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The Effects of the Bank of Japan's Corporate and Government Bond Purchases on Credit Spreads

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Abstract

We examine the effects of corporate and government bond purchases by the Bank of Japan (BOJ) on Japanese firms' credit spreads. Using a micro dataset covering 5,614 corporate bonds over the period from 1997 to 2016, we empirically show that credit spreads are explained by the risk-taking channel and the local and global supply channels, in addition to the conventional default risk channel. We quantify the effects of the BOJ's bond purchases on credit spreads through these three channels. In so doing, we emphasize that policy effects through the local and global supply channels crucially depend on the degree of risk appetite at the financial institutions.

Keywords: Credit spreads; Default risk channel; Local supply channel; Global supply channel; Risk taking channel; Monetary policy
JEL classification: E44, E58, G12

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1. Introduction

Central banks such as the Bank of Japan (BOJ), the European Central Bank, and the Bank of England have relied on both corporate and government bond purchases as accommodative policy measures in the aftermath of the global financial crisis. Yet, while there is a wide body of literature examining the effects of government bond purchases and their transmission channels, there is a very small literature on the effects of corporate bond purchases.[1] To deepen our understanding of bond purchases as a monetary policy tool, this study empirically investigates the effects of the BOJ's corporate and government bond purchases on Japanese firms' credit spreads.

For the assessment of the effects of the BOJ's corporate and government bond purchases on credit spreads, we attempt to unravel causal connection between central bank bond purchases and credit spreads. As the key variables of the causality, we focus on firms' default risk, the relative scarcity of corporate bonds to government bonds, and the risk appetite of financial intermediaries (FIs) following the recent literature reviewed below. We empirically show that the three key variables are significant determinants of credit spreads, and at the same time that the BOJ's bond purchases influence the three variables.

Studies on U.S. firms' credit spreads such as Gilchrist and Zakrajšek (2012), referred to as GZ hereafter, Longstaff, Mithal, and Neis (2005) and Mahanti *et al.* (2008) show that firm-specific default risk and a vector of bond-specific variables including the liquidity measures of corporate bonds are determinants of credit spreads. In addition to these variables, Nakashima and Saito (2009) argue that economy-wide variables affecting all bonds, for instance, high-powered money, also play an important role in determining credit spreads in Japan.

Following these studies, we build a regression model of credit spreads that extends GZ's model and estimate it using a micro dataset covering 5,614 bonds issued by 383 firms over the period from 1997 to 2016. We regress credit spreads on novel market-wide variables such as the relative scarcity measures of corporate bonds to government bonds and FIs' risk appetite measures in addition to conventional measures including firms' default risk.

Our focus on the market-wide variables is based on the studies on the effects of

[1] In a very small literature, Beirne *et al.* (2011) estimate the effect of the European Central Bank's covered bond purchase program, and Boneva, de Roure, and Morley (2018) assess the impact of the Bank of England's corporate bond purchase scheme.

central bank asset purchases. These studies include D'Amico and King (2013), Greenwood, Hanson, and Liao (2017), Greenwood and Vayanos (2014), He and Krishnamurthy (2013), Krishnamurthy and Vissing-Jorgensen (2011), and Vayanos and Vila (2009). While these lines of studies mainly examine government bond purchases, few studies investigate corporate bond purchases.

Vayanos and Vila (2009), D'Amico and King (2013) and Greenwood and Vayanos (2014), using preferred habitat models, show that government bond purchases by the central bank, by reducing the supply of bonds, reduce the yields of bonds with similar maturities (the local supply channel) as well as the entire yield curve (the global supply channel). Greenwood, Hanson, and Liao (2017) develop a theoretical model of preferred habitat investors in multiple asset markets and show that a positive shock to the supply of government bonds increases the yield of government bonds through the local supply channel and the yield of corporate bonds through the global supply channel. Moreover, the response of government bond yields to the shock is greater than that of corporate bond yields. As a result, a positive shock to the supply of government bonds reduces credit spreads. Another important theoretical prediction of the preferred habitat models is that the local supply effect declines as FIs become aggressive toward taking arbitrage opportunities arising from the supply effect.

As a natural experiment for investigating the multiple markets preferred habitat model, the case of the BOJ's bond purchases is quite appealing since a notable feature of the BOJ's corporate bond purchases enables us to identify the effect of the bond purchases on credit spreads. The BOJ's corporate bond purchases target only bonds with a high credit rating and short-term maturities, while the government bond purchases are not limited to certain maturities. By examining the difference in credit spreads between corporate bonds within and outside the BOJ purchase criteria, we can identify the local supply effect within corporate bond market. Table 1 overviews the BOJ's corporate bond purchase program and further details of the BOJ's corporate bond purchase program are shown in Appendix A.

In addition to the supply effect within corporate bond market, we provide evidence of the supply effect across corporate and government bond markets. Our empirical results suggest that the BOJ's corporate bond purchases reduced overall credit spreads by increasing the scarcity of corporate bonds, while the BOJ's government bond purchases exerted upward pressure on credit spreads by increasing the scarcity of government bonds. Moreover, we show that the effect of BOJ bond purchases is larger when FIs are more

risk averse.

Regarding the effect of central bank bond purchases on firms' default risk and credit spreads, Krishnamurthy and Vissing-Jorgensen (2011) argue that central bank bond purchases change financial market participants' views on the macro economy and, as a result, improve perceptions regarding firms' default risk. Consequently, the bond purchases result in reducing credit spreads (the default risk channel).[2]

Turning to the connection of central bank bond purchases with FIs' risk appetite and credit spreads, He and Krishnamurthy (2013) examine the risk-taking channel. Their intermediary asset pricing theory implies that central bank bond purchases can ease FIs' equity capital constraint and eventually increase FIs' willingness to invest in risky assets. A theoretical prediction of the theory is that by relaxing FIs' capital constraint, government and corporate bond purchases reduce credit spreads, especially of particular lower-grade corporate bonds.[3] We define the risk-taking channel following He and Krishnamurthy (2013) as a channel to transmit corporate and government bond purchases to credit spreads through changes in FIs' risk appetite. In line with He and Krishnamurthy (2013), GZ and Adrian and Shin (2011) argue that the fluctuations in FIs' risk appetite are mainly due to constraints faced by the FIs rather than their preferences.

To clarify a causal link between the BOJ's bond purchases and credit spreads, we investigate the impact of the bond purchases on the future values of firms' default risk measure and FIs' risk appetite measure using univariate forecasting specification employed in GZ. Meanwhile, we can easily quantify the impact of the bond purchases on the relative scarcity of corporate bonds to government bonds based on the total outstanding amount of corporate and government bonds available to the public. By combining the estimated elasticity of credit spreads with respect to firms' default risk, FIs' risk appetite and the relative scarcity of corporate bonds with the estimated impact of the bond purchases on three variables, we quantitatively evaluate the effects of the BOJ's bond purchases on credit spreads. We also decompose the effects into the local and

[2] In addition to the default risk, Krishnamurthy and Vissing-Jorgensen highlight the role of default risk premiums in determining credit spreads. They argue that investor risk aversion falls as the economy recovers, meaning that they require lower default risk premiums, while increases in FIs' financial health and/or capital potentially further lower default risk premiums. They do not separate the effects through changes in default risk and default risk premiums, while we attempt to identify each effect. We label the former channel the default risk channel and the latter channel the risk-taking channel.

[3] This risk-taking channel is somewhat different from the risk-taking channel proposed by Adrian and Shin (2011), who explore the effect of a change in the short-term policy interest rate on FIs' risk appetite.

global supply effects, the default risk effect, and the risk-taking effect.

Our quantitative assessment focusing on the effects through the local and global supply channels shows that an increase of 10 percent in the BOJ's government and corporate bond holdings from the averages of these values in 2016 is associated with a change in credit spreads of bonds within the BOJ purchase criteria of -0.6 to 1.5 percent over the subsequent quarter. We use two different specifications for the assessment. The effect estimated using one specification is negative, *i.e.* -0.6 percent, since the downward pressure by corporate bond purchases is larger than the upward pressure by government bond purchases. Meanwhile, when using the other specification, the total effect is positive, i.e., 1.5 percent, since the effect of corporate bond purchases is smaller than that of government bond purchases. Outside the purchase criteria, credit spreads increase by 2 percent over the same period. The difference of the effects between within and outside the purchase criteria shows that the increase of the relative scarcity of corporate bonds within the criteria for the corporate bond purchases causes the reduction of credit spreads by 0.4 to 2.7 percent.

We also find that the BOJ's bond purchases have significantly suppressed credit spreads through the default risk channel and the risk-taking channel. Our simulation exercise of an increase of 10 percent in the BOJ's government and corporate bond holdings from their averages in 2016 indicates that over the subsequent quarter, the decline in overall credit spreads reaches around 7 percent through the default risk channel and ranges from 2 to 8 percent through the risk-taking channel.

Overall, an increase of 10 percent in the BOJ's government and corporate bond holdings leads to a decline in credit spreads of around 6 to 14 percent over the subsequent quarter. Of the different effects, the effect through the default risk channel is the largest in terms of reducing credit spreads.

The remainder of this paper is organized as follows. Section 2 provides our credit spread model and data sources. Section 3 then presents the estimation results of our credit spread regressions. Section 4 shows our empirical results regarding the effects of the BOJ's corporate and government bond purchases on credit spreads. Section 5 concludes.

2. Credit spread regressions

This section presents our credit spread model focusing on the determinants of credit spreads as well as the micro-level corporate bond data and firms' balance sheet data that

we use for the analysis.

2.1 Credit spread model and data sources

We assume that the log of the credit spread in the secondary market at time t of bond j issued by firm i, $CS_{it}[j]$, is linearly related to firm-specific default risk, DD_{it}, a vector of bond-specific characteristics, $\boldsymbol{X}_{it}[j]$, and a vector of market-wide characteristics, $\boldsymbol{Z}_{it}[j]$. The specification is given by

$$\begin{aligned} \ln(CS_{it}[j]) \quad &= \alpha + \beta DD_{it} + \boldsymbol{\gamma}'\boldsymbol{X}_{it}[j] + \boldsymbol{\theta}'\boldsymbol{Z}_{it}[j] \\ &+ \sum_m \eta_m D_{rating,imt} + \sum_n \omega_n D_{industry,in} + \varepsilon_{it}[j], \end{aligned} \tag{1}$$

where $D_{rating,imt}$ and $D_{industry,in}$ are credit rating and industry dummies, and the zero-mean disturbance $\varepsilon_{it}[j]$ represents the pricing error. Taking the log of credit spreads provides a useful transformation to control for heteroskedasticity, given that the distribution of credit spreads is highly skewed. The time frequency is monthly. The credit spread regression (1) is estimated using ordinary least squares (OLS). We will give a detailed explanation of the proxy variables for DD_{it}, $\boldsymbol{X}_{it}[j]$, $\boldsymbol{Z}_{it}[j]$, and the two dummy variables in the following two sub-sections.

For this analysis, we use data on 5,614 corporate bonds issued by 383 firms in Japan as well as balance sheet data on the issuing firms from Bloomberg.[4] The prices of the corporate bonds are the reference prices published by the Japanese Securities Dealers Association. Table 2 contains details of our data selection criteria and summary statistics for the key characteristics of the bonds in our sample. We use only straight corporate bonds and exclude subordinate, callable, and stock convertible bonds. Moreover, we exclude bonds such as those issued by banks and foreign firms and those issued by Japanese firms but in overseas markets. To calculate accurate credit spreads, we derive hypothetical government bond yields with the same coupon rate and maturity as each of the bonds used in the estimation. The hypothetical government bond yields are estimated based on fitting results using zero coupon government yield curves.[5]

[4] Among balance sheet data, we use the face value of the firm's debt, *i.e.*, the sum of the firm's current liabilities and one-half of its long-term liabilities. Following GZ, we interpolate the balance sheet data to daily frequency using a step function for empirical analysis.

