JSPS Grants-in-Aid for Scientific Research (S)

Understanding Persistent Deflation in Japan

Working Paper Series

No. 078

December 2015

First Draft: July, 2015
This Draft: December, 2015

Transmission Channels and Welfare Implications of Unconventional Monetary Easing Policy in Japan

Hiroshi Ugai

UTokyo Price Project
702 Faculty of Economics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5841-5595
E-mail: watlab@e.u-tokyo.ac.jp
http://www.price.e.u-tokyo.ac.jp/english/

Transmission Channels and Welfare Implications of Unconventional Monetary Easing Policy in Japan[*]

Hiroshi Ugai[†]
Hitotsubashi University
First Draft: July, 2015
This Draft: December, 2015

Abstract

This paper examines the effects of the Quantitative and Qualitative Monetary Easing Policy (QQE <2013-current>) of the Bank of Japan (BOJ) by transmission channels in comparison with those of the Comprehensive Monetary Easing Policy (CE) and the subsequent monetary easing policies (2010-2012), based on the event study using financial market data. As for the QQE under normal market conditions, depreciation of foreign exchange rate in the context of portfolio balance channel functions quite strongly, while as for the CE, signaling channel through the commitment and credit easing channel at the dysfunctional markets work. The direct inflation expectation channel is weak for both QQE and CE, although the QQE has adopted various ways to exert a direct and strong influence on inflation expectation. It can be conjectured that the gradual rise in inflation expectation comes mainly from other channels like the depreciation of the yen.

The most crucial characteristic of the QQE is to maximize the potential effects of easing policy by explicitly doubling and later tripling the purchased amount of JGBs and then the monetary base proportionally. The amount of JGB purchases by the BOJ surpasses the issuance amount of JGBs, thereby reducing the outstanding amount of JGBs in the markets. Shortage of safety assets would increase the convenience yield, which itself would reduce the economic welfare and not permeate the yields of other risky assets theoretically. This paper then examines the impact of reduction in JGBs on yield spreads between corporate bonds and JGBs based on money-in-utility type model applied to JGBs, and finds that at least severe scarcity situations of JGBs as safe assets are avoided, since the size of Japan's public debt outstanding is the largest in the world.

Even so, the event study shows no clear evidence that the decline in the yield of long-maturity JGBs induced by the QQE permeates the yields of corporate bonds. Recently demands for JGBs have been increasing from both domestic and foreign investors as collaterals after the Global Financial Crisis and from financial institutions that have to correspond to strengthened global liquidity regulation, while the Government of Japan is planning to consolidate the public debts. These recent changes as well as market expectation for future path of JGB amounts should also be taken account of to examine the scarcity of safe assets in case of further massive purchases of JGBs.

Keywords: Quantitative easing, Credit easing, Inflation expectation, Safety asset
JEL Classification: E43, E44, E52

---

[*] I would like to thank Kosuke Aoki, Masahiko Takeda, Kazuo Ueda, Junko Koeda, Takashi Kano, and many participants of the 17th Macroeconomics Conference for their comments and suggestions, and Naohiko Baba and Yuriko Tanaka for provision of the data-calculation method using Flow of Funds data. Mr. Yang Lyu made the database of credit default swap. The views expressed herein are those of the author alone.

[†] School of International and Public Policy, Hitotsubashi University, hugai@ics.hit-u.ac.jp.

Introduction

Facing the zero lower bound of short-term interest rate, the Bank of Japan (BOJ) conducted the Quantitative Easing Monetary Policy (QEP) from 2001 to 2006, well in advance of other developing countries. At that time there were heated discussions about its effects (Ugai (2007)). After the Global Financial Crisis (GFC) in 2008, most of the major central banks have also faced the zero interest rate lower bound (Graph 1), and the Federal Reserve pursued the Large Scale Asset Purchases (LSAPs), followed by the Bank of England and the BOJ. Recently, although the Federal Reserve has terminated the LSAP, European Central Bank has newly adopted unconventional monetary policy including an expanded asset purchase program. Although researchers have started to summarize the effects and side-effects of these unconventional monetary easing policies theoretically and empirically (IMF (2013)), there is no consensus about them so far.

<Graph 1>

The most difficult factors to discern the effects and side-effects of these unconventional policies are that they usually contain two purposes at once; to counter against the situations that the financial intermediary functions are disrupted, and that the economies are in danger of going into deflation or of not exiting from deflation. Even if the effect on the deflation is small, it is hard to judge its effectiveness because the disrupted financial intermediation function could have been an obstacle to make the unconventional monetary easing policy function against deflation. In addition, there was always a discussion that it must be because the degree of the monetary easing was small. By adopting the very aggressive monetary easing policy in the normalized markets, the BOJ provides a good opportunity to further deepen the understanding of those impacts.

The unconventional monetary easing policy facing zero interest rate lower bound consists of two variations in general: So called credit easing that focuses on the asset side of central bank balance sheet, that is, the purchase of risky assets in the malfunctioning markets, or so called quantitative easing that focuses on the liability side of central bank balance sheet, that is, the purchase of government bonds and the subsequent expansion of the monetary base. Central banks sometimes have combined either or both with various other measures for emergency in the financial system. Sometimes signaling for future monetary policy stance is added to affect expectation of the public and markets. In case of Japan, since the GFC hit Japanese economic and financial conditions, the BOJ cut the policy rate in 2008 and introduced some operational device to enhance the monetary easing in 2009. In 2009 the BOJ introduced market operations with CP, ABCP, and corporate bonds for short maturity as collaterals, which was designed as a market maker of last resort (Suda (2014)). After easing monetary policy more by encouraging a decline in longer-term interest rates in the money markets at the end of 2009 and introducing the fund-providing measure to support financial institutions' efforts toward strengthening the foundations for economic growth in June 2010, the BOJ adopted Comprehensive Monetary Easing Policy (CE) that had strong characteristics of credit easing in October 2010, and subsequently adopted a variety of measures against the dysfunction of financial intermediary and the deflationary pressure within this framework (Table 1). Then in February 2012 the BOJ adopted the price stability goal in the medium to long term, within a positive range of 2 percent CPI inflation or lower, setting a goal of 1 percent for the time being. Since Prime Minister Abe took office in December 2012, he has introduced Abenomics that consists of the new package of three-pronged approach, that is, bold monetary easing, flexible fiscal policy, and growth strategy as a structural reform to revitalize Japan's economy. In line with Abenomics, in January 2013 the BOJ introduced price stability target at 2 percent CPI inflation, and the Government of Japan and the BOJ published joint statement on overcoming deflation and achieving sustainable economic growth that clarified each role. After that in April 2013 it adopted Quantitative and Qualitative Monetary Easing Policy (QQE) that has both characteristics but strong characteristics of quantitative easing, and further enhanced it (sometimes called "QQE2") in October 2014 (Table 2). The QQE was adopted to conquer the deflation after the financial intermediary function returned to the normal.

<Table 1>

<Table 2>

One of the important characteristics of the QQE in Japan is their purpose to drastically change the deflationary mindset. This purpose is different from those of unconventional policies in the other economies in that other countries are to deal with credit frictions and to promote economic growths while maintaining the inflation rates at around their target level. To attain this purpose, BOJ has tried to affect inflation expectation directly with various tools: First, under the QQE it has promised to attain the 2 percent price target with a specific time horizon of about 2 years. Second, BOJ has adopted the commitment to continue the current QQE as long as it is necessary to attain the target in a stable manner. Third, QQE (especially "QQE2") has planned to purchase and hold the largest amounts ever of assets among the central banks that consist mainly of JGBs (Graph 2), where the asset size of the BOJ and that of monetary base will expand to almost 80 percent of GDP in the near future. How large is the combined effects of such drastic monetary easing scheme on inflation expectation, compared to the effect of credit easing where a central bank purchases the risky assets that are not traded smoothly in the financial markets?

Then, turning the perspective to future operations of the BOJ, since the amount of BOJ's purchasing Japanese government bonds (JGBs) is at an unprecedented level, the BOJ is said to be almost the sole agent to purchase the JGBs in the secondary markets, and there are many issues the BOJ and Japanese government will have to deal with, such as the management of the BOJ's balance sheet, the management of public debt, and so on. Among them, this paper picks up the perspective of the central bank's purchasing the largest amount of safe assets, and studies the welfare implications of this operation.

<Graph 2>

With those issues in mind, this paper will examine the effects of the BOJ's QQE in comparison with those of CE and the subsequent monetary easing policies by transmission channels. This paper omits BOJ's easing policy during 2008 and 2009 just after the Lehman shock for comparison, because most of them were accompanied with cut in the policy rate, or with only the expansion of the collaterals. After that, welfare implications of purchasing massive amount of JGBs will specifically be examined.

The remainder of this paper is organized as follows. Section 1 considers the theoretical transmission channels of the CE and QQE, and Section 2 extracts the effects by various channels based on the event study. Next, Section 3 and 4 show the welfare implications of massive purchases of JGBs with a theoretical model and its empirical results. Section 5 provides the conclusion and challenges for future research.

1. Theoretical Transmission Channels of Unconventional Monetary Easing Policy

This section begins by classifying the assumed transmission channels of unconventional monetary easing policies based on the BOJ's CE and QQE.

This section does not treat the effect of pure quantitative easing, that is, the provision of the reserves and monetary base (the monetary liabilities of the central bank) by purchasing the short-term Government bonds. The abundant provision of liquidity under the quantitative easing framework in general successfully maintains extremely easy monetary conditions, but once the interest rate reaches zero and the opportunity cost of the money is eliminated, it has no more reason to affect the economy. When the real money balance exceeds a certain threshold (satiation level), the interest rate becomes zero, and there is no marginal utility gained from liquidity service. There, the demand for reserves becomes infinitely elastic and can be provided indefinitely without influencing the economy. Aside from this pure quantitative easing channel, the credit and / or quantitative easing themselves still have many channels. Most of them are through the asset side of the central bank and the expectation about the future. This section discusses five channels in details.

A) Signaling channel

If the central bank makes some commitment about future path of expected interest rates, it can not only reduce the volatility of expected future policy rate (Filardo and Hofmann (2014)), but also lower the path of expected future interest rates if the commitments are more expansive than the expectation of the public and markets (Ugai (2007)). These channels are generally called signaling channel, or forward guidance channel.

The BOJ adopted the commitment under the CE that would maintain the virtually zero interest rate policy until it judges, on the basis of the understanding of the medium- to long-term price stability (in a positive range of 2 percent or lower, and midpoints around 1 percent), that price stability would be in sight, on condition that no problem would be identified in examining risk factors, including the accumulation of financial imbalances. This commitment is clear about future policy rates with some conditions. Then under the QQE the BOJ has made two commitments: the first is to achieve the price stability target of 2 percent CPI inflation rate at the earliest possible time with a time horizon of about two years, and the second is to continue with the QQE, aiming to achieve the price stability target of 2 percent, as long as it is necessary for maintaining that target in a stable manner. The first one is unclear about whether that is a commitment in the sense of this paper because there is no concrete path to attain that commitment, while the second one is a clear commitment though their operating target is changed from uncollateralized overnight call rate to monetary base. Both CE and the latter part of QQE are state contingent commitments linked to inflation rate, which is consistent with the theory in that even under the optimal commitment in a theoretical base, the target path for the gap-adjusted price level would not be deterministic, as Woodford (2012) shows.

As for monetary base, according to Eggertsson and Woodford (2003), the monetary base would also have an immediate positive impact on economic activity during the period of the zero interest rate lower bound through the role of commitment if it were to assume a permanent increase in the size of monetary base. In other words, if the monetary base were planned to increase in consistent with future economic and price outlook, this would be believed by the public and markets to be the commitment for future monetary policy stance, thereby the classic proposition that $MV = PY$ would hold on average. However, the currently planned amount of providing monetary base in Japan is so enormous that the future path of the monetary base will be expected to be reduced to the amount required by the 2 percent inflation target at normal times. Thus it is difficult for the current huge amount of monetary base to function through the signaling channel (Woodford (2012)). In addition, Miyao (2015) points out the merit of the commitment of massive and open-ended purchases of government bonds as a device to avoid the time-inconsistency that the commitment to continue zero interest rate would have when the exit approaches. Indeed, it takes time to shrink the asset size of the BOJ because most of the assets it holds are long-term JGBs. However, if the central bank fears the excessive easing in future, it can choose the combination of the measures that it raises the short-term policy rate while not selling the purchased long-term bonds. In this case the policy of expanding the monetary base could still face the same time-inconsistency situation.

Even more, at the time the BOJ adopted such commitments, even long-term interest rates were low, suggesting a little room for expansionary effects. The degrees of the effects of the commitments are subject to the empirical test.

B) Credit easing (targeted asset purchase) channel

If the central bank holds less of an asset and more of other assets, the private sector holds more of the former and less of the latter. Does this change their behavior about consumption? Eggertsson and Woodford (2003) suggests the irrelevance proposition, Modigliani-Miller Theorem for the central bank operations, as follows: The market price of any assets should be determined by the present value of the random returns, using an asset pricing kernel derived from the household's marginal utility of income in different future states of the world. As far as an exchange of financial assets between the central bank and the private sector does not change the real quantity of resources available for consumption in each state of the world, the household's marginal utility of income in the different states of the world would not change. If this theory holds, the fact that the central bank takes risks onto its balance sheet through open market operations would not make the risks disappear from the economy. Required assumptions here are that the assets are valued only for their pecuniary returns rationally, that all investors can purchase arbitrary quantities of the same assets at the same market prices, and that markets are frictionless.

There are three possible exceptions of the assets being valued for their pecuniary returns. First possible exception is a binding constraint for participating in the markets. When the private financial markets are sufficiently impaired, the purchase of private sector assets in targeted markets by the central bank could smooth their financial intermediary function. During a financial crisis like the GFC, a sharp decline in investors' ability to take risks reduces market liquidity in certain segments of the financial system. In addition, interbank markets can become dysfunctional due to heightened counterparty risks. Under such conditions, purchasing the targeted assets can have impacts on the markets. Curdia and Woodford (2009, 2011) introduces credit friction into the model and shows that financial disturbances increase the marginal social benefit of the central bank credit policy to a greater extent, if the zero interest rate lower bound prevents the policy rate from declining in response to the negative shock. Curdia and Woodford (2009, 2011) suggests also that the appropriateness of active credit policy is likely to depend on conditions that are specific to the markets for particular financial instrument, and that cannot be assessed solely from the macroeconomic perspective.

These dysfunctional markets were seen after the GFC in Japan, so the CE of the BOJ aimed to make those markets and financial system function well along with other purposes like exiting from deflation. On the other hand, when the BOJ adopted the QQE, the financial system already returned to the normal conditions. The next section will show the empirical results concerning the credit easing policy.

C) Portfolio balance channel

If the above irrelevance proposition holds, the so called portfolio balance would not function. The question here is to what extent the assets are valued for their state contingent pecuniary returns and investors are able to rationally anticipate the consequences of their portfolio choices.

The second possible counterargument goes back to the preferred-habitat view proposed by Culbertson (1957) and Modigliani and Sutch (1966). They assume that there are investors with preferences for specific maturities, and the interest rate for a given maturity is influenced by demand and supply shocks that are peculiar to that maturity. It was widely recognized quite recently by practitioners but came into modern theory when Vayanos and Vila (2009) built a formal model for this view. They assume that term structure of interest rates is determined through the interaction between investors with preferences for specific maturities and risk-averse arbitragers. Major preferred habitat buyers seem to be the BOJ, insurance companies, and pension funds. Bond yields are determined by two mean-reverting factors; short-term rate and demand factor. If the degree of an arbitrager's risk aversion is high, the short-term rate is not a dominant risk factor anymore, and the location of demand shock from preferred habitat investors for a specific bond maturity influences both the magnitude of the demand effect and its relative importance across maturities (Vayanos and Vila (2009)). This paper takes a stance that the preferred-habitat demand is applied to all fixed income securities, not limited to JGBs. This broad perspective has not been theoretically discussed, but reflects the views of those central banks that have adopted the unconventional monetary policies. In this setting, the central bank's massive purchases of the government bonds could influence the demand-supply conditions of those markets and alter the yield curve, and then could permeate the yields of other bonds. The QQE focuses mainly on purchasing the government bonds by expecting the portfolio balance to function broadly, although it also purchases other risky assets as well. However, to what extent the price effects of local shocks are transmitted to the term structure of many bonds is still subject to the empirical test.

The BOJ has purchased more than the issuance amount of JGBs as a net of their issue and redemption, and has accelerated purchasing them since the adoption of QQE2 (Graph 3). Major sellers are financial institutions, as JGBs are owned mostly by them. Domestically licensed banks and Japan Post Bank are the largest net sellers, and quite recently even insurance companies and public and private pension funds have sold them. Note here that under the irrelevance proposition if the central bank buys more of JGBs by selling money, private investors should act to undo the activity of the central bank. Thus the change in the contents of their portfolio itself cannot tell whether the portfolio balance channel works or not. Under the portfolio balance channel function, a change in relative prices of all the assets is required to induce them to adjust their portfolio, which is subject to the empirical test.

<Graph 3>

This paper takes a stand that this preferred-habitat demand is applied also to exchange rates through rebalancing of the international portfolio. Stock prices are not treated in this paper because it is thought to mainly reflect the result of changes in prices of other securities and foreign exchange rates indirectly. In addition, when investors try to rebalance both JGBs and foreign securities, the effect on the exchange rate has to take into account the other countries' relative economic and financial conditions. As for the Japanese yen/the US dollar exchange rate, after Lehman shock the Fed had also adopted and terminated LSAP, and thus the relative difference and stance of economic and financial conditions should also be assessed. To explain the movement of the exchange rate, the next section will also check the uncovered interest rate parity and introduce the idea of Bansal and Shaliastovich (2013)'s long-run risk model that real uncertainty (such as uncertainty about expected growth) decreases bond risk premiums because of flight to quality while nominal uncertainty (such as uncertainty about expected inflation) decreases bond premiums at short maturities and raises them at longer maturities by gradually dominating the flight to quality effect.

That said, there still remains a question of why preferred habitat exists except for the central bank theoretically (Waller (2015)). Whether preferred-habitat demand really reflects a representative's inherent preference, or his forced behavior by external factors such as regulations or rules is an open question. There is no clear and theoretically firm background behind this idea.

D) Safety channel

Last possible exception is that they may also be valued for facilitating transactions. In this context, Krishnamurthy and Vissing-Jorgensen (2012-a) provides the idea that government bonds have the characteristics of high safety that lower their yields compared to those of other assets. They show the evidence that the yield spread between long-maturity AAA-rated corporate bonds and long-maturity Treasury bonds in the US has an inverse relationship with the government debt-to-GDP ratio that shows the demand function of Treasury bonds. When the supply of government bonds is few, the value that investors assign to the safety (convenience yield) provided by the government bonds is high, thereby letting the yield on government bonds low relative to the yield on the AAA corporate bonds of less safety. This paper applies this idea to Japan and plots the yield spread between 10 year-maturity AA-rated corporate bonds[1] and 10 year-maturity JGBs against the JGB-to-GDP ratio (Graph 4), and get the almost same inverse relationship.

<Graph 4>

This spread is not the same as risk premium of a standard asset-pricing model. This is an extra premium investors are willing to pay for safe assets. Krishnamurthy and Vissing-Jorgensen (2011) plots the price of an asset against its expected default rate, and shows that the curve of asset price against its expected default rate is very steep for low default rates, and flattens as the supply of government bonds increases. The upward distance of this curve from the line hypothetically determined by a consumption-based capital asset-pricing model (C-CAPM) is the convenience yield, and this upward deviation becomes steeper as the supply of government bonds decreases.

Since the BOJ adopted the QQE, it has absorbed the amount of JGBs more than the issuance amount of JGBs as net basis which is expected to exceed the gross issuance amount of JGB in near future (Graph 3). Thus the outstanding amounts of JGBs are decreasing (Graph 5). The JGB-to-GDP ratio of consolidated government (Government of Japan plus BOJ) peaked at

[1] In Japan, there are few AAA-rated corporate bonds available in the markets. Here AA-rated corporate bonds are used alternatively. They are less safe than AAA-rated corporate bonds, but can still be regarded as relatively safe assets.

147.7 percent in 3Q/2012, declined to 138.5 percent in 4Q/2014, and keeps on declining (Graph 5).

<Graph 5>

When a central bank purchases massive amount of government bonds from the markets, this reduces the amount of government bonds available for the market participants, thereby raising the convenience yield for them. Therefore, this safety channel derived from the net supply of the government bonds can be expected to function especially for the QQE. According to Woodford (2012), even though such massive purchases of government bonds by a central bank could raise the prices of government bonds, this would not necessarily imply any reduction in the interest rates of other risky financial assets. This is because the increase in the prices of government bonds would reflect an increase in the convenience yields. There would not necessarily be any benefit for private borrowers, and not any stimulus to aggregate expenditure.

