The Effects of Monetary Policy Announcements at the Zero Lower Bound

Natsuki Arai*

First Version: November, 2013

This Version: December 9, 2015

Abstract

This paper investigates the effects of monetary policy announcements at the zero lower bound using Japanese data from 1998 to 2013. I find that the effect of expansionary monetary policy shocks is directly passed on to corporate bond yields, notably for high-grade corporate bond yields. However, the magnitude of estimated pass-through to stock prices and the exchange rate is substantially smaller than in the U.S., and not statistically significant in most cases.

Keywords: Zero Lower Bound, Unconventional Monetary Policy, Identification through Heteroscedasticity, Bank of Japan

J.E.L. codes: E43, E44, E52, E58

*Department of International Business, National Chengchi University, Taiwan: narai@nccu.edu.tw. This paper is based on Chapter 1 of my dissertation submitted to Johns Hopkins University. I am grateful to Jonathan Wright and an anonymous referee for their extremely helpful comments and suggestions. I thank Larry Ball, Chris Carroll, Varanya Chaubey, Jon Faust, Yoichi Goto, Takashi Kano, Matt Raskin, Katsuhiro Oshima, Yuya Sasaki, Rodrigo Sekkel, Richard Spady, Ruli Xiao, Egon Zakrajsek, and seminar participants at Bank of Canada, Hitotsubashi university, National Chengchi University and National Tsing Hua University for their helpful comments. All errors are the sole responsibility of the author.

1 Introduction

The effect of unconventional monetary policy at the zero lower bound (ZLB), that include forward guidance and asset purchases, has been a centerpiece of the debate in macro-finance since many advanced economies reached the ZLB after the financial crisis of 2008. Since the crisis, a number of important contributions have been made regarding this topic.[1] However, the analysis in the literature primarily focuses on the U.S. economy after the crisis, which is restricted by a short sample, and researchers are not sure about the effect of unconventional monetary policy in a different environment.

In this paper, I study the effects of unconventional monetary policy in Japan, which has experienced a substantially longer period at the ZLB, from 1995 to the present.[2] Specifically, I use the method of identification through heteroscedasticity, which was originally proposed by Rigobon (2003) and Rigobon and Sack (2003, 2004) and has been widely used in the recent literature,[3] to estimate the pass-through of monetary policy shock. Identification is based on the assumption that the variance of monetary policy shocks is particularly high on important announcement days, whereas nothing unusual happens to other shocks on these days.

To assess the stimulative effect of monetary policy on aggregate demand, I focus on the pass-through of monetary policy shock to three financial assets, which are commonly targeted by central banks: corporate bonds, stocks and the exchange rate. First, I study the pass-through to corporate bond yields, because the reduction in the borrowing cost of firms is a key channel through which monetary policy could stimulate aggregate demand. Second, I analyze the pass-through to stock prices, which is relevant because the response of stock prices could increase consumption through the wealth effect. Finally, I evaluate the pass-through to the exchange rate, through which aggregate demand can be boosted via the trade balance.

The results show that there is a stark contrast between the pass-through to corporate bond yields and the pass-through to stock prices and the exchange rate. For corporate bond yields, there

[1] For example, see D'Amico and King (2013), Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), and Wright (2012) for the Fed's Large-Scale Asset Purchases (LSAPs) programs, and see Joyce et al. (2012) for the Bank of England's asset purchases. For more comprehensive review, see Bernanke (2012). For the comparison across advanced economies, see Rogers et al. (2014).

[2] Figure 1 shows the comparison between policy rates in Japan and the U.S.

[3] For example, see Gilchrist and Zakrajsek (2013) and Raskin (2013).

is a statistically significant and about one-to-one pass-through, notably for high-grade corporate bond yields. On the other hand, the pass-through to stock prices and the exchange rate is not statistically significant in most cases. However, these estimates in Japan are markedly different from the estimates in U.S. based on the data from 2008 to the present. While I find one-to-one pass-through to corporate bond yields in the U.S., which is broadly similar to Japan, the U.S. pass-through to stock prices and the exchange rate is statistically significant, and its magnitude is substantially larger than that of Japan.

In addition, I use a simple event study to analyze the effects of announcements in 2013, to show that these announcements have substantial effect even on stock prices. The announcements in 2013 are associated with the regime change of Bank of Japan's (BOJ) monetary policy to commit to the 2-percent inflation target by 2015. Unlike the previous announcements, these announcements had substantial effects, not only on corporate bonds, but also on stock prices. This difference may be due to the different nature of the BOJ's commitment after 2013; the commitment is open-ended and the BOJ announces that it will do whatever it takes to achieve the target.

Lastly, I provide several robustness checks, to which the main results are generally robust. First, I analyze the pass-through to other financial assets: (1) real estate investment trusts (REIT), (2) credit default swaps (CDS), and (3) the exchange rate of the OECD and Asian economies. Second, I estimate the pass-through based on more selected set of announcements. Third, I consider subsamples focusing on different programs: 2001-2006, 2006-2010, and 2010-2013. Fourth, I provide the analysis based on the principal component of government bond yields with different maturities. Last, I use alternative sets of non-announcement days.

The remainder of the paper is organized as follows: Section 2 describes the methodology used in the paper, Section 3 explains the data and background of Japanese monetary policy, Section 4 presents the results. Section 5 concludes.

2 Method

This section describes an analytical framework to estimate the pass-through of monetary policy shocks on various financial assets. Based on the standard setup of two simultaneous equations, I present a simple event study and the framework of identification through heteroscedasticity. In addition, I introduce the weak-identification robust confidence set to address the issue of weak identification.

2.1 Setup

Consider the system of two simultaneous equations between the change in the interest rate and the growth rate of the asset price, Δi_t and Δs_t. The notation follows Rigobon and Sack (2004):

$$\Delta i_t = \beta \Delta s_t + \gamma X_t + \varepsilon_t, \quad (1)$$

$$\Delta s_t = \alpha \Delta i_t + \delta X_t + \eta_t, \quad (2)$$

where X_t is a common exogenous shock that simultaneously affects both the interest rate and the asset price, ε_t is a monetary policy shock, and η_t is a shock to the asset price.

In this system, I primarily focus on estimating the parameter α because it indicates how much monetary policy shocks affect asset prices through the changes in the interest rate. However, the OLS estimate of the pass-through, α, is biased since both variables, Δi_t and Δs_t, are simultaneously determined in the system.[4]

2.2 Event Study

An event study is a simple way to estimate the pass-through using a directly measured monetary policy surprise. By picking the important announcements and regarding them as a complete surprise, we can use the corresponding changes in the asset prices to estimate the effect of monetary policy shocks. Gagnon et al. (2011) directly measured the effect of the Fed's Large-Scale Asset Purchases (LSAP) by assuming that the announcements about the LSAP were complete surprises, and added up the changes on the announcement days. Though the event study is based on the strong assumption that no other material news came within the announcement window, it can provide useful benchmark results.

[4] For the derivation of the OLS estimate and its bias, see Appendix A.1.

2.3 Identification through Heteroscedasticity

To obtain a consistent estimate of the pass-through under weaker assumptions, we employ a scheme called identification through heteroscedasticity, proposed by Rigobon (2003) and Rigobon and Sack (2003, 2004). Essentially, it uses the shift of the variances of endogenous variables between the announcement days and non-announcement days as instruments for the identification.

I introduce some notation and assumptions to describe this scheme of identification. First, I denote a subset of the policy announcement days as A and a subset of the non-announcement days as $\bar{A}$.[5] Second, I denote the number of announcement days and non-announcement days as T_A and $T_{\bar{A}}$, and thus the total number of days as $T \equiv T_A + T_{\bar{A}}$. Finally, I assume that the variance of monetary policy shock is larger on the announcement days than on the non-announcement days, but the variance of other shocks are the same across these two sets of days. Under this assumption, the difference of the conditional variance-covariance matrices in these two sets of days, $\mathbf{\Omega}_A$ and $\mathbf{\Omega}_{\bar{A}}$, only depends on the variance of monetary policy shocks. Specifically, we can compute the difference of the variances, $\Delta\mathbf{\Omega}$, as follows:

$$\Delta\mathbf{\Omega} \equiv \mathbf{\Omega}_A - \mathbf{\Omega}_{\bar{A}} = \frac{\sigma^2_{\varepsilon|A} - \sigma^2_{\varepsilon|\bar{A}}}{(1-\alpha\beta)^2} \begin{pmatrix} 1 & \alpha \\ \alpha & \alpha^2 \end{pmatrix}, \tag{3}$$

where $\sigma^2_{\varepsilon|A}$ and $\sigma^2_{\varepsilon|\bar{A}}$ are the conditional variances of monetary policy shocks on the announcement days and the non-announcement days, respectively.[6] This is because the effect of other shocks cancels out by taking the difference between the announcement days and non-announcement days.

As discussed in Rigobon and Sack (2004), α can be estimated by using $\Delta\mathbf{\Omega}$ as the instruments for identification. To formalize the instruments, we first define endogenous variables. Let $\mathbf{\Delta i}_A$ and $\mathbf{\Delta s}_A$ be $T_A \times 1$ vectors of variables on the announcement days, and $\mathbf{\Delta i}_{\bar{A}}$ and $\mathbf{\Delta s}_{\bar{A}}$ be $T_{\bar{A}} \times 1$ vectors of variables on the non-announcement days. Then, we can combine these two vectors into $T \times 1$ vectors of endogenous variables:

[5] Unlike Rigobon and Sack (2004), all business days that do not belong to A are treated as the non-announcement days. To make this point clear, I denote a subset of the non-announcement days as $\bar{A}$. The results using alternative sets of the non-announcement days are presented in Section 4.4.5.

