Transmission Channels and Welfare Implications of the Quantitative and Qualitative Monetary Easing Policy in Japan

Hiroshi Ugai
Doctor Course (16GD503)
Graduate School of Humanities and Social Sciences
Saitama University

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Abstract

This paper comprehensively integrates the recently developed theoretical frameworks of unconventional monetary easing policies since Ugai (2007), based on the Bank of Japan's (BOJ) Quantitative and Qualitative Monetary Easing Policy (QQE) (2013–2015) and the Comprehensive Monetary Easing Policy (CE) and subsequent monetary easing policies (2010–2012), and examines the effects of the BOJ's QQE by transmission channels compared to the CE and subsequent policies through an event study using financial market data. Furthermore, this is the first paper to examine the side effect of the BOJ's huge Japanese Government Bonds (JGB) purchases on the shortage of safe assets in the markets and their implications for economic welfare. Since the negative interest rate policy (NIRP) and the yield curve control (YCC) include the traditional interest rate channel, this paper does not assess the QQE with NIRP (2016) and the QQE with YCC (2016–present).

First, this paper discusses and examines five theoretical channels of the unconventional monetary easing policy, namely, the signaling channel, credit easing channel, portfolio balance channel, safety channel, and inflation channel. Among them, the effect of the signaling channel to affect the public's and markets' expectations for the future path of interest rates is theoretically clear and is widely used in central banks of developed countries. An irrelevance proposition denies the effects of the credit channel, portfolio channel, and safety channel, but recent theories tolerate the existence of these effects by assuming a binding constraint for participating in the markets due to a decline in investors' ability to take risks or to heightened risks of financial assets, a coexistence of investors with preferences for specific maturities and risk-averse arbitragers, or valuing safe assets for facilitating financial transactions. Therefore, their effectiveness is subject to empirical analysis. Furthermore, in Japan the direct inflation expectation channel had not been discussed in the past when the BOJ conducted a quantitative easing policy, but the QQE explicitly aims at raising inflation through this channel.

Next, according to the event study, for the QQE under normal market conditions, the depreciation of the yen, not the decrease in yields of JGBs and corporate bonds, possibly through the portfolio balance channel functions quite strongly, while for the CE in dysfunctional market conditions, the commitment and credit easing function strongly. Signaling channel does not function for the QQE. The direct inflation expectation channel is weak for both the QQE and CE, although the QQE has adopted various ways to exert a direct and strong influence on inflation expectations. The gradual increase in inflation expectations came mainly from other channels, such as the depreciation of the yen. In other words, the QQE cannot significantly decrease real interest rates directly, but decrease them through the indirect effect of the yen's depreciation on inflation expectations. The overall effects are not strong enough to raise the CPI inflation to the 2 percent target level within the committed period.

The most crucial characteristic of the QQE is its maximization of the potential effects of an easing policy by explicitly doubling and later tripling the purchased amount of long-term JGBs and the monetary base proportionally. However, the JGB purchases by the BOJ surpass the issued JGBs, thereby reducing the outstanding JGBs in the markets. Theoretically, a shortage of safe assets would increase the convenience yield, which would reduce economic welfare, and would not permeate the yields of other risky assets, thereby not stimulating the economy. Therefore, this paper examines the impact of a reduction in long-term JGBs on yield spreads between corporate bonds and JGBs based on a money-in-utility–type model and an additional finance approach. The results indicate that a severe scarcity of JGBs as safe assets has been avoided because Japan's outstanding public debt is the largest in the world.

Nonetheless, a convenience yield has been priced in since the introduction of the QQE, and the event study shows no clear evidence that a decline in the yield of long-maturity JGBs induced by the QQE permeates the yields of corporate bonds. Aside from other channels, while no change in the yields of corporate bonds suggests no welfare gains for these large purchases of JGBs from the perspective of safety channels, the existence of the convenience yield itself reduces economic welfare despite not being large so far. Since the global financial crisis (GFC) in 2008, the demand for JGBs as collateral has increased from investors and from financial institutions that have to uphold strengthened global liquidity regulations. In addition, since the introduction of the QQE, market expectations for future planned JGB purchases by the BOJ and a partial shortage of safe assets due to market imperfection may also work. The scarcity of safe assets should be examined with due consideration of these recent changes and their welfare implications when the BOJ designs the future path of JGB purchases.

Keywords: quantitative easing, credit easing, inflation expectation, safe asset
JEL Classification: E43, E44, E52

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Introduction

When faced with the zero lower bound of the short-term interest rate, the Bank of Japan (BOJ) implemented the Quantitative Easing Monetary Policy (QEP) from 2001 to 2006, well in advance of other developed countries. At that time, there were heated discussions regarding the policy's effectiveness (Ugai 2007). Following the global financial crisis (GFC) in 2008, most major central banks have also faced the zero lower bound (Figure 1). Subsequently, the Federal Reserve pursued large-scale asset purchases (LSAPs), followed by the Bank of England and the BOJ. Recently, although the Federal Reserve terminated LSAPs and has begun to increase the policy rate, the European Central Bank (ECB) has adopted an unconventional monetary policy that includes an expanded asset purchase program. Although researchers have begun to summarize the effects and side effects of these unconventional monetary easing policies theoretically and empirically (IMF 2013), they are yet to reach a consensus. Quite recently, both the ECB and the BOJ have adopted a negative interest rate policy (NIRP) in addition to the quantitative easing policy. Furthermore, in September 2016 the BOJ switched from the QQE with NIRP to the QQE with yield curve control (YCC) to take into account the side effects on financial institutions and the limits on the increase in the Bank's JGB purchases.

It is especially difficult to discern the effects of these unconventional policies, since they usually serve two purposes: to counter situations that disturb financial intermediary functions and to prevent economies from experiencing deflation. Even if the effect on deflation is small, it is hard to judge it because the disrupted financial intermediation function could have impeded the unconventional monetary easing policy function. In addition, there has always been a discussion that this ineffectiveness could be due to the small degree of the monetary easing. It is also difficult to discern their side effects by almost the same token. By adopting an aggressive monetary easing policy in normalized markets, the BOJ's recent policy stance provides the opportunity to deepen the understanding of its impacts.

The unconventional monetary easing policy when facing the zero rate lower bound consists generally of two variations: credit easing that focuses on the asset side of the central bank's balance sheet, such as the purchase of risky assets in malfunctioning markets; and quantitative easing that focuses on the liability side of the central bank's balance sheet, such as the purchase of government bonds and the subsequent expansion of the monetary base. Central banks have combined either or both with various other measures during emergencies in the financial system. In addition to these easing tools, signaling a future monetary policy also affects the public's and market's expectations. Furthermore, the NIRP intends to lower the short-term real interest rates below the quite low natural rate of interest directly, and the YCC is a new policy to set the appropriate shape of the yield curve.

Chronologically, since the GFC negatively impacted Japanese economic and financial conditions, the BOJ cut the policy rate in 2008 and introduced operational devices to enhance monetary easing in 2009. In 2009, the BOJ introduced market operations with commercial paper (CP), asset-backed commercial paper (ABCP), and corporate bonds with short maturity as collateral as a last resort (Suda 2014). The BOJ eased the monetary policy by encouraging a decline in longer-term interest rates in the money markets at the end of 2009, and introduced a fund-providing measure to support financial institutions' strengthening of the foundations for economic growth in June 2010. Subsequently, the BOJ adopted the Comprehensive Monetary Easing Policy (CE) that had strong credit easing characteristics in October 2010 and implemented measures to improve the dysfunction of financial intermediaries and the deflationary pressure within this framework (Table 1). In February 2012, the BOJ adopted a medium- and long-term price stability goal of a positive range of 2 percent consumer price index (CPI) inflation or lower, and a short-term goal of 1 percent. Prime Minister Abe, who took office in December 2012, introduced Abenomics, which consists of the three-pronged approach of bold monetary easing, flexible fiscal policy, and a growth strategy as a structural reform to revitalize Japan's economy. In line with Abenomics, in January 2013 the BOJ introduced a price stability target of 2 percent CPI inflation, and the Government of Japan and the BOJ published a joint statement on overcoming deflation and achieving sustainable economic growth that clarified each role. In April

2013, the BOJ adopted the 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. On January 29, 2016, the BOJ newly introduced the NIRP (lowering the short-term rate on excess reserves to -10bp) in addition to the QQE, entering a new dimension of monetary easing that is called QQE with NIRP. On September 21, 2016, the BOJ again changed the monetary policy framework to QQE with YCC (setting the short-term rate on excess reserves to -10bp, and targeting the 10-year JGB yield at 0 percent), with a view to appropriately adjusting the shape of the yield curve to stimulate the economy while avoiding the significant side effects on the profitability of financial institutions, and avoiding reaching the limits on purchasing JGBs. As of now, a core CPI inflation (excluding fresh food) is -0.4 percent year-on-year as of October 2016, and even the CPI inflation (excluding fresh food and energy) that the BOJ regarded as a better indicator of the trend of inflation is 0.3 percent, far short of the 2 percent price stability target.

One important characteristic of the QQE in Japan is the BOJ's intention to drastically change the deflationary mindset. This differs from other countries' unconventional policies that handle credit frictions and promote economic growth while maintaining the inflation rate at a target level. To attain this, the BOJ has attempted to affect inflation expectations directly with various tools. First, under the QQE, the BOJ promised to attain the 2 percent price target in about two years. Second, the BOJ committed to continuing the current QQE as long as it attains the target in a stable manner. This commitment was reinforced by introducing the inflation-overshooting commitment of continuing the expansion of the monetary base until the CPI exceeds the 2 percent target in a stable manner, when the BOJ introduced the framework of the QQE with YCC. Third, the QQE (especially QQE2) plans to purchase and hold the largest amount of assets among the central banks, mainly Japanese government bonds (JGBs) (Figure 2). The asset size of the BOJ and that of the monetary base expands to almost 80 percent of GDP. Thus, it is important to determine the combined effects of such a drastic monetary easing scheme on inflation expectations as compared to the effects of credit easing, where central banks purchase risky assets that are not traded smoothly in the financial markets.

At the same time, since the BOJ is purchasing long-term JGBs at an unprecedented level, the BOJ is essentially the sole purchaser of JGBs in the secondary markets. Therefore, considering the continuation of the QQE by the BOJ in a foreseeable future, the BOJ and Japanese government must handle many issues, such as the possible side effects on financial institutions, management of the BOJ's balance sheet, and the management of public debt. Among these issues, this paper examines and studies the welfare implications of a central bank's large purchase of safe assets.

Correspondingly, this paper examines the effects of the BOJ's QQE compared to the effects of the CE and subsequent monetary easing policies by transmission channels. To extract the effects of unconventional monetary policy transmission channels, this paper omits the following monetary policies: the BOJ's easing policies during 2008 and 2009 following the Lehman shock, because most were accompanied with a cut in the policy rate within a positive range or an expansion of collateral; and the QQE with NIRP and QQE with YCC, since the NIRP and the YCC include the traditional interest rate channel, although short-term rates break the zero lower bound and are accompanied by other unconventional channels. Finally, the welfare implications of purchasing a massive amount of JGBs by the BOJ will be specifically examined.

The remainder of this paper is organized as follows. Chapter 1 considers the theoretical transmission channels of the CE and QQE. Chapter 2 extracts the effects by various channels based on an event study. Chapter 3 shows the welfare implications of the massive purchases of JGBs through a theoretical model and discusses its empirical results. The final chapter provides the conclusion and discusses challenges for future research.

1. Theoretical Transmission Channels of Unconventional Monetary Easing Policies

This chapter first classifies the assumed transmission channels of unconventional monetary easing policies based on the BOJ's CE and QQE.

This chapter does not consider 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 short-term government bonds. In general, the abundant provision of liquidity under the quantitative easing framework successfully maintains extremely easy monetary conditions. However, once the interest rate reaches zero and the opportunity cost of the money is eliminated, there is no marginal utility gained from liquidity service when the real money balance exceeds a certain threshold (satiation level). Therefore, the demand for reserves becomes infinitely elastic and can be provided indefinitely without influencing the economy. Aside from this pure quantitative easing channel, credit and/or quantitative easing still have many channels, most through the asset side of the central bank and future expectations of its monetary policy stance. This chapter discusses five channels in detail, based largely on Ugai (2007). However, since the BOJ has developed the monetary easing framework further in comparison to the QEP (2001–2006), this chapter combines new theories with the original framework.

A) Signaling channel

If a central bank commits to expected future interest rates lower than the markets and public expect, it can reduce the volatility of the expected future policy rates (Ugai 2007, Filardo and Hofmann 2014) and lower the expected future interest rates (Ugai 2007). This channel is generally referred to as the signaling channel or the forward guidance channel.

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

Woodford (2012).

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 lower bound through the commitment if it were to assume a permanent increase in the size of the monetary base. In other words, if the monetary base were planned to increase consistently with future economic and price outlooks, the public and markets would view this as a commitment to the future monetary policy, and thereby, the classic proposition that $MV = PY$ would hold on average. However, the current planned monetary base in Japan is so large that the future path of the monetary base is expected to reduce to the amount required by the 2 percent inflation target during 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 to the merit of the commitment to massive and open-ended purchases of government bonds as a device to avoid the time inconsistency that the commitment to continue the zero interest rate would have when the end approaches. Indeed, it takes time to decrease the asset size of the BOJ, because most of its assets are long-term JGBs. However, if the central bank fears future excessive easing, it can combine measures to increase the short-term policy rate while not selling the purchased long-term bonds. In this case, expanding the monetary base could still experience time inconsistency.

Moreover, when the BOJ adopted such commitments, even long-term interest rates were low, suggesting little room for expansionary effects. Thus, the degree of the effects of these commitments is subject to an empirical test.

B) Credit easing (targeted asset purchase) channel

If a central bank holds less of one asset and more of other assets, the private sector holds more of the former and less of the latter. Whether this changes consumption behavior has been an important topic of debate. Eggertsson and Woodford (2003) suggest an irrelevance proposition, the Modigliani-Miller Theorem for central bank operations, as follows: The market price of any asset 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, a household's marginal utility of income in the different states would not change. If this theory holds, a central bank that takes risks onto its balance sheet through open market operations would not make the risks disappear from the economy. This assumes 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 for assets being valued for their pecuniary returns.

The first possible exception is a binding constraint for participating in the markets. When 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 such as 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 impact the markets. Curdia and Woodford (2009, 2011) introduced credit friction into the model and showed that financial disturbances increase the marginal social benefit of the central bank's credit policy to a greater extent, given that the zero lower bound prevents the policy rate from declining in response to a negative shock. They also suggested that the appropriateness of an active credit policy is likely to depend on conditions that are specific to the markets for a particular financial instrument, which cannot be assessed solely from the macroeconomic perspective.

These dysfunctional markets occurred after the GFC, and the CE of the BOJ, in addition to other purposes, such as exiting from deflation, aimed to make the markets and the financial system function well. On the other hand, when the BOJ adopted the QQE, the financial system had returned to its normal conditions.

C) Portfolio balance channel

If the irrelevance proposition holds, the portfolio balance channel would not function. This questions the extent to which assets are valued for their state-contingent pecuniary returns and whether investors can rationally anticipate the consequences of their portfolio choices (Ugai 2007).

The second possible counterargument refers to the preferred-habitat view proposed by Culbertson (1957) and Modigliani and Sutch (1966). They assume that some investors have preferences for specific maturities, and the interest rate for a given maturity is influenced by demand and supply shocks that are unique to that maturity. This has been widely recognized by practitioners but was established in modern theory when Vayanos and Vila (2009) built a formal model. This model assumes that the term structure of interest rates is determined through the interaction between investors with preferences for specific maturities and risk-averse arbitragers. The major preferred habitat buyers appear to be the BOJ, insurance companies, and pension funds. Bond yields are determined by two mean-reverting factors: the short-term rate and the demand factor. If an arbitrager's risk aversion is high, the short-term rate is not a dominant risk factor and the location of the 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 considers that the preferred-habitat demand is applied to all fixed-income securities, not just JGBs. This broad perspective has not been theoretically discussed but reflects the views of those central banks that have adopted unconventional monetary policies. In this setting, the central bank's massive purchases of government bonds could influence the demand-supply conditions of those markets and alter the yield curve, and could then permeate the yields of other bonds. The QQE focuses mainly on purchasing government bonds by expecting the portfolio balance to function broadly, although it also purchases other risky assets. However, to what extent the price effects of local shocks are transmitted to the term structure of many bonds is still subject to empirical testing. According to Ugai (2007), this channel was weak when the BOJ introduced the QEM (2001–2006). However, this may change now that Japan's financial system works normally, with few nonperforming loans, and the BOJ purchases more JGBs.

The BOJ has purchased more than the issued JGBs as a net of their issue and redemption, and has accelerated this purchase behavior since the adoption of QQE2 (Figure 3). The major sellers are financial institutions, as JGBs are owned mostly by them. Domestically licensed banks and the Japan Post Bank are the largest net sellers, and quite recently even insurance companies and public and private pension funds sell JGBs. It is worth noting that according to the irrelevance proposition, if a central bank buys more of JGBs by selling money, private investors should negate the activity of the central bank. Thus changes to the contents of the private investors' portfolios cannot determine whether the portfolio balance channel works. Under the portfolio balance channel function, a change in the relative prices of all assets is required to induce private investors to adjust their portfolios, which is a subject to empirical testing.

This paper considers that this preferred-habitat demand is applied also to exchange rates through rebalancing the international portfolio. Stock prices are not evaluated in this paper because they indirectly reflect changes in the prices of other securities and foreign exchange rates. In addition, when investors try to rebalance both JGBs and foreign securities, the effect on the exchange rate has to take into account other countries' relative economic and financial conditions. As for the USD/JPY exchange rate, after the Lehman shock, the Federal Reserve also adopted and terminated LSAPs. 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 chapter assesses also the uncovered interest rate parity and introduces the long-run risk model of Bansal and Shaliastovich (2013) that real uncertainty (such as uncertainty of expected growth) decreases bond risk premiums because of flight to quality (preferring investment in safe bonds), while nominal uncertainty (such as uncertainty of expected inflation) decreases bond premiums at short maturities and raises them at longer maturities by gradually dominating the flight-to-quality effect.

Nevertheless, the question of why the preferred-habitat demand exists theoretically except for the central bank (Waller 2015) remains. Whether the preferred-habitat demand reflects an inherent preference or forced behavior by external factors, such as regulations or rules, is unknown.