E) Inflation expectation channel

The other important channel is to raise the inflation expectation directly. There are possible two routes to raise inflation expectation; raising the inflation expectation through some of the above channels, and through directly shifting up such expectation. As for the latter, Ugai (2007) does not mention it for the quantitative easing policy (QE) from 2001 to 2006 because there is no concrete path affecting the economy. However, Kuroda (2013) points out that Japan needs to exit from the deflationary equilibrium and what differs from the BOJ’s past monetary easing policies and from the current monetary easing policies adopted by other major central banks is to pay utmost attention to a drastic upward shift of the inflation expectations. The QQE aims to directly raise inflation expectations by changing the expectations of the public and market participants through the commitment and the actual monetary easing that underpins it. The Bank of Japan (2015) insists in a recent “Outlook for Economic Activity and Prices” that inflation expectation is raised through the commitment to achieving the price stability target of 2 percent.

The next section will examine the strength of this inflation expectation channel by using the inflation swap rates and the break-even inflation rates of inflation-indexed government bonds. Inflation swap is a financial derivative instrument used to hedge against inflation, and the fixed payments the fixed-rate payor makes measure the expected inflation rate over the life of the swap. A break-even inflation rate implied in the inflation-indexed government bonds is almost equal to a yield spread between the nominal yield on a fixed-rate bond and an inflation-indexed bond. Both are commonly used measures of inflation expectation of market participants. In the following it is examined whether inflation expectation shown by such financial instruments actually increases or not right after the monetary easing decision. By picking up the market reaction in two days, the effect of other channels on inflation expectation that takes time can be removed. It has to be kept in mind that due to lack of sufficient liquidities in the market, liquidity premium of inflation-indexed bonds cannot be ignored. Inflation swap is also traded by a limited number of market participants in Japan, but is superior in that it does not have the cash constraint (Imakubo *et al.* (2015)). Since both instruments have some distorting factors, other inflation expectation indicators will also be compared later. It should be reminded that the aim of this analysis is to extract the direct impact on the inflation expectation, not the overall impacts on inflation through various other channels such as a depreciation of the exchange rate and / or a reduction of output gap.

F) Summary

In analogy with Krishnamurthy and Vissing-Jorgensen (2011)[2], the above five channels can be shown on a real rate of *t*-year long-term, risky financial asset at *t* ($r_{t,risky,long-term}$) such as a corporate bond. $i_{t,safe,short-term}$ is a nominal yield of short-term, safe asset at *t*, and π_t^e is an expected inflation at *t*. This decomposition is analogous to the CAPM, where the return on assets is decomposed as the asset's beta multiplied by the market risk premium.

$$\begin{aligned} r_{t,risky,long-term} = & \frac{1}{T}\sum_{t=1}^{T} E[i_{t,safe,short-term}] - \pi_t^e \\ & + Credit\ friction_t \times P_{t,Credit\ friction\ risk} \\ & + Maturity_t \times P_{t,Maturity\ risk} \\ & + Lack\ of\ Safety_t \times P_{t,Safety} \end{aligned} \quad (1)$$

where the first line indicates the signaling channel and the inflation expectation channel: The long-term real yield reflects the average of expected future real short-term interest rates. Signaling channel affects $\frac{1}{T}\sum_{t=0}^{T} E[i_{t,safe,short-term}]$ and inflation channel affects π_t^e. The second line gives the room for credit easing channel. The third line gives the room for the portfolio balance channel. Note that the credit easing channel sometimes overlaps the portfolio balance channel. The fourth term shows the extra yield on the non-safe assets since it lacks safety like government bonds.

2 Note that this is just analogy, and that the channels are different from that of Krishnamurthy and Vissing-Jorgensen (2011).

This equation does not cover the exchange rate. Thus the movement of the exchange rate is assessed through the portfolio balance channel as well as through relative economic and financial performances of related countries.

Based on this framework, the event study of BOJ's credit and quantitative easing policy will be conducted at the next section.

2. Evidence from CE and QQE

This section picks up the data of QQE, and of CE and subsequent policy changes to compare the effects, and analyzes their transmission channels by using an event-study methodology. This event study uses the reaction of financial market data at the timing of all policy changes.

Following the approach of Krishnamurthy and Vissing-Jorgensen (2011) with slight modification, this section treats those policies as important events and examines two-day changes in yields, that is, how the yields of many financial assets change one day after the policy change compared with that of one day before the policy change. More concretely, as for the signaling channel, the events of CE and QQE are examined, and are also compared with "QQE2" that have not made additional explicit commitment. Since the BOJ's current bold monetary easing is backed by the Government of Japan with the framework of Abenomics, the relevant movement not necessarily reflected at the timing of adoption of QQE is also examined. As for the credit easing channel and portfolio balance channel, the events of all actual easing policies are examined. Then as for the inflation expectation channel, the events of CE, QQE, "QQE2", and of setting price stability goal and target are examined.

All the tables of this section provide focus on the total change in yields or prices of daily data from the beginning of 2010 through November 2014. Since all the data periods are within the period of zero interest rate lower bound, there is no need to control for the zero lower bound conditions. The data of overnight index swap rates, yields of JGBs by maturities (10 year, 5 year, 3 year, and 1 year) and of corporate bonds by ratings (AA, A, and BBB) and by maturities (10 year only for AA, 5year, 3 year, and 1 year for all ratings)[3], logarithm of the yen/dollar spot exchange rate, and inflation swap rates and break-even inflation rates of inflation-indexed government bonds (10 year and 5 year) are used. This study regresses the daily changes for the variable in question on the dummy on the announcement day and the subsequent day of each policy change to take into account that some policy actions were

[3] The above choice is conducted from the perspective to secure ample number of issuers. The yields of 10 year maturity of AA, A, and BBB can be changed largely by idiosyncratic shocks due to fewer issuers.

announced late in the afternoon. Some outlier events are also controlled in the corporate bond yields by dummy variables, such as the distortion in ratings of some large companies caused by the partial revision of the Act on Regulation, etc. of Loan Business (from December 20, 2006 through June 18, 2010) and by occurrence of Great East Japan Earthquake (March 11, 2011). These regressions are estimated using ordinary least squares estimation method with robust standard errors to take into account heteroskedasticity by applying Newey-West's HAC estimator. To test for statistical significance of the sum of the coefficients of two-day changes of the entire monetary easing, F-test is used.

This event study captures the prompt reactions of the markets after the announcement of the policy change, based on the assumption that bond prices and exchange rates react fully to those news. This presumption is reasonable because the BOJ fully explains the intention at policy changes, and consistent with the analysis for the Fed's LSAP by Gagnon *et al.* (2011). That said, as for credit easing channel, portfolio balance channel, and safety channel, if investors act not so efficiently at the news but act partially on the actual demand and supply conditions, they may react to the actual market operations by the BOJ. This case is beyond the perspectives of this paper[4].

A) Signaling channel

The events of BOJ introducing the commitment at CE and at QQE are chosen to examine the existence of signaling channel. Here the changes in Overnight Index Swap (OIS) rates after such policy actions are examined because OIS in Japan provides a swap rate between overnight uncollateralized call rate and fixed term rates, and a good indicator to reflect the market expectation for future policy rate of monetary policy. Graph 6 shows the development of OIS rates one day after the CE and QQE and one day before those policy actions, along with those of "QQE2". It is clear that CE suggested to the market participants that it would extend the easing period longer than their expectation, especially for the periods of longer than 3 years later. QQE, on the contrary, raised the expected policy rates of 2 to 5 year future. "QQE2" has no additional signaling effect, which is consistent with the theory. These facts are identified at Table 3 where F-test shows 1 percent significance.

<Graph 6>

[4] Fukunaga *et al.* (2015) conducts the event study at the time of market operations and concludes that duration risk channel (almost the same as portfolio balance channel) exists in the JGB markets. That said, they do not separate the duration risk channel from the safety channel.

<Table 3>

The reasons behind the market response to QQE can be thought in two ways: The first possible explanation is that since the BOJ has made two commitments, the overall signal may be unclear for the markets. Since it has committed to attain 2 percent inflation around 2 years, if market participants believe it, the expected policy rate will rise from 2 years later. On the other hand, it has also committed to continue the QQE until it attains the target in a stable manner, suggesting the zero rate being kept longer. Since both commitments show the opposite directions, the markets cannot factor in the extension of the easing period. The second possible explanation is that the state-contingent commitment about the continuity of QQE is linked to monetary base without explicit forward guidance about policy rate, so that it may be hard for market participants to imagine the future monetary easing path of policy rate (Filardo and Hofmann (2014)). However, even during the years 2001-2006 when BOJ adopted QE, it is shown to have signaling effects of lowering expected future path of short-term interest rates and of reducing term premium of interest rates (Baba, *et al*. (2005), Ugai (2007)). Thus the first explanation is more likely.

That said, markets may have reacted in advance of the actual adoption of QQE by expecting the coming drastic monetary easing in line with Abenomics. To check this possibility, the two events are introduced here. The first is the day setting the 2 percent price stability target on January 22, 2013 where both the Government of Japan and the BOJ published the joint statement assuring to coordinate and work together in that the BOJ pursues monetary easing to achieve the price stability target while the Government of Japan manages the flexible fiscal policy and strengthens competitiveness and growth potential of Japanese economy. The second is the day Governor Kuroda’s first general policy speech at the House of Representatives of the Diet on March 4, 2014. According to Graph 7, markets do not extend the easing period longer based on these events. Therefore, as far as the major events in relation to Abenomics are seen, the conclusion of the QQE is not changed.

<Graph 7>

B) Credit easing (targeted asset purchase) channel

The CE in 2010 and the monetary easing right after the Great East Japan Earthquake had characteristics of credit easing policy, and the subsequent monetary easing policies (before adoption of QQE) also had them to some extent. This section mainly focuses on the effect of these policy changes. The impact on JGB yields are shown in Table 4, and that on corporate bond yields by credit ratings in Table 5. To control the situation that credit evaluation of companies is changing faster than the credit ratings, Table 6 shows the result of adjusting their creditworthiness by daily changes in CDS spreads of each rating to compare the changes in yields with the same creditworthiness. Table 6 also shows the impact on the yen/dollar rate.

<Table 4>

<Table 5>

<Table 6>

The results show that the impact of CE and the monetary easing right after the earthquake on yields of JGBs, corporate bonds, and CDS-adjusted corporate bonds are substantially larger than that of subsequent monetary easing policies. F-test is significant at 1 percent level except for low credit rating bonds in which distortional factors for low rating bonds may not be deducted fully. On the other hand, they are not influential in letting the yen/dollar exchange rate depreciate.

However, this result might also include the signaling channel. To exclude the effect of such a channel, the event study is also conducted for the spreads between CDS-adjusted corporate bond yields and JGB yields. Although this treats credit channel in a narrow sense, it can capture the pure effect of credit easing in that the successful credit easing has more influence on the corporate bonds than on the JGBs if the corporate bond markets are dysfunctional. Table 7 shows again that during the period of the CE and the subsequent monetary easing, the credit easing channel works, especially for longer-term yields and for the BBB-rating corporate bonds. While there are a fewer cases that the monetary policy narrows the credit spread, at least a large effect is seen at the monetary easing right after the Great East Japan Earthquake.

<Table 7>

Overall, the results of CE suggest that the malfunctioning of the financial markets continued after the GFC, and that the purchase of a variety of financial assets through the asset purchase program slashed the yields of those assets. There is also a tendency that the degree of lowering the yields of long-term bonds is generally larger than those of shorter-term bonds. This may be because investors who cannot take large risks face more uncertainty about longer future.

When the QQE was adopted, financial markets had already returned to “normal” situation, so that it is not surprising that the impact of QQE through credit easing channel is not extracted here.

C) Portfolio balance channel

The QQE purchased the massive amount of JGBs and risk assets in the already normal financial markets. According to Table 4, 5, and 6, it is clear that the degree of lowering the yields of JGBs and corporate bonds is smaller than that of the CE and the monetary easing right after the earthquake[5]. To be more precisely, the QQE lowers the yield of 10 year JGBs possibly reflecting the fact that the QQE focuses on lengthening the duration of purchased JGBs, and that of 10 year CDS-adjusted corporate bonds less. However, the impacts on the yields of other maturities of JGBs and corporate bonds are not consistent with the portfolio balance channel. All of them suggest that purchasing massive amount of JGBs does not lower the yields of a variety of maturities of corporate bonds. Actually many companies have started to issue the bonds with the lower limit on the interest rates since autumn 2014[6], suggesting that they have behaved to offset the impact of BOJ’s operation to induce investors to purchase them. This may also be consistent with the fact that even at the bank lending market banks generally suffer from squeeze of lending margin and do not lower the lending rates more.

On the other hand, the impact on the exchange rate shows a remarkable contrast with the above yields of financial assets. The QQE has a large impact on depreciating the yen/dollar exchange rate, contrasted with the CE and the monetary easing right after the earthquake that have no such impact. Based on the portfolio-balance channel, if the BOJ’s massive JGB purchases lower their long-term yields, it could prompt investors to take foreign assets, thereby letting the yen depreciate. However, taking into account the above result that the QQE has a smaller impact on lowering yields of many assets than the CE and the subsequent monetary easing policies, it needs to consider why the effect on the exchange rate is so large at the QQE.

There are two hypotheses to explain this. The first hypothesis is the difference of stance between domestic investors and foreign investors towards QQE. There may be the case that domestic investors did not react strongly to the QQE, while foreign investors reacted strongly with expectation that QQE has large effects. In the domestic securities markets domestic investors are dominant players, and in the FOREX markets foreign investors are

---

[5] Because the signaling channel does not work during the QQE period, these results about QQE do not include the signaling channel.

[6] At least 27 companies issued the bonds with the lower limit on the interest rates from October 2014 to April 2015, according to Mizuho Securities.

dominant players and reacted to the QQE. Actually some foreign hedge funds are said to react to the BOJ's easing policies by selling the yen. Fukuda (2014) and Ueda (2013) examine the investor behavior and extract the difference between the behavior of domestic investors and of foreign investors. Following Fukuda (2014), let the accumulated changes in the yen/dollar exchange rate be divided into those at Tokyo daytime and at Tokyo nighttime. Tokyo daytime is defined from 9 am to 5 pm in Tokyo when domestic investors are assumed to play dominantly, whereas Tokyo nighttime is defined from 5 pm in Toyo to 5 pm in New York when foreign investors are assumed to play dominantly. The trading from 5 pm in New York to 9 am in Tokyo is excluded here, because both domestic investors and foreign investors trade during this time zone. Graph 8 clearly shows that the yen/dollar exchange rate depreciated through the trading of Tokyo nighttime[7] during this entire period and especially around the timing of the adoption of the QQE and of the QQE2, not through the trading of Tokyo daytime, thereby suggesting that foreign investors react to these policies more than domestic investors. The reasons behind this asymmetry should be investigated by further analysis.

<Graph 8>

The second one is focusing on the yield differentials between Japan and the US. A major concern here is whether the depreciation of the yen/dollar exchange rate during this period has stronger sensitivity to the yield differentials of longer maturities that the QQE has influence on than those of shorter maturities, and / or owes to the US economic and financial factors as well. To check them, this section conducts simple Fama regression exercise based on Kano and Wada (2015) with modification of periods of samples and subsamples. Let z_t denote the logarithm of the yen/dollar exchange rate at period *t*, and $y_{t,n}$ the JGB yield to maturity *n*, and $y^*_{t,n}$ the US Treasury yield to maturity *n*. The following are the regression specification identical with that of Kano and Wada (2015).

$$z_{t+1} - z_t = \alpha_n + \beta_n\left(y_{t,n} - y^*_{t,n}\right) + \epsilon_{t,n} \tag{2}$$

where α_n is constant, β_n is the Fama coefficient, and $\epsilon_{t,n}$ is an i.i.d. error term.

$$rx_{t+1} = \alpha_n^{rx} + \beta_n^{rx}\left(y_{t,n} - y^*_{t,n}\right) + \epsilon_{t,n}^{rx} \tag{3}$$

where α_n^{rx} is constant, β_n^{rx} is the alternative Fama coefficient with one-period excess currency return $rx_{t+1} \equiv z_{t+1} - z_t - (y_{t,1} - y^*_{t,1})$, and $\epsilon_{t,n}^{rx}$ is an i.i.d. error term.

This section picks up the monthly data from January 2003 to September 2015, and divide the whole period into three phases based upon the difference of economic and financial conditions both in Japan and the US; the first phase is from January 2003 through July 2007, the Goldilocks period, when there were no huge shocks like September 11 attacks nor financial

[7] Note that this analysis does not tell the reason behind such asymmetric behavior.

crisis while the quantitative easing policy was terminated by the BOJ in the middle. The second phase is from August 2007 through November 2012, Lehman shock period, when Lehman shock with Paribas shock as a starting point broke out in September 2008 and LSAPs were eventually introduced by the Fed while the credit easing policies including CE were introduced by the BOJ. The third phase is from December 2012 through September 2015, QQE period in a broad sense, when Abe administration started and disclosed the new macro-policy package, and QQE has been introduced by the BOJ while LSAP 3 was adopted and terminated by the Fed.

Table 8 shows the OLS regression results of Fama coefficients by maturity for the above two specifications. The alternative Fama coefficients show that the movement of the yen/dollar rate has negative correlation with yield differentials of every maturity in the whole period and at shorter maturities in Goldilocks period, but has positive correlations at longer maturities in QQE period which is consistent with the uncovered interest rate parity. There is also a tendency during QQE period that longer the maturities, larger the positive coefficients.

<Table 8>

To interpret the changes in the alternative Fama coefficients, this section introduces the model of Bansal and Shaliastovich (2013) to explain the relation between a nominal exchange rate and a term structure of nominal bond yield differential of two countries. This model is a long-run risk model that permits persistent components of consumption growth rate (real long-run risk) and inflation risk rate (nominal long-run risk) with the correspondent time varying conditional volatilities, based on Kreps and Poteus (1978), and Epstein and Zin (1989). The exchange rate is determined by the difference between the log pricing kernels of the two countries, as described by Backus, Foresi, and Telmer (2001). Now consider two countries in each of the representative agent lives in *n*-finite periods. From this model, Fama coefficients (the unconditional covariance between the depreciation rate of the currency and the yield differential to maturity *n*) can be decomposed into unconditional covariance between the yield differential to the one-period maturity and that to the maturity *n*, and unconditional covariance between the excess currency return and the yield differential to maturity *n*.

$$Cov\left(z_{t+1} - z_t,\ \tilde{y}^{\$}_{t,n}\right) = Cov\left(\tilde{y}^{\$}_{1,n},\ \tilde{y}^{\$}_{t,n}\right) + Cov\left(rx_{t+1},\ \tilde{y}^{\$}_{t,n}\right) \qquad (4)$$

where $Cov\left(\tilde{y}^{\$}_{1,t},\ y^{\$}_{t,n}\right) = \frac{1}{n} B^{\$}_{xc,1} B^{\$}_{xc,n} V\left(\tilde{x}_{c,t}\right) + \frac{1}{n} B^{\$}_{x\pi,1} B^{\$}_{x\pi,n} V\left(\tilde{x}_{\pi,t}\right) + \frac{1}{n} B^{\$}_{sc,1} B^{\$}_{sc,n} V\left(\tilde{\sigma}^2_{xc,t}\right)$

$$+ \frac{1}{n} B^{\$}_{s\pi,1} B^{\$}_{s\pi,n} V\left(\tilde{\sigma}^2_{x\pi,t}\right) \qquad (5)$$

$$Cov(rx_{t+1}, \tilde{y}^{\$}_{t,n}) = \frac{1}{2n}\lambda^2_{sc}B^{\$}_{sc,n}V(\tilde{\sigma}^2_{xc,t}) + \frac{1}{2n}(\lambda^2_{s\pi}B^{\$}_{s\pi,n}V(\tilde{\sigma}^2_{x\pi,t}) \quad (6)$$

where any random variable $\tilde{f}_t$ for the home and foreign countries shows $\tilde{f}_t \equiv f_t - f^*_t$, B and $B^{\$}$ are the sensitivities of real and nominal bond prices to the aggregate risks, and c and π are consumption growth and inflation. x_c and x_π are expected consumption growth and inflation, and sc and $s\pi$ are the real and nominal volatilities. λ_{sc} and $\lambda_{s\pi}$ are market prices of real and nominal volatility risks. σ^2_{xc} and $\sigma^2_{x\pi}$ are unconditional means of the real and nominal volatilities. V is the mathematical conditional variance operator.

