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J-liquidity Measure: the Term Structure of the Liquidity Premium and the Decomposition of the Municipal Bond Spread

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Abstract

We interpret the yield spread between government-guaranteed bonds and government bonds as market liquidity, and use this measure to decompose the municipal bond spread into credit and liquidity premiums in the Japanese market. Our model-free approach not only provides the term structure of the liquidity premium, but also captures the impact of illiquidity events and the illiquidity condition of the fixed-income market. The liquidity factor plays an important role in the municipal bond spread, which suggests local governments have the opportunity to reduce their financing costs through enhancing market liquidity. The liquidity measure is provided publically for future applications.

JEL codes: G12, G13

Keywords: bond liquidity, liquidity risk, term structure of liquidity premium, municipal bond market

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政府保証債による流動性プレミアムの推定と地方債利回りの分解

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ノンテクニカルサマリー（Non-Technical Summary in Japanese）

本論文の特徴は、政府保証債に着目をすることで、新たな流動性指標を構築する点にある。政府保証債には通常、国債より高い利回りが付されているが、政府保証債に対して政府が明示的な保証をしていることを考えると、政府保証債の対JGBのスプレッドは流動性プレミアムと解釈することができる。

金融危機以降、市場流動性の分析の必要性は増している。流動性危機時に中央銀行による流動性の供給は必要であるものの、市場流動性を正確に把握できなければ政策の実施は困難である。また、近年、金融規制に伴い市場流動性の低下に係る懸念が市場参加者から挙げられているが、その判断においても正確な市場流動性の分析が求められる。

流動性指標は売買高、Bid-ask spreadなど多数存在するが、政府保証債を用いることのメリットは以下の3点にまとめられる。一点目は、金融危機時など、しばしば高い相関をもつ信用リスクプレミアムと流動性プレミアムを、特定のモデルを使わずに正確に分解することができる点である。二点目は政府保証債という金融商品から算出するがゆえ、投資家の期待を織り込んだ流動性指標（フォワードルッキングな流動性指数）をつくることができる点である。三点目は1年や10年といった期間別の流動性プレミアムを構築できるがゆえ、流動性プレミアムの期間構造を把握できる点である。

本論文は日本の政府保証債を活用して流動性指標を作成した最初の論文であるが、米国・欧州については先行研究が複数存在する。Longstaff (2004)は、Refcorp (Resolution Funding Corporation、整理資金調達公社）とUS Treasuryのスプレッドを用いて米国国債の市場流動性を分析している。Monfort and Renne (2014)とSchuter and Uhrig-Homberg (2015)は、ドイツ復興金融公社 (KfW)が発行する政府保証債を用いて流動性プレミアムを分析している。Schwart (2016)はKfWを用いて流動性指標を構築したうえで、K-measureという名称を付し、データをウェブサイトで公開している。

本論文では日本の政府保証債から算出した流動性指標が、流動性指標として望ましい

性質を有することをHu et al. (2013)をベースに評価を行っている。すなわち、流動性指標が望ましい性質をもつ条件として、①金融危機時など流動性危機をシャープに捉えられること、②政府保証債にとどまらず債券市場全体の流動性を捉えられること、③その他の流動性指標でとらえられない流動性を捉えられること、という3点の検討を行っている。筆者は、政府保証債から算出した流動性指標が、構造変化の検定や（その他の流動性指標との）相関関係を分析することでこれらを全て満たすことを示した一方で、売買高などしばしば使われる流動性指標の中にはこの条件を満たさないものがあることを指摘している。

本論文は、政府保証債から算出した流動性プレミアムを応用するケースとして我が国の地方債市場をとりあげ、地方債の対JGBスプレッドを①流動性要因と②クレジット要因に分解している。政府保証債から抽出した流動性プレミアムを地方債に適用する理由として政府保証債との売買動向や流動性指標が似通っていることに加え、政府保証債から算出した流動性プレミアムが夕張ショックといった地方債特有の事象をとらえられる点が挙げられる。本稿では、発行残高・信用力といった観点で地方債の中でも東京都を事例として取り上げている。本論文の結果は、Tスプレッドの半分以上、流動性プレミアムである可能性を示しており、流動性の向上によりスプレッドの縮小の可能性を示唆するものである。

1. INTRODUCTION

This paper examines market liquidity based on Japanese government-guaranteed bonds (JGGBs). The basic idea is quite simple. We interpret the yield spread between JGGBs and Japanese government bonds (JGBs) as a liquidity premium. This is because the Japanese government explicitly guarantees JGGBs and they have considerably less liquidity than JGBs. Thus, the spread between JGGBs and JGBs is a direct measure of the liquidity premium. We refer to this liquidity premium as the J-liquidity measure, and apply this measure to decompose the Japanese municipal bond spread into its credit and liquidity components.

Understanding market liquidity is an important task for several reasons. An abundant literature has explored the asset-pricing implications of liquidity theoretically and empirically. Especially during financial crisis, measurement of liquidity has great importance for central bankers because monetary policy could restore market function when the crisis stems from illiquidity. Recently, market participants have become concerned that market liquidity is waning, and that financial institutions are no longer providing liquidity because of stricter and more complicated regulation. As Duffie (2012) pointed out, there is a need for the assessment of a cost-effective method in this respect, and this requires the accurate analysis of market liquidity itself.

Measuring market liquidity using the yield spread between JGGB and JGB has several major advantages. First, we can estimate the liquidity measure directly from asset prices without imposing a specific model. This model-free approach provides a robust liquidity measure, whereas other approaches require a specific model to decompose liquidity from other factors such as credit risk (Longstaff et al. 2005, Chen et al. 2007). Second, this approach extracts the liquidity "premium" and this includes the forward-looking component of liquidity. As this measure is constructed using forward-looking variables, the premium should include investors' expectations of future market liquidity, thus enabling us to capture the liquidity premium accurately, especially during a period of financial crisis. Third, this proposed measure can adequately capture the term structure of the liquidity premium. According to Kempf et al. (2012), short- or long-term liquidity shocks could have different effects on asset prices. In addition, other liquidity measures do not necessarily provide information on the term structure, and our approach is then quite useful when economists are interested in the term structure of interest rates.

Our paper relates to several existing strands of research. For example, Longstaff (2004) examines the spread between US government-guaranteed bonds (RefCorp) and US Treasury bonds to capture the flight-to-liquidity premium in the US Treasury market. Likewise, Kempf et al. (2012) uses the spread between Pfandbriefe and German government bonds (Bunds) to extract the term structure of the liquidity premium, while Monfort and Renne (2014) and Schuter and Uhrig-Homburg (2015) employ the guaranteed bonds issued by Kreditanstalt für Wiederaufbau (KfW) to calculate the KfW-Bund spread. Lastly, Schwartz (2016) constructs a "K-measure" also using KfW bonds and provides a useful index via her website.

We apply the J-liquidity measure to Tokyo Metropolitan Bonds (TMBs). TMBs are the largest and safest municipal bonds on issue in Japan, and have very similar characteristics to JGGBs, suggesting TMBs are a natural application for the J-liquidity measure because the liquidity of JGGB and TMB is highly correlated (the correlation is 0.96 according to the liquidity measure proposed by Hu et al. 2013). As Schwert (2016) argued, financial economists have largely explored the relative contributions of default and liquidity risk in municipal bond spreads. The academic literature on municipal bonds has also focused on tax effects as important issues in the US market (Green 1993, Ang et al. 2010, Longstaff 2011), but we can realistically omit the tax effect when it comes to Japanese municipal bonds. This implies that we can concentrate our attention on the liquidity and credit risk and this enables us to decompose these factors more accurately.

We show that the liquidity premium drives 65–70% of the variation in the average municipal yield spread relative to government bonds. Even after the recent financial crisis, the liquidity component explains more than half of the total fluctuation in the spread. Our estimates have strong implications for public policy as this implies that local governments in Japan could potentially reduce more than half of their funding cost through enhancing liquidity, even if the credit risk of the issuers remains the same. For example, reopening the Japanese municipal bond market could be one way to enhance liquidity.

The main contributions of this paper are threefold. First, we construct a liquidity measure using the spread of JGGBs and JGBs (J-liquidity measure), and provide it publically through our website (https://sites.google.com/site/hattori0819/data). We also elaborate upon the characteristics of the J-liquidity measure and assert that this measure adequately captures illiquidity events by implementing structural change tests.

Second, we argue that the J-liquidity measure has better properties as a market liquidity measure than other more conventional liquidity measures. In fact, the J-liquidity measure spikes up much more prominently than other liquidity measures during liquidity crisis, whereas other common liquidity measures such as turnover and the on-the-run premium cannot even capture the effect of financial crisis. Furthermore, we show that the J-liquidity measure also has a high correlation with several other liquidity measures (including the bid-ask spread, Amihud measure, and yield curve fitting noise), implying our measure captures the illiquidity condition of the fixed-income market overall.

Finally, we conduct model-free analysis to decompose the yield spread of TMBs. We estimate the credit risk premium using the J-liquidity measure, and show that the liquidity premium explains about 65–70% of the total movement of the municipal spread. As far as we are aware, no comparable study examines the term structure of the municipal bond spread and decomposes into its credit and liquidity components on a daily basis.

The remainder of the paper is organized as follow. Section 2 describes the construction of the J-liquidity measure and provides the results of a structural change test of trends in this measure. Section 3 compares the J-liquidity measure with the other measures of liquidity, demonstrating that the J-liquidity measure has good properties for capturing both illiquidity events and aggregate market liquidity. In Section 4, we decompose the TMB spread into its credit and liquidity premiums. Section 5 concludes.

2. J-LIQUIDITY MEASURE: THE SPREAD OF JGGBs AND JGBs

2.1 Japanese Government-Guaranteed Bond (JGGBs)

Incorporated administrative agencies run businesses for public purposes in Japan in their role as government agencies.[1] The central government guarantees their debt within the maximum amount provided in the budget. Figure 1 illustrates the scheme of issuance of JGGBs. The incorporated administrative agencies issue bonds and the central government explicitly and fully guarantees these bonds. In 2015, 10 agencies issued JGGBs with an amount outstanding of 34.9 trillion yen (equivalent to about 4% of the JGBs on issue). Ten years is the typical bond maturity, though bonds are or have been on issue with maturities ranging from two to thirty years.

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[1] An incorporated administrative agency is an organization responsible for indispensable public services that the government does not have to provide by itself.

Table 1 compares JGGBs and JGBs. As shown, the number of individual JGGBs issued exceeds that of JGBs because several agencies issue JGGB on a regular basis and the reopening has not been implemented in JGGBs. During 2011–2015, there were 342 JGBs and 605 JGGBs outstanding on average, amounting to some 737.5 and 35.8 trillion yen, respectively. For this reason, we could suspect that the two segments differ markedly in their liquidity in that the ratio of amount outstanding to bonds on issue is 36 times higher for JGBs than JGGBs. Ministry of Finance Japan started implementing a reopening rule from March 2001 for JGBs to enhance market liquidity.

