5	5
		139.98	20	25
		139.97	10	35
		-139.96	15	50

Volume of orders which are tradable at the best-ask price

Volume of orders which are tradable at the best-bid price

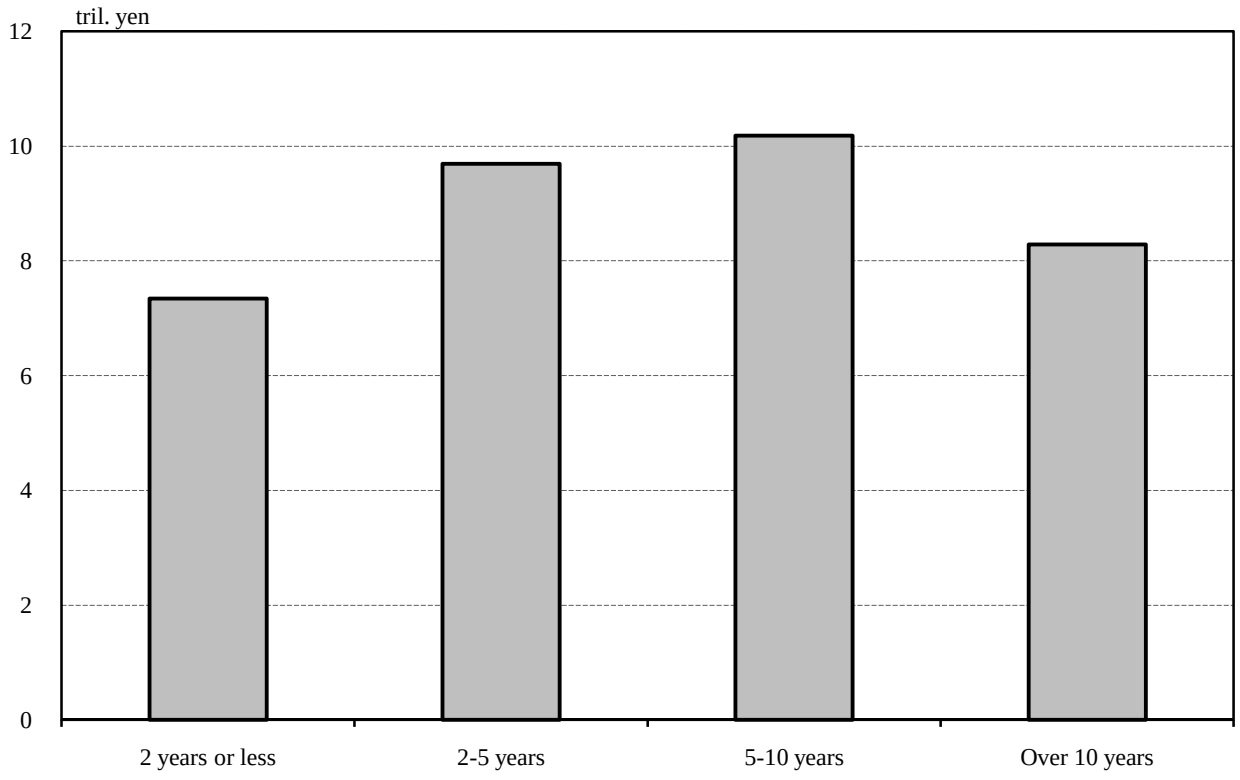
Depth Indicator:
Volume of Limit Orders
at the Best-ask (-bid) Price

Yensai



Depth Indicator:
Best-worst Quote Spread
(= Spread between the Best and the Worst Quotes Offered by Dealers)

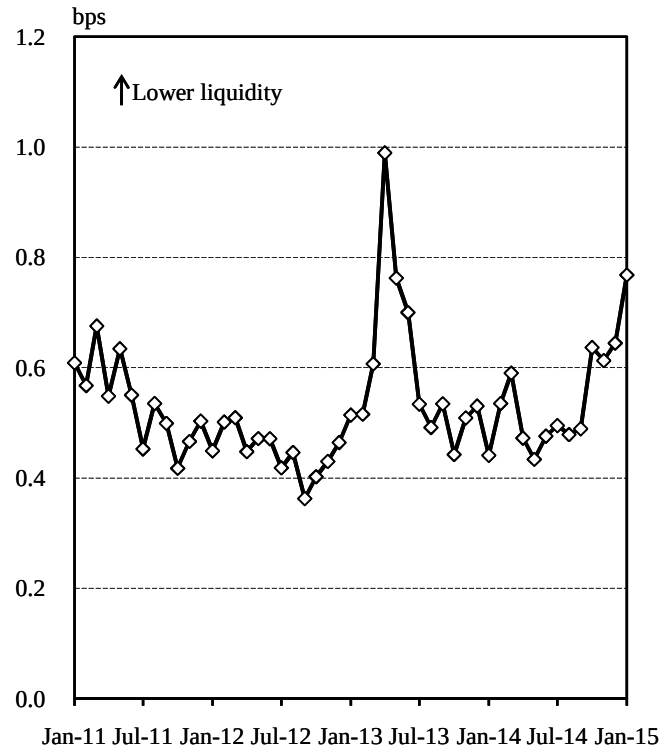
(2) Transaction Volume via Yensai (CY 2014, by Residual Maturity)



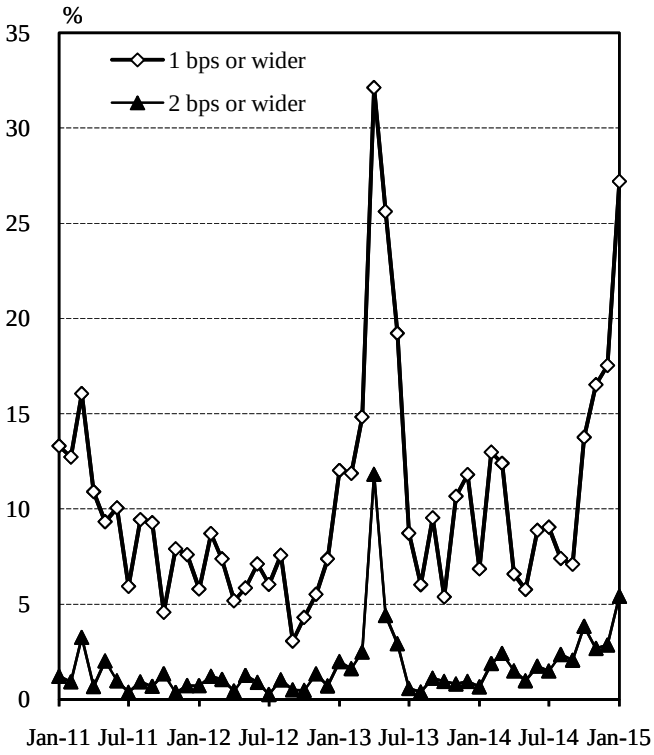
Note: Only transactions which had quote offers from five dealers are counted.
Source: Yensai.com.