According to their long-run risk model, bond yields respond to real uncertainty like consumption volatility negatively because of the flight to quality effect, while they respond to nominal uncertainty like inflation or other nominal volatilities negatively at the short time horizon but positively at the long time horizon because the nominal premium dominates the flight to quality effect. This theory suggests that the alternative Fama coefficients (the unconditional covariance between excess currency return and the yield differential) are negative at least at the short time horizon, which is a necessary condition to explain the violations of the uncovered interest rate parity condition, and these violations become less prominent at longer maturities. In QQE period, the longer the maturities, the wider the yield differentials become (Graph 9). Kano and Wada (2015) conducts the calibration using this model to explain the structural shift from negative coefficients to positive ones after the introduction of Abenomics, and finds that they can replicate the shift up of coefficients by assuming a mitigation of real uncertainty after the Lehman shock and a dominance of nominal uncertainty. The remaining issue is which country's policy has a major impact on the exchange rate. According to the alternative Fama coefficients, the widening of yield differentials of longer maturities such as 10 year yield differential can depreciate the yen/dollar exchange rate more than that of shorter maturities. In this sense the QQE can affect the yen/dollar exchange rate. That said, since the development of yield differentials is dominated by the rise in the long-term yields of the US relative to the decline in that of Japan (Graph 9), it can be conjectured that during the entire period of QQE the depreciation of the yen/dollar exchange rate may be explained by the US factors more than the QQE. This assessment needs detailed analysis about the movement of long-term JGB yields by incorporating the asymmetry of foreign and domestic investors.

<Graph 9>

D) Safety channel

When the safety channel works, it is expected that the JGB yields decline much, while the corporate bond yields does not decline so much. Furthermore, the yields of AA corporate bonds that are to some extent close to safe assets may decline somewhat after adjusting the CDS spreads, while the yields of less creditworthy bonds may decline less.

Since the CE and the monetary easing right after the earthquake did not purchase JGBs massively enough to decrease the amount of JGBs outstanding in the markets, this section focuses on the QQE and extracts the characteristics of its impact from Table 4, 5, 6, and 7. According to those tables, the 10 year long-term yield of JGBs declines, but the yield of CDS-adjusted AA corporate bonds of 10 years declines less, and the yields of other maturities of JGBs and of corporate bonds rather increase. Yield spreads between corporate bonds and JGBs are somewhat expanding.

These relationships seem to correspond more to safety channel than to the portfolio balance channel. However, so far no distinction between portfolio balance channel and safety channel has been made. The existence of safety channel will be examined in more details along with its welfare implication at the next section.

E) Inflation expectation channel

The channel of affecting inflation expectation directly is a marked purpose of the QQE. In addition, aside from actual change in the conduct of monetary policy, establishment of price stability goal and target may also influence it.

The results of the event study from 2010 to 2014 by using the inflation swap rates and the break-even inflation rates (BEIs) of inflation-indexed bonds are shown in Table 9.

<Table 9>

Inflation swap rate shows that the positive effects are shown at many events while BEI shows the positive effects mainly since the monetary easing in December 2012 through the QQE. However, F-test shows 1 percent significance only for the BEI for 10 years where most of events are not covered except for QQE2, suggesting that both QQE and CE do not have significant effects on inflation expectation channel.

It should also be taken into account that BEI is influenced by the liquidity condition of the inflation-indexed bonds in Japan (Kamada and Nakajima (2013)). To avoid the distortion caused by the liquidity condition, this section compares other indexes showing inflation expectation. Those financial indicators are, as Mandel and Barnes (2013) suggests, the weighted average of inflation swap rates or BEIs of the US and the UK adjusted for the expected depreciation of exchange rates. They are equal to the inflation expectation in Japan if purchasing power parity holds. They may be superior to Japan's inflation swap rate and BEI in that the liquidity premiums of those in the US and the UK are more stable than those in Japan. As far as assuming the purchasing power parity, it is unreasonable to use them for calculating the daily changes in inflation expectation. Thus this section uses them as quarterly basis. Although Mandel and Barnes (2013) defines the changes in the expected inflation rates in Japan as the combination of the daily changes in BEI and the daily changes in forward exchange rate, here calculation method is based on the theory of purchasing power parity more formally. As Kamada and Nakajima (2013) suggests, the following equations are assumed to hold.

$$FII = Foreign\ Inflation\ swap\ rate + [{}^{FX\ forward\ spread}/_{spot\ rate}] \tag{7}$$

$$FBI = Foreign\ BEI + [{}^{FX\ forward\ spread}/_{spot\ rate}] \tag{8}$$

where FII is Foreign Inflation-swap implied Index, and FBI is Foreign BEI implied Index. They are calculated as daily basis, and transformed to quarterly data.

Furthermore, perception of the price levels (five years from now) by households conducted by BOJ's Opinion Survey on the General Public's Views and Behavior is also used as a proxy for inflation expectation. This can be transformed to CPI inflation rate by quantifying them with the Carlson-Parkin method suggested by Sekine *et al*. (2008). All those indexes are shown in Graph 10.

<Graph 10>

Graph 10 shows that inflation swap rate and BEI in Japan start rising from 2009 until 2013 and that the inflation swap rate turns to be flat since early 2013. Compared to them, households' inflation expectation, FII, and FBI look different in that their speed in rising from 2009 to 2012 is milder, and look the same in that they have turned to be flat since 2013[8]. Overall, it cannot be denied that inflation expectation increases during the QQE period, but most of them are not accelerated, and none of inflation expectation reaches the 2 percent level.

Comparing these indicators to the yen/dollar exchange rate, they look the same direction except for FY 2014 when consumption tax was introduced (Graph 11). Using OLS to regress inflation swap indicators (5yr, 10yr) on the change in the yen/dollar exchange rate and

[8] Kamada and Nakajima (2013) shows that the expansion of real interest rate differential between Japan and the US contributes largely to the deviation of FBI from BEI.

the dummy for consumption tax hike (April 2014) with the adjustment of serial correlation, the yen/dollar rate is significant at the 1 percent level. Combining this result with that of the event study, it can be conjectured that the depreciation of the yen/dollar exchange rate has positive influence on inflation expectations possibly through, for example, the rise in imported prices.

This section does neither provide rigorous statistical test based on the theoretical model, nor study the other factors like the output gap and recent price setting behavior of corporate behavior. Having said that, these analyses may be consistent with the hypothesis of weak direct impact on inflation expectation. This may support the result of Fujiwara *et al.* (2014) that no sizable difference in perceptions about long-term inflation expectations has been found before and after the introduction of Abenomics[9].

<Graph 11>

F) Summary of the event study

This section examines the effects of QQE in comparison with those of CE and the subsequent easing policies by transmission channels. This event study captures the prompt reactions of the markets after the announcement of the policy change, and concludes the following points:

a) Signaling channel works at the CE that explicitly disclosed the commitment for the future path of interest rates. On the other hand, QQE does not have such an effect. Even if this event analysis broadens the events to those with strong relation to Abenomics, it comes to the same conclusion.
b) During the period when financial markets does not function well (CE and the monetary easing right after the Great East Japan Earthquake), credit easing channel works.
c) Portfolio balance channel at the QQE does not affect the broad range of yields of JGBs and corporate bonds much except for 10 year JGBs, but affects the dollar/yen rate strongly. This asymmetry between JGB markets and exchange rate markets may be explained by the difference of stance between domestic and foreign investors towards the QQE. There is another possibility that the yen's huge depreciation during the entire period of QQE may also be explained by the US economic and financial conditions. These hypotheses need further analysis.
d) The reaction of the yields of JGBs and corporate bonds seems to be consistent with the existence of safety channel. Whether this channel actually works and has side-effects on the

[9] On the other hand, Kaihatsu and Nakajima (2015) argues that Japan's trend inflation shifted after the introduction of the price stability target and the QQE.

welfare of private sector is the next issue to be examined.

e) Inflation expectation channel is weak for both QQE and CE. Although the QQE tries to exert its influence strongly on inflation expectation, there is no clear evidence that QQE has a stronger effect on inflation expectation directly. It can be conjectured that the gradual rise in inflation expectation comes mainly from other channels like the depreciation of the yen.

3. Theoretical model of massive purchase of government bonds

To discuss the impact of a central bank's purchasing massive amount of government bonds on economic welfare, this section provides the theoretical background that government bonds are valued for their own role in facilitating transactions, aside from the money. Especially, based on Krishnamurthy and Vissing-Jorgensen (2012-a) that shows the US Treasuries increasing their market values beyond their state-contingent pecuniary returns, this and the subsequent sections show how the stock amounts of government bonds affect the convenience yield in Japan. If a central bank purchases massive amounts of government bonds that surpass the increase in the new issuance of government bonds, it reduces the net supply of government bonds to the private sector, thereby raising the convenience yield.

According to Woodford (2012), an increase in the convenience yield by making safety assets scarcer through the massive purchase of a central bank would reduce the economic welfare. By reducing the supply of government bonds, the economy will lose the extremely safe and liquid assets. If that policy action cannot stimulate the economy, then it would reduce the welfare (Krishnamurthy and Vissing-Jorgensen (2012-b)). As described at section 1, this contrasts with the credit easing that increases the welfare if the zero interest rate lower bound is binding on the policy rate in the case of financial disturbance (Curdia and Woodford (2009, 2011)).

To see explicitly the effect of a central bank's massive purchase of government bonds on convenience yield, the utility function of a representative agent that includes holding of convenience asset is defined. The utility function combines the credit frictions suggested by Woodford and Curdia (2009, 2011) with the basic money-in-utility formulation of Sidrauski (1967) applied to the convenience benefits from holding government bonds based on Krishnamurthy and Vissing-Jorgensen (2012-a):

$$U_t = E\sum_{t=1}^{\infty} \beta^t U(C_t) \tag{9}$$

$$C_t = c_t(\frac{GDP_t}{Q_t}; \varphi_t) + v(\theta_t^A, GDP_t;\ \xi_t) \tag{10}$$

where C_t is the flow of real consumption per unit of time (c_t) plus flow of services per unit of time (v) from real holdings of convenience assets (θ_t^A). Note that the term GDP shows the income of the representative agent at *t*, and Q_t is the price level at *t*. The model developed here is the representative agent model, and the investment in real assets is omitted. Financial intermediary is not defined here for simplicity because there is no fundamental difference of roles for services from holding convenience assets between financial institutions and households.

The term φ_t shows a measure of inefficiency of the allocation of expenditure owing to imperfect financial intermediation[10], which is treated as an exogenous shock. This was actually seen during the GFC. When the financial intermediation is disrupted, the utility falls. As far as there is inefficiency of the allocation of expenditure owing to imperfect financial intermediation, a room for the credit easing policy by a central bank discussed above to raise the utility exists. This inefficiency will be reduced if the financial intermediation function recovers, thereby increasing the welfare as Curdia and Woodford (2009, 2011) suggests.

On the other hand, v denominates the function that holding more government bonds reduces costs of transaction. θ_t^A generally consists of money, government bonds, and any other privately produced debts that provides services similar to the government bonds. Both money and government bonds have values for their safety and liquidity, and both are believed to secure the nominal value of repayment. ξ_t is a preference shock.

However, investors differentiate the long-term government bonds from money as safe assets because they can store long-term value without fear of capital losses. Greenwood and Vayanos (2010) discusses that investors such as pension funds, insurance companies, and mutual funds have longer time horizons than arbitragers to back long-term nominal obligations. Government bonds have non-zero interest rates, which differs from money of zero interest rate[11]. There are other specific benefits of holding long-term government bonds. As Caballero and Fahri (2013) shows, replacement of long-term government bonds by short-term government

[10] Curdia and Woodford (2009, 2011) shows the aggregated demand for the Dixit-Stiglitz composite goods by assuming the existence of both borrower and savor, denominates a measure of inefficiency by the marginal-utility ratio of borrower and savor, and adds another variables like resources consumed by intermediaries to explain the impact of credit friction on the economy. However, to analyze the function of convenience assets, specific function of financial intermediation is not required. Thus, the representative agent model assumes that φ_t is given. Private debt is zero on a net basis, and so this is not the budget constraint. If φ_t were modelled rigorously, the general equilibrium model could be derived. However, since the analysis here focuses on safety asset, establishing Dixit-Stiglitz type model is beyond the purpose of this section.

[11] Note that if the yields of long-term government bonds are getting closer to zero, this benefit will also be reduced.

bills would reduce the supply of safe assets because an expansion of the long-term government bonds would create a hedge that transforms some risky private assets into safe assets. Short-term government bills would not have such hedging effect. Furthermore, Greenwood, Hanson, and Stein (2013) suggests that a shift towards short-term government bills is likely to crowd out short-term borrowing by financial intermediaries because their short-term bills are much closer substitutes for government bills, and they cannot create long-term safety assets like government bonds. Thus longer-term government bonds have higher convenience yields.

A main benefit of holding government bonds is that they can be utilized for safe collateral for financial transactions such as repos, and so on. When there exists the presence of limited pledgeability and agency problems, companies may not be able to transfer enough wealth across periods to finance later investment since private agents cannot commit their future endowments, suggesting that private markets have limited capacity for inter-temporal transfers. Since the existence of Knightian agents that are infinitely risk averse prompts the excess demand for safe assets while the amount of traded pledge is limited, there is a role for government bonds (Caballero and Fahri (2013)). Government bonds can be used to transfer wealth inter-temporally because the government can tax and can commit funds for private agents (Holmström and Tirole (1998)). As Gorton and Ordoñez (2013) shows, especially when market participants are conscious of the tail risk like crisis, since agents cannot verify final output, collateral is needed to back companies' borrowing. According to them, there is a complementarity between government bonds and private collaterals. When there is a possibility of crisis, lenders have incentives to acquire information about the value of the privately-produced collateral assets and lend only to companies with high value of collateral assets. However, as Saint-Paul (2005) suggests, when the borrowers have government bonds, the need for monitoring is reduced. By supplying the government bonds, the government can support the loans by reducing the incentive of lenders to acquire information about the quality of private collateral, thus borrowers need not scale back the size of borrowing. Therefore, a small amount of government bonds can have large effects on the consumption and investment. Actually repo transactions decreased after the GFC, but have recently increased globally. In Japan more than 90 percent of collaterals for repo transactions are JGBs (Ono *et al.* (2015)). 5- through 10-year JGBs are used mostly as collaterals rather than shorter maturity JGBs, and JGBs of more than 10-year remaining maturities are said by market participants to be gaining the share after the GFC (Graph 12). Seeing the spreads of JGB repo rates and interbank interest rates (Graph 13), the trend has clearly gone to the negative area since 2014, suggesting a squeeze of JGBs as collateral.

<Graph 12>

<Graph 13>

On the other hand, if money were provided beyond the satiation level by quantitative easing policy, ample additional provision of money itself would not affect the economy anymore. In Japan, since 1995 short-term interest rates have been almost zero, the economy has faced the zero interest rate lower bound, and the additional utility of holding money as convenience assets is expected to be zero. The appropriateness of this assumption will be checked at the next section. Under the condition of short-term interest rates facing zero lower bound, it is reasonable to simplify the assumption that θ_t^A consists only of government bonds (θ_t^G) and other private-sector assets (θ_t^P) that provides services similar to government bonds as follows. Note that the framework of the following is the same as that of Krishnamurthy and Vissing-Jorgensen (2012-a), and this section introduces its essence for discussion of the empirical analysis in Japan at the next section.

$$\theta_t^A = \theta_t^G + k^P \theta_t^P \tag{11}$$

where k^P measures the convenience services provided by the private-sector assets relative to government bonds. The convenience yields on long-term government bonds are different from those of short-term government bills. The role of short-term government bills is similar to money in that their maturities are short term and that they are complete alternatives to money at the zero short-term interest rate conditions.

The convenience function is assumed to be homogeneous of degree one in GDP, and θ_t^A.

$$v(\theta_t^A, GDP_t; \xi_t) \equiv v(\frac{\theta_t^A}{GDP_t};\ \xi_t)GDP_t \tag{12}$$

It is assumed that convenience function is increasing in $\frac{\theta_t^A}{GDP_t}$, but the marginal convenience benefit is decreasing in $\frac{\theta_t^A}{GDP_t}$, that is, $\lim_{\frac{\theta_t^A}{GDP_t}\to\infty} v'\left(\frac{\theta_t^A}{GDP_t};\xi_t\right) = 0$.

Now maximize the welfare (equation (9)) subject to the following budget constraint;

$$Q_t c_t + P_t^G \frac{Q_t}{P_t^G}\theta_t^G + P_t^P \frac{Q_t}{P_t^P}\theta_t^P = P_t^G \frac{Q_{t-1}}{P_{t-1}^G}\theta_{t-1}^G + P_t^P \frac{Q_{t-1}}{P_{t-1}^P}\theta_{t-1}^P + Q_t y_t \tag{13}$$

where P_t^G is the nominal price of a zero-coupon government bond, and P_t^P is the nominal price of a zero-coupon corporate bond. This equation shows that current nominal consumption plus nominal purchase of assets are equal to nominal return from the past investment in bonds plus nominal income.

Then from the first order condition for government bond holdings, government bond price and corporate bond price are calculated taking into account the convenience yield and default risk (following Duffie-Singleton (1999) formulation), and the yield spread between corporate bond and government bond at τ-period can be derived as follows (See the technical appendix for details);

$$S_{t,\tau} = i_{t,\tau}^{P} - i_{t,\tau}^{G}$$

$$= \sum_{j=t}^{t+\tau-1} \frac{1}{\tau} E_t[v'(\frac{\theta_j^A}{GDP_j};\xi_j)] + \sum_{j=t}^{t+\tau-1} \frac{1}{\tau} E_t[\rho_j L_j] - \sum_{j=t}^{t+\tau-1} \frac{1}{\tau} Cov_t(m_{j+1}, R_{j+1}) \quad (14)$$

where $S_{t,\tau}$ is the τ-period spread between corporate bonds and government bonds, $i_{t,\tau}^{P}$ is τ-period yields of corporate bonds, $i_{t,\tau}^{G}$ is τ-period yields of government bonds, ρ_j is the default probability of corporate bonds, L_j denotes adapted process to simplify the risk-neutral expected recovery in the event of default at $j+1$ (see the technical appendix equation (a-15)), $m_{j+1}$is the log pricing kernel, and $R_{j+1}$is the one-period excess return of corporate bonds over government bonds. Assume $v'' < 0$, then $S_{t,\tau}$ decreases in increase in $(\theta_t^G + k^P\theta_t^P)/GDP_t$. If θ_t^A/GDP_t decreases with decrease in θ_t^G/GDP_t by reduced supply of government bonds, $S_{t,\tau}$ will expand. This would reduce the welfare as the constraint of holding θ_t^G becomes strengthened. Therefore, the yield spread can be interpreted to change through the three factors: (i) the expected average convenience yield of holding a government bond over the next τ-periods, (ii) the expected average amount of default, and (iii) a risk premium that depends on the covariance between the pricing kernel and the excess return on corporate bonds over government bonds.

4. Evidence from QQE

A) Impact of squeeze in demand-supply conditions of government bonds (linear)

Based on the above model, regression form to explain the impact of squeeze in demand and supply condition of government bonds is as follows. To simplify the model, the current figures are used for public debt (consolidated government base) of the above (i) of the equation (14). Default risk factor corresponding to (ii) and (iii) is used to control the regression equation[12].

[12] Krishnamurthy and Vissing-Jorgensen (2012) uses a slope of Treasury yield curve as a proxy of business cycles for (iii). However, a default risk factor also reflects the changes in business cycles,

$$Spread(Corporate\ Bond - Government\ Bond)_t =$$

$$a + b\ ln\frac{Public\ Debt_t}{GDP_t} + c\ Default\ Risk_t + error_t \qquad (15)$$

where government bond covers 10 year JGBs and corporate bond covers 10 year AA-rated corporate bonds. Public debt covers the outstanding amount of JGBs and of Fiscal Investment Loan Program bonds[13] minus the amount of JGBs held by the BOJ, which are held and used by private sector as safe assets. Japanese government bills are excluded from this variable. Median expected default frequency (EDF)[14] of Moody's Analytics is used for indicating default risk because changes in ratings have substantial time lags and do not reflect subtle changes in default risk. EDF captures the default risk both at the financial crisis in Japan during late 1990s and the GFC and at each phase of business cycles. Because EDF is based on option pricing, the key factor is stock return volatility, but superior to the volatility of stock indicators in that EDF examines the default points of individual companies. Sample period is from 4Q 1997 through 4Q 2014. Because Japan has faced zero interest rate lower bound during those periods, there is no need to control the zero interest lower bound in the regression model. The regression is estimated using OLS estimation method. In recent Japan the changes in ratings and default risk inherent in specific companies have also affected the corporate bond yields, and thus dummy variable for the Great East Japan Earthquake is added. By checking Breusch-Godfrey serial correlation LM test, error terms are adjusted with AR(1) and AR(2).