2.2 J-liquidity measure

We estimate the zero-coupon yield of JGBs and JGGBs to construct the J-liquidity measure. To obtain the coupon and price, we use Reference Statistical Prices [Yields] for OTC Bond Transactions compiled by the Japan Securities Dealers Association (JSDA). The JSDA collects bond prices and coupons on a daily basis from 18 main securities firms and provides the data on its website.

We employ a spline-based approach to estimate the zero-coupon yield. According to the Bank for International Settlement (2005), the spline-based approach is widely used by many central banks. The financial market data sources such as Bloomberg L.P. also use the spline-based approach to estimate the zero-coupon yield. Following Steeley (1991) and Kikuchi and Shintani (2012), we interpolate the discount factors based on the B-spline method. We estimate the 1- to 10-year zero-coupon yield from 2005/5–2014/9.[2]

We define the s year zero-coupon yield at time t for JGBs and JGGBs as $y_t^{JGB}(m)$, $y_t^{JGGB}(m)$(where m denotes the time to maturity), and define the liquidity premium as:

$$J - liquidity\ measure_t(m) \coloneqq y_t^{JGGB}(m) - y_t^{JGB}(m) \tag{1}$$

We refer to this liquidity premium as J-liquidity measure. As the measure draws on the yield

[2] JGGBs with maturities exceeding 10 years were on issue after May 2005. The impact of Japan's negative interest rates is evident in the short term after September 2014.

curve for JGGBs and JGBs, it enables us to capture the term structure of the liquidity premium.

Figure 2 plots the time series variation of the 2-, 5-, and 10-year J-liquidity measures (Table 2 provides summary statistics). The behavior of the J-liquidity measure should be as follows. First, the liquidity premium for each should move closely together (the correlation between the 2- and 5-year measures is 0.96, while that between the 2- and 10-year measures is 0.88). Second, there is a sharp hike around 2007–2008, which is in the middle of the global financial crisis. Furthermore, this measure also captures specific events in Japan, such as the Yūbari shock (the insolvency of Yūbari City)[3] in 2006 and the Great East Japan Earthquake in March 2011. Third, the short-term liquidity spread increased during the latter stages of the most-recent financial crisis, causing the liquidity spread curve to flatten. Figure 3 plots the spread (relative value) of the J-liquidity measure (5- to 2-year, 10- to 2-year, and 10- to 5-year measures). As shown, these spreads have fluctuated between 2 and −2 basis points (bps). However, the spread decreased sharply in late 2008 and early 2009 even though the level of the illiquidity peaked from late 2007 to early 2008, corresponding to BNP Paribas' decision to terminate withdrawals from its hedge fund and the sales of Bear Stearns to JP Morgan. After the default of Lehman Brothers, long-term illiquidity declined in Japan while short-term illiquidity remained relatively high. This suggests investors faced a short-term liquidity shock in late 2008 and early 2009, even though the risk of long-term illiquidity generally declined during this period.

2.3 Identifying structural change

We now empirically test whether our J-liquidity measure adequately captures the illiquidity condition of the fixed-income market. Hu et al. (2013) have argued that a good liquidity measure should capture illiquidity events sharply. In this section, we empirically test whether the J-liquidity measure can capture the illiquidity crisis using a structural break test. We employ the same methods as Trebbi and Xiao (2016), who apply tests for multiple breakpoint estimation (Bai and Perron 1998, 2003a) to liquidity measures of US Treasury bonds. The underlying assumption of these tests is that the level of J-liquidity moves around some stable mean in the absence of structural changes, and that these tests can detect the structural breakpoints when the

[3] In 2006, Yūbari City in Hokkaido prefecture became insolvent and declared a public finance emergency, an event widely known as the Yūbari shock. See Hattori and Miyake (2015) for details.

level of liquidity changes.

As in Trebbi and Xiao (2016), we follow the approach recommended by Bai and Perron (1998, 2003a). Bai and Perron (1998, 2003a) first suggest using the UD max or WD max test to see if at least one break is present in the entire sample; if there is at least one break, then conduct the sequential approach. We apply this same approach to the 2-, 5-, and 10-year J-liquidity measures.

Table 3 includes double-maximum test statistics of breaks in the means of the J-liquidity measures, the results of which indicate there is at least one break in the 2-, 5-, and 10-year J-liquidity measures. Table 4 provides sequential test statistics of multiple breaks in the means of the J-liquidity measures, while Figure 4 plots the 2-, 5-, and 10-year J-liquidity measures with the estimated mean for each sub period. The estimates of the break dates use the Bai and Perron (1998, 2003a) approach at the 5% significance level. Figure 4 shows that the J-liquidity measure can capture both the Yūbari shock in 2006–2007 and the global financial crisis in 2007–2009. The increase in illiquidity during the Yūbari shock particularly supports our argument that the municipal yield spread to government bonds should be a good application for the J-liquidity measure.

3. COMPARISON WITH OTHER LIQUIDITY MEASURES

This section describes the advantages of the J-liquidity measure over other more common liquidity measures. As already pointed out, the J-liquidity measure provides new information with respect to the term structure of the liquidity premium on a daily basis. However, there are alternative measures of market liquidity,[4] and so we now investigate the relation between our measure and these other measures of market liquidity. Drawing on Hu et al. (2013), we argue that the J-liquidity measure should have the following properties to qualify as a good liquidity measure. First, it should provide new information about market liquidity beyond existing

[4] The analysis of liquidity in the Japanese fixed-income market has mainly focused on JGBs and JGB futures with studies such as Tsuchida et al. (2016). Following the Quantitative and Qualitative Easing Policy pursued by the Bank of Japan, market participants have begun to pay much more attention to JGB liquidity, and the Bank of Japan has begun to release data on more than ten market liquidity measures regularly through its reports (Liquidity Indicators in the JGB Markets).

liquidity measures (i). Second, it should work as a good indicator during liquidity crises (ii). Third, it should help us to understand liquidity in the overall market beyond the JGGB market[5] (iii). As we have already seen, the J-liquidity measure provides completely new information about liquidity (both the "premium" and the term structure), so we conclude the J-liquidity measure meets the requirements of (i). Thus, the purpose of this section is to demonstrate empirically that the J-liquidity measure satisfies (ii) and (iii) when compared with the other liquidity measures.

First, we employ the same structural break test (Bai and Perron 1998, 2003a) with the other liquidity measures, and show that popular measures such as turnover and the on-the-run premium cannot capture illiquidity events in the Japanese fixed-income market. In addition, we compare how much these measure sharply capture illiquidity during the financial crisis, and conclude that the performance of our measure is considerably better, especially during the period from late 2007 to early 2008. Second, we follow previous studies (Flemming 2003, Goyenko et al. 2009) and show that the J-liquidity measure is highly correlated with the other liquidity measures (including the bid-ask spread, Amihud, and the yield curve-fitting noise), suggesting our proposed measure adequately captures aggregate liquidity risk in the fixed-income market.

3.1 Other measures of market liquidity

We use several empirical proxies for liquidity, including (i) turnover, (ii) the bid-ask spread, (iii) the Amihud measure, (iv) the yield curve-fitting noise, and (v) the on-the-run premium. The definitions and data sources follow:

3.1.1 Turnover (negative)

The annualized turnover is the annualized trading volume divided by the amount outstanding. To convert this to a measure of illiquidity, we take the negative of turnover. The data source is monthly turnover data for JGBs, JGGBs, and Japanese corporate bonds from the JSDA.

3.1.2 Bid-ask spread

The bid-ask spread is a widely used measure of liquidity and reflects the costs of executing

[5] Hu et al. (2013) originally focused on the liquidity factor as a way to understand better the returns on assets.

trades. The spread itself is the difference between the bid and offer price. We obtain the bid-ask spread for JGB futures from Bloomberg on a daily basis.

3.1.3 Amihud measure

Amihud (2002) constructs an illiquidity measure defined as the ratio:

$$\text{Amihud} = \text{average}\left(\frac{|r_t|}{Volume_t}\right)$$

where r_t is return and $Volume_t$ is the trading volume on day t. This then captures price impact, reflecting the price response associated with trading volume. We calculate this measure using daily data on JGB futures from Bloomberg and compute the monthly average.

3.1.4 Yield curve-fitting noise

Hu et al. (2013) propose a market-wide liquidity measure by exploiting the relation between the amount of arbitrage capital in the market and the observed noise in US Treasury bonds. The inference is that a shortage of arbitrage capital allows yields to deviate more freely from the yield curve, thereby resulting in more noise in prices. As we follow Hu et al. (2013), we construct the noise measure by fitting daily data for JGBs, JGGBs and TMBs into a smooth yield curve using the approach in Svensson (1994), and then compute the mean squared errors as the illiquidity measure. As in Hu et al. (2013), we only use bonds with maturities between 1 and 10 years in constructing the noise measure.

3.1.5 On-the-run premium

The on-the-run premium is the difference between the yield of a newly issued (on-the-run) bond and the yield of a previously issued bond and this premium is interpreted as a liquidity premium. We take the spread between the on-the-run yield and the off-the-run spreads without interpolation when the maturity exactly matches. We interpolate the off-the-run yield when the same maturity as the current yield does not exist.[6] We compute the on-the-run premium for 2-

[6] We interpolate the yield using the B-spline method developed by Steeley (1991) and following Kikuchi and

and 5-year JGBs for which we use the daily data from JSDA.

3.2 Structural change in the other liquidity measures

Figure 5 plots each of the five other liquidity measures with their estimated mean for each subperiod. Table 5 provides summary statistics for the liquidity measures. As discussed in Section 2.3, we estimate the break dates following Bai and Perron approach (1998, 2003a) at the 5% significance level.[7] As illustrated, the bid-ask spreads, Amihud measure, and yield curve-fitting noise can capture the spike during the financial crisis, but not turnover and the on-the-run premium during the financial crisis. The trend in the turnover ratio implies that illiquidity during the financial crisis was contradictorily lower than the illiquidity after the financial crisis. In addition, the on-the-run premium does not consistently display a positive value (ranging from −2 to 2 bps).[8] These features lead us to conclude that turnover and the on-the-run premium are not good proxies of illiquidity.

Next, following Hu et al. (2013), we compare the level of illiquidity during the financial crisis period (September 2007–March 2008, April 2008–September 2009) using the standard deviation to demonstrate that the J-liquidity measure can capture the very rapid increase in illiquidity during the financial crisis. Table 6 details the ratio of the standard deviations for each subsample period to the full sample period. In the first subperiod, the standard deviations of the subsample period for the 2-, 5-, and 10-year J-liquidity measures were 1.67, 2.08, and 1.99 times larger than those of the full sample period, respectively. In contrast, the standard deviations of the other liquidity measures within the first subsample period were even smaller than for the full sample period. In the second subperiod, the standard deviations of the 2-, 5-, and 10-year J-liquidity measures were 1.39, 1.37, and 1.39 times larger than for the full sample period, respectively, and were almost the same as those for the Amihud measure and the bid-ask spread. During this

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Shintani (2012).