Liquidity Indicators in the JGB Cash Market: Best-worst Quote Spreads (Depth)

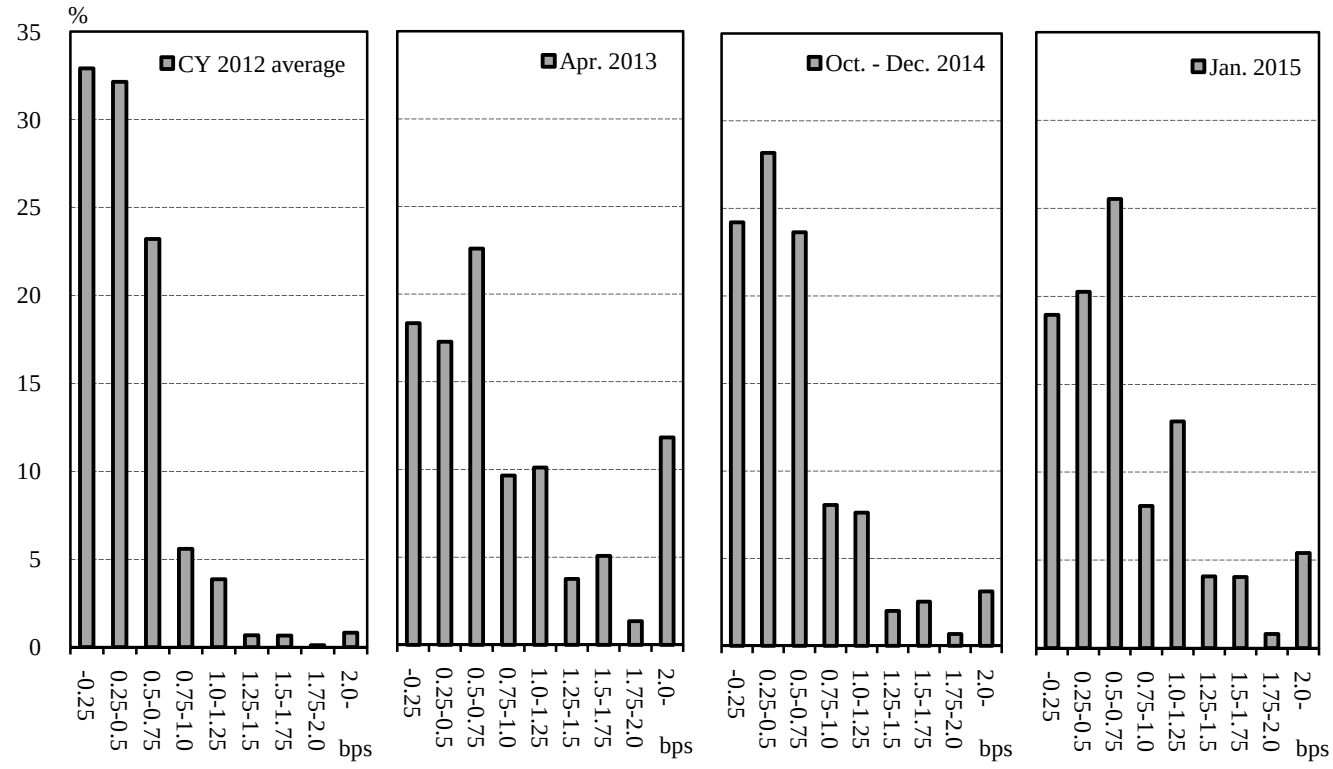
(1) Best-worst Quote Spreads (Average)



(2) Probability that the Best-worst Quote Spread is 1 bps (2 bps) or wider



(3) Histogram of Best-worst Quote Spreads

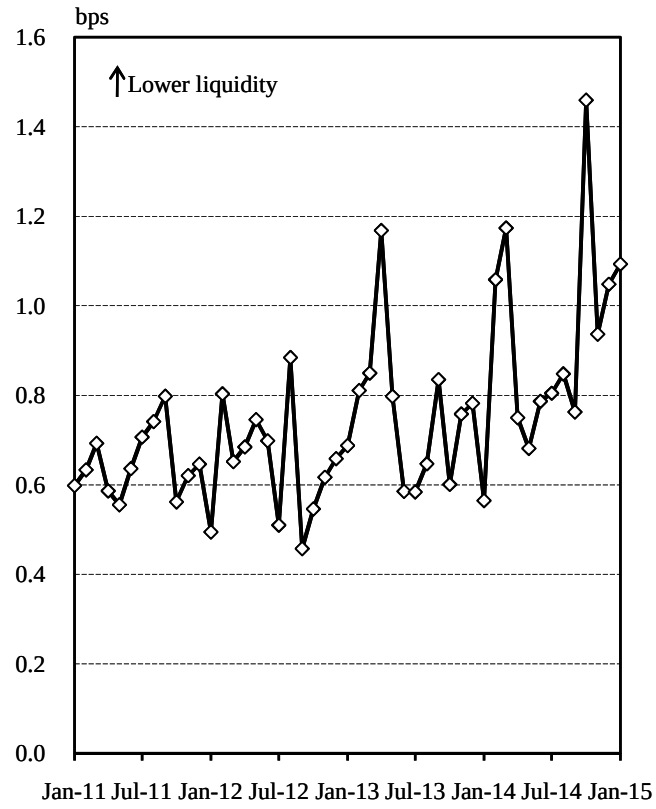


Note: A portion of transactions with the spread wider than 10 bps is excluded from the calculation.
As for figures (1) and (2), the latest data are as of January 2015.

