Policy Commitment and Market Expectations: Survey Based Evidence under Japan's Quantitative Easing Policy (very preliminary)

Yoshiyuki Nakazono*and Kozo Ueda†

October 26, 2010

Abstract

Using the survey on inflation expectations as well as interest rate expectations, we evaluate the effect of Japan's quantitative easing policy adopted from March 2001 to March 2006. We focus on the CPI commitment policy, under which the Bank of Japan promised to keep their accommodative policy until the CPI inflation rate became stably zero or higher. The survey shows a kinked response of expectations: market participants anticipated a continuation of the quantitative easing policy as long as their inflation expectations were below a threshold, while they anticipated the exit from it when their inflation expectations exceeded the threshold. The threshold inflation rate is about 0 percent annually. The survey also suggests that for the medium-term interest rates, the CPI commitment policy lowered interest rate expectations by about 0.2 percent points given the same level of inflation expectations.

*Waseda University (E-mail: ynakazono@fuji.waseda.jp)

†Director and Senior Economist, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: kouzou.ueda@boj.or.jp). The authors thank the QUICK corporation for the permission of using panel data on each individual forecast. The authors also thank Kosuke Aoki, Toni Braun, Shinichi Fukuda, Yuichi Fukuta, Yasuo Hirose, Yukinobu Kitamura, Akira Sadahiro, Mototsugu Shintani, Michio Suzuki, Kenichiro Tamaki, Kazuo Ueda, seminar participants at Osaka University, University of Tokyo, Waseda University, and the staff of the Institute for Monetary and Economic Studies (IMES), the Bank of Japan, for their useful comments. Views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Bank of Japan.

1 Introduction

In the 1990s and 2000s, while the zero lower bound (ZLB) on nominal interest rates constrained the effectiveness of monetary policy, the Bank of Japan (BOJ) adopted a series of unprecedented policy. Quantitative easing policy (QEP) and CPI commitment policy as a part of it were among them, which were conducted from March 2001 to March 2006. Under the CPI commitment policy, the BOJ promised to keep their accommodative policy until the CPI inflation rate became stably zero or higher. Although this type of commitment was unprecedented in those days, it is no more unique in Japan. In the recent global financial crisis, similar policy was implemented by other central banks such as Bank of Canada and Riksbank.[1]

In this paper, we evaluate the effect of Japan's CPI commitment policy on market participants' expectations. We use a rich panel survey, QSS (QUICK Survey System), provided by QUICK corporation. This survey asks market participants about their views on the future interest rates and inflation rates. To examine the effect of the CPI commitment policy, it is essential to check developments in expectations on not just interest rates but inflation rates. In particular, the latter data are valuable, because otherwise it is difficult to identify whether low interest rate expectations are due to the CPI commitment policy or simply due to low inflation expectations. In this respect, the QSS provides extremely useful information to analyze the role of the CPI commitment policy. Its panel data are available from July 2004 to November 2008, covering the latter half of the CPI commitment policy period.

By analyzing the relation between interest rate expectations and inflation rate expectations, we find two things. First, Japan's CPI commitment policy lowered market participants' expectations on interest rates. That reduction was observed mainly in medium-term interest rates, in particular, 2-years government bonds, but not in the long-term interest rates. Our estimation reveals that the CPI commitment policy lowered the interest rate expectations by about 0.2 percent point for a given level of inflation expectations.

Second, under the CPI commitment policy, a threshold inflation rate existed, yielding a kinked curve between interest rates and inflation rates. The threshold inflation rate was about 0 percent for short to medium-term interest rates. When inflation expectations were below the level, market participants anticipated the continuation of the zero rate policy. When inflation expectations were above the level, market participants anticipated the rise in the call rate.

[1] In April 2009, Bank of Canada introduced a conditional commitment, stating "Conditional on the outlook for inflation, the target overnight rate can be expected to remain at its current level until the end of the second quarter of 2010 in order to achieve the inflation target. The Bank will continue to provide such guidance in its scheduled interest rate announcements as long as the overnight rate is at the effective lower bound."

Riksbank regularly announces their inflation and policy rate forecasts. By showing low levels of inflation and policy rate forecasts, it helps lower expectations on the future path of interest rates.

That response is consistent with the BOJ's CPI commitment policy, which set the stably zero or higher CPI inflation rate as a necessary condition for the exit from their policy.