[7] The appendix provides the test statistics for the Bai and Perron structural break test for the various liquidity measures.

[8] There is strong evidence that an on-the-run premium exist in the US Treasury bond market (Krishnamurthy 2002). However, the on-the-run premium has only a negligible effect on liquidity in the German government bond market (Ejsing and Sihvonen 2009).

period, the yield curve-fitting noise increased markedly, which is the consistent with the results in Hu et al. (2013).

3.3 Correlation between the J-liquidity and other liquidity measures

To discuss whether J-liquidity measure can capture the liquidity of the fixed-income market overall, we analyze its correlation with the other liquidity measures following Fleming (2003) and Goyenko et al. (2009). As shown in Table 7, we find the bid-ask spread and yield curve-fitting noise display a high correlation with the J-liquidity measure. The correlation for both exceeds 0.5, while the correlation between the 2- and 5-year J-liquidity measures and the yield curve-fitting noise for JGBs is especially high (over 0.6). These results imply that the J-liquidity measure captures the liquidity of JGBs and this is consistent with the fact that Longstaff (2004) use the spread of US government-guaranteed bonds and US Treasury bonds to calculate the liquidity premium in the Treasury market. The Amihud measure, which is a proxy of the price impact of JGB futures, also has a positive correlation (between 0.2 and 0.4). Basically, the correlation with these other measures (bid-ask spread, yield curve-fitting noise, and the Amihud measure) is stronger with the 2-year J-liquidity measure, implying these other measures have stronger power capturing short-term illiquidity risk.

On the other hand, there is no positive correlation between the J-liquidity measure and turnover/the on-the-run premium. In particular, the correlation between the turnover of JGBs and the corresponding J-liquidity measure is about from −0.8 to −0.9 As we pointed out in Section 3.2, the reason for this is that turnover and the on-the-run premium are not generally good liquidity indicators.

4. DECOMPOSITION OF THE LIQUIDITY PREMIUM: TOKYO METROPOLITAN BONDS IN JAPAN

In this section, we use the J-liquidity measure to decompose the spread between JGBs and TMBs (T-spread) into its credit and liquidity premiums. Especially during the financial crisis, this can be quite difficult because the respective premiums can be highly correlated. However, our approach does not depend on any model to disentangle these premiums, enabling us to obtain robust estimates. Furthermore, the J-liquidity premium provides the term structure of the liquidity premium and we can avoid the maturity mismatch problem when decomposing the spread.

4.1 Advantages of municipal bonds in Japan

We consider the application of J-liquidity measure to TMBs, which is the largest and the safest municipal bond in Japan. The reasons for our choice are threefold. First, the yield curve-fitting noise (proxy of liquidity) of JGGBs and TMBs are highly correlated (correlation is 0.96). Second, the buying and selling trends for JGGB and Japanese municipal bonds are similar (see the Appendix for details), suggesting that the products and their investors have similar characteristics. Third, as we have previously shown, the J-liquidity measure is able to capture the Yūbari shock, which is the largest illiquidity event in the municipal bond market in Japan.

As mentioned, one of the biggest advantages to selecting the Japanese municipal bond market for analysis is that we can ignore the tax effect. Existing studies of the municipal bond in the US focus on not only market liquidity, but also the tax effects (Wang et al. 2008, Ang et al. 2014, Schwert 2016). However, we can concentrate on the liquidity and credit factors in the Japanese municipal bond market because tax-exempt bonds do not exist.

The size of the Japanese municipal bond market is also considerably larger than in most comparable economies. As of 2013, total outstanding municipal debt, comprising debt loans and bonds, owned by Japanese local governments was $1.7 trillion, which is second only to the US among developed economies.

4.2 Tokyo Metropolitan Bonds (TMBs)

TMBs are the largest municipal bonds on issue in Japan. In March 2016, more than 6.8 trillion yen in TMBs were on issue, representing 20% of total publicly offered municipal bonds in Japan. In addition, TMBs are Japan's safest municipal bonds in terms of them having the lowest T-spread and the highest credit rating. For this reason, the T-spread of TMBs often serves as the basis rate for municipal bonds in Japan.

TMBs have a wide range of maturities, including 3, 5, 6, 7, 10, 20, and 30 years (although more than half of total issuance is 10-year bonds). The frequency of issuance is also high (e.g., monthly issuance of 10-year bonds) and TMBs do not have reopening. In 2015, there were 184 TMBs on issue.

4.3 Decomposition

Following Schwert (2016), we express the yield of TMBs as:

$$y_{s,t} = r_{s,t} + \gamma_{s,t} + \mu_{s,t}$$
$$\Leftrightarrow y_{s,t} - r_{s,t} = \gamma_{s,t} + \mu_{s,t} \qquad (2)$$

where s denotes the maturity and t represents the time. The parameter $r_{s,t}$ denotes the risk-free rate, $\gamma_{s,t}$ represents the default premium, and $\mu_{s,t}$ represents the liquidity premium. Schwert (2016) originally models the wedge between tax-exempt and taxable yields, but we can omit this effect because municipal bonds in Japan do not incorporate these differences.

Equation (2) indicates that we decompose the municipal bond T-spread into two factors: the credit premium and the liquidity premium. We consider the J-liquidity measure as a proxy of the liquidity premium of TMBs, attributing the remaining liquidity spread to the credit risk. This methodology is in line with previous studies in the areas such as Dick-Nielsen et al. (2012) and Schwert (2016). We estimate the zero-coupon yield of TMBs based on the B-spline method using JSDA data.

Figure 6 plots the trend of the T-spread (2, 5, and 10 year) with the decomposed credit premium and liquidity premium. As shown, the credit premium increased during the Yūbari shock (2006–2007) and the global financial crisis (2008–2009). Table 8 summarizes the mean of the credit/liquidity premium and the proportion of T-spread for each premium over each period. As detailed, liquidity accounts for about 60–70% of the average municipal bond spread, and this result is similar to that in Ang et al. (2014), which found that liquidity accounts for 74% of the total spread in the US municipal bond market.

Table 8 breaks the sample into four subperiods: (i) before the Yūbari shock (2005/5–2006/4), (ii) during the Yūbari shock (2006/5–2007/7), (iii) during the financial crisis (2007/8–2009/12), and (iv) after the financial crisis (2010/1-2014/9). As shown, before the Yūbari shock, the credit premium was stable and low although its premium increased after Yūbari shock. The average credit spread from 2005/5 to 2006/4 was 0.6 bps (2 year), 1.1 bps (5 year), and 0.9 bps (10 year), and from 2006/5 to 2007/7, the credit spread increased to 1.4 bps (2 year), 1.6 bps (5 year), and 1.3 bps (10 year), respectively. The credit premium peaked during the financial crisis, averaging 3.5 bps (2 year), 3.6 bps (5 year), and 4.8 bps (10 year) from 2007/8 to 2009/12. However, the premium was steady with some decrease after the crisis, averaging 2.3 bps (2 year), 1.6 bps (5 year), and 2.2 bps (10 year) from 2010/1 to 2014/9. This result is consistent with Hattori and Miyake (2015), who showed that (i) before the Yūbari shock, credit risk had no impact on the yield spread, (ii) after Yūbari City's insolvency in 2006, investors had begun accounting for local government outstanding debt, and (iii) during the financial crisis, investors became more aware of the presence of credit risk.

5. CONCLUSION

We argue that the J-liquidity measure (the spread between JGGBs and JGBs) displays good properties for capturing market liquidity. This model-free approach can capture illiquidity events and the illiquidity condition of the fixed-income market overall. In addition, this measure provides the term structure of liquidity premiums, which is completely new information that other liquidity measures cannot evidently capture.

We demonstrate the application of the J-liquidity measure to decompose the yield spread of municipal bonds into its credit and liquidity components based on TMB. There is ongoing debate about whether the credit premium plays an important role in the T-spread in the US municipal bond market, and our result shows the liquidity is not a negligible factor in the Japanese market. This has strong policy implications: local governments have the opportunity to reduce their financing costs by enhancing market liquidity for their debt securities.

Given the importance of market liquidity for macroeconomics and finance, we openly provide our J-liquidity measure and dataset, which are available on the author's website (https://sites.google.com/site/hattori0819/data).

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Table 1 Summary Statistics for JGB and JGGB

	JGB(outstanding)		JGGB(outstanding)	
	No. of Issues	Amount of Issued (trillion yen)	No. of Issues	Amount of Issued (trillion yen)
2000-2005	257	351.7	491	34.6
2006-2010	323	523.2	554	37.0
2011-2015	342	737.5	605	35.8

Notes: The data excludes T-bill, Inflation-Indexed Bonds, Floating-Rate JGB (CMT)

Source: Japan Securities Dealers Association

Table 2 Summary Statistics of J-liquidity Measure

J-Liquidity Measure	N	Mean	Median	Max	Min	SD	Skewness	Kurtosis	JB
2 year	2312	5.48	3.97	12.73	1.89	3.06	0.73	1.98	306.48
5 year	2312	5.60	4.16	13.47	2.14	3.01	0.89	2.33	345.81
10 year	2312	5.39	3.93	14.58	0.64	3.45	0.95	2.50	370.63

Notes: This table shows the summary statistics of J-liquidity measure (2 year, 5 year, and 10 year). J-measure is calculated as the difference between zero coupon rate of JGGB and that of JGB. The sample period is from May 2005 to September 2014. The data frequency is daily.

Table 3 Double Maximum Test Statistics of Breaks in the means of J-liquidity measure

Measure	WDmax	5% critical value of WDmax	UDmax	5% critical value of WDmax
2 year	2177.62	10.39	1442.97	9.52
5 year	1644.36	10.39	840.71	9.52
10 year	1063.02	10.39	832.52	9.52

Notes: This table shows the Double Maximum Test Statistics of break in the means of J-liquidity measure (the yield spread of JGGB and JGB). The sample period is from May 2005 to September 2014 in the daily basis. The dates are estimated by the Bai and Perron (1998, 2003) approach with 5 percent significance level. The null hypothesis is that there is no break, and the alternative hypothesis is that there is at least one break. The critical values are obtained from Bai and Perron (2003b) with 10% of Trimming rate.

Table 4 Sequential Test Statistics of Multiple Breaks in the means of J-liquidity measure

J-Liquidity Measure	F(2|1)	5% critical value of F(2|1)	F(3|2)	5% critical value of F(3|2)	F(4|3)	5% critical value of F(4|3)
2 year	558.48	10.55	204.79	11.36	182.88	12.35
5 year	698.55	10.55	77.04	11.36	24.24	12.35
10 year	802.64	10.55	29.56	11.36	6.95	12.35

J-Liquidity Measure	F(5|4)	5% critical value of F(5|4)	F(6|5)	5% critical value of F(6|5)	F(7|6)	5% critical value of F(7|6)
2 year	38.80	12.97	12.85	13.45		13.88
5 year	19.79	12.97	19.51	13.45	4.99	13.88
10 year						

Notes: This table shows the Sequential Test Statistics of break in the means of J-liquidity measure (the yield spread of JGGB and JGB). The sample period is from May 2005 to September 2014 in the daily basis. The dates are estimated by the Bai and Perron (1998, 2003) approach with 5 percent significance level. The critical values are obtained from Bai and Perron (2003b) with 10% of Trimming rate.