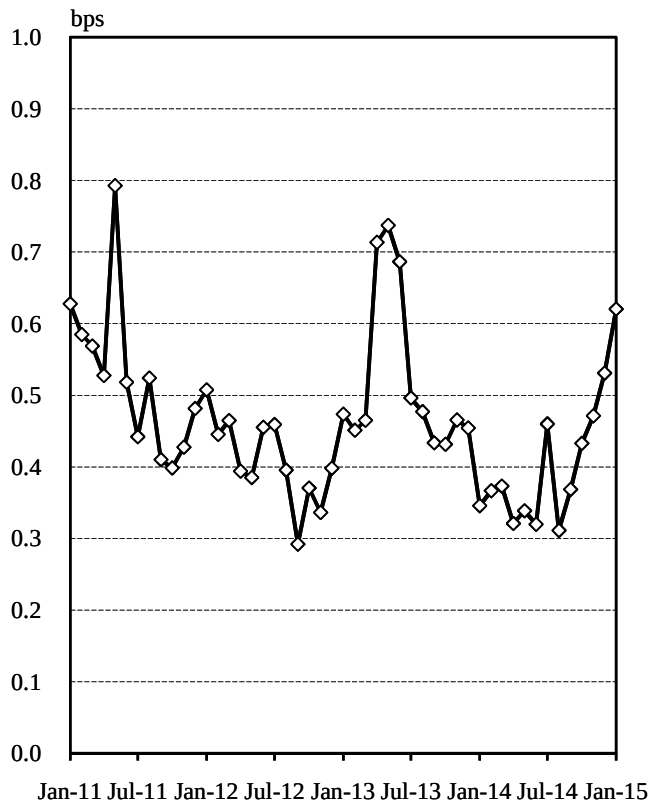
Source: Yensai.com.

Best-worst Quote Spreads (by Residual Maturity)

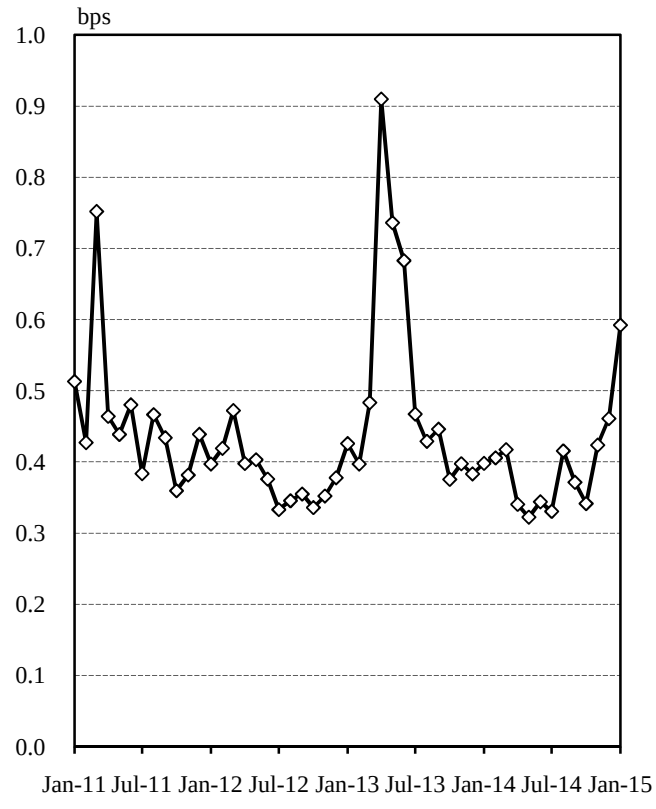
(1) Short-term (2 years or less)



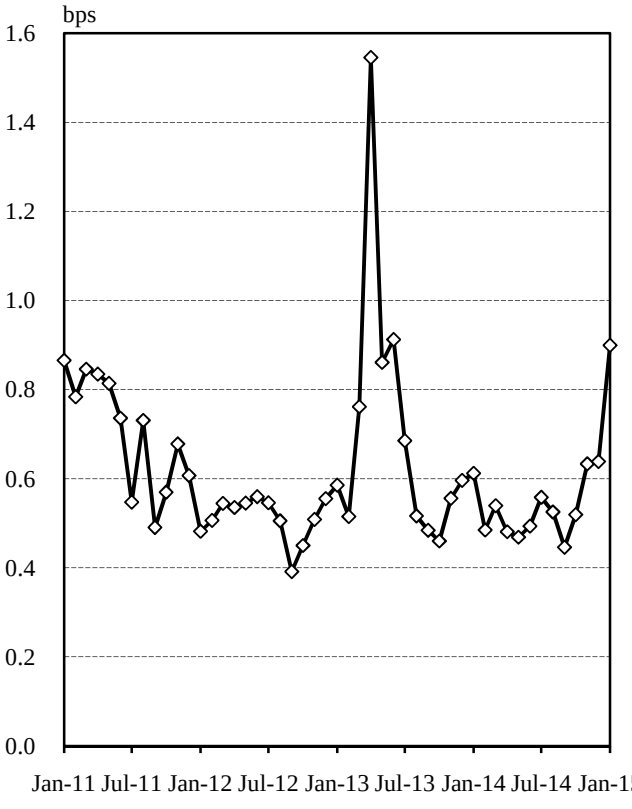
(2) Medium-term (2-5 years)



(3) Long-term (5-10 years)