There are many empirical studies on the effect of unconventional policy measures. As for Japan's QEP, an excellent survey is done by Ugai (2007). He concludes that the CPI commitment policy, which is the focus of our paper, has a clear effect on lowering the future path of interest rates on the short- to medium-term range.[2] For example, Baba *et al.* (2005) develop a macro-finance model to calculate the difference of the future path of interest rates with and without the CPI commitment policy. The difference is as much as 0.4 to 0.5 percent point for 3- and 5-years bonds, suggesting a reduction in the yield curve by the CPI commitment policy. The difference is not as large for 10-years bonds, however. Oda and Ueda (2007) as well as Baba *et al.* (2005) further search for the CPI inflation threshold that the BOJ judges as necessary for terminating their commitment policy. They report the threshold of about 1 percent, suggesting that the market participants expected that as long the CPI inflation rate was below 1 percent, the BOJ would continue their commitment policy. Those results are not remote from ours, but imply stronger effects of the CPI commitment policy. Differences arise partly due to the identification of inflation expectations. Without the knowledge, it is difficult to rule out the possibility that the low yield curve is simply the result of low inflation expectations, which may lead to overestimation of the effect of the CPI commitment policy. Thanks to the QSS, we overcome such difficulty, and in turn, obtain relatively smaller effects.

This paper is structured as follows. In Section 2, we provide the simple model of the CPI commitment policy and discuss our estimation strategy. In Section 3, we explain the QSS and estimate the effect of the CPI commitment policy. Section 4 concludes.

2 Model

2.1 Overview of the CPI Commitment Policy

Facing the prolonged stagnation following the burst of the asset price bubble in the early 1990s, the BOJ lowered their policy rates to reach the zero lower bound (ZLB) of nominal interest rates (Figure 1) and adopted a series of unprecedented policy. Among many, one notable policy adopted in March 2001 was the QEP. Under the policy, the BOJ changed the main operating target for money market operations from the uncollateralized overnight call rate to

[2]Regarding other aspects in the QEP, he argues, first, that there were phases in which an increase in the current account balances held by financial institutions at the BOJ bolstered people's expectation. Second, mixed results exist as to whether expansion of the monetary base and a change in the composition of the BOJ's balance sheet led to portfolio rebalancing. Third, the QEP created an accommodative environment in terms of corporate financing. Fourth, the QEP's effect on the real economy was limited.

the outstanding current account balances held by financial institutions at the BOJ. See Ugai (2007) and Table 1 for details.

At the same time, the BOJ committed themselves to continuing the QEP until the year-on-year rate of change in the CPI (excluding perishables)[3] registered zero percent or higher on a sustainable basis. In October 2003, the BOJ further clarified its commitment by specifying necessary conditions for the termination of the QEP. In March 2006, the year-on-year CPI inflation rate that was available to the public was 0.5 percent (Figure 2).[4] The BOJ then judged that the year-on-year change in the CPI was expected to remain positive and the conditions laid out in the commitment under the QEP had been fulfilled. Consequently, the BOJ exited the QEP. In the recent global financial crisis, other central banks such as Bank of Canada and Riksbank introduced similar policy commitment.

Theoretically, the CPI commitment policy is expected to delay a rise in policy rates and lower the future path of interest rates, thereby helping more effectively support the economy. In what follows, we consider how the CPI commitment policy influences the interest rate in more detail.

2.2 Model of the CPI Commitment Policy

In this section, we develop a simple model of the CPI commitment policy that was implemented by the BOJ.

2.2.1 Short-Term Interest Rate

We consider a monetary policy rule as

$$i_t^* = r^* + \pi^* + \phi(\pi_t - \pi^*) + \varepsilon_t. \tag{2.1}$$

We denote a latent nominal interest rate by i_t^*, which can take a negative value. In the presence of the ZLB, the interest rate becomes

$$i_t = \begin{cases} 0 & \text{if } i_t^* \leq 0 \\ i_t^* & \text{if } i_t^* > 0, \end{cases} \tag{2.2}$$

[3] In Japan, it is often called the core CPI.