Table 5 Summary Statistics of Other Liquidity Measures

J-Liquidity Measure	N	Mean	Median	Max	Min	SD	Skew ness	Kurtosis	JB
Turnover (JGB)	113	-1.2	-1.1	-0.8	-2.3	0.4	-1.0	3.1	19
Turnover (JGGB)	113	-0.1	0.0	0.0	-0.2	0.0	-1.5	4.1	48
Turnover (Corporate Bond)	113	-0.1	-0.1	0.0	-0.1	0.0	-1.2	3.8	30
Bid Ask Spread (JGB futures)	2305	0.0	0.0	0.1	0.0	0.0	1.8	7.2	2985
Amihud (JGB futures)	113	1.2	1.1	3.7	0.4	0.5	1.6	7.2	135
Noise (JGB)	2312	2.2	2.1	6.7	0.8	0.8	1.3	5.7	1375
Noise (JGGB)	2312	1.9	1.8	6.7	0.7	0.6	2.1	10.3	6878
Noise (Tokyo)	2312	1.8	1.7	5.5	0.8	0.6	2.0	9.4	5477
On-the-run Premium (2year)	2312	0.0	0.0	0.0	0.0	0.0	-0.4	4.8	357
On-the-run Premium (5year)	2312	0.0	0.0	0.0	0.0	0.0	0.0	5.4	553

Notes: This table shows the summary statistics of turnover, bid-ask spread, Amihud measure, yield curve fitting noise and on-the-run premium. The sample period is from May 2005 to September 2014. The data frequency of bid-ask spread, yield curve fitting noise and on-the-run premium is daily and that of turnover and Amihud measure is monthly.

Table 6 Standard Deviations Compared with the Sample Average

	J-liquidity measure			Turnover			Bid Ask
	2 year	5 year	10 year	JGB	JGGB	Corporate	Futures
2007/9-2008/3	1.67	2.08	1.99	-1.96	-0.45	-0.38	0.25
2008/4-2008/9	1.39	1.37	1.39	-1.24	0.41	-0.14	1.55

	Amihud	Noise			On the run premium	
	Futures	JGB	JGGB	TMB	2 year	5 year
2007/9-2008/3	-0.29	0.51	0.91	0.66	0.16	-0.47
2008/4-2008/9	1.36	1.79	2.10	2.06	0.26	0.35

Notes: This table shows the ratio of the standard deviation for each subsample period to full sample. The average of full sample is computed using the data from 2005/5 to 2014/9.

Table 7 Correlations of J-liquidity Measures for the Other Liquidity Measures

	Turnover			Bid Ask	Amihud
	JGB	JGGB	Corporate	Futures	Futures
2 year	-0.822	-0.214	-0.247	0.620	0.472
5 year	-0.840	-0.297	-0.298	0.589	0.365
10 year	-0.880	-0.315	-0.306	0.506	0.202

	Noise			On the run premium	
	JGB	JGGB	TMB	2year	5year
2 year	0.673	0.656	0.558	-0.086	-0.102
5 year	0.645	0.620	0.508	-0.138	-0.137
10 year	0.503	0.496	0.376	-0.195	-0.144

Notes: This table shows the correlation of J-liquidity measure and the other liquidity measures: turnover, bid-ask spread, Amihud measure, yield curve fitting noise and on-the-run premium. Data is monthly basis.

Table 8 Decomposition of T-spread of Tokyo Metropolitan Bond (TMB)

(1) Average Basis Points among Each Periods

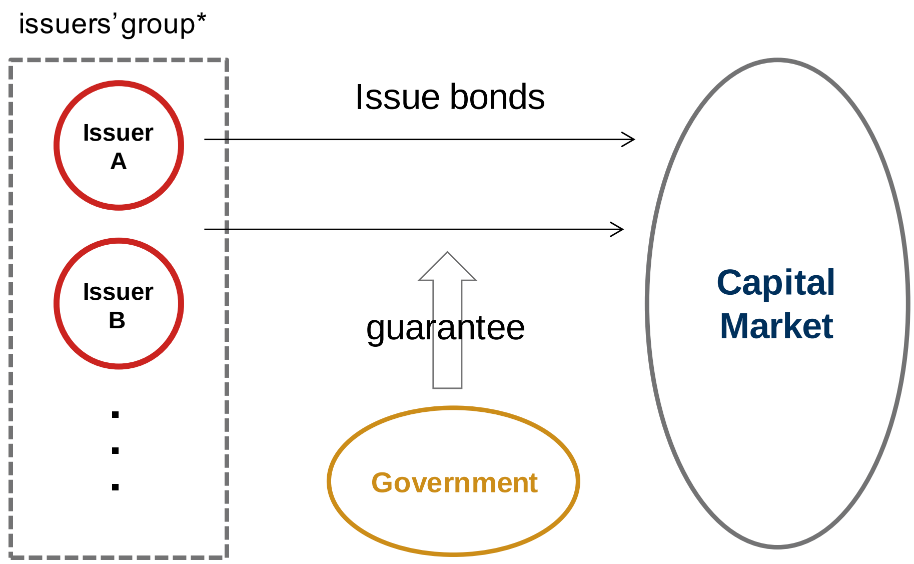
		Whole Sample	2005/5-2006/4	2006/5-2007/7	2007/8-2009/12	2010/1-2014/9
2 year	T-Spread	8.0	4.9	10.0	12.3	5.5
	Liquidity	5.5	4.3	8.6	8.8	3.2
	Credit	2.5	0.6	1.4	3.5	2.3
5 year	T-Spread	7.8	6.2	10.1	12.4	4.9
	Liquidity	5.6	5.1	8.5	8.7	3.3
	Credit	2.2	1.1	1.6	3.6	1.6
10 year	T-Spread	8.3	5.4	10.8	13.4	5.2
	Liquidity	5.4	4.5	9.5	8.6	3.0
	Credit	2.9	0.9	1.3	4.8	2.2

(2) Proportion of Liquidity and Credit Premium to T-spread among Each Period

		Whole Sample	2005/5-2006/4	2006/5-2007/7	2007/8-2009/12	2010/1-2014/9
2 year	Liquidity	67.4%	86.9%	86.6%	67.9%	57.9%
	Credit	32.6%	13.1%	13.4%	32.1%	42.1%
5 year	Liquidity	72.5%	82.4%	84.2%	66.7%	70.3%
	Credit	27.5%	17.6%	15.8%	33.3%	29.7%
10 year	Liquidity	64.9%	83.4%	87.5%	57.0%	59.0%
	Credit	35.1%	16.6%	12.5%	43.0%	41.0%

Notes: T-spread is computed as the difference between yields of TMB and JGB. Liquidity is J-liquidity measure (the difference between yield on JGGB and JGB). Credit is the spread of TMB’s T spread and J-liquidity measure.

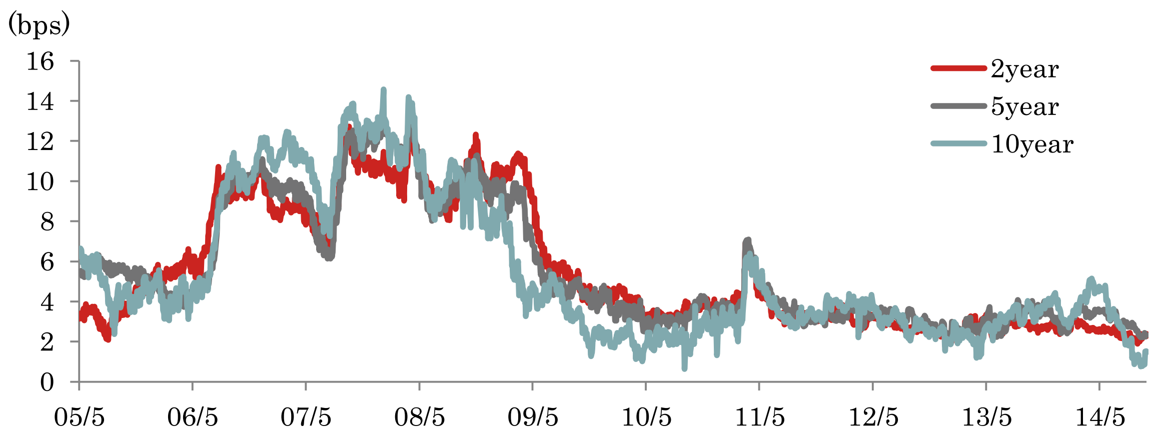
Figure 1 Scheme of Japanese Government Guaranteed Bond (JGGB)



* The issuers of Japan's Government Guaranteed Bond have to satisfy the following conditions; i) Conducting businesses for highly public purposes as agencies for the government. ii) Their financial accounting and administration are under governmental supervision.

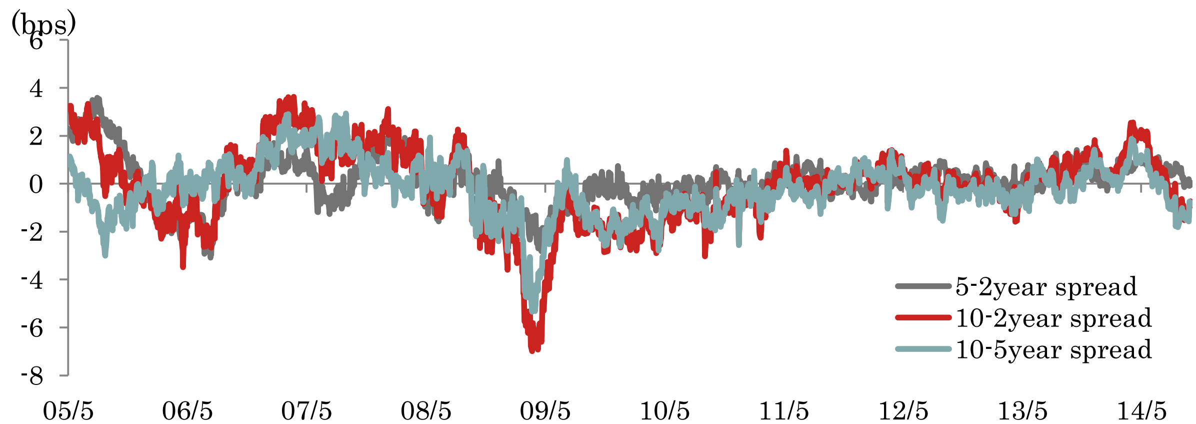
(Source) Ministry of Finance Japan

Figure 2 Time Series of J-Liquidity Measure (2 year, 5 year, and 10 year)