[6] For the derivation, see Appendix A.2.

$$\begin{aligned}\mathbf{\Delta i} &\equiv [\,\mathbf{\Delta i}_A, \quad \mathbf{\Delta i}_{\bar{A}}\,]', & (4)\\ \mathbf{\Delta s} &\equiv [\,\mathbf{\Delta s}_A, \quad \mathbf{\Delta s}_{\bar{A}}\,]'. & (5)\end{aligned}$$

Given these endogenous variables, $\mathbf{\Delta i}$ and $\mathbf{\Delta s}$, instruments are constructed by normalizing with the number of days in each subset of days, and by flipping the signs of the variables on the non-announcement days:

$$\begin{aligned}\mathbf{z_i} &\equiv \left[\frac{1}{T_A}\mathbf{\Delta i}_A, \quad -\frac{1}{T_{\bar{A}}}\mathbf{\Delta i}_{\bar{A}}\right]', & (6)\\ \mathbf{z_s} &\equiv \left[\frac{1}{T_A}\mathbf{\Delta s}_A, \quad -\frac{1}{T_{\bar{A}}}\mathbf{\Delta s}_{\bar{A}}\right]'. & (7)\end{aligned}$$

It is easy to see that $\mathbf{z_i}$ and $\mathbf{z_s}$ are relevant and valid instruments to identify the pass-through in Equation (2). First, these instruments are correlated with the endogenous variables as long as the variances on the announcement days and non-announcement days are different. On the other hand, these instruments are uncorrelated with the shocks to the asset prices as presented in Equation (3).[7]

In this paper, I use the orthogonality of both instruments as the moment conditions for GMM estimation. Though I can estimate the pass-through by IV estimation using just one instrument, as implemented in Rigobon and Sack (2004), GMM estimation should provide more efficient estimates. The moment conditions are described as follows:

$$E[f_t(\alpha)] = 0, \tag{8}$$

where

$$\begin{aligned}f_t(\alpha) &= Z_t \cdot e_t,\\ Z_t &= [z_{i,t},\, z_{s,t}]',\\ e_t &= \Delta s_t - \alpha \Delta i_t.\end{aligned}$$

[7]For the proof of the orthogonality, see Appendix A.3.

The GMM estimate of α can be obtained by solving the minimum distance problem:

$$\alpha_{GMM} = \arg\min_{\alpha} f_T(\alpha)' W f_T(\alpha), \tag{9}$$

where $f_T(\alpha) = \sum_{t=1}^{T} f_t(\alpha)$ and W is an appropriate 2×2 weighting matrix. I use the two-step GMM for the estimation, in which I first use the identity matrix as a weighting matrix to solve the minimization problem, and then use the inverse of estimated variance-covariance matrix of the moment conditions in the first step as a weighting matrix in the second step. Inference for the GMM estimation is based on heteroscedasticity-robust standard errors.

3 Data and Background

This section describes the data and background to show that there is enough variation to identify the pass-through of monetary policy shock. After describing the data, I provide a brief summary of Japanese monetary policy. Then, I explain the selection of important announcements and provide a statistical analysis showing that the selection is valid in terms of identification.

3.1 Data

I estimate the pass-through of monetary policy shocks to three financial assets: (1) corporate bond yields, (2) stock prices, and (3) the exchange rate. The analysis is based on daily data from April 1998 to December 2013, all of which are obtained from the Bloomberg.

The details of the series are described as follows:

1. Japanese Government Bond (JGB) yield: generic yield with a maturity of 5, 10 and 20 years;

2. Corporate bond yield: the Bloomberg Fair Value (BFV) indices of AA and BBB corporate bond yields for the industrial sector, with a maturity of 5 and 10 years;[8]

3. Stock prices: Nikkei 225;

4. Exchange rates: spot exchange rates of the U.S. dollar, measured by the Japanese yen.

[8]The AA index and the BBB index are available from June 8, 1999 and January 30, 2003, respectively. The BBB index with a maturity of 10 years is not available from February 6, 2012.

I compute the daily changes in levels for the JGB and corporate bond yields, and the continuously compounding rate of daily change for stock prices and the exchange rate. The data between March 11 and March 18, 2011 is excluded from the analysis to eliminate the effect of the earthquake in March 2011.

3.2 Brief Summary of Japanese Monetary Policy

The BOJ's overnight interest rate has been reduced to nearly zero for approximately two decades, and three different programs of unconventional monetary policies have been implemented. Table 1 summarizes the timeline of the important events in Japanese monetary policy, and Figure 2 shows the volume of monetary base.[9]

The first program was called "quantitative easing" (QE) and implemented from March 2001 to March 2006 under Governors Hayami and Fukui. Under the QE program, the BOJ set its current account balance as the main policy target and purchased long-term JGBs to achieve this target.[10] The QE program was terminated in March 2006, and the overnight interest rate was gradually raised to 0.5 percent. However, in response to the global financial crisis in 2008, the BOJ reduced the overnight interest rate to zero again.

The second program was called "comprehensive monetary easing" (CME) and implemented from October 2010 to April 2013 under Governor Shirakawa. Under the CME program, the BOJ purchased not only JGBs, but also commercial paper and risky assets such as ETFs and REITs, while also making a commitment to keep the policy rate at zero. This is the policy prescription proposed by Eggertsson and Woodford (2003). In addition, the BOJ provided various forms of lending programs to financial institutions.

Most recently, the BOJ substantially expanded its asset purchase program and launched it as "quantitative and qualitative monetary easing" (QQME). The QQME program has been implemented since April 2013 under Governor Kuroda. Under the QQME program, the BOJ commits to achieving 2 percent inflation by 2015. To achieve this goal, the BOJ announced that it would

[9] For more comprehensive accounts of BOJ's monetary policy, see Ito and Mishkin (2006) and Ueda (2012b).

[10] For an analysis of the QE program, see Ugai (2007) and Shiratsuka (2010). More recently, Shibamoto and Tachibana (2013) analyze the effects of the QE program using the method of identification through heteroscedasticity. Kimura and Nakajima (2013) use a variant of regime-switching structural VAR using the data from 1981 to 2012, with ad hoc shrinkage in certain parameters.

increase the monetary base at a pace of 60 to 70 trillion yen per year, and extend the average maturity of its JGB holdings from three years to seven years.[11]

3.3 Selection of Monetary Policy Announcements

The selection of the important announcements is crucial for the analysis in this paper, and I select 41 announcement days from April 1998 to July 2013 based on Ueda (2012a). The exact dates and overview are listed on Table 2. These dates are associated with the BOJ's "official" change in its monetary policy.[12]

In addition, I include other dates when strong signals concerning future changes in BOJ's monetary policy were made. For example, I include the days when the new BOJ governor was nominated and the confirmation hearing was held by the National Diet in 2013. On the other hand, I do not include other meeting days or the days of speeches by the BOJ governor or other board members. This is because including trivial or indirect news announcement days will make the distinction between the announcement days and the non-announcement days unclear, which undermines the identification as discussed in Wright (2012).

3.4 Standard Deviations of the Series

To see whether the actual data is consistent with the assumptions for the identification, Table 3 compares the standard deviations of the daily changes on the announcement days and non-announcement days. Consistent with the assumptions, the standard deviations are higher on the announcement days than on the non-announcement days for almost all series, except for the BBB yield with a maturity of 10 years.

To test whether the variances in these two sets of days are significantly different, I conduct three statistical tests: the F-test, the block bootstrap and the stationary bootstrap. All tests are based on the null hypothesis that the population variance in these two sets of days are equal. Since the F-test assumes that each observation is independent, I use the block bootstrap and the

[11] For details, see Kuroda (2013).

[12] I exclude two dates from the list in Ueda (2012a), April 13, 1999 and March 14, 2011. First, I exclude April 13, 1999 because the commitment to keep the policy rate at zero made by the BOJ governor is not entirely clear. Ueda (2012a) also notes that the market reacted to this event very slowly. However, including this date does not materially change the results. Second, I exclude March 14, 2011 since this is the meeting right after the earthquake.

stationary bootstrap to take the heteroscedasticity observed in the daily data into account. In the block bootstrap, I construct an artificial sample by resampling the block of 10 days to preserve heteroscedasticity. On the other hand, in the stationary bootstrap, the length of the block is randomly determined.[13] After constructing an artificial sample, I compute the variance ratio in the artificial sample. By repeating this exercise, I can form the bootstrap distribution of the variance ratio and compute the p-values based on the percentile of the sample variance ratio.

The null hypothesis is rejected for most series, with the sample variance ratio larger than one, except for the 10-year BBB corporate bond yields. Therefore, we could conclude that the variance is significantly larger on the announcement days. The F-test tends to reject the null hypothesis more often than the other two tests based on the bootstrap.

4 Results

In this section, I present GMM estimates showing that the pass-through of monetary policy shock is one to one for corporate bond yields, but it is smaller than the U.S. estimates for stock prices and the exchange rate. In addition, I provide an event study showing that the announcements in 2013 have substantial effects on asset prices. Lastly, I present several robustness checks using additional variables and subperiods to confirm the main results.

4.1 Event Study

Table 4 presents the results of the event study focusing on the QQME program in 2013. The results show that the announcements of the QQME program led to a substantial decline in the long-term JGB and corporate bond yields. Furthermore, stock prices substantially increased on these announcement days, but the effect on exchange rates was mixed.

The results show that the long-term JGB and corporate bond yields substantially declined responding to the announcements. Specifically, the JGB yields declined 11.4 (10 years) and 17.7 (20 years) basis points on April 4th, and the cumulative decline on all announcements was 14.0 (10 years) and 23.3 (20 years) basis points, respectively. Corporate bond yields also declined on

[13] More specifically, an artificial sample is constructed by the Bernoulli trial, either to pick a random sample or the sample on the next day. I set the probability of the latter as 0.9 to make the expected length of the block 10 days.

these days, but the magnitude is smaller than JGB yields. The 10-year AA bond yield declined 9.72 basis points on April 4, and the cumulative decline was 10.65 basis points.[14]

The results also show that stock prices substantially increased on the announcement days. The cumulative increase of the Nikkei 225 and TOPIX indices was 5.18 percent and 3.68 percent, respectively. On the other hand, the effect on exchange rates was mixed. Even though the announcement on April 4 led to a substantial depreciation of the Japanese yen, 3.49 percent for the U.S. dollar and 4.16 percent for the euro, this effect was quickly offset on subsequent announcements.