[4] Until August 2006, the base-year of the CPI was 2000. That CPI statistics indicated a positive inflation rate, for example, 0.5 percent in March 2006 in a real-time basis. However, when the CPI's base year changed to 2005 in August 2006, the revised CPI inflation rate decreased. For example, the above inflation rate decreased from 0.5 to -0.1 percent.

without CPI commitment. Figure 3 illustrates the relationship between interest rates and inflation rates. The inflation rate at which $i_t^* = 0$ is given by

$$\pi^0 = -\frac{r^* - (\phi - 1)\pi^*}{\phi}, \tag{2.3}$$

without ε_t. As a case for Japan, suppose $r^* = 2\%$, $\pi^* = 1\%$, and $\phi = 1.5$, and we have $\pi^0 = -1\%$. Thus, even if the inflation rate is negative, the policy rate may be raised from zero.

With CPI commitment, we assume that the interest rate is determined as

$$i_t = \begin{cases} 0 & \text{if } i_t^* \leq 0 \\ 0 & \text{if } \pi_t \leq \pi^c \\ i_t^* & \text{otherwise} \end{cases} . \tag{2.4}$$

A variable π^c indicates the threshold inflation rate. While the inflation rate is below the threshold, the central bank continues the zero interest rate policy. We assume that the latent interest rate is positive when the inflation rate equals the threshold:

$$r^* + \pi^* + \phi(\pi_t^c - \pi^*) > 0. \tag{2.5}$$

In other words, $\pi^0 < \pi^c$, meaning that the CPI commitment extends the duration of the zero rate policy.[5, 6] Due to this assumption, the interest rate under the CPI commitment is simplified as

$$i_t = \begin{cases} 0 & \text{if } \pi_t \leq \pi^c \\ i_t^* & \text{if } \pi_t > \pi^c \end{cases} \tag{2.6}$$

$$= I(\pi_t - \pi^c) \cdot i_t^*. \tag{2.7}$$

$I(x)$ is a function which yields one if x is non-negative and zero otherwise. Figure 4 illustrates the relationship between interest rates and inflation rates. A difference from Figure 3 represents the effect of the CPI commitment.

[5] A policy inertia, described by the dependence on the lagged interest rate, is another reason for extending the duration of the zero interest rate policy. In particular, the commitment policy under the ZLB is known to have history dependence. For example, Reifschneider and Williams (2000) propose the policy rule that responds to the accumulation of the latent nominal interests that are negative. We, however, do not incorporate this factor as a benchmark because the BOJ did not officially commit to the Reifschneider and Williams (2000) type of rule, and it is empirically difficult to calculate the size of the accumulation of the latent nominal interests if any. See Section 3.4 and Appendix B for an attempt to consider the policy inertia.

[6] When setting the interest rate under the CPI commitment policy, the BOJ refers to the current state of inflation, but not to the accumulation or the spell of the past negative inflation. This mitigates complexity and time-inconsistency problems intrinsic to the optimal commitment policy. In this respect, the CPI commitment policy is close to the one proposed by Ueda (2010) than that by Eggertsson and Woodford (2003).

2.2.2 Medium- to Long-Term Interest Rates

When estimating the model, we use data for medium to long-term interest rates and inflation expectations. From a term structure model, a medium to long-term interest rate with a maturity month of T, i_t^T, is described as

$$i_t^T = \frac{1}{T}\mathrm{E}_t\left[\sum_{j=0}^{T-1} i_{t+j}\right]. \tag{2.8}$$

A k-month forecast of the medium to long-term interest rates is described as

$$\mathrm{E}_t i_{t+k}^T = \frac{1}{T}\mathrm{E}_t\left[\sum_{j=k}^{T+k-1} i_{t+j}\right] \tag{2.9}$$

$$= \frac{1}{T}\sum_{j=k}^{T+k-1} I(\mathrm{E}_t\pi_{t+j} - \pi^c)\cdot\{r^* + \pi^* + \phi(\mathrm{E}_t\pi_{t+j} - \pi^*)\}. \tag{2.10}$$

Considering a non-negative term premium α, we rewrite the above as

$$\begin{aligned}\mathrm{E}_t i_{t+k}^T &= \frac{1}{T}\sum_{j=k}^{T+k-1}\alpha\{1 - I(\mathrm{E}_t\pi_{t+j} - \pi^c)\}\\ &+ \frac{1}{T}\sum_{j=k}^{T+k-1} I(\mathrm{E}_t\pi_{t+j} - \pi^c)\cdot\{\alpha + r^* + \pi^* + \phi(\mathrm{E}_t\pi_{t+j} - \pi^*)\}.\end{aligned}$$