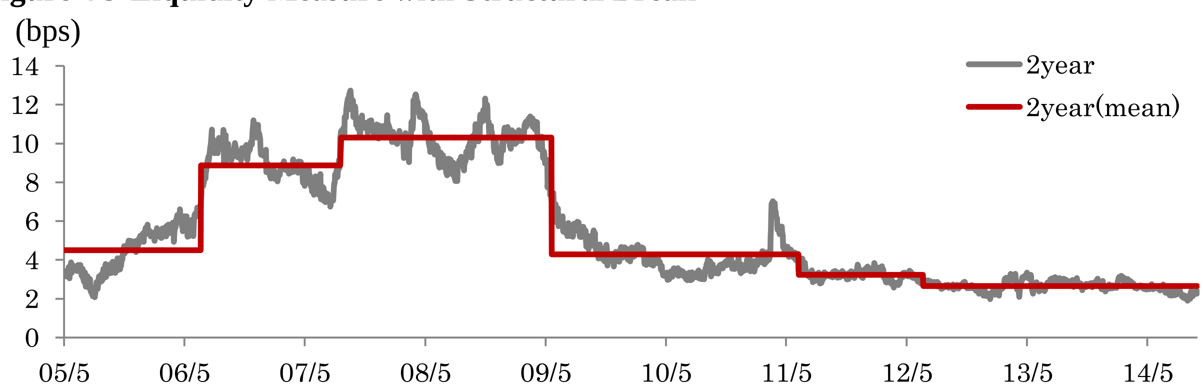
Notes: This graph shows the time series of J-liquidity measure (2-, 5-, and 10-year). J-measure is calculated as the difference between zero coupon rate of JGGB and that of JGB. The sample period is from May 2005 to September 2014. The data frequency is daily.

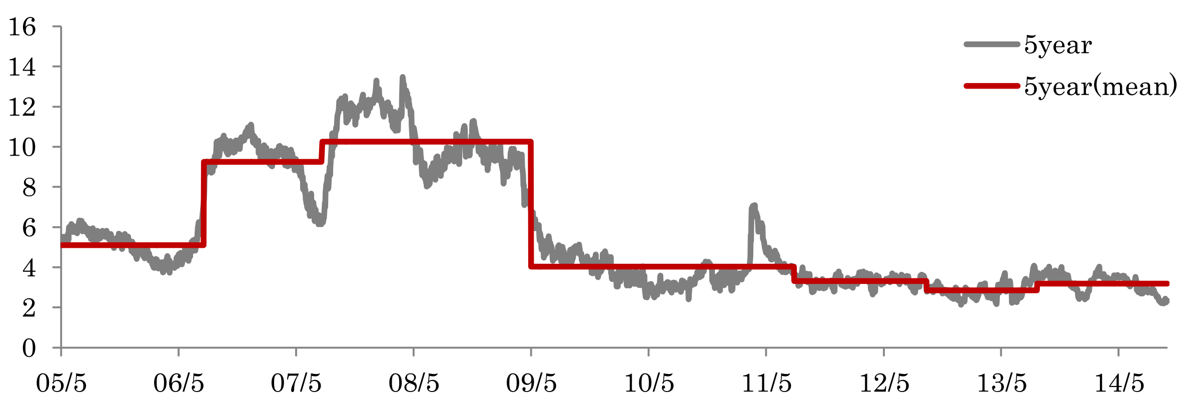
Figure 3 Spreads of J-Liquidity Measure

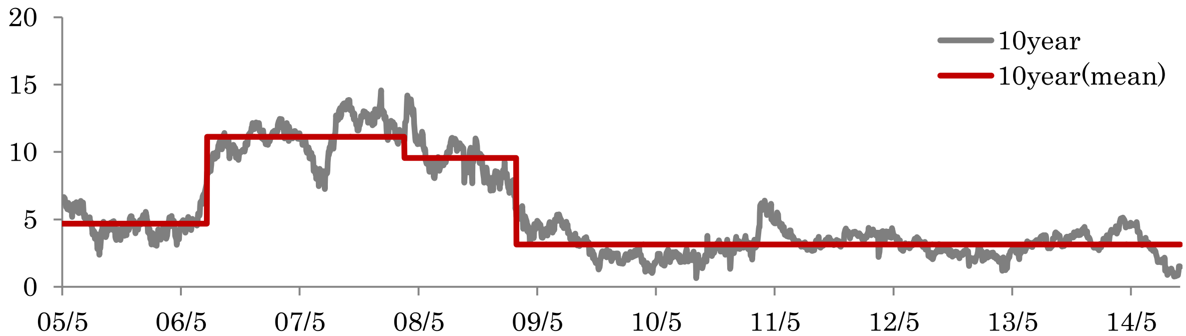


Notes: This graph shows the spread of J-liquidity measure (2-, 5-, and 10-year). J-measure is calculated as the difference between zero coupon rate of JGGB and that of JGB. The sample period is from May 2005 to September 2014. The data frequency is daily.

Figure 4 J-Liquidity Measure with Structural Break



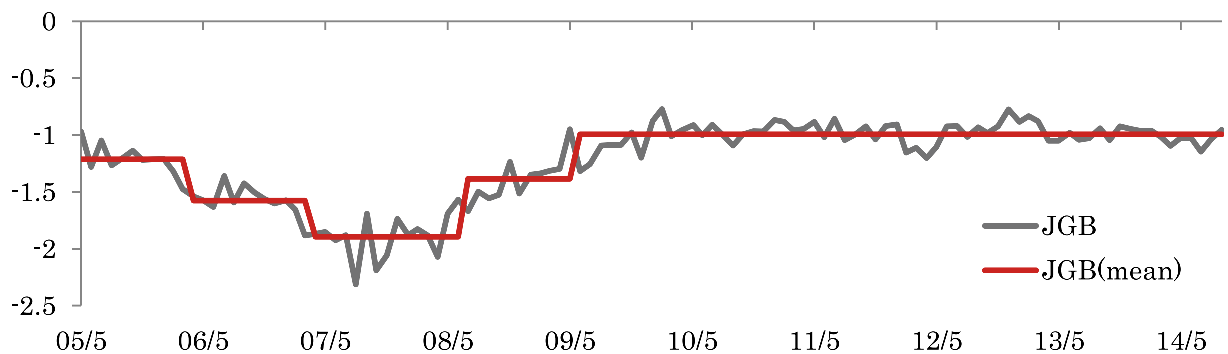




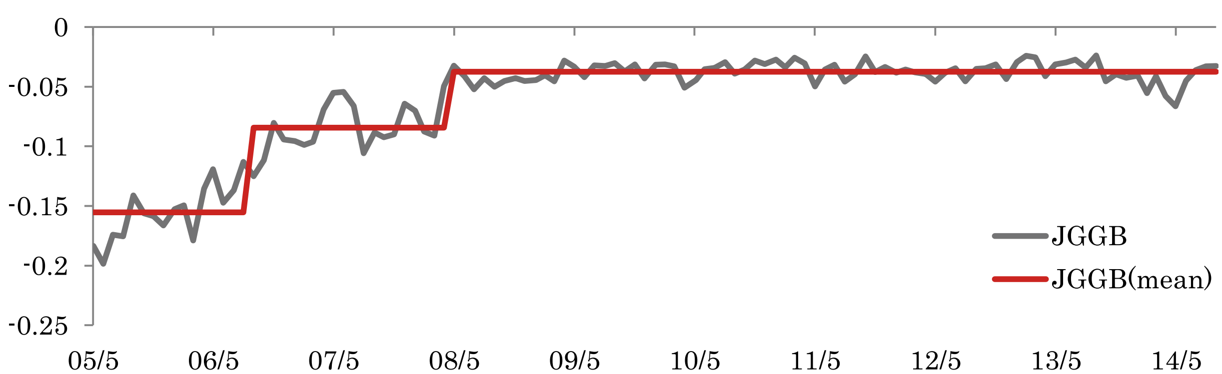
Notes: This graph shows the time series of J liquidity measures (gray line), and the estimated mean for each subperiod (red dashed line). The break dates are estimated by the Bai and Perron (1998, 2003) approach with 5% significance level. The sample period is from May 2005 to September 2014. The data frequency is daily. The critical values are obtained from Bai and Perron (2003b) with 10% of Trimming rate.

