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An Evaluation from Detailed Transaction Data

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Abstract

The Bank of Japan releases "Liquidity Indicators in the JGB Markets" consisting of several indicators each quarter, as part of monitoring liquidity in the JGB markets. In particular, for the JGB futures market, the Bank examines in detail market liquidity including liquidity during the day by creating indicators based on individual transaction data called detailed transaction data.

In this study, we attempt to expand liquidity indicators for the JGB cash market since it is increasingly necessary to grasp liquidity in the JGB markets in more detail. Specifically, by utilizing newly acquired detailed transaction data of inter-dealer transactions, we compiled some indicators that enable us to get a grasp of intraday market liquidity of all JGB issues.

Examining new liquidity indicators suggests that, as a whole, indicators have gradually improved since the fall of 2016, after considerably worsening at the beginning of 2016. Considering price and volume of orders, this suggests that it is easier to trade now than it was following the introduction of "QQE with a Negative Interest Rate." However, we must continue to pay attention to future development of market liquidity because transaction volume has not increased while some indicators have improved. In addition, we find that improvement of short-term and off-the-run bonds is relatively delayed and

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observe situations where market liquidity temporarily worsens within a day. These points are consistent with market participants' views.

Based on the above consideration, it is useful to examine liquidity in the JGB markets, using the newly compiled indicators in this paper. Since market liquidity cannot be grasped by quantitative indicators alone, it is important to continue to check market liquidity from a multifaceted perspective such as by capturing the viewpoint of market participants through surveys, meetings, etc.

1. Introduction

Interest in liquidity in government bond markets continues to rise at home and abroad. Strengthening of financial regulations after the Lehmann crisis, increasing presence of High Frequency Trading, and unconventional monetary policies by major central banks in advanced countries—especially the purchase of government bonds—may have effects on liquidity in the government bond markets. Especially, in Japan, it is heard that the Bank of Japan purchases massive amounts of government bonds, which affects the liquidity in the JGB markets.

Against this background, the Bank of Japan examines the liquidity in the JGB markets from a broader range of perspectives by utilizing both qualitative and quantitative information, such as comments heard at meetings and survey results from market participants, as well as liquidity indicators compiled with individual transaction data. Regarding liquidity indicators which have started to release from August 2015, it is characterized that these indicators include not only indicators for the JGB futures market (which was often taken up in past research) but also those for the JGB cash market, which had few prior studies even overseas because of data limitation. At that time, we focused on the relatively stagnant dealer-to-client transactions and compiled some indicators for dealer-to-client transactions in the JGB cash market.[1]

To expand existing liquidity indicators, the Bank of Japan decided to compile new indicators of inter-dealer transactions in the JGB cash market with newly acquired data. For two primary reasons, the need to finely grasp liquidity in the JGB markets is increasing, particularly within the JGB cash market (dealer-to-client transactions and inter-dealer transactions). First, the Bank of Japan is purchasing massive amounts of cash JGBs after the introduction of "Quantitative and Qualitative Monetary Easing (QQE)" in April 2013. In September 2016, the Bank introduced a new framework, "QQE with Yield Curve Control," and now operates purchase of cash JGBs to control

[1] Transactions of cash JGBs can be roughly divided into inter-dealer, dealer-to-client, and government bidding/purchase under the Bank of Japan market operation.

yield curve. As a result, the Bank holds over 40% of all JGB issuances (Chart 1). Therefore, it is important to grasp in more detail the situation of liquidity in the JGB cash market, specifically where the Bank is purchasing JGBs under monetary operation.

Second, interest in liquidity and functioning of the JGB cash market by market participants is rising. For example, results from Bond Market Survey on the JGB cash market reveal a considerably large portion of responses claiming that market function is "low" (Chart 2). In addition, in Bond Market Group meetings, opinions on difficulty of transactions were expressed, especially concerning the difference in liquidity by issue. For this reason, it is important to compile liquidity indicators in the JGB cash market and to examine whether evaluation of market participants can be explained with objective data. However, it is necessary to understand the fact that market participants' ways of seeing and feeling do not always appear in indicators. For example, Bond Market Group meetings point out the influence of low volatility environment on trading revenues, the decrease of market participants, the deterioration in price discovery function, and the concern of future changes in the market environment. It is considered that these points are difficult to be grasped even with new liquidity indicators.

The structure of this paper is as follows: Section 2 briefly presents initiatives by the Bank of Japan to capture the situation of liquidity in the JGB markets; Section 3 explains the details of newly acquired data, and then examines the situation of liquidity in the JGB cash market after the fall of 2015 with new liquidity indicators compiled by this data; Section 4 concludes with a summary of this paper. The appendix presents our attempt to quantitatively capture the situation of large amount transactions, which is one aspect of market liquidity.

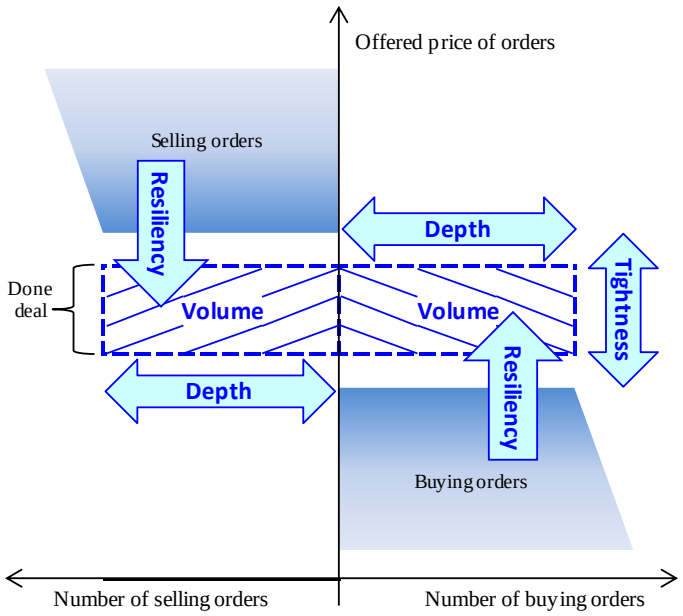
2. Grasping market liquidity in the JGB cash market — Initiatives thus far

The situation of high market liquidity is thought as one in which "market participants are able to smoothly buy and sell their intended amount at a price close to the market price," or "purchases and sales by each market participant have little impact on the market price." The definition of "market liquidity" is not necessarily uniform and its

quantitative measurement is not simple.[2] Therefore, the Bank of Japan is trying to capture market liquidity from a broader range of perspectives by utilizing liquidity indicators, market surveys and dialogues with market participants, while remaining conscious of several limitations about definition and measurement of market liquidity.

A. Liquidity indicators in the JGB markets[3]

The Bank of Japan has been releasing "Liquidity Indicators in the JGB Markets" each quarter since August 2015. In compiling liquidity indicators, we focus on four evaluation axes: volume, tightness, depth, and resiliency.[4] These four evaluation axes are visually captured as shown in the below chart.



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

[2] Concerning definition discrepancies and measurement of market liquidity, see Nishizaki, Tsuchikawa, and Yagi (2013) and Kurosaki *et al*. (2015).

[3] http://www.boj.or.jp/en/paym/bond/index.htm/

[4] Measurement from a multiple evaluation axes is also proposed in Kyle (1985), which is a classic study on market liquidity.

- Volume: Frequent transactions and large amount transactions become easier with larger transaction volume.
- Tightness: The narrower the price range (the spread between selling and buying prices) is, the traders can execute transactions at a price closer to their intended prices, resulting in a smaller transaction cost.
- Depth: The deeper the market (larger volume of orders at the current price level) is, the smaller the difference between the investors' intended prices and the actual prices. Prices do not easily change even with large amount transactions.
- Resiliency: The more resilient the market (the speed at which prices revert to the equilibrium prices when there are shocks to prices) is, the more smoothly and rapidly traders can execute transactions, therefore less impact on prices.

Regarding the JGB futures market, we grasped market liquidity in detail by compiling indicators with individual transaction data of JGB futures listed on the Osaka Exchange from the viewpoint of the four evaluation axes mentioned above.[5] Here, individual transaction data of the JGB futures market specifically indicate (1) quotation and volume of bid-ask data per minute and (2) price and volume of transaction data per transaction. Characteristically, such high frequency and granular data (sometimes called detailed transaction data) have much more information than data with only one point per day or aggregate data. On the other hand, regarding the JGB cash market, there are limitations in obtaining such detailed transaction data because most transactions of cash JGBs are bilateral among market participants. Therefore, by using daily and monthly data, we worked on compiling indicators related to volume, tightness, and depth for dealer-to-client transactions of cash JGBs in addition to an indicator related to volume for inter-dealer transactions of cash JGBs. Then we released them in "Liquidity Indicators in the JGB Markets" (Chart 3).

[5] Tick data provided by Nikkei NEEDS.

B. "Bond Market Survey" and "Bond Market Group" meetings[6]

The Bank of Japan introduced the quarterly Bond Market Survey in February 2015 to continuously understand market participants' views on the functioning of the bond market and outlook of long-term interest rates. In addition, the Bank has held Bond Market Group meetings twice per year since June 2015 to enhance dialogue with market participants in reference to the survey results.

Regarding Bond Market Survey, major institutional investors were added to eligible institutions for the Bank's outright purchases and sales of JGBs in February 2018. As a result, we are able to capture a wider coverage of market participants. Bond Market Group meetings are divided into relatively small groups for conducting detailed dialogue with market participants. The discussions at the meetings were lively, and following comments were heard at December 2017 meeting: "It has become difficult to deal off-the-run bonds," and "number and volume of bidding and offering have decreased recently," and "there is a movement to make dealing lots for transactions smaller beforehand in order to trade smoothly." These voices suggest that there are rising interests in liquidity of the JGB cash market for market participants. The existing liquidity indicators cannot fully capture liquidity of all JGB issues and situation of large amount transactions as mentioned at the meeting.

3. Expansion of liquidity indicators in the JGB cash market ― Recent situation of market liquidity

Although the Bank of Japan tried to grasp liquidity in the JGB markets from a broader range of perspectives, compilation of liquidity indicators in the JGB cash market is not enough due to difficulty of obtaining detailed transaction data. Some indicators of dealer-to-client transactions are compiled from daily and monthly data, but it is not possible to comprehend situations in intraday market liquidity in detail. Furthermore, it is difficult to construct indicators of inter-dealer transactions other than transaction

[6] http://www.boj.or.jp/en/paym/bond/index.htm/

volume.

Hence, we decided to acquire tick data from the Japan Bond Trading, the largest company for intermediation of inter-dealer transactions, and expand liquidity indicators of inter-dealer transactions in the JGB cash market. In this section, we compile new liquidity indicators related to tightness, depth, and resiliency on the basis of detailed transaction data of inter-dealer transactions. Then, adding them to current indicators related to volume, we can examine situations about market liquidity of inter-dealer transactions in the JGB cash market using the four evaluation axes. These indicators allow us to capture market liquidity in more detail, i.e., liquidity in intraday market and of all JGB issues. In addition, we expect to evaluate some comments voiced at Bond Market Group meetings based on the indicators compiled with objective data.[7]

A. Details of newly acquired detailed transaction data

The Bank of Japan compiled new liquidity indicators by using tick data provided by the Japan Bond Trading, such as that of bonds traded and/or ordered at the electric trading system.[8,9] Tick data acquired from the Japan Bond Trading consists of information related to both (1) execution such as price and amount per transaction and (2) orders such as best-bid and best-ask prices presented during intraday—best prices presented by buyers and sellers—as well as the amount of these orders (we call this information detailed transaction data). In this study, we analyzed 2-year, 5-year, 10-year, 20-year, 30-year, and 40-year JGBs; Further, we took into consideration seven hours per day (morning session from 8:40 to 11:05 and afternoon session from 12:25 to 17:00).[10]

[7] Liquidity indicators for dealer-to-client transactions in the JGB cash market are not covered in this paper, but the Bank of Japan expanded coverage of respondents of the Bond Market Survey from the survey in February 2018, intending to capture clients' views of how well the bond market functions.

[8] The Japan Bond Trading is providing electric trading system, BB Super Trade, and intermediating inter-dealer transaction of mostly domestic bonds such as cash JGBs.

[9] In the past, the Bank of Japan acquired data (from April 2002 to September 2003) and analyzed the JGB cash market in terms of mainly bid-ask spreads. For details, see Inamura *et al.* (2004).

[10] There are about 300 issues of cash JGBs as at January 2018.

B. Volume

Concerning volume in the JGB cash market, we release information for both dealer-to-client and inter-dealer transactions in the current "Liquidity Indicators in the JGB Markets." From the trend of inter-dealer transactions since 2016, we found that transaction volume remained close to the same level. The ratio of transactions of on-the-run bonds to total transactions seemed to gradually increase, and the fluctuation of transaction volume became somewhat larger than before (Chart 4 (1)). However, from the assessment of dealer-to-client transactions in the JGB cash market, transaction volume decreased primarily because of a decrease in transactions of long-term and medium-term bonds traded by domestic investors. The volume of transactions has remained generally flat since mid-2016 (Chart 4 (2)).

Recently, we have been able to examine the number of issues of cash JGBs traded with detailed transactional data, which amounted to 50–80 each day since the fall of 2015, and then decreased several times to less than 50 in the second half of 2017 (Chart 4 (3)).

C. Tightness

We release bid-ask spreads based on the data of dealer-to-client transactions of on-the-run bonds at 15:00 each day in the current "Liquidity Indicators in the JGB Markets" to understand tightness in the JGB cash market. These bid-ask spreads, once widened in the summer of 2016, gradually shrank from the fall of 2016, and were recently at the lowest level in the past five years (Chart 5).