According to this hypothesis of convenience yield, if the BOJ purchases massive amount of government bonds, the spread between AA corporate bond yield and government bond yield will expand. This hypothesis suggests that convenience yield is expanding as public debt/GDP decreases. Table 10 shows the regression results.

<Table 10>

The regression result satisfies the theoretical signs of all variables, although the explanatory power of the JGBs is not strong. This result implies a decreasing trend of increase in the JGB-to-GDP ratio on yield spreads, suggesting the increasing trend of convenience yield component. BOJ's massive JGB purchases would increase the yield spreads and would not

---

and thus putting both into the same equation may induce the multicollinearity of this regression. Thus this section avoids using a business cycle factor in addition to the default risk factor. In addition, since Japan has faced the zero interest lower bound for a long time, the slope of JGBs is almost equal to the long-term yield that BOJ tries to suppress.

[13] Characteristics of FILP bonds are the same as Japanese government bonds.

[14] This EDF covers almost 3,200 firms in Japan.

depress the yields of corporate bonds. This is consistent with the result of the event study of the former section that only the 10 year yield of JGBs is lowered without arbitrage transaction with JGBs of other maturities, and that the yield spreads are somewhat expanding. That said, since the explanatory power of the JGBs is not strong, the function might be nonlinear. This hypothesis will be checked at the next section.

In addition, it is important to check the robustness of whether the role of JGBs to provide safety assets is actually different from the role of money as the theory suggests. Then the monetary base (*m*) is added to equation (10), and then to the above regression form (15).

$$C_t = c_t(\frac{GDP_t}{Q_t}; \varphi_t) + v(\frac{m_t + \theta_t^A}{GDP_t};\ \xi_t)GDP_t \qquad (10')$$

$$Spread(Corporate\ Bond - Government\ Bond)_t =$$
$$a + b_1\, ln\frac{Public\ Debt_t}{GDP_t} + b_2 ln\frac{Monetary\ Base_t}{GDP_t} + c\ Default\ Risk_t + error_t \qquad (15')$$

Table 11 confirms that monetary base does not have the explanatory power as that of the JGBs and other variables keep almost the same coefficients, suggesting that the monetary base is not priced.

<Table 11>

B) Threshold of the convenience yield (nonlinear)

This section treats the nonlinear property between the spread and the JGB-to-GDP ratio by applying Krishnamurthy and Vissing-Jorgensen (2012-a). As far as seeing the Graph 4, the relationship between the spread and the JGB-to-GDP ratio seems to be asymptote. The theoretical background is that convenience yield will eventually reach at the satiation level where the amounts of the safety assets are so large that there is no additional convenience yield for holding the JGBs. This seems to be an analogy to the function of the monetary base though the function of the JGBs is different from the money as described earlier. This section tries to quantify the asymptote between them and the satiation level. Assuming that there is some threshold of demanding safety assets, this section models the convenience yield with a function that is piecewise linear in government bond supply as follows.

$$Spread(Corporate\ Bond - Government\ Bond)_t =$$

$$a + b_1 \max\left[b_2 - ln\left(\frac{Public\ Debt_t}{GDP}\right),\ 0\right] + c\ Default\ Risk_t + error_t \quad (16)$$

If $b_2 < ln(\frac{Public\ Debt_t}{GDP})$, there is no value for convenience yields. The regression is estimated by using the nonlinear least squares with robust standard errors to take into account heteroskedasticity. Results are shown in Table 12, using the AR(1) and AR(2) to adjust error terms, which is the same as the regression of the log function.

<Table 12>

Table 12 shows that this regression is significant in all coefficients, and the coefficient of public debt is more significant than that of the symmetric log function. b_2 is -0.299, implying that the value of convenience goes to zero at the 74 percent level of the JGB-to-GDP ratio. Seeing the Graph 4, it is reasonable to specify that the curve is refracted around this level, with taking confidence interval of this estimation into account. That said, this level is quite smaller than that of the US, which is inferred from the analysis of Krishnamurthy and Vissing-Jorgensen (2012-a) to be around 170 to 180 percent. The current debt amounts in Japan far exceed the threshold level. To be more precisely, there are some phases showing that the yield spread declines somewhat compared to this satiation point, but at least there is no phase that suggests the large decline in the spread. Since the debt amount per GDP of Japanese government is the biggest in the world, as far as such threshold is assumed, even the BOJ’s massive JGB purchases have not induced the scarcity of the safety assets in the markets so far in general.

In addition, conducting also the same nonlinear least squares regression analysis for the monetary base instead of the JGBs as a robustness check, it is assured that the monetary base does not have such an explanatory power as the JGBs (Table 13).

<Table 13>

How should this satiation point be evaluated? Suppose the amount of JGB issuance increases from fiscal year 2015 through 2018 at the same pace as that of fiscal year 2014, and GDP growth will follow the median forecast of real GDP and CPI by the majority of Policy Board Members of the BOJ at the July 2015 statement on monetary policy (except for fiscal year 2018 where the forecast is regarded the same as that of 2017). Then JGB-to-GDP ratio would decline to 90 percent level by the end of fiscal year 2018. Since Japanese government is currently trying to reduce the issue amount of JGBs, this ratio would actually decline more. Still, this simulation suggests that BOJ would probably not lower the economic welfare from the perspective of convenience yield at least during fiscal year 2015 - 2017.

Having said that, there are three reservations that suggest that the BOJ might face the situation that lowers the economic welfare of convenience yield, and all of them are subject to further research. First, this analysis of the demands for safe assets does not take into account fully the recent increase in the demand in two ways: i) Since the GFC, market participants have paid much attention to credit risks concerning the money market transactions, thereby expanding the collateralized financial transactions while reducing the uncollateralized financial transactions as a trend (Graph 14). They cannot ignore the tail risk of financial turbulence anymore. These transactions are expanding not only for domestic financial institutions and investors, but also for foreign investors.

<Graph 14>

ii) Global financial regulations have also been paying much attention to the funding liquidity risks. Basel III introduced from 2015 the Liquidity Coverage Ratio (LCR) that ensures that a bank has an adequate stock of unencumbered high-quality liquid assets, where Level 1 assets are limited to cash equivalent assets and marketable and safe securities like government bonds. As the global regulations emphasize the importance of banks holding the liquid and safe assets, the demands for the government bonds increase. Furthermore, according to CGFS (2015), longer-term repos and subsequently longer-term government bonds are and will be more favorable for banks because LCR counts total cash outflow over the next 30 calendar days and because Net Stable Funding Ratio (requirement of maintaining a stable funding profile) will regard funding with maturities over six months with all types of counterparties as available amount of stable funding from 2018.

To quantify this current change in demands for safe assets, Arslanalp and Botman (2015) shows an example of the limit that BOJ could reach in purchasing JGBs under current policies from major investors. Most of JGBs are now held in Japan’s financial institutions, and domestically licensed banks have reduced their JGB holding since 2012 (Graph 15). On the other hand, GPIF, the largest public pension funds, announced the new portfolio allocation ratios that lower the share of domestic bonds, consistent with other major countries, to increase return on assets while reducing the portfolio of JGBs. Insurance companies have gradually raised the foreign securities holdings while maintaining a strong bias towards holding JGBs under the constraint of the asset-liability management (Table 14). They assume that other public and private pension funds would follow the strategy of GPIF, and that insurance companies would raise the share of holding foreign securities to the level consistent with the practices seen in major countries. Then they calculate the downside scenario by assuming that banks would decrease the amount of holding JGBs to 10 percent of total assets that is the lowest since 2003 but the higher end of the sovereign bond holdings by banks in other G7 countries, by taking into account higher demand under Basel III. According to them, the BOJ may reach the point of tapering its JGB purchases by the end of 2016. On the contrary, if banks would decline the amount of JGB holdings to 5 percent that is almost the minimum level before 1998 and the lower end of the sovereign bond holding of banks in other G7 countries, it may reach the point by the end of 2018. This simulation does not show theoretical background and has a lot of assumptions that can be changed. That said, it still could be a starting point of discussion to think how the timing where the BOJ's massive JGB purchases reach the point of lessening the economic welfare would change, depending on the effect of recent strengthening of global financial regulation.

<Graph 15>

<Table 14>

Second, the theoretical model of the satiation point of public debt is originally the τ-period expectation. Because the BOJ purchases JGBs with a fixed speed, market participants can anticipate the future shortage of JGBs in advance[15]. This may shorten the period that JGBs come to have a convenience yield.

Third reservation is that since the BOJ is acting so dominant a player of JGB transactions (Graph 3), it might still induce shortage of safe assets partially, due to a lack of mechanism to adjust imbalance of safe asset holdings by market participants. In this case the squeeze of net flow of JGB issuance, not that of net stock of JGB issuance, might induce the shortage of safe assets for specific purposes, such as collaterals of repo transactions (Graph 13). Economic welfare for them who do not have enough safe assets could be reduced.

5. Conclusion

This paper has examined the transmission channels of the QQE by checking the reaction of various financial markets to think of its effectiveness, and has considered the welfare

[15] For example, the article of Financial Times (2015) starts to treat the future limits on large-scale asset purchases by the BOJ.

implications of the drastic market operations purchasing huge amount of safe assets to think of the potential side-effects.

The first principal contribution of this paper is to compare the effects of the QQE (and so called “QQE2”) with that of the CE to grasp the effective transmission channels. According to the event study, signaling channel, the credit easing channel and its permeation through other yields function more with the CE than those with the QQE. In contrast, depreciation of foreign exchange rate in the context of portfolio balance functions quite strongly with the QQE. On the other hand, though QQE tries to affect the inflation expectation directly, the direct effect so far has not been large to the extent that the results of this event study show. Bernanke (2014) discusses that the BOJ’s commitment can be regarded as credible because of support by the government, consistency of the target with an international norm, and no important cost of the commitment to raise inflation expectation. Hausman and Wieland (2015) tries to explain the weakness of rise in inflation expectation by the lack of credibility, but cannot specify the sources. This paper does not discuss the cause, but weak direct inflation expectation channel suggests that at least clear transmission channels are needed for the credibility of monetary policy to function in Japan.

There remains an issue to be examined more rigorously why the QQE affects the foreign exchange rate exclusively without lowering clearly the yields of bonds. Analysis here and various other studies suggest that foreign investors may be the main driving force to move the yen/dollar exchange rate reacting to QQE, and that during the entire period of QQE changes in the US economic and financial conditions may also move it. Such a large depreciation of the yen may result in raising inflation gradually possibly through, for example, the rise in import prices and tightening output gap, despite the lack of strong direct inflation expectation channel.

The most crucial characteristic of the QQE is to try to maximize the potential effects of the easing policy by doubling and tripling the purchases of JGBs and then monetary base proportionally to affect the inflation expectation. The amount of JGB purchases by the BOJ surpasses that of JGB issuance, resulting in reducing the outstanding amount of JGBs in the markets. The second principal contribution of this paper is to consider the effect of such operations on the economic welfare. The results depend on whether asymptote property of convenience yield exists or not, but as the size of the Japan’s public debt outstanding (per GDP) is the largest in the world, at least severe scarcity situations of JGBs as safe assets are avoided.

Further studies are needed to assess the challenges that the outcome of this analysis raises as follows. First, the above event study shows no clear evidence that the decline in the yield of long-maturity JGBs induced by the QQE permeates the yields of corporate bonds. Further examination is needed whether the scarcity of JGBs is not the challenge now in Japan even taking into account the globally strengthened sensitivity to credit risks in the money markets and regulatory demands for safe assets, market expectation for future path of the amount of safe assets, and the government plan to consolidate the public debts. This study will especially be strongly related to a case where the BOJ has to expand the monetary easing more, and the implication for scarcity of safe assets in case of further massive purchases of JGBs should be examined.

Lastly, while this paper focuses on the impact of massive safe-asset purchases by the BOJ from an asset holder side, it may also be worth examining the possibility of turning the safe assets into risky assets at the exit phase of the QQE from a debt issuer side. The massive JGB purchases by the BOJ shorten the debt maturities of the consolidated government balance sheet, thereby making them more sensitive to changes in the yields as a whole. If the inflation rate is coming to be closer to stable 2 percent and the BOJ decides to terminate the QQE, the yields would go up to the level consistent with the 2 percent inflation expectation, potential economic growth rate, and uncertainty about Japan’s economy and government debt. Even if the BOJ continues the QQE further to constrain such jump, further depreciation of the yen and inflation may emerge and eventually raise the yields. Therefore, checking the consistency of the rise in yields with the sustainability of the public debt would be one of the remaining important areas to study. This aspect is beyond the issue of scarcity of safety assets.

Technical Appendix

This appendix shows how to derive the regression form (equation (14)) to explain the impact of squeeze of safety assets from the perspective of the maximization of utility (equation (9)). Although the entire framework is slightly different, the following calculation process is the same as and is quoted from Krishnamurthy and Vissing-Jorgensen (2012-a) with some additional explanation for deepening the understanding of this model.

The budget constraint of equation (13) at the Section 3 can be rewritten as real-based budget constraint as follows;

$$c_t + \theta_t^G + \theta_t^P = \frac{P_t^G}{Q_t}\frac{Q_{t-1}}{P_{t-1}^G}\theta_{t-1}^G + \frac{P_t^P}{Q_t}\frac{Q_{t-1}}{P_{t-1}^P}\theta_{t-1}^P + y_t \qquad \text{(a-1)}$$

The intuition of equation (a-1) is that, for example, the nominal capital gain of government bond is given by $\frac{P_t^G}{P_{t-1}^G}$, while inflation is given by $\frac{Q_t}{Q_{t-1}}$ and that the real return of the government bond is given by $\frac{P_t^G/P_{t-1}^G}{Q_t/Q_{t-1}} = \frac{P_t^G}{Q_t}\frac{Q_{t-1}}{P_{t-1}^G}$, which is shown at the right hand side of equation (a-1). The real return of private-sector assets of the right hand side is derived similarly. Then define the real cash balance (a_t) as the right hand side of equation (a-1);

$$a_t \equiv \frac{P_t^G}{Q_t}\frac{Q_{t-1}}{P_{t-1}^G}\theta_{t-1}^G + \frac{P_t^P}{Q_t}\frac{Q_{t-1}}{P_{t-1}^P}\theta_{t-1}^P + y_t \qquad \text{(a-2)}$$

Then the budget constraint (a-1) is rewritten as follows; (a-3)

$$c_t + \theta_t^G + \theta_t^P = a_t$$

where a_t evolves according to;

$$a_{t+1} = \frac{P_{t+1}^G}{Q_{t+1}}\frac{Q_t}{P_t^G}\theta_t^G + \frac{P_{t+1}^P}{Q_{t+1}}\frac{Q_t}{P_t^P}\theta_t^P + y_{t+1} \qquad \text{(a-4)}$$

Therefore, the maximization problem can be written as

$$max\ E\sum_{t=1}^{\infty}\beta^t U(C_t)$$

subject to (a-3) and (a-4).

To solve this problem, define the value function $W(a_t)$ associated with this maximization problem as;

$$W(a_t) = U(C_t) + \beta E_t W(a_{t+1}) = \mathrm{U}\left(c_t(GDP_t; \varphi_t) + v(\theta_t^A, GDP_t; \xi_t)\right)$$

$$+\beta E_t W(\frac{P_{t+1}^G}{Q_{t+1}} \frac{Q_t}{P_t^G} \theta_t^G + \frac{P_{t+1}^P}{Q_{t+1}} \frac{Q_t}{P_t^P} \theta_t^P + y_{t+1})$$

subject to (a-4).

The Lagrangian is;

$$L = \mathrm{U}\left(c_t(GDP_t; \varphi_t) + v(\theta_t^A, GDP_t; \xi_t)\right) + \beta E_t W\left(\frac{P_{t+1}^G}{Q_{t+1}} \frac{Q_t}{P_t^G} \theta_t^G + \frac{P_{t+1}^P}{Q_{t+1}} \frac{Q_t}{P_t^P} \theta_t^P + y_{t+1}\right)$$

$$-\lambda[c_t + \theta_t^G + \theta_t^P - a_t]$$

Therefore, the first order condition is given by;

with respect to c_t, $U'(C_t) = \lambda$ (a-5)

with respect to θ_t^G, $U'(C_t)v' + \beta E_t\left[W'(a_{t+1})\frac{P_{t+1}^G}{Q_{t+1}}\frac{Q_t}{P_t^G}\right] = \lambda$ (a-6)

with respect to θ_t^P, $U'(C_t)v'k^P + \beta E_t\left[W'(a_{t+1})\frac{P_{t+1}^P}{Q_{t+1}}\frac{Q_t}{P_t^P}\right] = \lambda$ (a-7)

From the envelop theorem,

$$W'(a_t) = U'(C_{t+1}) \qquad \text{(a-8)}$$

Then, the following equation is derived;

$$-U'(C_t) + \beta E_t\left[U'(C_{t+1})\frac{P_{t+1}^G}{Q_{t+1}}\frac{Q_t}{P_t^G}\right] + U'(C_t)v' = 0 \qquad \text{(a-9)}$$

Or equivalently,

$$-\frac{P_t^G}{Q_t}U'(C_t) + \beta E_t\left[U'(C_{t+1})\frac{P_{t+1}^G}{Q_{t+1}}\right] + \frac{P_t^G}{Q_t}U'(C_t)v' = 0$$

Then, define the pricing kernel for those assets as;

$$M_{t+1} = \beta\frac{U'(C_{t+1})}{U'(C_t)}\frac{Q_t}{Q_{t+1}} \qquad \text{(a-10)}$$

Therefore, government bond price ("Convenience" asset price) can be expressed as;

$$P_t^G = E_t\left[M_{t+1}P_{t+1}^G\right] + P_t^G v'$$

$$P_t^G = \frac{E_t[M_{t+1}P_{t+1}^G]}{1-v\prime} \quad \text{(a-11)}$$

Define the τ-period yields of government bonds as;

$$i_{t,\tau}^G = -\frac{1}{\tau} lnP_t^G \quad \text{(a-12)}$$

Rewrite (a-11) by using the approximation that $1 - v' \approx -e^{v'}$, then the return from t to t+1 of government bonds satisfies;

$$1 = e^{v'} E_t\left[M_{t+1}\frac{P_{t+1}^G}{P_t^G}\right] = E_t[M_{t+1}e^{-(\tau-1)i_{t+1,\tau-1}^G + \tau i_{t,\tau}^G + v\prime}] \quad \text{(a-13)}$$

Furthermore, denote ρ_t as the default probability of corporate bonds at the next period and D_t as the loss amount at the time of default, then corporate bond price can be described as;

$$P_t^P = \rho_t E_t^D[M_{t+1}(1 - D_{t+1})] + (1 - \rho_t)E_t^N[M_{t+1}P_{t+1}^P] \quad \text{(a-14)}$$

where E^D is expectation conditional on default, while E^N is expectation conditional on non default.

Using the assumption of recovery of market value (RMV) by Duffie and Singleton (1999), the expected present value of corporate bond prices in default can be expressed as;

$$E_t^D[M_{t+1}(1 - D_{t+1})] = E_t[M_{t+1}P_{t+1}^P](1 - L_t) \quad \text{(a-15)}$$

where RMV assumes the risk-neutral expected recovery value of the bond at *t* to be a fraction of the risk-neutral expected survival-contingent market value at *t*+1 in the event of default at *t*+1. Given the assumption that the default event is nonsystematic, the conditional expectation on default can be transformed into unconditional expectation. L_t denotes some adapted process, bounded by 1.

Then, the expected present value of corporate bond prices can be expressed as;

$$P_t^P = [\rho_t(1 - L_t) + (1 - \rho_t)]E_t[M_{t+1}P_{t+1}^P] \approx e^{-\rho_t L_t}E_t[M_{t+1}P_{t+1}^P] \quad \text{(a-16)}$$

Define the τ-period yields of corporate bonds as;

$$i_{t,\tau}^P = -\frac{1}{\tau} lnP_t^P \quad \text{(a-17)}$$

Then, the return from t to t+1 on holding corporate bonds is as follows by rewriting (a-16) like (a-13);

$$1 = e^{-\rho_t L_t} E_t\left[M_{t+1}\frac{P_{t+1}^P}{P_t^P}\right] = E_t[M_{t+1}e^{-(\tau-1)i_{t+1,\tau-1}^P+\tau i_{t,\tau}^P-\rho_t L_t} \tag{a-18}$$

Next, define the τ-period spread between those bonds as;

$$S_{t,\tau} = i_{t,\tau}^P - i_{t,\tau}^G \tag{a-19}$$

The one-period excess return on corporate bonds over government bonds is;

$$R_{t+1} = \frac{P_{t+1}^P}{P_t^P} - \frac{P_{t+1}^G}{P_t^G} \approx -(\tau-1)S_{t+1,\tau-1} + \tau S_{t,\tau} \tag{a-20}$$

Assume that $m_{t+1}(= lnM_{t+1})$ and all interest rates are normally distributed, and that innovation in both corporate bonds and government bonds have approximately the same variance. Then subtract (a-13) from (a-18) and make the approximation. Then yield spread between corporate bond and government bond at τ-period can be derived.

$$0 = \frac{1}{\tau}[-\rho_t L_t - v'] - \frac{\tau-1}{\tau}E_t\left[S_{t+1,\tau-1}\right] + S_{t,\tau} - \frac{1}{\tau}Cov_t[m_{t+1},(\tau-1)S_{t+1,\tau-1} - \tau S_{t,\tau}] \tag{a-21}$$

Solving (a-21) recursively for $S_{t,\tau}$, the following equation is derived;

$$S_{t,\tau} = \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}E_t[v'(\frac{\theta_j^A}{GDP_j};\xi_j)] + \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}E_t\left[\rho_j L_j\right] - \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}Cov_t(m_{j+1},R_{j+1}) \tag{a-22}$$

Assume $v''(\cdot) < 0$, then $S_{t,\tau}$ decreases in increase in $(\theta_t^G + k^P\theta_t^P)/GDP_t$. If θ_t^A/GDP_t decreases with decrease in θ_t^G/GDP_t by reduced supply of government bonds, $S_{t,\tau}$ will expand.