4.2 GMM Estimates of Pass-Through

Table 5 presents the pass-through to corporate bond yields, stock prices, and the exchange rate. The results show that there is a statistically significant and nearly one-for-one pass-through to corporate bond yields, notably for high-grade bond yields. On the other hand, the pass-through to stock prices and the exchange rate is negative but the estimated magnitude is quite small and not statistically significant in most cases. It is important to note that this analysis estimates the *average* effects of unconventional policies, and these estimates cannot be interpreted as the effects of individual policies, forward guidance, or asset purchases.

I present the estimates of the pass-through to different asset prices based on an individual JGB yield. This is because monetary policy shocks primarily influence the overall level of the JGB yields, and the change in JGB yield with any maturity should reflect such shocks.

4.2.1 Corporate Bond Yields

For the AA corporate bond yields, most of the pass-through is statistically significant, with a magnitude from 0.84 to 0.99. It implies that an expansionary monetary policy shock, which lowers the 20-year JGB yield by 100 basis points, will lower the 10-year AA corporate bond yield 84 basis points. All estimates are smaller than one and statistically significant.

On the other hand, the estimates of the pass-through to the medium-grade corporate bond yields varies; the estimated magnitude is from -2.90 to 1.12. The estimates are positive in most

[14]The effects for yields with shorter maturities are trivial, primarily because they are all stuck at the zero lower bound.

cases, which suggests that monetary policy shocks are passed on to BBB corporate bond yields to some extent. However, no estimate is statistically significant because of the large standard errors.

4.2.2 Stock Prices

The estimates of the pass-through to stock prices are mostly negative, ranging between -1.19 and -0.12. These estimates imply that an expansionary monetary policy shock, which lowers JGB yields by 100 basis points, increases stock prices by 0.12 to 1.19 percent. However, few of them is statistically significant. In other words, the estimated magnitude of the pass-through to stock prices is so small that the estimates are not significantly different from zero in most cases.

4.2.3 Exchange Rates

The results show that the pass-through to the exchange rate is mostly negative, with the magnitude between -0.4 and -0.2. These estimates imply that an expansionary monetary policy shock, which lowers JGB yields by 100 basis points, leads a depreciation of the Japanese yen by 0.2 percent to 0.4 percent.[15] However, only the pass-through from the 20-year JGB yield, -0.2, is statistically significant.

These results are consistent with the prediction of conventional interest rate parity, which suggests that the expected return on domestic assets should be the same as the exchange-rate adjusted expected return on foreign assets. In other words, a decline in the JGB yield should be adjusted by a depreciation of the Japanese yen, which would boost the stimulative effect of expansionary monetary policy shocks. However, the estimated magnitude of the pass-through is quite small and few estimates are statistically significant.

4.3 Discussion of the Results

Given these results, I first provide the comparison between Japanese and the U.S. results. Though Japanese results are similar to the U.S. results in their signs, the estimated magnitude of pass-through is considerably smaller for stock prices and the exchange rate.

[15] Since I use the exchange rate that measures the value of non-Japanese currency by the Japanese yen, a rise in the exchange rate implies depreciation of the Japanese yen.

4.3.1 Comparison with the U.S. Estimates

Table 5 also presents the estimates of pass-through in the U.S. using the same methodology. For corporate bond yields, Japanese and U.S. estimates are similar in their signs and magnitudes. On the other hand, the magnitude of the Japanese estimates for stock prices and the exchange rate is substantially smaller than that of the U.S. estimates, though the sign of Japanese estimates is consistent with the predictions of economic theories.

To measure the monetary policy shock in the U.S., I used the daily data of zero-coupon bond yields computed by Gürkaynak et al. (2007) with the maturities of 5, 10, and 20 years. To estimate the pass-through to corporate bond yields, stock prices, and the exchange rate, I used Bank of America Merrill Lynch effective corporate bond yields with AA and BBB ratings, the Dow Jones Industrial Average, and the spot exchange rate against the Euro. I used the sample from December 2008 to April 2015, when the U.S. economy was at the ZLB.

For corporate bond yields, the pass-through to corporate bond yields is broadly similar in Japan and in the U.S. Similar to the Japanese case, the pass-through to high-grade bond yields with the rating of AA is statistically significant, and its magnitude is close to one, which is consistent with Raskin's (2013) findings.[16] In addition, I found a significantly positive pass-through to the BBB bond yields in the U.S.

For stock prices, the pass-through is negative in both Japan and the U.S., but the estimated magnitudes are substantially smaller in Japan. While the Japanese estimates are marginally negative and statistically insignificant, the U.S. estimates are between -7.19 and -10.80 and are statistically significant.[17] Though these estimates are slightly larger than the estimates Gürkaynak et al. (2005) and Bernanke and Kuttner (2005) obtained before the Great Recession, they are consistent with recent findings in Claus et al. (2014): Using the estimated shadow short rate, they found that the monetary policy surprise has a larger impact on asset prices at the ZLB period and suggest

[16] To explain the limited pass-through to the medium-grade bond yields found in Krishnamurthy and Vissing-Jorgensen (2011), Krishnamurthy and Vissing-Jorgensen (2012) propose the safety premium, which is the premium investors pay to satisfy their unique demand for safe long-term assets. Since the medium-grade corporate bonds are not regarded as safe assets, the decline of the government bond yields do not affect their yields. Krishnamurthy and Vissing-Jorgensen (2011) argue that the effect of the Fed's LSAP announcements is primarily due to reduction in the safety premium.

[17] These estimates are larger than Kiley's (2013) estimates at the ZLB, which range from -3.0 to -1.5. This difference is likely due to a different methodology of identification, since Kiley (2013) uses intraday data and focuses on a much narrower window around the announcements.

some kind of structural change in the monetary transmission mechanism at the ZLB. Similar to the Japanese situation, Rosa (2012) documents that the Bank of England's announcements about gilt purchases do not have statistically significant effects on stock prices.

For the exchange rate, the magnitude of Japanese estimates, -0.2, is also substantially smaller than the U.S. estimates, even though the sign of pass-through is negative in both countries. The U.S. estimates are between -6.57 and -9.27 and highly statistically significant. These estimates are largely consistent with the findings in Neely (2013) and Glick and Leduc (2013), which report that the pass-through to the exchange rate during the Great Recession is around -3 to -4. The difference in the magnitude could be due to the difference in the methodology and the usage of intraday data.

4.3.2 Comparison of Announcements Before and After 2013

The comparison of the event study and GMM show that the announcements in 2013 had substantial effects, not only on corporate bonds, but also on stock prices. It may be because the announcements in 2013 were associated with the BOJ's regime change, in which the BOJ made an open-ended commitment to achieve the inflation target, creating a huge surprise.

Before 2013, number of papers including Ito and Mishkin (2006) are critical of the passive stance of the BOJ.[18] However, Romer (2013) describes the policy change in 2013 as "an honest-to-goodness regime shift" and "(the BOJ) took dramatic actions and pledged convincingly to do whatever it takes to end deflation." Consistent with her argument, some survey measures show that inflation expectations have substantially increased in 2013. For example, Figure 3 shows the upward shift of the inflation expectation in the mean of the ESP Forecast (survey of professional forecasters in Japan) in 2013, which could be up to 0.8 percent. Hausman and Wieland (2014, 2015) also provide similar analysis and conclude that the set of policy package called "Abenomics," which includes the introduction of the QQME program in 2013, raised long-run inflation expectation.[19]

However, even though the announcements in 2013 have had substantial effects on stock prices, the GMM estimates in this paper are not statistically significant since I have estimated an average

[18] Based on a New-Keynesian model with two different regimes (a targeted-inflation regime and a deflation regime), Aruoba et al. (2014) provide an interpretation that the BOJ's passive stance has triggered an adverse shock that moves the economy into the deflation regime.

[19] On the other hand, Fujiwara et al. (2014) argue that there is no significant increase in inflation expectation at 10-year horizon after the introduction of the QQME, and the effect of monetary policy is quite limited.

effect over the full sample from 1998 to 2013. As presented in Table 4, the average effects of monetary policy announcements based on the pre-2013 event study have been much smaller than those in 2013. This finding is consistent with those of other studies in the literature. For example, Ueda (2012a) conducted an event study of monetary policy announcements between 1999 and 2011 and showed that the announcements regarding the QE programs lowered the JGB and corporate bond yields but did not significantly affect stock prices or exchange rates. Lam (2011) conducted an event study from 2008 to 2011, which covered part of the CME program, and obtained similar results as Ueda (2012a).

4.4 Robustness Checks

In this section, I provide several robustness checks, to which the main results are generally robust. First, I analyze the pass-through to other financial assets. Second, I conduct the analysis based on the set of selected announcements. Third, I consider subsamples focusing on different programs. Fourth, I provide the analysis based on the principal component of JGB yields. Last, I use alternative sets of non-announcement days.

4.4.1 Additional Variables

I extend the analysis using three kinds of additional variables: (1) REITs, (2) CDS index, and (3) exchange rates in other OECD and Asian economies.[20] These variables are of interest for slightly different reasons. First, REITs are of interest because the BOJ purchased them in the QE programs. Second, the analysis of the CDS index will shed some light on the effects of the QE programs on credit default risk as discussed in Gilchrist and Zakrajsek (2013). Lastly, I focus on exchange rates relative to these countries because the so-called "yen-carry trade," in which investors borrow money in the Japanese yen and invest in high-interest rate currencies, has been prominent since the late 1990s. These high-yield currencies include the Australian and New Zealand dollars and other emerging Asian currencies.[21]

Table 6 presents the standard deviations and variance ratios of these variables. Consistent with

[20] The REIT index is available from April 2003.
[21] For details, see Hattori and Shin (2008).

the assumptions of the identification, the standard deviations are higher on the announcement days than on the non-announcement days for all series. In addition, most of these differences are statistically significant.