$$\begin{aligned}\mathrm{E}_t i_{t+k}^T &= \frac{1}{T}\sum_{j=k}^{T+k-1}\alpha\{1 - I(\mathrm{E}_t\pi_{t+j} - \pi^c)\}\\ &+ \frac{1}{T}\sum_{j=k}^{T+k-1} I(\mathrm{E}_t\pi_{t+j} - \pi^c)\cdot\{\beta + \phi(\mathrm{E}_t\pi_{t+j} - \pi^c)\},\end{aligned} \tag{2.11}$$

where

$$\beta = \alpha + r^* + \pi^* - \phi(\pi^* - \pi^c). \tag{2.12}$$

Due to the assumption of equation (2.5), we require

$$\beta > \alpha. \tag{2.13}$$

2.2.3 Model without the CPI Commitment Policy

For comparison, we consider the expected interest rate without the CPI commitment. Such policy corresponds to equation (2.11) with the constraints $\beta = \alpha$ and $\pi^0 = \pi^c$:

$$\begin{aligned}\mathrm{E}_t i_{t+k}^T &= \frac{1}{T}\sum_{j=k}^{T+k-1}\alpha\left\{1 - I(\mathrm{E}_t\pi_{t+j} - \pi^0)\right\}\\ &+ \frac{1}{T}\sum_{j=k}^{T+k-1} I(\mathrm{E}_t\pi_{t+j} - \pi^0)\cdot\left\{\alpha + \phi(\mathrm{E}_t\pi_{t+j} - \pi^0)\right\},\end{aligned} \tag{2.14}$$

where

$$\pi^0 = -\frac{r^* - (\phi - 1)\pi^*}{\phi} < \pi^c. \tag{2.15}$$

From equation (2.12), it is easy to show

$$\beta - \alpha = \phi(\pi^c - \pi^0). \tag{2.16}$$

2.2.4 Estimation Strategy

We regress equation (2.11) to examine the effect of the CPI commitment policy. In doing so, we use the QSS. As we will explain below, from the QSS, we know only the following inflation expectations for each forecaster: $\mathrm{E}_t\pi_{t+12}$, $\mathrm{E}_t\pi_{t+24}$, and $\mathrm{E}_t\pi_{t+120}$. In addition, we know the real-time based inflation rate available at the time when survey is conducted, π_t. From the four series, we linearly interpolate inflation expectations at the other horizons:

$$\mathrm{E}_t\pi_{t+m} = \begin{cases} \left\{(12-m)\pi_t + m\mathrm{E}_t\pi_{t+12}\right\}/12 \text{ for } 1 \leq m \leq 12 \\ \left\{(24-m)\mathrm{E}_t\pi_{t+12} + (m-12)\mathrm{E}_t\pi_{t+24}\right\}/12 \text{ for } 13 \leq m \leq 24 \\ \left\{(120-m)\mathrm{E}_t\pi_{t+24} + (m-24)\mathrm{E}_t\pi_{t+120}\right\}/96 \text{ for } 25 \leq m \leq 120 \\ E_t\pi_{t+120} \text{ for } 121 \leq m \end{cases}. \tag{2.17}$$

By regressing $\mathrm{E}_t i_{t+k}^T$ using explanatory variables of $\mathrm{E}_t\pi_{t+m}$, we can estimate π^c, α, β, and ϕ. As for π^c, we employ a grid-search method for maximizing the likelihood function.

3 Estimation

3.1 QSS Data

We use the QSS (QUICK Survey System) provided by QUICK corp. The QSS is a broad and continuing survey about market participants' sentiments. From July 1996, it asks market participants monthly about their views on the equity and bond markets and the real economy. Respondents include market participants from securities firms, banks, investment trusts, insurance firms, pension funds, and other private financial institutions. The QSS is an unbalanced panel and asks about 150 people per month.

Among many survey items, we focus on surveys on expectations about interest rates and inflation rates (see Table 2). As for interest rates, we use TIBOR 3 months and newly issued government bonds with a maturity of 2, 5, 10, and 20 years. For each, 1, 3, and 6-months ahead expectations of the interest rates are available. As for inflation rates, we use the year-on-year rate of change in the CPI (excluding perishables). For each, average inflation expectations over next 1, 2, and 10 years are available. The survey on inflation rates started in July 2004, so we are unable to analyze the effect of the adoption of QEP in 2001 on inflation expectations.