References

Arslanalp, S., and D. Botman, "Portfolio Rebalancing in Japan: Constraints and Implications for Quantitative Easing," IMF Working Paper, WP/15/186, 2015.

Baba, N., S. Nishioka, N. Oda, M. Shirakawa, K. Ueda, and H. Ugai, "Japan's Deflation, Problems in the Financial System and Monetary Policy," *Monetary and Economic Studies*, Vol. 23, No. 1, Institute for Monetary and Economic Studies, Bank of Japan, 2005, pp. 47–111.

Backus, D., Foresi, S., and C. Telmer, "Affine Term Structure Models and the Forward Premium Anomaly," *Journal of Finance*, Vol. 56, No. 1, February 2001, pp. 279-304.

Backus, D., Gavazzoni, F., Telmer, C., and S. Zin, "Monetary Policy and the Uncovered Interest Rate Policy Puzzle," Working Paper, 2013.

Bank of Japan, "Outlook for Economic Activity and Prices," April, 2015.

Bansal, R., and I. Shaliastovich, "A Long-Run Risks Explanation of Predictability Puzzles in Bond and Currency Markets," *Review of Financial Studies*, Vol. 26, No. 1, 2013, pp. 1-33.

Basel Committee on Banking Supervision, "Basel III: International framework for liquidity risk measurement, standards and monitoring," Bank for International Settlements, 2010.

Basel Committee on Banking Supervision, "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools," Bank for International Settlements, 2013.

Basel Committee on Banking Supervision, "Basel III: the net stable funding ratio," Bank for International Settlements, 2014.

Bernanke, B., "Comment on 'Abenomics: Preliminary Analysis and Outlook,'" at the Brookings Papers on Economic Activity / Spring 2014 Conference, 2014.

Benigno, P., and M. Woodford, "Inflation Stabilization And Welfare: The Case Of A Distorted Steady State," *Journal of the European Economic Association*, 3, 2005, pp. 1185-1236.

Caballero, G., "On the Macroeconomics of Asset Shortages," In The Role of Money: Money and Monetary Policy in the Twenty-First Century The Fourth European Central Banking Conference 9-10 November, Andreas Beyer and Lucrezia Reichlin, editors, 2006, pp. 272-283.

Caballero, R., and E. Fahri, "A Model of the Safe Asset Mechanism (SAM): Safety Traps and Economic Policy," Working Paper, Harvard University, 2013.

Chalmers, J., "Default Risk Cannot Explain the Muni Puzzle: Evidence from Municipal Bonds That Are Secured by U.S. Treasury Obligations," *the Review of Financial Studies*, Vol. 11, No. 2 (Summer), 1998, pp. 281-308.

Committee on the Global Financial System Markets Committee, "Regulatory change and monetary policy," CGFS Papers No. 54, 2015.

Culbertson, J., "The Term Structure of Interest Rates," *Quarterly Journal of Economics*, Vol. 71, No. 4, 1957, pp. 485-517.

Curdia, V. and M. Woodford, "Credit Frictions and Optimal Monetary Policy," BIS Working

Papers No. 278, 2009.

Curdia, V. and M. Woodford, “The Central-Bank Balance Sheet as an Instrument of Monetary Policy,” *Journal of Monetary Economics,* vol. 58(1), 2011, pp. 54-79.

Dornbusch, R., “Expectations and Exchange Rate Dynamics,” *Journal of Political Economy,* Vol. 67 (5), 1976, pp. 1161-76.

Duffie, D., and K. Singleton, “Modelling Term Structures of Defaultable Bonds,” The Review of Financial Studies, Vol. 12, Issue 4, 1999, pp. 687-720.

Eggertsson, G., and M. Woodford, “The Zero Bound on Interest Rates and Optimal Monetary Policy,” *Brookings Papers in Economic Activity,* 2003:1, 2003, pp. 139-211.

Epstein, L., and S. Zin, “Substitution, risk aversion and the temporal behavior of consumption and asset returns: A theoretical framework,” *Econometrica*, Vol. 57, Issue 4, 1989, pp. 937-969.

Filardo A., and B. Hofmann, “Forward Guidance at the Zero Lower Bound,” BIS Quarterly Review, March 2014.

Fleckenstein, M., Longstaff, F., and H. Lustig, “The TIPS-Treasury Bond Puzzle,” *the Journal of Finance*, Vol. LXIX, No. 5, 2014.

Fujiwara, I., Nakazono, Y., and K. Ueda, “Policy Regime Change against Chronic Deflation? Policy option under a long-term liquidity trap,” RIETI Discussion Paper Series, 14-E-019, 2014.

Fukuda, S., “Abenomics: Why was it so successful in changing market expectations?,” Working Paper, 2014.

Fukunaga, I., Kato, N., and J. Koeda, “Maturity Structure and Supply Factors in Japanese Government Bond Markets,” Working Paper presented at the BOJ-IMES Conference, 2015.

Gagnon, J., Raskin, M., Ramache, J., and B. Sack, “The Financial Market Effects of the Federal Reserve’s Large-Scale Asset Purchases,” *International Journal of Central Banking,* Vol. 7, No. 1, March 2011.

Gorton, G., and G. Ordoñez, “The Supply and Demand for Safe Assets,” NBER Working Paper 18732, 2013.

Greenwood, R., Hanson, S., and J. Stein, “A Comparative-Advantage Approach to Government Debt Maturity,” *Journal of Finance (forthcoming)*, 2015.

Greenwood, R., and D. Vayanos, “Bond Supply and Excess Bond Returns,” Working Paper, Harvard Business School, 2013.

Hausman, J., and J. Wieland, “Abenomics: Preliminary Analysis and Outlook,” Working Paper presented at the Brookings Papers on Economic Activity / Spring 2014 Conference, 2014.

Hausman, J., and J. Wieland, “Abenomics:An update,” Working Paper presented at the Brookings Papers on Economic Activity Conference, September 10-11, 2015.

Holmström, B., and J. Tirole, “Private and Public Supply of Liquidity,” *Journal of Political Economy,* 106, 1998, pp. 1-40.

Imakubo, K., and J. Nakajima, "Estimating inflation risk premia from nominal and real yield curves using a shadow-rate model," Bank of Japan Working Paper Series, No. 15-E-1, 2015.

International Monetary Fund, "Unconventional Monetary Policies – Recent Experience and Prospects," April, 2013.

Iwata, K., and I. Fueda-Samikawa, "Quantitative and Qualitative Monetary Easing Effects and Associated Risks," Japan Financial Report, 2013-1, Japan Center for Economic Research, 2015.

Kaihatsu S., and J. Nakajima, "Has Trend Inflation Shifted?: An Empirical Analysis with a Regime-Switching Model," Bank of Japan Working Paper Series, No. 15-E-3, 2015.

Kano T., and K. Wada, "The First Arrow Hitting the Currency Target: A Long-run Risk Perspective," Working Paper, 2015.

Kamada, K., and J. Nakajima, "On the Reliability of Japanese Inflation Expectations Using Purchasing Power Parity," Bank of Japan Working Paper Series, No. 13-E-13, 2013.

Kreps, D., and E. Porteus, "Temporal resolution of uncertainty and dynamic choice theory," *Econometrica*, Vol. 46, No. 1, 1978, pp. 185-200.

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

Krishnamurthy A. and A. Vissing-Jorgensen, "The Aggregate Demand for Treasury Debt," *Journal of Political Economy*, Vol. 120, No. 2, 2012-a, pp. 233-267.

Krishnamurthy A. and A. Vissing-Jorgensen, "Why an MBS-Treasury Swap Is Better Policy than the Treasury Twist," mimeo, Kellogg School of Management, 2012-b.

Krishnamurthy A. and A. Vissing-Jorgensen, "The Ins and Outs of Large Scale Asset Purchases," presented at the 2012 symposium of the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, 2013.

Kuroda, H., "Overcoming Deflation and After," speech at the Meeting of Councilors of Nippon Keidanren (Japan Business Federation), Tokyo, 2013.

Kurosaki, T., Kumano, Y., Okabe, K., and T. Nagano, "Liquidity of Government Bond Markets: Testing Transaction Data (available only in Japanese)," Bank of Japan Working Paper Series, No. 15-J-2, 2015.

Longstaff, F., "The Flight-to-Liquidity Premium in U.S. Treasury Bond Prices," *Journal of Business*, Vol. 77, No. 3, 2014.

Mandel, B., and G. Barnes, "Japanese Inflation Expectations, Revisited," Liberty Street Economics, Federal Reserve Bank of New York, 2013.

McCallum, B., "Theoretical analysis regarding a zero lower bound on nominal interest rates," *Journal of Money, Credit and Banking*, Vol. 32, 2000, pp. 870-904.

Miyao R., "Challenging in Shaping Monetary Policy," speech at the Daiwa Investment

Conference Tokyo, 2015.

Modigliani, F., and R. Sutch, “Innovations in Interest Rate Policy,” *American Economic Review*, Vol. 56, No. 1/2, 1966, pp. 178-197.

Mohi-uddin, M., “Tide starts to turn for yen as policy shifts boost revival hopes,” Financial Times, November 17, 2015.

Ono, N., Sawada, T., and A. Tsuchikawa, “Towards the Further Development of Repo Markets (available only in Japanese),” Bank of Japan review, 2015-J-5, 2015.

Saint-Paul, G., “Fiscal Policy and Economic Growth: The Role of Financial Intermediation,” *Review of International Economics*, Vol. 13, 2005, pp. 612-629.

Sekine, T., Yoshimura K., and C. Wada, “On Inflation Expectations (available only in Japanese),” Bank of Japan Review, 2008-J-15, 2008.

Sidrauski, M., “Rational Choice and Patterns of Growth in a Monetary Economy,” *the American Economic Review*, Vol. 57, Issue 2, 1967.

Suda, S., *Fight against Risks (Risuku tono Tatakai)*, available only in Japanese, Nihon Keizai Shimbun, 2014.

Ueda, K., “Response of Asset Prices to Monetary Policy under Abenomics,” *Asian Economic Review*, 2013, pp. 252-273.

Ugai, H., “Effects of Quantitative Easing Policy: A Survey of Empirical Analyses,” *Monetary and Economic Studies*, Vol. 25, No. 1, Bank of Japan, 2007, pp. 1-47.

Vayanos, D., and J. Vila, “A Preferred-Habitat Model of the Term Structure of Interest Rates,” Working Paper, London School of Economics, 2009.

Waller, C., “Discussion of Maturity Structure and Supply Factors in Japanese Government Bond Markets,” presented at the BOJ-IMES Conference, 2015.

Woodford, M., “Methods of Policy Accommodation at the Interest-Rate Lower Bound,” presented at the 2012 symposium of the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, 2012.

Table 1 Outline of Comprehensive Monetary Easing Policy (CE) in October 2010 and the Subsequent Monetary Easing Policies

- Encouraging the uncollateralized O/N call rate to remain around 0-0.1 percent.
- Maintaining the virtually zero interest rate policy until it judges, on the basis of "the understanding of the medium- to long-term price stability (in a positive range of 2 percent or lower, and midpoints around 1 percent in CPI)," that price stability is in sight, on condition that no problem will be identified in examining risk factors, including the accumulation of financial imbalances.
- Establishment of Asset Purchase Program (government securities, CP, corporate bonds, ETFs, and J-REITs. Total 35 tril. yen, then expanded to 40 tril. yen in Mar. 2011, 50 til. yen in Aug. 2011, 55 tril. yen in October 2011, 65 tril. yen in Feb. 2012, 70 tril. yen in Apr. 2012, 80 tril. yen in Sep. 2012, 91 tril. yen in Oct. 2012, and 101 tril. yen in Dec. 2012)
- Introduction of Measures to Support Strengthening the Foundations of Economic Growth (from Jun. 2010, gradually expanding to equity investments and asset-based lending, small lot investments and loans, and the US. dollar lending arrangement)
- Introduction of Measure to Stimulate Bank Lending (from Dec. 2012)
- (Establishment of Price Stability Goal in the medium to long term, within a positive range of 2 percent or lower in CPI, setting a goal at 1percent for the time being in Feb. 2012)

Table 2 Outline of Quantitative and Qualitative Monetary Easing Policy (QQE) in April 2013

- (Establishment of Price Stability Target at 2 percent in CPI in Jan. 2013)
- Strong commitment of the achievement of the price stability target of 2 percent as its responsibility at the earliest possible time, with a time horizon of about 2 years.
- The adoption of monetary base control (60-70 tril. yen per year <double in 2 years>, then expanded to 80 tril. yen per year in October 2014)
- An increase in the JGB purchases (50 tril. yen per year, then expanded to 80 tril. yen per year in October 2014) and their maturity extension (extended to about 7 years <more than double>, then extended to about 7-10 years in October 2014)
- An increases in ETF (1 tril. yen per year, then expanded to 3 tril. yen per year in October 2014) and in J-REIT (30 bil. yen per year, then expanded to 90 bil. yen per year in October 2014)
- Continuation of QQE as long as it is necessary for maintaining the price stability target in a stable manner.

Table 3 **Changes in OIS Rates around CE and QQE**

Basis points

Event \ Asset	Overnight Index Swap							
	2 year	3 year	4 year	5 year	6 year	7 year	8 year	9 year
CE (2010/10/5)	-1	-1	-4	-7	-5	-6	-7	-8
QQE (2013/4/4)	1	3	4	5	4	2	0	-1
Ref. QQE 2(2014/10/31)	0	0	0	1	1	1	0	-1
Sum of CE & QQE	1	2***	1***	-2***	-1***	-5***	-7***	-9***

Source: Bloomberg.

Note: 1. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics. Newey-West's HAC estimator is applied.

2. All changes are over 2 days, from the day before to the day after the monetary easing.

3. Sample period is from the beginning of January, 2010 to November 19, 2014.

Table 4 **Changes in Japanese Government Bond Yields around CE and QQE**

Basis points

Event \ Asset	Japanese Government Bond yields			
	10 year	5 year	3 year	1 year
CE (2010/10/5)	-10	-5	-2	-1
Monetary easing (2011/3/14)	-3	-5	0	1
Monetary easing (2012/4/27)	-2	-2	-1	0
Monetary easing (2012/9/19)	-1	-2	-1	0
Monetary easing (2012/12/20)	-1	-2	0	0
QQE (2013/4/4)	-3	3	1	2
QQE2 (2014/10/31)	-1	0	0	0
Sum of the above seven dates	-21***	-13***	-3***	2***

Source: Bloomberg.

Note: 1. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics. Newey-West's HAC estimator is applied.

2. All changes are over 2 days, from the day before to the day after the monetary easing.

3. Sample period is from the beginning of January, 2010 to November 19, 2014.

Table 5 Changes in Corporate Bond Yields around CE and QQE

Basis points

Asset / Event	Corporate Bond yields									
	AA	AA	A	BBB	AA	A	BBB	AA	A	BBB
	10 year	5 year			3 year			1 year		
CE (2010/10/5)	-9	-6	-5	-5	-3	-3	2	-1	-1	4
Monetary easing (2011/3/14)	3	-2	-6	-12	1	-3	-23	6	1	-13
Monetary easing (2012/4/27)	-2	-2	-2	-2	-1	-1	0	0	0	-1
Monetary easing (2012/9/19)	-2	-1	-1	2	0	0	2	0	0	5
Monetary easing (2012/12/20)	6	-1	1	-5	-2	-1	0	0	0	0
QQE (2013/4/4)	-3	5	5	2	3	3	3	2	2	0
QQE2 (2014/10/31)	-1	1	1	1	1	1	1	1	1	1
Sum of the above seven dates	-8***	-6***	-8***	-17	-1***	-4***	-15	7***	3	-4

Source: Bloomberg.

Note: 1. AA, A, BBB are rated by Rating and Investment Information.

2. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics. Newey-West's HAC estimator is applied.

3. All changes are over 2 days, from the day before to the day after the monetary easing.

4. Other than the monetary easing actions, some dummy variables are used for removing the distortion of some specific companies caused by deteriorated business conditions of credit companies and by occurrence of Great East Japan Earthquake.

5. Sample period is from the beginning of January, 2010 to November 19, 2014.

Table 6 Changes in Corporate Bond Yields Adjusted by Credit Default Swap Rates, and the Yen/Dollar Exchange Rate around CE and QQE

Basis points

Event \ Asset	Adjusted Corporate yields										FOREX
	AA	AA	A	BBB	AA	A	BBB	AA	A	BBB	yen/dollar
	10 year	5 year			3 year			1 year			Spot
CE (2010/10/5)	-7	-4	-5	-5	-2	-3	2	-1	0	5	-52
Monetary easing (2011/3/14)	-17	-19	-25	-30	-11	-16	-35	-2	-6	-20	-138
Monetary easing (2012/4/27)	-2	-2	6	0	-1	5	1	0	4	-1	-146
Monetary easing (2012/9/19)	-4	-3	-4	6	-2	-3	7	-2	-2	10	-74
Monetary easing (2012/12/20)	5	-1	1	-6	-3	1	0	-3	-1	2	-20
QQE (2013/4/4)	-1	6	9	7	4	6	5	2	3	2	475
QQE2 (2014/10/31)	1	3	2	3	2	1	2	1	1	2	434
Sum of the above seven dates	-25***	-21***	-16***	-25	-13**	-8***	-17	-4***	-1**	0	480***

Source: Bloomberg, Markit

Note: 1. AA, A, and BBB are rated by Rating and Investment Information. Credit Default Swap rates are provided by Markit. The yen/dollar rate is expressed as the log return.

2. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics. Newey-West's HAC estimator is applied.

3. All changes are over 2 days, from the day before to the day after the monetary easing.

4. Other than the monetary easing actions, some dummy variables are used for removing the distortion of some specific companies caused by partial revision of the Act on Regulation, etc. of Loan Business and by occurrence of Great East Japan Earthquake.

5. Sample period is from the beginning of January, 2010 to November 19, 2014.

Table 7 Difference between Changes in CDS-Adjusted Corporate Bond Yields and Changes in Japanese Government Bond Yields around CE and QQE

Basis points

Event \ Asset	Adjusted Corporate yields — Japanese Government Bond Yields									
	AA	AA	A	BBB	AA	A	BBB	AA	A	BBB
	10 year	5 year			3 year			1 year		
CE (2010/10/5)	3	0	-1	0	0	-1	4	0	1	6
Monetary easing (2011/3/14)	-14	-14	-20	-25	-11	-16	-35	-3	-8	-22
Monetary easing (2012/4/27)	0	0	8	2	0	6	2	1	5	-1
Monetary easing (2012/9/19)	-2	-1	-2	8	-1	-2	7	-2	-2	10
Monetary easing (2012/12/20)	6	1	3	-4	-3	1	1	-3	-1	2
QQE (2013/4/4)	1	3	6	3	2	5	4	0	1	0
QQE2 (2014/10/31)	2	3	2	3	2	1	2	2	1	3
Sum of the above seven dates	-3***	-8***	-3***	-12	-11	-5***	-14	-6	-3*	-2

Source: Bloomberg, Markit

Note: 1. AA, A, and BBB are rated by Rating and Investment Information. Credit Default Swap rates are provided by Markit.

2. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics. Newey-West's HAC estimator is applied.

3. All changes are over 2 days, from the day before to the day after the monetary easing.

4. Other than the monetary easing actions, some dummy variables are used for removing the distortion of some specific companies caused by partial revision of the Act on Regulation, etc. of Loan Business and by occurrence of Great East Japan Earthquake.