[5] We use zero coupon yield curve data from Bloomberg. Since the data are not continuous in maturity, to interpolate the curves, we use an extended Nelson-Siegel model following Söderlind and Svensson (1997).

A typical firm in our sample has only a few senior unsecured issues outstanding at any point in time. The median firm, for example, has three such issues trading in any given month. The distribution of the number of bonds per firm/month, however, is significantly positively skewed, as some firms have many more issues trading in the secondary market at any particular point in time. The distribution of the market value of these issues is similarly skewed, ranging from ¥1.5 billion to ¥220 billion. The maturity of these debt instruments is long, with an average maturity at issue of 9.1 years. The average remaining time to maturity is 5.2 years. In terms of the default risk as measured by credit ratings, our sample spans the entire spectrum of credit quality from "triple C" (CCC) to "triple A" (AAA). The median observation is at "single A" (A) in the investment-grade category. An average bond has an expected return of 10.2 basis points above the comparable risk-free rate, while the standard deviation of 21.6 basis points and the maximum of 11 percent reflect the wide range of credit quality in our sample.

2.2 Firm- and bond-specific characteristics

As the proxy for firm-specific default risk, DD_{it}, we use the one year distance to default in period t derived based on Metron's (1974) model for each issuer firm i from the firm's stock price and the value of the firm's debt and equity capital. Following GZ, Vassalou and Xing (2004), and Bharath and Shumway (2008), we calculate DD_{it} using variables including the market capitalization of firm i and the amount of firm i's debt outstanding. Details of the calculation of DD_{it} are shown in Appendix B.

The vector of bond-specific characteristics, $\boldsymbol{X}_{it}[j]$, includes the time to maturity, the age of the bond, and the amount outstanding of each corporate bond as control variables. Longstaff, Mithal, and Neis (2005) and Mahanti *et al*. (2008) argue that these variables can be used as proxies for the liquidity of the corporate bond, and that corporate bonds with a longer time to maturity, more years since issuance, and a smaller amount outstanding tend to have larger credit spreads due to lower liquidity. While GZ, Longstaff, Mithal, and Neis (2005), and Mahanti *et al*. (2008) include the coupon rate as a control variable, we do not. In the United States, holding corporate bonds provides investors with a tax advantage, while holding government bonds does not. This tax advantage means that, when comparing otherwise identical corporate bonds, U.S. investors will prefer those with a higher coupon rate. Consequently, the credit spread of a corporate bond with a higher coupon rate is smaller than that with a lower coupon rate. In Japan, corporate bonds do not provide a tax advantage over government bonds. Therefore, we do not use the coupon rate as a control variable.

Regarding the credit rating dummies, $D_{rating,imt}$, Longstaff, Mithal, and Neis (2005) and Mahanti *et al*. (2008) use credit ratings to control for any systematic (time-invariant) differences in liquidity across bonds, assuming that the higher a corporate bond's rating, the higher is the degree of liquidity and the prices of the corporate bonds. Credit ratings are provided by Rating and Investment Information, Inc. (R&I), a major credit rating company in Japan.[6] We divide credit ratings into four subsets to avoid as far as possible having subsets with no observations. For example, after February 2012, there do not exist any AAA-rated firms in our sample. Following GZ, we do not include time fixed effects. To avoid any estimation bias potentially resulting from credit rating dummies acting as time fixed effects, we need to avoid to the greatest extent possible having subsets with no observations in each period. Based on these considerations, we construct the following four credit rating groups. The highest subset of ratings consists of the highest credit rating, AAA, and the second highest rating, AA. The second highest subset of ratings consists only of A. The third subset consists only of BBB and is set as the base subset. Ratings of BB and lower form the lowest and fourth subset of ratings. $D_{rating,imt}$ takes 1 if the credit rating of firm i in period t is within subset m of credit ratings, and 0 otherwise.

Following GZ, we use industry fixed dummies, $D_{industry,in}$, to control for any systematic (time-invariant) differences in expected recovery rates given a default across industries. Our definition of industries is based on the Bloomberg 2-digit classification. The number of industries examined in our analysis is 57. n then takes a value from 1 to 56 and the utility sector is set as the base industry. $D_{industry,in}$ takes 1 if the industry of firm i is industry n, and 0 otherwise.

2.3 Market-wide characteristics

As market-wide characteristics, $\boldsymbol{Z}_{it}[j]$, we use variables measuring the supply of corporate and government bonds as well as FIs' risk appetite.

To identify the impact of the relative scarcity of corporate bonds to government bonds on credit spreads, we use the ratio of corporate bond supply to government bond supply, assuming that the supply effects operate as "stock effects" defined as the long-lasting impact that the BOJ's bond purchases had on credit spreads by shifting the level

[6] R&I changed its rating method in April 1998. This results in a discontinuity in credit ratings by R&I. In addition, the number of firms given credit ratings by R&I before April 1998 is not very large. In order to include the Japanese banking crisis at the end of 1997 in our analysis, we extrapolate the credit ratings of R&I from March 1998 backward using Moody's credit ratings. We use changes in Moody's credit ratings to extend the credit ratings data.

of the relative scarcity of bonds available for purchase by the public. The ratio is a measure of the difference of the overall scarcity. If corporate and government bond markets are segmented, *i.e.*, arbitrage between the two markets does not work well, the relative scarcity influences credit spreads. In addition, the impact becomes larger when FIs' risk appetite is weaker.

We also examine the degree of segmentation within the corporate bond market across credit ratings or maturities. To this end, we employ an eligibility dummy that takes one if an individual corporate bond is eligible for the BOJ's corporate bond purchase program, and zero otherwise. Given that the BOJ's corporate bond purchases target only bonds with a high credit rating and short-term maturities, the estimated coefficient on the eligibility dummy and its statistical significance provide information on the extent to which the corporate bond market is segmented across credit ratings or maturities. When examining the difference in credit spreads between corporate bonds within and outside the criteria, we need not pay much attention to the BOJ's purchases of government bonds, since these purchases are not limited to certain maturities. If government bond purchases focused on the same maturity as corporate bond purchases, the relative scarcity of corporate bonds within the criteria might not increase even after the BOJ's corporate bond purchases and, as a result, we would not be able to observe lower credit spreads of bonds within the criteria compared with bonds outside the criteria. Moreover, since we infer that the magnitude of the impact of the BOJ's corporate bond purchases depends on the amount of corporate bonds purchased, we also employ the interaction term of the eligibility dummy and the BOJ's corporate bond holdings.

Turning to FIs' risk appetite, we use two different proxy variables for robust analysis. The two proxies are based on information taken from the Senior Loan Officer Opinion Survey on Bank Lending Practices at Large Japanese Banks (or "Loan Survey" for short) and the Short-Term Economic Survey of Enterprises in Japan (*Tankan*).[7] The proxies for FIs' risk appetite used in this paper are related to their risk attitude toward large firms, since most bond issuers in Japan are large firms. In our empirical analysis using the credit spread model, we linearly interpolate the proxies to change their frequency from a quarterly to a monthly frequency to match the frequency of other variables.

[7] Using the survey data on FIs' risk appetite mainly reflecting their capital constraint, we can isolate the effect of the change in risk appetite on credit spreads. There are other proxy variables for FIs' risk appetite. GZ show that the condition of FIs balance sheet in particular its return on assets (ROA) can be used as a proxy variable for FIs' risk appetite as well as the risk attitudes of FIs based on survey data. While we exploit only the survey data in this paper, ROA or market capital ratio proposed in Inoue, Nakashima and Takahashi (2017) and Sarin and Summers (2016) can be used as other proxy variables.

The Loan Survey is a quarterly survey that measures the view of senior loan officers at large Japanese banks concerning the loan market. Respondents are officers at the 50 largest domestically licensed banks in terms of the average amount of loans outstanding. The aggregated loan amount of the 50 banks included in the survey accounts for around 75 percent of the total amount of loans outstanding held by all domestically licensed banks. The survey contains multiple choice questions on respondents' views on firms' loan demand and the lending policies of the bank to which the respondent belongs. The survey is broadly modeled on a similar survey conducted by the Federal Reserve Board, the Senior Loan Officer Opinion Survey on Bank Lending Practices.

Regarding banks' lending policies, respondents are asked the following question: "Over the past three months, how have your bank's credit standards for approving applications for loans from large firms changed?" We use the answers to this question to calculate the following diffusion index: diffusion index for credit standards = (percentage of respondents selecting "eased considerably" + percentage of respondents selecting "eased somewhat" × 0.5) - (percentage of respondents selecting "tightened considerably" + percentage of respondents selecting "tightened somewhat" × 0.5). The survey started from April 2000. Panel (a) of Figure 1 shows the developments in the diffusion index for credit standards. As stated by the BOJ in the introduction of the survey, sufficient data have not been accumulated so far to detect whether the survey has biases.[8] Taking into account that the survey might be biased and the diffusion index is constructed using the questionnaire on the change in credit standards, we calculate the proxy for FIs' risk appetite by adjusting the diffusion index so as to have zero mean (subtracting the sample mean) and cumulatively summing the adjusted diffusion index.

In the *Tankan*, over 10,000 enterprises are asked each quarter to answer multiple choice questions regarding their view about business conditions, their own cash position, FIs' lending attitude, and so on. Since the *Tankan* goes back to 1957, unlike the Loan Survey, plenty of historical data has been accumulated. Another advantage of the *Tankan* is the breadth of the sample coverage, which makes it easy to obtain unbiased measures of FIs' risk appetite, even though respondents are enterprises, not FIs.

To correct for any possible bias arising from not gauging the views of FIs directly, we make some adjustments to the survey results. Employing three diffusion indexes from the *Tankan*, we extract a proxy of FIs' risk appetite. The first of the three diffusion indexes

[8] The introduction states that "the results of the survey may have biases that can only be detected after accumulation of results over several quarters or years. Therefore, at this stage they should be interpreted with considerable caution."

focuses on the assessment of FIs' attitude toward lending as perceived by large enterprises. The second focuses on large enterprises' assessment of their general cash position, taking into account levels of cash and cash equivalent, the lending attitude of financial institutions, and payment and repayment terms. The third focuses on large enterprises' assessment of general business conditions, primarily in light of their profits. We regress the first diffusion index on the second and third to estimate FIs' attitude toward risk not explained by firms' default risk captured by demand-side factors such as their cash position and business conditions. We use the residual of the regression as another proxy variable for FIs' risk appetite. Panel (b) of Figure 1 shows the developments in the proxy variable constructed from *Tankan*, *i.e.*, the residual of the regression.

3. Estimation results of credit spread regressions

In this section, we present the estimation results of credit spread regressions. As shown in Table 3, 4 and 5, we estimate nine different specifications. All of specifications provide evidence that firm- and bond-specific characteristics and market-wide characteristics explained above are significant determinants of credit spreads.

3.1 Estimation results on firm- and bond-specific characteristics

Specification (a) shown in Tables 3 is the baseline specification to investigate the validity of firm- and bond-specific characteristics as determinants of credit spreads in Japanese corporate bond market. In specification (a), we regress log of credit spreads on the distance to default, log of age, log of issue size, log of maturity, and credit rating and industry dummies.

The coefficients on all variables in specification (a) are significant and have the expected sign. According to the estimated coefficients, the smaller the distance to default is, the wider the credit spread becomes.[9] Moreover, the estimates for the age of the bond, the issuing amount, and the time to maturity all show that the less liquid a corporate bond is, the wider the credit spread becomes. Even after controlling for firms' default risk by the distance to default, the estimates for credit rating dummies imply that the higher a corporate bond's rating is, the smaller the credit spread becomes. This is consistent with

[9] To confirm that the estimated results in specification (a) do not suffer from endogeneity bias arising from using as an independent variable the distance to default in the same period as the dependent variable, the credit spread, we estimate an alternative specification in which the distance to default is one-period lagged to the dependent variable. While the results are not reported here to conserve space, we find that the difference between the estimated coefficients in the two specifications is quite small and conclude that the estimated coefficients in specification (a) do not suffer from endogeneity bias.

the hypothesis that the prices of corporate bonds with higher credit ratings reflect not only lower default risk but the higher degree of liquidity.