Table 7 shows the GMM estimates of the pass-through to the REITs, the CDS index, and exchange rates using the baseline announcement days. For the REITs, the pass-through is mostly negative and some of them are statistically significant. The negative pass-through implies that an expansionary monetary policy shock lead to the increase in the price of these financial assets. The magnitude of the pass-through to the REITs is between -0.46 and -0.16. The pass-through to the CDS index is positive, but the magnitude varies substantially with the maturity of the JGB yields and none are statistically significant. The pass-through to exchange rates in the OECD and Asian economies is negative in almost all cases, with a magnitude between -0.14 and -0.22. The estimates are similar to the estimates for the U.S. dollar and the euro, which suggests that the expansionary monetary policy shocks lead a depreciation of the Japanese yen relative to all other currencies. However, the magnitude of the depreciation is quite small.

4.4.2 Selected Announcements

In order to shed some light on the effects of the asset purchases, I have conducted an analysis using a selected set of announcements explicitly related to asset purchase programs, both in Japan and the U.S.[22] Though estimating the effects of individual policies is extremely difficult because the announcements often contain information about different policies, the results based on the selected set of announcements could still serve as a useful benchmark.

As presented in Table 8, the results are broadly similar to the results of the baseline case: The pass-through to corporate bond yields is statistically significant, and its magnitude is close to one in most cases. On the other hand, the pass-through to stock prices and the exchange rate is mostly negative, but its magnitude is small and not statistically significant. In addition, the estimated magnitude of the U.S. pass-through is substantially larger than that of Japan for stock prices and the exchange rate and is statistically significant in most cases.

I also report the weak-identification robust confidence sets in the online appendix to determine

[22]The selection of U.S. monetary policy announcements is based on Rogers et al. (2014).

if the differences in the variances on the announcement and non-announcement days are large enough for identification.[23] While the weak-instrument robust confidence sets often fail to identify the relevant confidence sets in the baseline case, they do identify the relevant confidence sets in many cases for the selected announcements. This result suggests that eliminating less-relevant announcements greatly improves identification.

4.4.3 Analysis of Subsamples

To analyze how different QE programs affect corporate bond yields and asset prices, I conduct the same analysis in three subsamples focusing on the different QE programs: (1) the QE program (2001-2006), (2) the period between the QE and the CME programs (2006-2010), and (3) the CME program (2010-2013). The results are presented in Table 9. The period before the QE program (1998-2001) and the QQME program (2013-) are excluded since the number of announcements are too small.

The findings are broadly similar to the main results. The QE programs have statistically significant pass-through to corporate bond yields, mostly one-to-one, but the pass-through to the stock prices or exchange rates is not statistically significant. For the high-grade corporate bond yields, pass-through is mostly one-to-one with a magnitude between 0.36 and 1.87. Unlike the main results, the pass-through to the medium-grade bond yields is statistically significant in some cases, with the magnitude between 0.44 and 1.98. Such a wide range of estimates may reflect their volatility due to small samples in the subperiods. The signs of pass-through to stock prices are mixed but none are statistically significant. The pass-through to exchange rates is negative in most cases, but only a few estimates are statistically significant.

Furthermore, there is no obvious difference in the pass-through in different subperiods, which suggests that the effects of different QE programs are broadly similar over time. One evident difference is that the pass-through from the 5-year JGB yield is not statistically significant during the CME program between 2010 and 2013. But this is because the 5-year JGB yield is extremely low in this period.

[23] I use two statistics presented in Appendix A.4 to derive weak-instrument robust confidence sets: the S statistic in Stock and Wright (2000), an extension of Anderson and Rubin's (1949) statistic to GMM, and the K statistic in Kleibergen (2005).

4.4.4 Analysis Using the Principal Component of JGB Yields

To jointly analyze the pass-through from the JGB yields with different maturities, I conduct the same analysis using a principal component of these JGB yields. Table 10 presents the results for main and additional variables. The results are broadly similar to the main results. The pass-through to the high-grade corporate bond yields is positive and statistically significant, whereas the pass-through to the stock prices and exchange rates is negative but not statistically significant in most cases.

4.4.5 Alternative Set of Non-Announcement Days

I use two alternative definitions of non-announcement days to estimate the pass-through of monetary policy shock. First, following Rigobon and Sack (2004), a non-announcement day is defined as one business day prior to the announcement day. Accordingly, the number of announcement days and non-announcement days are the same. Second, following Gilchrist and Zakrajsek (2013), I exclude all the BOJ meeting days from the set of non-announcement days because some trivial or indirect news released on these meeting days may contaminate the identification. The estimates using these alternative definitions are not listed to conserve space, but the results are essentially the same as the baseline set of non-announcement days.

5 Conclusion

This paper analyzes the effects of unconventional monetary policy in Japan, which has been stuck at the ZLB for a substantially longer period than any other economy. To discuss if we could learn any lessons from Japanese experience, this paper compares the estimates of the pass-through of monetary policy shocks with the U.S. estimates.

By using the tools of an event study and identification through heteroscedasticity, I find that the effects of expansionary monetary policy shocks are directly passed on to corporate bond yields, notably for high-grade bond yields. However, the pass-through to stock prices and the exchange rate is not statistically significant in most cases. These results contrast with the U.S. results, where the pass-through to all assets is statistically significant.

To interpret such differences in the effects of unconventional monetary policy, one may focus on the characteristics of the financial markets. For example, because of various institutional reasons, the Japanese financial markets may be more segmented than the U.S. markets and may not be responsive to monetary policy shocks. On the other hand, one could focus on the different economic environment in Japan and the U.S. to explain different pass-through. More specifically, since the Japanese economy has been stuck at the ZLB for two decades, it would be extremely difficult for any announcement to change expectations about future inflation or short rates. Investigating the reason for such differences across countries is critical for the evaluation of the effects of unconventional monetary policy and is a question for future research.

References

Anderson, T. W. and Herman Rubin, "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations," *The Annals of Mathematical Statistics*, 03 1949, *20* (1), 46–63.

Aruoba, S. Borağăn, Pablo Cuba-Borda, and Frank Schorfheide, "Macroeconomic Dynamics Near the ZLB: A Tale of Two Countries," Working Paper 2014.

Bernanke, Ben S., "Monetary Policy since the Onset of the Crisis," August 2012. Speech.

_ **and Kenneth N. Kuttner**, "What Explains the Stock Market's Reaction to Federal Reserve Policy?," *Journal of Finance*, 06 2005, *60* (3), 1221–1257.

Claus, Edda, Iris Claus, and Leo Krippner, "Asset Markets and Monetary Policy Shocks at the Zero Lower Bound," CAMA Working Papers 2014-42, Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, The Australian National University May 2014.

D'Amico, Stefania and Thomas B. King, "Flow and Stock Effects of Large-scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, 2013, *108* (2), 425 – 448.

Eggertsson, Gauti B. and Michael Woodford, "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, 2003, *34* (1), 139–235.

Fujiwara, Ippei, Yoshiyuki Nakazono, and Kozo Ueda, "Policy Regime Change against Chronic Deflation? Policy option under a long-term liquidity trap," RIETI Discussion Paper Series NO.14-E-019 2014.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack, "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking*, March 2011, *7* (1), 3–43.

Gilchrist, Simon and Egon Zakrajsek, "The Impact of the Federal Reserve's Large-Scale Asset Purchase Programs on Corporate Credit Risk," *NBER working paper*, August 2013.

Glick, Reuven and Sylvain Leduc, "The Effects of Unconventional and Conventional U.S. Monetary Policy on the Dollar," Working Paper Series, Federal Reserve Bank of San Francisco 2013.

Gürkaynak, Refet S., Brian Sack, and Eric Swanson, "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, May 2005, *1* (1), 55–93.

_ , _ , and Jonathan H. Wright, "The U.S. Treasury yield curve: 1961 to the present," *Journal of Monetary Economics*, November 2007, *54* (8), 2291–2304.

Hattori, Masazumi and Hyun Song Shin, "Yen Carry Trade and the Subprime Crisis," Working Paper August 2008.

Hausman, Joshua K. and Johannes Wieland, "Abenomics: Preliminary Analysis and Outlook," *Brookings Papers on Economic Activity*, 2014, *48* (2014-1).

_ and _ , "Abenomics: An update," *Brookings Papers on Economic Activity*, fall 2015.

Ito, Takatoshi and Frederic S. Mishkin, "Two Decades of Japanese Monetary Policy and the Deflation Problem," in Takatoshi Ito and Andrew K. Rose, eds., *Monetary Policy under Very Low Inflation in the Pacific Rim*, Vol. 15 of *NBER-EASE*, University of Chicago Press, 2006, chapter 4, pp. 131–202.

Joyce, Michael, David Miles, Andrew Scott, and Dimitri Vayanos, "Quantitative Easing and Unconventional Monetary Policy - an Introduction," *The Economic Journal*, 2012, *122* (564), 271–288.

Kiley, Michael T., "The Response of Equity Prices to Movements in Long-term Interest Rates Associated With Monetary Policy Statements: Before and After the Zero Lower Bound," Finance and Economics Discussion Series, Federal Reserve 2013.

Kimura, Takeshi and Jouchi Nakajima, "Identifying conventional and unconventional monetary policy shocks: A latent threshold approach," Working Paper Series NO.13-E-7, Bank of Japan May 2013.

Kleibergen, Frank, "Testing Parameters in GMM Without Assuming that They Are Identified," *Econometrica*, 2005, *73* (4), 1103–1123.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen, "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brookings Papers on Economic Activity*, Fall 2011, pp. 215–265.

_ and _ , "The Aggregate Demand for Treasury Debt," *Journal of Political Economy*, 2012, *120* (2), 233 – 267.

Kuroda, Haruhiko, "Quantitative and Qualitative Monetary Easing," Speech April 12, 2013.

Lam, W. Raphael, "Bank of Japan's Monetary Easing Measures: Are They Powerful and Comprehensive?," *IMF Working Papers*, 2011, pp. 1–18.

Neely, Christopher J., "Unconventional Monetary Policy Had Large International Effects," Working Paper, Federal Reserve Bank of St. Louis July 2013.

Raskin, Matthew, "The Effects of Monetary Policy on Corporate Bond Yield," Working Paper 2013.