In addition to the bid-ask spreads, we compiled new bid-ask spreads of inter-dealer transactions as an indicator to enable analysis of liquidity in intraday market by issue. Furthermore, we will compile a new indicator named total observation time of bid-ask spreads for inter-dealer transactions to complement bid-ask spreads, because, unlike in JGB futures transactions, there are time periods during which bid and/or ask prices are not submitted.

a. Bid-ask spread

The bid-ask spreads (average of the widest 10 percent) of both on-the-run and first off-the-run bonds were compiled with detailed transaction data of inter-dealer transactions.[11] Once they widened in the summer of 2016, then gradually shrank from the fall of 2016; however, recently they were the same or less compared to those in the latter half of 2015, similar to the development of bid-ask spreads of dealer-to-client transactions (Chart 6). This suggests that trading as a whole is easier now than during the last few years, considering the difference between prices submitted by sellers and buyers. Comments by market participants, such as "based on close communication between the Bank of Japan and market participants, predictability about future interest rates is high, and therefore trading is easy to do," support the evidence from Chart 6 (at Bond Market Group meeting held in December 2017). However, we must pay attention to the observation that there have been occasional events where bid-ask spreads have widened since the beginning of 2016 (depending on residual maturity or issue, e.g., 5-year first off-the-run bond).

b. Total observation time of bid-ask spreads

Regarding bid-ask spreads of inter-dealer transactions compiled and explained above, we first calculated spreads over each time period in which both bid and ask prices are submitted, and then filtered out 10 percent of the widest spreads and calculated the average. However, it should be noted that there are times when bid and/or ask prices are not submitted in inter-dealer transactions, differing from the fact that prices are submitted almost all the time in the JGB futures market, owing to the market-maker system. Thus, a reduction in bid-ask spreads does not necessarily mean an improvement of liquidity conditions, if bid and/or ask prices are not submitted. To compensate for this, we also compiled a new indicator of total observation time of bid-ask spreads in

[11] Average of the widest 10 percent is calculated by averaging the widest 10 percent of bid-ask spreads with a 1-second frequency. It is possible to compile an indicator with different levels of percentile and/or simple average.

addition to bid-ask spreads.

The indicator we call total observation time of bid-ask spreads indicates a length of hours when both bid and ask prices were submitted within a day (seven hours). First, the indicators of first off-the-run bonds are lower and the swing width of the indicators are larger compared with on-the-run bonds. Second, the indicators of both on-the-run bonds and first off-the-run bonds decreased considerably at the beginning of 2016, then gradually improved from during the fall of 2016 to the spring of 2017. However, long- and super-long-term first off-the-run bonds had some days in which there is not enough observation time of bid-ask spreads (Chart 7). These results coincide with voices from market participants (at Bond Market Group meeting held in December 2017) such that "with the increase of the proportion of the JGB amounts which the Bank of Japan holds, trading is difficult, especially for off-the-run issues," and "there are situations where neither bid nor ask prices are seen."

D. Depth

As for measuring depth in the JGB cash market, we release best-worst quote spreads (monthly basis) in the current "Liquidity Indicators in the JGB Markets."[12] The spread greatly expanded at the beginning of 2016, meaning that market liquidity decreased, then it gradually shrank, and recently fell below the level which was in the latter half of 2015 (Chart 8).

In addition to best-worst quote spreads, we compiled two new indicators for inter-dealer transactions with detailed transaction data. The volume of orders at the best-ask (best-bid) price enables us to capture liquidity in intraday market by issue, and the ratio of issues by total observation time of the best-ask (best-bid) price represents how orders are submitted.

[12] The best-worst quote spread was calculated by averaging the spreads between the best and the worst quotes offered by dealers against each client request. This spread is close to the measure of market depth, in the sense that a tight best-worst quote spread means that a client has many dealers to make transactions at a price level near the best quote.

a. Volume of orders at the best-ask (best-bid) price

The indicator we call volume of orders at the best-ask (best-bid) price in inter-dealer transactions greatly decreased at the beginning of 2016, meaning that market liquidity decreased, then has gradually increased since fall 2016, similar to best-worst quote spreads in dealer-to-client transactions[13] (Chart 8). This suggests that trading as a whole is easier for dealers now than the last few years, reflecting that prospects for interest rates among market participants have converged since around the fall of 2016, consistent with the development of bid-ask spreads. However, we note that the volume of orders at the best-ask (best-bid) price does not recover to the level in the beginning of 2016, differing from best-worst quote spreads (monthly basis). By examining the volume of orders at the best-ask price in more detail, in terms of residual maturity per issue, we see that volumes of super-long-term bonds are recovering while short-term bonds and 10-year off-the-run bonds have a low degree of recovery (Chart 9). It is also noted that the volume of orders at the best-ask price is calculated by summing up all issues and therefore is not directly related to the ease of large amount transactions (see an appendix for the discussion of large amount transactions).

b. Ratio of issues by total observation time of best-ask (best-bid) price

The volume of orders at the best-ask (best-bid) price shows market depth from the size of the order amount traded at the best price. Here, we tried to capture depth in the JGB cash market based on the number of issues with a lengthy observation time of the best-ask (best-bid) price. Specifically, we compiled a new indicator of ratio of issues by total observation time of the best-ask (best-bid) price, capturing the percentage of issues according to the length of time that the best-ask (best-bid) price is submitted. For example, if the ratio of issues with a lengthy observation time of the best-ask (best-bid) price is high in short-term maturity, prices of other issues with short maturities are unlikely to be affected even when supply and demand conditions for a certain issue in

[13] The volume of orders at the best-ask (best-bid) price is calculated by summing up the median of volume at the best-ask (best-bid) price with a 1-second frequency per issue.

short-term maturity tightens. We can consider this as an indicator for market depth.

First, looking at the ratio of issues by total observation time of the best-ask price, we find that the proportion of issues whose prices were submitted for more than six hours per day (less than one hour) drastically decreased (increased) at the beginning of 2016, then gradually increased (decreased) from the fall of 2016. Recently, the proportion improved (declined) to the level it was at the beginning of 2016. Next, concerning the ratio of issues by total observation time of the best-bid price, we found that it is similar to the best-ask price, but the degree of improvement of the best-bid price has been smaller than that of the best-ask price since around fall 2016 (Chart 10).

Thus, we observed the ratio of issues by total observation time of the best-bid price by residual maturity. We found that indicators for super-long-term maturity are recovering, while the indicator of more than six hours for short-term maturity is just slightly recovering and the indicator of less than one hour for short-term maturity is still high. This suggests a possibility that if large amount transactions of a certain bond in short-term maturity are conducted, prices of other bonds in short-term maturity are affected (Chart 11).

E. Resiliency

We are not releasing indicators related to resiliency in the JGB cash market in the current "Liquidity Indicators in the JGB Markets." However, for on-the-run bonds in inter-dealer transactions, we observed daily price range to transaction volume ratio[14] (Chart 12). These indicators had large rises around the spring of 2016, and the indicator of 10-year on-the-run bond had a large increase in December 2017. However, this indicator was limited in that intraday developments cannot be grasped because it is not calculated with detailed transaction data but with only daily data.

[14] The daily price range to transaction volume ratio is defined as the daily price range (the difference between the highest and lowest transaction prices of the day) divided by the transaction volume within the day.

To overcome this limitation, there is an option to calculate price impact for inter-dealer transactions as Kurosaki *et al.* (2015) did for JGB futures transactions based on a concept of Fleming (2003). The price impact indicator needs information related to execution such as transaction volume, but it is possible to miss out on information about execution regarding the JGB cash market, depending on a specific date and/or time slot. The variation of transaction volume in the JGB cash market tends to be larger than the JGB futures market.

This paper references to Cont, Kukanov, and Stoikov (2014) in that price impact indicator—the influence of change per unit volume of orders on the market price—was compiled with information related to orders such as the best-bid and best-ask prices, and is frequently updated rather than information related to execution. Assuming that order flow imbalances (OFI) for the following equations, and we measure the impact per unit of OFI on the market price (in the JGB cash market) by dividing change width of the best-bid (best-ask) prices by OFI.[15]

$$OFI_n^b = q_n^b I_{[P_n^b \geq P_{n-1}^b]} - q_{n-1}^b I_{[P_n^b \leq P_{n-1}^b]},$$

$$OFI_n^a = q_{n-1}^a I_{[P_n^a \geq P_{n-1}^a]} - q_n^a I_{[P_n^a \leq P_{n-1}^a]},$$

$$\beta_n^b = \Delta P_n^b \left(= P_n^b - P_{n-1}^b\right) / OFI_n^b,$$

$$\beta_n^a = \Delta P_n^a (= P_n^a - P_{n-1}^a) / OFI_n^a,$$

$$\beta \ = \left(\sum_{n=1}^{N_b} \beta_n^b + \sum_{n=1}^{N_a} \beta_n^a\right) / (N_b + N_a).$$

Here, N_b is a number representing the best-bid price updated on a day, N_a is a number for the best-ask price updated on a day, $P_n{}^b$ is the best-bid price, $P_n{}^a$ is the best-ask price, $q_n{}^b$ is the volume at the best-bid price, $q_n{}^a$ is the volume at the best-ask price. *OFI* is

[15] Consider, for example, a case where market participants strongly want to purchase cash JGBs and a new bid order (volume, *q*) is submitted at a price (*P'*) higher than current best-bid price (*P*). In this case, OFI is *q*, the change width of the best-bid prices is (*P'*–*P*), and the price impact of this order becomes (*P'*–*P*)/*q*. For the price impact of the day, we first calculate all the price impacts of ask and bid orders of that day, and then average those price impacts.

order flow imbalances. $I_{[\,.\,]}$ is a function that is 1 if the condition in [ ] is satisfied and 0 otherwise.

The price impacts (β) of on-the-run bonds largely increased in the spring and summer of 2016, then fell from the fall of 2016, and recently were lower than the levels in the spring and summer of 2016, which is similar to indicators of daily price range to transaction volume ratio. The improvement of market resiliency indicates the market price is hard to move drastically even with large amount transactions. However, it also suggests that market liquidity in short-term maturity is still relatively low because indicators of first off-the-run bonds in short-term maturity continue to greatly fluctuate (Chart 13). In addition, a spike in the daily price range to transaction volume ratio for 10-year on-the-run bond in December 2017 was not observed in the price impact for the same bond. This may suggest that daily price range to transaction volume ratio spiked because transaction volume of 10-year on-the-run bond at that time was low, yet the price impact (β) complied with detailed transaction data did not spike because the volume of orders was higher.

We note the voices from market participants that "based on transaction volume at the market, investors and securities companies reduce the amount to a range that can be transacted smoothly" (at Bond Market Group meeting in December 2017). It is important to understand that this behavior of reducing the amount may have the indicator of the price impact (β) to improve (see an appendix for the discussion of large amount transactions).

4. Conclusion

This paper explained new market liquidity indicators for tightness, depth, and resiliency with detailed transaction data of inter-dealer transactions in the JGB cash market. These indicators greatly expand upon the current indicators in "Liquidity Indicators in the JGB Markets," because they can grasp intraday market liquidity of all JGB issues.

New liquidity indicators for inter-dealer transactions in the JGB cash market

considerably worsened at the beginning of 2016, and then have gradually improved since the fall of 2016, as confirmed in section 3. This development is similar to indicators for the JGB futures market and dealer-to-client transactions in the JGB cash market.

Observations about the JGB cash market suggested that, from the perspective of bid-ask spreads and volume of orders, we are in a better environment for trading than after the introduction of negative interest rate policy. These bid-ask spreads and volume of orders improve as prospects of market participants' interest rates converge under QQE with Yield Curve Control.

We must pay attention that such improvement of liquidity indicators is not accompanied by an increase in transaction volume. There is no major obstacle in executing each transaction when needs for transactions are relatively small, while it is possible that stabled liquidity indicators, such as bid-ask spreads and volume of orders, will deteriorate or destabilize if needs for transactions rapidly increase with change in future market conditions.

For this reason, it is important to carefully observe various liquidity indicators for a sign of deterioration or destabilization in market liquidity, and which type of transactions is more vulnerable to change in market conditions. According to newly compiled liquidity indicators with detailed transaction data, especially for short-term and off-the-run bonds, the improvement of indicators was delayed and indicators temporarily deteriorated during intraday. We have to continue to analyze market liquidity deeply.

Thus, we can capture market liquidity in more detail with newly compiled liquidity indicators. It is beneficial to continue examining the JGB markets, including these indicators.

However, market liquidity cannot be grasped by quantitative indicators alone.[16] Change

[16] In this point, Miyanoya, Inoue, and Higo (1999) analyzed market microstructure of the JGB markets.

in market participants' stance on trading is considered to have an impact on not only transaction volume but also subjective views against market liquidity. In addition, even if market participants are in the same market conditions, evaluation of market liquidity by each participant differs according to their business model and/or size of transaction volume. Therefore, liquidity in the JGB markets is important to be examined continuously from a broader range of perspectives including communication with market participants through Bond Market Survey and Bond Market Group meetings.

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(Appendix) Attempt to capture large amount transactions

In the main text, we described the compilation of new liquidity indicators with detailed transaction data of inter-dealer transactions in the JGB cash market to grasp market liquidity during the day and of all JGB issues. Here, we try to consider large amount transactions in a quantitative way. As dealers must conduct transactions according to their clients' needs, transaction volume of dealers is sometimes very large. Large amount transactions are considered difficult in terms of "smoothly buy and sell their intended amount at a price close to the market price," compared with small amount transactions. Therefore, the ease of large amount transactions is an important aspect of market liquidity.