3.2 Estimation results on market-wide characteristics

Next, specifications (b) to (g) in Table 3 are employed to examine the roles of market-wide characteristics, *i.e.*, eligibility dummy, the ratio of corporate bond supply to government bond supply, and FIs' risk appetite. The difference of the observation period among specifications reflects data availability of independent variables. The ratio of corporate bond supply to government bond supply is available only from January 1998, and the proxy for FIs' risk appetite constructed using the Loan Survey is available only from February 2000.

In specifications (b), (f), and (g), the estimated coefficient on the eligibility dummy is significant and has the expected sign. The estimated coefficient in specification (b) implies that if a corporate bond is under the criteria set by the BOJ, the credit spread is reduced by 0.56 percent on average, that is, $\ln(CS_{it}[j]) - \ln(CS_{it}[k]) =$ -0.56 percent for bond j under the criteria and bond k outside the criteria. Consequently, this shows that even within corporate bond market, arbitrage across credit ratings or maturities does not work well, and the BOJ's corporate bond program has a significant impact on credit spreads through the local supply channel.

The estimated coefficient on the ratio of the supply of corporate bonds to that of government bonds in specifications (c), (f), and (g) is significant and has the expected sign. The estimated coefficient in specification (c) indicates that a decrease in the ratio of the supply of corporate bonds to that of government bonds by 1 percent results in a decrease in all credit spreads by 5.6 percent. The positively estimated coefficient suggests that the BOJ's corporate bond purchases decrease the ratio and reduce credit spreads, while government bond purchases increase the ratio and widen credit spreads. This supports the theoretical prediction of the multiple markets preferred habitat model.

Furthermore, the estimation results of specifications (d) to (g) highlight the importance of FIs' risk appetite. The estimated coefficient on the proxy for FIs' risk appetite constructed from the Loan Survey or *Tankan* is significant and has the expected sign. The magnitude of the estimated coefficients implies that there is an economically significant positive relationship between credit spreads and FIs' risk appetite. For example, an increase of one standard deviation in the proxies for FIs' risk appetite is associated with a decline in credit spreads of 3 to 22 percent. Here, the difference of the magnitude of the effects reflects not only the estimated coefficients but also the variation

in each of the proxies. The absolute value of the estimated coefficient on the proxy constructed using the *Tankan* is around twenty times larger than that on the proxy constructed using the Loan Survey, although the standard deviation of the proxy constructed using the Loan Survey is around three times larger than that of the proxy constructed using the *Tankan*.[10]

Turning to the results for the log of the issue size, we find that in specifications (c), (f), and (g), the coefficient estimate does not have the expected sign, unlike in specifications (a), (b), (d), and (e). A possible reason is that the issue size and the ratio of corporate bond supply to government bond supply are correlated. Since the end of the 1990s, the average size of bond issuances has decreased along with the decline in the total amount of corporate bonds outstanding. Although not shown here to conserve space, we find that the ratio of corporate bond supply to government bond supply co-moves with the average of the log of the issue size in each period. Based on this, we conjecture that the marginal information value of the issue size of corporate bonds is reduced by the inclusion of the ratio as an independent variable.

3.3 Estimation results of full specifications

Finally, Table 4 and 5 show the estimation results of full specifications to examine whether the market-wide characteristics influence credit spreads, even when controlling for all of the market-wide characteristics simultaneously. The difference between specifications in Table 4 and 5 lies in which proxy variable for FIs' risk appetite is used: in Table 4, the proxy constructed using the Loan Survey is employed, while in Table 5 the proxy constructed using the *Tankan* is employed.

As reviewed in Section 1, the local and global supply effects depend on the degree of FIs' risk appetite, and the risk-taking effect strongly operates on lower-grade corporate bonds. To investigate these theoretical predictions, we employ several interaction terms consisting of the ratio of the supply of corporate bonds to that of government bonds, the proxies for FIs' risk appetite, the eligibility dummy, the BOJ's corporate bond holdings and credit rating dummies.

Regarding the local and global supply effects across corporate and government bond markets, the estimation results are consistent with the theoretical prediction. In both Table 4 and 5, the estimated coefficients on the ratio of the supply of corporate bonds to

[10] The standard deviation of the proxy constructed form the Loan Survey is 17.2, while that of the proxy constructed from the *Tankan is* 5.45.

government bonds are significantly positive, while the estimated coefficients on the interaction terms between the ratio of the supply of corporate bonds to government bonds and the proxies for FIs' risk appetite are negative. These results suggest that the local supply effect become larger as FIs risk appetite weakens more.

In case of the supply effects within corporate bond market, the theoretical prediction is strongly supported. Here, we infer that the magnitude of the impact of the BOJ's corporate bond purchases depends on the amount of corporate bonds purchased, and then we employ the interaction term of the eligibility dummy and the BOJ's corporate bond holdings. In addition, we also use the interaction term consisting of the eligibility dummy, the BOJ's corporate bond holdings, and the proxies for FIs' risk appetite to examine the relationship between the local and global supply effects and FIs' risk appetite. In both Table 4 and 5, the estimated coefficient on the interaction term between the eligibility dummy and the BOJ's corporate bond holdings is significantly negative, while the estimated coefficient on the interaction term consisting of the eligibility dummy, the BOJ's corporate bond holdings, and the proxies for FIs' risk appetite is significantly positive. Consequently, theoretical prediction about the connection between the local and global supply effects and FIs' risk appetite is also supported.

Lastly, we investigate the risk-taking effect by using interaction terms between FIs' risk appetite and credit rating dummies. In the same manner as Table 3, the estimated coefficients on the proxy for risk appetite in Table 4 and 5 are significant and have the expected sign. Moreover, the estimated coefficients on the interaction terms with credit ratings imply that credit spreads in the lower rating categories respond to a change in FIs' risk appetite more strongly than those in the highest rating category. These results suggest that the risk taking effect operate strongly in Japanese corporate bond market.

3.4 Additional evidence

In this sub-section, we provide additional evidence to confirm that FIs' risk appetite and the relative scarcity of corporate bonds affect credit spreads.

Our estimation results have shown that FIs' risk appetite has a significant impact on overall credit spreads. Further evidence of this is provided by the fact that, as illustrated in Figure 1, the average of the pricing errors of specification (a) in Tables 3, $\varepsilon_{it}[j]$, in each period moves in tandem with the proxies for FIs' risk appetite. Panel (a) of Figure 1 shows that the average of pricing errors is synchronized with the diffusion index for credit standards in the Loan Survey, while panel (b) shows the same for the risk appetite estimated from the *Tankan*. The specification (a) does not include a proxy for FIs' risk

appetite. Consequently, the connection between the average of the pricing errors of specification (a) and the proxies highlight the important role of FIs' risk appetite in determining credit spreads.

Turning to the relative scarcity of corporate bonds to government bonds, in particular the local supply effect arising from the BOJ's corporate bond purchases, we examine the historical movement of the distributions of the pricing errors of specification (a), $\varepsilon_{it}[j]$. Figure 2 shows the distributions of the pricing errors standardized using the simple average in the period.[11] Each of the panels in Figure 2 shows two distributions: the distribution of bonds meeting the BOJ's criteria ("Within") and of those not meeting the criteria ("Outside"). The distributions are constructed using monthly values for the pricing error of individual corporate bonds for the two groups of bonds and are obtained using Gaussian kernel estimation. It is worth noting that specification (a) does not include, as independent variables, the supply measures of corporate and government bonds, and then the distribution of the pricing errors provide information on how important the supply measures are.

Panels (a) to (f) of Figure 2 are useful to investigate how strongly the local supply effect operates. Before the introduction of the corporate bond purchase program, the distribution of the pricing errors of corporate bonds with a maturity between one and three years and a credit rating of BBB or higher was almost the same as that of corporate bonds with maturities outside the one- to three-year region and credit ratings lower than BBB as shown in panel (a). After the restart of the program in October 2010, the two distributions are clearly different, as shown in panel (b). Looking at developments in the distributions as shown in panels (c) to (f), the difference between the two distributions is not constant due to changes in the BOJ's corporate bond holdings. Although the increase in the BOJ's corporate bond holdings following the start of the program in 2009 was not substantial as shown in panel (a) of Figure A, it nevertheless resulted in a stark difference between the two distributions by reducing the credit spreads of bonds within the criteria, as shown in panel (c) of Figure 2. Panel (d) of Figure 2 shows that after the suspension of the program, the distribution of the pricing errors of bonds within the criteria moved to right due to the decrease in the BOJ's corporate bond holdings and the difference between the two distributions diminished. From 2011 onward, with the corporate bond holdings having increased and reached its peak as shown in panel (a) of Figure A, the difference

[11] The standardized pricing errors are given by $\varepsilon_{it}[j] - \overline{\varepsilon_{it}[j]}$, where $\overline{\varepsilon_{it}[j]}$ is the simple average of pricing errors in the period. As explained above, we do not include time fixed effects when estimating equation (1). Consequently, $\overline{\varepsilon_{it}[j]}$ can take non-zero values.

between the two distributions increased again, as shown in panels (e) and (f) of Figure 2.

Next, panels (g) to (j) of Figure 2 show the changes in the distributions from 2013 to 2016. Since the BOJ's corporate bond holdings during this period remained almost unchanged as shown in panel (a) of Figure A, changes in the distributions show the link between the local and global supply effects and FIs' risk appetite. As shown in Figure 1, the two proxies of FIs' risk appetite suggest that FIs' risk-taking stance was the most aggressive in 2014 since the introduction of the corporate bond purchase program. The change in attitude toward risk can be also seen in the change in the distributions of the pricing errors. While the BOJ's corporate bond holdings remained more or less unchanged, the difference in the two distributions, as can be seen in panel (h), is the smallest in 2014. This fact is consistent with the theoretical prediction that as FIs become more aggressive in their risk-taking, the local supply effect declines and the global supply effect becomes larger.

The above observations are confirmed by bond trading data published by the Japan Securities Dealers Association, which are available from November 2015 onward. The data only include information on corporate bonds with an AA rating or higher. Figure 3 shows that the yields of traded bonds within the criteria of the BOJ's corporate bond purchases, *i.e.*, with maturities from one to three years, are clearly below those of bonds outside the criteria.

4. The effect of corporate and government bond purchases on credit spreads

In this section, we propose a method to identify the effect of corporate and government bond purchases on credit spreads. Putting all the channels together with the use of specifications in Tables 4 and 5, we examine the impact of the BOJ's bond purchases on credit spreads through each of the channels, that is, the default risk channel, the local and global supply channels, and the risk-taking channel. To assess the effect of each channel based on recent circumstances, we examine the case of an increase of 10 percent in the BOJ's corporate and government bond holdings from the level in 2016.

To explain how we identify the effect of bond purchases through each transmission channel, Figure 4 provides a schematic diagram of the transmission channels that link bond purchases to credit spreads. The key variables are firms' default risk, the relative scarcity of corporate bonds to government bonds, and FIs' risk appetite. Our identification strategy consists of two steps. In the first step, completed in the last section, we estimated a credit spread model including these key variables to measure the effect of changes in

them on credit spreads. In the second step, described in this section, we quantify the effect of the BOJ's bond purchases on these key variables. Based on these two steps, we can identify the effect of bond purchases through each transmission channel. The followings provide a more detailed explanation of the second step.

4.1 Link between the BOJ's bond purchases and firms' default risk

In this subsection, we examine the effects of corporate and government bond purchases by the BOJ on stock market participants' perceptions of the average firm default risk. As shown in Tables 3 to 5, the smaller the distance to default is, the wider the credit spread becomes. In addition to this finding, if we find that the BOJ's corporate and government bond purchases have a significant effect on Japanese firms' distance to default as implied in their stock price, this shows that the default risk channel plays a role.