Figure 5 Other Liquidity Measures

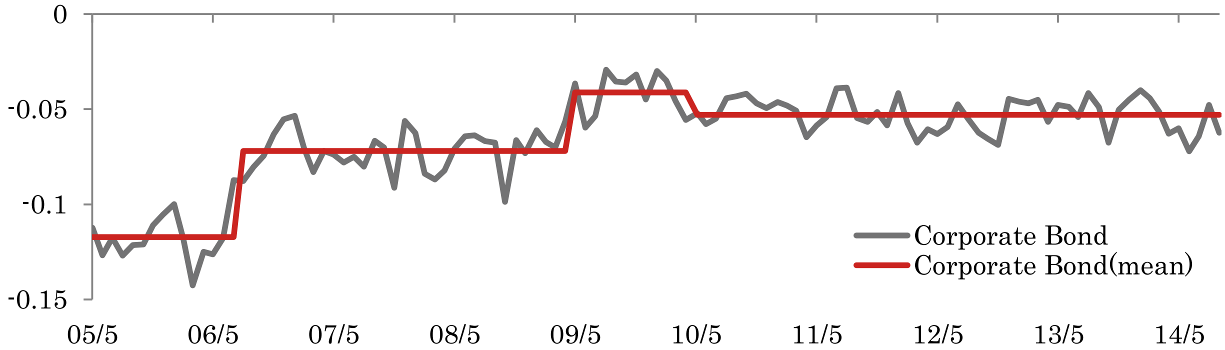
Turnover: JGB



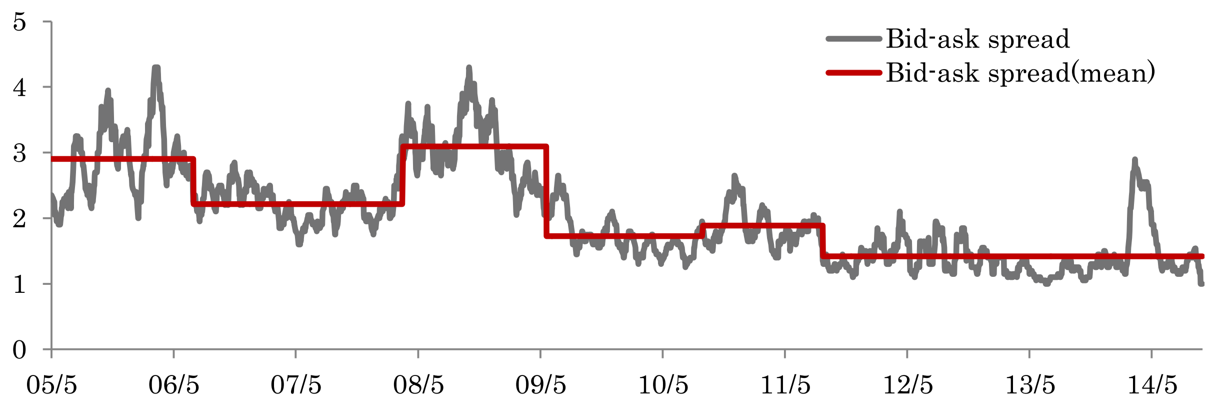
Turnover: JGGB



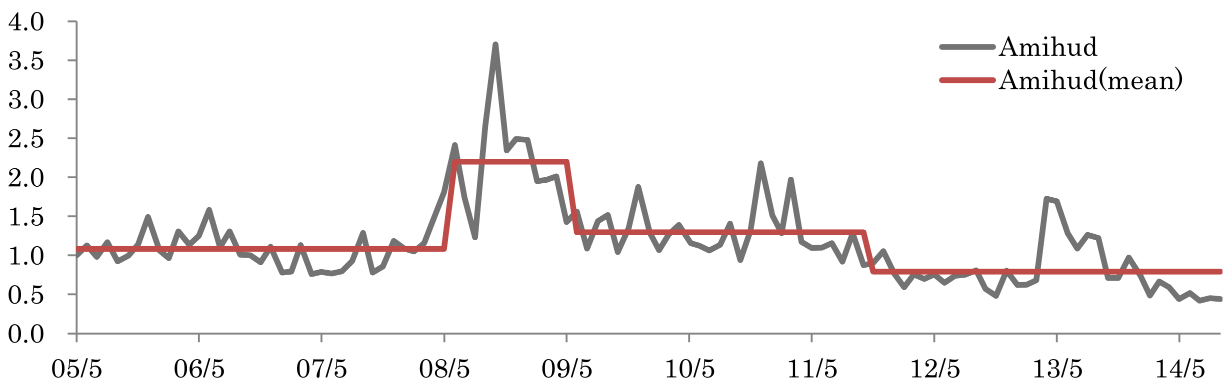
Turnover: Corporate Bond



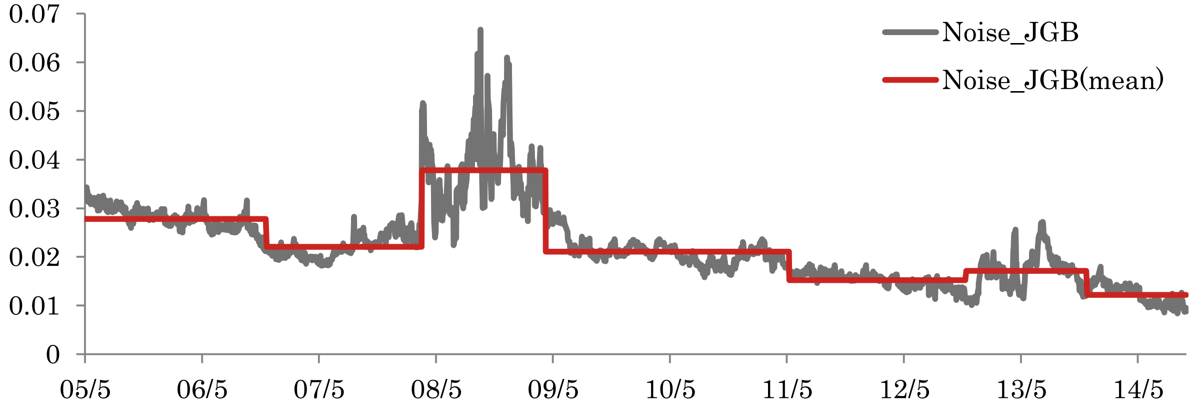
Bid-ask spreads: JGB futures



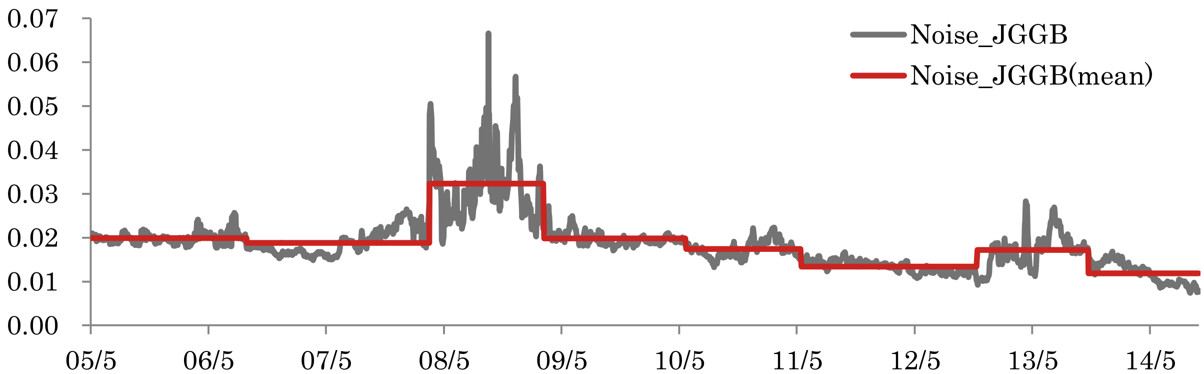
Amihud measure: JGB futures



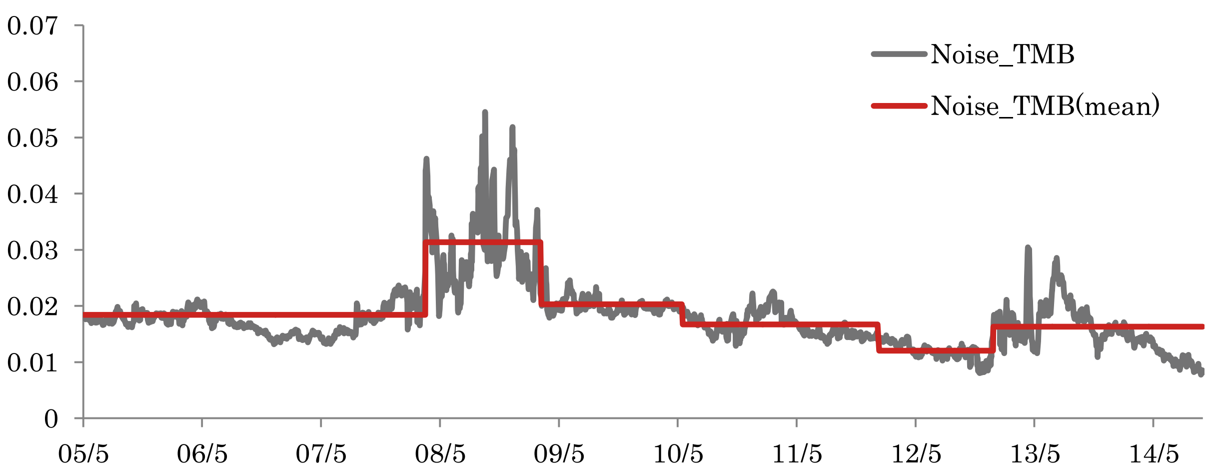
Yield curve fitting noise: JGB



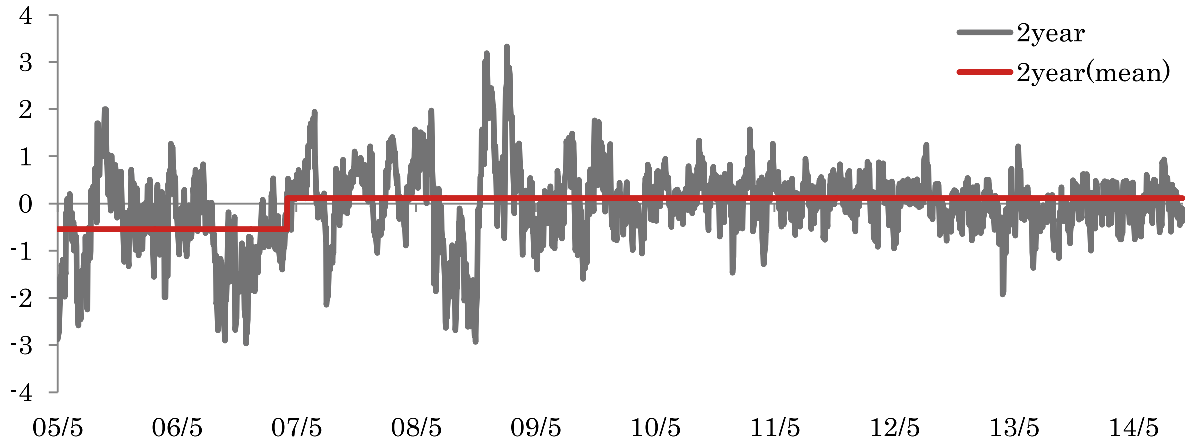
Yield curve fitting noise: JGGB



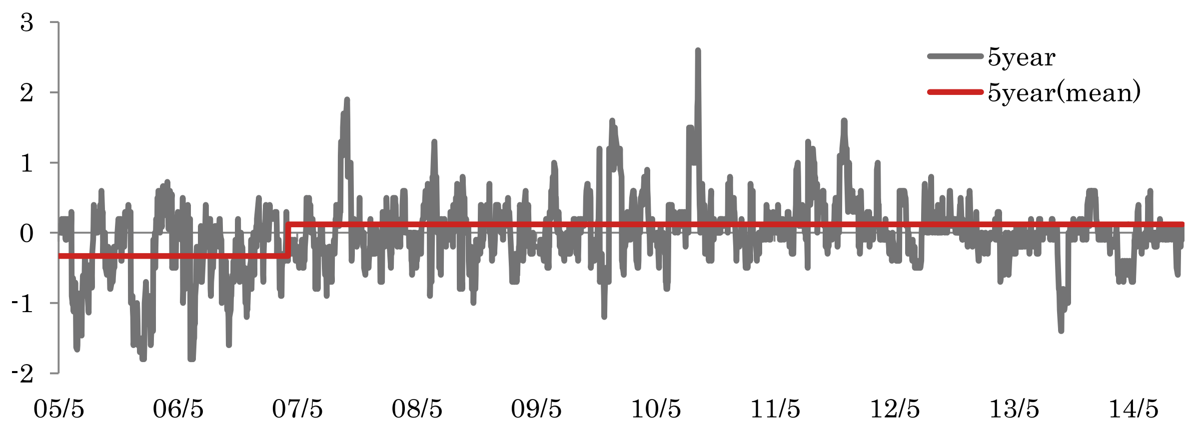
Yield curve fitting noise: Tokyo Metropolitan Bond