Rigobon, Roberto, "Identification through Heteroskedasticity," *The Review of Economics and Statistics*, 2003, *85* (4), pp. 777–792.

_ and Brian Sack, "Measuring The Reaction of Monetary Policy to The Stock Market," *The Quarterly Journal of Economics*, May 2003, *118* (2), 639–669.

_ and _ , "The Impact of Monetary Policy on Asset Prices," *Journal of Monetary Economics*, November 2004, *51* (8), 1553–1575.

Rogers, John H., Chiara Scotti, and Jonathan H. Wright, "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Multi-Country Review," *Economic Policy*, 2014, *29* (80), 749–799.

Romer, Christina, "It Takes a Regime Shift: Recent Developments in Japanese Monetary Policy through the Lens of the Great Depression," *NBER Macroeconomics Annual*, August 2013, *28.*

Rosa, Carlo, "How Unconventional Are Large-Scale Asset Purchases? The Impact of Monetary Policy on Asset Prices," Staff Report, Federal Reserve Bank of New York 2012.

Shibamoto, Masahiko and Minoru Tachibana, "The Effect of Unconventional Monetary Policy on the Macro Economy: Evidence from Japan's Quantitative Easing Policy Period," Discussion Paper Series DP2013-12, Kobe University April 2013.

Shiratsuka, Shigenori, "Size and Composition of the Central Bank Balance Sheet: Revisiting Japan's Experience of the Quantitative Easing Policy," *Monetary and Economic Studies*, November 2010, *28*, 79–106.

Stock, James H. and Jonathan H. Wright, "GMM with Weak Identification," *Econometrica*, 2000, *68* (5), 1055–1096.

_ , _ , and Motohiro Yogo, "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments," *Journal of Business & Economic Statistics*, October 2002, *20* (4), 518–29.

Ueda, Kazuo, "The Effectiveness of Non-Traditional Monetary Policy Measures: The Case of The Bank of Japan," *The Japanese Economic Review*, March 2012, *63* (1), 1–22.

_ , "Japan's Deflation and the Bank of Japan's Experience with Nontraditional Monetary Policy," *Journal of Money, Credit and Banking*, 2012, *44*, 175–190.

Ugai, Hiroshi, "Effects of the Quantitative Easing Policy: A Survey of Empirical Analyses," *Monetary and Economic Studies*, March 2007, *25* (1), 1–48.

Wright, Jonathan H., "What does Monetary Policy do to Long-term Interest Rates at the Zero Lower Bound?," *The Economic Journal*, 2012, *122* (564), 447–466.

A Appendix

A.1 Derivation of the OLS Estimate

Describe the system of equations (1) and (2) in matrix form:

$$\begin{pmatrix} 1 & -\beta \\ -\alpha & 1 \end{pmatrix} \begin{pmatrix} \Delta i_t \\ \Delta s_t \end{pmatrix} = \begin{pmatrix} \gamma \\ \delta \end{pmatrix} X_t + \begin{pmatrix} \varepsilon_t \\ \eta_t \end{pmatrix}. \tag{10}$$

By solving this equation, we obtain the reduced-form solution of the system,

$$\begin{pmatrix} \Delta i_t \\ \Delta s_t \end{pmatrix} = \frac{1}{1-\alpha\beta} \left[\begin{pmatrix} \beta\delta + \gamma \\ \alpha\gamma + \delta \end{pmatrix} X_t + \begin{pmatrix} 1 \\ \alpha \end{pmatrix} \varepsilon_t + \begin{pmatrix} \beta \\ 1 \end{pmatrix} \eta_t \right]. \tag{11}$$

Let σ_X^2, σ_ε^2, and σ_η^2 as the variance of each shock. Then, the OLS estimate of α in equation (2) is

$$\hat{\alpha}_{OLS} = \frac{Cov(\Delta i_t, \Delta s_t)}{Var(\Delta i_t)}, \tag{12}$$

$$= \frac{(\beta\delta + \gamma)(\alpha\gamma + \delta)\sigma_X^2 + \alpha\sigma_\varepsilon^2 + \beta\sigma_\eta^2}{(\beta\delta + \gamma)^2\sigma_X^2 + \sigma_\varepsilon^2 + \beta^2\sigma_\eta^2}. \tag{13}$$

Accordingly, the bias of the OLS estimate is

$$\hat{\alpha}_{OLS} - \alpha = \frac{(1-\alpha\beta)[\delta(\beta\delta + \gamma)\sigma_X^2 + \beta\sigma_\eta^2]}{(\beta\delta + \gamma)^2\sigma_X^2 + \sigma_\varepsilon^2 + \beta^2\sigma_\eta^2}. \tag{14}$$

Equation (14) indicates that the OLS estimate has a non-zero bias, unless there is a certain restriction on parameters (such as $\alpha\beta = 1$). For the discussion about the signs of the bias in the OLS estimates, see Gilchrist and Zakrajsek (2013).

A.2 Derivation of Conditional Variance

Denote the conditional variances of the shocks on the announcement days as $\sigma_{X|A}^2$, $\sigma_{\varepsilon|A}^2$, and $\sigma_{\eta|A}^2$. Similarly, denote the conditional variances of the shocks on the non-announcement days as $\sigma_{X|\bar{A}}^2$, $\sigma_{\varepsilon|\bar{A}}^2$, and $\sigma_{\eta|\bar{A}}^2$. Given the reduced-from solution of the system in equation (11), the conditional variance-covariance matrices of the system, $\mathbf{\Omega}_A$ and $\mathbf{\Omega}_{\bar{A}}$, are computed as follows:

$$\mathbf{\Omega}_A = \frac{1}{(1-\alpha\beta)^2}\left(\begin{array}{c:c} (\beta\delta+\gamma)^2\sigma^2_{X|A}+\sigma^2_{\varepsilon|A}+\beta^2\sigma^2_{\eta|A} & (\beta\delta+\gamma)(\alpha\gamma+\delta)\sigma^2_{X|A}+\alpha\sigma^2_{\varepsilon|A}+\beta\sigma^2_{\eta|A} \\ \hdashline \cdot & (\alpha\gamma+\delta)^2\sigma^2_{X|A}+\alpha^2\sigma^2_{\varepsilon|A}+\sigma^2_{\eta|A} \end{array}\right), \quad (15)$$

$$\mathbf{\Omega}_{\bar{A}} = \frac{1}{(1-\alpha\beta)^2}\left(\begin{array}{c:c} (\beta\delta+\gamma)^2\sigma^2_{X|\bar{A}}+\sigma^2_{\varepsilon|\bar{A}}+\beta^2\sigma^2_{\eta|\bar{A}} & (\beta\delta+\gamma)(\alpha\gamma+\delta)\sigma^2_{X|\bar{A}}+\alpha\sigma^2_{\varepsilon|\bar{A}}+\beta\sigma^2_{\eta|\bar{A}} \\ \hdashline \cdot & (\alpha\gamma+\delta)^2\sigma^2_{X|\bar{A}}+\alpha^2\sigma^2_{\varepsilon|\bar{A}}+\sigma^2_{\eta|\bar{A}} \end{array}\right). \quad (16)$$

Assume that the variance of the monetary policy shock is larger on the announcement days than on the non-announcement days, but the variance of the other shocks are the same across these two sets of days. Namely, we assume that

$$\sigma^2_{\varepsilon|A} > \sigma^2_{\varepsilon|\bar{A}}, \quad (17)$$

$$\sigma^2_{X|A} = \sigma^2_{X|\bar{A}}, \quad (18)$$

$$\sigma^2_{\eta|A} = \sigma^2_{\eta|\bar{A}}. \quad (19)$$

When taking the difference between $\mathbf{\Omega}_A$ and $\mathbf{\Omega}_{\bar{A}}$ in equations (15) and (16), only the variances of the monetary policy shock remain and the variances of other shocks cancel out. Thus we obtain

$$\mathbf{\Omega}_A - \mathbf{\Omega}_{\bar{A}} = \frac{\sigma^2_{\varepsilon|A}-\sigma^2_{\varepsilon|\bar{A}}}{(1-\alpha\beta)^2}\begin{pmatrix} 1 & \alpha \\ \alpha & \alpha^2 \end{pmatrix}. \quad (20)$$

A.3 Orthogonality of Instruments

To see that two instruments, $\mathbf{z_i}$ and $\mathbf{z_s}$, are orthogonal to the residuals $\mathbf{e}$, compute $\sum_{t=1}^{T} Z_t \cdot e_t$.

$$\begin{aligned}
\sum_{t=1}^{T} Z_t \cdot e_t &= \mathbf{Z}' \cdot \mathbf{e} && (21)\\
&= \begin{pmatrix} \mathbf{z}_i' \\ \mathbf{z}_s' \end{pmatrix} (\mathbf{\Delta s} - \alpha \mathbf{\Delta i}) && (22)\\
&= \begin{bmatrix} \frac{1}{T_A}\mathbf{\Delta i}'_A, & -\frac{1}{T_{\bar{A}}}\mathbf{\Delta i}'_{\bar{A}} \\ \frac{1}{T_A}\mathbf{\Delta s}'_A, & -\frac{1}{T_{\bar{A}}}\mathbf{\Delta s}'_{\bar{A}} \end{bmatrix} [\mathbf{\Delta s}_A - \alpha \mathbf{\Delta i}_A,\ \mathbf{\Delta s}_{\bar{A}} - \alpha \mathbf{\Delta i}_{\bar{A}}] && (23)\\
&= \begin{bmatrix} \frac{1}{T_A}\mathbf{\Delta i}'_A \cdot (\mathbf{\Delta s}_A - \alpha \mathbf{\Delta i}_A) - \frac{1}{T_{\bar{A}}}\mathbf{\Delta i}'_{\bar{A}} \cdot (\mathbf{\Delta s}_{\bar{A}} - \alpha \mathbf{\Delta i}_{\bar{A}}) \\ \frac{1}{T_A}\mathbf{\Delta s}'_A \cdot (\mathbf{\Delta s}_A - \alpha \mathbf{\Delta i}_A) - \frac{1}{T_{\bar{A}}}\mathbf{\Delta s}'_{\bar{A}} \cdot (\mathbf{\Delta s}_{\bar{A}} - \alpha \mathbf{\Delta i}_{\bar{A}}) \end{bmatrix} && (24)\\
&= \begin{bmatrix} (\hat{\Omega}_{A,12} - \alpha \hat{\Omega}_{A,11}) - (\hat{\Omega}_{\bar{A},12} - \alpha \hat{\Omega}_{\bar{A},11}) \\ (\hat{\Omega}_{A,22} - \alpha \hat{\Omega}_{A,21}) - (\hat{\Omega}_{\bar{A},22} - \alpha \hat{\Omega}_{\bar{A},21}) \end{bmatrix} && (25)\\
&= \begin{bmatrix} \Delta\hat{\Omega}_{12} - \alpha \Delta\hat{\Omega}_{11} \\ \Delta\hat{\Omega}_{22} - \alpha \Delta\hat{\Omega}_{21} \end{bmatrix} && (26)
\end{aligned}$$

Since $\mathbf{\Delta \Omega} = C \begin{pmatrix} 1 & \alpha \\ \alpha & \alpha^2 \end{pmatrix}$, we have

$$\sum_{t=1}^{T} Z_t \cdot e_t \longrightarrow_p 0. \qquad (27)$$

Accordingly, we have moment condition $E[Z_t \cdot e_t] = 0$.