To examine the effect of the BOJ's corporate and government bond purchases on the distance to default, we start by extracting the common component in the distances to default by regressing each firm's distance to default on a time fixed effect in addition to the credit rating and industry dummies described in Section 2.2. We label the time fixed effect "excess distance to default" (EDD_t), since the estimated coefficient is a component common to all firms and not explained by the default risk implied by the credit rating and industry. The estimation results are shown in Table 6. The estimated coefficients suggest that the distances to default are consistent with credit ratings. As shown in Figure 5, the excess distance to default is strongly procyclical, implying that Japanese equity investors generally expect defaults to increase during an economic downturn. In fact, during the Japanese banking crisis of 1997-1998 and the recent global financial crisis in the autumn of 2008, the measure fell to record lows.

Next, to examine the effect of corporate and government bond purchases on the excess distance to default, we follow GZ's approach. The univariate forecasting specification used in GZ is appropriate to quantify the effect of corporate and government bond purchases in a certain period on the key variables in subsequent periods. Many studies on the effect of central bank government bond purchases employ the event study approach (e.g., Krishnamurthy and Vissing-Jorgensen, 2011; Gilchrist and Zakrajšek, 2013). However, as pointed out by Greenwood, Hanson, and Liao (2017), who extended the slow-moving capital theory proposed by Duffie and Strulovici (2012), there is a risk of bias in the event study approach. The slow-moving capital theory, which provides a rationale why investors take time to change their portfolio after a shock, is supported by empirical studies (Carpenter *et al*., 2013; Neely, 2016; Saito and Hogen, 2014). By

employing the univariate forecasting specification, we can avoid the risk of bias when considering the contemporaneous effect using the event study approach.

We estimate the following specification using OLS with heteroscedasticity and autocorrelation consistent (HAC) standard errors following Newey and West (1987):

$$\Delta^h EDD_{t+h} = \alpha + \sum_{i=1}^{p} \beta_i \Delta EDD_{t-i} + \gamma_1 TS_t + \gamma_2 RPR_t + \gamma_3 \ln\left(JGB_t + CB_t)/(JGB_{t-3} + CB_{t-3}\right)) + \epsilon_{t+h} \quad (2)$$

where TS_t is the term spread, *i.e.*, the difference between ten-year and three-month government bond yields, RPR_t is the real policy interest rate, and JGB_t and CB_t denote the BOJ's government and corporate bond holdings, respectively. The time frequency is monthly. We use the three-month log difference in the estimation to adjust for the seasonality of $JGB_t + CB_t$. To overcome the non-linearity caused by the effective lower bound on nominal interest rates, instead of the nominal policy interest rate, we use the shadow rate estimated by Ueno (2017) as a measure of the monetary policy stance to calculate the proxy for the real policy interest rate.[12] $\Delta^h EDD_{t+h}$ represents the change in the excess distance to default between h quarters ahead and quarter $t-1$, that is, $EDD_{t+h} - EDD_{t-1}$. ΔEDD_t represents $EDD_t - EDD_{t-1}$. We set h to either three or six to examine the marginal effect on excess distance to default three and six months ahead. Further, the lag length of ΔEDD_{t-i}, *i.e.*, p, is determined by the Akaike information criterion (AIC).

In this framework, we examine the marginal information content or effect of the BOJ's bond purchases on the excess distance to default conditional on the slope of the yield curve and the real policy interest rate, two key indicators of the stance of monetary policy. We examine equation (2) using data from 2001, when the BOJ started the quantitative easing policy in March, to examine the effect of unconventional monetary policy measures on stock market participants' perceptions of the average firm default risk.

[12] The shadow rate is equal to the short-term government bond yield when the shadow rate is positive, while the shadow rate takes a negative value when the short-term government bond yield is around zero. Wu and Xia (2016) show that in the case of the United States, the shadow rate is an effective measure of the monetary policy stance at the zero lower bound. In the case of Japan, Iwasaki and Sudo (2017) show that the shadow rate provides a common metric of the monetary policy stance under conventional and unconventional monetary policy. The headline consumer price index (adjusted to exclude the effect of the consumption tax rate hikes) is used as a deflator.

The results are shown in Table 7 and indicate that changes in the BOJ's government and corporate bond holdings are a statistically significant predictor of the excess distance to default both three and six months ahead. Moreover, the magnitude of the estimated coefficients implies that there is an economically significant positive relationship between the default risk implied by stock prices and the BOJ's government and corporate bond holdings. For example, an increase of 10 percent in the BOJ's government and corporate bond holdings means that there is an increase of around 0.6 points in the excess distance to default over the subsequent three months and of around 1.3 points over the subsequent six months.

The results in Table 7 based on equation (2) above examine the impact of *changes* in the BOJ's bond holdings. As such, they can be regarded as measuring the "flow effects" of ongoing bond purchases. To check whether there were also any "stock effects," we estimated the same equation but using the BOJ's bond holdings instead of the change in the bond holdings. However, the results were insignificant (and are therefore not shown here to conserve space). This implies that the key factor affecting stock market participants' perceptions of the average firm default risk is the ongoing bond purchases.

4.2 Link between the BOJ's bond purchases and FIs' risk appetite

Turing to the effect of the BOJ's corporate and government bond purchases on FIs' risk appetite, as in the case of firms' default risk, we estimate the following univariate forecasting specification using OLS with HAC standard errors:

$$\Delta^h RA_{t+h} = \alpha + \sum_{i=1}^{p} \beta_i \Delta RA_{t-i} + \gamma_1 TS_t + \gamma_2 RPR_t + \gamma_3 \Delta \ln(SP_t) + \gamma_4 \Delta ln(JGB_t + CB_t) + \epsilon_{t+h} \quad (3)$$

where RA_t is the proxy for FIs' risk appetite, TS_t and RP_t are the same as in equation (2), and SP_t is the stock price index, that is, the Tokyo Stock Price Index (TOPIX).[13] We use the term spread and the short-term real interest rate as control variables following Adrian and Shin's (2011) argument that these variables affect FIs' risk appetite. The reason for including the TOPIX is to control for the effect of changes in stock prices. The time frequency is quarterly. To examine the marginal effect on FIs' risk appetite one and two quarters ahead, we set h to either one or two. Further, the lag

[13] The TOPIX is a free-float adjusted market capitalization-weighted index that is calculated based on all domestic common stocks listed on the First Section of the Tokyo Stock Exchange.

length of ΔRA_{t-i}, *i.e.*, p, is determined by the AIC. We examine equation (3) using data from 2001 as in the case of equation (2).

The estimation results in Table 8 show that changes in $JGB_t + CB_t$ are a statistically significant predictor of FIs' risk appetite both one and two quarters ahead. Moreover, the magnitude of the estimated coefficients implies that there is an economically significant positive relationship between FIs' risk appetite and changes in the BOJ's government and corporate bond holdings. For example, an increase of 10 percent in the BOJ's government and corporate bond holdings is associated with a 0.4-0.5 standard deviation increase in the risk appetite over the subsequent one quarter and a 0.5-0.7 standard deviation increase over the subsequent two quarters.

Further, as in the case of the excess distance to default, we find that when we replace the *change* in the BOJ's bond holdings with the level of the BOJ's bond holdings, the results are insignificant (Again, the results are not shown to conserve space). In other words, the *ongoing* purchases of bonds by the BOJ, *i.e.*, "flow effect," change FIs' risk appetite by relaxing their capital constraints rather than the bond holdings.

4.3 Quantitative assessment of the default risk channel

As shown in Section 4.1, an increase of 10 percent in the BOJ's government and corporate bond holdings increases the excess distance to default by around 0.6 points over the subsequent quarter and around 1.3 points over the subsequent two quarters.

Based on the estimated coefficients in Tables 4 and 5, these increases in the excess distance to default lead to a decline of around 7 percent in the overall credit spread, and around 15 percent over the subsequent two quarters. The estimation results suggest that the default risk channel operates strongly by changing the expectation of stock market participants regarding the default risk of corporations, which is consistent with Krishnamurthy and Vissing-Jorgensen (2011).

4.4 Quantitative assessment of the local and global supply channels

The measurement of the local and global supply channels is not straightforward, since the magnitudes of the effects depend on the degree of FIs' risk appetite, which is influenced by the BOJ's bond purchases. To quantify the effects based on recent circumstances, we use the averages of these values in 2016 as the starting point for the assessment below.

By relating the change in FIs' risk appetite shown in Section 4.2 to credit spreads based on the estimated coefficients in Table 4 and 5, we find that an increase of 10 percent

in the BOJ's government and corporate bond holdings is associated with a change in credit spreads of bonds within the criteria of the BOJ's corporate bond purchase program of around -0.6 to 1.5 percent over the subsequent quarter as shown in panel (a) of Table 10. As explained above, we employ two specifications using a different proxy for FIs' risk appetite. Consequently, the assessment of the local and global supply effect depends more or less on which specification is used. Outside the criteria, credit spreads increase by 2 percent over the same period. We also find that over the subsequent two quarters, credit spreads of bonds within the criteria change around -0.5 to 1.1 percent, while credit spreads of bonds outside the criteria increase by 1.5 to 3.4 percent.

The estimated effects within the criteria over the subsequent quarter and two quarters using the Loan Survey are negative, although when using *Tankan*, the estimated effects within the criteria are positive. This divergence arises from the differences of the estimated coefficients on the proxies for FIs' risk appetite in Tables 4 and 5 and those on the BOJ's government and corporate bond holdings in Table 8.

The size of the overall change results from the fact that in 2016 government bonds made up a much larger share of the BOJ's total bond holdings than corporate bonds. Government bond holdings amounted to 320 trillion yen, while corporate bonds holdings came only to 3.2 trillion yen, meaning that government bond holdings were about 100 times as large as corporate bond holdings. The difference in the impact on bonds within and outside the BOJ's purchase criteria reflects the local supply effect within the corporate bond market.

A 10 percent increase in the BOJ's government bond holdings reduces the scarcity of corporate bonds relative to government bonds in the market, leading to an increase in overall credit spreads, although this effect is somewhat offset by the increase in the BOJ's corporate bond holdings within the criteria of the BOJ's program. The former effect arises through the local supply channel across corporate and government bond markets, while the latter effect arises through the local supply channel within the corporate bond market.

When focusing only on corporate bond purchases, the differences of the effects between within and outside the BOJ's purchase criteria show that the increase of the relative scarcity of corporate bonds within the criteria causes the reduction of credit spreads by 0.4 to 2.7 percent over the subsequent quarter and by 0.4 to 3.9 percent over the subsequent two quarters.

To clarify the findings above, we consider two more hypothetical scenarios in addition to the baseline scenario shown above. In the first alternative scenario, only the

corporate bond holdings increase by 10 percent of the BOJ's corporate and government bond holdings in 2016. In the second alternative scenario, only the government bond holdings increase by the same amount.

Panel (b) of Table 10 shows the result of the first alternative scenario. This exercise indicates that if BOJ bond purchases target only corporate bonds, the local and global supply effects increase to a large extent. Meanwhile, the magnitudes of the default risk effect and the risk taking effect do not change since the total amount of bonds purchased stays at the same level as that in the baseline scenario. Consequently, of the different channels, the local and global supply channels have the largest impact.

Panel (c) of Table 10 shows the result of the second alternative scenario. Compared with the baseline scenario, a larger amount of government bonds purchased lessens the relative scarcity of corporate bonds given that the total amount of bonds purchased is unchanged. This results in the smaller effect of BOJ bond purchases on credit spreads.

4.5 Quantitative assessment of the risk-taking channel

Next, we examine the effect of corporate and government bond purchases on credit spreads through the risk-taking channel. We do so by combining the estimated elasticity of credit spreads with respect to the proxies for FIs' risk appetite in Table 4 and 5 with the economically significant positive relationships between the proxies and the BOJ's government and corporate bond holdings shown in Table 8. As shown in Table 9, over the subsequent quarter following an increase of 10 percent in the BOJ's government and corporate bond holdings, credit spreads of corporate bonds in the highest credit rating category (AAA and AA) declined by 0 to 4 percent, while those in the lowest credit rating category (BB and lower) declined by 6 to 12 percent.