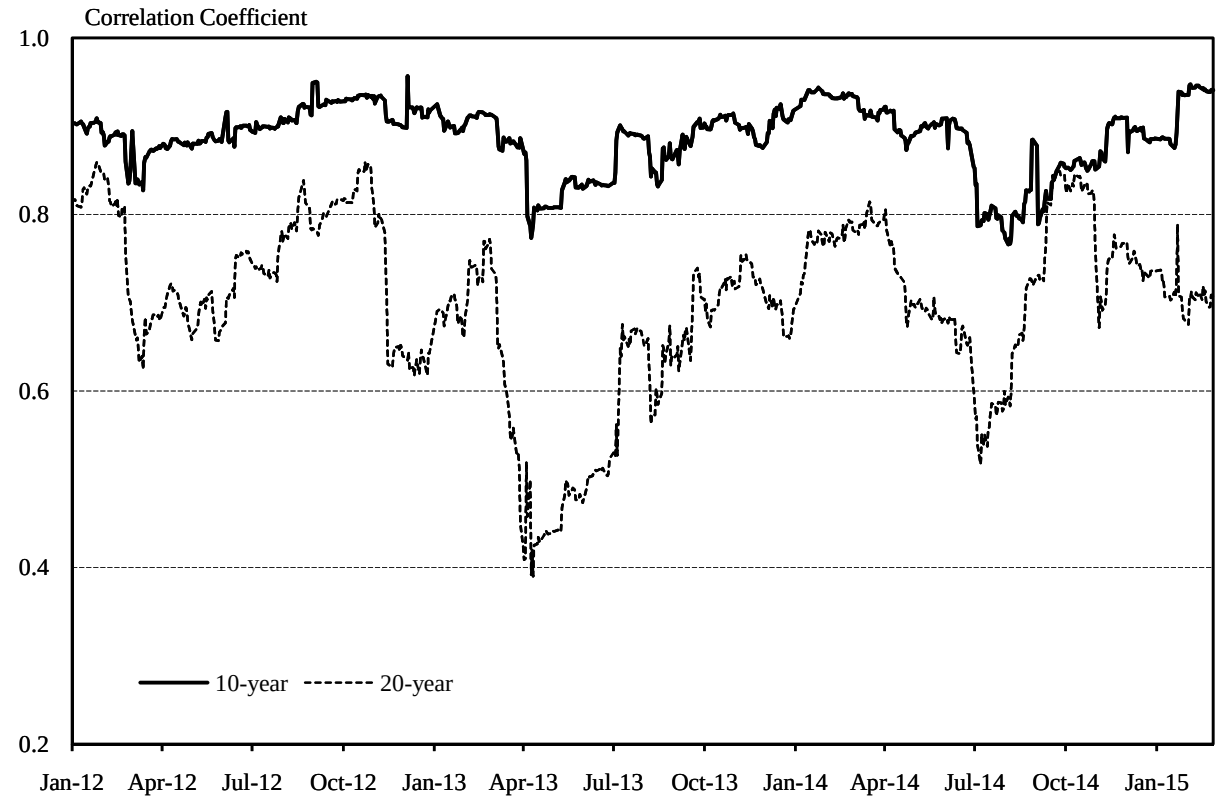
(4) Super-long-term (over 10 years)



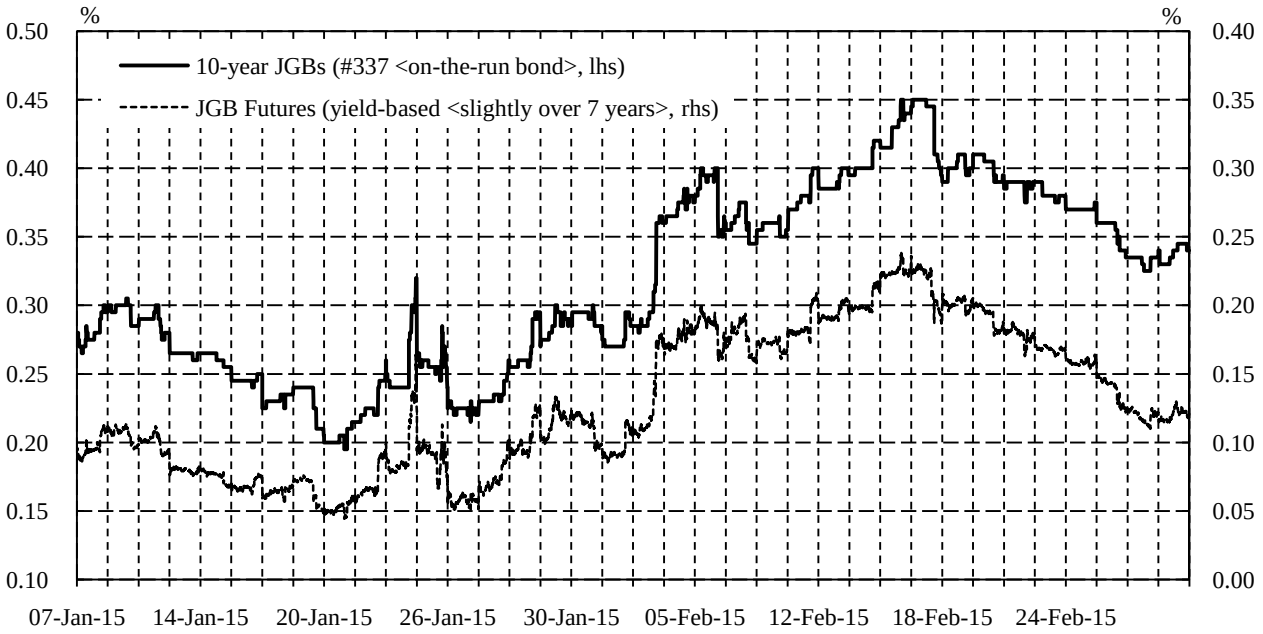
Note: A portion of transactions with the spread wider than 10 bps is excluded from the calculation. The latest data are as of January 2015.
Source: Yensai.com.

Correlation between JGBs and JGB Futures

(1) Daily Correlation Coefficients of Yields between JGBs and JGB Futures



(2) Intraday Yields of JGBs and JGB Futures with a 1-minute Frequency



Notes: 1. The latest data are as of end-February 2015.