It is not necessarily easy to quantitatively measure the ease of large amount transactions. First, acquiring data related to large amount transactions is not an easy task. While newly acquired data obtained from the Japan Bond Trading includes information related to execution, the amount of each transaction is divided into 5 billion yen at most, reflecting market practices related to settlement practices.[17] The amount of each transaction which is actually executed before the transaction is divided is unclear, thus it is difficult to identify and analyze large amount transactions.[18] Second, market participants present a small amount of transactions in advance. According to Bond Market Survey answers to the question "whether transaction is conducted at the intended amount for each transaction," evaluation by market participants declined greatly after it peaked in August 2015, and has generally been improving since November 2016 (Appendix Chart 1). However, this question of the survey is not limited to an issue of large amount transactions. In addition, there are voices from market

[17] As a market practice related to settlement practice, from a viewpoint of smoothness for settlement and reduction of settlement risk, it is required that settlement amount must be less than 5 billion yen per transaction. See for details, "The Japanese Government Securities Guidelines for Real Time Gross Settlement," The Japan Securities Dealers Association.

[18] Because the obtained data does not include names of market participants, it is not possible to estimate the actual transaction amount before division based on a market practice by summing up multiple data while considering each participant's transactions.

participants such that “they reduce the amount to be able to execute transaction smoothly in advance,” and “large amount transactions are difficult unless the amount is reduced.” The survey results should not be used to interpret the level of difficultly of large amount transactions.

By recognizing restrictions, we analyze transactions that can be reckoned as large amount transactions with newly acquired data, including information related to execution and orders. First, with information related execution, we assume that the transaction equals 5 billion yen is part of large amount transactions, then we calculate the number of issues with said amount. This indicator appears to be on a gradual declining trend since the beginning of 2016 with some fluctuation (Appendix Chart 2). However, more than 10 billion yen is considered a large amount transaction by market participants in general. Therefore, it is necessary to note that not all the large amount transactions defined here are large amount transactions recognized by market participants.

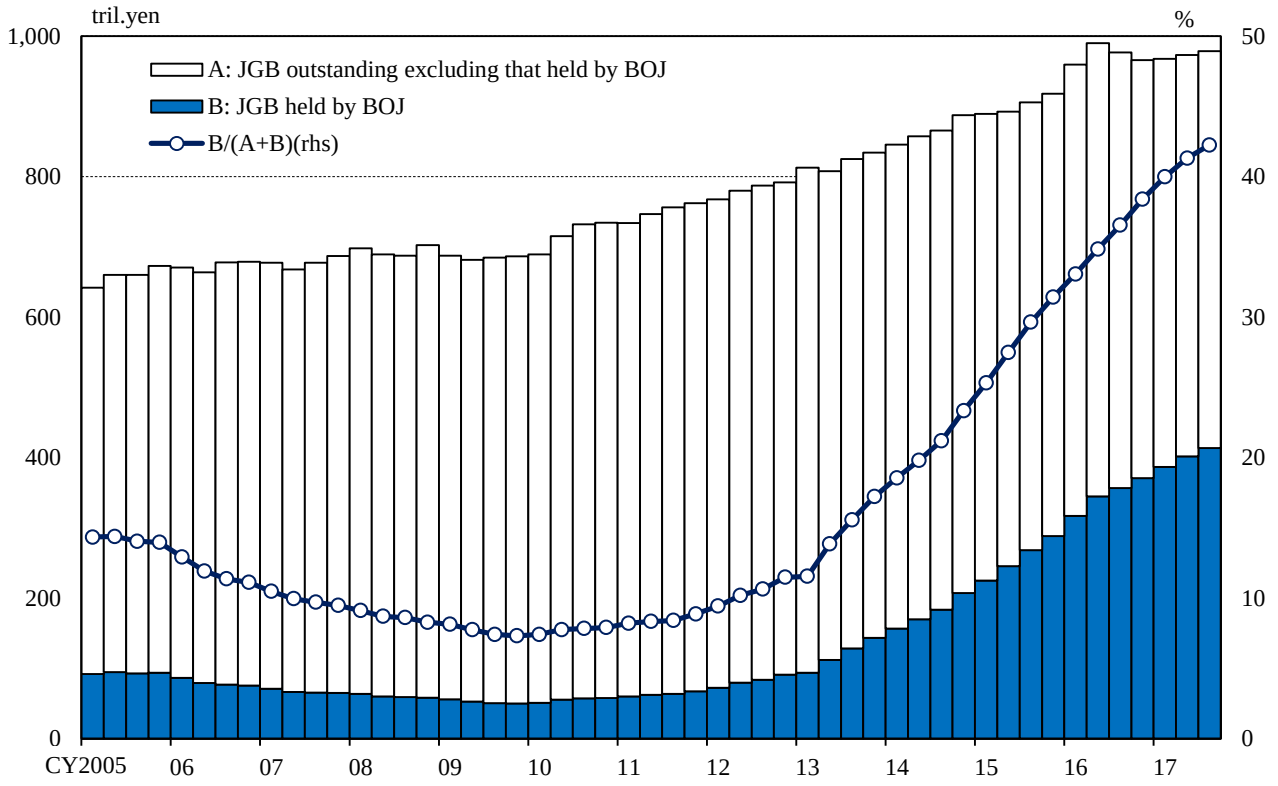
Next, with information related to orders, we assume that a bond whose volume of orders at the best-ask price is larger than 2.5 billion yen on average throughout the day is the bond that market participant can conduct large amount transactions. We examined how many such issues and how large volume of orders at the best-ask price per such issue (Appendix Chart 2). Considering this chart, we see that the number of issues decreased from the beginning of 2016 to the fall of 2016, and the volume per issue also decreased. After the fall of 2016, while the number of such issues was still small, the volume per issue recovered to the levels of the latter half of 2015. This means that market participants have more easily conducted large amount transactions with some specific issues such as on-the-run bonds since the fall of 2016, but the number of such issues did not increase enough.

The above results express the difficulty of large amount transactions often heard from market participants to some extent. There are some points, e.g., large amount transactions that we cannot grasp very well with indicators and other quantitative

methods. Thus, it is important to carefully examine these points by using communications with market participants as well as indicators.

Chart 1

Share of JGB holdings by BOJ

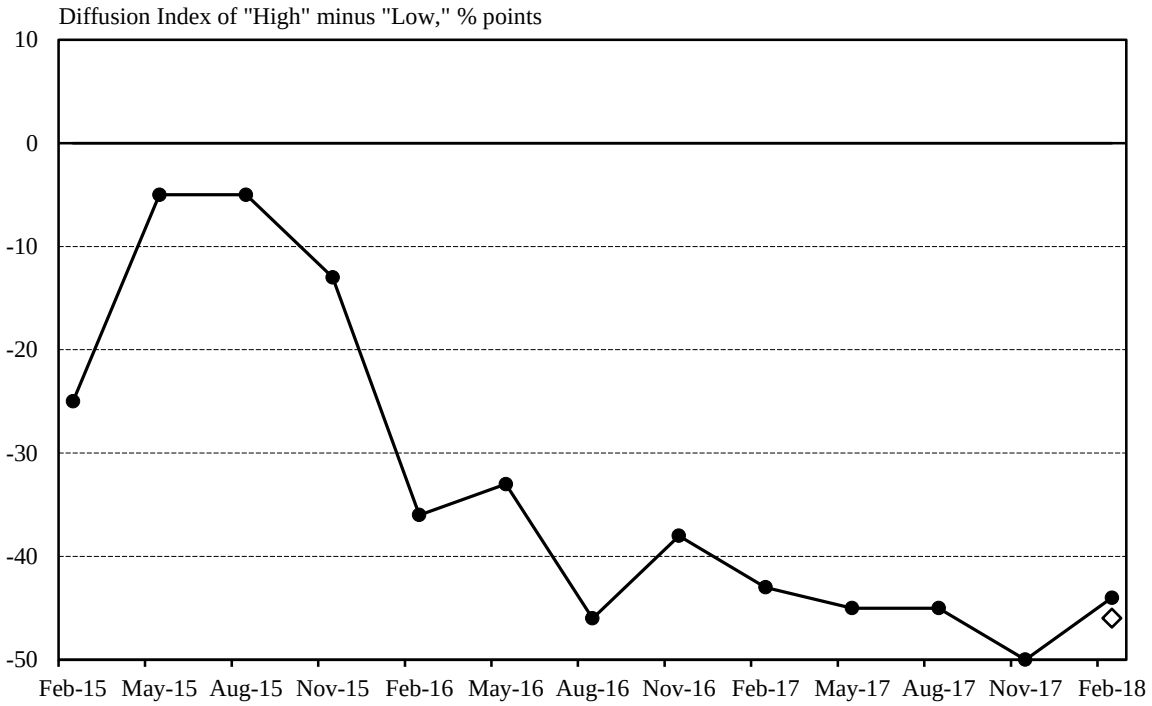


Source: Bank of Japan

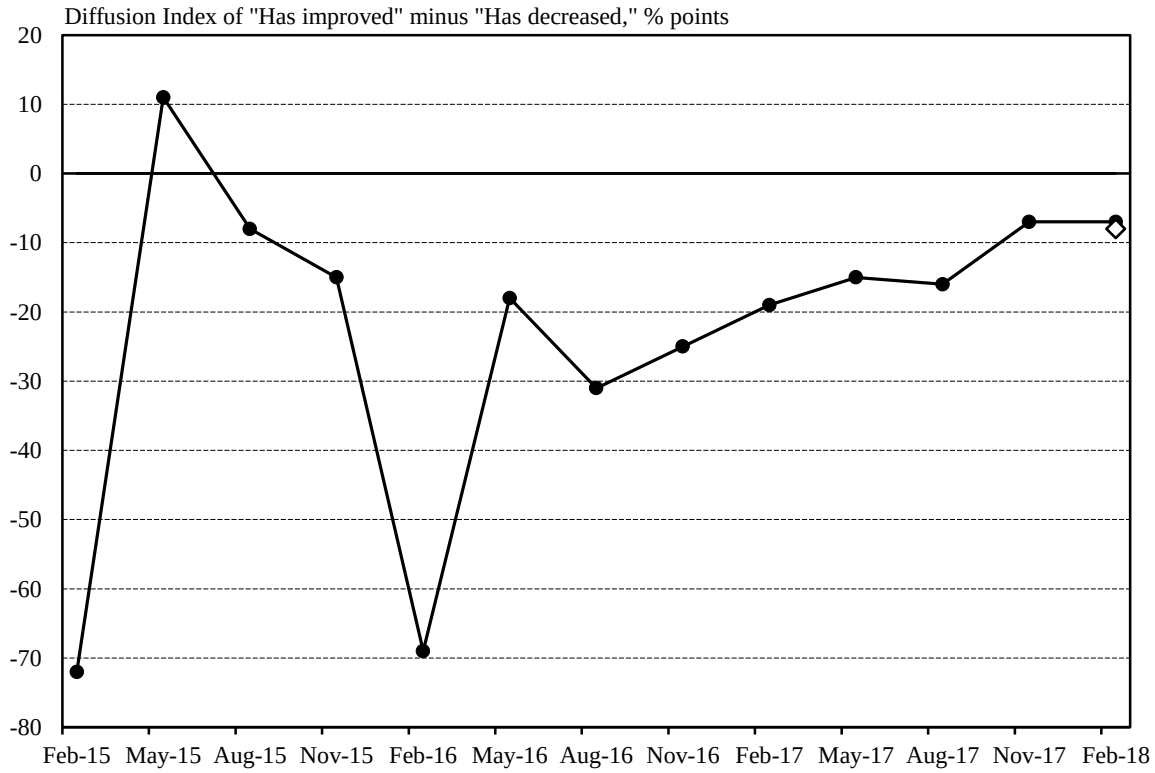
Chart 2

Bond Market Survey

(1) Degree of bond market functioning <Current situation>



(2) Degree of bond market functioning <Change from three months ago>



Notes: 1. The survey from February 2018 onward includes responses from major insurance companies, asset management companies, etc., in addition to those from eligible institutions for the Bank's outright purchases and sales of JGBs.

2. Regarding the figures for February 2018, the filled circle indicates the reference data which are based on responses only from eligible institutions for the Bank's outright purchases and sales of JGBs, and the hollow square indicates the data which include responses from major insurance companies, asset management companies, etc.