Table 3 and Figures 1 and 2 provide the basic statistics and movements of the expectations about interest rates and inflation rates. Under the QEP, inflation expectations rose steadily in accordance with actual inflation (Figure 2). This results in a rise in actual interest rates, as the QEP came closer to end (Figure 1). See Appendix A for details.

3.2 Nonparametric Perspective on the CPI Commitment Policy

3.2.1 Period under the CPI Commitment Policy

We begin with providing a graphical view on the effect of the CPI commitment policy. Figures 5 to 7 show the relation between interest rate expectations and inflation expectations under the CPI commitment policy. The sample period is from July 2004 to February 2006; the initial period is the month when the survey on inflation rates started; and the end period is one month before the termination of the CPI commitment policy. Each dot indicates a respondent's expectation at a certain month. Interest rate expectations are 3-months ahead expectations of the interest rates for different maturities. Figure 5, 6, and 7 use 1, 2, and 10-years inflation expectations, respectively. A solid line indicates the mean of interest rate expectations obtained from a kernel smoothing regression.[7]

From the figures, we find a kinked change in interest rate expectations with a change in inflation expectations. The kink is clear, in particular, in Figure 5 and for medium-term government bonds. For 2-years government bonds, the kink occurs somewhere between 0 and 1 percent of inflation expectations. Let us call this level a threshold. If inflation expectations are below the threshold, the slope of interest rate expectations is flat. If inflation expectations exceed the threshold, the slope becomes steep. Such a shape resembles Figure 3 that is predicted by the theory of the CPI commitment policy. The threshold level, 0 and 1 percent, is close to the inflation rate to which the BOJ referred under the commitment policy, that is, 0 percent or higher on a sustainable basis. Albeit less clear, similar observations can be made for 5-years government bonds and 3-months TIBOR. In contrast, for 10 and 20-years government bonds and for 10-years inflation expectations (Figure 7), the relation between interest rate expectations and inflation expectations is ambiguous.

Those observations provide supporting evidence that the BOJ's CPI commitment policy influenced market participants' expectations. The policy lowered the interest rate expectations, in particular, those of 2-years government bonds for a given low level of inflation expectations. When inflation expectations surpassed a certain threshold, market participants anticipated the policy exit from CPI commitment policy, yielding a steeper rise in their interest rate

[7] The kernel smoothing regression is one of nonparametric regression approaches. We adopts the Nadaraya-Watson method, and for the kernel, the Epanechnikov function. The band width is set 0.15 times data width.

expectations.

3.2.2 Post Period of the CPI Commitment Policy

For comparison, we next plot interest rate expectations vis-a-vis inflation expectations after the CPI Commitment Policy ended. Figure 8 shows interest rate expectations vis-a-vis inflation expectations. Considering the BOJ raised the call rate from almost zero to 0.25 percent in July 2006, we use the sample after August 2006. The sample ends in November 2008, so it includes the time of the global financial turmoil. Note, however, that the BOJ did not introduce the CPI commitment policy in that turmoil. The forecast horizon of inflation is 1 year. To highlight the differences between two policy regimes, Figure 9 plots their means obtained from a kernel smoothing regression with those during the CPI commitment policy. Red solid lines and blue dashed lines represent the means during and after the CPI commitment policy, respectively.

Figures 8 and 9 illustrate mainly three things. First, for short to medium-term maturities, interest rate expectations after the CPI commitment policy ended are higher than those during the CPI commitment policy for a given level of inflation expectations. For 3-months TIBOR, 2-years bonds, and 5-years bonds, their differences amount to about 0.7, 0.5 and 0.2 percent points, respectively, for a given level of inflation expectations. Second, in contrast, for long-term yields, their differences are negligible. Third, after the CPI commitment policy ended, interest rate expectations are more broadly scattered. Their dependence on the CPI inflation rate is ambiguous, and no clear kink is observed for all maturities. Those results confirm the effect of the CPI commitment policy, in particular, on short to medium-term interest rate expectations.

3.3 Estimation Results

So far we have examined the effect of the CPI commitment policy graphically. In this subsection, we analyze the effect quantitatively by estimating the model.