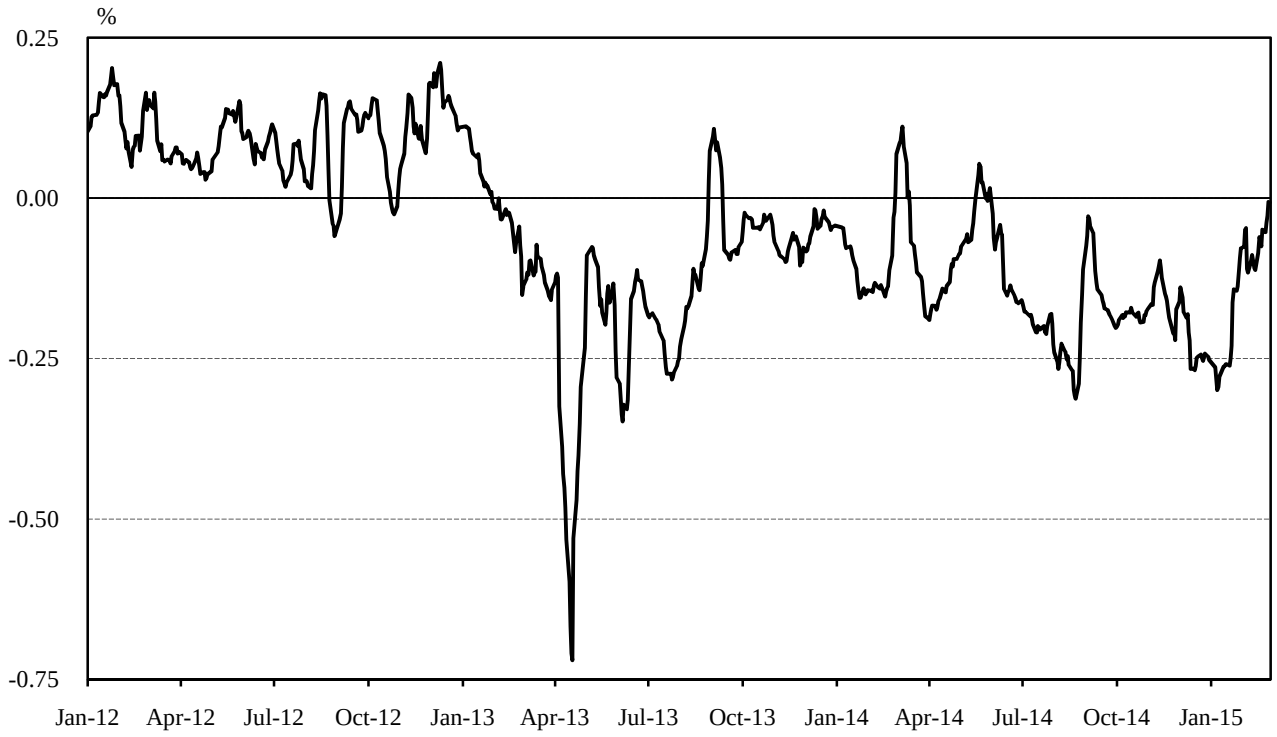
2. 10-year JGB yields are based on execution prices on the Japan Bond Trading. JGB futures yields are estimated by converting JGB futures' price in line with the coupon and the residual maturity (slightly over 7 years) of the cheapest-to-deliver bonds.

3. As for figure (1), correlation coefficients are calculated for daily change of yields with a 60 business-day rolling window.

Sources: Bloomberg; QUICK.

(Chart 13)

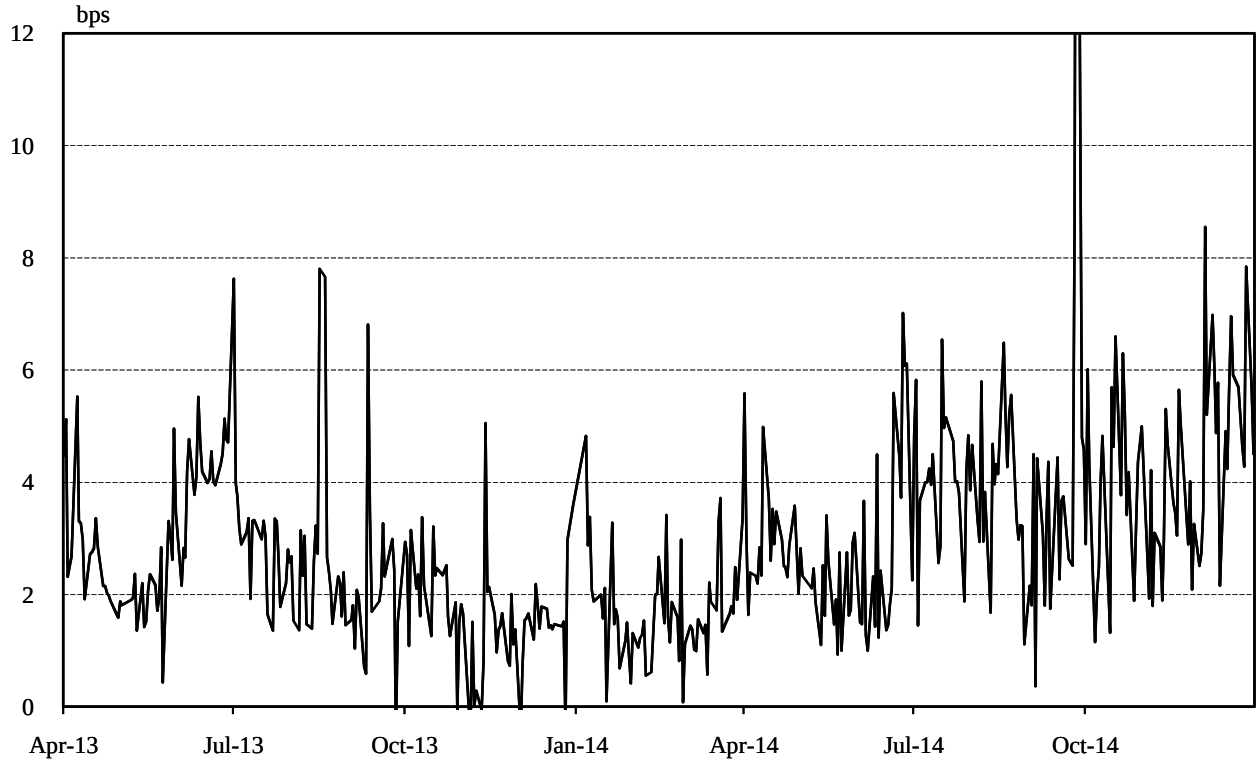
Implied Repo Rate for the Cheapest-to-deliver Bond and JGB Futures