Source: Bank of Japan

Chart 3

Compiling indicators for the JGB cash market

▽ "Liquidity Indicators in the JGB Markets" released by the Bank of Japan

	JGB futures market	JGB cash market	
		Dealer-to-client	Inter-dealer
Volume	◎ Transaction volume	△ Transaction volume	○ Transaction volume
Tightness	◎ Bid-ask spread	○ Bid-ask spread	
Depth	◎ Volume of orders at the best-ask price	△ Best-worst quote spread	
Resiliency	◎ Price impact		

▽ Newly compiled Liquidity Indicators

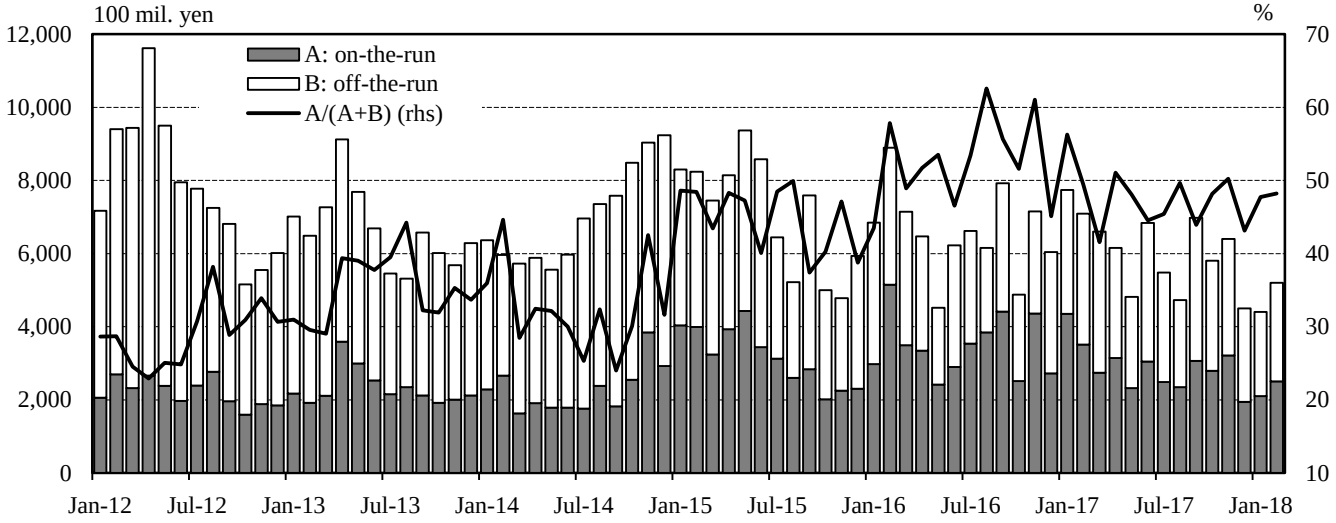
	JGB cash market
	Inter-dealer
Volume	◎ Transaction volume
Tightness	◎ Bid-ask spread ◎ Total observation time of bid-ask spreads※
Depth	◎ Volume of orders at the best-ask (best-bid) price ◎ Ratio of issues by total observation time of the best-ask (best-bid) price※
Resiliency	◎ Price impact

Notes: 1. ◎ : compiled with detailed transaction data, ○ : compiled with daily data, △ : compiled with monthly data.

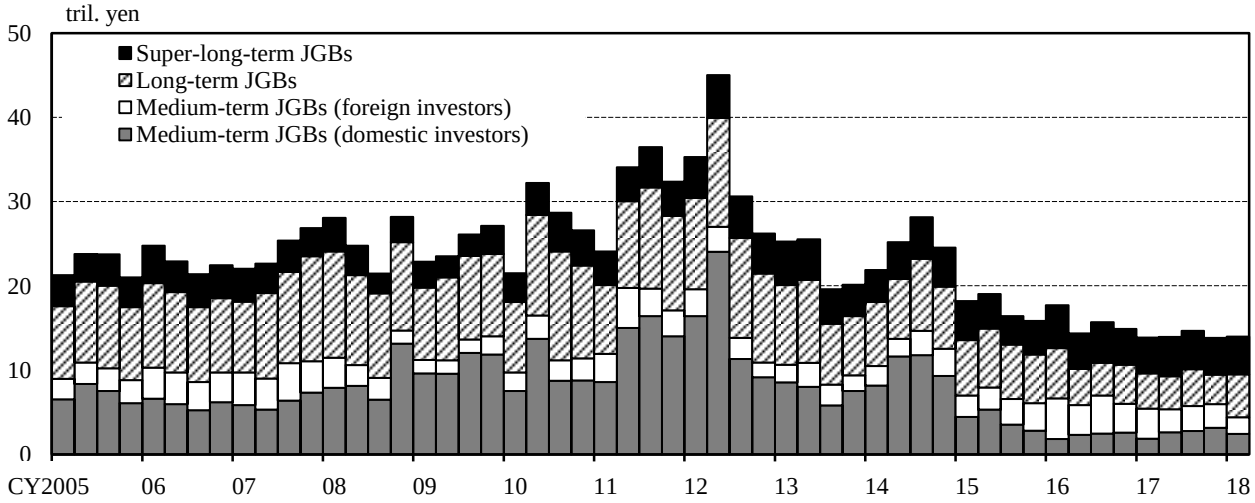
2. ※: compiled from new perspectives.

Transaction volume (volume)

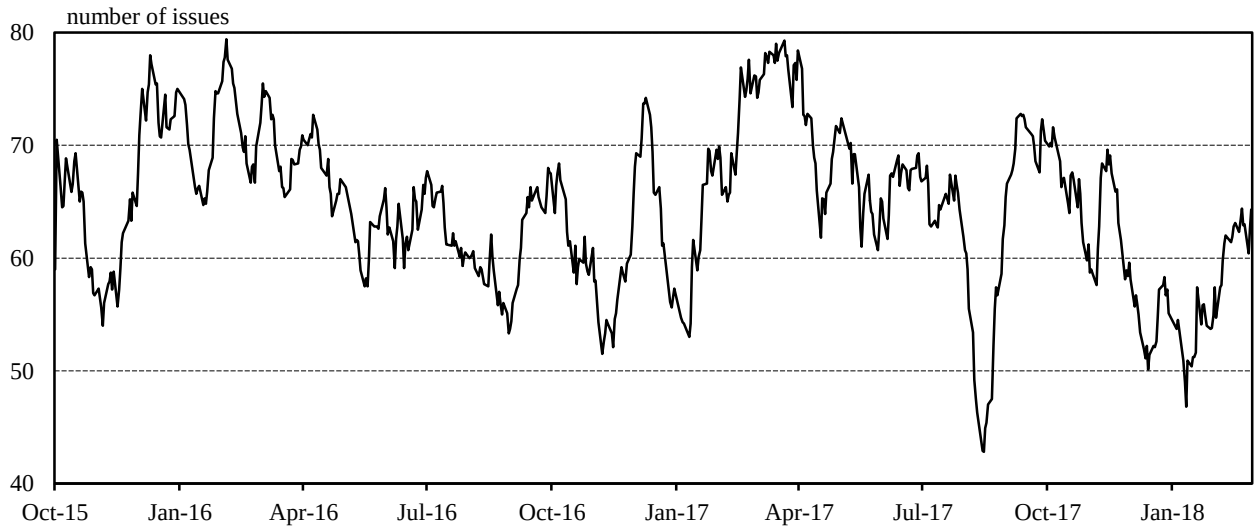
(1) Inter-dealer daily transaction volume



(2) Dealer-to-client monthly transaction volume (Gross amount purchased by clients)



(3) Inter-dealer daily traded issues

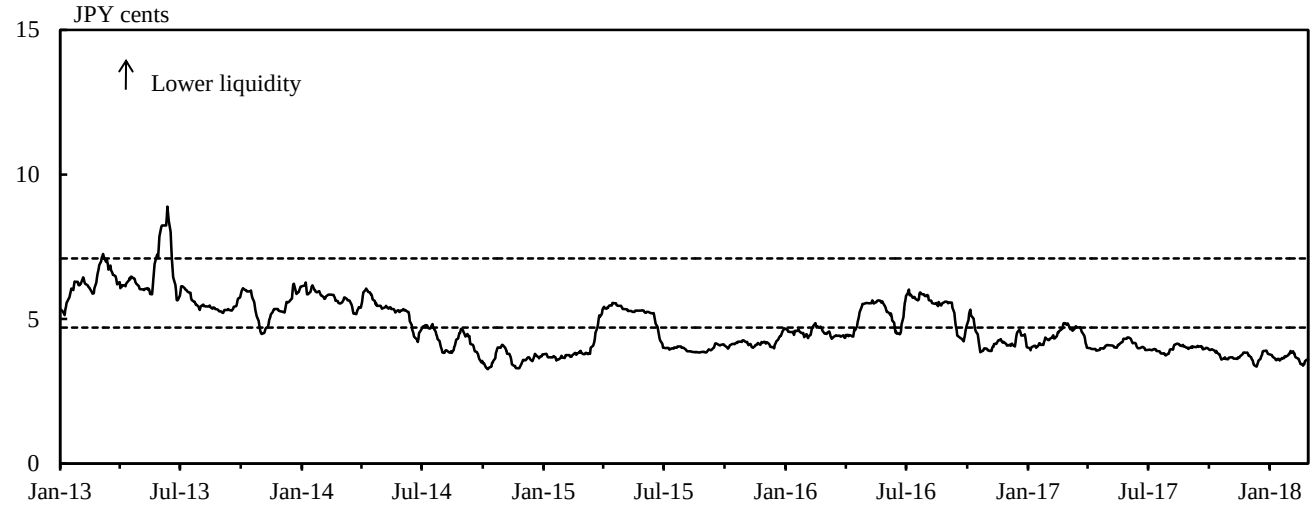


Notes: 1. Figure (1) is the sum of 2-year, 5-year, 10-year, 20-year, 30-year, and 40-year JGBs via Japan Bond Trading.
2. Treasury Discount Bills, etc. are excluded from figure (2).
3. "Clients" include city banks, regional financial institutions, investors, and foreigners. Other institutions (government, Bank of Japan, Japan Post Bank, Japan Post Insurance, business corporations, other financial institutions, etc.) are excluded from "clients."
4. 10-day backward moving average is applied to figure (3). Latest data as at end-February 2018.

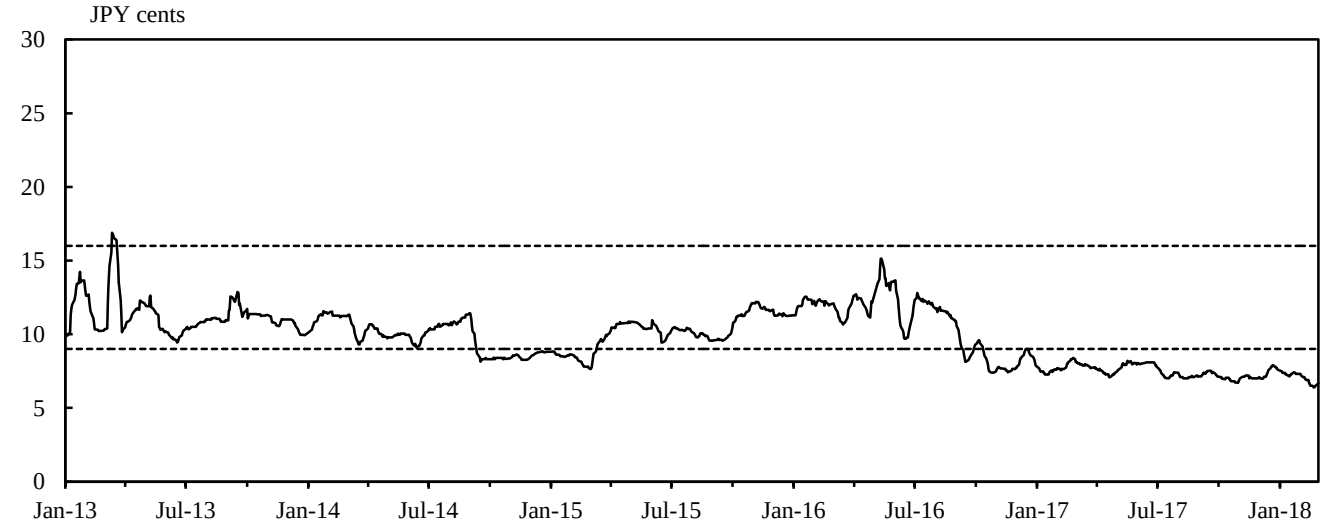
Sources: QUICK; Japan Bond Trading; Japan Securities Dealers Association.

Bid-ask spreads of dealer-to-client transactions (tightness)

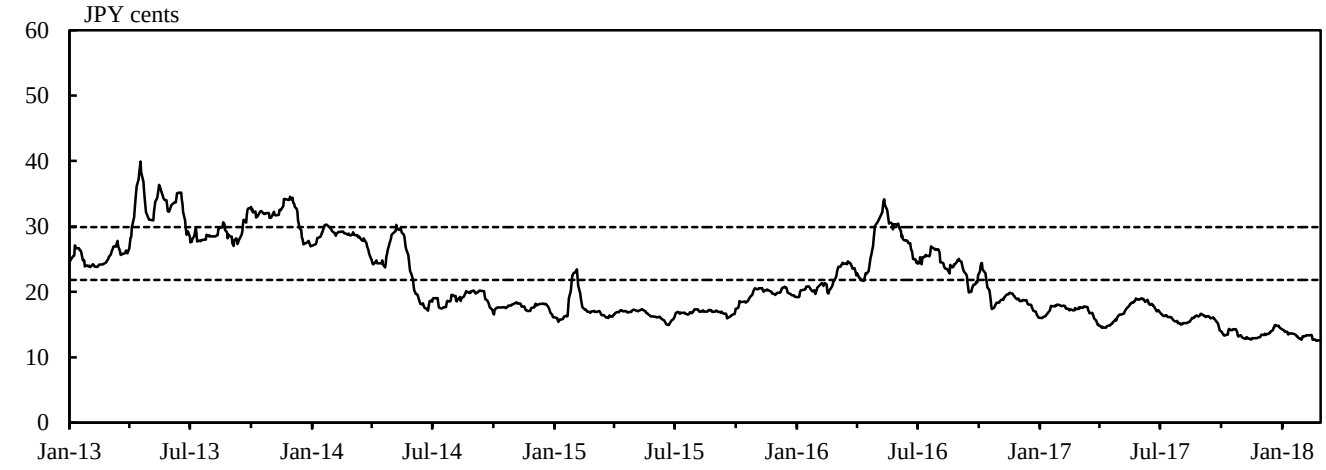
(1) 5-year



(2) 10-year



(3) 20-year



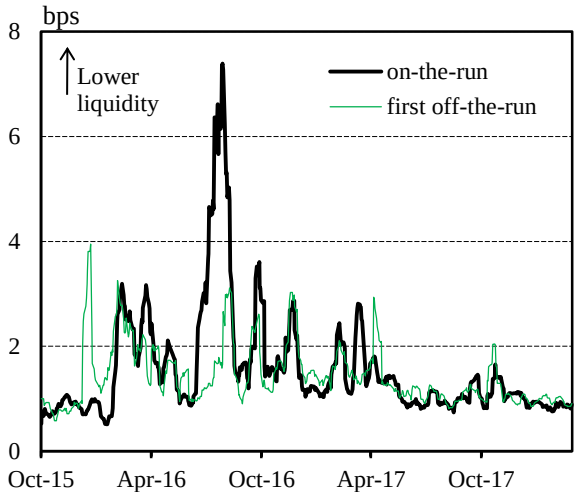
Notes: 1. Quotations through Trade web as of 3:00 p.m. Dotted lines indicate the first/third quartile spreads between January 2010 and March 2013.