A.4 Weak-Identification Robust Confidence Set

One concern of identification through heteroscedasticity is that the difference between the announcement days and non-announcement days may not be large enough for strong identification. In order to address the issue of weak identification, I employ the two statistic that could derive weak-instrument robust confidence sets: the S statistic in Stock and Wright (2000), an extension of the Anderson and Rubin's (1949) statistic to GMM, and the K statistic in Kleibergen (2005).[24] These statistics test the null hypothesis for a hypothesized value of the parameter, based on the moment conditions evaluated at the hypothesized value. The confidence set is derived as the set of parameter values for which the test accepts the null hypothesis.

The S statistic is defined as follows:

$$S(\alpha_0) = \left[\sqrt{\frac{1}{T}} f_T(\alpha_0)\right]' \hat{V}_{ff}(\alpha_0)^{-1} \left[\sqrt{\frac{1}{T}} f_T(\alpha_0)\right], \tag{28}$$

where

$$\hat{V}_{ff}(\alpha) = Var\left(\sqrt{\frac{1}{T}} f_T(\alpha)\right), \tag{29}$$

which is an estimate of the asymptotic variance-covariance matrix of the moment conditions. Note that the S statistic is based on the objective function in the minimization problem in Equation 9, but the value is evaluated at the hypothesized value of the parameter, α_0. The S statistic has a chi-square null limiting distribution, with the number of moment conditions as the degrees of freedom.

The K statistic is defined as follows:

$$K(\alpha_0) = \frac{1}{4T}\left(\left.\frac{\partial S(\alpha)}{\partial \alpha}\right|_{\alpha_0}\right)[\hat{D}_T'(\alpha_0)\hat{V}_{ff}(\alpha_0)^{-1}\hat{D}_T(\alpha_0)]^{-1}\left(\left.\frac{\partial S(\alpha)}{\partial \alpha}\right|_{\alpha_0}\right)', \tag{30}$$

$$= \left[\sqrt{\frac{1}{T}} f_T(\alpha_0)\right]' \left[\hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}} P_{\hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}}\hat{D}_T(\alpha_0)} \hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}}\right] \left[\sqrt{\frac{1}{T}} f_T(\alpha_0)\right], \tag{31}$$

[24] For details, see Stock et al. (2002).

where

$$\hat{D}_T(\alpha) = q_T(\alpha) - \hat{V}_{\alpha f}(\alpha)\hat{V}_{ff}(\alpha)^{-1} f_T(\alpha),$$

$$q_T(\alpha) = \frac{\partial f_T(\alpha)}{\partial \alpha},$$

$$\hat{V}_{\alpha f}(\alpha) = Cov\left(\sqrt{\frac{1}{T}} f_T(\alpha), \sqrt{\frac{1}{T}} q_T(\alpha)\right), \quad \text{and}$$

$$P_{\hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}}\hat{D}_T(\alpha_0)} = \hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}}\hat{D}_T(\alpha_0)[\hat{D}_T(\alpha_0)'\hat{V}_{ff}(\alpha_0)^{-1}\hat{D}_T(\alpha_0)]^{-1}\hat{D}_T(\alpha_0)'\hat{V}_{ff}(\alpha_0)^{-\frac{1}{2}}.$$

Essentially, the K statistic uses an optimal subset of moment conditions to improve the power of the tests. In other words, by using a subset of more relevant moment conditions, we could improve the efficiency of the test statistic, which leads to the higher power of the tests. The only difference between the S statistic in Equation (28) and the K statistic in Equation (31) is that the K statistic uses the variance-covariance matrix adjusted by the projection matrix based on $\hat{D}_T(\alpha)$. $\hat{D}_T(\alpha)$ is a residual of the gradient of moment conditions, $q_T(\alpha)$, after projecting it on the level of the moment conditions, $f_T(\alpha)$. By construction, $\hat{D}_T(\alpha)$ is orthogonal to $f_T(\alpha)$ and we use this orthogonality to improve the efficiency. The K statistic also has a chi-square null limiting distribution, with the number of parameters as the degrees of freedom.

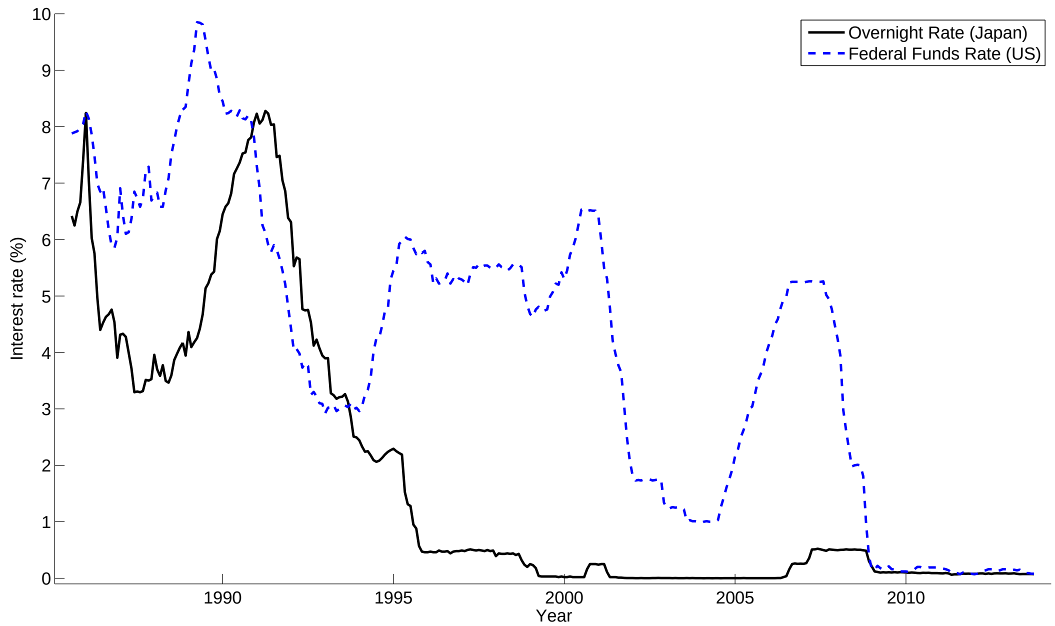

Figure 1: BOJ's overnight policy rate and Fed's federal fund rate from 1985 to the present