D) Safety channel

The last possible exception is that JGBs may also be valued for facilitating transactions. In this context, Krishnamurthy and Vissing-Jorgensen (2012-a) theorize that government bonds have high safety characteristics that lower their yields compared to those of other assets. Evidence shows that the yield spread between long-maturity AAA-rated corporate bonds and long-maturity US Treasury bonds have an inverse relationship with the government debt-to-GDP ratio that shows the demand function of the Treasury bonds. When there is a limited supply of government bonds, investors assign higher value to the safety (convenience yield) provided by the government bonds, thereby decreasing the yield on government bonds relative to the yield on the less-safe AAA corporate bonds. This paper applies this 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 (Figure 4), which illustrates a similar inverse relationship.

[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.

This spread is not the same as the risk premium of a standard asset-pricing model. This is an additional premium that investors are willing to pay for safe assets. Krishnamurthy and Vissing-Jorgensen (2011) plot the price of an asset against its expected default rate and show that the curve of the asset price against its expected default rate is 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 increases as the supply of government bonds decreases.

Since the BOJ adopted the QQE, it has absorbed more JGBs than are issued, which is expected to exceed the gross issuance amount of JGBs in the near future (Figure 3). Thus, the amount of outstanding JGBs is decreasing (Figure 5). The JGB-to-GDP ratio of the consolidated government (Government of Japan plus BOJ) peaked at 147.7 percent in 3Q/2012 and continues to decline (Figure 5).

When a central bank purchases massive amounts of government bonds from the markets, the amount of government bonds available for market participants is reduced and the convenience yield increases. Therefore, the safety channel derived from the net supply of 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, nor any stimulus to aggregate their expenditure.

E) Inflation expectation channel

The final important channel is raising the inflation expectation directly. There are two possible routes to raise inflation expectations: through some of the aforementioned channels or through directly increasing such expectations. Ugai (2007) does not mention the latter route for the QEM 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 that the BOJ's current monetary easing policy differs from the current monetary easing policies adopted by other major central banks by aiming for the 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 BOJ's commitment to and the increase in the monetary base and the decrease in various yields that underpin it. The BOJ (2015) insists in "Outlook for Economic Activity and Prices" that inflation expectations have increased due to its commitment to achieve the price stability target of 2 percent, although the BOJ admits that Japan's inflation expectations have strong adaptive expectation characteristics.[2]

The next chapter examines the strength of this inflation expectation channel by using the inflation swap rates and break-even inflation rates of inflation-indexed government bonds. Inflation swap is a financial derivative instrument used to hedge inflation, and the fixed-rate payer measures the expected inflation rate over the life of the swap in an efficient market. The 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 the inflation expectations of market participants. The following chapter examines whether inflation expectations shown by such financial instruments increase after the decision to implement monetary easing. By examining a market reaction in two days, the effect of other channels on inflation expectations that take more time can be removed. However, due to a lack of sufficient liquidities in the market, a 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 a cash constraint (Imakubo et al. (2015)). Since both instruments have some distorting factors, this paper will also compare other inflation expectation indicators. The aim of this analysis is to extract the direct impact on inflation expectations, not the overall impact on inflation through various other channels, such as a

[2] Recently the BOJ (2016) has clearly admitted that Japan's inflation expectations have highly adaptive characteristics, and that it may take time to shift up the inflation expectations.

depreciation of the exchange rate and/or a reduction of the output gap.

F) Summary

Similar to Krishnamurthy and Vissing-Jorgensen (2011),[3] the above five channels can be shown as the real rate of a *t*-year long-term, risky financial asset at time *t* ($r_{t,risky,long-term}$), such as a corporate bond. The nominal yield of a short-term, safe financial asset at time *t* is $i_{t,safe,short-term}$, with π_t^e being the expected inflation at time *t*. This decomposition is analogous to the CAPM, where the return on assets is decomposed as the asset's betas, multiplied by the market risk premium:

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

where the first line indicates the signaling channel and the inflation expectation channel. The long-term real yield reflects the average of the expected future real short-term interest rates. The signaling channel affects $\frac{1}{T}\sum_{t=0}^{T} E[i_{t,safe,short-term}]$, and the inflation expectation channel affects π_t^e. The second line is for the credit easing channel and the third line is for the portfolio balance channel. It is important to note that the credit easing channel occasionally overlaps the

[3] This is just an analogy, and the channels differ from that of Krishnamurthy and Vissing-Jorgensen (2011).

portfolio balance channel. The fourth term shows the extra yield on the non-safe assets since they lack safety, such as government bonds.

However, 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 the relative economic and financial performance of related countries.

Based on this framework, the event study of BOJ’s CE and QQE will be conducted and assessed in the next chapter.

2. Empirical Results by Transmission Channels from the QQE and CE

This chapter employs data from the QQE, CE, and subsequent policy changes to compare their effects and analyze their transmission channels by using an event-study methodology. This event study uses the reaction of financial market data at the time of each policy change. Because it is hard to theoretically derive the specific model to incorporate all these channels, and because even a vector auto regression (VAR) model cannot discern all these channels, it is appropriate and common to use the event study for the analysis of an unconventional monetary policy. In addition, this method is superior, especially for the BOJ's QQE, because this policy had not been fully expected by the markets.

Following the approach of Krishnamurthy and Vissing-Jorgensen (2011) with slight modifications, this chapter treats these policies as important events and examines two-day changes in yields, specifically, the yields of many financial assets one day after the policy change as compared to the day before the policy change. More concretely, for the signaling channel, this chapter examines the events of the QQE and of the QQE2 that did not have an explicit additional commitment from the BOJ. Since the BOJ's current bold monetary easing is backed by the government of Japan within the framework of Abenomics, the relevant movement not necessarily reflected at the time of the adoption of the QQE is also examined. For the credit easing and portfolio balance channels, the events of all actual easing policies are examined. Then, for the inflation expectation channel, the events of the CE, QQE, and QQE2, and of setting the price stability goal and target, are examined.

The tables in this chapter focus on the total change in yields or prices of daily data from the beginning of 2010 through November 2014. Since all data periods are during a 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 the JGBs by maturities (10-year, 5-year, 3-year, and 1-year), and corporate bonds by ratings (AA, A, and BBB) and by maturities (10-year only for AA, and 5-year, 3-year, and 1-year for all ratings),[4] the logarithm of the USD/JPY spot exchange rate, and the inflation swap rates and break-even inflation rates of the 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 announced late in the afternoon. Some outlier events are also controlled in the corporate bond yields by dummy variables, such as the distortion in the ratings of some large companies that were caused by the amendment of the Money Lending Business Law (from December 20, 2006 through June 18, 2010) and by the Great East Japan Earthquake (March 11, 2011). These regressions are estimated using the ordinary least squares (OLS) estimation method with robust standard errors to consider heteroscedasticity by applying

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[4] This is to secure ample number of issuers. The yields of 10-year AA, A, and BBB maturities can change largely by idiosyncratic shocks due to fewer issuers.

Newey-West's HAC estimator. Finally, an F-test is used to test for the statistical significance of the sum of the coefficients of two-day changes of the entire monetary easing policy.

This event study captures the reactions of the markets following the announcement of a policy change based on the assumption that bond prices and exchange rates react fully to that news. For the credit easing channel, portfolio balance channel, and safety channel, if investors act partially on the demand and supply conditions from the policy change announcement, they may react to the actual market operations by the BOJ.[5] However, this presumption is reasonable because the BOJ fully explains its intentions for policy changes, and the markets digest the BOJ's announcements immediately. Indeed, the prior research of Lam (2011) investigated the impact of the BOJ's asset purchase program from 2005 to 2011, and concluded that the announcement effect outweighed that of the actual asset purchases. This treatment is also consistent with the analysis of the Federal Reserve's LSAP by Gagnon et al. (2011).

A) Signaling channel

The events of the BOJ announcing its commitment to the CE and QQE are chosen to examine the existence of a signaling channel. Here, the changes in the overnight index swap (OIS)

[5] Fukunaga et al. (2015) conducted an event study at the time of market operations and concluded that the duration risk channel (almost the same as the portfolio balance channel) exists in the JGB markets. That said, they did not separate the duration risk channel from the safety channel.

rates following such policy actions are examined because the OIS in Japan provides the swap rate between the overnight uncollateralized call rate and fixed-term rates, and is a reflection of the market expectations of the future policy rates of the monetary policy. Figure 6 shows the development of the OIS rates the days before and after the CE and QQE announcements, along with those of the QQE2. It is clear that the market participants expected the CE to extend the easing period longer than their expectations, especially for periods of longer than three years. The QQE, on the contrary, raised the expected policy rates for 2-5 years. The QQE2 had no additional signaling effect, which is consistent with the theory. These results are shown in Table 3, where the F-test indicates a 1-percent significance.

Nonetheless, the markets may have reacted before the actual adoption of QQE by expecting drastic monetary easing in line with Abenomics. To verify this possibility, two events are introduced here. The first is the 2 percent price stability target that was set on January 22, 2013, where both the government of Japan and the BOJ published a joint statement promising to work together, with the BOJ pursuing monetary easing to achieve the price stability target while the government managed the flexible fiscal policy and strengthened the competitiveness and growth potential of the Japanese economy. The second is Governor Kuroda's first general policy speech at the House of Representatives of the Diet on March 4, 2014. According to Figure 7, the markets did not extend the expectations for easing period based on these events. Therefore, the conclusion of the QQE remains after considering these major events in relation to Abenomics. The market response to the QQE can be explained in two ways. First, since the BOJ made two commitments, the overall signal may have been unclear for the markets. If a market participant believes the BOJ's commitment to attaining 2 percent inflation in about two years, the expected policy rate should increase two years later. On the other hand, the BOJ also committed to continuing the QQE until it attained the target in a stable manner, suggesting that the zero rate would be maintained. Since these commitments were contradictory, the markets could not factor in the extension of the easing period. The second possible explanation is that the state-contingent commitment about the continuity of the QQE was linked to the monetary base without explicit forward guidance about the policy rate, so that market participants may not have been able to imagine the future monetary easing path of the policy rate (Filardo and Hofmann 2014). Based on the past fact that the commitment of the BOJ's QEP (2001–2006) linked to the monetary base was effective (Ugai 2007), the first hypothesis has more likely explanatory power. That said, since it took almost three and a half years since the BOJ introduced the QQE, the signaling of "around two years" has lost its meaning recently. On the other hand, when the BOJ newly adopted the NIRP in 2016, the long-term yields declined dramatically. The NIRP is an interest rate policy and provides the signal of an interest rate path explicitly.[6] Thus the second hypothesis may be also

[6] The inflation-overshooting commitment that the QQE with YCC has adopted in 2016 is intended to reinforce the effect of the commitment on inflation expectations, but this paper does not treat this issue.

applicable.

B) Credit easing (targeted asset purchase) channel

The CE in 2010, and the monetary easing following the Great East Japan Earthquake, had the characteristics of a credit easing policy, as did the subsequent monetary easing policies (before the adoption of the QQE) to some extent. This chapter focuses on the effect of these policy changes. The impact on JGB yields are shown in Table 4, and those on corporate bond yields by credit ratings are shown in Table 5. To control for the credit evaluation of companies changing faster than the credit ratings, Table 6 shows the results of adjusting their creditworthiness by the daily changes in the credit default swap (CDS) spreads of each rating to compare the changes in yields with the same creditworthiness. Finally, Table 6 shows the impact on the USD/JPY exchange rate.

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

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See Ugai (2016-a) for the assessment of the effects of this new commitment.

the USD/JPY exchange rate depreciate.

However, this result might include the signaling channel. To exclude the effect of such a channel, the event study was also conducted for the spreads between CDS-adjusted corporate bond yields and JGB yields. Although this treats the credit channel narrowly, it can capture the pure effect of credit easing in that successful credit easing has more influence on the corporate bonds than on the JGBs if the corporate bond markets are dysfunctional. Table 7 shows that during the CE and the subsequent monetary easing, the credit easing channel worked, especially for longer-term yields and for BBB-rated corporate bonds. While there were fewer instances where the monetary policy narrowed the credit spread, a large effect occurred during the monetary easing immediately following the Great East Japan Earthquake.

Overall, the results of the CE suggest that the financial markets continued to malfunction after the GFC, and that the purchase of a variety of financial assets through the asset purchase program slashed the yields of those assets. This result is consistent with the empirical results of the LSAP1 of the Federal Reserve that was introduced after Lehman Brothers collapsed in 2008 (Krishnamurthy and Vissing-Jorgensen 2011). Further, there is 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 are more uncertain about longer futures.

Finally, when the QQE was adopted, the financial markets had already returned to "normal" conditions. Therefore, it is not surprising that the impact of the QQE through the credit easing channel is not extracted here.

C) Portfolio balance channel

During the QQE, the BOJ purchased massive amounts of JGBs and risky assets in already normal financial markets. According to Tables 4, 5, and 6, the degree of the decreased yields of the JGBs and corporate bonds is smaller than that of the CE and the monetary easing immediately following the earthquake.[7] More precisely, the QQE lowered the yield of the 10-year JGBs, possibly reflecting the fact that the QQE focused on lengthening the duration of the purchased JGBs. However, the impacts on the yields of other maturities of JGBs and corporate bonds are not consistent with the portfolio balance channel. All suggest that purchasing massive amounts of JGBs does not lower the yields of a variety of maturities of corporate bonds. Since the autumn of 2014, many companies have begun to issue bonds with the lower limit on the interest rate,[8] suggesting that they have offset the impact of the BOJ's work to induce investors to purchase bonds. This may also be consistent with banks generally suffering from a tightened lending margin and not lowering the lending rates more.

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[7] Because the signaling channel does not work during the QQE period, the results for the QQE do not include the signaling channel.

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

It is possible that the effect of the portfolio channel of the QQE is inherently weak, partly offset by the safety channel. The next chapter will evaluate the possibility of the safety channel working. But before that, the following analysis checks the other possibility that the announcement of the QQE and QQE2 surprised the markets so much that the rise in the uncertainty of the BOJ's reaction function may have weakened their effect on the yields in the short term. If the volatility continued for more than two days after the introduction and expansion of the QQE, this analysis would underestimate the size of the portfolio balance channel. Figure 8 presents a plot of every trading price of JGB 10-year futures (tick) for two consecutive days after the change in the monetary policy. Compared to the introduction of the CE, the introduction of the QQE and its expansion made the markets more volatile. However, even following the introduction of the QQE, the markets calmed down by the end of the next day. Therefore, this hypothesis can be discarded, implying that the effect of this channel is inherently weak.

On the other hand, the impact on the exchange rate shows a remarkable contrast with the above yields of financial assets. The QQE had a large impact on depreciating the USD/JPY exchange rate, differing from the CE and the monetary easing following the earthquake, which had no such impact. Based on the portfolio-balance channel, the BOJ's massive JGB purchases could prompt investors to take foreign assets if there are lower long-term yields, thereby letting the yen depreciate. However, considering that the QQE had a smaller impact than the CE and subsequent monetary easing policies on lowering the yields of many assets, it is necessary to determine why the QQE's effect on the exchange rate was so large.

There are two hypotheses to explain this. The first hypothesis is the difference between how domestic investors and foreign investors view the QQE. Domestic investors may not have reacted as strongly to the QQE, while foreign investors may have reacted strongly. Domestic investors are dominant players in domestic securities markets, as are foreign investors in the foreign exchange markets (forex), and the foreign investors reacted to the QQE. Some foreign hedge funds reacted to the BOJ's easing policies by selling yen. Fukuda (2014) and Ueda (2013) examined investor behavior and the difference between the behavior of domestic investors and foreign investors. Following Fukuda (2014), this paper divides the accumulated changes in the USD/JPY exchange rate into those that occurred during Tokyo daytime and Tokyo nighttime. Tokyo daytime is defined as from 9 am to 5 pm in Tokyo, when domestic investors are assumed to be dominant, whereas Tokyo nighttime is defined as from 5 pm in Tokyo to 5 pm in New York, when foreign investors are assumed to be dominant. The trading from 5 pm in New York to 9 am in Tokyo is excluded, because both domestic investors and foreign investors trade during this time. Figure 9 clearly shows that the USD/JPY exchange rate depreciated during the Tokyo nighttime, especially around the adoption of the QQE and the QQE2, and not during Tokyo daytime, thereby suggesting that foreign investors reacted to these policies more than domestic investors. These asymmetric reactions between foreign and domestic investors may be attributed to asymmetric risk tolerance or asymmetric information about the QQE across investors, as Fukuda (2014) infers. For example, overconfidence in the QQE by foreign investors and pessimistic views by local investors may explain the asymmetry. The reasons behind this asymmetry should be investigated by further analysis.

The second hypothesis focuses on the yield differentials between Japan and the United States. A major concern here is whether the depreciation of the USD/JPY exchange rate during this period was more sensitive to the yield differentials of longer maturities that the QQE influences, and/or US economic and financial factors as well. This section conducts a simple Fama regression exercise based on Kano and Wada (2015) with a modification for the periods of samples and subsamples. This paper lets z_t denote the logarithm of the USD/JPY exchange rate at period *t*, $y_{t,n}$ the JGB yield to maturity *n*, and $y^*_{t,n}$ the US Treasury yield to maturity *n*. The following are the regression specifications as per 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; and

$$rx_{t+1} = \alpha^{rx}_n + \beta^{rx}_n\left(y_{t,n} - y^*_{t,n}\right) + \epsilon^{rx}_{t,n} \tag{3}$$

where α^{rx}_n is constant, β^{rx}_n 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 $\epsilon^{rx}_{t,n}$ is an i.i.d. error term.

This section employs monthly data from January 2003 to September 2015, and divides this period into three phases based upon the difference in economic and financial conditions in both Japan and the United States. The first phase is from January 2003 through July 2007, "the Goldilocks period," when there were no significant shocks like financial crises but the QEP was terminated by the BOJ in the middle. The second phase is from August 2007 through November 2012, the Lehman shock period: the Lehman shock occurred in September 2008, with the initial Paribas shock in August 2007, and LSAPs were eventually introduced by the Federal Reserve, while credit easing policies, including CE, were introduced by the BOJ. The third phase is from December 2012 through September 2015, the QQE period in a broad sense, when the Abe administration initiated and disclosed the new macropolicy package and the QQE was introduced by the BOJ, while LSAP3 was adopted and terminated by the Federal Reserve.

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

To interpret the changes in the alternative Fama coefficients, this section introduces the model of Bansal and Shaliastovich (2013) to explain the relationship between a nominal exchange rate and a term structure of the nominal bond yield differential of two countries. This model is a long-run risk model that permits persistent components of the consumption growth rate (real long-run risk) and inflation risk rate (nominal long-run risk) with the corresponding time varying conditional volatilities based on Kreps and Poteus (1978) and Epstein and Zin (1989). According to this model, the real bond is held for hedging an expected future consumption risk. A lower expected consumption growth increases the demand for the real bond and lowers the real bond yield (flight to quality). A higher expected future inflation causes deterioration in the future consumption growth and lowers the real bond yield (flight to quality). The real and nominal volatilities lower the real bond yield. On the other hand, hedging the expected future consumption risk also explains the positive nominal bond yield. A higher expected inflation raises the nominal bond yield. Also, the nominal volatility lowers the real bond yield through a flight-to-quality effect. The real volatility induces the flight to quality of the bond investment and lowers the nominal bond yield. Finally, the sign of the nominal bond yield loading on the nominal volatility changes over maturities.