On-the-run premium: JGB 2 year

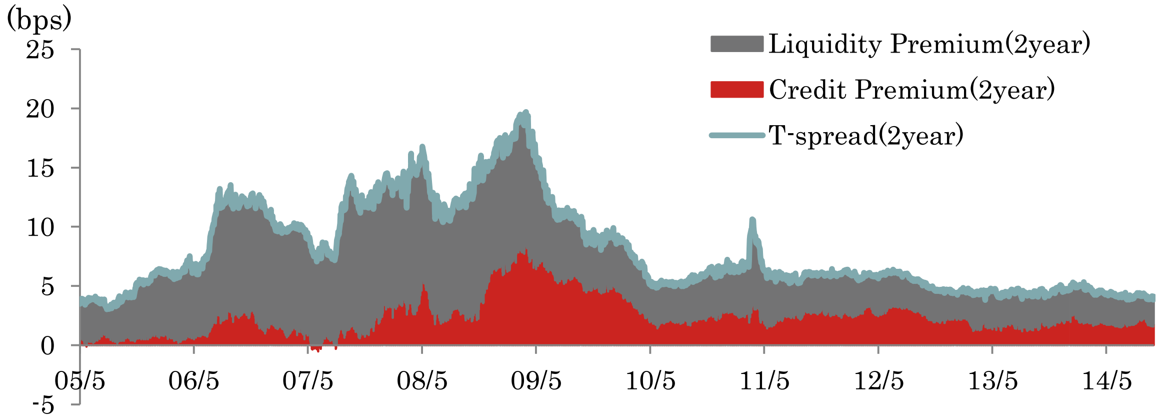


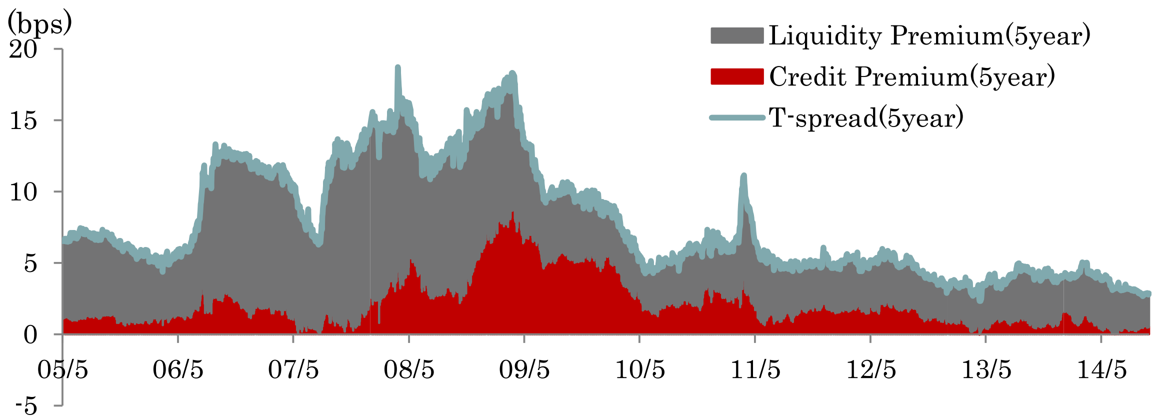
On-the-run premium: JGB 5 year

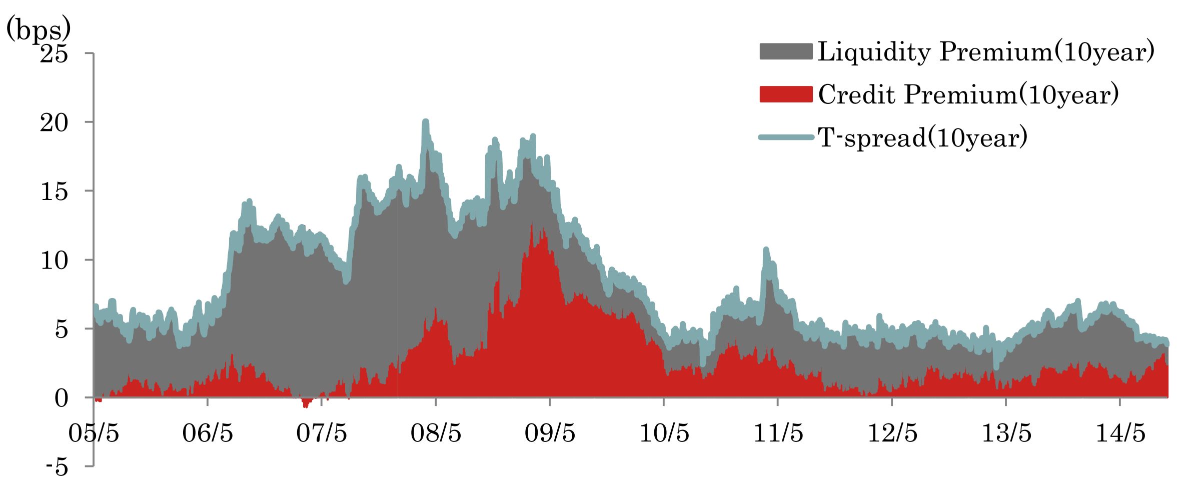


Notes: This graph shows the time series of liquidity measures: turnover, Amihud measure, Bid ask spread, Yield curve fitting noise, On-the-run premium (gray line), and the estimated mean for each subperiod (red dashed line). The break dates are estimated by the Bai and Perron (1998, 2003a) approach with 5% significance level. Trimming rate is 10%. The sample period is from May 2005 to September 2014. The data frequency of Bid-ask spread, Yield curve fitting noise and On-the-run premium is daily, and the data frequency of turnover and Amihud measure is monthly.

Figure 6 Decomposition of Tokyo Metropolitan Bond





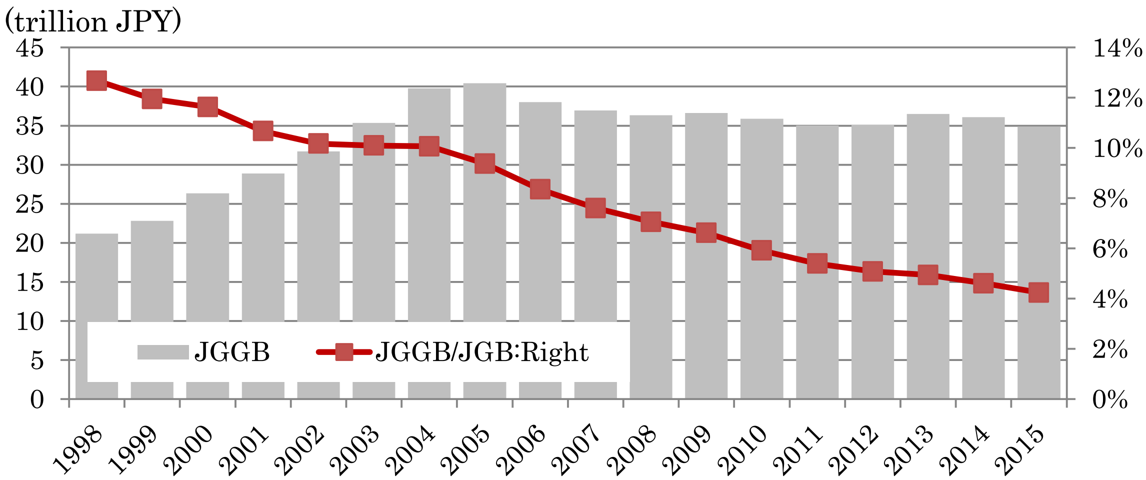


Notes: This figure presents the time series of decomposed spread (T-spread, Credit Premium and Liquidity Premium) of Tokyo Metropolitan Bond.

Appendix

1. Japanese Government-Guaranteed Bond (JGGB)

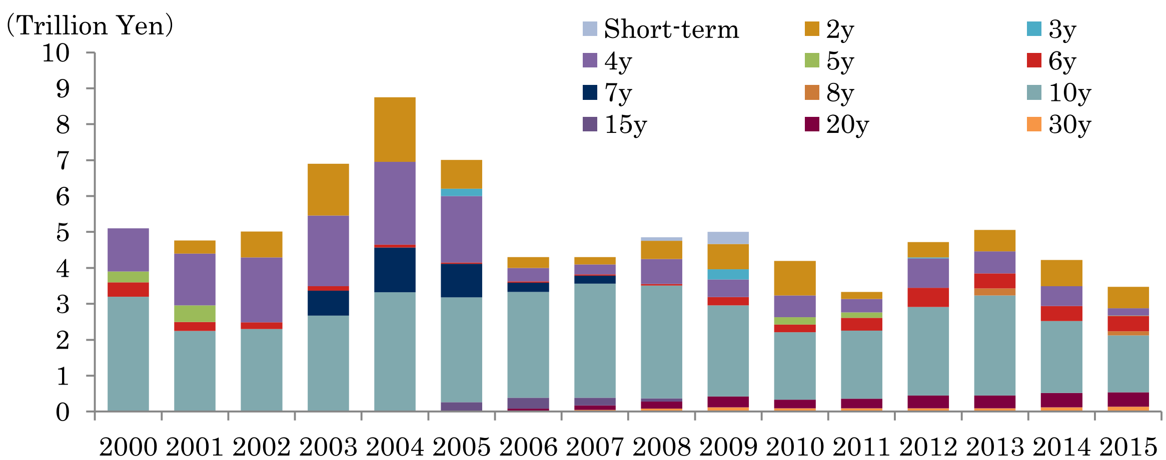
Table A1 Time Series of JGGB and Ratio of JGGB to JGB



Notes：JGB consists of the coupon bearing bond (2-40year). Fiscal Year.

Source：Japan Securities Dealers Association

Table A2 Time Series of Issuance Amount of JGGB



Notes: Fiscal Year

Source: Ministry of Finance Japan

2. The Results of Structural Break Test by Bai and Perron (1998, 2003a): Turnover, Bid-ask spread, Amihud measure, Yield curve fitting noise and On-the-run premium

Table A3 Double Maximum Test Statistics of Breaks in the means of the Liquidity Measure

Measure	WDmax	5% critical value of WDmax	UDmax	5% critical value of WDmax
Turnover (JGB)	353.60	10.39	193.12	9.52
Turnover (JGGB)	231.02	10.39	176.91	9.52
Turnover (Corporate)	229.36	10.39	229.36	9.52
Bid-Ask Spread (JGB futures)	267.57	10.39	267.57	9.52
Amihud (JGB futures)	62.67	10.39	30.80	9.52
Noise (JGB)	1228.35	10.39	497.01	9.52
Noise (JGGB)	513.85	10.39	216.72	9.52
Noise (TMB)	442.28	10.39	214.35	9.52
Off The Run Premium:2 year	43.77	10.39	42.37	9.52
Off The Run Premium:5 year	49.36	10.39	49.36	9.52

Notes: This table shows the double maximum statistics of break dates in the means of the liquidity measures (Turnover, Bid-ask spread, Amihud measure, Yield curve fitting error, On-the-run premium). The sample period is from May 2005 to September 2014. Turnover and Amihud measure are the monthly basis while the Bid-ask spread, Yield Curve fitting error and On-the-run premium are the daily basis. The dates are estimated by the Bai and Perron (1998, 2003a) approach with 5% significance level. Trimming rate is 10%. The null hypothesis is that there is no break and the alternative hypothesis is that there is at least one break. The critical values are obtained from Bai and Perron (2003b).