2. 10-day backward moving average. Latest data as at end-February 2018.

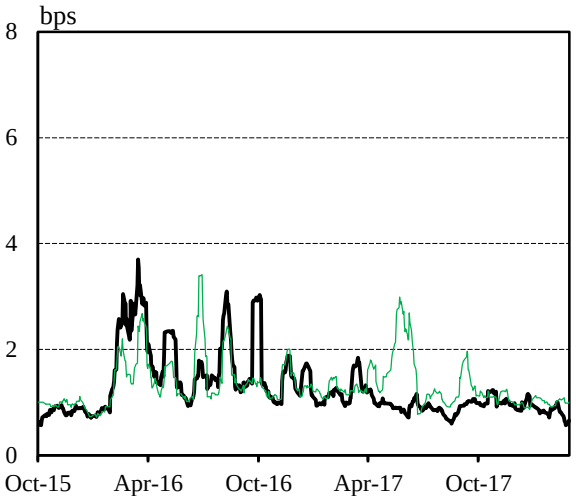
Source: Thomson Reuters.

Bid-ask spreads of inter-dealer transactions (tightness)

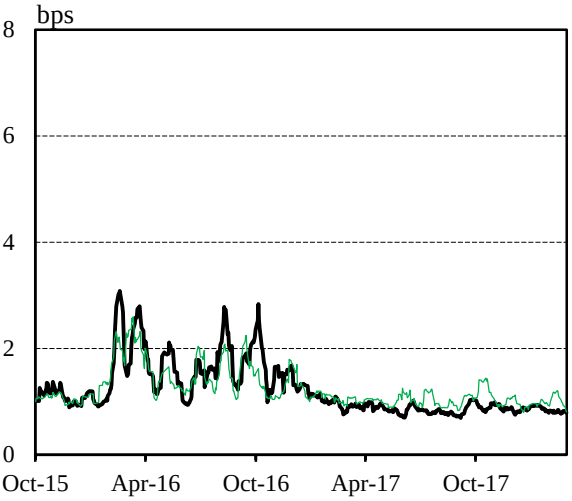
(1) 2-year



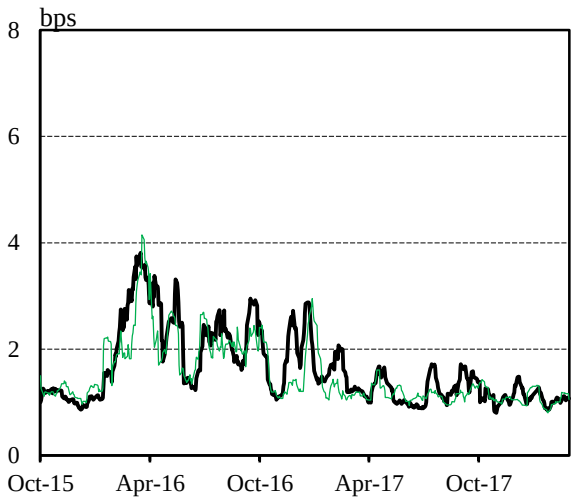
(2) 5-year



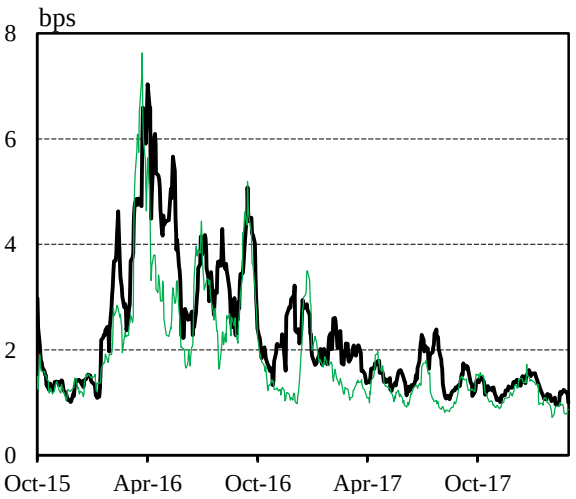
(3) 10-year



(4) 20-year



(5) 30-year

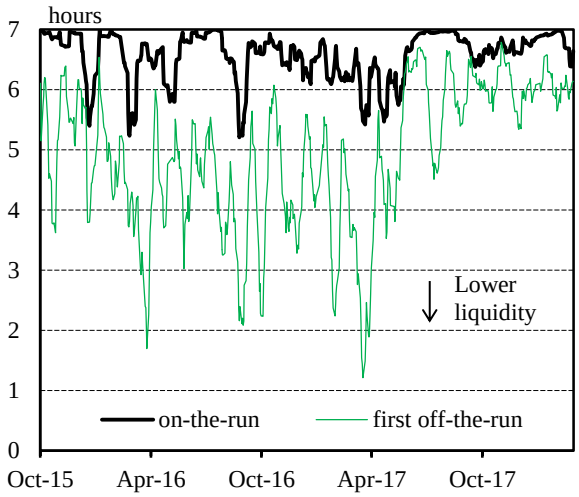


Notes: 1. Figures indicate the average of the widest 10 percent of bid-ask spreads with a 1-second frequency.
2. Bid-ask spreads are calculated only for time periods in which both best-bid and best-ask prices were submitted.
3. 10-day backward moving average. Latest data as at end-February 2018.

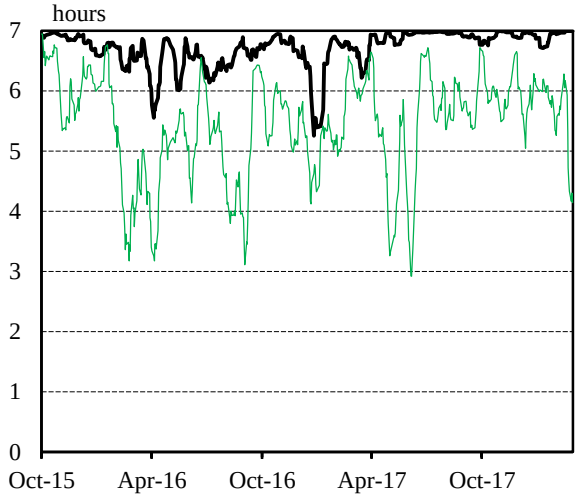
Source: Japan Bond Trading.

Total observation time of bid-ask spreads of inter-dealer transactions (tightness)

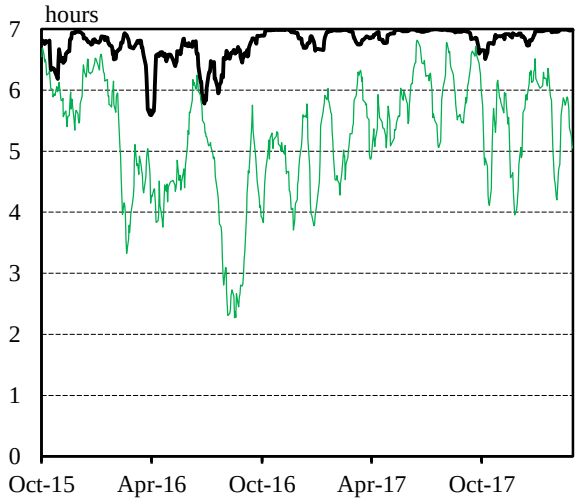
(1) 2-year



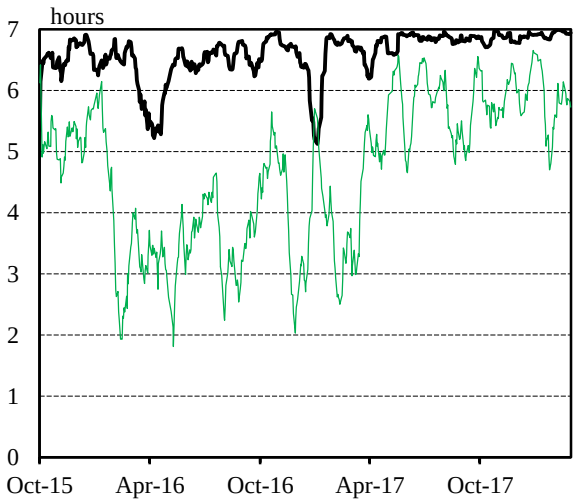
(2) 5-year



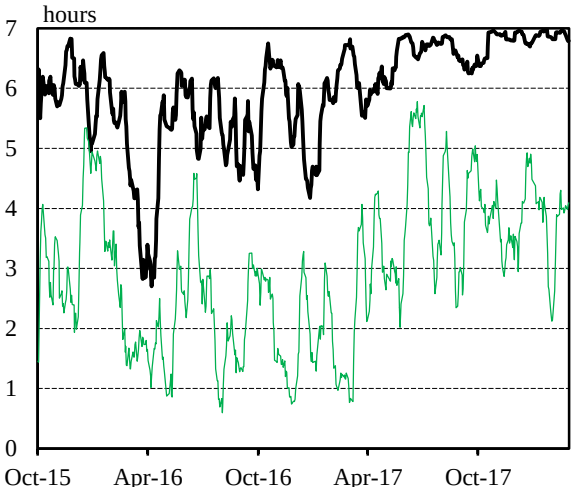
(3) 10-year



(4) 20-year



(5) 30-year



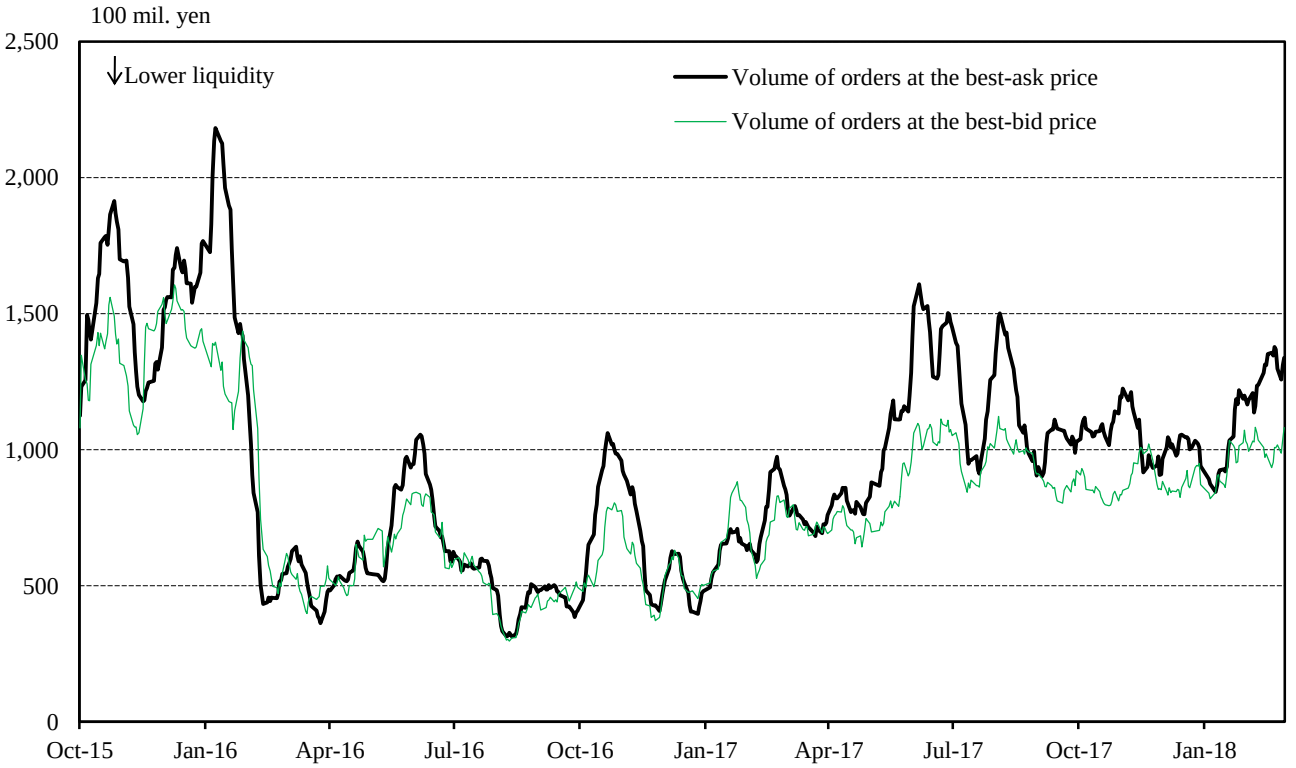
Notes: 1. Figures indicate the total length of time in which both best-bid and best-ask prices were submitted.
2. 10-day backward moving average. Latest data as at end-February 2018.