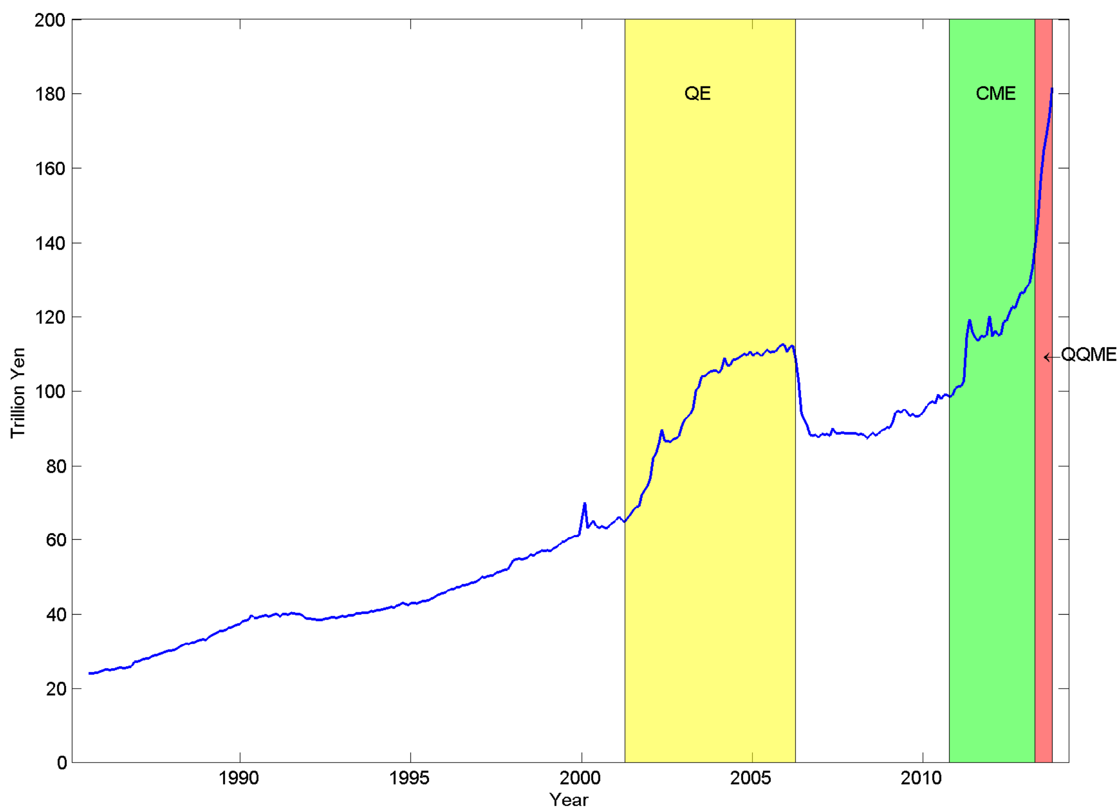

Figure 2: Monetary Base from 1985 to the present

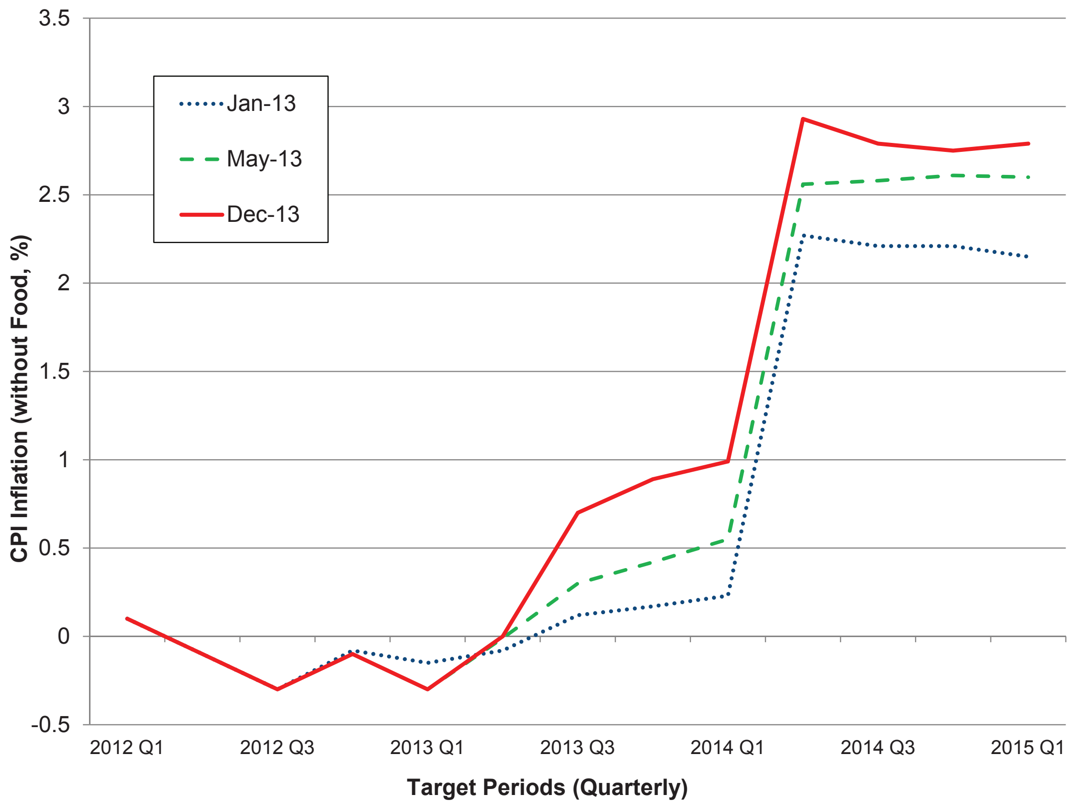

Figure 3: ESP Inflation Forecast in 2013 (Target Periods of 2013–2015)

Date	Event	Policy Rate(%)	Governer
4/14/1995		1.0	Matsushita
9/8/1995		0.5	
4/1/1998	The revised BOJ act came in effect	0.5	Hayami
2/12/1999		0	
8/11/2000		0.25	
3/19/2001	Quantitative Easing (QE) launched	0	
3/9/2006	QE terminated	0	Fukui
7/14/2006		0.25	
2/21/2007		0.5	
10/31/2008		0.3	Shirakawa
12/19/2008	JGB purchase increased	0	
10/5/2010	Comprehensive Monetary Easing (CME) launched	0	
4/4/2013	CME terminated, and Quantitative and Qualitative Monetary Easing (QQME) launched	0	Kuroda

Table 1: Timeline of BOJ's Monetary Policy

Date	Event	Summary
9/9/1998	BOJ Statement	Policy rate reduced to 0.25 percent
2/12/1999	*BOJ Statement*	Policy rate reduced close to zero
8/11/2000	BOJ Statement	Policy rate raised to 0.25 percent
3/19/2001[*]	*BOJ Statement*	*Quantitative easing (QE) launched (policy rate close to zero)*
8/14/2001[*]	*BOJ Statement*	*QE expanded*
12/19/2001[*]	*BOJ Statement*	*QE expanded*
2/28/2002[*]	*BOJ Statement*	*JGB purchase increased*
9/18/2002[*]	BOJ Statement	Stock purchase announced
10/30/2002[*]	*BOJ Statement*	*QE expanded*
3/25/2003[*]	BOJ Statement	Stock purchase expanded
4/8/2003[*]	BOJ Statement	ABS purchase announced
4/30/2003[*]	*BOJ Statement*	*QE expanded*
5/20/2003[*]	*BOJ Statement*	*QE expanded*
10/10/2003[*]	*BOJ Statement*	*QE expanded*
1/20/2004[*]	*BOJ Statement*	*QE expanded*
3/9/2006[*]	*BOJ Statement*	*QE terminated*
7/14/2006	BOJ Statement	Policy rate raised to 0.25 percent
2/21/2007	BOJ Statement	Policy rate raised to 0.5 percent
9/18/2008[*]	BOJ Statement	Dollar swap
10/31/2008	BOJ Statement	Policy rate reduced to 0.3 percent
12/2/2008[*]	BOJ Statement	Facilitation of corporate finance
12/19/2008[*]	*BOJ Statement*	*JGB purchase increased (policy rate reduced close to zero)*
2/3/2009[*]	BOJ Statement	Stock purchase restarted
3/18/2009[*]	*BOJ Statement*	*JGB purchase increased*
12/1/2009[*]	BOJ Statement	Fixed-rate 3-month operation
12/18/2009[*]	BOJ Statement	"Inflation target" clarified
3/17/2010[*]	BOJ Statement	Fixed-rate operation expanded
5/21/2010[*]	BOJ Statement	Growth enhancing operation
8/30/2010[*]	BOJ Statement	Fixed-rate 6-month operation
10/5/2010[*]	*BOJ Statement*	*Comprehensive monetary easing (CME) launched*
8/4/2011	*BOJ Statement*	*CME expanded*
10/27/2011	*BOJ Statement*	*CME expanded*
2/14/2012	*BOJ Statement*	*CME expanded*
4/10/2012	*BOJ Statement*	*CME expanded*
4/27/2012	*BOJ Statement*	*CME expanded*
10/30/2012	*BOJ Statement*	*CME expanded and the joint statement with the government issued*
12/20/2012	*BOJ Statement*	*CME expanded*
1/22/2013	*BOJ Statement*	*CME expanded and inflation target clarified*
2/25/2013	*Nomination of the new governor*	
3/4/2013	*Confirmation hearing from the new governor at the National Diet*	
4/4/2013	*BOJ Statement*	*Quantitative and qualitative monetary easing (QQME) launched*

a. Dates with superscript are listed in Table 2 of Ueda (2012a). The announcement days that are directly related to the JGB purchase and the QE programs are written in italics.

Table 2: Dates of BOJ's Monetary Policy Announcements

Series	Announcement	Non-Announcement	Variance Ratio
JGB			
5 year	3.18	2.85	1.25
10 year	4.28	3.28	$1.70^{**}_{\dagger}$
20 year	4.88	3.55	$1.89^{**}_{\dagger}$
Corporate Bond Yield			
AA, 5 year	3.50	2.68	$1.71^{**}_{\ddagger}$
AA, 10 year	3.92	2.88	$1.85^{**}_{\ddagger}$
BBB, 5 year	3.64	2.74	$1.76^{**}_{\ddagger}$
BBB, 10 year	3.21	3.13	1.06
Stock Prices			
Nikkei 225	2.19	1.56	$1.96^{**}_{\dagger}$
TOPIX	2.02	1.41	$2.07^{**}_{\dagger}$
Exchange Rates			
US Dollar	1.06	0.71	$2.22^{**}_{\ddagger}$
Euro	1.24	0.84	$2.17^{**}_{\ddagger}$

a. This table compares the standard deviation of daily changes on the announcement days and non-announcement days. Daily changes of the yield in basis points and daily percent changes of the stock prices and exchange rates are used.

b. Superscripts $*, **$ denote the significance at the level of 10% and 5%, respectively, based on the F-test.

c. Subscripts $\dagger, \ddagger$ denote the significance at the level of 10% and 5%, respectively, based on the block bootstrap with 10,000 replications. The stationary bootstrap leads to similar results as the block bootstrap.

Table 3: Standard Deviations and Variance Ratio on the Announcement Days and the Non-Announcement Days

Date	Event	JGB 5 Year	JGB 7 Year	JGB 10 Year	JGB 20 Year	AA 5 Year	AA 10 Year	BBB 5 Year	Nikkei 225	TOPIX	US Dollar	Euro
2/25/2013	*Nomination*	-1.30	-2.00	-2.20	-2.00	-1.37	-1.71	-0.73	2.40	1.77	-1.73	-2.71
3/4/2013	*Confirmation Hearing*	-1.90	-2.30	-4.40	-7.30	-0.69	0.88	-0.96	0.30	0.11	0.79	1.87
4/4/2013	*BOJ Statement*	-1.20	-5.50	-11.40	-17.70	-2.08	-9.72	-1.65	2.18	2.67	3.49	4.16
4/26/2013	BOJ Statement	1.50	1.40	0.80	-0.70	3.02	-0.71	1.83	-0.30	-0.99	-1.23	-1.10
5/22/2013	BOJ Statement	-1.20	0.50	1.20	1.70	-1.04	1.27	-1.02	1.59	0.44	0.64	0.26
6/11/2013	BOJ Statement	4.20	6.30	4.70	4.50	5.39	5.57	5.19	-1.47	-0.98	-2.80	-2.39
7/11/2013	BOJ Statement	-0.80	-3.80	-2.70	-1.80	-3.94	-2.61	-2.06	0.39	-0.04	-0.72	0.20
Baseline Events		**-4.40**	**-9.80**	**-18.00**	**-27.00**	**-4.14**	**-14.17**	**-3.76**	**4.97**	**5.24**	**1.64**	**1.37**
Cumulative		**-0.70**	**-5.40**	**-14.00**	**-23.30**	**-0.71**	**-10.65**	**0.18**	**5.18**	**3.68**	**-2.47**	**-1.65**
Average before 2013 (Negative Surprise)		-2.31	-2.48	-2.12	-1.70	-2.14	-1.75	-2.11	-0.61	-0.54	-0.15	0.11
Average before 2013 (Positive Surprise)		2.13	3.45	2.73	2.77	2.03	2.52	1.59	0.24	0.29	0.12	0.36

a. This table shows the daily changes of the yields and the daily percent changes of stock prices and exchange rates on the days listed above.
b. Baseline events are listed in Table 2 and written in *Italic*.
c. This table also shows the average effects using the pre-2013 data when there are positive/negative changes in 5-year JGB yield as a reference.