5. Sample period is from the beginning of January, 2010 to November 19, 2014.

Table 8　Fama Coefficients (Relation between the Yen/Dollar Exchange Rate and Yield Differential (Japan and the US))

Sample Period		Yields to Maturity 1 year	2 years	3 years	5 years	7 years	10 years
		$z_{t+1} - z_t = \alpha_n + \beta_n (y_{t,n} - y^*_{t,n}) + \epsilon_{t,n}$					
2003/1–2015/9	$\widehat{\beta_n}$	0.063	0.077	0.110	0.241	0.400*	0.547**
	t–statistic	[0.54]	[0.58]	[0.74]	[1.29]	[1.76]	[2.04]
2003/1–2007/7	$\widehat{\beta_n}$	−0.233	−0.315	−0.396	−0.698	−0.839	0.877
	t–statistic	[−1.16]	[−1.24]	[−1.21]	[−1.12]	[−0.76]	[0.56]
2007/8–2012/11	$\widehat{\beta_n}$	0.467	0.539	0.620	0.876**	0.989**	1.116**
	t–statistic	[1.44]	[1.42]	[1.55]	[2.06]	[2.24]	[2.31]
2012/12–2015/9	$\widehat{\beta_n}$	4.335	3.224	2.413	2.163*	1.977*	2.339*
	t–statistic	[1.14]	[1.48]	[1.61]	[1.85]	[1.86]	[1.97]
		$rx_{t+1} = \alpha^{rx}_n + \beta^{rx}_n (y_{t,n} - y^*_{t,n}) + \epsilon_{t,n}$					
2003/1–2015/9	$\widehat{\beta^{rx}_n}$	−0.937***	−1.038***	−1.116***	−1.206***	−1.217***	−1.202***
	t–statistic	[−7.92]	[−7.76]	[−7.32]	[−5.98]	[−4.77]	[−3.91]
2003/1–2007/7	$\widehat{\beta^{rx}_n}$	−1.233***	−1.571***	−1.986***	−3.594***	−5.273***	−1.317
	t–statistic	[−6.15]	[−6.19]	[−6.04]	[−5.56]	[−4.23]	[−0.65]
2007/8–2012/11	$\widehat{\beta^{rx}_n}$	−0.533	−0.604	−0.516	−0.165	0.052	0.130
	t–statistic	[−1.64]	[−1.59]	[−1.28]	[−0.37]	[0.11]	[0.26]
2012/12–2015/9	$\widehat{\beta^{rx}_n}$	3.335	2.712	2.141	2.049*	1.908*	2.355*
	t–statistic	[0.88]	[1.24]	[1.43]	[1.76]	[1.80]	[2.00]

Source: CEIC

Note: 1. Revised estimation of Kano and Wada (2015).

2. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of t-statistics.

Table 9 Changes in Inflation Swap Rates, Break-even Inflation Rates of Inflation-indexed Government Bonds around CE and QQE

Basis points

Event \ Asset	Inflation Swaps (10 year)	Break-even Inflation Rate (10 year)	Inflation Swaps (5 year)	Break-even Inflation Rate (5 year)
CE (2010/10/5)	6	NA	0	-1
Monetary easing (2011/3/14)	6	NA	3	-1
Price stability goal (2012/2/14)	0	NA	0	-2
Monetary easing (2012/4/27)	0	NA	0	1
Monetary easing (2012/9/19)	1	NA	3	1
Monetary easing (2012/12/20)	10	NA	2	4
Price stability target (2013/1/22)	3	NA	5	6
QQE (2013/4/4)	4	NA	7	6
QQE2 (2014/10/31)	0	5 ***	0	NA
Sum of the above nine dates	29	5	19	14

Source: Bloomberg, Barclays Capital.

Note: 1. Asterisks show statistical significance at the ***1 percent, **5 percent, and *10 percent of F-statistics.

2. All changes are over 2 days, from the day before to the day after the monetary easing.

3. Sample period is from the beginning of January, 2010 to November 19, 2014. As for the break-even inflation rate for 10 year, the sample period is from October 16, 2013 to November 19, 2014, and as for the break-even inflation rate for 5 years, the sample period is from the beginning of January, 2010 to April 22, 2014.

Table 10 Impact of Japanese Government Bond Supply on Bond Spreads: Log Function

	AA10yr–JGB10yr
Log(debt/GDP)	−0.266
	[−1.32]
EDF	0.074
	[2.50]
Earthquake dummy	0.076
	[2.30]
Intercept	0.203
	[2.88]
$adj.R^2$	0.943
$F-statistic$	217.405
Observations	69

Source: Bloomberg, Bank of Japan (Flow of Funds), Cabinet Office (Quarterly Estimates of GDP), Moody's Analytics.

Note: 1. AA is rated by Rating and Investment Information.

2. Debt is the outstanding amount of Japanese government bonds and of FILP bonds minus the amount of JGBs held by the BOJ.
3. EDF is the expected default frequency for corporate bonds. 1-year 50th percentile of Japan's corporates is used.
4. Great East Japan Earthquake changed drastically the creditworthiness and rating of some large company, thereby providing the distortion of the yields of AA corporate bonds. This distortion is removed by adding earthquake dummy.
5. Sample period is from 4Q/1997 to 4Q/2014.
6. Error terms are adjusted with AR(1) and AR(2).

Table 11 Comparison of the Supply of Japanese Government Bonds and of Monetary Base

	AA10yr−JGB10yr
Log(debt/GDP)	−0.251
	[−1.19]
Log(MB/GDP)	−0.022
	[−0.29]
EDF	0.076
	[2.49]
Earthquake dummy	0.075
	[2.22]
Intercept	0.168
	[1.216]
$adj.R^2$	0.947
$F-statistic$	178.470
Observations	69

Source: Bloomberg, Bank of Japan (Flow of Funds, Monetary Base), Cabinet Office (Quarterly Estimates of GDP), Moody's Analytics.

Note: 1. AA is rated by Rating and Investment Information.

2. Debt is the outstanding amount of Japanese government bonds and of FILP bonds minus the amount of JGBs held by the BOJ.

3. EDF is the expected default frequency for corporate bonds. 1-year 50th percentile of Japan's corporates is used.

4. Great East Japan Earthquake changed drastically the creditworthiness and rating of some large company, thereby providing the distortion of the yields of AA corporate bonds. This distortion is removed by adding earthquake dummy.

5. Sample period is from 4Q/1997 to 4Q/2014.

6. Error terms are adjusted with AR(1) and AR(2).

Table 12 Impact of Japanese Government Bond Supply on Bond Spreads: Piecewise-Linear Function

	AA10yr–JGB10yr
b_1	2.143
	[7.10]
b_2	–0.299
	[–14.12]
EDF	0.072
	[3.02]
Earthquake dummy	0.070
	[2.52]
Intercept	0.146
	[5.15]
$adj. R^2$	0.965
$F - statistic$	277.699
Observations	69

Source: Bloomberg, Bank of Japan (Flow of Funds), Cabinet Office (Quarterly Estimates of GDP), Moody's Analytics.

Note: 1. AA is rated by Rating and Investment Information.

2. Debt is the outstanding amount of Japanese government bonds and of FILP bonds minus the amount of JGBs held by the BOJ.
3. EDF is the expected default frequency for corporate bonds. 1-year 50th percentile of Japan's corporates is used.
4. Great East Japan Earthquake changed drastically the creditworthiness and rating of some large company, thereby providing the distortion of the yields of AA corporate bonds. This distortion is removed by adding earthquake dummy.
5. The function estimated is $b_1 \max[b_2 - debt/GDP, 0]$.
6. Sample period is from 4Q/1997 to 4Q/2014.
7. Error terms are adjusted with AR(1) and AR(2).

Table 13 Impact of Monetary Base Supply on Bond Spreads: Piecewise-Linear Function

	AA10yr–JGB10yr
b_1	0.063
	[0.38]
b_2	−1.014
	[−0.77]
EDF	0.073
	[2.42]
Earthquake dummy	0.077
	[2.13]
Intercept	0.134
	[1.12]
$adj. R^2$	0.940
$F - statistic$	174.511
Observations	69

Source: Bloomberg, Bank of Japan (Flow of Funds, Monetary Survey), Cabinet Office (Quarterly Estimates of GDP), Moody's Analytics.

Note: 1. AA is rated by Rating and Investment Information.

2. Monetary Base is the outstanding amount of the quarterly average to exclude the fluctuation of end day of every quarter.

3. EDF is the expected default frequency for corporate bonds. 1-year 50th percentile of Japan's corporates is used.

4. Great East Japan Earthquake changed drastically the creditworthiness and rating of some large company, thereby providing the distortion of the yields of AA corporate bonds. This distortion is removed by adding earthquake dummy.

5. The function estimated is $b_1 \max[b_2 - debt/GDP, 0]$.

6. Sample period is from 4Q/1997 to 4Q/2014.

7. Error terms are adjusted with AR(1) and AR(2).

Table 14 Asset Allocation of Non-bank Financial Institutions

Asset Allocation of Pension Funds

(%)

	Domestic Stocks	International Stocks	Domestic Bonds	International Bonds	Other
Australia	27	25	9	6	34
Denmark	3	20	41	9	27
France	17	12	55	4	12
Germany	4	7	59	5	25
Netherlands	5	18	43	6	28
Switzerland	13	18	20	26	23
UK	14	25	37	3	21
Chile	18	25	18	20	20
Honk Kong	35	30	9	10	16
Average	15	20	32	10	23
Japan old	12	12	60	11	5
Japan new	25	25	35	15	0

Asset Allocation of Insurance Compenies

(%)

	Domestic Stocks	Domestic Bonds	Foreign Securities	Other
Australia	50.0	23.7	9.1	17.2
France	27.5	32.6	31.8	8.1
Germany	38.5	5.6	13.1	42.7
Italy	7.5	45.3	19.8	27.4
Korea	7.4	59.4	27.3	5.9
Norway	28.7	27.6	29.4	14.3
Sweden	29.6	26.9	34.8	8.7
UK	11.6	28.1	24.9	35.4
US	…	36.4	…	63.6
Average	25.1	31.7	23.8	19.4
Japan	7.4	61.1	15.4	16.1

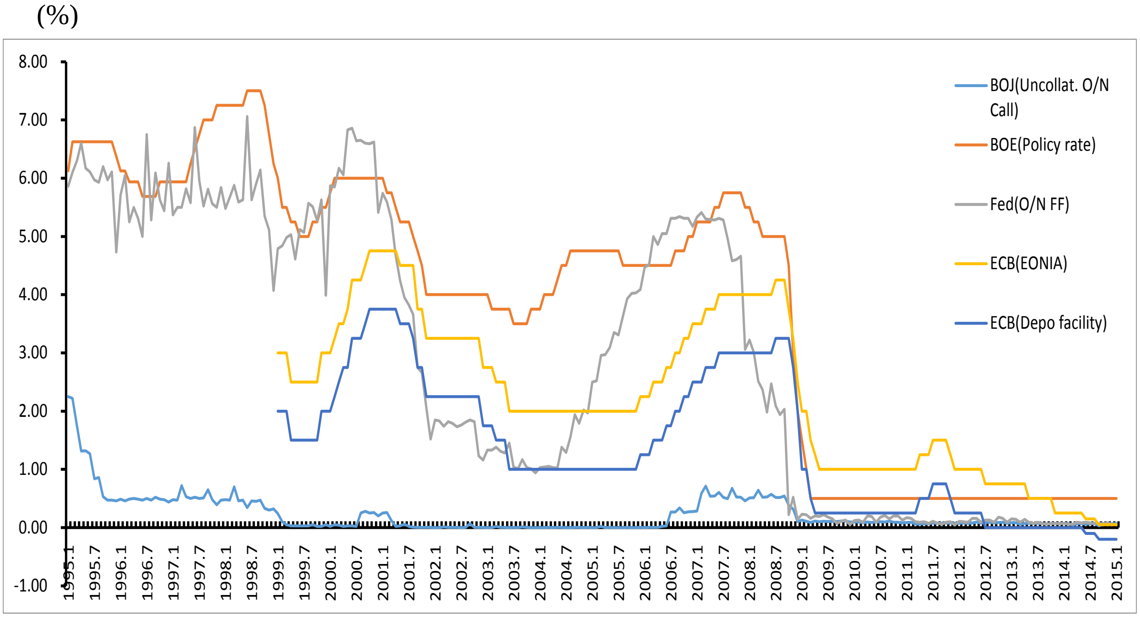
Source: Arslanalp and Botman (2015)

Note: 1. All data are as of end-2014 or latest available.

2. Domestic bonds are government bonds and corporate bonds.

3. Average means average of all countries shown above, excluding Japan.

Graph 1 **Policy Rates of Major Central Banks**



Source: CEIC

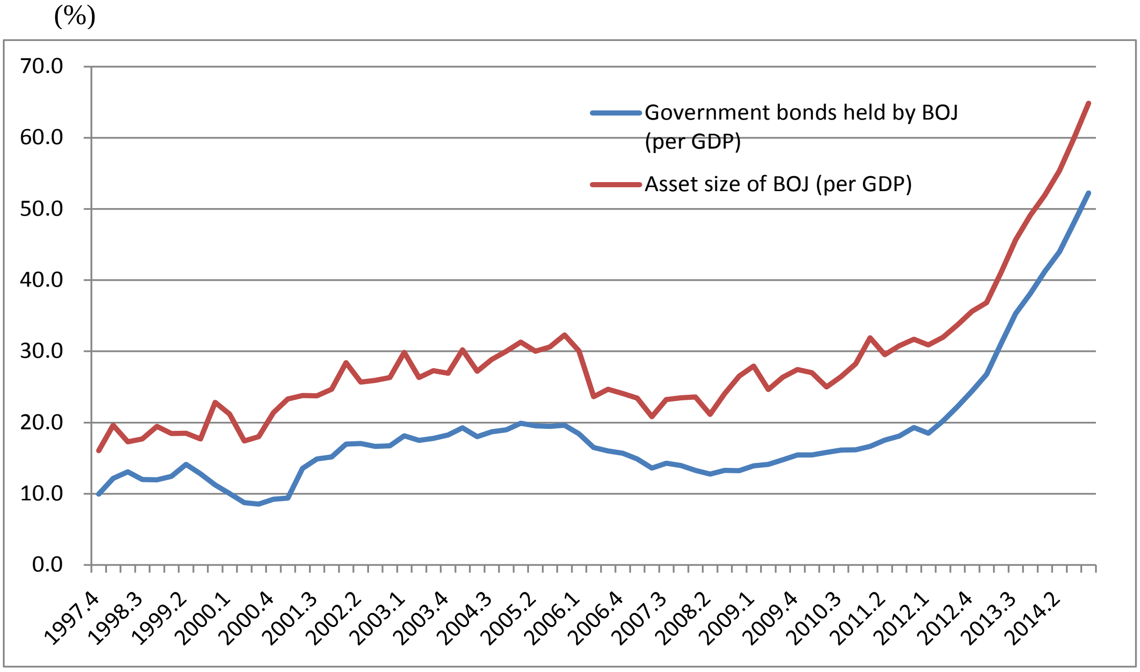
Note: 1. Bank of Japan: Uncollateralized Overnight Call Rate

2. US. Federal Reserve: Overnight Federal Funds Rate

3. Bank of England: Official Bank Rate

4: European Central Bank: EONIA and Deposit Facility Rate

Graph 2 **Asset size of the Bank of Japan**

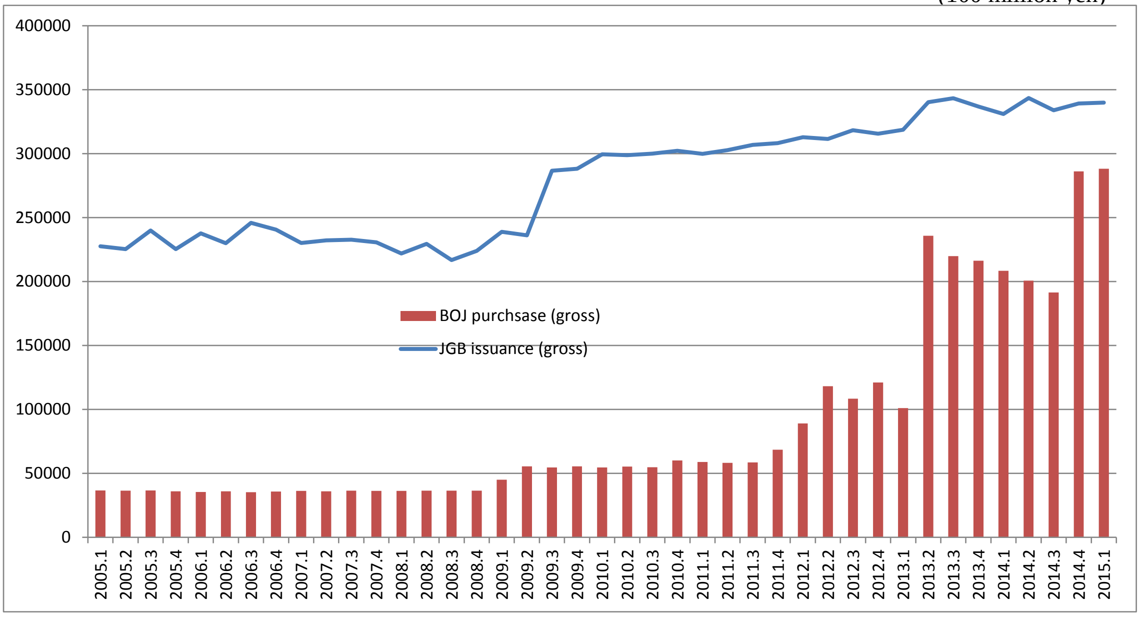


Source: Bank of Japan (Flow of Funds), Cabinet Office (Quarterly Estimate of GDP)

Graph 3 Japanese Government Bond Issuance and Purchase by the Bank of Japan

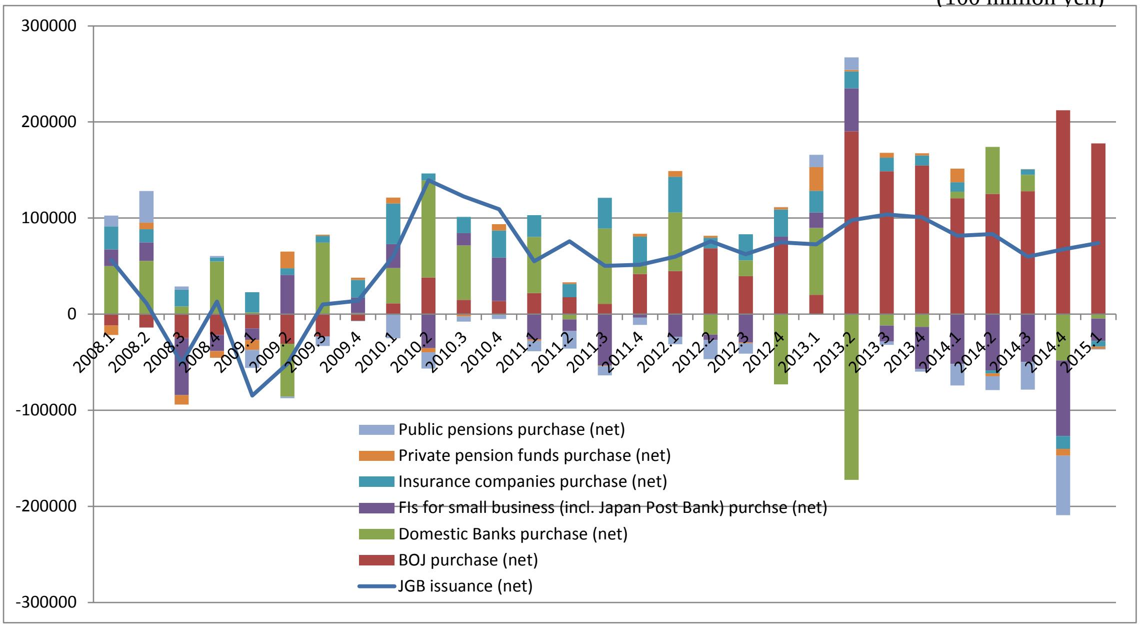
(1) Gross amount

(100 million yen)



(2) Net amount

(100 million yen)

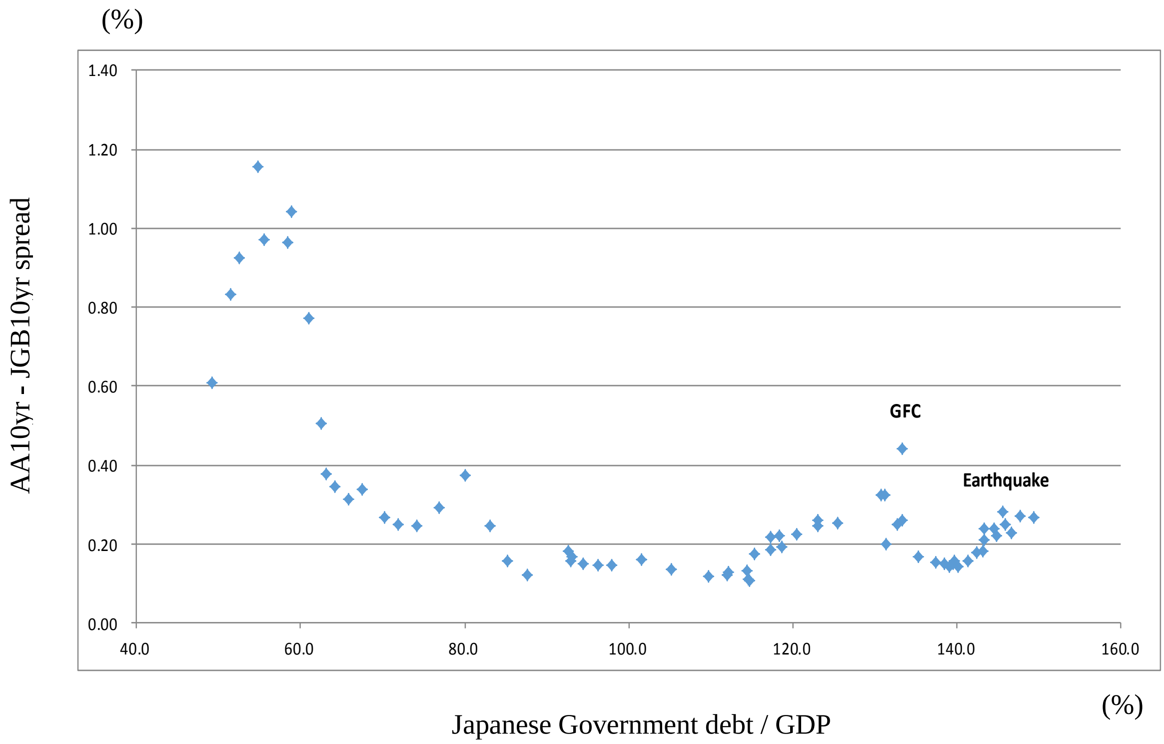


Source: Bank of Japan (Flow of Funds), Japan Dealers Securities Association.