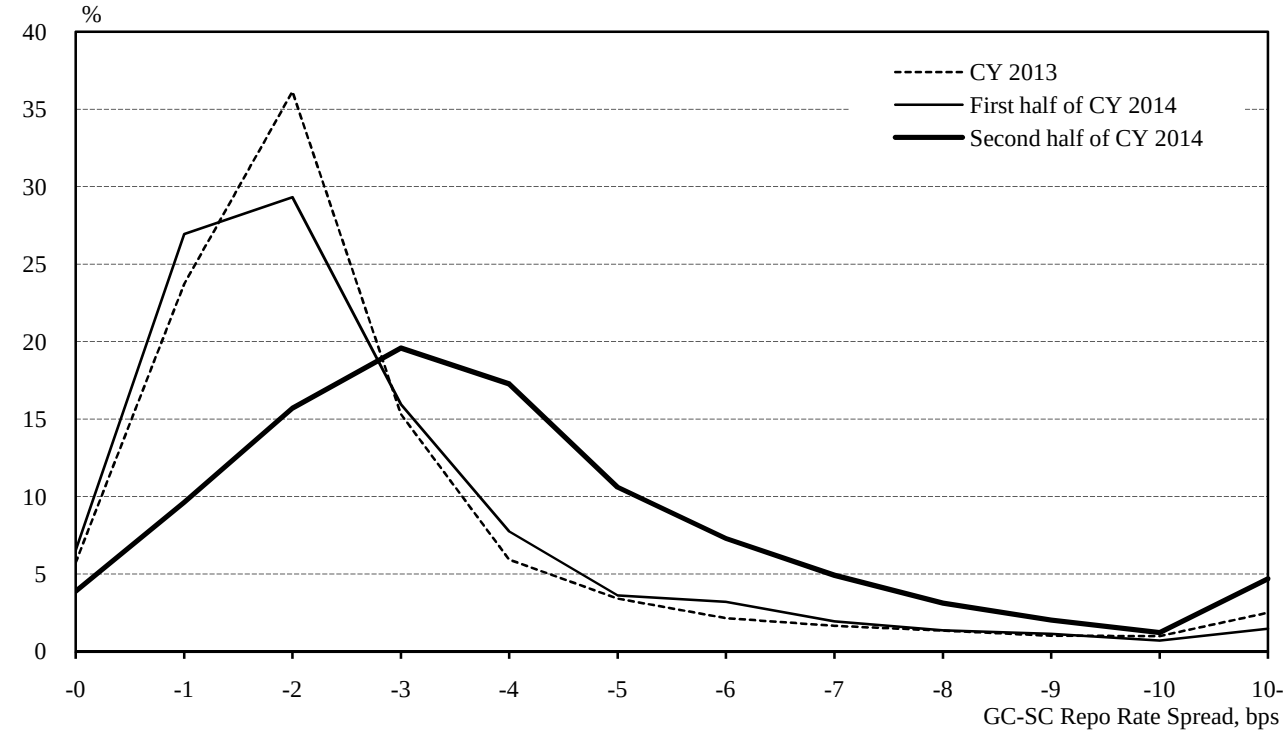
Note: Estimations are based on closing prices on the Japan Bond Trading. 10-day backward moving average.
The latest data are as of end-February 2015.
Sources: Bloomberg; Thomson Reuters.

SC Repo Market

(1) GC-SC Repo Rate Spreads (Simple Average of All the Traded Issues)



(2) Histogram of GC-SC Repo Rate Spreads



Notes: 1. As for figure (1), the latest data are as of end-December 2014.
2. Figure (2) illustrates the average of appearance frequencies on each business day for each calculation period. CY 2013 is the average of April to December 2013.

Sources: Japan Securities Dealers Association; JBond Totan Securities.

(Chart 15)

Ranking of JGB Market Special Participants by Total Purchasing Amount of Long-term JGBs

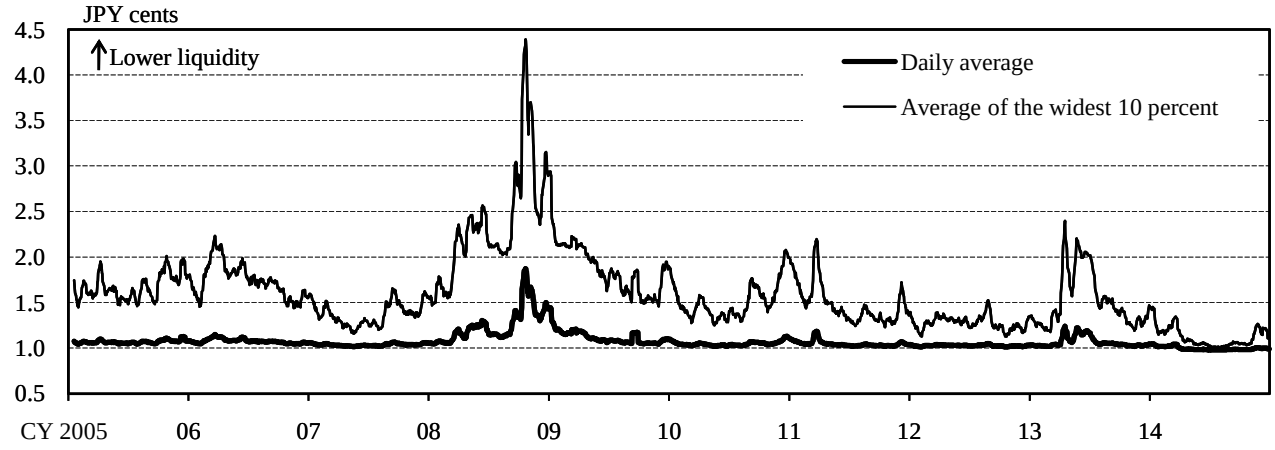
	Jan. - June 2011	July - Dec. 2012	Jan. - June 2012	July - Dec. 2012	Jan. - June 2013	July - Dec. 2013	Jan. - June 2014	July - Dec. 2014
1	Deutsche Securities	Mitsubishi UFJ Morgan Stanley Securities	Mitsubishi UFJ Morgan Stanley Securities	Mizuho Securities	Nomura Securities	Mizuho Securities	Nomura Securities	Mitsubishi UFJ Morgan Stanley Securities
2	Nomura Securities	Barclays Capital Japan	Goldman Sachs Securities	Mitsubishi UFJ Morgan Stanley Securities	Barclays Securities Japan	Nomura Securities	Daiwa Securities	Daiwa Securities
3	Mizuho Securities	Nomura Securities	The Bank of Tokyo-Mitsubishi UFJ	The Bank of Tokyo-Mitsubishi UFJ	Daiwa Securities	Merrill Lynch Japan Securities	Mitsubishi UFJ Morgan Stanley Securities	Nomura Securities
4	Barclays Capital Japan	JPMorgan Securities Japan	Barclays Securities Japan	Daiwa Securities	Mitsubishi UFJ Morgan Stanley Securities	Mizuho Bank	The Bank of Tokyo-Mitsubishi UFJ	Mizuho Bank
5	RBS Securities Japan	Credit Suisse Securities (Japan)	Deutsche Securities	Barclays Securities Japan	Mizuho Securities	Daiwa Securities	Merrill Lynch Japan Securities	Mizuho Securities
6	Goldman Sachs Securities	SMBC Nikko Securities	JPMorgan Securities Japan	Deutsche Securities	The Bank of Tokyo-Mitsubishi UFJ	Mitsubishi UFJ Morgan Stanley Securities	Mizuho Securities	BNP Paribas Securities (Japan)
7	Mitsubishi UFJ Morgan Stanley Securities	Deutsche Securities	Nomura Securities	SMBC Nikko Securities	SMBC Nikko Securities	SMBC Nikko Securities	SMBC Nikko Securities	Merrill Lynch Japan Securities
8	SMBC Nikko Securities	Mizuho Securities	Merrill Lynch Japan Securities	Nomura Securities	Goldman Sachs Securities	The Bank of Tokyo-Mitsubishi UFJ	Mizuho Bank	SMBC Nikko Securities
9	JPMorgan Securities Japan	RBS Securities Japan	Credit Suisse Securities (Japan)	JPMorgan Securities Japan	JPMorgan Securities Japan	Barclays Securities Japan	BNP Paribas Securities (Japan)	Morgan Stanley MUFG Securities
10	BNP Paribas Securities (Japan)	Citigroup Global Markets Japan	Mizuho Securities	RBS Securities Japan	Merrill Lynch Japan Securities	JPMorgan Securities Japan	Goldman Sachs Securities	JPMorgan Securities Japan