Based on this long-run risk model framework, bond yields respond to real uncertainty, such as consumption volatility, negatively because of the flight-to-quality effect, while they respond to nominal uncertainty, such as inflation or other nominal volatilities, negatively in the short-term and positively in the long-term because the nominal premium becomes larger at longer maturities and gradually dominates the flight-to-quality effect.

The home currency depreciation is determined by no arbitrage opportunity under frictionless markets, that is, the difference between the log pricing kernels (m_t) of the two countries, as described by Backus, Foresi, and Telmer (2001):

$$z_{t+1} - z_t = m_t^* - m_t \tag{4}$$

Two countries are considered in each of the representative agent lives for *n*-finite periods. From this model, the Fama coefficients (the unconditional covariance between the depreciation rate of the currency and the yield differential to maturity *n*) can be decomposed into the unconditional covariance between the yield differential to the one-period maturity and to maturity *n*, and the unconditional covariance between the excess currency return and the yield differential to maturity n.

$$Cov\big(z_{t+1} - z_t,\ \tilde{y}_{t,n}^{\$}\big) = Cov\big(\tilde{y}_{1,n}^{\$}, \widetilde{y}_{t,n}^{\$}\big) + Cov(rx_{t+1}, \widetilde{y}_{t,n}^{\$}) \tag{5}$$

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

$$+\frac{1}{n} B_{s\pi,1}^{\$} B_{s\pi,n}^{\$} V(\tilde{\sigma}_{x\pi,t}^{2}) \tag{6}$$

$$Cov\left(rx_{t+1},\ \tilde{y}^{\$}_{t,n}\right) = \frac{1}{2n}\lambda^{2}_{sc}B^{\$}_{sc,n}V\left(\tilde{\sigma}^{2}_{xc,t}\right) + \frac{1}{2n}(\lambda^{2}_{s\pi}B^{\$}_{s\pi,n}V(\tilde{\sigma}^{2}_{x\pi,t}) \qquad (7)$$

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 the real and nominal bond prices to the aggregate risks, and c and π are consumption growth and inflation. The variables x_c and x_π are the expected consumption growth and inflation, and *sc* and $s\pi$ are the real and nominal volatilities. The variables λ_{sc} and $\lambda_{s\pi}$ are the market prices of real and nominal volatility risks, and σ^2_{xc} and $\sigma^2_{x\pi}$ are the unconditional means of the real and nominal volatilities. Finally, *V* is the mathematical conditional variance operator.

Equation (6) is always positive except for a longer maturity, and equation (7) is negative over short maturities. This theory suggests that the alternative Fama coefficients (the unconditional covariance between excess currency return and the yield differential) are negative at least in the short term, which is a necessary condition to explain the violations of the uncovered interest rate parity condition, and these violations become less prominent with longer maturities. In the QQE period, longer maturities had wider yield differentials (Figure 10). Kano and Wada (2015) conducted the calibration using this model to explain the structural shift from negative to positive coefficients after the introduction of Abenomics, and they found that the shift of coefficients can be replicated 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 the major impact on the exchange rate. According to the alternative Fama coefficients, the widening of the yield differentials of longer maturities, such as a 10-year yield differential, can depreciate the USD/JPY exchange rate more than that of shorter maturities. In this sense, the QQE can affect the USD/JPY exchange rate. However, since the development of the yield differentials was dominated more by the rise in the long-term yields of the US relative to their decline in Japan (Figure 10), it can be conjectured that during the QQE, the depreciation of the USD/JPY exchange rate can be explained by the US rather than the QQE. This assessment requires detailed analysis about the movement of long-term JGB yields by incorporating the asymmetry of foreign and domestic investors.

D) Safety channel

When the safety channel works, the JGB yields are expected to decline but the corporate bond yields are expected not to decline. More precisely, the yields of the AA corporate bonds that are relatively safe assets may decline somewhat after adjusting the CDS spreads, while the yields of less creditworthy bonds may not decline.

Since JGBs were not purchased massively enough by the CE and the monetary easing after the earthquake to decrease the amount of JGBs outstanding in the markets, this section focuses on the QQE and extracts its impact from Tables 4, 5, 6, and 7. According to these tables, the 10-year long-term yield of JGBs declines and the yield of the 10-year CDS-adjusted AA corporate bonds declines less. Conversely, the yields of other maturities of JGBs and of corporate bonds increase. The yield spreads between corporate bonds and JGBs somewhat expand.

These relationships correspond more to the safety channel than to the portfolio balance channel. However, no distinction between the portfolio balance channel and safety channel has been made. The existence and welfare implications of a safety channel will be examined in more detail in the next chapter.

E) Inflation expectation channel

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

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

The inflation swap rate has positive effects on many events, while the BEI has had positive effects mainly since the monetary easing in December 2012 through the QQE. However, the F-test shows a 1-percent significance only for the BEI for the 10 years when most events were not covered except for the QQE2. Therefore, both the QQE and CE did not have significant effects on the inflation expectation channel.

Before concluding, it should also be taken into account that the BEI is possibly distorted 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 with inflation expectations. Those financial indicators are, as Mandel and Barnes (2013) suggest, the weighted average of the inflation swap rates or BEIs for the US and UK adjusted for the expected depreciation of the exchange rates. These are equal to the inflation expectations in Japan if the purchasing power parity holds. They may be superior to Japan's inflation swap rate and BEI in that the liquidity premiums of the US and the UK are more stable than in Japan. As purchasing power parity is assumed, it is unreasonable to use this to calculate the daily changes in inflation expectations. Thus, this section uses purchasing power parity on a quarterly basis. Although Mandel and Barnes (2013) define the changes in the expected inflation rates in Japan as the combination of the daily changes in the BEI and the daily changes in the forward exchange rate, this paper's calculation method is more formally based on the theory of purchasing power parity. As Kamada and Nakajima (2013) suggest, the following equations are assumed to hold:

$$FII = Foreign\ \ Inflation\ \ swap\ \ rate + [{}^{FX\ \ forward\ \ spread}/_{spot\ \ rate}] \tag{8}$$

$$FBI = Foreign\ \ BEI + [{}^{FX\ \ forward\ \ spread}/_{spot\ \ rate}] \tag{9}$$

where FII is the foreign inflation-swap implied index, and FBI is the foreign BEI implied index.

Both indexes are calculated on a daily basis, and are transformed to quarterly data.

Furthermore, the perception of the price levels (five years from now) by households, as collected by BOJ's Opinion Survey on the General Public's Views and Behavior, is also used as a proxy for inflation expectations. This can be transformed into the CPI inflation rate by quantifying the perceptions with the Carlson-Parkin method, as suggested by Sekine et al. (2008). All indexes are shown in Figure 11. This figure illustrates how the inflation swap rate and BEI in Japan increased in 2009 until 2013, and that the inflation swap rate has been stable since early 2013. Compared to these rates, the households' inflation expectation, FII, and FBI differ based on their speed of increase from 2009 to 2012, but have been similarly stable since 2013.[9] Overall, some inflation expectation indicators increased during the QQE period, but most are not accelerated and none reaches the 2 percent level.

These indicators have the same direction as the USD/JPY exchange rate, except for FY 2014, when the consumption tax was introduced (Figure 12). Using OLS to regress the inflation swap indicators (5-year, 10-year) on the change in the USD/JPY exchange rate and the dummy for the hike in consumption tax (April 2014) with the adjustment of serial correlation, the USD/JPY rate is significant at the 1 percent level. Combining this result with that of the event

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

study, it can be conjectured that the depreciation of the USD/JPY exchange rate positively influences inflation expectations possibly through, for example, the rise in import prices. Furthermore, Ugai (2016-b) estimates the correlation between various inflation expectation indicators and the nominal effective exchange rate of the yen with the same motivation, and finds that inflation expectations, especially not those priced in the market transactions, have a tendency to lag as much as one to five quarters behind the movement of the yen exchange rate (Table 10). This suggests that the yen rate tends to influence inflation expectations. Market indicators like the inflation swap rate have both simultaneous and lag correlations with the yen exchange rate, which may suggest the speedier response of the market expectations to the exchange rate.

These analyses do not provide a rigorous statistical test based on a theoretical model or study of other factors, such as the output gap and recent price-setting corporate behavior. Nevertheless, this event study with a variety of the above supplementary analyses is consistent with the hypothesis of a weak direct impact on inflation expectations. This result has an implication that the BOJ's aim to lift inflation expectations does not work well. This supports the result of Fujiwara et al. (2014) and Nakazono (2016) that no sizable difference in long-term inflation expectations has been found before and after the introduction of Abenomics.[10] Rather, some indirect impact through the yen exchange rate can be expected. But to attain the 2 percent

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

price stability target through the exchange rate, possibly by raising imported prices and by narrowing the output gap through increasing exports, it is necessary to continuously depreciate the yen rate. However, the USD/JPY exchange rate had already peaked in the middle of 2015 at around 125 dollars/yen, then declined until recently (Figure 10). Actually, the BOJ (2016) recently assesses Japan's inflation expectations, saying that a further rise in inflation expectations through the adaptive mechanism is uncertain and may take time since the observed inflation rate is subdued.

F) Summary of the event study

This chapter examines the effects of the QQE compared to those of the CE and the subsequent easing policies by transmission channels. This event study captures the reactions of the markets immediately following the announcement of the policy change, and makes the following conclusions:

(a) The signaling channel worked for the CE since the BOJ explicitly disclosed its commitment to the future path of interest rates. On the other hand, the QQE did not have such an effect. This event analysis also has similar conclusions when applied broadly to events strongly related to the QQE.

(b) During the period when financial markets did not function well (the CE and the monetary easing right after the Great East Japan Earthquake), the credit easing channel worked.

(c) The portfolio balance channel during the QQE did not significantly affect the broad range of yields of the JGBs and corporate bonds, except for the 10-year JGBs, but did affect the dollar/yen rate strongly. This asymmetry between JGB markets and exchange rate markets may be explained by the different reactions of domestic and foreign investors toward the QQE. There is another possibility that the yen's large depreciation during the QQE may also be explained by US economic and financial conditions. These hypotheses need further analysis.

(d) The reaction of the yields of JGBs and corporate bonds is consistent with the existence of a safety channel. Whether this channel actually worked and had side effects on the welfare of the private sector is to be examined in the next chapter.

(e) The inflation expectation channel was weak during both the QQE and CE. Although the QQE attempted to strongly influence inflation expectations, there is no clear evidence that the QQE had a stronger effect on inflation expectations directly. It can be conjectured that the gradual rise in inflation expectations came mainly from other channels, such as the depreciation of the yen.

Therefore, this chapter concludes that the BOJ could not drastically decrease the nominal interest rates of each maturity to fully lower the real interest rates. The reason why the Bank could not lower the nominal rates will be discussed further in the next chapter. Rather, by depreciating the yen rate, it succeeded in raising inflation expectations indirectly and to gradually lower the real interest rates, although this result may also have been largely affected by US financial conditions. It has been three and a half years since the BOJ introduced the QQE, and the CPI inflation is far less than the BOJ's price stability target. The overall effects of the QQE are not strong enough to raise the CPI inflation to the 2 percent target level within the committed period.

3. Safety channel – Theoretical Model and Empirical Results

A) Theoretical model

To discuss the impact on economic welfare of a central bank's purchasing massive amounts of government bonds, this section provides the theoretical background for government bonds being valued for their role in facilitating transactions, aside from the money. Based on Krishnamurthy and Vissing-Jorgensen (2012-a), which shows that US Treasury securities increased 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 enough government bonds to surpass an increase in the new issuance of government bonds, it reduces the net supply of government bonds in the private sector, thereby raising the convenience yield.

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

To determine explicitly the effect of a central bank's massive purchase of government bonds on the convenience yield, the utility function of a representative agent that includes the holding of convenience assets needs to be 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) and is applied to the convenience benefits from holding government bonds based on Krishnamurthy and Vissing-Jorgensen (2012-a):

$$U_t = E\sum_{t=1}^{\infty}\beta^t U(C_t) \tag{10}$$

$$C_t = c_t(\frac{GDP_t}{Q_t};\varphi_t) + v(\theta_t^A, GDP_t;\ \xi_t) \tag{11}$$

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

The term φ_t is a measure of the inefficiency of the allocation of expenditure owing to imperfect financial intermediation,[11] which is treated as an exogenous shock. This occurred

[11] Curdia and Woodford (2009, 2011) show the aggregated demand for Dixit-Stiglitz composite goods by assuming the existence of both borrower and saver, denominate a measure of inefficiency by the marginal-utility ratio of borrower and saver, and add other variables, such as resources consumed by

during the GFC. When the financial intermediation is disrupted, the utility decreases. As far as there is inefficiency in the allocation of expenditures owing to imperfect financial intermediation, the credit easing policy by a central bank could increase the utility. This inefficiency would be reduced if the financial intermediation function recovers, thereby increasing economic welfare, as Curdia and Woodford (2009, 2011) suggest.

On the other hand, v denominates the function that holding more government bonds reduces costs of transactions. Furthermore, θ_t^A generally consists of money, government bonds, and any other privately produced debts that provide services similar to 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. Finally, ξ_t is a preference shock.

However, investors differentiate long-term government bonds from money as safe assets because they can store long-term value without the fear of capital losses. Greenwood and Vayanos (2010) discuss that investors, such as those in pension funds, insurance companies, and mutual funds, have longer time horizons than arbitragers to back long-term nominal obligations. Government bonds have nonzero interest rates, which differs from money's zero interest rate.[12]

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intermediaries, to explain the impact of credit friction on the economy. However, to analyze the function of convenience assets, the 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 modeled rigorously, the general equilibrium model could be derived. However, since the analysis here focuses on safety assets, establishing a Dixit-Stiglitz–type model is beyond the purpose of this section.

[12] If the yields of long-term government bonds approach zero, this benefit will also be reduced.

There are other specific benefits of holding long-term government bonds. As Caballero and Fahri (2013) show, the replacement of long-term government bonds by short-term government bills would reduce the supply of safe assets because an expansion of 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 a hedging effect. Furthermore, Greenwood, Hanson, and Stein (2013) suggest that a shift toward 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 safe assets such as government bonds. Thus, longer-term government bonds have higher convenience yields.

A main benefit of holding government bonds is that they can be utilized as safe collateral for financial transactions, such as repurchase agreements (repos). When limited pledgeability and agency problems exist, companies may not be able to transfer enough wealth across periods to finance later investments since private agents cannot commit their future endowments. This suggests that private markets have limited capacity for intertemporal transfers. 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, and creates a role for government bonds (Caballero and Fahri 2013). Government bonds can be used to transfer wealth intertemporally because the government can tax and commit funds for private agents (Holmström and Tirole 1998). As Gorton and Ordoñez (2013) show, especially when market participants are conscious of a tail risk crisis and since agents cannot verify final output, collateral is needed to back companies' borrowing. Accordingly, there is a complementarity between government bonds and private collaterals. When there is a possible crisis, lenders have incentives to acquire information about the value of the privately produced collateral assets and lend only to companies with a high value of collateral assets. However, as Saint-Paul (2005) suggests, when borrowers have government bonds, the need for monitoring is reduced. By supplying government bonds, the government can support the loans by reducing lenders' incentive to acquire information about the quality of private collateral. Thus, borrowers do not need to scale back the size of borrowing. Therefore, a small amount of government bonds can have large effects on consumption and investment. Repos actually decreased after the GFC but have recently increased globally. In Japan, more than 90 percent of the collateral for repos are JGBs (Ono et al. 2015). JGBs with 5-10-year maturities are used mostly as collateral rather than JGBs with shorter maturities, and JGBs with more than 10-year maturities are gaining shares following the GFC (Figure 13). The spreads of the JGB repo rates and interbank interest rates (Figure 14) show a negative trend since 2014, suggesting a squeeze of the JGBs as collateral.

On the other hand, if money were provided beyond the satiation level by a quantitative easing policy, ample additional provisions of money would not affect the economy. In Japan, since 1995, short-term interest rates have been almost zero and the economy has faced the zero interest rate lower bound. Thus, the additional utility of holding money as convenience assets is expected to be zero. Then as far as long-term government bonds are differentiated from money as safe assets, 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 provide services similar to government bonds, as follows. The framework of the following is the same as Krishnamurthy and Vissing-Jorgensen (2012-a), and this section introduces it to discuss the empirical analysis of Japan in the next section.

$$\theta_t^A = \theta_t^G + k^P \theta_t^P \tag{12}$$

where k^P measures the convenience services provided by the private-sector assets relative to the 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 they are alternatives to money at the zero short-term interest rate condition.

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

$$v(\theta_t^A, GDP_t; \xi_t) \equiv v(\frac{\theta_t^A}{GDP_t};\ \ \xi_t) GDP_t. \tag{13}$$

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

The economic welfare (Equation (9)) is maximized subject to the following budget constraint:

$$Q_t c_t + P_t^G \frac{Q_t}{P_t^G}\theta_t^G + P_t^P \frac{Q_t}{P_t^P}\theta_t^P = P_t^G \frac{Q_{t-1}}{P_{t-1}^G}\theta_{t-1}^G + P_t^P \frac{Q_{t-1}}{P_{t-1}^P}\theta_{t-1}^P + Q_t y_t \tag{14}$$

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 the current nominal consumption plus the nominal purchase of assets is equal to the nominal return from the past investment in bonds plus the nominal income.

From the first-order conditions for government bond holdings, the government bond price and corporate bond price are calculated by taking into account the convenience yield and default risk (following Duffie-Singleton's 1999 formulation), and the yield spread between corporate bonds and government bonds at τ-period can be derived as follows (see the Technical Appendix for details):

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

$$= \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}E_t[v'(\frac{\theta_j^A}{GDP_j};\xi_j)] + \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}E_t[\rho_j L_j] - \sum_{j=t}^{t+\tau-1}\frac{1}{\tau}Cov_t(m_{j+1},R_{j+1}) \tag{15}$$

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. With the assumption that $v'' < 0$, $S_{t,\tau}$ decreases with an increase in θ_t^A/GDP_t. If θ_t^A/GDP_t decreases with a decrease in θ_t^G/GDP_t, the reduced supply of government bonds, $S_{t,\tau}$ will expand. This would reduce economic welfare as the constraint of holding θ_t^G strengthens. Therefore, the yield spread can be interpreted to change through the following three factors: (i) the expected average convenience yield of holding a government bond over the next τ-periods, (ii) the expected average amount of loss induced by 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.