Source: Japan Bond Trading.

Market depth (depth)

(1) Best-worst quote spreads of dealer-to-client transactions

(2) Volume of orders at the best-ask (best-bid) price of inter-dealer transactions



Notes: 1. (1) is calculated by averaging the spreads between the best and worst quotes offered by dealers against each client request. Transactions with spreads wider than 10 bps are excluded from the calculation.

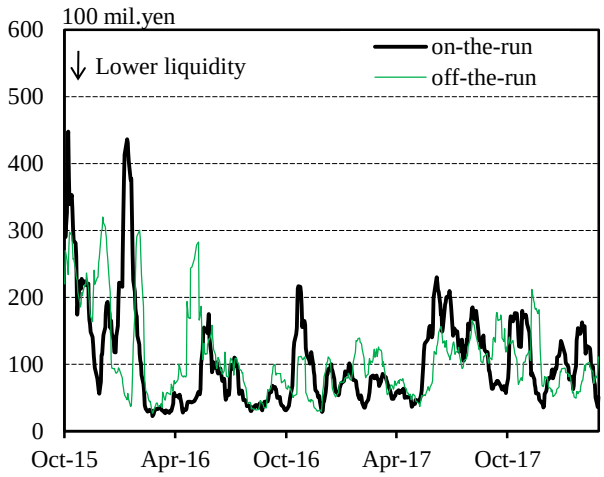
2. (2) is calculated by summing up the median of volume of orders at the best-ask (best-bid) price with a 1-second frequency per issue. 10-day backward moving average.

3. Latest data as at end-February 2018.

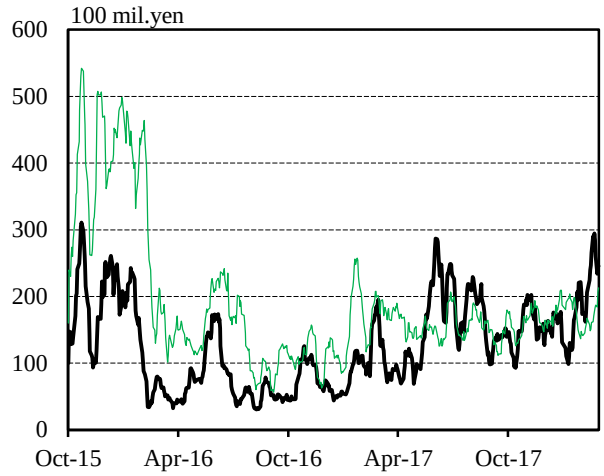
Sources: Yensai.com; Japan Bond Trading.

Volume of orders at the best-ask price by residual maturity of inter-dealer transaction (depth)

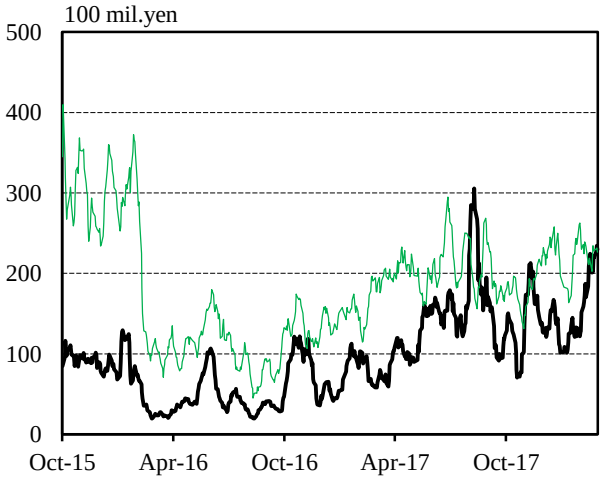
(1) 2-year



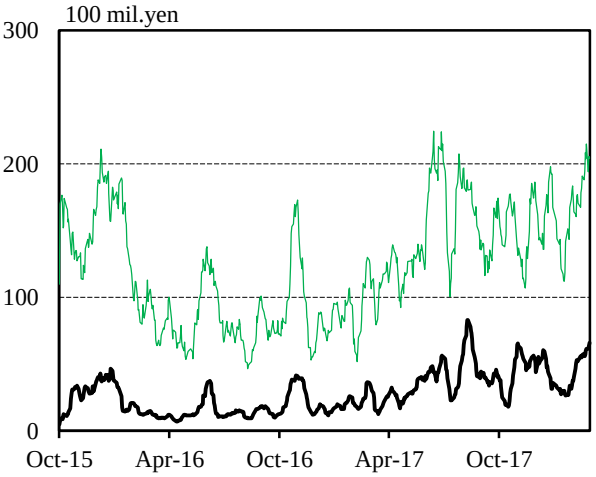
(2) 5-year



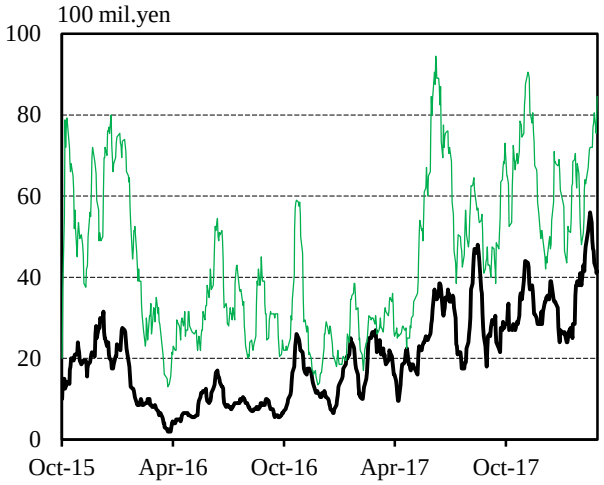
(3) 10-year



(4) 20-year



(5) 30-year



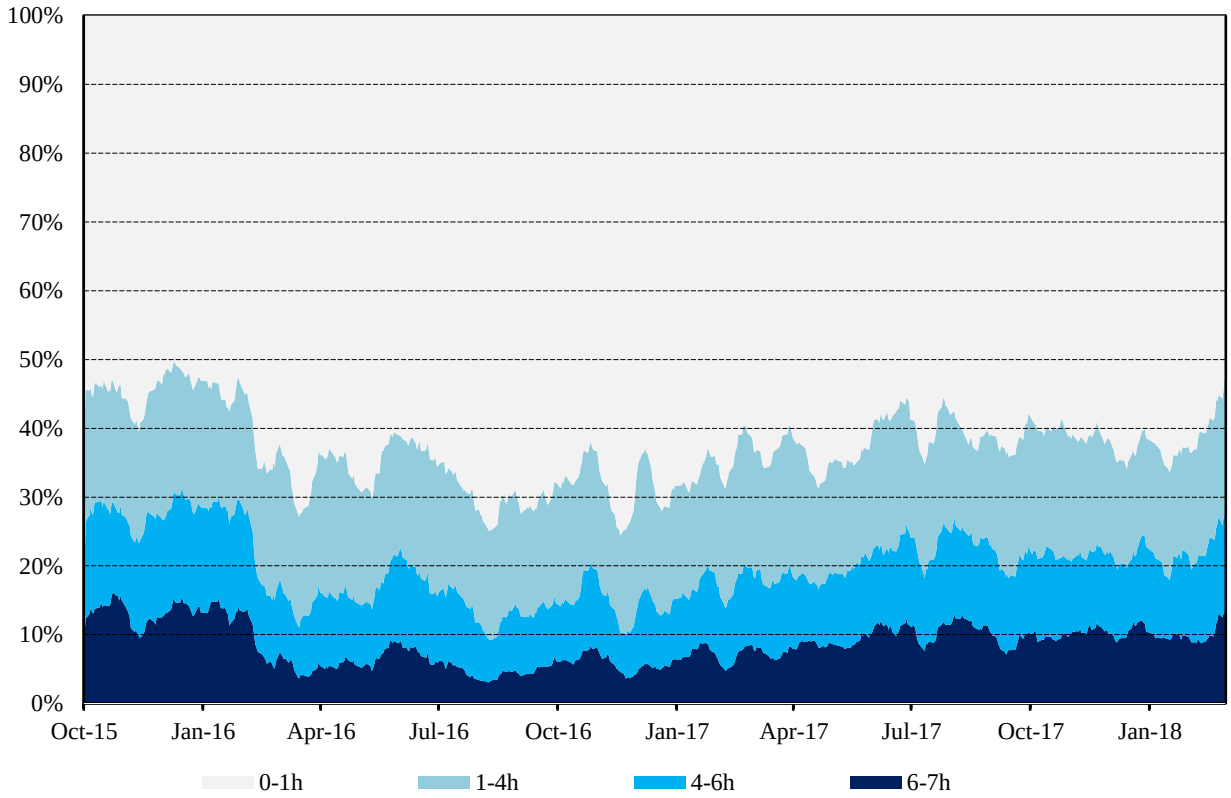
Notes: 1. Figures indicate the sum of the median of volume of orders at the best-ask price with a 1-second frequency per issue.

2. 10-day backward moving average. Latest data as at end-February 2018.

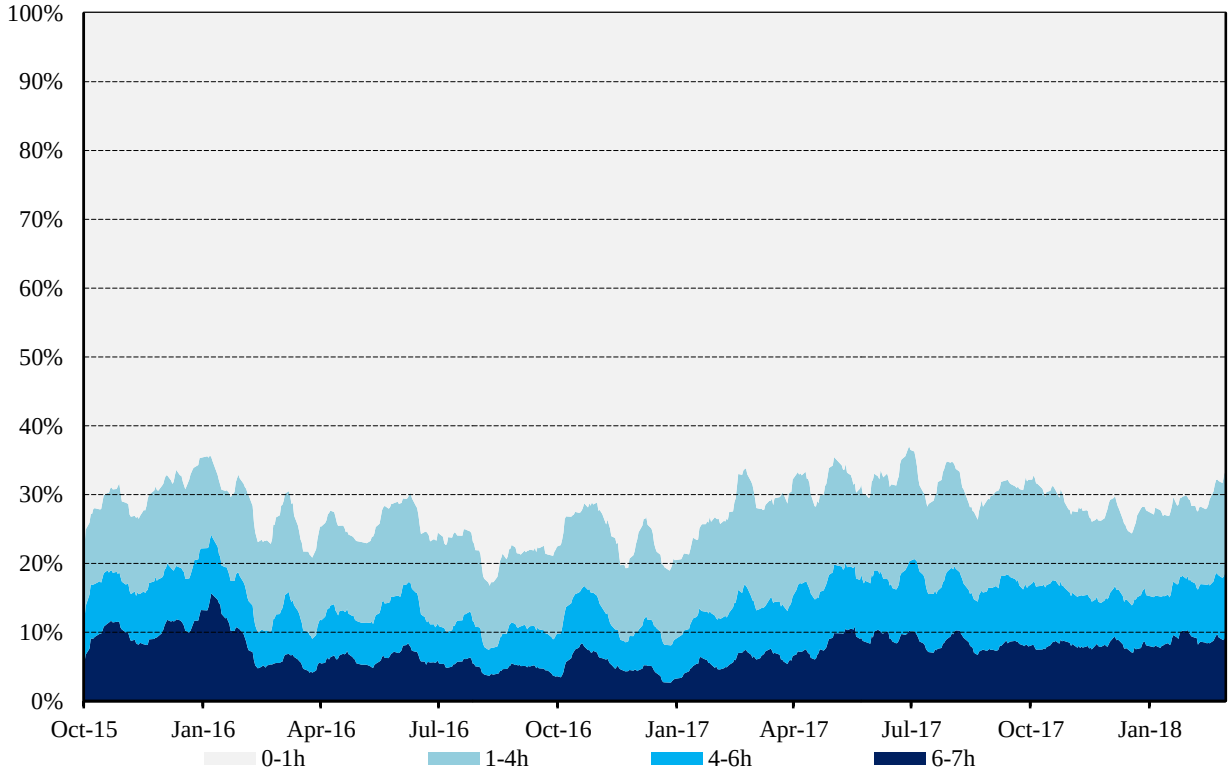
Source: Japan Bond Trading.

Ratio of issues by total observation time of the best-bid (best-ask) price of inter-dealer transactions (depth)

(1) Ratio of issues by total observation time of the best-bid price



(2) Ratio of issues by total observation time of the best-ask price



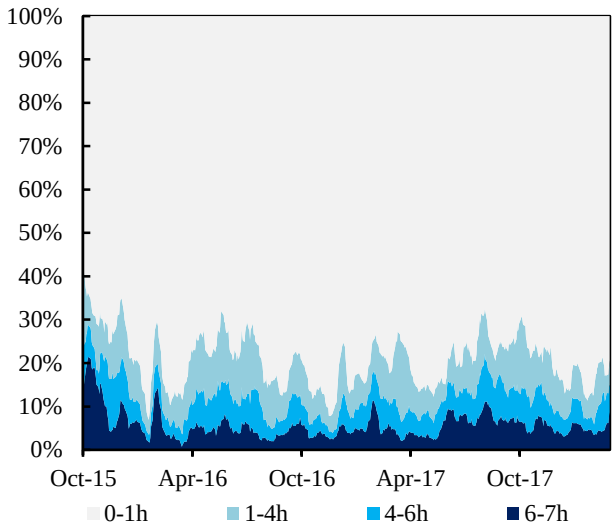
Notes: 1. Figures indicate the percentage of issues by daily observation time, 0-1hours, 1-4hours, 4-6hours, 6-7 hours, of best-bid (best-ask) prices.