Calculating the weighted average of credit spreads over the subsequent quarter using the share of bonds in each credit rating category in 2016 as weights, we find that a 10 percent increase in the BOJ's government and corporate bond holdings result in a 2 to 8 percent decline through the risk-taking channel as shown in panel (a) of Table 10. Finally, looking at the impact over the subsequent two quarters, the decline in the weighted average of credit spreads through the risk-taking channel ranges from 2 to 10 percent.

4.6 Overall assessment

Finally, we examine the overall impact of BOJ bond purchases on credit spreads through all three channels together. The results are presented in panel (a) of Table 10 and indicate that an increase of 10 percent in the BOJ's government and corporate bond holdings leads

to decline in credit spreads of around 6 to 14 percent over the subsequent quarter, and of around 14 to 25 percent over the subsequent two quarters.

Of the different channels, the default risk channel has the largest impact in terms of reducing credit spreads. This finding suggests that the BOJ's government and corporate bond purchases operate mainly through the default risk channel changing stock market participants' expectations regarding the default risk of corporations. This is consistent with Krishnamurthy and Vissing-Jorgensen's (2011) findings.[14]

It should be noted that the results of our analysis, suggesting that the impact via the default risk effect is the largest, strongly depends on the amount of corporate and government bonds purchased in the counterfactual simulation. In the baseline case, we examined the case of an increase of 10 percent in the BOJ's bond holdings from the average of the value in 2016 to consider a case in line with reality in Japan. If we assume that BOJ purchases of corporate bonds were larger than government bond purchases, the local and global supply effects would be the largest as shown in panel (b) of Table 10.

The findings in this paper shed light on the identification of the supply effects. We empirically find that although the supply effects arising from the BOJ's government bond purchases raise credit spreads by increasing the scarcity of government bonds, the magnitudes of the effects are not very large when compared with the downward pressure on credit spreads through the other channels. Our findings imply that to assess the supply effects accurately, we need to control for the effects through other channels. If we only consider the supply effects and observe the relationship between central bank government bond purchases and credit spreads, we might incorrectly conclude that the supply channels do not have any effect.

5. Conclusion

In this paper, we examined the effects and transmission mechanism of corporate and government bond purchases by the BOJ on credit spreads on corporate bonds of Japanese firms. Exploiting a novel micro dataset, we found that the BOJ's bond purchases have a significant impact on spreads through several channels, namely, the default risk channel,

[14] Krishnamurthy and Vissing-Jorgensen (2011) do not separate the default risk channel from the risk-taking channel and highlight that the risk-taking effect operated strongly in the case of the Federal Reserve's QE1 in 2008-09. They further argue that QE1 loosened FIs' capital constraints and led to a decline in credit spreads, since asset purchases by the Federal Reserve under QE1 included a large amount of mortgage backed securities, which imposed a heavy burden on FIs at the time because the market for such securities was not functioning well.

the local and global supply channels, and the risk-taking channel. Comparing the effect of each channel in the case of an increase of 10 percent in the BOJ's government and corporate bond holdings, the effect through the default risk channel is the largest. We show that over the subsequent quarter, the default risk channel and the risk-taking channel lead to a decline in spreads by 7 percent and 2 to 8 percent respectively, while supply effects lead to an increase in spreads of 2 percent outside the BOJ's purchase criteria.

We provided empirical evidence that the magnitudes of the effects through the local and global supply channels depend on the degree of FIs' risk appetite, which is consistent with the prediction of the preferred habitat theory. We also found that, through the risk-taking channel, the purchase of corporate and government bonds has a stronger effect on the credit spreads of lower-grade corporate bonds.

While our analysis helps to clarify the effects and transmission channels of corporate and government bond purchases by the BOJ on corporate bond credit spreads in Japan, two important questions for future research remain. One is the effects of BOJ's bond purchases on the real economy and inflation in Japan. The second question concerns the costs or risks of corporate bond purchases. Compared with government bond purchases, corporate bonds present a larger risk of price fluctuations, including a sudden drop in bond prices when default risk materializes. To evaluate monetary policy measures more carefully, we need to deepen our understanding of those costs as well as the effects.

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Appendix A: Overview of the BOJ's corporate bond purchase program

In this appendix, we provide a brief overview of the BOJ's corporate bond purchase program.

The BOJ started outright purchases of corporate bonds in February 2009 with the aim of ensuring stability in financial markets as well as facilitating corporate financing by conducting appropriate money market operations. The BOJ – with a temporary suspension – has implemented the corporate bond purchase program until the present. A notable feature of the corporate bond purchase program is that the program targets only bonds with a high credit rating and short-term maturities.

The maximum total outstanding amount of the BOJ's corporate bond holdings and the criteria for corporate bonds being purchased have been determined and modified by the BOJ as shown in Table 1. When the program started, to be eligible, corporate bonds had to have a credit rating of single A or higher and a maturity of less than one year. The maximum total outstanding amount of the corporate bond holdings was 1 trillion yen. The program was halted at the end of 2009 and then restarted in October 2010. Following the restart, all investment grade corporate bonds – *i.e.*, down to bonds with a BBB rating – were eligible. The maximum total outstanding amount was gradually expanded and the maturities eligible were slowly extended. The maximum total outstanding amount of the BOJ's corporate bond holdings at the restart of the program in October was 0.5 trillion yen, or about 0.1 percent of Japan's nominal gross domestic product (GDP), reaching 3.2 trillion yen, or about 0.6 percent of nominal GDP, in October 2012. This level has been maintained until the present. Meanwhile, at the restart of the program in October 2010, the maturity of eligible corporate bonds ranged from one to two years, while since April 2012 and up to the present, the maturity of eligible corporate bonds has spanned from one to three years.

Under this program, operations are conducted through conventional auctions. When conducting outright purchases of corporate bonds, the BOJ in advance announces (a) the total amount it plans to purchase, (b) the purchase date and time of payment, (c) the deadline for bid submissions, and (d) other relevant matters. Purchases are conducted using a multiple-price competitive auction based on the conventional method, in which eligible market participants submit bids stating their desired yield to the BOJ. With the desired yield, auction participants notify the BOJ of the amount of bonds they wish to sell per issue per desired yield, as well as any other matters stipulated by the BOJ, by the bid submission deadline. The BOJ accepts bids by starting with the highest desired yield and

continuing down so that the amount purchased of corporate bonds by a single issuer remains within the unused purchase value.

The BOJ's corporate bond holdings increased substantially following the restart of the program, as shown in panels (a) and (b) of Figure A, which show the BOJ's government bond holdings for comparison. Relative to the total outstanding amount of corporate bonds in Japan, the share of the BOJ's holdings is not very large, reaching around 5 percent in 2013 and then remaining at that level. Panel (c) in Figure A shows the ratio of corporate bond supply to government bond supply. Here, the supply of corporate and government bonds is defined as the total outstanding amount available to the public. Consequently, the BOJ's bond purchases result in the reduction of the supply of bonds. Data on the supply of corporate and government bonds is published by the Japan Securities Dealers Association. The supply of corporate bonds is the amount outstanding of corporate straight bonds from which the BOJ's corporate bond holdings is subtracted. The supply of government bonds is the amount outstanding of public offering government bonds from which the BOJ's government bond holding is subtracted. From 1999 to 2013, the ratio decreased, reflecting the fact that more government bonds than corporate bonds were issued. However, the ratio stopped falling in 2013 and then started to rise due to massive government bond purchases by the BOJ.

Appendix B: Method of calculating the distance to default

This appendix explains the method we use to calculate the distance to default, DD. We closely follow the method employed by GZ, who in turn employ the distance to default framework developed by Merton (1974).

The first assumption in this framework is that the total value of firm V follows a geometric Brownian motion:

$$dV = \mu_V V dt + \sigma_V V dW,$$

where μ_V denotes the expected continuously compounded return on V; σ_V is the volatility of the total value of the firm V; and dW is the increment of the standard Weiner process. The second assumption is that the firm has just issued a single discount bond of amount D that will mature in T periods.

These two assumptions imply that the value of the firm's equity E is given as a call option on the total value of the firm V with a strike price equal to the face value of the firm's debt D and a time to maturity of T. In this setting, the value of the firm's equity E satisfies

$$E = V\Phi(\delta_1) - e^{-rT} D\Phi(\delta_2), \qquad \text{(B-1)}$$

where r denotes the instantaneous risk-free interest rate, $\Phi(\cdot)$ is the cumulative standard normal distribution function, and

$$\delta_1 = \frac{\ln(V/D) + (r + 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}} \qquad \text{and} \qquad \delta_2 = \delta_1 - \sigma_V\sqrt{T}.$$

The distance to default DD over a one-year horizon (*i.e.*, $T = 1$) is implied by the two assumptions as follows:

$$DD = \frac{\ln(V/D) + (\mu_V - 0.5\sigma_V^2)}{\sigma_V}.$$

The corresponding probability of default is given by $\Phi(-DD)$.

In the implementation of the model, we take several steps: First, we estimate σ_E from historical daily stock returns using a 250-day moving window. Second, we assume that the face value of the firm's debt D is equal to the sum of the firm's current liabilities and one-half of its long-term liabilities. Third, the estimated values of V, μ_V, and σ_V

can be solved using the iterative procedure proposed by Bharath and Shumway (2008) with the observed values of E, D, σ_E and r (the daily one-year constant-maturity Japanese government bond yield). In the iterative procedure, by letting $\sigma_V = \sigma_E E/(E + D)$ and using (B-1), we infer the total value of firm V for every day of the 250-day moving window. Next, by calculating the implied daily log-return on the total value of the firm, we generate the updated estimates of σ_V and μ_V. We continue the iterative procedure until the convergence of σ_V.

Employing this methodology, we compute the year-ahead DD for all firms that issued corporate bonds within our data selection criteria shown in Table 2.

Table 1: Overview of the BOJ's corporate bond purchase program

	Amount to be purchased (maximum)	Criteria	
		Credit rating	Maturity
19-Feb-09	1 trillion yen	A or higher	Up to one year
31-Dec-09		Abolished	
28-Oct-10	0.5 trillion yen	BBB or higher	One to two years
14-Mar-11	2 trillion yen		
4-Apr-11	2.9 trillion yen		
27-Apr-12			One to three years
30-Oct-12	3.2 trillion yen		

Table 2: Data selection criteria and summary statistics for the key characteristics of bonds in our sample

(a) Data selection criteria

Criterion	Selected
Issue country and market	Japan
Issue currency	Japanese yen
Coupon payment	Fixed coupon rate
Senior/Subordinate	Senior only
Callable clause	No
Stock conversion	No
Sector	Non-financial firms (firms excluding commercial and investment banks)

(b) Summary statistics for the key characteristics of bonds

	Mean	Standard deviation	Min	Median	Max
Number of bonds per firm/month	7.02	10.16	1.00	3.00	96.00
Issue size (Japanese yen bil.)	21.2	18.9	1.5	15.0	220.0
Maturity at issue (years)	9.1	5.0	1.0	9.5	40.0
Time to maturity (years)	5.2	4.3	0.02	4.1	40.0
Credit rating	-	-	CCC	A	AAA
Coupon rate (pct.)	1.79	0.85	0.001	1.75	6.00
Credit spread (basis points)	10.2	21.6	0.0003	5.1	1101.6

Notes: Observation period: 1997:4-2016:10. Observations=360,770. Number of bonds=5,614. Number of firms=383.