3.3.1 Benchmark

We regress equation (2.11) to examine the effect of the CPI commitment policy using the sample period under the CPI commitment policy.[8] As for explanatory variables, we use not

[8] We employ simple pooled regression, without considering fixed nor random effects associated with panel data and without introducing the Tobit model. Therefore, the estimates may be subject to a bias. We choose so for the following reasons. First, observed interest rates are not strictly zero due to a term premium. The simplest type of the Tobit model is thus not applied. Also, the term premium may differ across market participants. Second, when regressing qualitative dependent variable using a panel data, an incidental parameter problem arises. This problem, which has been long pointed out (see for example Neyman and Schott [1948], Honore [1992] and Lancaster [2000]), stems from a difficulty in identifying simultaneously a threshold which determines

only inflation expectations over three different forecast horizons (1, 2, and 10 years) but also the actual inflation rate. This is because, as equation (2.17) shows, we need to match the time horizon of interest rates with that of the inflation rates. Regarding the actual inflation rate, we use the real-time year-on-year CPI (excluding perishables) inflation rate that was available to market participants at the time of survey. We search for π^c using a grid of 0.01 percent point so that it maximizes the likelihood function. The sample period is from July 2004 to February 2006. There are about 3,000 samples.[9] Table 4 reports the estimated coefficients of π^c, α, β, and ϕ, with adjusted R^2.

Estimation results are in line with the theory discussed in Section 2.2 for all maturities and forecast horizons, in particular, for 2-years government bonds. First, we have $\alpha < \beta$, so the assumption of equation (2.13) is satisfied. Although their differences are marginal for short- and long-term interest rates, β is twice as large as α for the 2-years interest rate. That suggests a jump in the policy rate at the threshold π^c. As the maturity lengthens, both α and β become bigger, indicating larger term premiums. Second, ϕ, the slope of the Taylor rule, is positive and significant, which is consistent with the theory. However, it is less than 1, violating the determinacy condition.[10] Third, the threshold inflation rate for the commitment policy, π^c, is around 0 percent, which coincides with the BOJ's commitment that promised to keep their accommodative policy until the CPI inflation rate became stably zero or higher. For 2-years government bonds, it is 0.10 percent. Last, of all the maturities, adjusted R^2 is the highest for 2-years government bonds, reaching 0.4. As the maturity lengthens, adjusted R^2 decreases. In particular, 10- and 20-years government bonds, adjusted R^2 does not exceed 0.1. For the 1 month forecast of the 20-years government bonds, adjusted R^2 is as low as 0.012. It implies a good fit of the model for medium-term bonds and a bad fit for long-term bonds.

From those estimates, we can calculate the effect of the CPI commitment policy on interest rates. It is given by an estimated $\beta - \alpha$. The underlying idea is as follows: when the inflation rate is just below π^c, equation (2.11) suggests that the interest rate equals α without the CPI commitment policy; and the interest rate is β under the CPI commitment policy. Note that the effect of the CPI commitment policy depends on the level of inflation expectations, and that $\beta - \alpha$ is the maximum of the effects. If the level of inflation expectations is low enough,

a kink in the dependent variable and a fixed effect. To check our results, we try a modified Tobit model. See Section 3.4 and Appendix B.

[9]We confirm that when we draw the log-likelihood with varying π^c, the curve becomes a clear inverse U shape.

[10]Several reasons are considered. First, the zero lower bound may have caused the passive response of the interest rate to inflation. Second, other economic varibles, which are not available in the survey, may have caused a bias in estimates. Third, the policy inertia may have led to a slow response to a change in inflation, thereby yielding a low ϕ. The last possibility is examined in Section 3.4.

irrespective the CPI commitment policy, the policy rate is zero (or α due to a term premium). Thus, no effect exists from the CPI commitment policy. As inflation expectations increase, the effect of the CPI commitment policy increases, until inflation expectations exceed a threshold, terminating the CPI commitment policy and raising the policy rate above β.

According to our estimates, the effect of the CPI commitment policy on interest rates is roughly 0.2 percent point for medium term maturities. For 2-years government bonds, $\beta - \alpha$ is about 0.15 percent point; for 5-years bonds, it is about 0.20 percent point; and for 3-months TIBOR, it is as small as 0.01 percent point.

The size of the policy effect is slightly smaller than that reported by earlier studies. For example, Baba *et al.* (2005) report the effect as large as 0.4 to 0.5 percent point for 3 and 5-years bonds. This difference is considered to arise partly because we use survey data on inflation expectations. As we discussed in Introduction, low interest rate expectations may reflect not the role played by the CPI commitment policy but simply the fact that in those days inflation expectations were low. Threfore, without controling inflation expectations, we may obtain overestimated effects of the CPI commitment policy. We use the data on inflation expectations and obtain the smaller effects of the CPI commitment policy.