Note: 1. Gross issuance amount of JGBs are calculated by deducting the amount of issuance amount for individuals and of Treasury Bills from the total issuance amount of Government bonds.

2. Net issuance means the amount of issuing JGBs minus their redemption. Net purchase means the amount of purchasing JGBs minus their sale.

Graph 4 **Corporate Bond Spread and Consolidated Government Debt**



Source: Bloomberg, Bank of Japan (Flow of Funds), Cabinet Office (Quarterly Estimate of GDP)

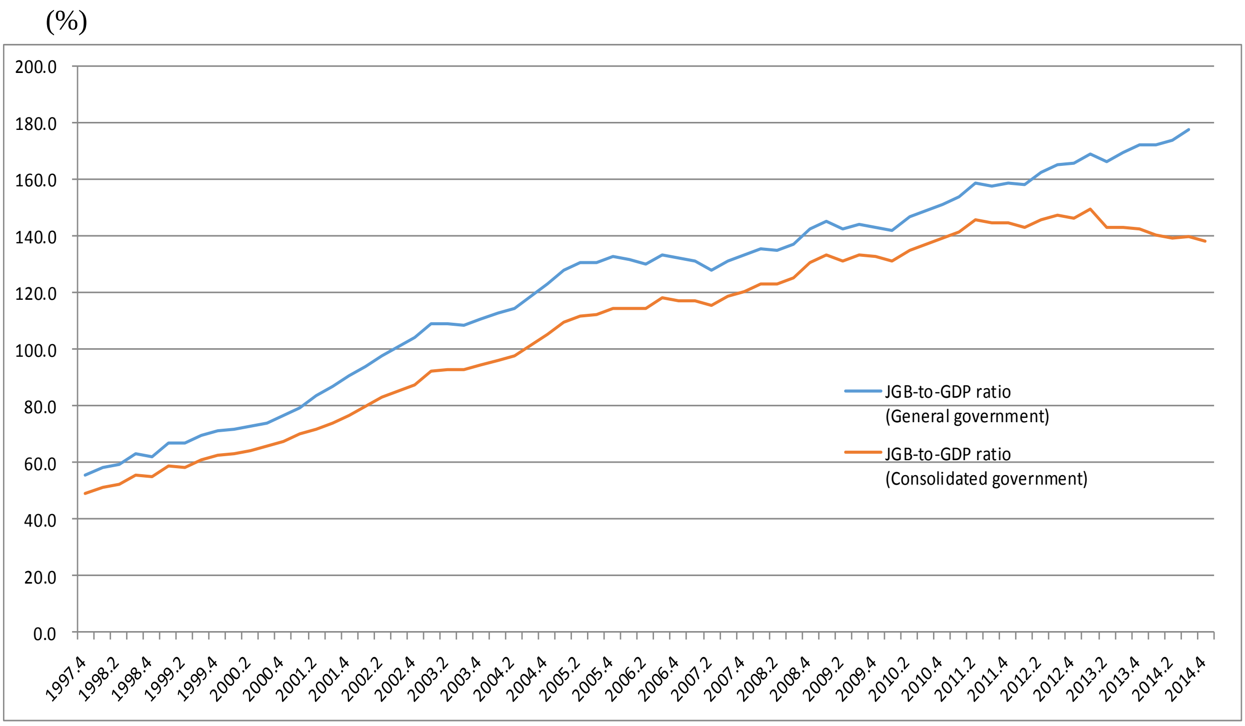
Note: 1. AA is rated by Rating and Investment Information.

2. Bond spread is the difference between the percentage yield of AA rated 10 year corporate bonds and the percentage yield of 10 year Japanese government bonds.

3. Government debt is consolidated government debt, that is, the outstanding amount of JGBs and of FILP bonds minus the amount of JGBs held by the BOJ.

4. Sample period is from 4Q 1997 to 4Q 2014.

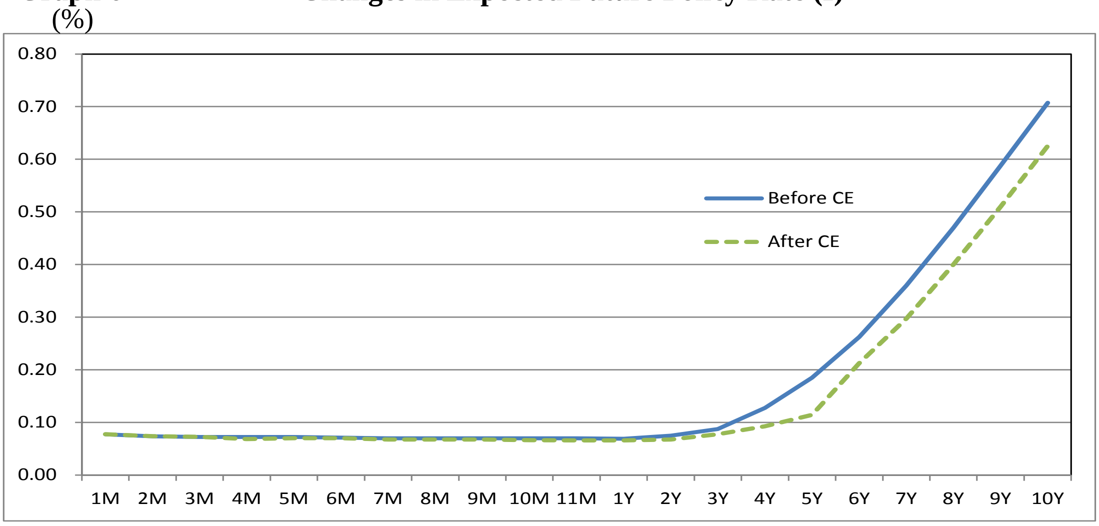
Graph 5 Outstanding Amount of Japanese Government Bonds: General Government and Consolidated Government

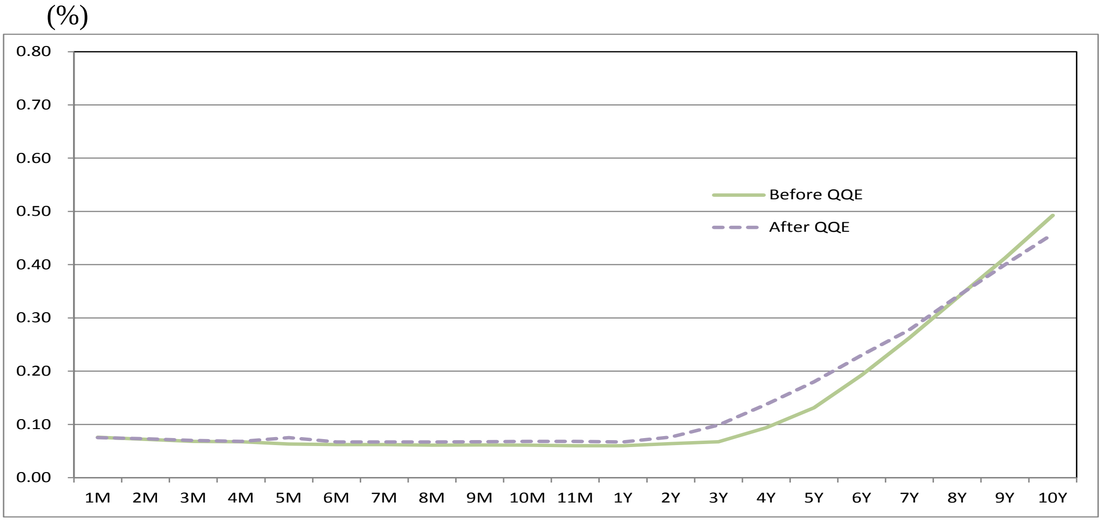


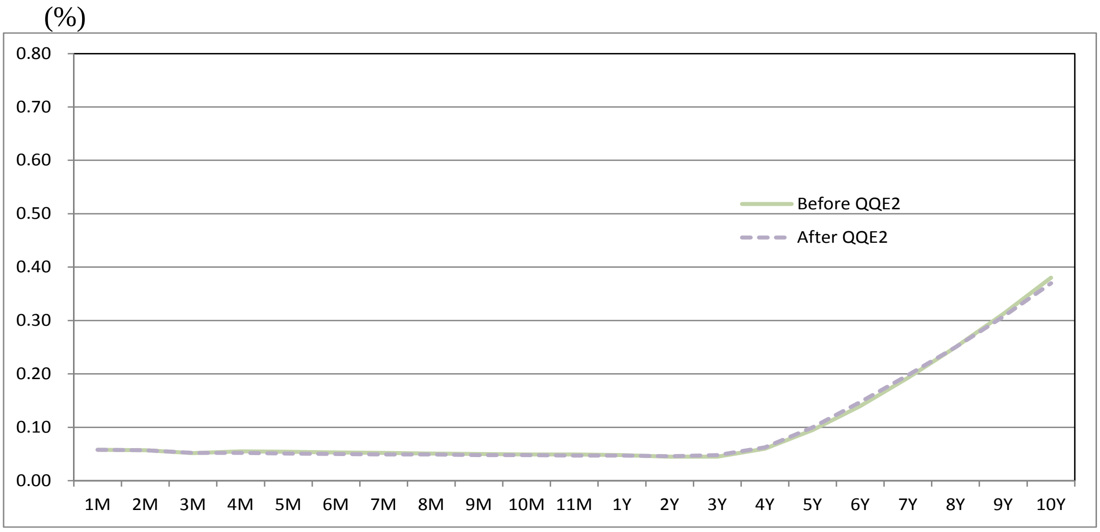
Source: Bank of Japan (Flow of Funds), Cabinet Office (Quarterly Estimated of GDP)

Note: Consolidated Government incorporates the General Government (Central Government and Fiscal Investment and Loan Program) with the Bank of Japan.

Graph 6 **Changes in Expected Future Policy Rate (I)**



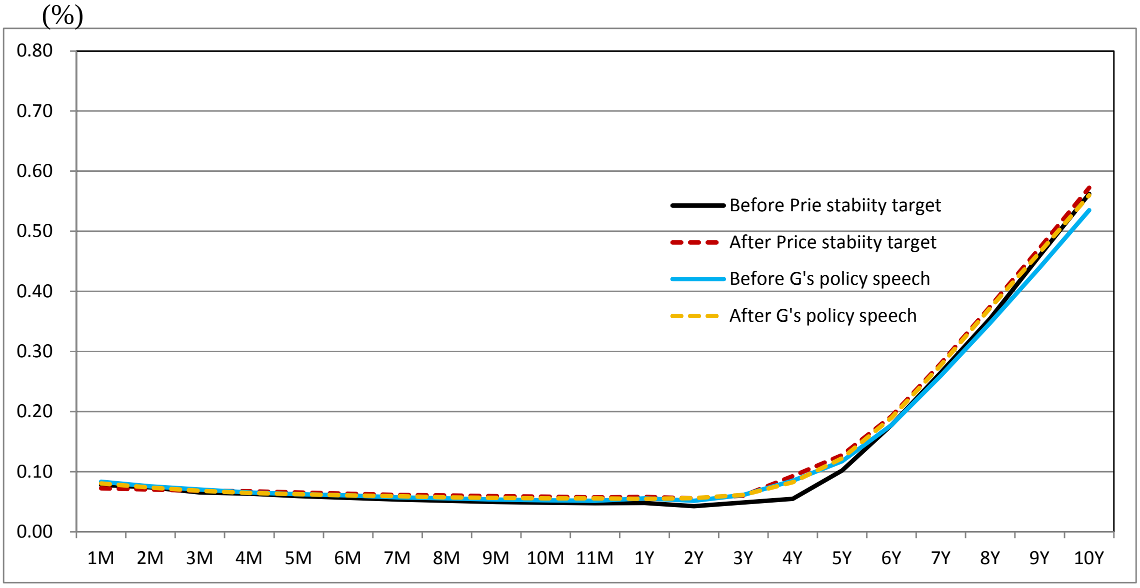




Source: Bloomberg

Note: All changes are over 2 days, from the day before to the day after the monetary easing.

Graph 7 Changes in Expected Future Policy Rate (II)

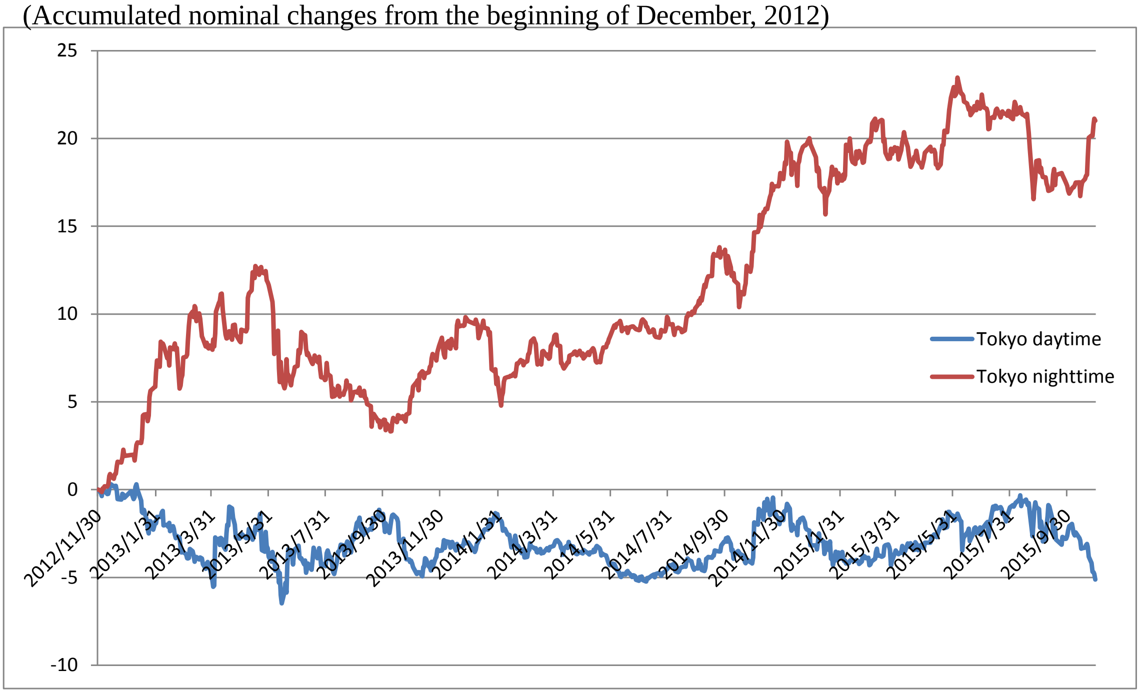


Source: Bloomberg

Note: All changes are over 2 days, from the day before to the day after the monetary easing.

Graph 8 Accumulated Changes in the Yen/Dollar Exchange Rate

(Accumulated nominal changes from the beginning of December, 2012)



Source: BOJ, Bloomberg

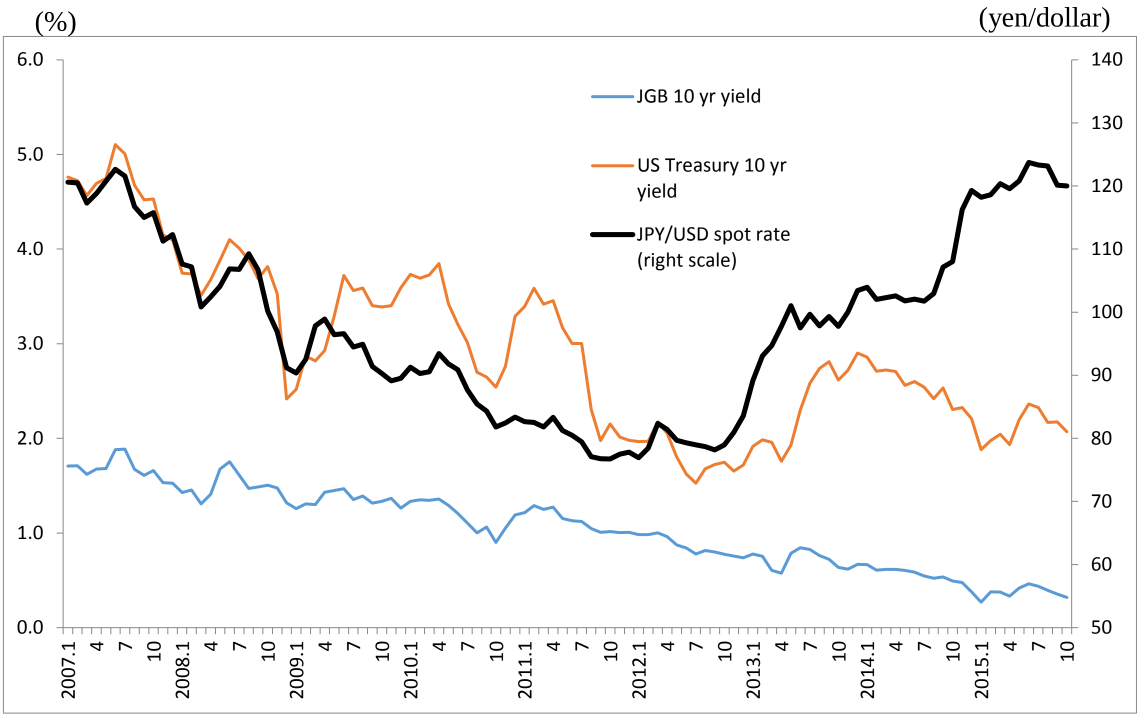
Note: 1. Revised estimation of Fukuda (2014).