Table 3: Specifications to examine the roles of firm- and bond-specific characteristics and the relative scarcity of corporate bonds

	Dependent variable: Log of credit spreads						
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Observation period	1997:4-2016:10	1997:4-2016:10	1998:1-2016:10	1997:4-2016:10	2000:2-2016:10	2000:2-2016:10	1998:1-2016:10
Distance to default	-0.16 ***	-0.16 ***	-0.13 ***	-0.13 ***	-0.15 ***	-0.12 ***	-0.12 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log of age	0.19 ***	0.19 ***	0.24 ***	0.26 ***	0.20 ***	0.27 ***	0.26 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log of issue size	-0.04 ***	-0.03 ***	0.01 **	-0.01 ***	-0.04 ***	0.02 ***	0.01 ***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Log of maturity	0.86 ***	0.81 ***	0.83 ***	0.84 ***	0.86 ***	0.80 ***	0.81 ***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Eligibility dummy	-	-0.56 ***	-	-	-	-0.39 ***	-0.28 ***
		(0.005)				(0.005)	(0.005)
Ratio of CB supply to JGB supply	-	-	5.611 ***	-	-	2.987 ***	4.985 ***
			(0.023)			(0.029)	(0.023)
FIs' risk appetite:							
Loan Survey	-	-	-	-0.002 ***	-	-0.002 ***	-
				(0.000)		(0.000)	
Tankan	-	-	-	-	-0.040 ***	-	-0.044 ***
					(0.000)		(0.000)
Credit rating dummy:							
AAA or AA	-0.82 ***	-0.83 ***	-0.83 ***	-0.99 ***	-0.89 ***	-0.98 ***	-0.97 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
A	-0.76 ***	-0.72 ***	-0.72 ***	-0.82 ***	-0.78 ***	-0.72 ***	-0.66 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
BB or lower	0.93 ***	0.86 ***	0.86 ***	1.01 ***	0.97 ***	0.93 ***	0.93 ***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Industry dummy	yes	yes	yes	yes	yes	yes	yes
No. of observations	360,770	360,770	357,024	328,770	360,770	328,770	357,024
Adjusted R-squared	0.46	0.48	0.55	0.50	0.48	0.53	0.57

Notes: Asymptotic standard errors are in parentheses. ** and *** indicate statistical significance at the 5% and 1% level, respectively. JGB and CB stand for "Japanese government bond" and "corporate bond," respectively.

Table 4: Full specification (FIs' risk appetite: Loan Survey)

Dependent variable: Log of credit spreads	
Observation period	1997:4-2016:10
Distance to default	-0.12 ***
	(0.001)
Log of age	0.27 ***
	(0.001)
Log of issue size	0.02 ***
	(0.003)
Log of maturity	0.80 ***
	(0.002)
FIs' risk appetite (Loan Survey)	-0.005 ***
	(0.000)
Ratio of CB supply to JGB supply	2.847 ***
	(0.034)
FIs' risk appetite (Loan Survey)×Ratio of CB supply to JGB supply	-0.001
	(0.001)
Eligibility dummy×FIs' risk appetite (Loan Survey)	-0.049 ***
	(0.003)
Eligibility dummy×Log of the BOJ's CB holdings	-0.021 ***
	(0.001)
Eligibility dummy×FIs' risk appetite (Loan Survey)×Log of the BOJ's CB holdings	0.003 ***
	(0.000)
Credit rating dummy:	
AAA or AA	-1.18 ***
	(0.01)
A	-0.81 ***
	(0.01)
BB or lower	1.03 ***
	(0.02)
Credit rating dummy×FIs' risk appetite (Loan Survey):	
AAA or AA	0.005 ***
	(0.00)
A	0.002 ***
	(0.00)
BB or lower	-0.003 ***
	(0.00)
Industry dummy	yes
No. of observations	328,770
Adjusted R-squared	0.54

Notes: Asymptotic standard errors are in parentheses. *** indicates statistical significance at the 1% level. JGB and CB stand for "Japanese government bond" and "corporate bond," respectively.

Table 5: Full specification (FIs' risk appetite: *Tankan*)

Dependent variable: Log of credit spreads	
Observation period	1998:1-2016:10
Distance to default	-0.12 ***
	(0.001)
Log of age	0.26 ***
	(0.001)
Log of issue size	0.01 ***
	(0.002)
Log of maturity	0.82 ***
	(0.002)
FIs' risk appetite (*Tankan*)	-0.024 ***
	(0.001)
Ratio of CB supply to JGB supply	4.599 ***
	(0.029)
FIs' risk appetite (*Tankan*)×Ratio of CB supply to JGB supply	-0.073 ***
	(0.004)
Eligibility dummy×FIs' risk appetite (*Tankan*)	-0.158 ***
	(0.006)
Eligibility dummy×Log of the BOJ's CB holdings	-0.022 ***
	(0.000)
Eligibility dummy×FIs' risk appetite (*Tankan*)×Log of the BOJ's CB holdings	0.011 ***
	(0.000)
Credit rating dummy:	
AAA or AA	-0.96 ***
	(0.01)
A	-0.72 ***
	(0.01)
BB or lower	0.87 ***
	(0.02)
Credit rating dummy×FIs' risk appetite (*Tankan*):	
AAA or AA	0.005 ***
	(0.00)
A	-0.020 ***
	(0.00)
BB or lower	-0.027 ***
	(0.00)
Industry dummy	yes
No. of observations	357,024
Adjusted R-squared	0.58

Notes: Asymptotic standard errors are in parentheses. *** indicates statistical significance at the 1% level. JGB and CB stand for "Japanese government bond" and "corporate bond," respectively.

Table 6: Extraction of the excess distance to default

	Dependent variable: Distance to default
Credit rating dummy:	
AAA or AA	2.69 ***
	(0.01)
A	1.03 ***
	(0.01)
BB or lower	-2.17 ***
	(0.03)
Industry dummy	yes
Time fixed effect	yes
No. of observations	361,180
Adjusted R-squared	0.56

Notes: Observation period: 1997:4-2016:10. Asymptotic standard errors are in parentheses. *** indicates statistical significance at the 1% level.

Table 7: Effect of BOJ bond purchases on the excess distance to default

	Dependent variable: Excess distance to default	
	Three months ahead	Six months ahead
Term spread	0.63 **	1.50 ***
	(0.31)	(0.49)
Real policy interest rate	-0.03	-0.07
	(0.10)	(0.15)
Log of the BOJ's JGB and CB holdings (change over the last three months)	5.80 ***	12.88 ***
	(2.09)	(3.01)
Adjusted R-squared	0.18	0.31

Notes: Observation period: 2001:1-2016:6. Each specification includes a constant and p lags of ΔY_{t-1} (not reported), where p is determined by the AIC. HAC consistent standard errors are in parentheses. **, and *** indicate statistical significance at the 5% and 1% level, respectively. JGB and CB stand for "Japanese government bond" and "corporate bond," respectively.

Table 8: Effect of BOJ bond purchases on FIs' risk appetite

	Dependent variable: FIs' risk appetite			
	Loan Survey		*Tankan*	
	1Q ahead	2Q ahead	1Q ahead	2Q ahead
Term spread	13.99 ***	21.50 ***	3.45 ***	3.92
	(4.37)	(5.85)	(3.43)	(2.89)
Real interest rate	-1.28	-2.61 *	0.06	0.23
	(0.77)	(1.40)	(0.83)	(0.84)
TOPIX	8.38	17.38	6.43	11.88
(Quarterly log diff.)	(7.09)	(13.19)	(6.45)	(7.11)
BOJ's JGB and CB holdings	78.71 ***	112.27 ***	23.37 ***	29.23 **
(Quarterly log diff.)	(20.71)	(35.66)	(12.76)	(11.54)
Adjusted R-squared	0.66	0.65	0.07	0.19

Notes: Observation period: 2001:1-2016:4. Each specification includes a constant and p lags of ΔY_{t-1} (not reported), where p is determined by the AIC. HAC consistent standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. JGB and CB stand for "Japanese government bond" and "corporate bond," respectively.

Table 9: Quantitative assessment of the risk-taking channel

	Loan Survey		*Tankan*	
	1Q ahead	2Q ahead	1Q ahead	2Q ahead
AAA or AA	0.3%	0.5%	-4.3%	-5.3%
A	-1.8%	-2.6%	-10.2%	-12.7%
BBB	-3.7%	-5.3%	-5.5%	-6.9%
BB or lower	-5.9%	-8.4%	-12.0%	-15.0%

Note: The results are for the case of an increase of 10 percent in the BOJ's government and corporate bond holdings.

Table 10: Overall assessment

(a) Effect of a 10 percent increase in the BOJ's government and corporate bond holdings

	Loan Survey		*Tankan*	
	1Q ahead	2Q ahead	1Q ahead	2Q ahead
Default risk channel	-7.0%	-15.6%	-7.0%	-15.4%
Risk-taking channel	-1.5%	-2.1%	-8.1%	-10.2%
Local and global supply channels				
Within the BOJ's criteria	-0.6%	-0.5%	1.5%	1.1%
Outside the BOJ's criteria	2.1%	3.4%	1.9%	1.5%
Total				
Within the BOJ's criteria	-9.1%	-18.1%	-13.6%	-24.5%
Outside the BOJ's criteria	-6.4%	-14.3%	-13.1%	-24.1%

(b) Effect of the BOJ's bond purchases targeting only corporate bonds

	Loan Survey		*Tankan*	
	1Q ahead	2Q ahead	1Q ahead	2Q ahead
Default risk channel	-7.0%	-15.6%	-7.0%	-15.4%
Risk-taking channel	-1.5%	-2.1%	-8.1%	-10.2%
Local and global supply channels				
Within the BOJ's criteria	-25.1%	-39.0%	-57.1%	-57.4%
Outside the BOJ's criteria	-20.7%	-33.5%	-37.9%	-38.4%
Total				
Within the BOJ's criteria	-33.6%	-56.7%	-72.2%	-83.1%
Outside the BOJ's criteria	-29.2%	-51.2%	-53.0%	-64.0%

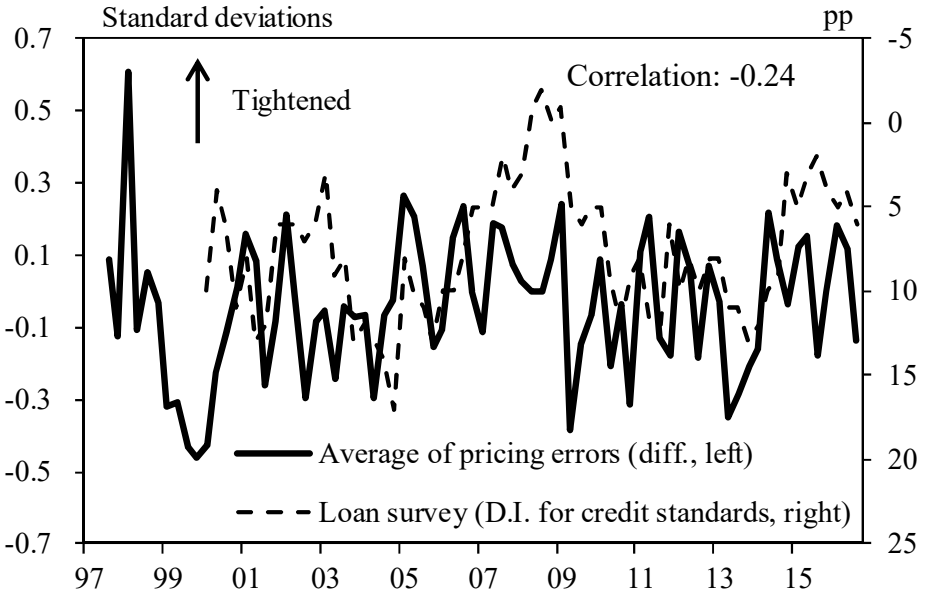
(c) Effect of the BOJ's bond purchases targeting only government bonds

	Loan Survey		*Tankan*	
	1Q ahead	2Q ahead	1Q ahead	2Q ahead
Default risk channel	-7.0%	-15.6%	-7.0%	-15.4%
Risk-taking channel	-1.5%	-2.1%	-8.1%	-10.2%
Local and global supply channels				
Within the BOJ's criteria	-0.4%	-0.1%	2.6%	2.3%
Outside the BOJ's criteria	2.3%	3.7%	2.3%	1.9%
Total				
Within the BOJ's criteria	-8.8%	-17.7%	-12.5%	-23.4%
Outside the BOJ's criteria	-6.2%	-14.0%	-12.8%	-23.8%

Notes: Panel (a) shows the case of an increase of 10 percent in the BOJ's government and corporate bond holdings in 2016. Panel (b) show the case that only the corporate bond holdings increase by 10 percent of the BOJ's corporate and government bond holding in 2016. Panel (c) shows the case that only the government bond holdings increase by the same amount as panel (b). The averages of FIs' risk appetite and the ratio of the corporate bond supply to the government bond supply in 2016 are used for this assessment.