B) Impact of a squeeze in the demand-supply conditions of government bonds (linear)

Based on the above model, a regression to explain the impact of a squeeze in the demand and supply conditions of government bonds is as follows. To simplify the model, current figures are used for public debt (consolidated government base) for factor (i) in Equation (15). The default risk factor corresponding to factors (ii) and (iii) is used to control the regression equation[13]

$$Spread(Corporate\ \ Bond - Government\ \ Bond)_t = a + b\ \ ln\frac{Public\ \ Debt_t}{GDP_t} + c\ \ Default\ \ Risk_t + error_t \quad (16)$$

where "government bond" means 10-year JGBs and "corporate bond" means 10-year AA-rated corporate bonds. Public debt covers the outstanding amount of JGBs and of Fiscal Investment Loan Program bonds[14] minus the amount of JGBs held by the BOJ, which are held and used by the private sector as safe assets. Japanese government bills are excluded from this variable. The median expected default frequency (EDF)[15] 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. The EDF captures the default risk both during the Japanese financial crisis of the late 1990s and the GFC and at each phase of the business cycle. Because the EDF is based on option pricing, the key factor is stock return volatility, but the EDF is superior to the volatility of stock indicators in that it examines the default points of individual companies. The sample period is

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

[14] The characteristics of FILP bonds are the same as Japanese government bonds.

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

from 4Q/1997 through 4Q/2014. Because Japan faced the zero lower bound during those periods, there is no need to control the zero lower bound in the regression model. The regression is estimated using the OLS estimation method. Recently in Japan, the changes in ratings and default risk inherent in specific companies have also affected the corporate bond yields, and thus a dummy variable for the Great East Japan Earthquake is included. By checking the Breusch-Godfrey serial correlation LM test, the error terms are adjusted with AR(1) and AR(2).

According to this hypothesis of convenience yield, if the BOJ purchases massive amounts of government bonds, the spread between the AA corporate bond yield and the government bond yield will expand. This hypothesis suggests that the convenience yield expands as the public debt/GDP ratio decreases. Table 11 shows the regression results.

The regression results satisfy the theoretical signs of all variables, although the explanatory power of the JGBs is not strong, less than the statistical significance at 10 percent. This result implies that it may have a decreasing trend for the increase in the JGB-to-GDP ratio on yield spreads, which suggests the increasing trend of the convenience yield component, but it is statistically weak. If this can be applied, the BOJ's massive JGB purchases would increase the yield spreads and would not depress the corporate bond yields. The existence of this linear relationship is consistent with the result of the event study that only the 10-year yield of JGBs is lowered without arbitrage transactions 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 in the next section.

In addition, it is important to check the robustness of whether the role of JGBs to provide safe assets differs from the role of money, as the theory suggests. Then, the monetary base (*m*) is added to Equation (11) and to the above regression Equation (16) to form Equations (11') and (16'), as follows:

$$C_t = c_t(\frac{GDP_t}{Q_t}; \varphi_t) + v(\frac{m_t + \theta_t^A}{GDP_t}; \ \xi_t)GDP_t \tag{11'}$$

$$Spread(Corporate\ \ Bond - Government\ \ Bond)_t = a + b_1\, ln\frac{Public\ \ Debt_t}{GDP_t} +$$

$$b_2 ln\frac{Monetary\ \ Base_t}{GDP_t} + c\ \ Default\ \ Risk_t + error_t \tag{16'}$$

Table 12 clearly shows that the monetary base does not have the explanatory power of the JGBs, and that other variables maintain almost the same coefficients, suggesting that the monetary base is not priced.

C) Threshold of the convenience yield (nonlinear)

This section treats the nonlinear property between the spread and the JGB-to-GDP ratio by applying the methods of Krishnamurthy and Vissing-Jorgensen (2012-a). As shown in Figure 4, the relationship between the spread and the JGB-to-GDP ratio is an asymptote. The theoretical background is that the convenience yield will eventually reach a satiation level where the amount of the safe assets is so large that there is no additional convenience yield for holding the JGBs. This is analogous to the function of the monetary base, even though the function of the JGBs is different. Therefore, this section quantifies the asymptote between them and the satiation level. Assuming that there is some threshold of safe asset demand, this section models the convenience yield with a function that is piecewise linear for the government bond supply, as follows:

$$Spread(Corporate\ Bond - Government\ Bond)_t = a + b_1 \max\left[b_2 - ln\left(\frac{Public\ Debt_t}{GDP}\right),\ 0\right] + c\ \ Default\ Risk_t + error_t \tag{17}$$

If $b_2 < ln(\frac{Public\ \ Debt_t}{GDP})$, there is no value for the convenience yields. The regression is estimated by using the nonlinear least squares with robust standard errors to take into account heteroscedasticity. The results are shown in Table 13, using the AR(1) and AR(2) to adjust the error terms, which is the same as the regression of the log function.

Table 13 shows that this regression is significant for all coefficients, and the coefficient of public debt is more significant than that of the symmetric log function. The 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. As shown in Figure 4, the curve is refracted around this level after taking the confidence interval of this estimation into account. That said, this level is 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 precise, there are some phases showing that the yield spread declines somewhat compared to this satiation point, but there is no phase that suggests a large decline in the spread. Since the debt amount per GDP of the Japanese government is the largest in the world, as far as such a threshold is assumed, even the BOJ's massive JGB purchases have not yet induced a scarcity of safe assets in the markets.

In addition, conducting the same nonlinear least squares regression analysis for the monetary base instead of the JGBs as a robustness check assures that the monetary base does not have such explanatory power as the JGBs (Table 14).

D) Discussion

This paper has two primary results. First, if the relationship between the spread and the JGB-to-GDP ratio is linear, the convenience yield has already increased. That said, it is statistically weak. Second, if the relationship is nonlinear, the convenience yield will not increase until the JGB-to-GDP ratio reaches the satiation point.

For the latter result, the satiation point must be evaluated. This paper supposes that the amount of JGB issuance increases from fiscal year 2015 through 2018, reflecting the Cabinet Office's calculation of Japan's economic and fiscal figures in the medium to long term plus the government's economic stimulus package as decided by the Cabinet in July 2016. Furthermore, the GDP growth will follow the median forecast of the real GDP and CPI by the majority of the Policy Board Members of the BOJ at the July 2016 statement on monetary policy. Then, the JGB-to-GDP ratio would not decline below the 100 percent level by the end of fiscal year 2018. However, since the Japanese government is attempting to reduce the issuance amount of JGBs, this ratio would decline more. Still, this simulation suggests that the BOJ would probably not lower the economic welfare from the perspective of the convenience yield at least during fiscal years 2015 through 2018. It is worth noting that this satiation level is a rough estimate, and cannot reflect its subtle pressure for raising the convenience yield.

Indeed, there are three reservations that suggest that the BOJ might lower the economic welfare of the convenience yield. First, the analysis of the demand for safe assets does not take into account the recent increase in demand in two ways:

(i) Since the GFC, market participants have paid more attention to credit risk concerning money market transactions, thereby expanding collateralized financial transactions while reducing uncollateralized financial transactions (Figure 15). Market participants can no longer ignore the tail risk of financial turbulence. These transactions are expanding not only for domestic financial institutions and investors but also for foreign investors.

(ii) Global financial regulations also strongly consider funding liquidity risks. The Basel III, as introduced from the 2015 the liquidity coverage ratio (LCR), 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 global regulations emphasize the importance of banks holding liquid and safe assets, the demand for the government bonds increases. Furthermore, according to the Committee on the Global Financial System (CGFS) (2015), longer-term repos and subsequently longer-term government bonds are and will be more favorable for banks because the LCR counts total cash outflow over the next 30 calendar days and the net stable funding ratio (NFR, a requirement for maintaining a stable funding profile) regards funding with maturities over six months with all counterparties as available stable funding as of 2018. If these hypotheses can be applied, the satiation level shifts right.

To quantify this change in the demand for safe assets, Arslanalp and Botman (2015) illustrate the limit that the BOJ could reach in purchasing JGBs under the current policies from major investors. Most of the JGBs are now held in Japan's financial institutions, and domestically licensed banks have reduced their JGB holdings since 2012 (Figure 16). On the other hand, the Government Pension Investment Fund (GPIF), the largest public pension fund, announced new portfolio allocation ratios that lower the share of domestic bonds, consistent with other major countries, to increase the return on assets while reducing the portfolio of JGBs. Insurance companies have gradually increased their foreign securities holdings while maintaining a strong bias toward holding JGBs under the constraint of asset-liability management (Table 15). They assume that other public and private pension funds will follow the strategy of the GPIF, and that insurance companies will increase their share of holding foreign securities to a level consistent with the practices seen in major countries. Then, they calculate the downside scenario by assuming that banks would decrease their amount of JGB holdings to 10 percent of their total assets, which is the lowest level since 2003 but higher than most sovereign bond holdings by banks in the other G7 countries, by taking into account higher demand under Basel III. The BOJ may reach the point of tapering its JGB purchases by the end of 2016. On the contrary, if banks decrease their amount of JGB holdings to 5 percent, which is almost the minimum level before 1998 and lower than most of the sovereign bond holdings by banks in the other G7 countries, Japan may reach that point by the end of 2018. However, this simulation does not have a theoretical background and is based on many assumptions that can change. This approach has no microfoundation as to how many JGBs each financial institution would hold. Recently, the BOJ stated that the reduction of JGBs held by Japanese banks is good so the banks can take risks in other credit or portfolio investments (portfolio balance). This thinking denies the historical experience of possessing JGBs.

Second, the theoretical model of the satiation point of public debt is originally the τ-

period expectation.[16] Especially because the BOJ purchases JGBs with a fixed speed, market participants can anticipate a future shortage of JGBs in advance.[17] This may shorten the period to attain the situation that JGBs have a convenience yield.

Third, since the BOJ is such a dominant player in JGB transactions (Figure 3), it might still induce a partial shortage of safe assets due to a lack of a mechanism to adjust an imbalance of safe asset holdings by market participants. In this case, the squeeze of the net flow of JGB issuance, not that of the net stock of JGB issuance, might induce a shortage of safe assets for specific purposes, such as collateral for repos (Figure 14). Finally, the economic welfare of those who do not have enough safe assets could also be reduced.

Thus, these outcomes should also be assessed by examining the actual pricing, which is the last part of this section. Indeed, because of many reasons discussed above, they may have priced them accordingly. The remaining part of this section examines the actual pricing of 10-year JGBs to determine whether the above factors have provided convenience yield to the 10-year JGB prices. The following finance approach provides estimation of convenience yield to compensate the weakness of the above macroeconomic approach. This analysis is based on Fukuta, Saito, and Takagi (2002) and assumes that the convenience yield of JGBs corresponds

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[16] Krishnamurthy and Vissing-Jorgensen (2012-a) did not treat this expectation channel, but this paper attempts to incorporate this channel.

[17] For example, an article in the *Financial Times* (2015) discusses future limits on large-scale asset purchases by the BOJ.

largely to the swap spread between the yen-denominated swap rate and the spot yield of JGBs. The interest rate swap is the exchange of interest payments without the exchange of the principal amounts, and since the counterparty is a bank with high credit ratings, the credit risk of this contract is low. According to Sorensen and Bollier (1994), the credit costs of the swaps denominated by the US dollar were within some basis points, while Fukuta, Saito, and Takagi (2002) quote Asano's (1996) article that those denominated by the Japanese yen were around one basis point. Both the JGBs and the interest rate swap have little credit cost, and the difference of the interest rates between them can be interpreted as reflecting the convenience yield that is attached to the JGBs, not the interest rate swap. The following analysis derives the theoretical price of 10-year JGBs by using the term structure of the swap rate and the contents of the JGB contracts, and regards the spread between the theoretical prices and the actual transaction prices of 10-year JGBs as the convenience yield:

$$\text{Theoretical price of } 10-\text{year JGB} = \sum_{w=1}^{W} \frac{\frac{d}{2}}{(1+h_{\frac{w}{2}})^{\frac{w}{2}}} + \frac{100}{(1+h_{\frac{W}{2}})^{\frac{W}{2}}} \qquad (18)$$

where *d* is the coupon, h_j is the j-year swap rate, *W* is two times the remaining years *T*, and *w* is denominated semiannually. The JGBs are selected by the criteria that the most recently issued bonds are the most traded bonds to avoid the liquidity problem besides the BOJ's purchasing JGBs. The JGB swap rate is selected by the criteria of the most traded bonds. Then, the convenience yield can be derived by the difference between the market price and this theoretical price:

$$Convenience\ yield = market\ price\ of\ JGB - theoretical\ price\ of\ JGB. \qquad (19)$$

The results are plotted in Figure 17. Naturally, the theoretical price may capture some other noise because the major JGBs in the spot market are not necessarily equal to the 10-year JGBs of the interest rate swap. Additionally, if the hypothesis that market participants pay more attention to credit risk after the GFC is true, even the swap rates may incorporate counterparty risk more than before. Accordingly, this section checks the convenience yield trend after the introduction of the QQE compared to that of the CE. The convenience yield increased immediately following the introduction of the QQE, but this did not occur after the introduction of the CE. Since then, although the BOJ continues to purchase huge amount of JGBs in the market, the convenience yield has been relatively stable. Although the BOJ continues to purchase large amounts of JGBs, the convenience yield has not risen much. Therefore, a severe scarcity of JGBs as safe assets has been avoided. At the same time, this suggests the nonlinearity of this relationship[18], and is not

[18] It is also worth noting to check whether recent expansion of dollar basis (premium of dollar funding) when finding the dollar by using yen as collateral has not truly caused the distortion of the JGB interest rate swap to shrink, thereby mitigating the expansion of the convenience yield after the QQE2. However, actually the dollar basis shrank in 2013 and has expanded since 2014, which is different from the expected effect on the convenience yield to offset its expansion. Therefore, this factor has not affected the shape of the estimated convenience yield.

consistent with the linear relationship as described in B). Rather, this result implies that some of the above three factors of C) raise the satiation level and induce the shortage of safe assets.

Conclusion

This paper examines the transmission channels of the QQE by investigating the reaction of various financial markets to determine the QQE's effectiveness, and considers the economic welfare implications and potential side effects of the central bank purchasing significant amounts of safe assets.

The first principal contribution of this paper is to comprehend the effective transmission channels of the QQE as compared to the CE for the first time. Compared to Ugai (2007), who discussed the transmission channels of the QEM during 2001-2006, both the QQE and CE have attempted to utilize broader channels. This paper is the first to incorporate all the possible channels of Japan's unconventional monetary easing policy and to examine which channels actually functioned. According to this paper's event study, the signaling channel and the credit easing channel and its permeation through other yields functioned more with the CE than with the QQE. In contrast, the depreciation of the foreign exchange rate in the portfolio balance functioned quite strongly with the QQE. In other words, the BOJ did not succeed in decreasing real interest rates directly and significantly by the QQE, while the Bank succeeded in decreasing real interest rates indirectly through the effects of the yen's depreciation on inflation expectations. On the other hand, although the QQE intended to affect inflation expectations directly, the direct effect has not been evident. Bernanke (2014) discusses how the BOJ's commitment to a 2 percent inflation target is credible because of government support, the consistency of the target with an international norm, and the lack of significant cost of the commitment to raise inflation expectations. However, inflation expectations have not shifted upward greatly, as the BOJ and Bernanke had expected, and Japan's inflation expectations and the CPI inflation rate have not yet reached 2 percent. Hausman and Wieland (2015) explain the weak rise in inflation expectations by a lack of credibility but cannot specify its sources. Although this paper does not discuss the cause, a weak direct inflation expectation channel suggests that clear transmission channels are needed for the credibility and function of the monetary policy in Japan. As a result, the overall effects are not strong enough to raise the CPI inflation to the 2 percent target level.

Why the QQE affects the foreign exchange rate exclusively without clearly lowering the bond yields must be examined more rigorously. This analysis and various other studies suggest that foreign investors may be the main driving force behind the USD/JPY exchange rate reaction to the QQE, and that during the entire period of the QQE, changes in the US economic and financial conditions may be another driving force. Such a large depreciation of the yen may result in raising inflation gradually, possibly through the rise in import prices and the decrease in the output gap, despite the lack of a strong direct inflation expectation channel.

The most crucial characteristic of the QQE is the attempt to maximize the potential effects of the easing policy by doubling and tripling the purchases of JGBs and the monetary base proportionally to affect inflation expectations. The amount of JGBs purchased by the BOJ surpasses that of the JGBs issued, which reduces the outstanding amount of JGBs in the markets. The second principal contribution of this paper is its consideration of the effect of such operations on economic welfare. This is the first paper to analyze this aspect of Japan's monetary policy quantitatively. Even though the microfounded macroapproach possibly suggests a satiation level of the outstanding amount of JGBs in the markets that is less than the current level, the recent increase in the demand for safe assets after the Lehman shock, market expectations for future JGB purchases by the BOJ, and a partial shortage of safe assets due to market imperfection all suggest the existence of a convenience yield since the BOJ introduced the QQE, and the finance approach confirms it. Aside from other channels, while the safety channel does not let the decline in JGB yields permeate the yields of corporate bonds, which indicates no welfare gains, the existence of the convenience yield itself reduces the welfare. Notwithstanding, the size of Japan's public debt outstanding (per GDP) is the largest in the world, and the analyses here indicated the stability of the convenience yield, suggesting that severe scarcity of JGBs as safe assets has been avoided.

Further studies are needed to assess the outcome of this analysis. Especially, further examination is needed to determine whether the scarcity of JGBs is not the challenge in Japan. This study has incorporated a microfounded macroapproach and finance approach but has not integrated both into a consistent model that reflects recent changes in market conditions. Although the BOJ changed the the QQE (and the subsequent QQE with NIRP) to the QQE with YCC in September 2016 and is less concerned about the size of the monetary base than when the BOJ adopted the QQE and QQE with NIRP, the Bank still continues to expand the monetary base. The implications for the scarcity of safe assets derived from this integrated approach would be especially important when the BOJ designs future possible paths for its JGB purchases and assesses their impact on the economy.