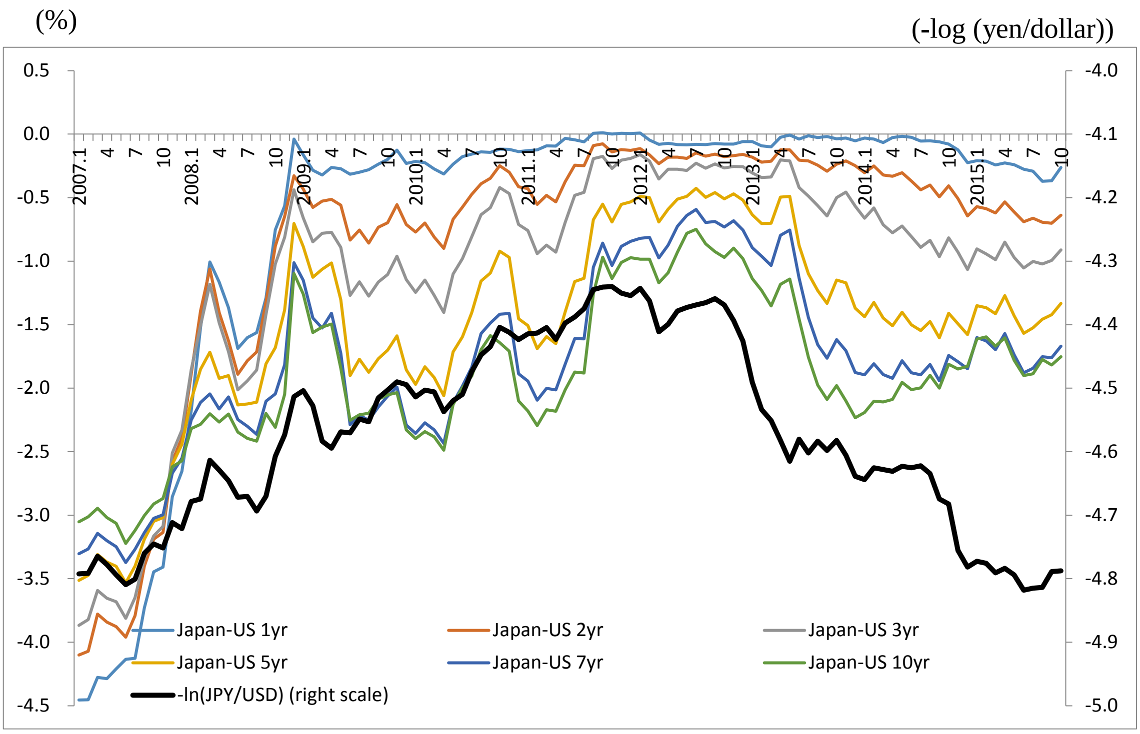
2. Tokyo daytime denotes the trading from 9 am in Tokyo to 5 pm in Tokyo.

3. Tokyo nighttime denotes the trading from 5 pm in Tokyo to 5 pm in New York.

4. The trading from 5 pm in New York to 9 am in Tokyo is excluded.

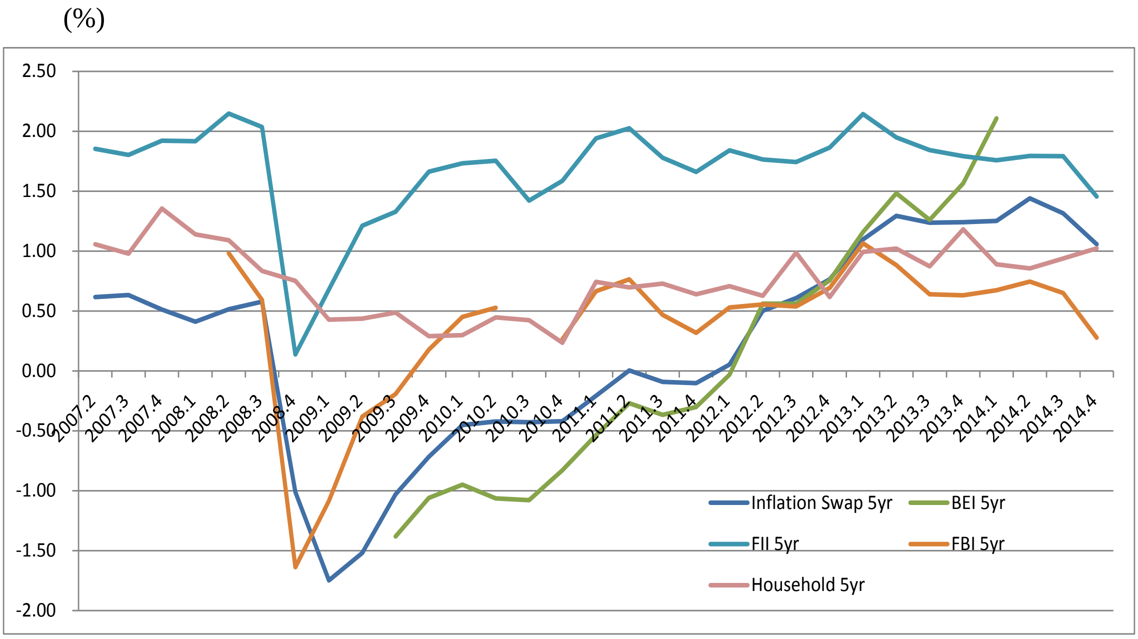
Graph 9　10-year Government Bond Yield Differential and the Yen/Dollar Exchange Rate





Source: CEIC

Graph 10 **Inflation Expectation**

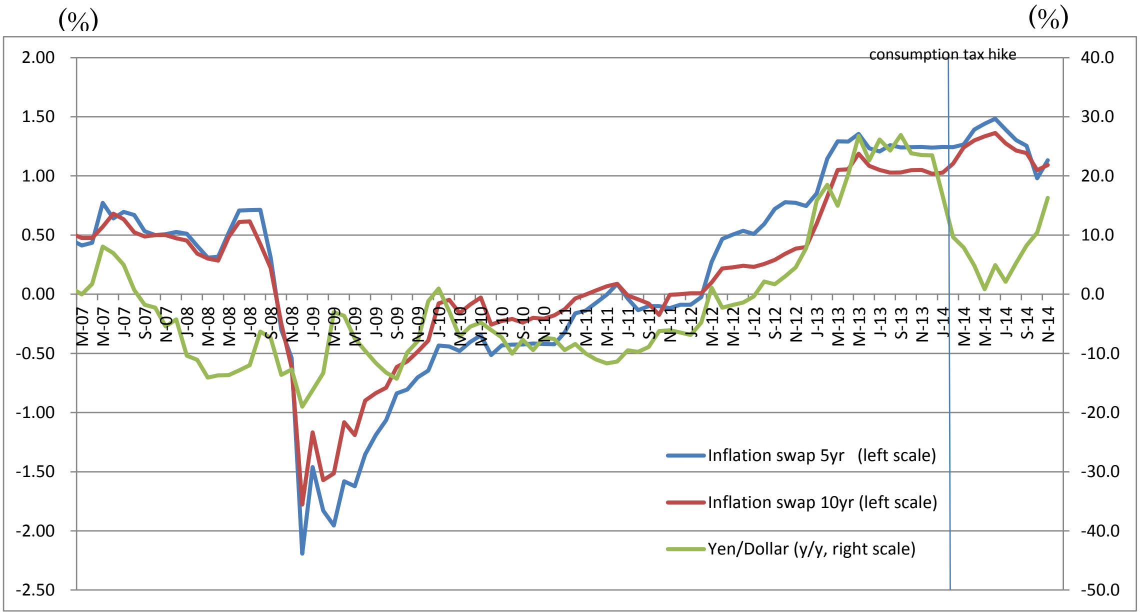


Source: Bloomberg, Barclays Capital, Bank of Japan (Opinion's Survey on the General Public's Views and Behavior, and estimation of inflation expectation by using Carlson-Parkin method)

Note: 1. Outlook for price levels over the next five years is transformed to inflation rate by using the Carlson-Parkin method of Sekine *et al*. (2008).

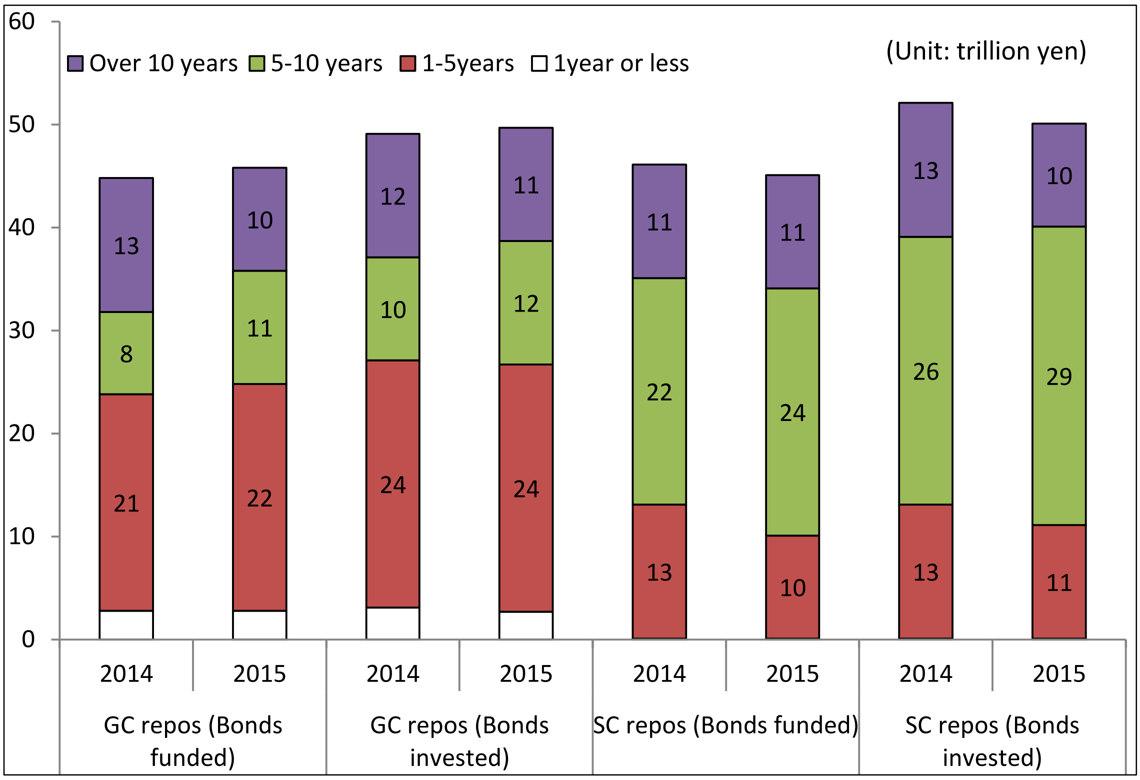
2. The definition of FII and FBI are explained at the section of inflation expectation channel.

Graph 11 **Inflation Expectation and Foreign Exchange Rate**



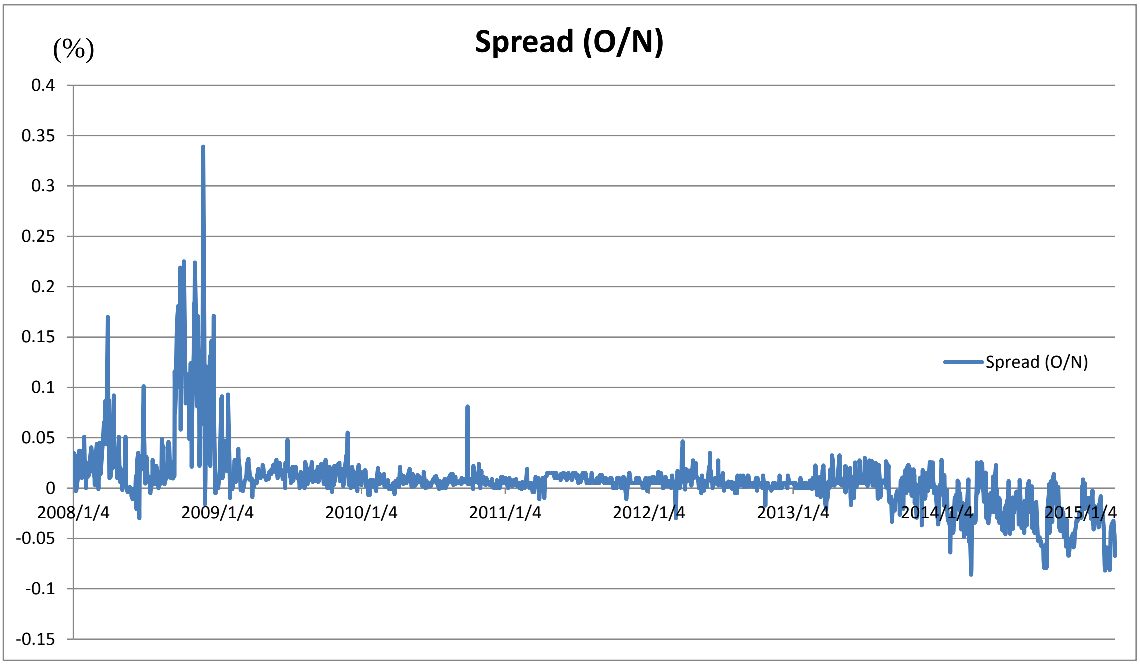
Source: Bloomberg, Barclays Capital

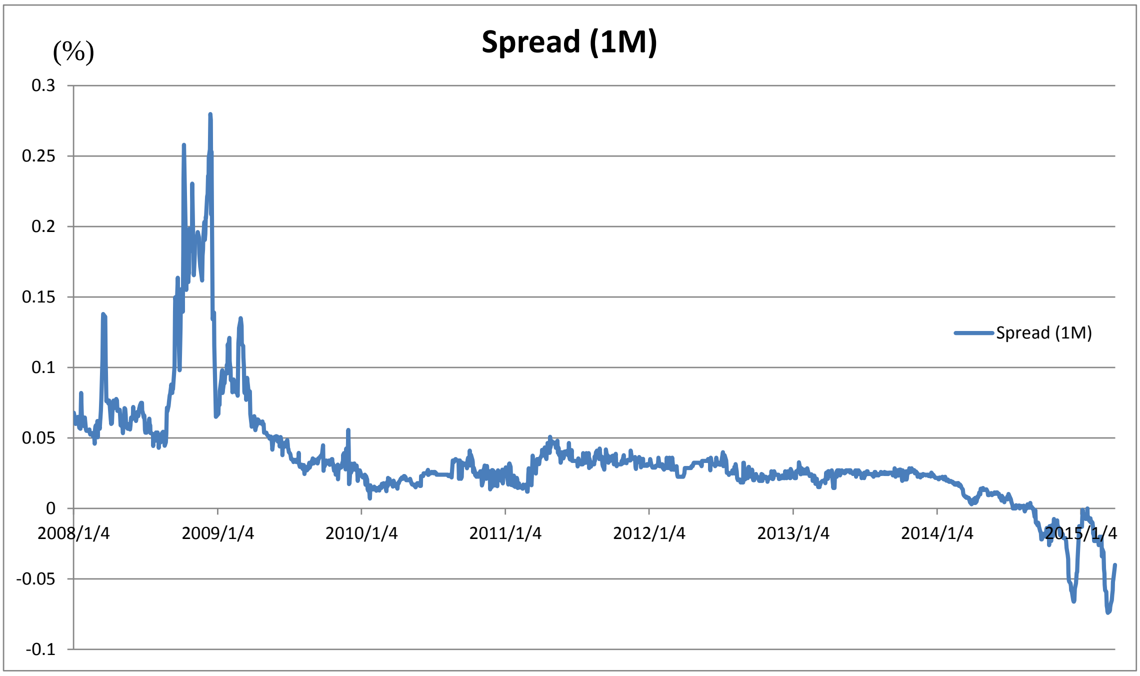
Graph 12　Amount Outstanding of Collateral Bonds of Repos by Remaining Maturities



Source: Bank of Japan (Tokyo Money Market Survey, 2015)

Graph 13 Spread of Repo Rates against Interbank Money Market Rates

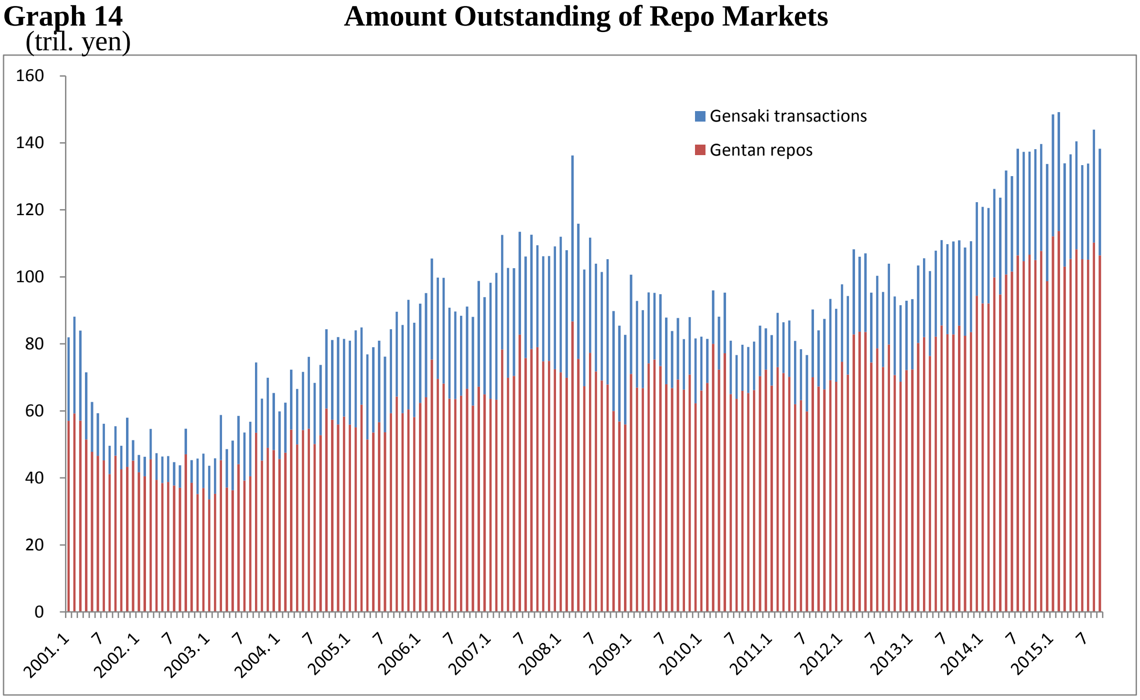




Source: Bloomberg

Note: Spreads (O/N, 1M) are defined as JGB repo rates (O/N, 1M) minus uncollateralized call rate (O/N) or OIS (1M).

Graph 14 **Amount Outstanding of Repo Markets**



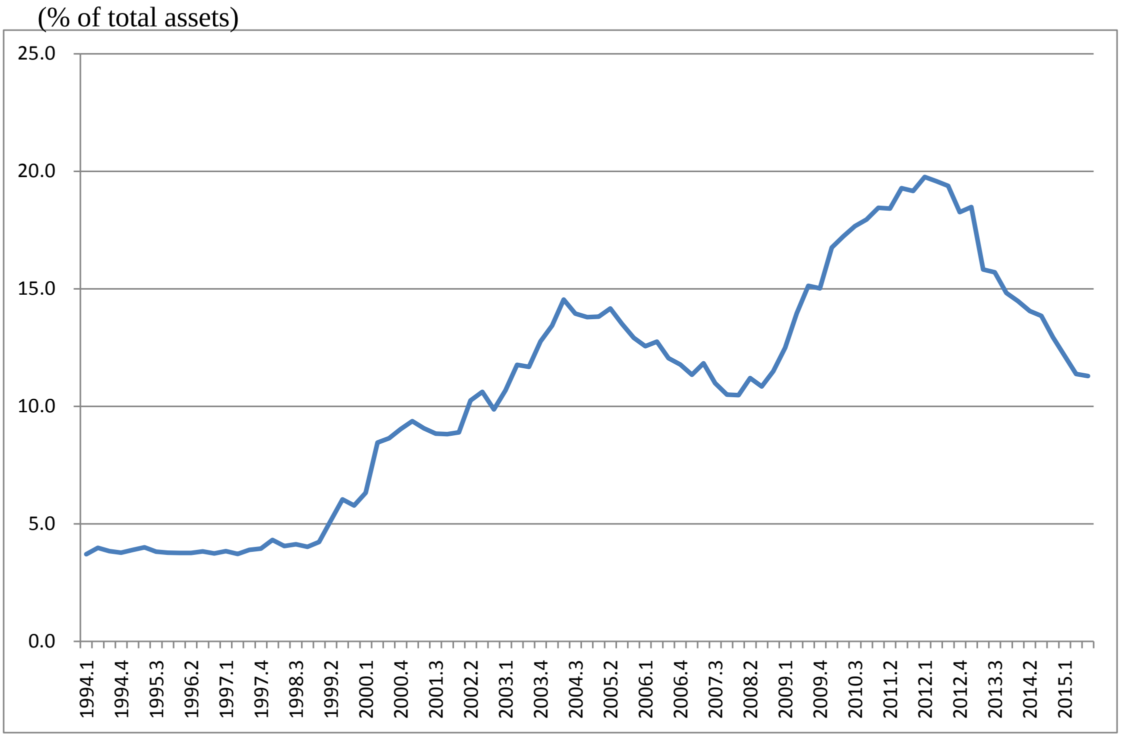
Source: Japan Securities Dealers Association

Note: 1. Repo transactions refer to Gensaki transactions and Gentan repos.

2. Gensaki transactions are repos configured as transactions consisting of a bond purchase with a promise to conduct a repurchase in the future.

3. Gentan repos are repos configured as transactions consisting of cash as collateral to borrow securities.

Graph 15 **JGB Holdings by Domestically Licensed Banks (Banking Accounts)**



Source: Bank of Japan (Monetary Aggregates)