Figure 1: Average of pricing errors and FIs' risk appetite

(a) Diffusion index for credit standards in Loan Survey



(b) Estimated FIs' risk appetite from *Tankan* data

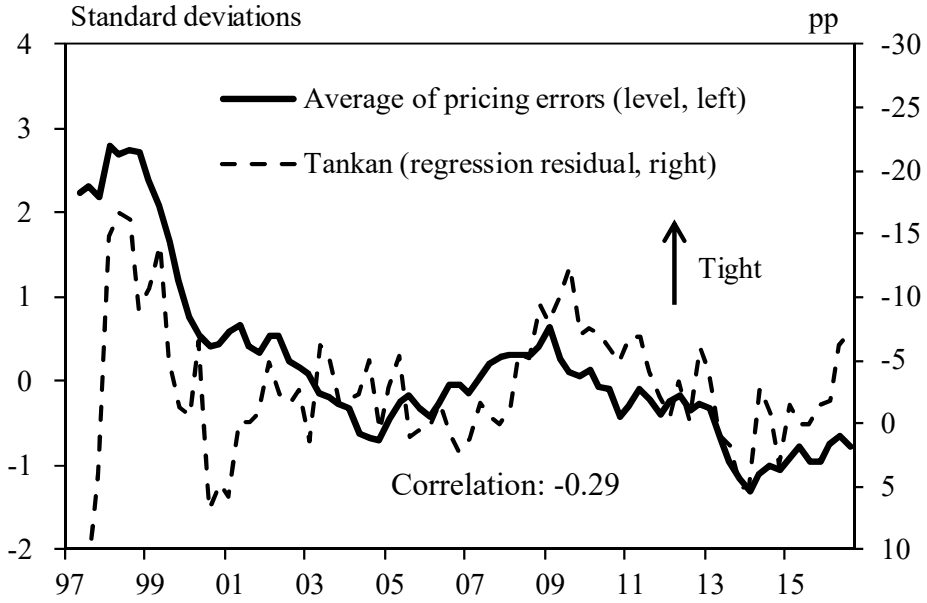
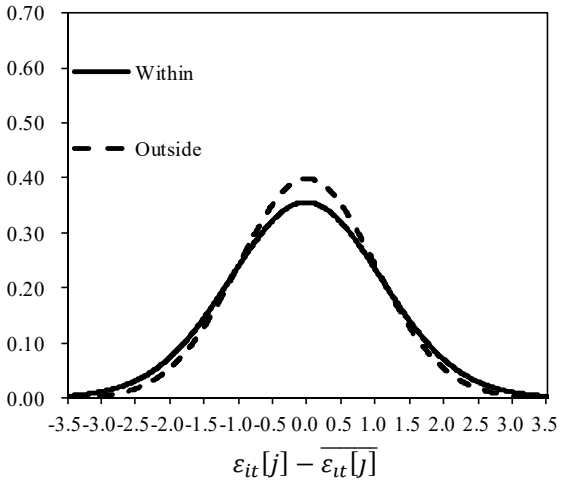
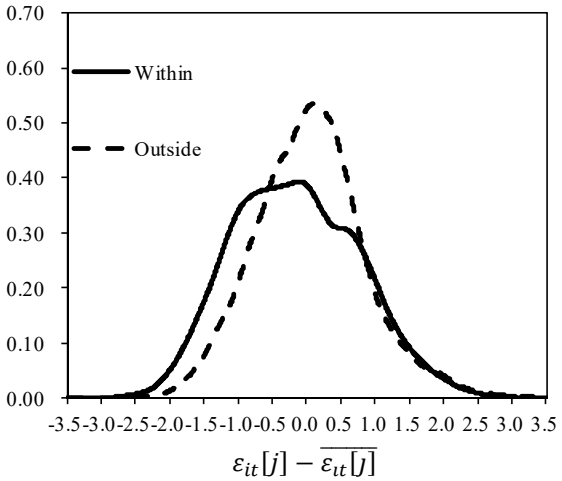


Figure 2: Distributions of pricing errors

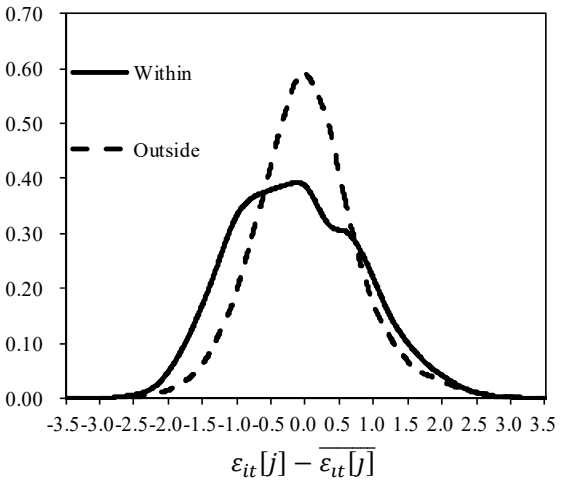
(a) Before start of the BOJ program



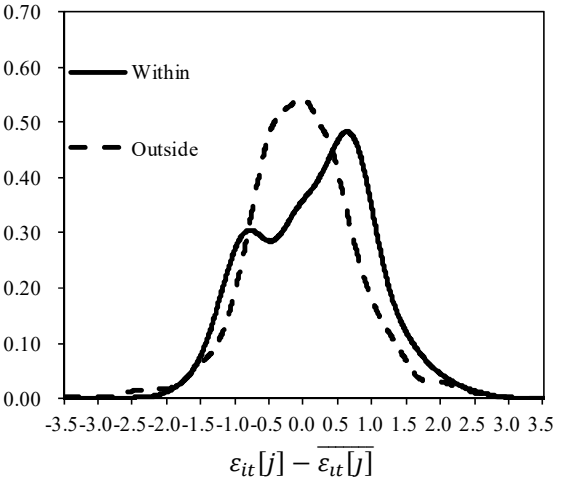
(b) After start of the BOJ program (after Oct. 2010)