Lastly, while this paper focuses on the impact of massive safe-asset purchases by the BOJ from the asset holder's perspective, it is worth examining the possibility of turning safe assets into risky assets at the exit phase of the QQE from the debt issuer's perspective. 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 becomes stable at 2 percent and the BOJ terminates the QQE, the yields would increase to the levels consistent with the 2 percent inflation expectation, Japan's potential economic growth rate, and the uncertainty about Japan's economy and government debt. Even if the BOJ continues the QQE to constrain such an increase, further inflation may emerge and eventually raise the yields. Therefore, checking the consistency of the rise in yields with the sustainability of the public debt is an important area to study. This importance of this perspective does not change even after the

BOJ newly introduced the QQE with YCC. This aspect is beyond the issue of the scarcity of safe assets.

Technical Appendix

This appendix details how to derive the regression form (Equation (15)) to explain the impact of squeezing safe assets from the perspective of the maximization of utility (Equation (10)). Although the entire framework is slightly different, the following calculation is the same as and is quoted from Krishnamurthy and Vissing-Jorgensen (2012-a), with some additional explanations for deepening the understanding of this model.

The budget constraint of Equation (14) in Chapter 3 can be rewritten as a real-based budget constraint, as follows:

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

The intuition of Equation (a-1) is that, for example, the nominal capital gain of a 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 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 on the right-hand side of Equation (a-1). The real return of private-sector assets of the right-hand side of the equation is derived similarly. Then, the real cash balance (a_t) is defined as the right-hand side of Equation (a-1):

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

The budget constraint of Equation (a-1) is rewritten as follows:

$$c_t + \theta_t^G + \theta_t^P = a_t \quad \text{(a-3)}$$

where a_t evolves according to:

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

Therefore, the maximization problem can be written as:

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

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

To solve this problem, the value function $W(a_t)$ associated with this maximization problem is defined as follows:

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

subject to Equation (a-3).

The Lagrangian is as follows:

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

Therefore, the first order conditions are given as follows:

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, the following equation is derived:

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

Then, from (a-5), (a-6), and (a-8), the following equation is derived:

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

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, the pricing kernel for those assets is defined as follows:

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

Therefore, the government bond price (the "convenience" asset price) can be expressed as follows:

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

$$P_t^G = \frac{E_t[M_{t+1}P_{t+1}^G]}{1-v'} \quad \text{(a-11)}$$

The τ-period yields of government bonds is defined as follows:

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

By rewriting Equation (a-11) using the approximation that $1 - v' \approx -e^{v'}$, the return from t to t+1 of government bonds satisfies the following equation:

$$1 = e^{v'} E_t\left[M_{t+1}\frac{P^G_{t+1}}{P^G_t}\right] = E_t[M_{t+1}e^{-(\tau-1)i^G_{t+1,\tau-1}+\tau i^G_{t,\tau}+v\prime}] \tag{a-13}$$

Furthermore, by denoting 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, the corporate bond price can be described as follows:

$$P^P_t = \rho_t E^D_t[M_{t+1}(1 - D_{t+1})] + (1 - \rho_t)E^N_t[M_{t+1}P^P_{t+1}] \tag{a-14}$$

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

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

$$E^D_t[M_{t+1}(1 - D_{t+1})] = E_t[M_{t+1}P^P_{t+1}](1 - L_t) \tag{a-15}$$

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 an unconditional expectation. The L_t denotes some adapted process, bounded by 1.

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

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

Next, the τ-period yields of corporate bonds is defined as follows:

$$i_{t,\tau}^P = -\frac{1}{\tau}lnP_t^P \tag{a-17}$$

Then, the return from t to t+1 on holding corporate bonds is as follows by rewriting Equation (a-16) like Equation (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, the τ-period spread between those bonds is defined as follows:

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

The one-period excess return on corporate bonds over government bonds is as follows:

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

Assuming 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, Equation (a-13) can be subtracted from Equation (a-18) to make the approximation. Then, the yield spread between the corporate bond and government bond at τ-period can be derived.

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

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

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

With the assumption that $v''(\cdot) < 0$, $S_{t,\tau}$ decreases with an in increase in θ_t^A/GDP_t. If θ_t^A/GDP_t decreases with a decrease in θ_t^G/GDP_t, the reduced supply of government bonds, $S_{t,\tau}$ will expand.

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

- Encourages the uncollateralized O/N call rate to remain around 0-0.1 percent.
- Maintains the virtually zero interest rate policy until the BOJ 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 the condition that no problem will be identified when examining risk factors, including the accumulation of financial imbalances.
- Establishes the Asset Purchase Program (government securities, CP, corporate bonds, ETFs, and J-REITs with a total of 35 trillion yen, then expanded to 40 trillion. yen in March 2011, 50 trillion yen in August 2011, 55 trillion yen in October 2011, 65 trillion yen in February 2012, 70 trillion yen in April 2012, 80 trillion yen in September 2012, 91 trillion yen in October 2012, and 101 trillion yen in December 2012).
- Introduces the Measures to Support Strengthening the Foundations of Economic Growth (from June 2010, gradually expanding to equity investments and asset-based lending, small lot investments and loans, and the US dollar lending arrangement).
- Introduces the Measure to Stimulate Bank Lending (from December 2012).
- (Establishes the Price Stability Goal in the medium-to-long term, within a positive range of 2 percent or lower in the CPI, setting a goal at 1 percent for the time being in February 2012.)

Source: Bank of Japan

Note: Parenthesis denotes the policy that does not belong to but is strongly linked to the CE.

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

- (Establishes the Price Stability Target at 2 percent of the CPI in Jan. 2013.)
- Commits to achievement of the price stability target of 2 percent at the earliest possible time, with a time horizon of about two years.
- Adopts the monetary base control (60-70 trillion yen per year [double in two years], then expanded to 80 trillion yen per year in October 2014).
- Increases the JGB purchases (50 trillion yen per year, then expanded to 80 trillion yen per year in October 2014) and extends their maturity (to about seven years, which is more than double, then to about 7-10 years in October 2014).
- Increases the ETF (1 trillion yen per year, then expanded to 3 trillion yen per year in October 2014) and the J-REIT (30 billion yen per year, then expanded to 90 billion yen per year in October 2014).
- Continues the QQE as long as it is necessary for maintaining the price stability target in a stable manner.

Source: Bank of Japan

Note: Parenthesis denotes the policy that does not belong to but is strongly linked to the QQE.

Table 3. Changes in the Overnight Index Swap Rates During the CE and QQE

Basis points

Asset / Event	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. QQE2 (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 ***1 percent, **5 percent, and *10 percent of F-statistics. The Newey-West's HAC estimator has been applied.

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

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

Table 4. Changes in the Japanese Government Bond Yields Around the CE and QQE

Basis points

Asset / Event	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 ***1 percent, **5 percent, and *10 percent of F-statistics. The Newey-West's HAC estimator has been applied.

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

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

Table 5. Changes in the Corporate Bond Yields Around the 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 the Rating and Investment Information.

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

3. All changes are over two 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 the partial revision of the Money Lending Business Law and the Great East Japan Earthquake.

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

Table 6. Changes in the Corporate Bond Yields Adjusted by Credit Default Swap Rates and the USD/JPY Exchange Rate Around the CE and QQE

Basis points

Event \ Asset	Adjusted Corporate Yields										FOREX
	AA	AA	A	BBB	AA	A	BBB	AA	A	BBB	USD/JPY
	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. The credit default swap rates are provided by Markit. The USD/JPY rate is expressed as the log return.

2. Asterisks show statistical significance at ***1 percent, **5 percent, and *10 percent of F-statistics. The Newey-West's HAC estimator has been applied.
3. All changes are over two 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 the partial revision of the Money Lending Business Law and the Great East Japan Earthquake.
5. The sample period is from the beginning of January 2010 to November 19, 2014.

Table 7. Difference Between the Changes in CDS-Adjusted Corporate Bond Yields and Changes in the Japanese Government Bond Yields Around the CE and QQE

Basis points

Asset / Event	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 ***1 percent, **5 percent, and *10 percent of F-statistics. The Newey-West's HAC estimator has been applied.

3. All changes are over two 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 the partial revision of the Money Lending Business Law and the Great East Japan Earthquake.

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

Table 8. Fama Coefficients (Relationship Between the USD/JPY Exchange Rate and the 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]
		$rx_{t+1} = \alpha_n^{rx} + \beta_n^{rx} (y_{t,n} - y^*_{t,n}) + \epsilon_{t,n}$					
2003/1-2015/9	$\widehat{\beta_n^{rx}}$	-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	$\widehat{\beta_n^{rx}}$	-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	$\widehat{\beta_n^{rx}}$	-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	$\widehat{\beta_n^{rx}}$	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 Data

Note: 1. This is a revised estimation of Kano and Wada (2015).

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

Table 9. Changes in the Inflation Swap Rates, Break-Even Inflation Rates of Inflation-Indexed Government Bonds Around the CE and QQE

Basis points

Event \ Asset	Inflation Swaps	Break-Even Inflation Rate	Inflation Swaps	Break-Even Inflation Rate
	10 year		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 ***1 percent, **5 percent, and *10 percent of F-statistics.

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

3. The sample period is from the beginning of January 2010 to November 19, 2014. For the break-even inflation rate for 10 years, the sample period is from October 16, 2013, to November 19, 2014. 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. Inflation Expectations and the Nominal Effective Exchange Rate of the Yen

Inflation expectation (%) = c+ α*(yen nominal effective exchange rate (% year-on-year))

	Inflation swap (10 year)	QSS forecast (2-10 years)	Tankan corporate output prices DI	Household opinion (5 year)
c	0.353***	1.171***	-12.628***	1.195***
t-statistic	[6.03]	[42.88]	[-13.46]	[54.35]
α	-0.029***			-0.009***
t-statistic	[-4.76]			[-4.41]
α(-1)		-0.006**		
t-statistic		[-2.56]		
α(-2)	-0.029***			
t-statistic	[-4.50]			
α(-4)			-0.676***	-0.007**
t-statistic			[-8.44]	[-2.02]
α(-5)				-0.009**
t-statistic				[-2.58]
R^2	0.788	0.170	0.710	0.810

Source: Ugai (2016-b)

Note: 1. The QSS forecast is the average of inflation forecasts collected by QUICK Survey.

2. DI in the Tankan represents the difference between the share of firms that raised prices in the preceding three months and the share of firms that lowered prices.

3. Household Opinion Survey figures exclude inflation expectations by respondents whose annual inflation expectations were ±5% or greater.

4. As Ugai (2016-b) does not disclose the t-statistics, this paper re-estimates the t-statistics.

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

6. Sample period is from 2Q/2008 to 3Q/2016.

Table 11. Impact of the Japanese Government Bond Supply on Bond Spreads: Log Function

	AA10yr-JGB10yr
Log(debt/GDP)	-0.266
t-statistic	[-1.32]
EDF	0.074**
t-statistic	[2.50]
Earthquake dummy	0.076**
t-statistic	[2.30]
Intercept	0.203***
t-statistic	[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. The one-year 50th percentile of Japan's corporations is used.
4. The Great East Japan Earthquake changed the creditworthiness and ratings of some large companies drastically, thereby distorting the yields of AA corporate bonds. This distortion is removed by adding the earthquake dummy variable.
5. Asterisks show statistical significance at ***1 percent, **5 percent, and *10 percent of t-statistics.
6. The sample period is from 4Q/1997 to 4Q/2014.
7. The error terms are adjusted with AR(1) and AR(2).

Table 12. Comparison of the Supply of Japanese Government Bonds and the Monetary Base

	AA10yr-JGB10yr
Log(debt/GDP)	-0.251
t-statistic	[-1.19]
Log(MB/GDP)	-0.022
t-statistic	[-0.29]
EDF	0.076**
t-statistic	[2.49]
Earthquake dummy	0.075**
t-statistic	[2.22]
Intercept	0.168
t-statistic	[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. The one-year 50th percentile of Japan's corporates is used.
4. The Great East Japan Earthquake changed the creditworthiness and rating of some large companies drastically, thereby distorting the yields of AA corporate bonds. This distortion is removed by adding the earthquake dummy variable.
5. Asterisks show statistical significance at ***1 percent, **5 percent, and *10 percent of t-statistics.
6. The sample period is from 4Q/1997 to 4Q/2014.
7. The error terms are adjusted with AR(1) and AR(2).

Table 13. Impact of Japanese Government Bond Supply on Bond Spreads: Piecewise-Linear Function

$$Spread(Corporate\ Bond - Government\ Bond)_t$$
$$= a + b_1 \max\left[b_2 - ln\left(\frac{Public\ Debt_t}{GDP}\right),\ 0\right] + c\ \ Default\ Risk_t + error_t$$

	AA10yr-JGB10yr
b_1	2.143***
t-statistic	[7.10]
b_2	-0.299***
t-statistic	[-14.12]
EDF	0.072***
t-statistic	[3.02]
Earthquake dummy	0.070**
t-statistic	[2.52]
Intercept	0.146***
t-statistic	[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. one-year 50th percentile of Japan's corporates is used.
4. The Great East Japan Earthquake changed the creditworthiness and rating of some large companies drastically, thereby distorting the yields of AA corporate bonds. This distortion is removed by adding the earthquake dummy variable.
5. Asterisks show statistical significance at ***1 percent, **5 percent, and *10 percent of t-statistics.
6. The sample period is from 4Q/1997 to 4Q/2014.
7. The error terms are adjusted with AR(1) and AR(2).

Table 14. Impact of the Monetary Base Supply on Bond Spreads: Piecewise-Linear Function

$$Spread(Corporate\ Bond - Government\ Bond)_t$$
$$= a + b_1 \max\left[b_2 - ln\left(\frac{Monetary\ \ Base}{GDP}\right),\ 0\right] + c\ \ Default\ Risk_t + error_t$$

	AA10yr-JGB10yr
b_1	0.063
t-statistic	[0.38]
b_2	-1.014
t-statistic	[-0.77]
EDF	0.073**
t-statistic	[2.42]
Earthquake dummy	0.077**
t-statistic	[2.13]
Intercept	0.134
t-statistic	[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 the end day of every quarter.
3. EDF is the expected default frequency for corporate bonds. The one-year 50th percentile of Japan's corporates is used.
4. The Great East Japan Earthquake changed the creditworthiness and rating of some large companies drastically, thereby distorting the yields of AA corporate bonds. This distortion is removed by adding the earthquake dummy variable.
5. Asterisks show statistical significance at ***1 percent, **5 percent, and *10 percent of t-statistics.
6. The sample period is from 4Q/1997 to 4Q/2014.
7. The error terms are adjusted with AR(1) and AR(2).

Table 15. Asset Allocation of Non-Bank Financial Institutions

1. 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
Hong 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

2. Asset Allocation of Insurance Companies

(%)

	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

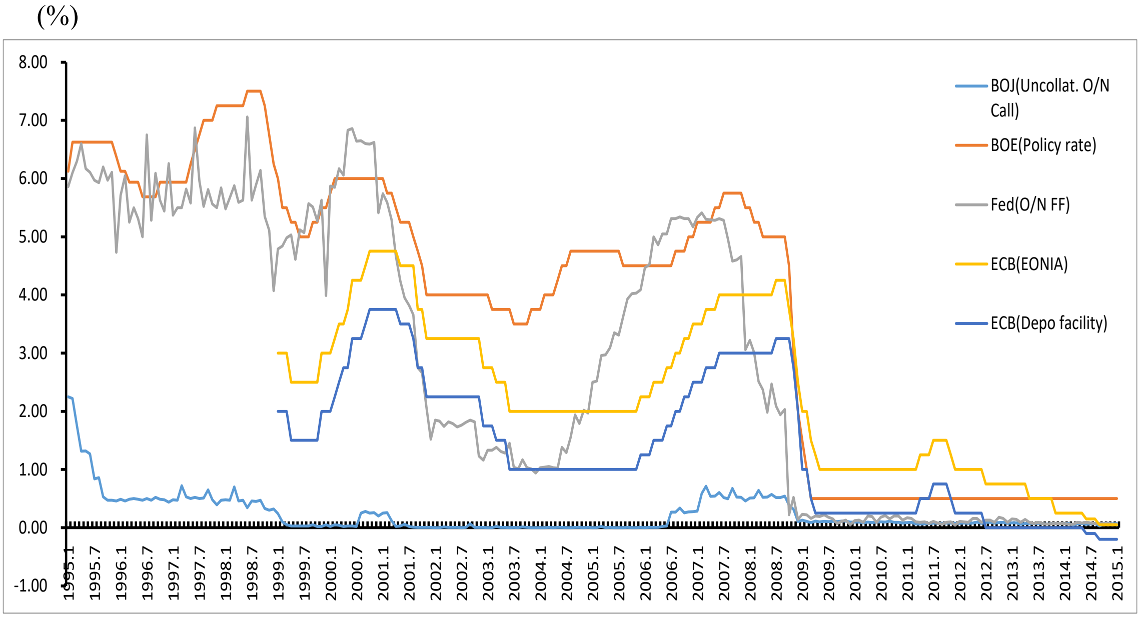
Source: Arslanalp and Botman (2015)

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

2. Domestic bonds are government bonds and corporate bonds.

3. The average is the average of all countries shown above, excluding Japan.

Figure 1. Policy Rates of Major Central Banks



Source: CEIC Data

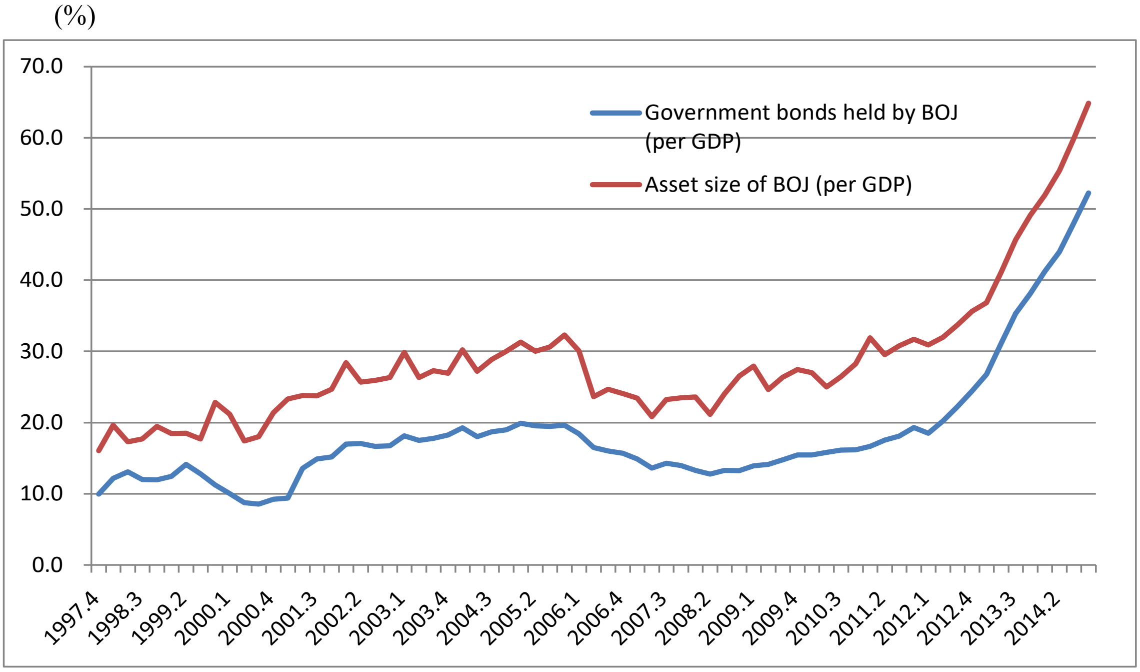
Note: 1. Bank of Japan: Uncollateralized overnight call rate.