Table A4 Sequential Test Statistics of Multiple Breaks in the Means of Liquidity

Liquidity Measure	F(2|1)	5% critical value of F(2|1)	F(3|2)	5% critical value of F(3|2)	F(4|3)	5% critical value of F(4|3)
Turnover (JGB)	29.85	10.55	14.28	11.36	80.26	12.35
Turnover (JGGB)	81.78	10.55	4.97	11.36		12.35
Turnover (Corporate)	70.83	10.55	11.93	11.36	2.80	12.35
Bid-Ask Spread (JGB futures)	27.07	10.55	15.48	11.36	31.32	12.35
Amihud (JGB futures)	12.87	10.55	20.34	11.36	10.97	12.35
Noise (JGB)	271.68	10.55	94.46	11.36	261.11	12.35
Noise (JGGB)	67.75	10.55	65.73	11.36	96.71	12.35
Noise (TMB)	86.28	10.55	115.15	11.36	86.01	12.35
On-the-run premium (2year)	9.79	10.55		11.36		12.35
On-the-run premium (5year)	28.09	10.55	10.66	11.36		12.35

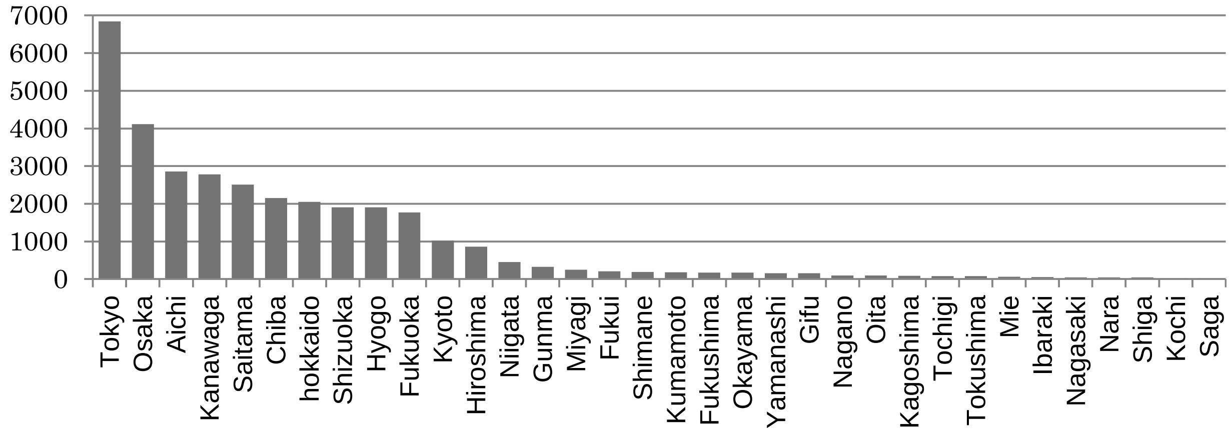
Liquidity Measure	F(5|4)	5% critical value of F(5|4)	F(6|5)	5% critical value of F(6|5)	F(7|6)	5% critical value of F(7|6)	F(8|7)	5% critical value of F(8|7)
Turnover (JGB)	1.92	12.97		13.45		13.88		14.12
Turnover (JGGB)		12.97		13.45		13.88		14.12
Turnover (Corporate)		12.97		13.45		13.88		14.12
Bid-Ask Spread (JGB futures)	13.50	12.97	3.68	13.45		13.88		14.12
Amihud (JGB futures)		12.97		13.45		13.88		14.12
Noise (JGB)	91.45	12.97	15.07	13.45	0.00	13.88	0.00	14.12
Noise (JGGB)	55.36	12.97	36.26	13.45	40.12	13.88	0.00	14.12
Noise (TMB)	53.52	12.97	16.84	13.45	0.00	13.88		14.12
On-the-run premium (2year)		12.97		13.45		13.88		14.12
On-the-run premium (5year)		12.97		13.45		13.88		14.12

Notes: This table shows the Sequential Test Statistics of break in the means of the liquidity measures (Turnover, Bid-ask spread, Amihud measure, Yield curve fitting noise, On-the-run premium). The sample period is from May 2005 to September 2014. The dates are estimated by the Bai and Perron (1998, 2003a) approach with 5% significance level. Trimming rate is 10%. The critical values are obtained from Bai and Perron (2003b).

3. Tokyo Metropolitan Bond

Table A5 Outstanding of Public Offering Municipal Bond in Japan(2016/3)

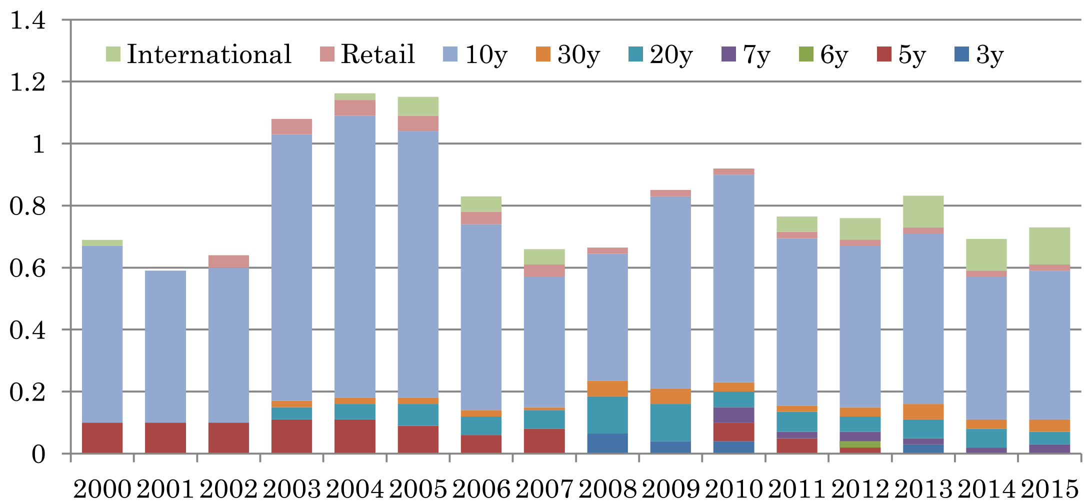
(Billion yen)



Source: Japan Local Government Bond Association

Table A6 Time Series of Issuance Amount of Tokyo Metropolitan Bond

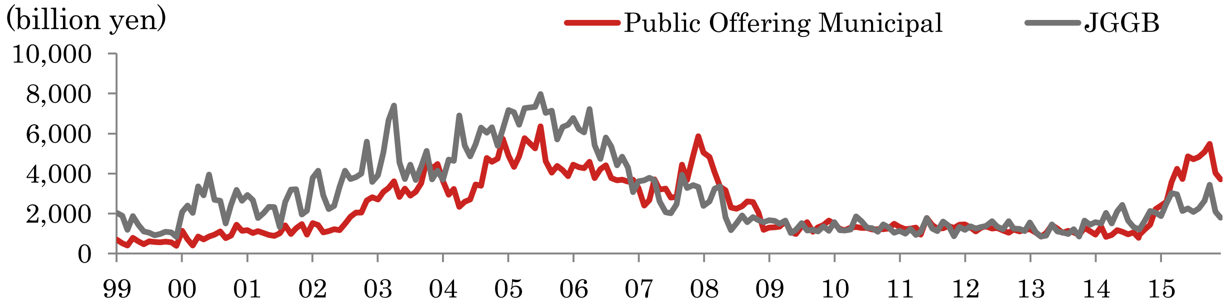
(trillion yen)



Notes: Fiscal Year

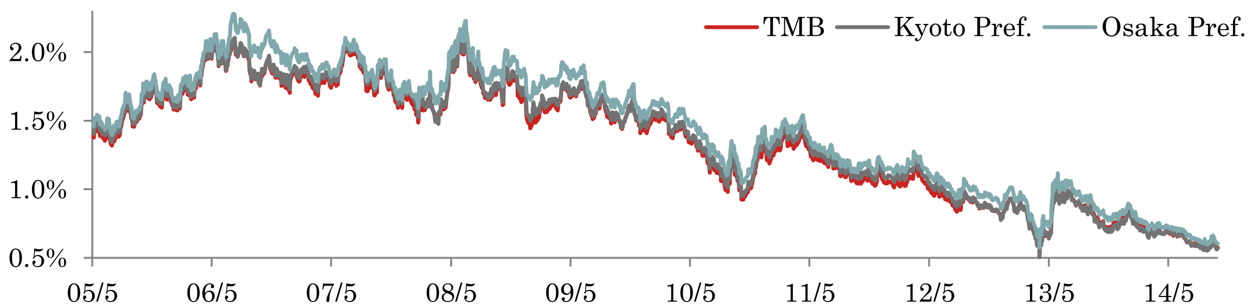
Source: Tokyo Metropolitan Government

Table A7 Buy/Selling Trend of JGGB and Japanese Municipal Bond



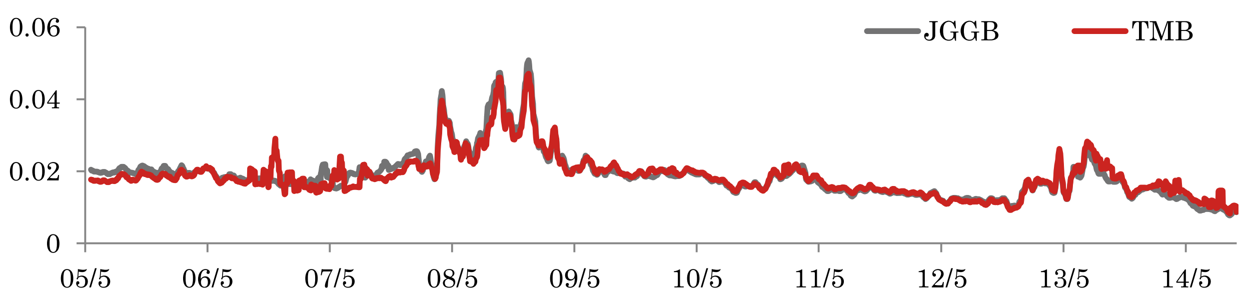
Source: Japan Securities Dealers Association

Table A8 Par Rate of Tokyo Metropolitan Bond, Kyoto Prefecture Bond and Osaka prefecture Bond



Source: Hattori and Miyake (2016)

Table A9 Yield Curve Fitting Noise: JGGB and TMB



Notes: 10 trading day's average. The yield curve fitting noise is computed based on Svensson (1994)

Source: Japan Securities Dealers Association