Note: "Long-term JGBs" are 10-year government bonds, including 10-year inflation-indexed bonds.
So-called "foreign securities companies" are shaded.
Source: Ministry of Finance.

(Appendix Chart 1)

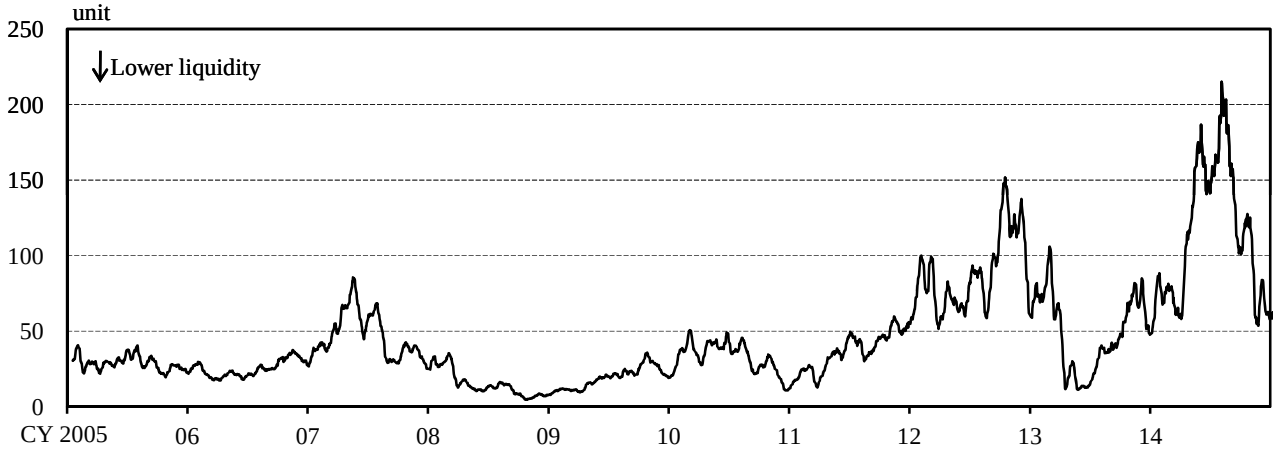
Liquidity Indicators in the JGB Futures Market (Long-term Time-series)

(1) Bid-ask Spreads



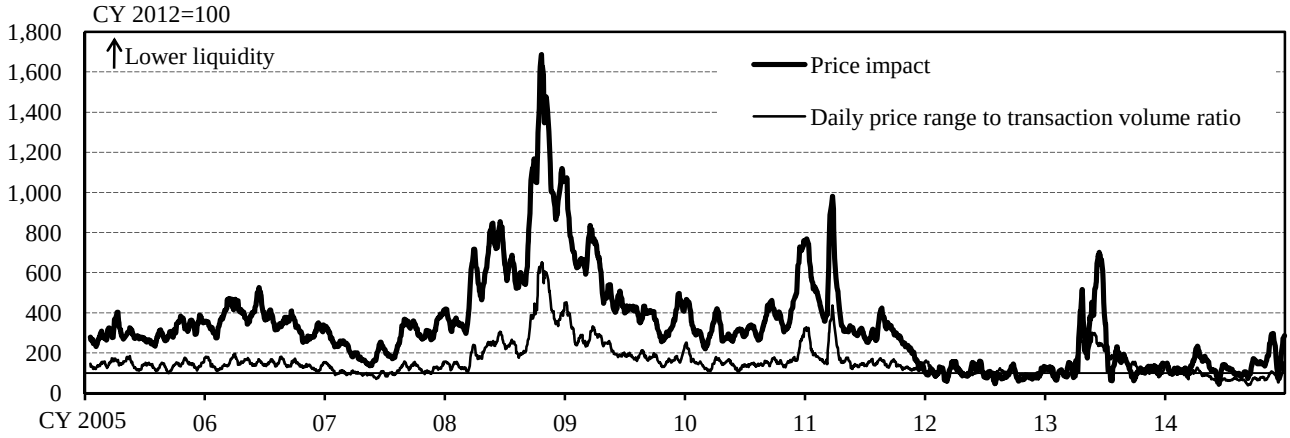
Notes: 1. The latest data are as of end-December 2014.
2. "Daily average" is the average of the bid-ask spread data with a 1-minute frequency within each business day. "Average of the widest 10 percent" is the average of the widest 10 percent of that data. A 10-day backward moving average is then applied to both time-series.

(2) Volume of Limit Orders at the Best-ask Price



Note: Figures are calculated by taking the median of the volume of limit orders at the best-ask price with a 1-minute frequency within each business day, and then applying a 10-day backward moving average. The latest data are as of end-December 2014.