2. Bank of England: Official bank rate.

3. Federal Reserve: Overnight Federal Funds rate.

4: European Central Bank: Euro overnight index average (EONIA) and deposit facility rate.

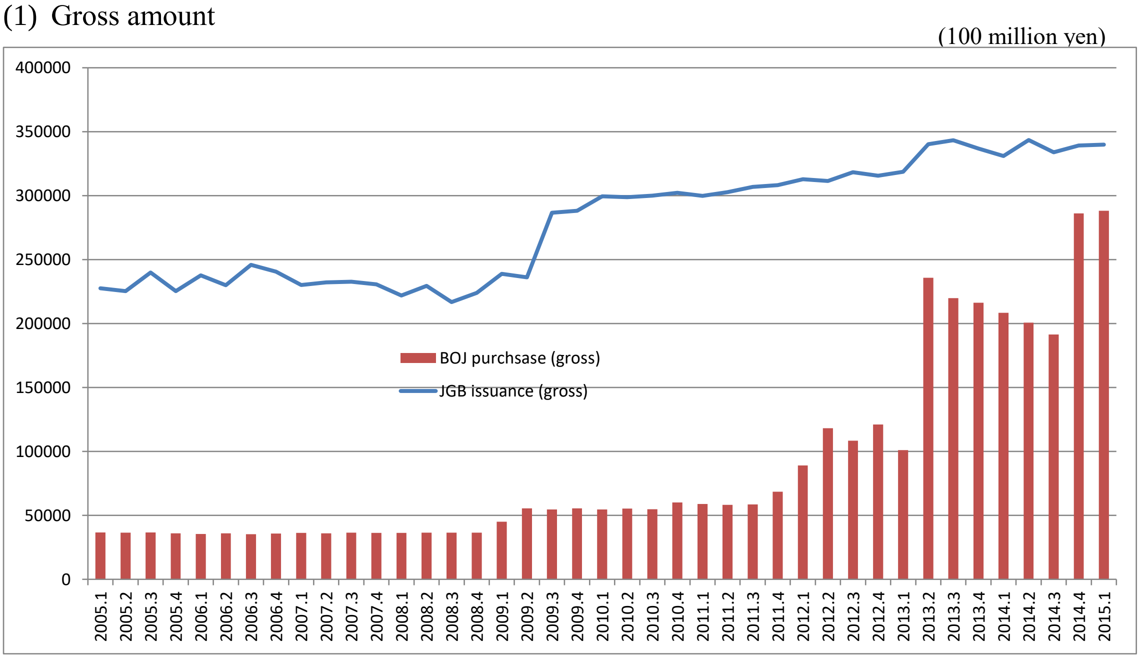
Figure 2. Asset Size of the Bank of Japan



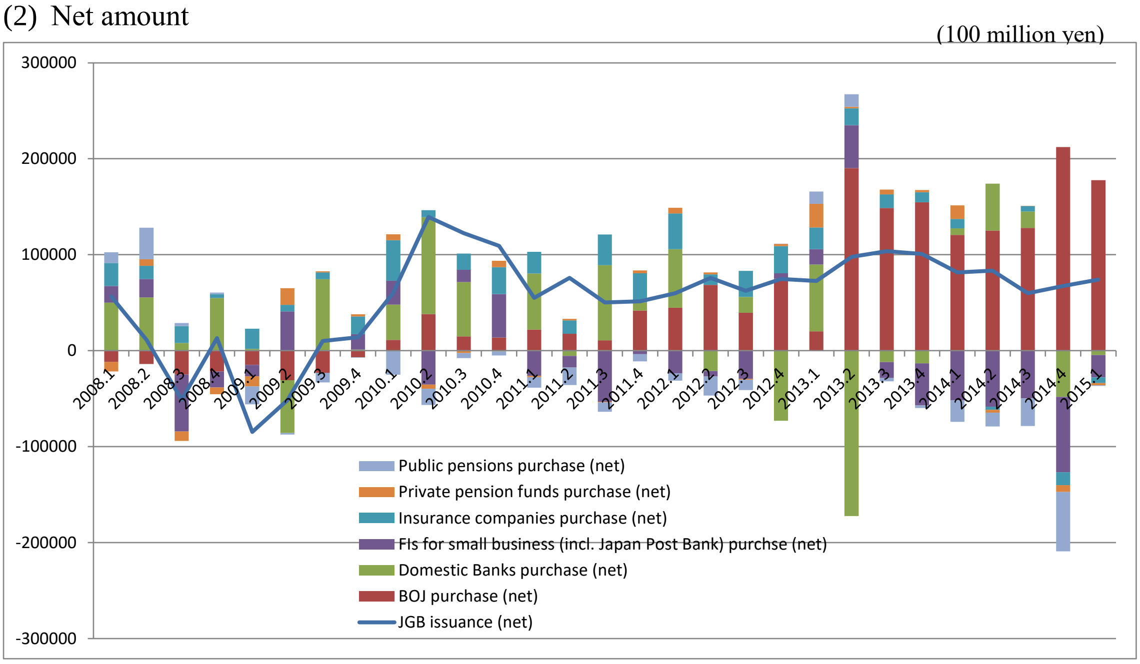
Source: Bank of Japan (flow of funds), Cabinet Office (quarterly estimate of GDP)

Figure 3. Japanese Government Bond Issuance and Purchases by the Bank of Japan

(1) Gross amount



(2) Net amount

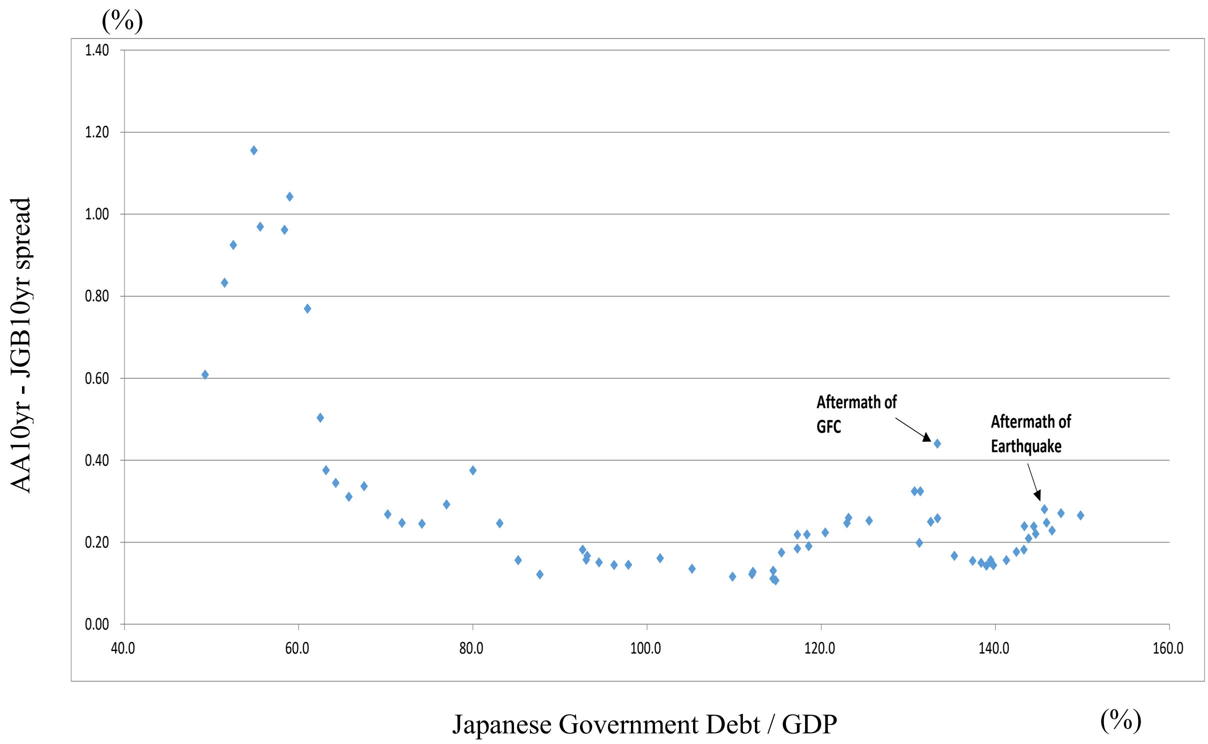


Source: Bank of Japan (flow of funds), Japan Dealers Securities Association.

Note: 1. The gross issuance of JGBs is calculated by deducting the amount of issuance for individuals and of treasury bills from the total issuance amount of government bonds.

2. The net issuance is the amount of issued JGBs minus their redemption. The net purchase is the amount of purchased JGBs minus their sale.

Figure 4. Corporate Bond Spread and Consolidated Government Debt



Source: Bloomberg, Bank of Japan (flow of funds), Cabinet Office (quarterly estimate of GDP)

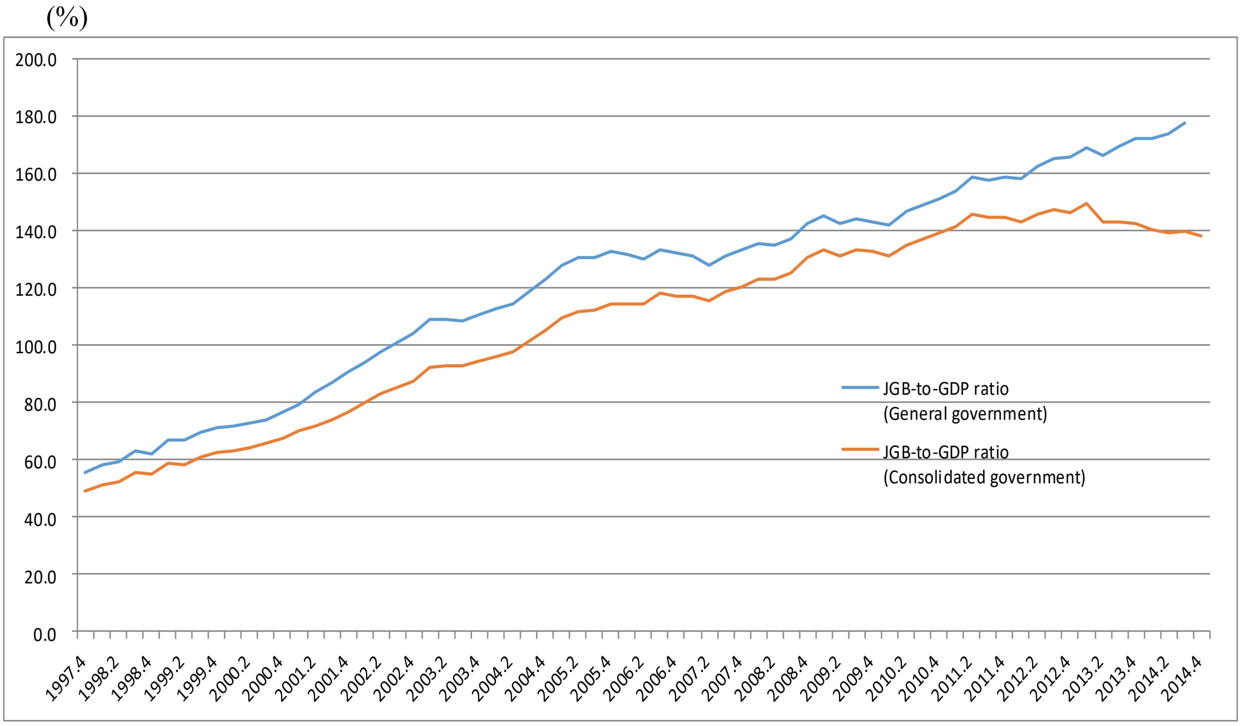
Note: 1. AA is rated by Rating and Investment Information.

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 FILP bonds minus the amount of JGBs held by the BOJ.

4. The sample period is from 4Q/1997 to 4Q/2014.

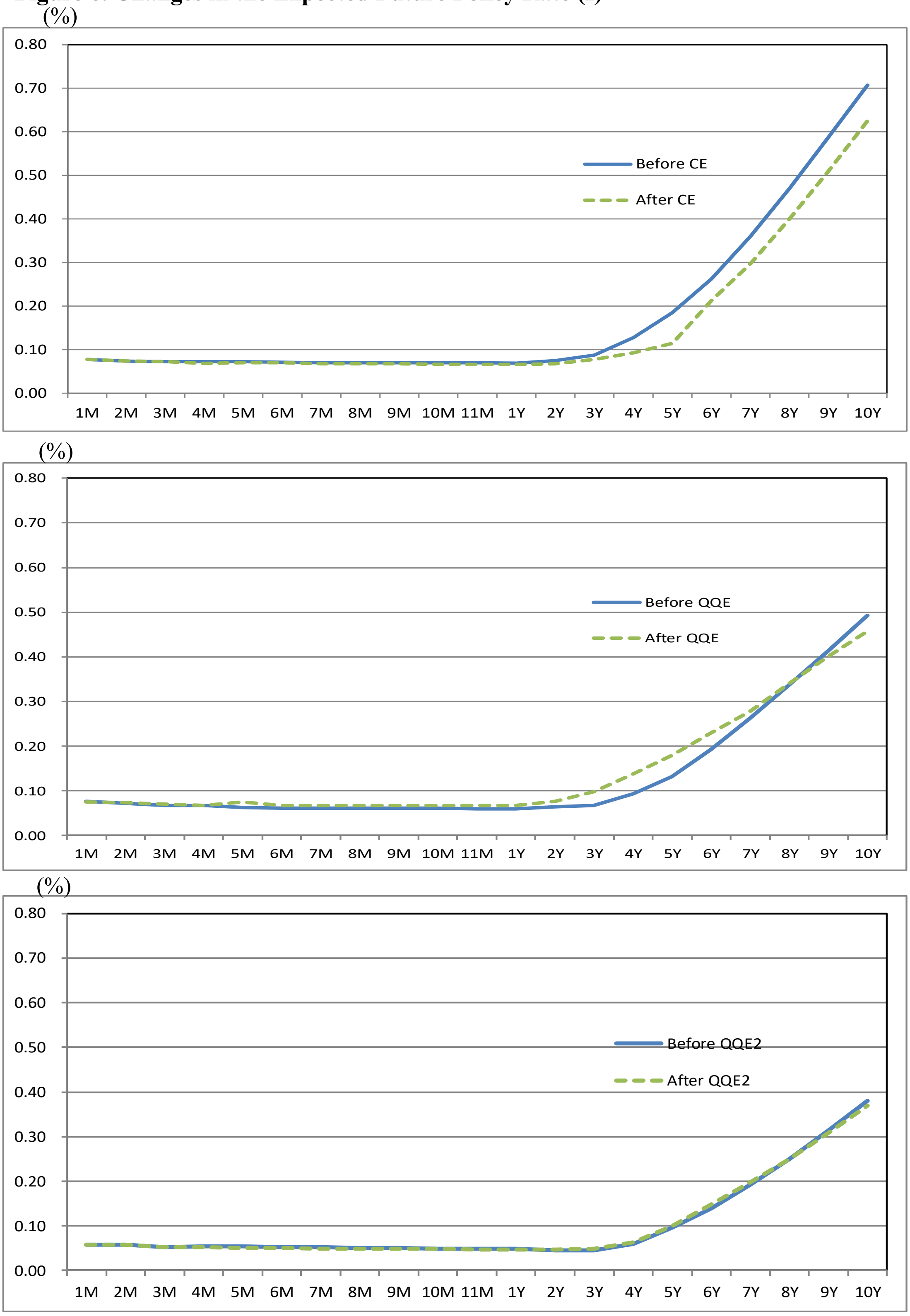
Figure 5. Outstanding Amount of Japanese Government Bonds: General Government and Consolidated Government



Source: Bank of Japan (flow of funds), Cabinet Office (quarterly estimate of GDP)

Note: The Consolidated Government incorporates the General Government (Central Government and Fiscal Investment and Loan Program) with the BOJ.