2. 10-day backward moving average. Latest data as at end-February 2018.

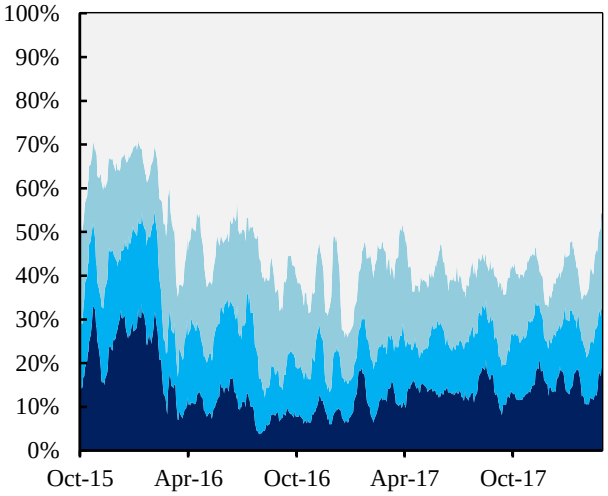
Source: Japan Bond Trading.

Ratio of issues by total observation time of the best-bid price by residual maturity of inter-dealer transactions (depth)

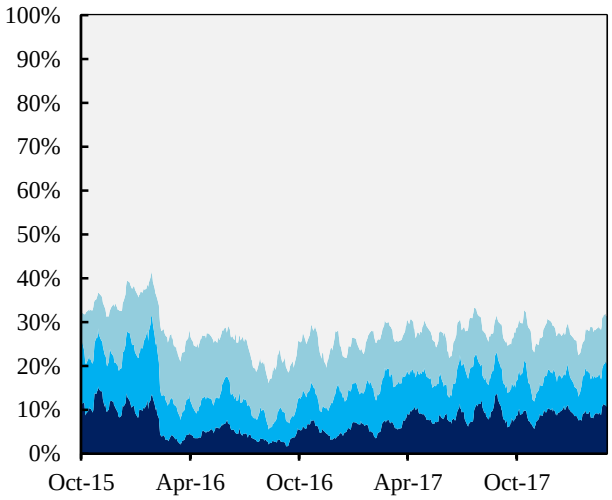
(1) Under 2 years



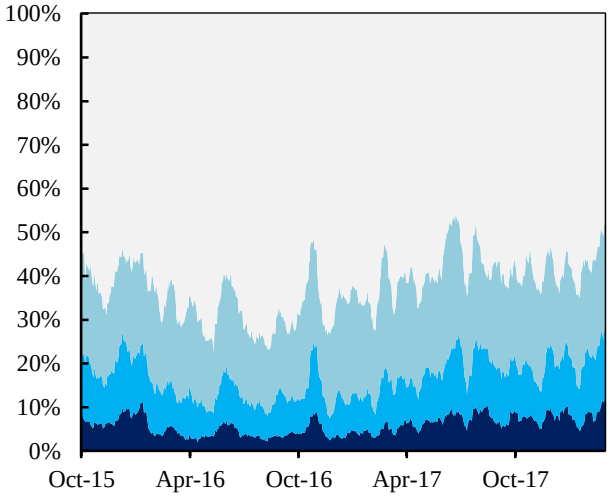
(2) From 2 years to 5 years



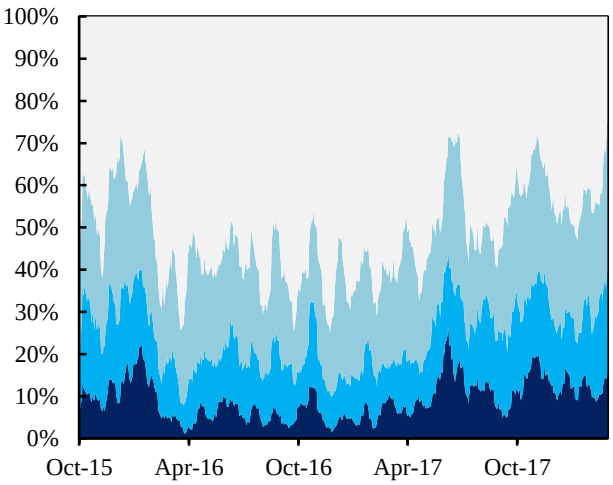
(3) From 5 years to 10 years



(4) From 10 years to 20 years



(5) From 20 years to 30 years



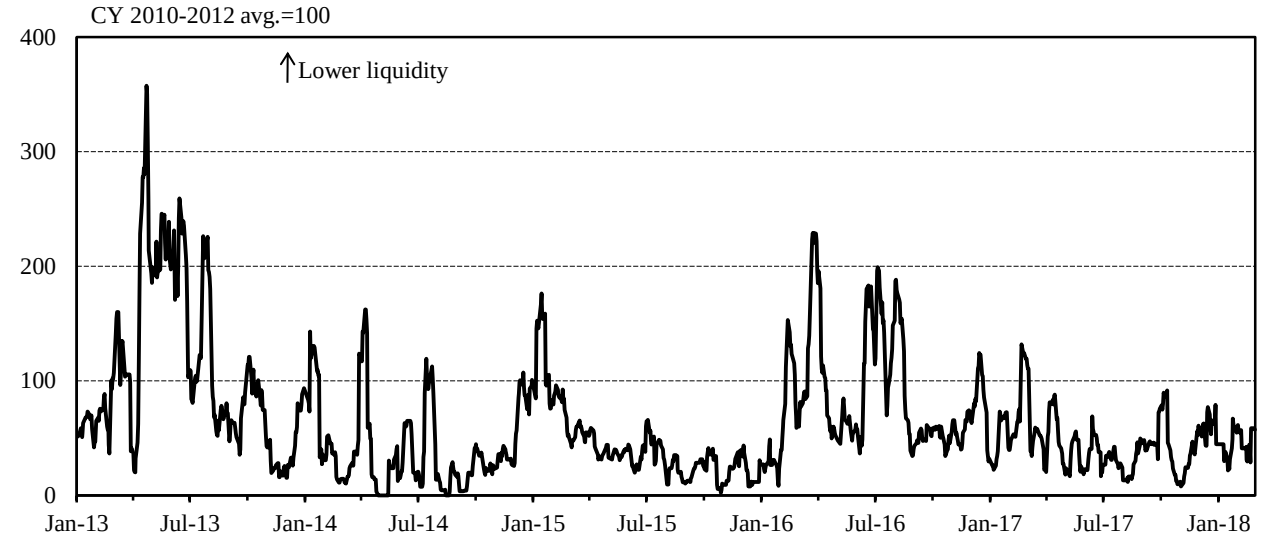
Notes: 1. Figures indicate the percentage of issues by daily observation time, 0-1hours, 1-4hours, 4-6hours, 6-7 hours, of best-bid price.

2. 10-day backward moving average. Latest data as at end-February 2018.

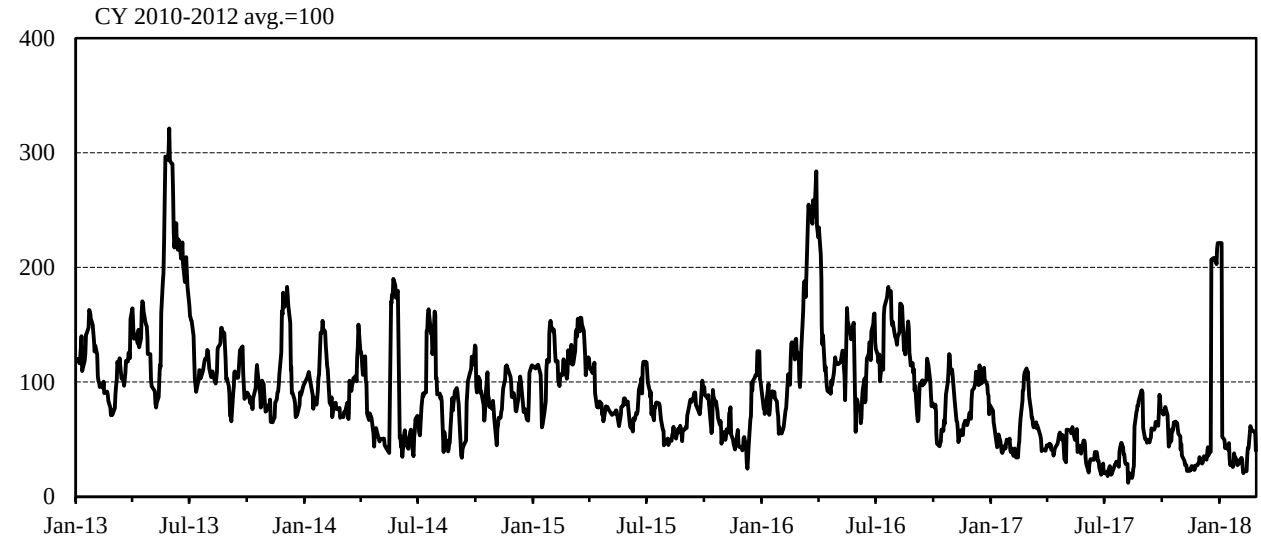
Source: Japan Bond Trading.

Daily price range to transaction volume ratio of inter-dealer transactions (resiliency)

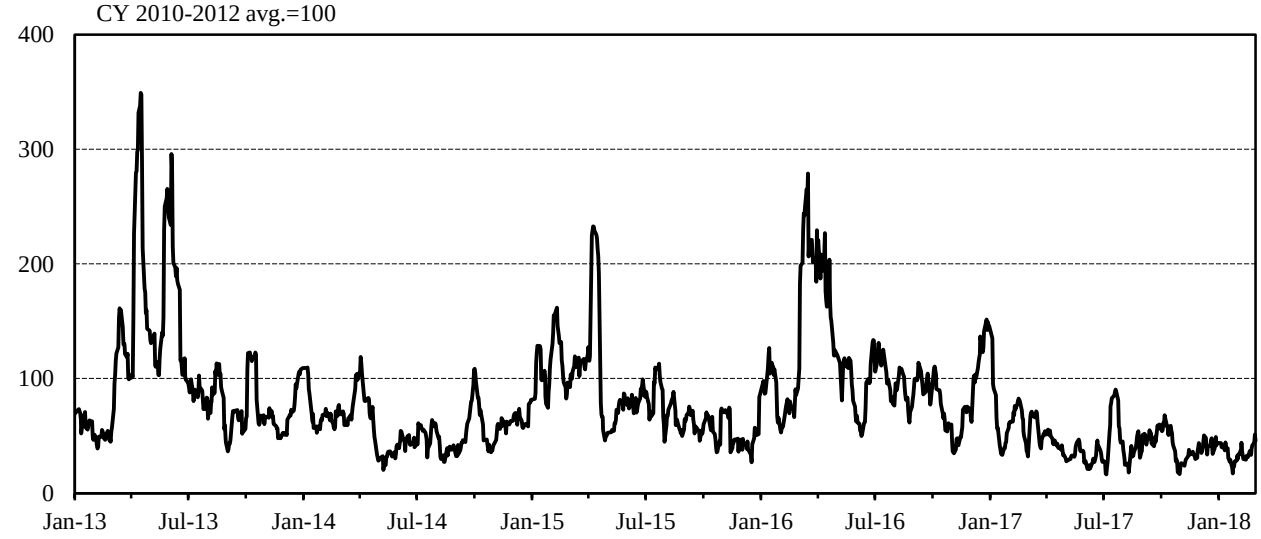
(1) 5-year



(2) 10-year



(3) 20-year

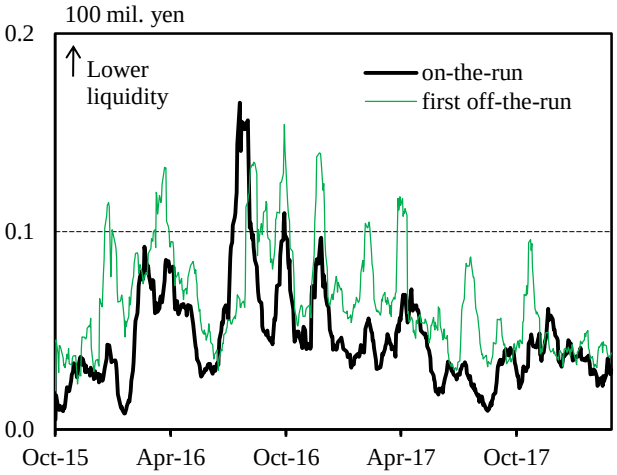


Note: 10-day backward moving average. Latest data as at end-February 2018.

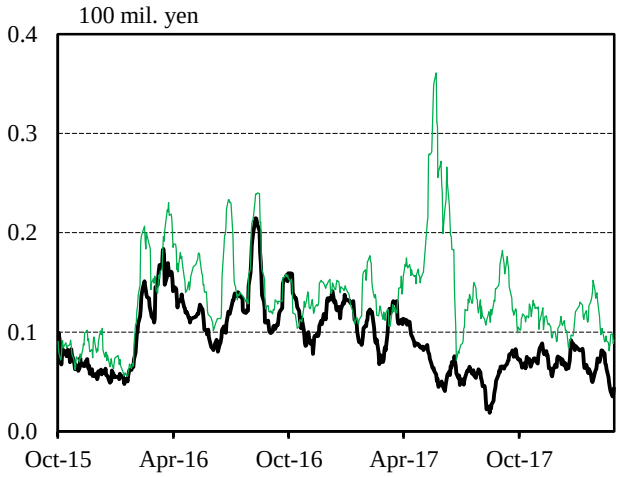
Source: QUICK.