Table 4: Effects of the QQME Announcements on JGB, Corporate Bond Yields, Stock Prices and Exchange Rates

	Japan		U.S.	
	Estimate	Std. Error	Estimate	Std. Error
Panel A: Pass-Through from 5-Year Government Bonds				
AA Corporate Bond	0.99**	(0.25)	0.70**	(0.07)
BBB Corporate Bond	1.12	(1.13)	0.61**	(0.09)
Stock Prices	-1.19	(1.59)	-8.07**	(3.81)
Exchange Rate	-0.40	(0.83)	-7.52**	(0.93)
Panel B: Pass-Through from 10-Year Government Bonds				
AA Corporate Bond	0.94**	(0.05)	0.63**	(0.07)
BBB Corporate Bond	1.09	(1.24)	0.58**	(0.07)
Stock Prices	-0.20	(0.17)	-7.19*	(3.74)
Exchange Rate	-0.20	(0.16)	-6.57**	(0.87)
Panel C: Pass-Through from 20-Year Government Bonds				
AA Corporate Bond	0.84**	(0.21)	0.73**	(0.33)
BBB Corporate Bond	-2.90	(14.96)	0.63**	(0.31)
Stock Prices	-0.12	(0.08)	-10.80*	(6.15)
Exchange Rate	-0.20**	(0.09)	-9.27**	(3.09)

a. This table shows the pass-through to the corporate bond yields, stock prices, and exchange rates. Superscripts $*, **$ denote the significance at the level of 10% and 5%, respectively. Heteroscedasticity-robust standard errors are presented in the parenthesis.

b. For Japan, the corporate bond yield with the maturity of 5 years is used for the pass-through from 5-year government bonds, and the corporate bond yield with the maturity of 10 years is used for the pass-through from 10- and 20-year government bonds. Nikkei 225 index is used for stock prices and the spot exchange rate against US dollar is used for the exchange rate.

c. For the U.S., the effective corporate bond yield are used for all maturities. Dow Jones industrial average index is used for stock prices and the spot exchange rate against Euro is used for the exchange rate.

Table 5: GMM Estimates of the Pass-through to Corporate Bond Yield, Stock Prices and Exchange Rates

Series	Announcement	Non-Announcement	Variance Ratio
Financial Assets			
REIT index	2.14	1.52	$1.99^{**}_{\dagger}$
CDS index	5.30	4.19	1.60^{*}
Exchange Rates: OECD Countries			
Australian Dollar	1.26	1.12	1.26
Canadian Dollar	1.22	0.94	$1.67^{**}_{\dagger}$
Korean Won	1.34	1.07	1.56^{**}
New Zealand Dollar	1.29	1.10	1.38^{*}
UK Pound	1.20	0.85	$2.01^{**}_{\dagger}$
Exchange Rates: Asian Economies			
Hong Kong Dollar	1.06	0.71	$2.26^{**}_{\ddagger}$
Singapore Dollar	0.90	0.69	$1.71^{**}_{\dagger}$
Taiwanese Dollar	1.01	0.75	$1.82^{**}_{\ddagger}$
Thai Baht	0.97	0.80	1.49^{**}

a. This table compares the standard deviation of daily changes on the announcement days and non-announcement days for additional variables: REITs, CDS, and the OECD and Asian exchange rates. Daily changes of the yield in basis points and daily percent changes of the exchange rates are used.

b. Other notes are the same as in Table 3.

Table 6: Standard Deviation and Variance Ratio of the Series on the Announcement Day and the Non-Announcement Day

Pass-through from	5-Year JGB		10-Year JGB		20-Year JGB	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
REIT Index	-0.43	(0.28)	-0.36*	(0.19)	-0.30**	(0.12)
CDS Index	1.09	(0.82)	0.77	(0.53)	0.30	(0.23)
Australian Dollar	0.07	(0.46)	-0.16	(0.14)	-0.14*	(0.08)
Canadian Dollar	-0.84	(1.44)	-0.24	(0.20)	-0.21**	(0.11)
Korean Won	-0.78	(1.23)	-0.18	(0.17)	-0.18**	(0.11)
New Zealand Dollar	-0.34	(0.75)	-0.21	(0.19)	-0.17**	(0.09)
UK Pound	0.03	(0.36)	-0.15	(0.18)	-0.20*	(0.11)
Hong Kong Dollar	-0.51	(1.02)	-0.21	(0.17)	-0.20**	(0.10)
Singapore Dollar	-0.04	(0.19)	-0.15	(0.13)	-0.15**	(0.07)
Taiwanese Dollar	0.02	(0.23)	-0.10	(0.12)	-0.15*	(0.08)
Thai Baht	-0.07	(0.28)	-0.15	(0.15)	-0.15**	(0.08)

a. This table shows the pass-through to additional variables: REIT, CDS, and the OECD and Asian-Pacific exchange rates.

b. Other notes are the same as in Table 5.

Table 7: GMM Estimates of the Pass-through to Additional Variables

	Japan		U.S.	
	Estimate	Std. Error	Estimate	Std. Error
Panel A: Pass-Through from 5-Year Government Bonds				
AA Corporate Bond	0.41	(0.26)	0.73**	(0.05)
BBB Corporate Bond	0.12	(0.22)	0.70**	(0.04)
Stock Prices	0.06	(0.26)	-7.77*	(4.12)
Exchange Rate	-0.14	(0.11)	-8.13**	(1.01)
Panel B: Pass-Through from 10-Year Government Bonds				
AA Corporate Bond	0.78**	(0.18)	0.69**	(0.03)
BBB Corporate Bond	0.86**	(0.21)	0.65**	(0.02)
Stock Prices	-0.24	(0.35)	-7.48*	(4.23)
Exchange Rate	0.09	(0.08)	-7.27**	(0.90)
Panel C: Pass-Through from 20-Year Government Bonds				
AA Corporate Bond	0.78**	(0.19)	1.23**	(0.19)
BBB Corporate Bond	0.81**	(0.15)	1.17**	(0.18)
Stock Prices	-0.39	(0.25)	-13.21*	(7.99)
Exchange Rate	0.05	(0.07)	-11.31**	(2.05)

a. This table shows the pass-through to the corporate bond yields, stock prices, and exchange rates, based on a selected set of the announcements.

b. Other notes are the same as in Table 5.

Table 8: GMM Estimates of the Pass-through to Corporate Bond Yields, Stock Prices and Exchange Rates (Selected Announcements)

	2001-2006 (QE)	2006-2010	2010-2013 (CME)
Panel A: Pass-Through from 5-Year JGB			
AA Corporate Bond	1.02**	1.03**	1.99
BBB Corporate Bond	1.04**	1.13**	1.81
Nikkei 225	-0.66	-0.43	0.52
US Dollar	-0.04	-0.05	8.19
Panel B: Pass-Through from 10-Year JGB			
AA Corporate Bond	0.98**	0.98**	2.26**
BBB Corporate Bond	0.60*	0.77**	1.98**
Nikkei 225	-0.05	1.59	0.41
US Dollar	-0.03**	-0.20	-0.03
Panel C: Pass-Through from 20-Year JGB			
AA Corporate Bond	0.97**	0.98**	0.71**
BBB Corporate Bond	0.44**	1.22**	1.08**
Nikkei 225	-0.06	0.89	0.12
US Dollar	-0.02	-0.19	0.06
Number of Announcements	13	13	9

a. This table shows the pass-through to the corporate bond yields, stock prices, and exchange rates in the subsamples: 2001-2006 (the QE program), 2006-2010, and 2010-2013 (the CME program).

b. Other notes are the same as in Table 5.

Table 9: GMM Estimates of the Pass-through in Subperiods

	Estimate	Std. Error
Panel A: Pass-Through to Main Variables		
AA, 5 year	0.57**	(0.32)
AA, 10 year	0.76**	(0.25)
BBB, 5 year	1.41	(0.80)
BBB, 10 year	0.58	(0.50)
Nikkei 225	-0.09	(0.22)
TOPIX	-0.05	(0.19)
US Dollar	-0.06	(0.11)
Panel B: Pass-Through to Additional Variables		
Euro	-0.00	(0.07)
REIT Index	-1.18	(1.52)
CDS Index	1.77	(2.54)
Australian Dollar	-0.05	(0.10)
Canadian Dollar	-0.15	(0.23)
Korean Won	-0.17	(0.26)
New Zealand Dollar	-0.08	(0.14)
UK Pound	-0.00	(0.08)
Hong Kong Dollar	-0.08	(0.14)
Singapore Dollar	-0.04	(0.08)
Taiwanese Dollar	-0.01	(0.05)
Thai Baht	-0.04	(0.08)

a. This table presents the pass-through based on the principal component of JGB yields with a maturity of 5,10 and 20 years.
b. Other notes are the same as in Table 5.

Table 10: GMM Estimates of the Pass-through based on the Principal Component of JGB Yields