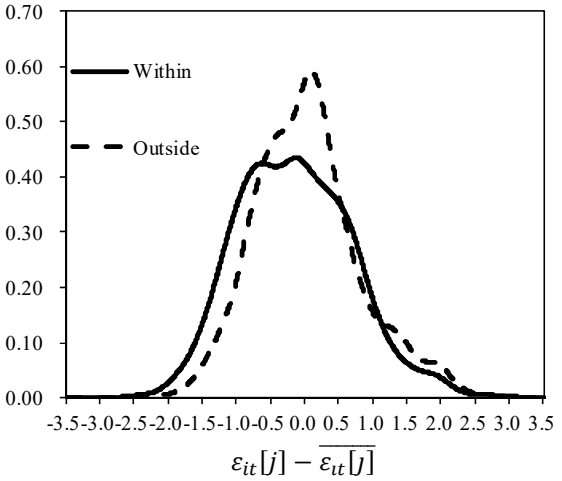
(c) Feb. 09 - Dec. 09



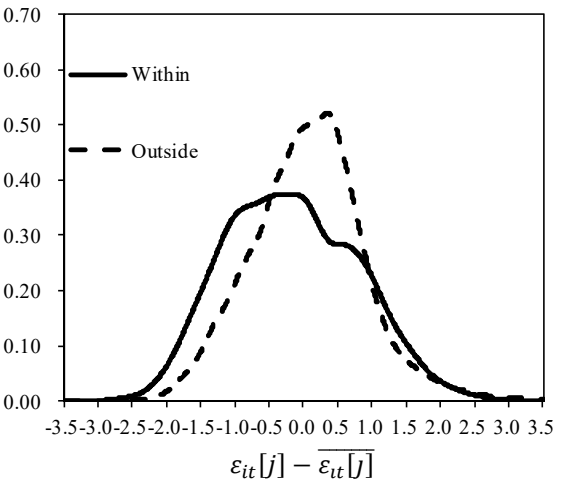
(d) Oct. 10 - Feb. 11



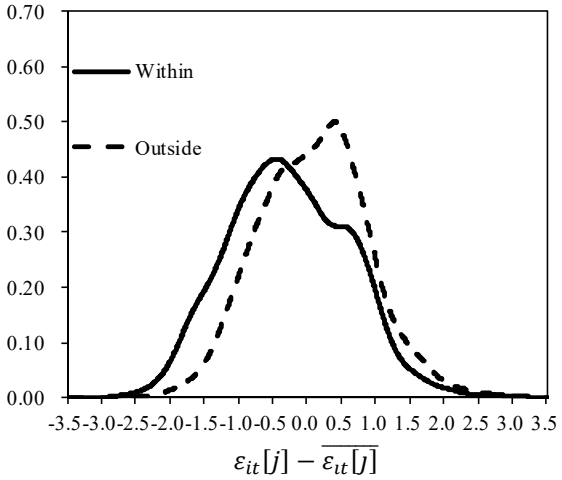
(e) Jan. 11 - Dec. 12



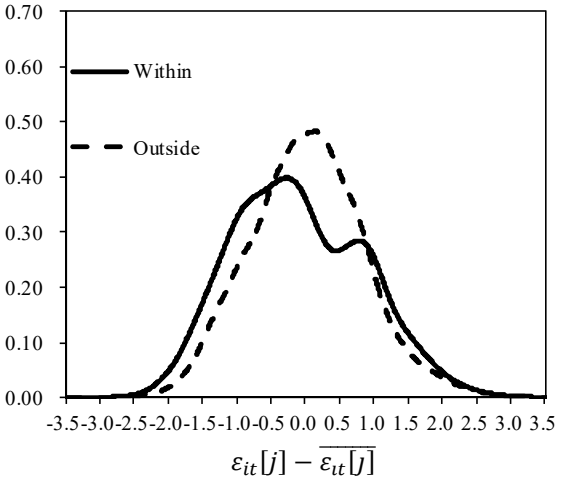
(f) Jan. 13 - Oct. 16



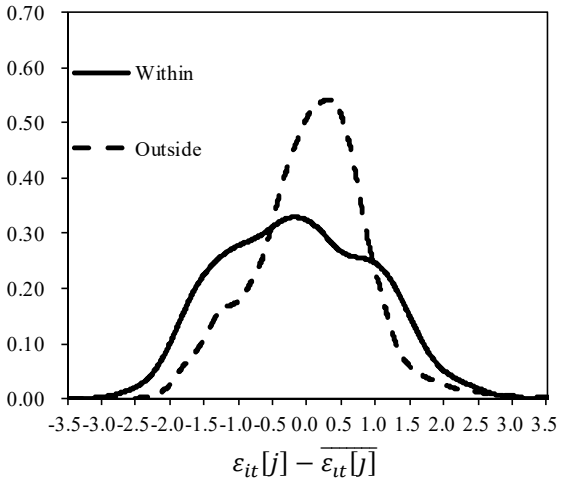
(g) Jan. 13 - Dec. 13



(h) Jan. 14 - Dec. 14



(i) Jan. 15 - Dec. 15



(j) Jan. 16 - Oct. 16

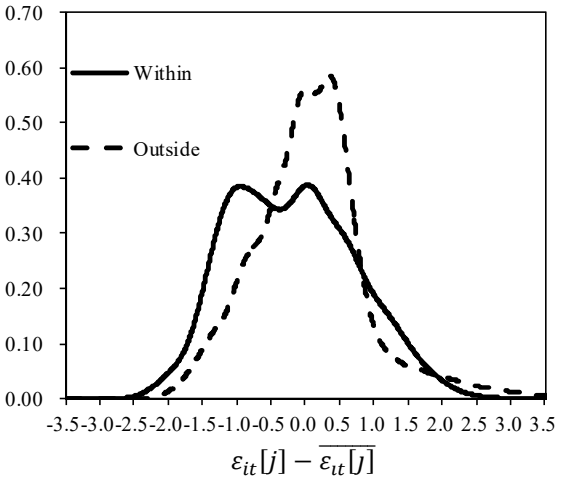


Figure 3: Yields of traded corporate bonds

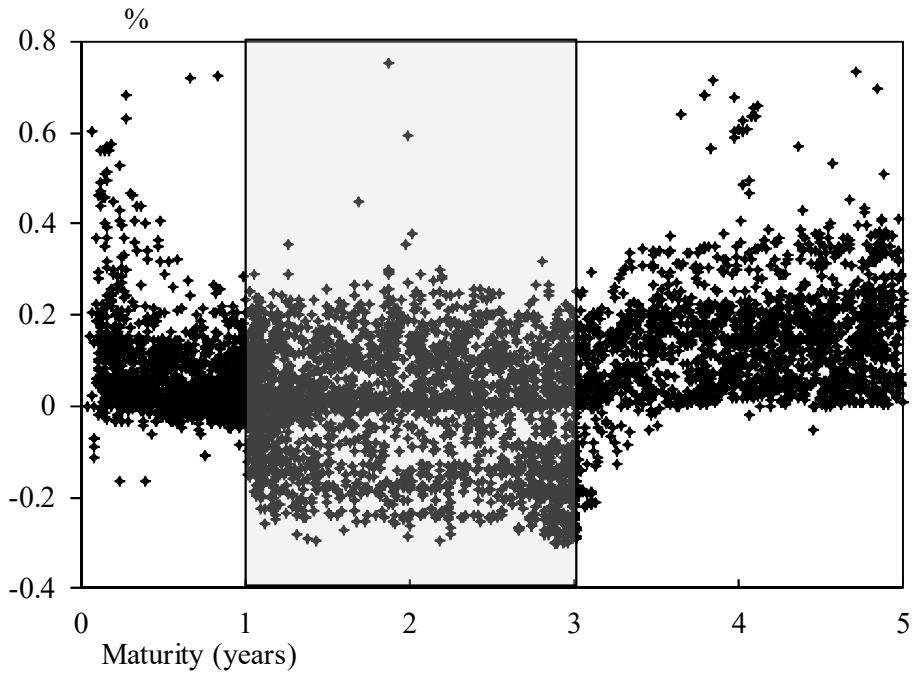


Figure 4: Schematic diagram of transmission channels of corporate and government bond purchases

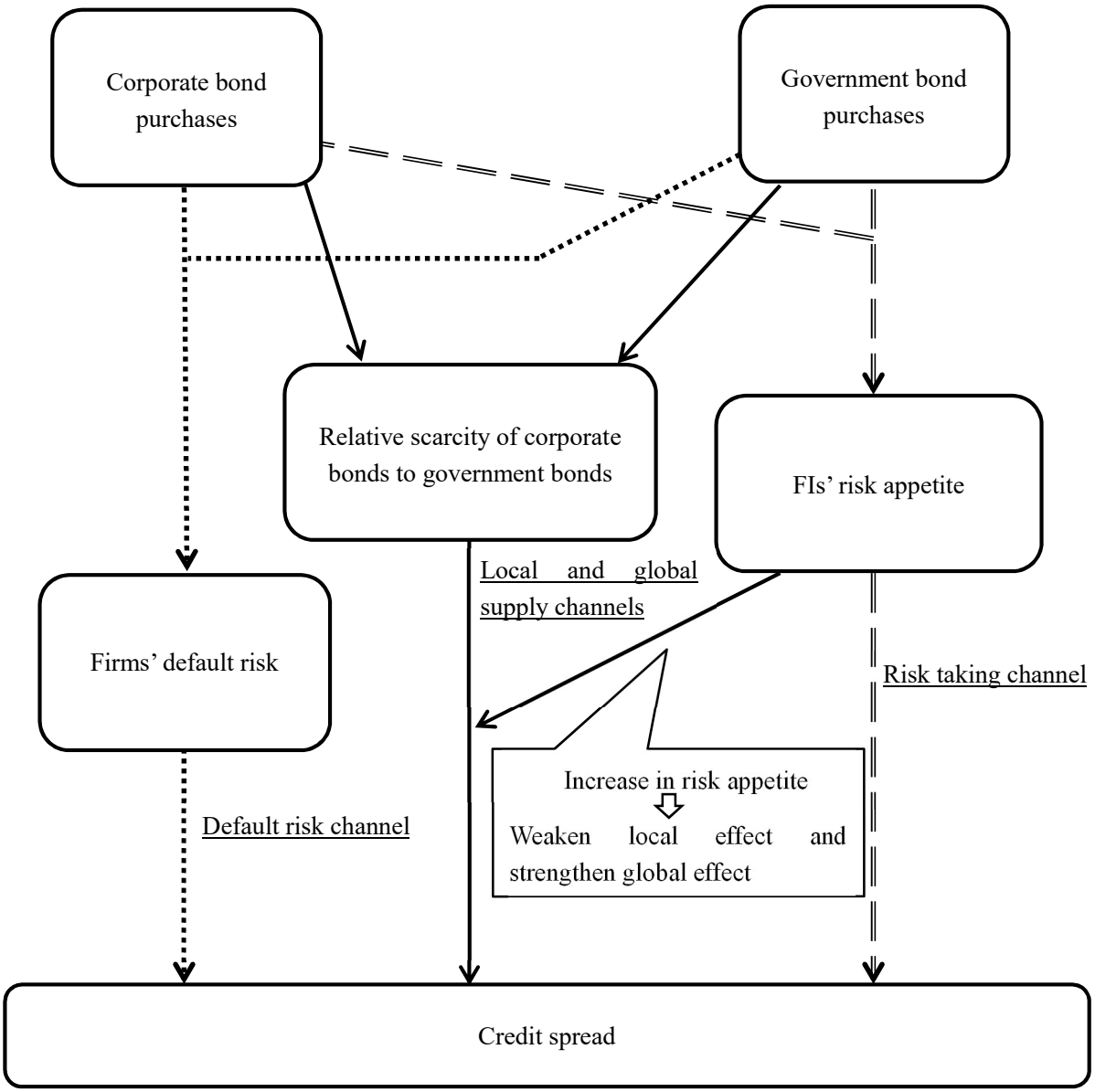


Figure 5: Excess distance to default

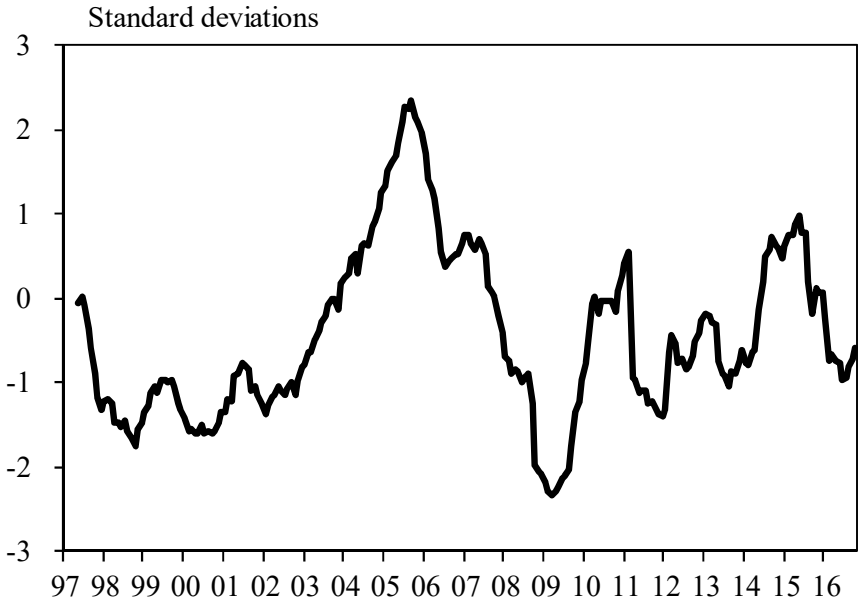
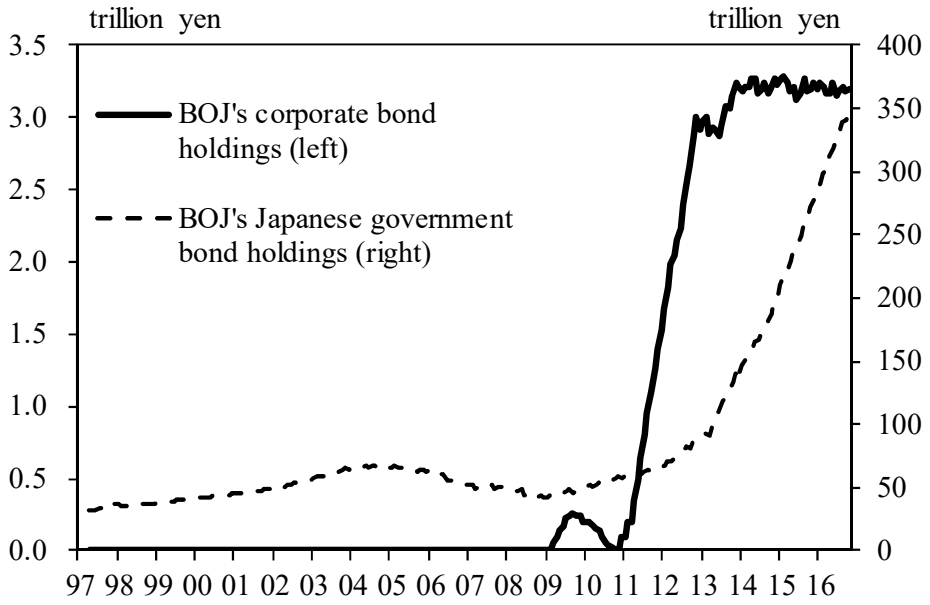
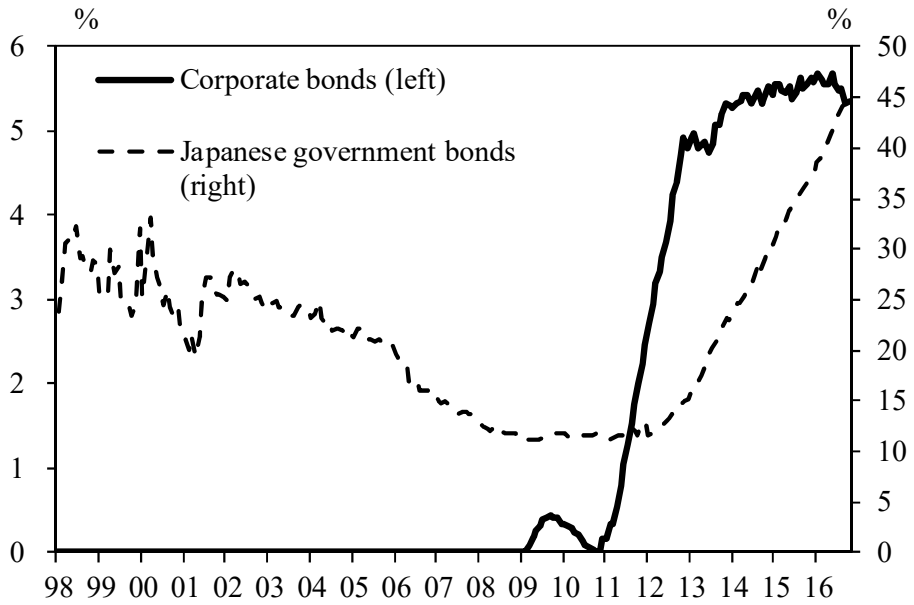


Figure A: The BOJ's corporate and Japanese government bond holdings and the ratio of corporate bond supply to government bond supply

(a) Level



(b) Share in total amount outstanding



(c) Ratio of corporate bond supply to government bond supply