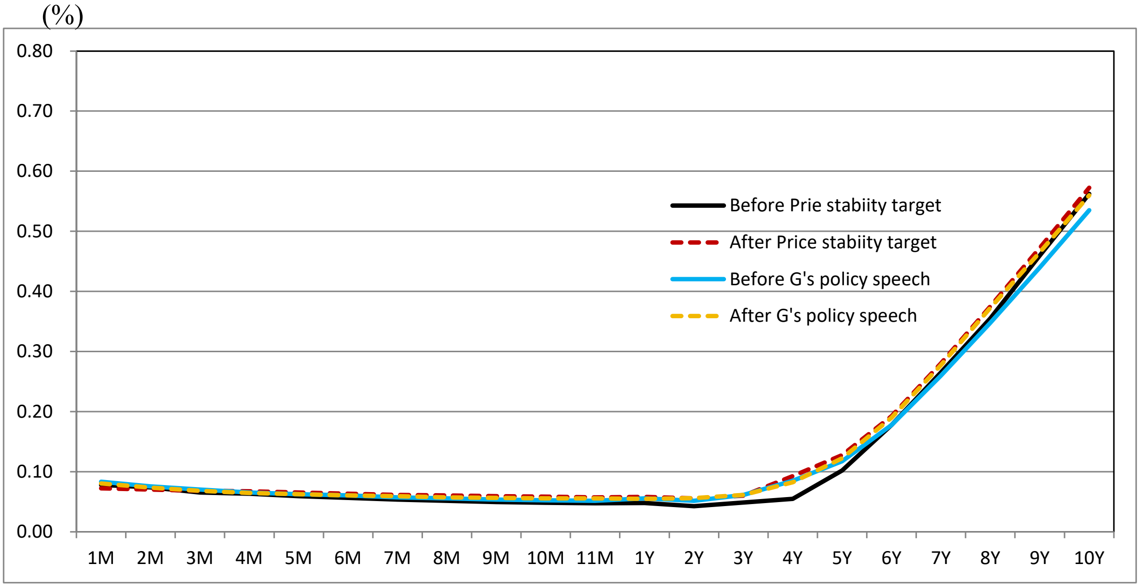
Figure 6. Changes in the Expected Future Policy Rate (I)



Source: Bloomberg

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

Figure 7. Changes in the Expected Future Policy Rate (II)

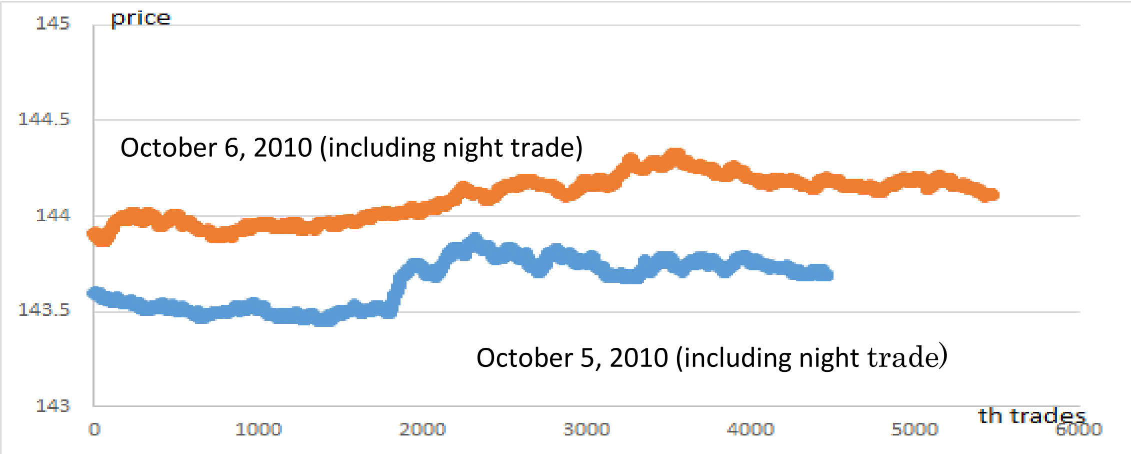


Source: Bloomberg

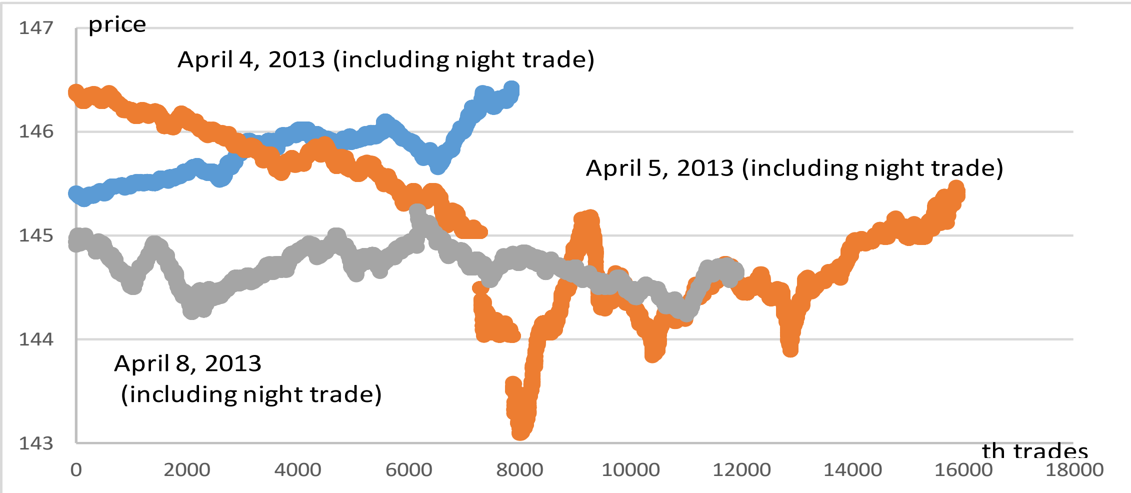
Note: All changes are over two days, from the day before to the day after the monetary easing.

Figure 8. Short-Run Volatilities of 10-Year JGB Prices

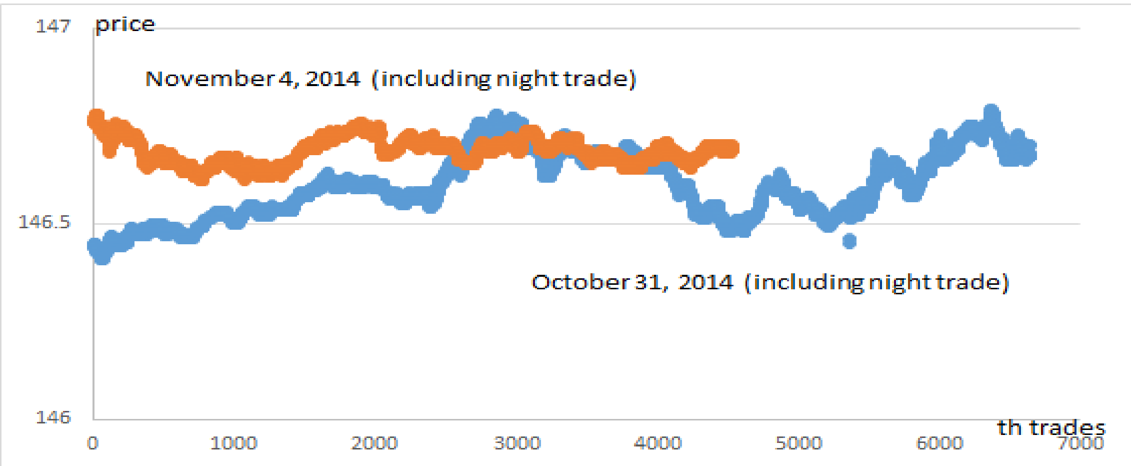
1. Introduction of the CE



2. Introduction of the QQE



3. Expansion of the QQE (QQE2)

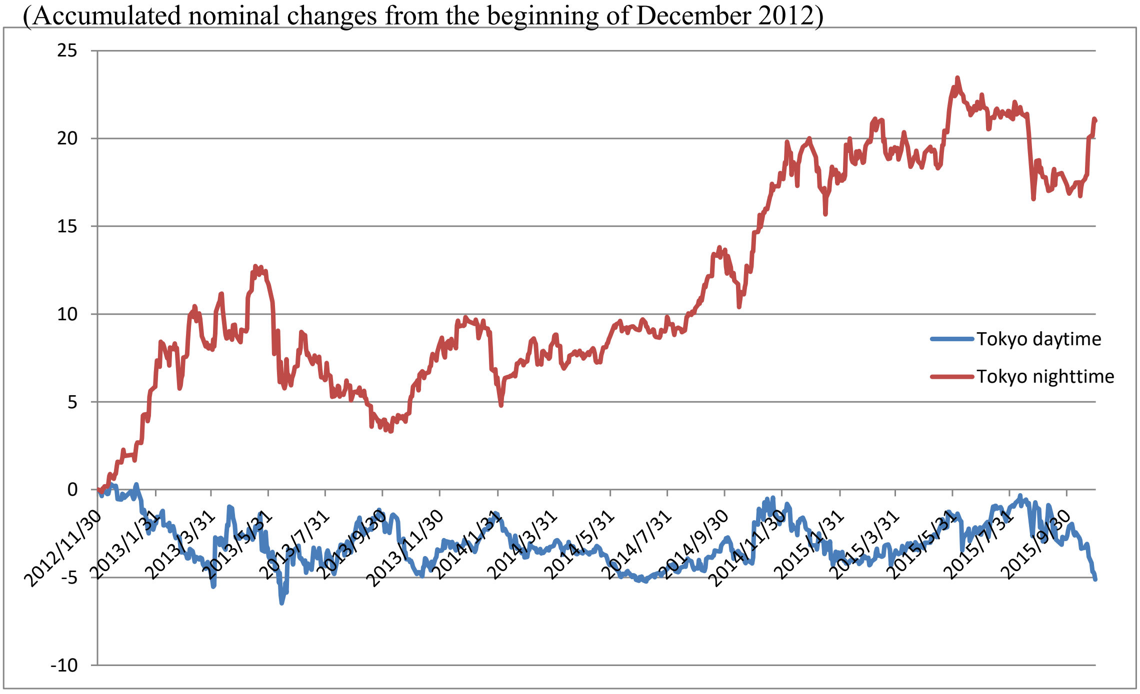


Source: JPX cloud data

Note: These three figures denote every transaction on the above-mentioned days.

Figure 9. Accumulated Changes in the USD/JPY Exchange Rate

(Accumulated nominal changes from the beginning of December 2012)



Source: BOJ, Bloomberg

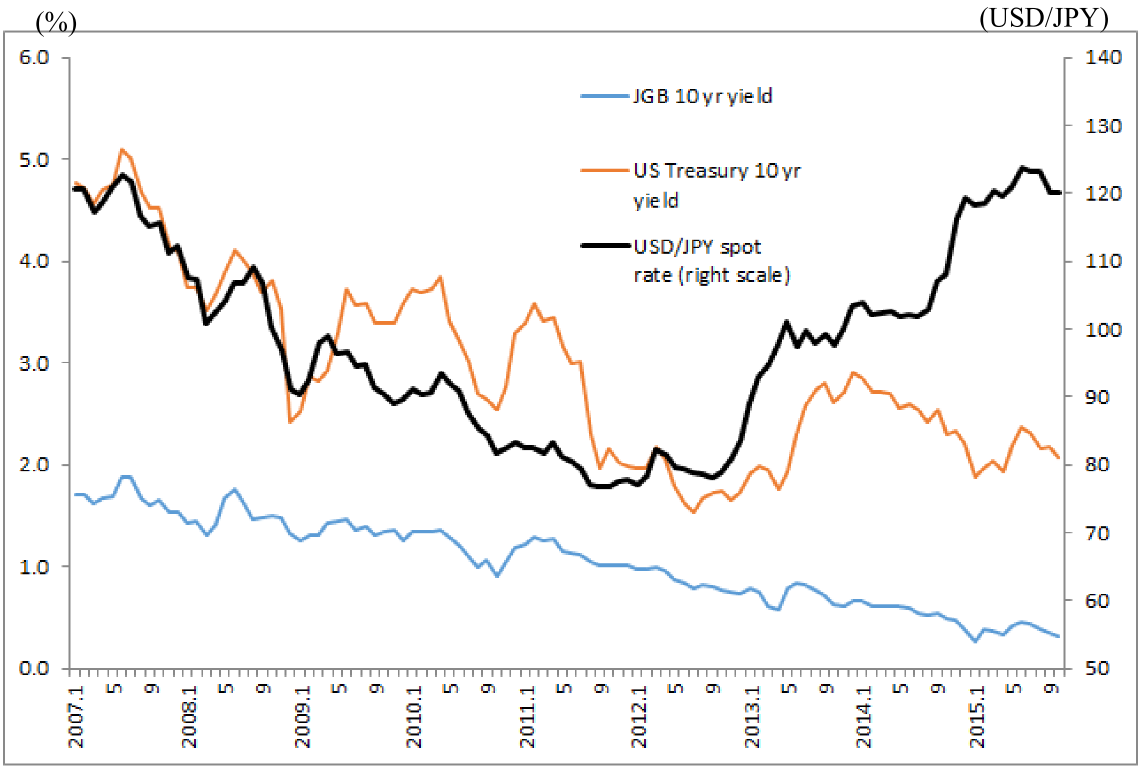
Note: 1. Revised estimation of Fukuda (2014).

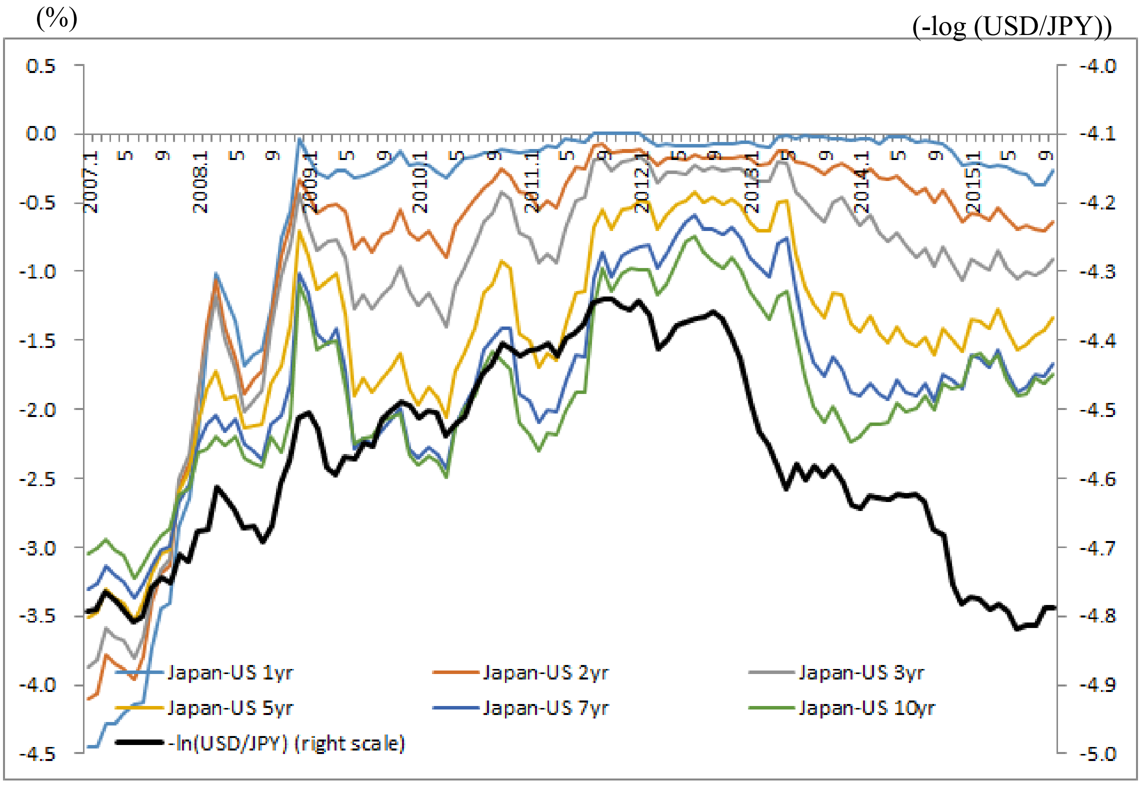
2. Tokyo daytime denotes trading from 9 am in Tokyo to 5 pm in Tokyo.

3. Tokyo nighttime denotes 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.

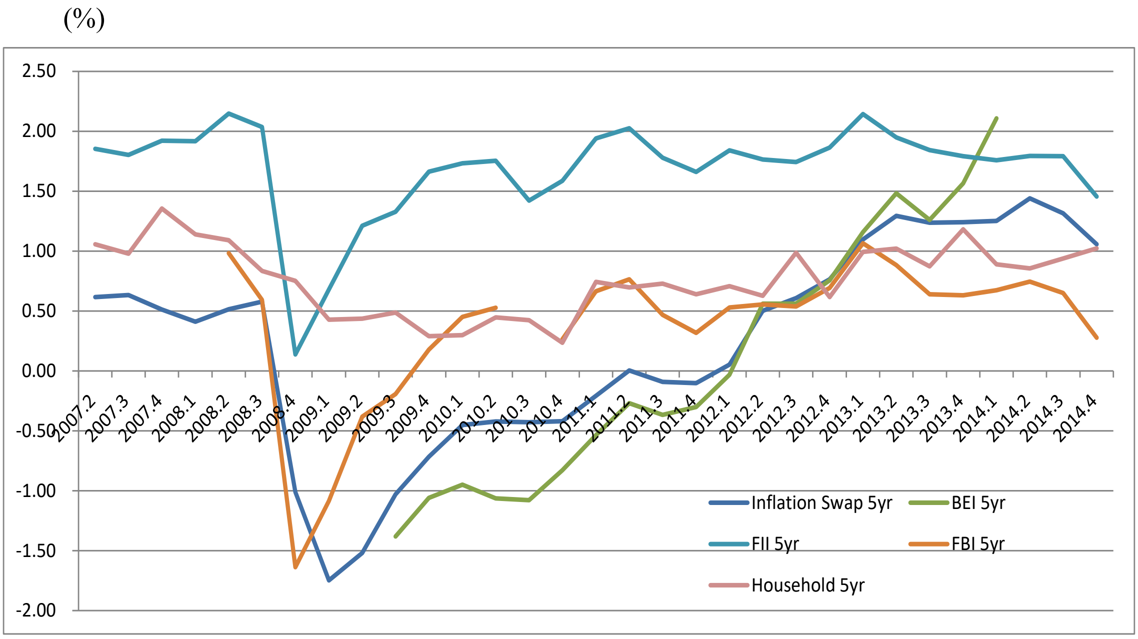
Figure 10. 10-Year Government Bond Yield Differential and the USD/JPY Exchange Rate





Source: CEIC Data

Figure 11. Inflation Expectations

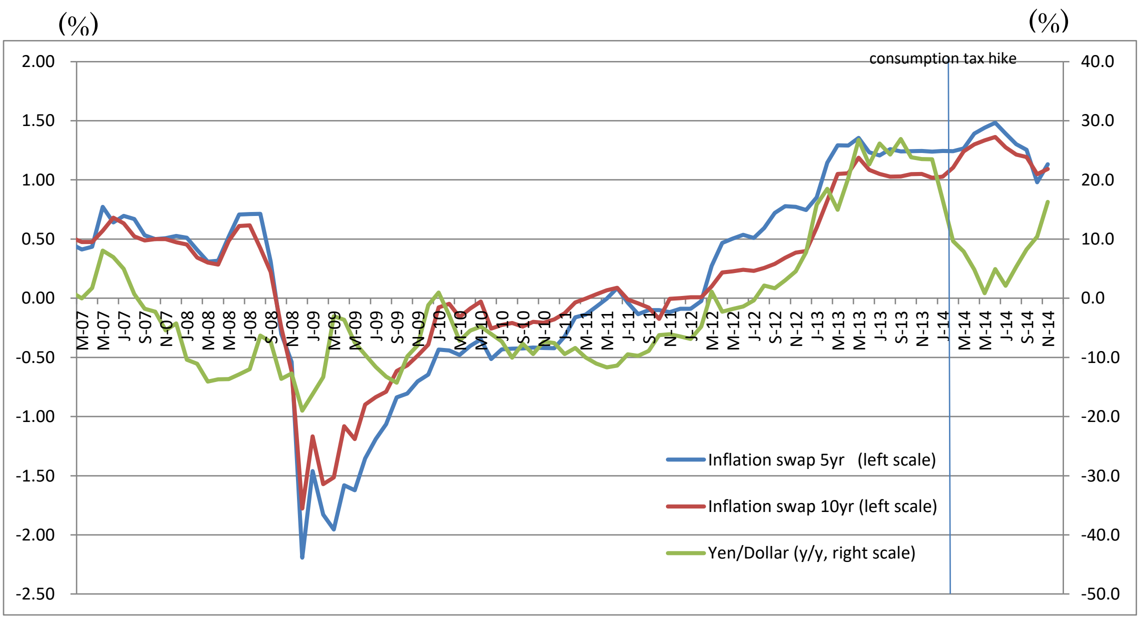


Source: Bloomberg, Barclays Capital, Bank of Japan (Opinion Survey on the General Public's Views and Behavior, and estimation of inflation expectation using the Carlson-Parkin method)