Price impact (β) of inter-dealer transactions (resiliency)

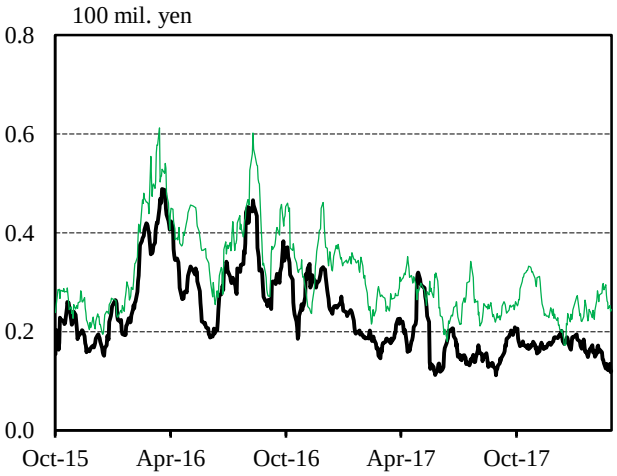
(1) Price impact (2-year)



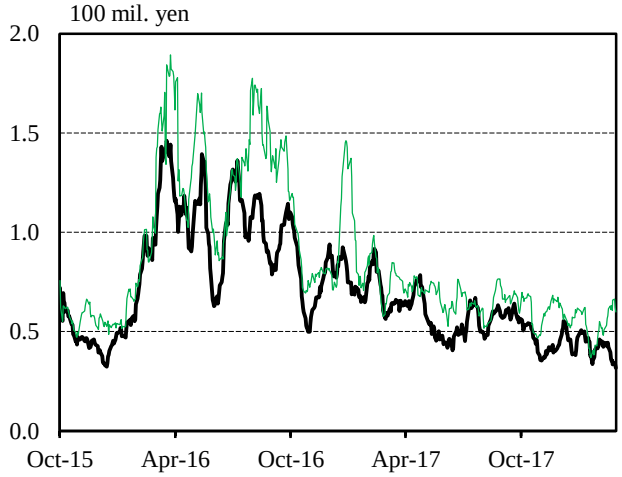
(2) 5-year



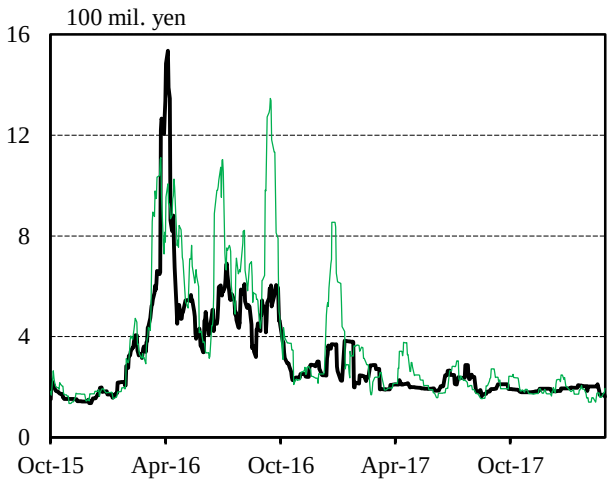
(3) 10-year



(4) 20-year



(5) 30-year



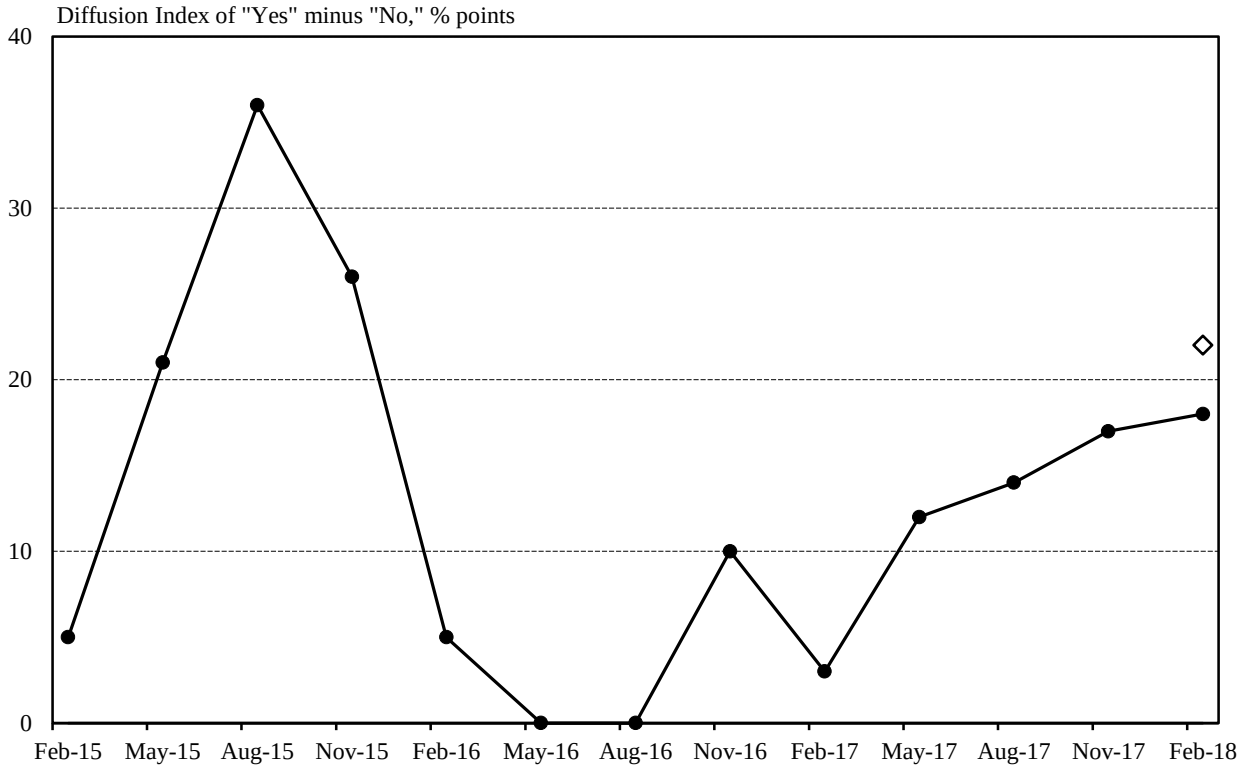
Note: 10-day backward moving average. Latest data as at end-February 2018.

Sources: QUICK; Japan Bond Trading.

Appendix Chart 1

Bond Market Survey

Availability to make dealings with expected dealing lots <Current situation>



Notes: 1. The survey from February 2018 onward includes responses from major insurance companies, asset management companies, etc., in addition to those from eligible institutions for the Bank's outright purchases and sales of JGBs.

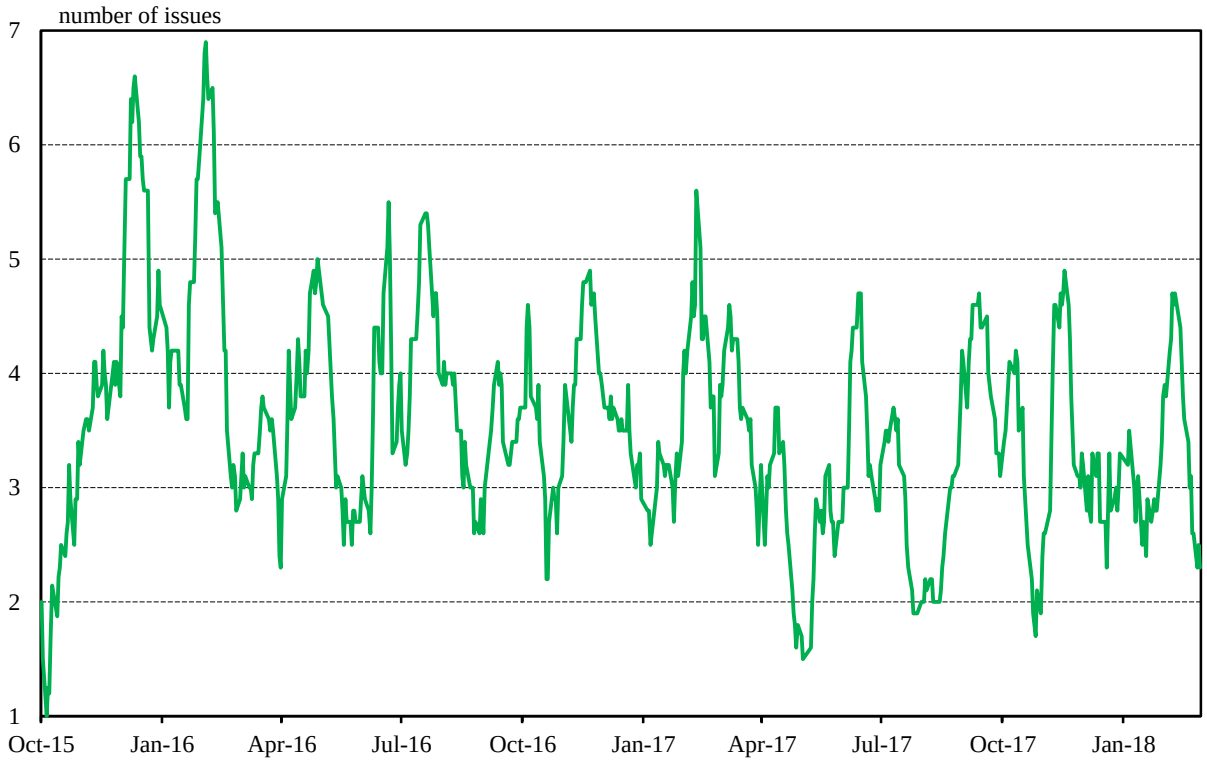
2. Regarding the figures for February 2018, the filled circle indicates the reference data which are based on responses only from eligible institutions for the Bank's outright purchases and sales of JGBs, and the hollow square indicates the data which include responses from major insurance companies, asset management companies, etc.

Source: Bank of Japan

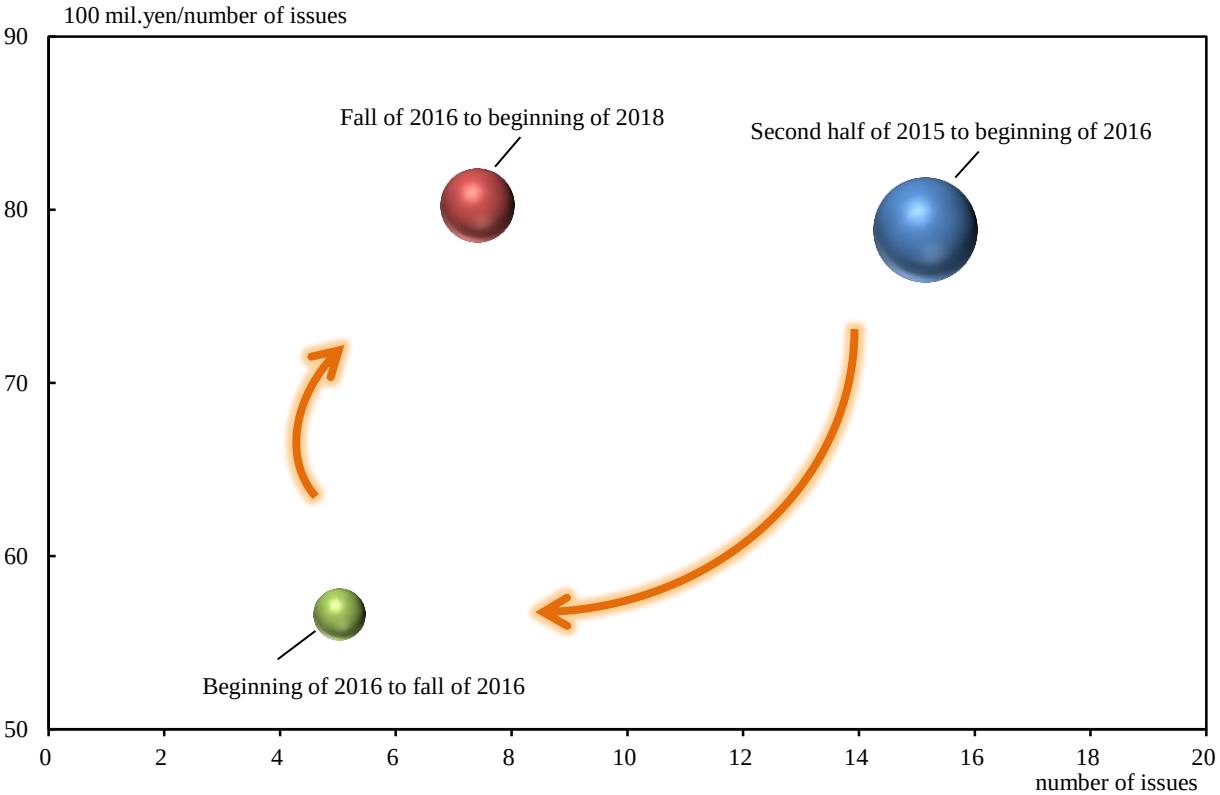
Appendix Chart 2

Large amount transactions

(1) Number of issues thought to be conducted as large amount transactions



(2) Number of issues and volume of orders thought to be possibly conducted as large amount transactions



Notes: 1. (1) assumes that transaction equals 5 billion yen is part of large amount transactions.
2. 10-day backward moving average. Latest data as at end-February 2018.
3. (2) uses issues whose volume of orders at the best-ask is larger than 2.5 billion yen on average per day.
Circle size represents the total volume of orders thought to be possibly conducted as large amount transactions.

Source: Japan Bond Trading.