(3) Price Impact



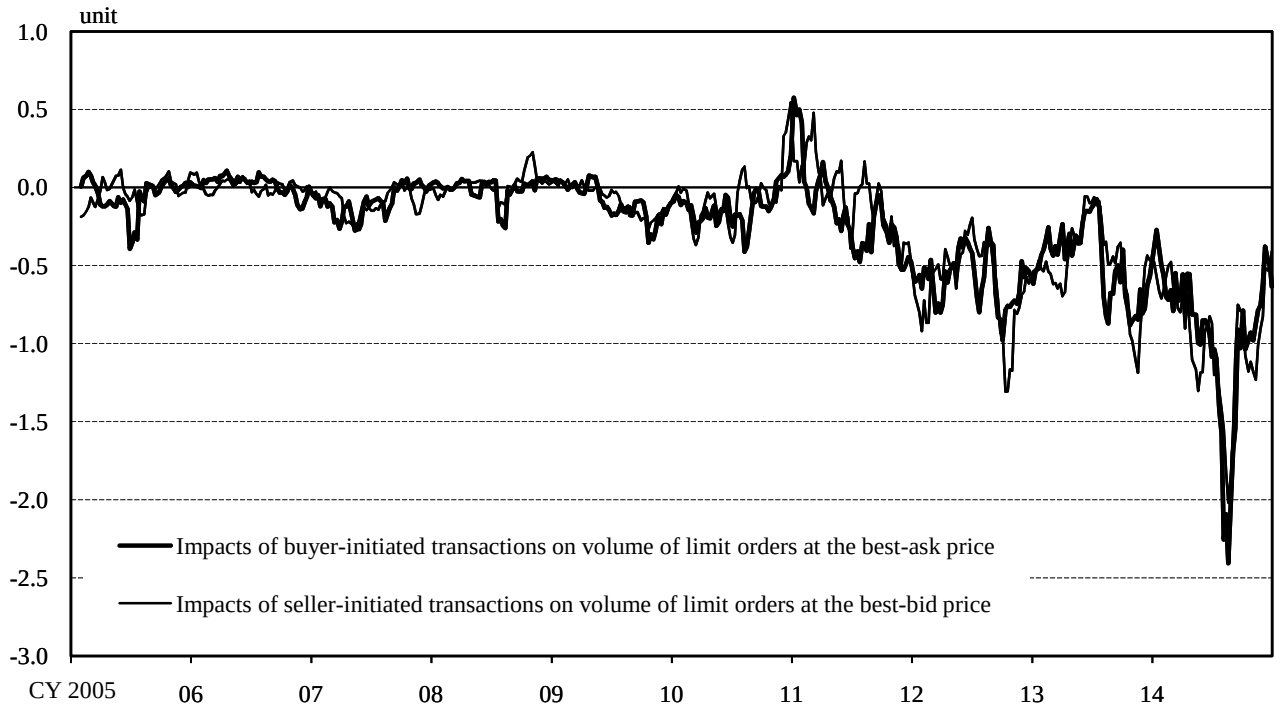
Note: "Price impact" is calculated by taking the average of each business day. A 10-day backward moving average is then applied to both time-series. The latest data are as of end-December 2014.

Source: Nikkei NEEDS.

(Appendix Chart 2)

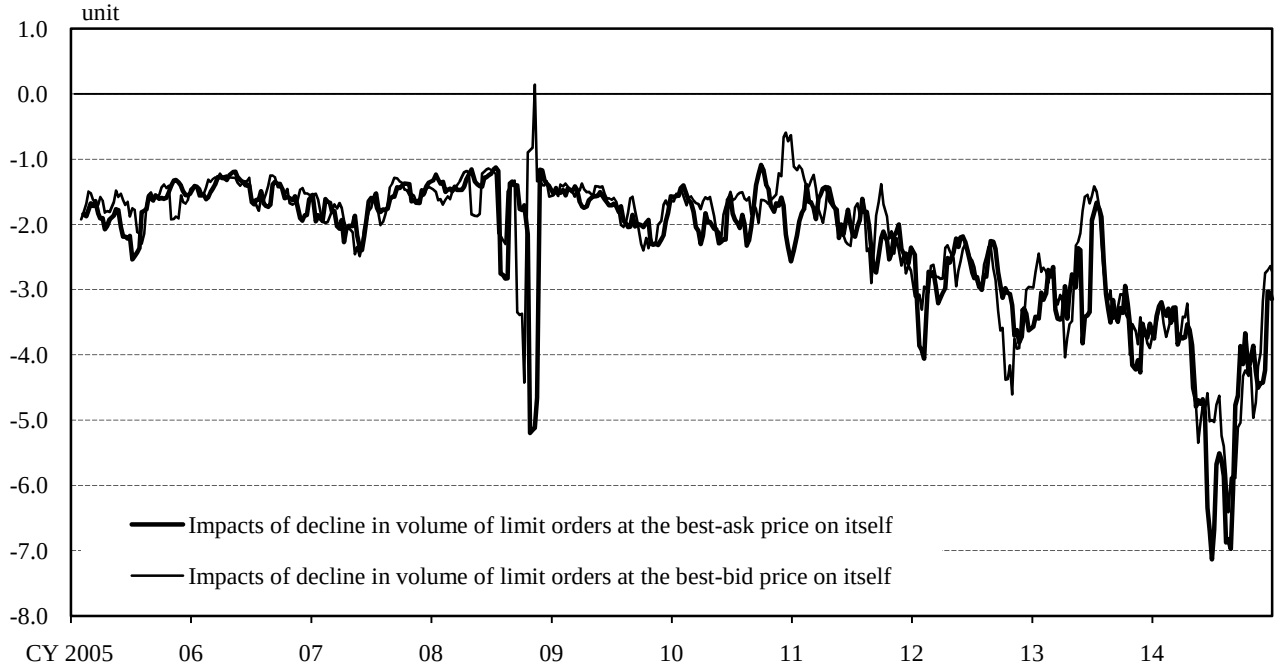
Resiliency of Volume of Limit Orders at the Best-ask (-bid) Price

(1) Impacts of Buyer-initiated (Seller-initiated) Transactions on Volume of Limit Orders at the Best-ask (-bid) Price



Notes: 1. 4-week backward moving average. The latest data are as of end-December 2014. Refer to appendix for the formulation of VAR.
2. 1-hour cumulative impulse responses of volume of limit orders at the best-ask (-bid) price to a positive 1-unit shock to a buyer-initiated (seller-initiated) transaction.

(2) Impacts of Decline in Volume of Limit Orders at the Best-ask (-bid) Price



Notes: 1. 4-week backward moving average. The latest data are as of end-December 2014. Refer to appendix for the formulation of VAR.
2. 1-hour cumulative impulse responses of volume of limit orders at the best-ask (-bid) price to a negative 1-unit shock to itself.

Source: Nikkei NEEDS.