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

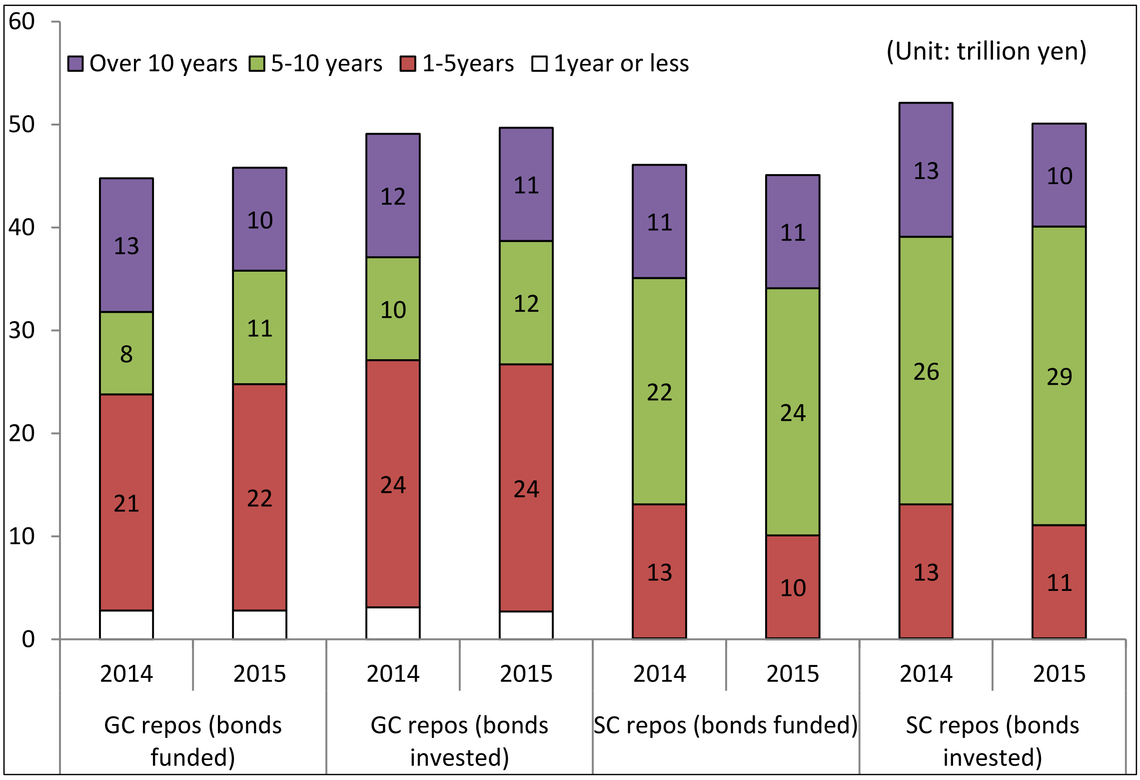
2. The definition of FII and FBI are explained in Chapter 2(E), the inflation expectation channel.

Figure 12. Inflation Expectation and the Foreign Exchange Rate



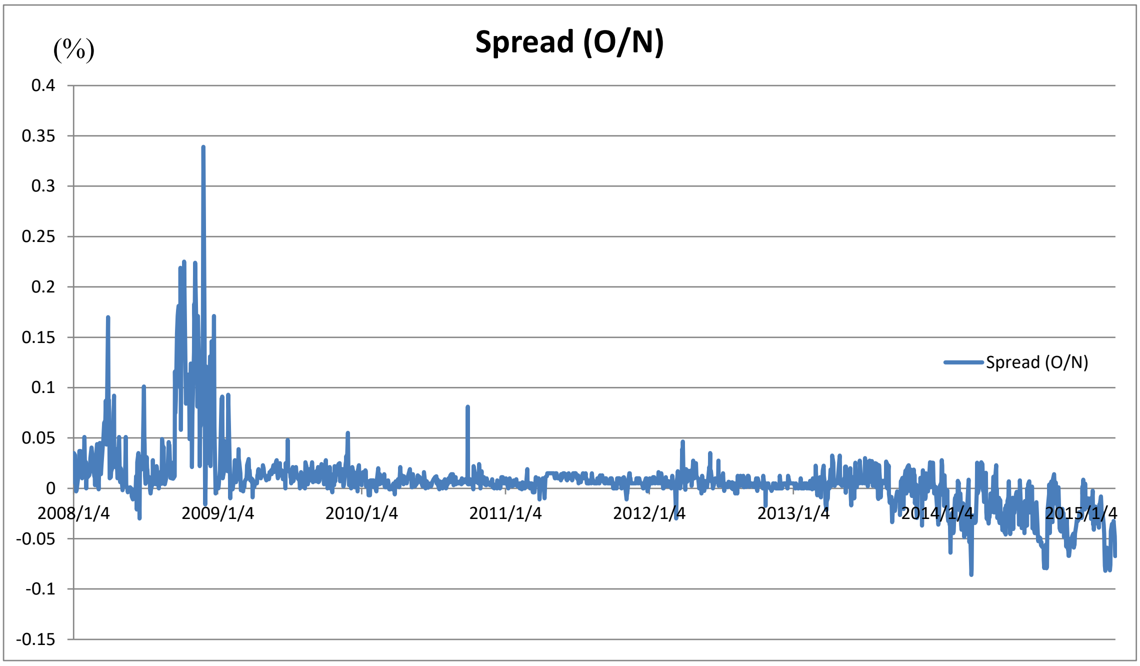
Source: Bloomberg, Barclays Capital

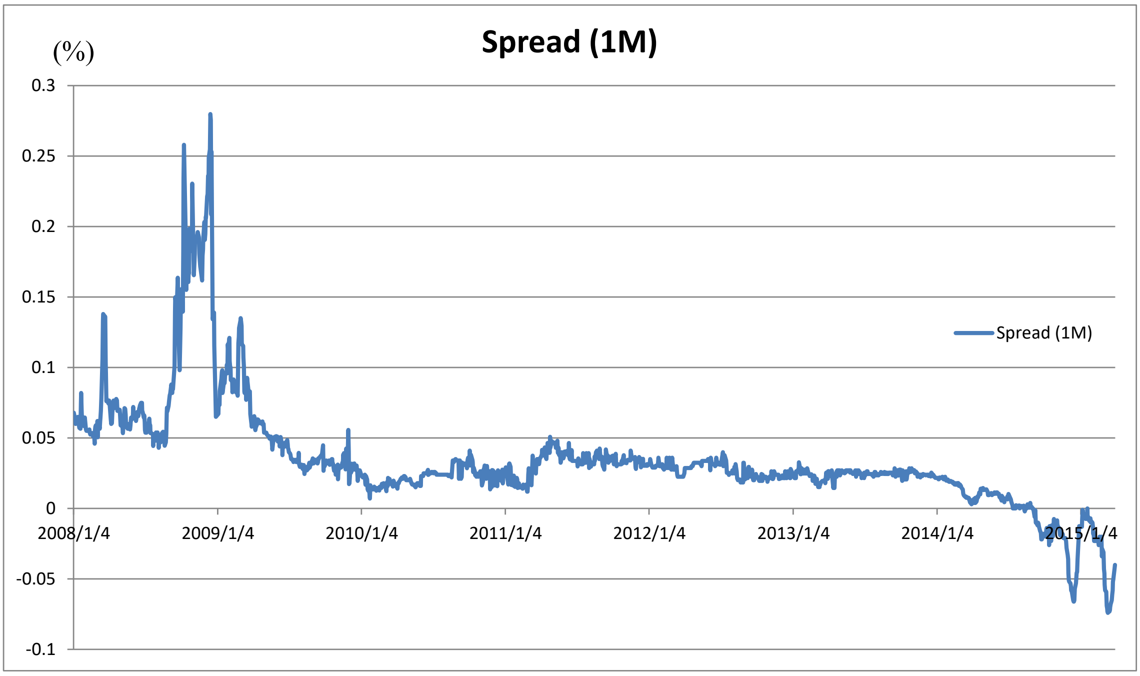
Figure 13. Amount Outstanding of Collateral Bonds of Repos by Remaining Maturities



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

Figure 14. Spread of Repo Rates Against Interbank Money Market Rates

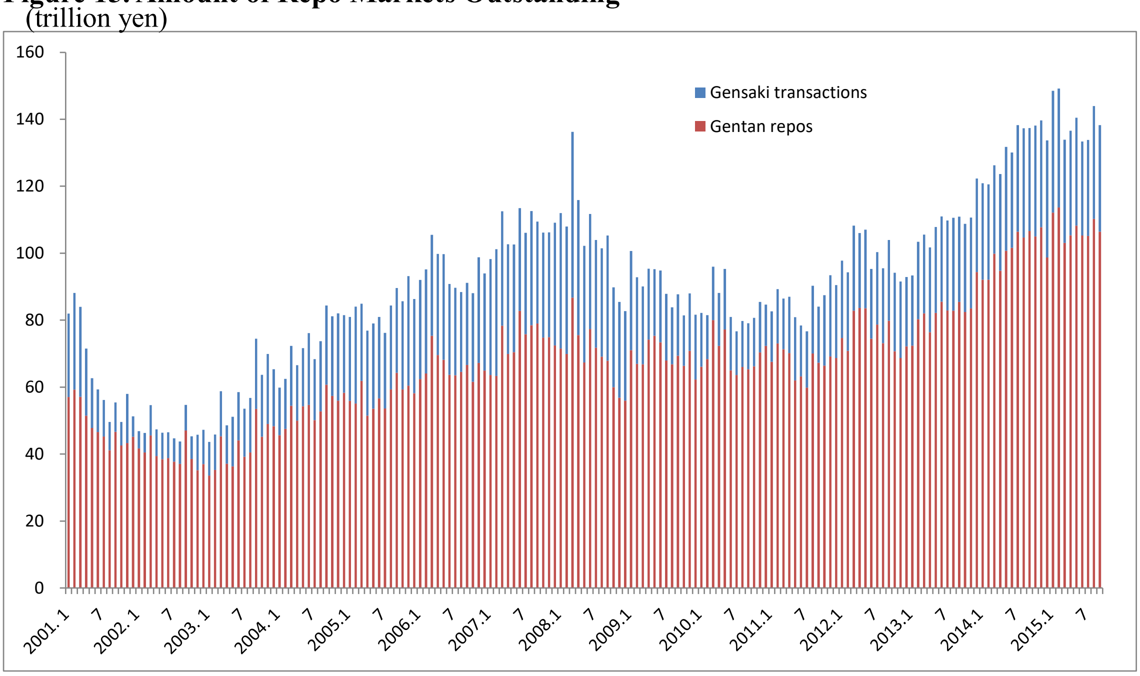




Source: Bloomberg

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

Figure 15. Amount of Repo Markets Outstanding



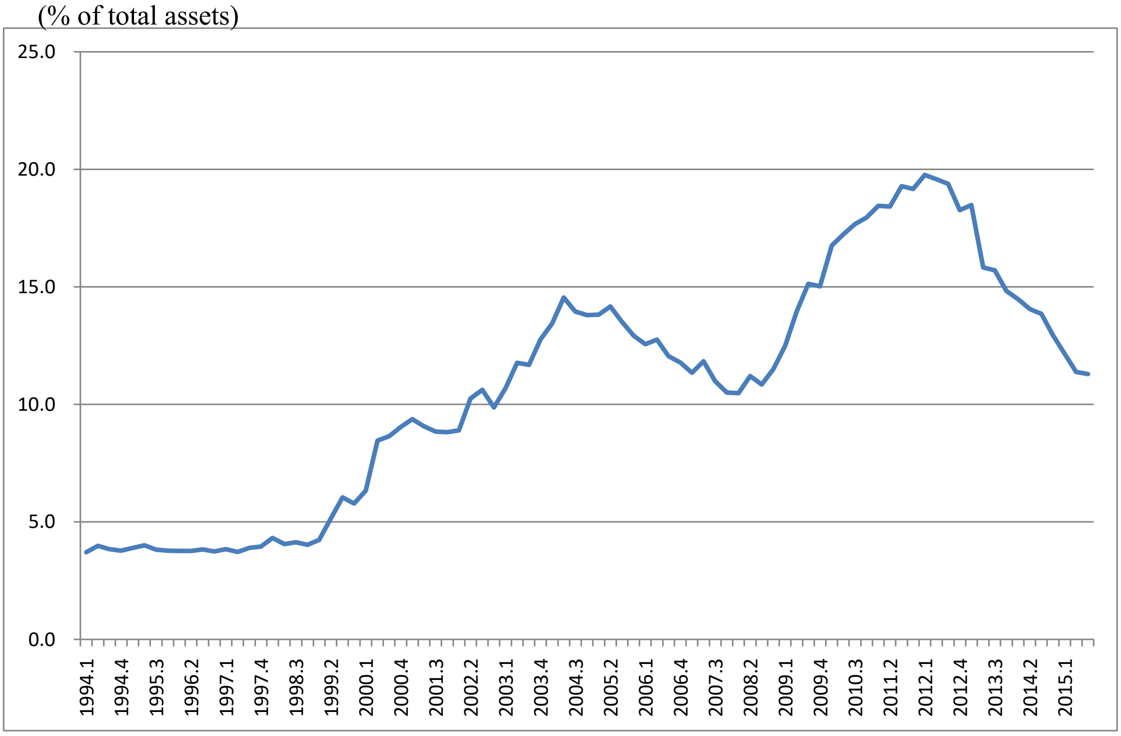
Source: Japan Securities Dealers Association

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.

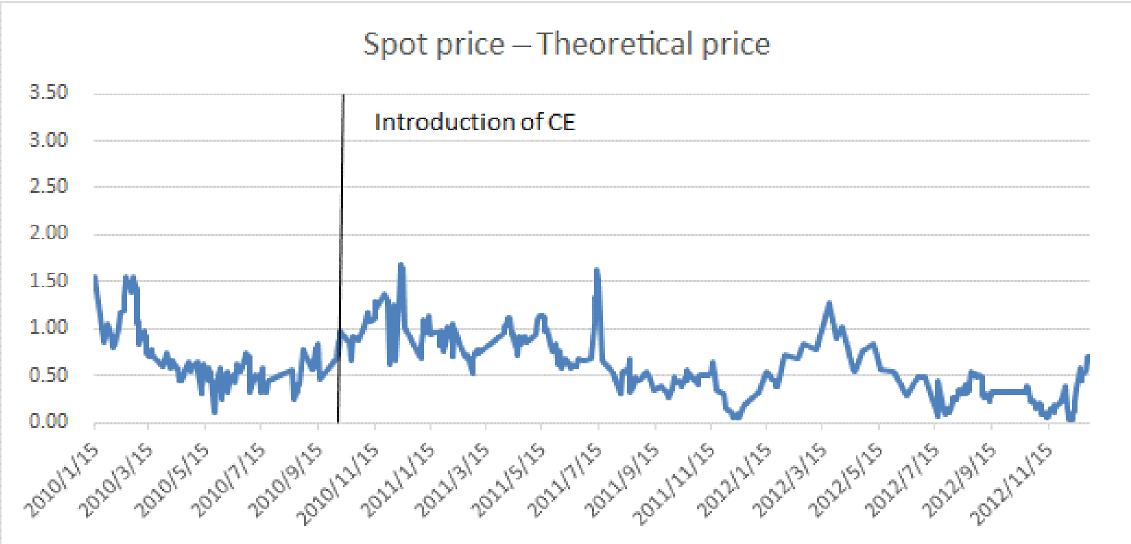
Figure 16. JGB Holdings by Domestically Licensed Banks (Banking Accounts)



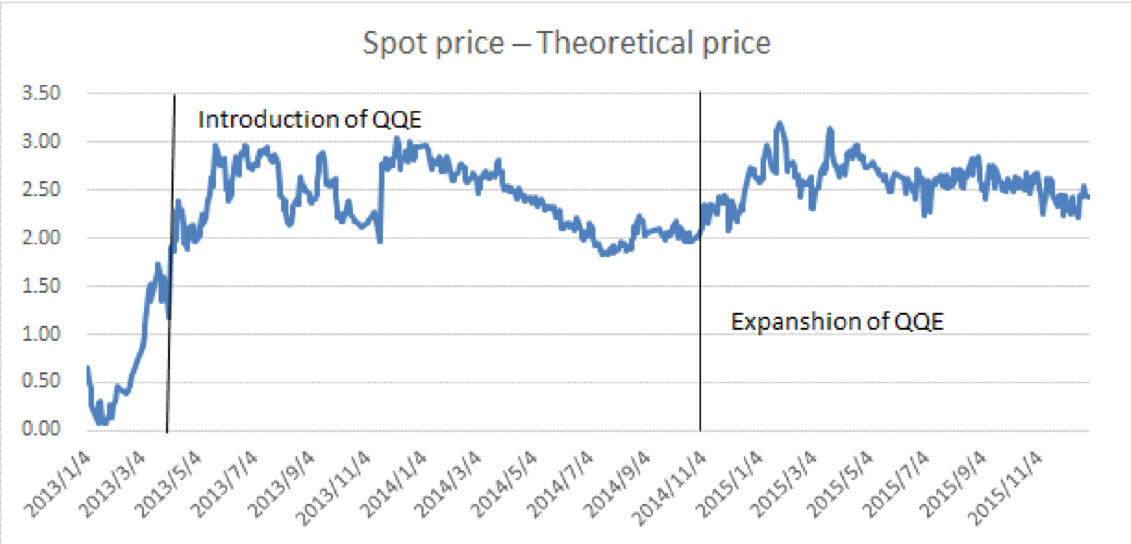
Source: Bank of Japan (Monetary Aggregates)

Figure 17. Convenience Yield Derived from the Spot Price and Theoretical Price of 10-Year JGBs

1. Before the QQE



2. Since the QQE



Source: Bloomberg, Nikkei Financial Quest

Note: See Fukuta, Saito, and Takagi (2002) for the method of deriving the convenience yield.