The size of the policy effect is also smaller than the interest rate difference between the two periods during and after the CPI commitment policy. The latter size was about 0.5 percent point according to Figure 9. This difference can be explained by differences in macroeconomic circumstances. Many factors, not reported in the survey, such as GDP, unemployment, are considered to contribute to higher interest rates in the post period, even if inflation expectations are the same.

3.3.2 Estimation of the Model without the CPI Commitment

Next, to check the validity of our formulation of the CPI commitment policy, we estimate equation (2.14) that abstracts the feature of the CPI commitment. Hereafter, we focus on 3-months forecasts of interest rates, because results are similar for 1 and 6-months forecasts of interest rates. Table 5 reports estimation results.

The table suggests the validity of our model of the CPI commitment policy. The performance of the model without the CPI commitment policy is poorer than that of the model with the CPI commitment. Adjusted R^2 is lower for all the maturities except for 3-months TIBOR. For example, for 2-years government bonds, adjusted R^2 is 0.35 while it is 0.41 in the model with the CPI commitment. According to the F test, its difference is significant.

The table also suggests that the CPI commitment policy makes the continuation of the QEP more probable. It reveals that π^0 is lower than or at most equal to π^c. For the inflation expectation rate of $\pi^0 < \pi < \pi^c$, the interest rate is above zero in the model without the CPI commitment, while it remains zero in the model with the CPI commitment. This implies that without consideration of the CPI commitment policy, we tend to find less binding commitment regarding the inflation rate. The difference of inflation rates, $\pi^c - \pi^0$, is 0.15 percent point for 2-years government bonds.

3.4 Robustness

In this section, we check the robustness of our results.

3.4.1 Sample Periods

First, we consider the robustness to sample periods. To examine a change in expectations under the CPI commitment policy, we divide the sample period of the CPI commitment policy into two. In Figure 10, the middle period of the CPI commitment policy is from July 2004 to June 2005, denoted by a circle (o), and the latter period is from July 2005 to June 2006, denoted by a plus (+). As for the latter period, we extend the sample period until June 2006 instead of February 2006. From March to July in 2006, the BOJ ended the QEP but maintained to target almost the zero interest rate until they raised the target to 0.25 percent in July 2006. Therefore, in a broader sense, the CPI commitment policy is considered to be active until July 2006. Comparing two periods, we find two things. First, dots in the figure move to the right, suggesting the increase in inflation expectations. This is accompanied by the increase in the actual CPI inflation rate. Second, interest rate expectations of 3-months TIBOR and 2-years government bonds are higher and steeper in the latter period than those in the middle period. That implies that as the QEP came to end, market participants anticipated its end more precisely. For 10-years government bonds, there was almost no change.

Table 6 reports estimation results for varying sample periods. Comparing with the middle and the latter periods, we find that the goodness of fit is far better in the latter period than in the middle period. For 2-years government bonds, adjusted R^2 is 0.62 in the latter period while it is 0.04 in the middle period. In the latter period, parameter estimates are mostly consistent with the theory, yielding $\beta > \alpha > 0$ and $\phi > 0$ albeit $\phi < 1$. The threshold inflation rate π^c is about 0.3 percent for 2 and 5-years government bonds. Parameter estimates in the middle period are sometimes inconsistent with theory prediction. The estimated ϕ is negative for 2-years government bonds, and even if it is positive for other maturities, its level is far below 1.

Those differences between the middle and latter periods may be explained by the difference of actual inflation rates, and in turn, the difference of market participants' attitudes in forming their expectations. In the middle period, the actual CPI inflation rate was sufficiently below a threshold. The necessary condition for the end of the CPI commitment policy was not satisfied at that time, and market participants did not anticipate the end of the CPI commitment policy in the near future, as well. Therefore, they did not need to pay much attention to inflation outlook to forecast interest rates. It makes the relation between inflation and interest rates ambiguous. However, in the latter period, the actual CPI inflation increased to the threshold. The market participants thus began to prepare for the end of the CPI commitment policy. They started to monitor actual inflation and forecast inflation carefully to forecast interest rates. This leads to a clearer relation between inflation and interest rates, and in turn, the better fit of the model in the latter period than in the middle period.

Table 6 also reports estimation results for the post period. The goodness of fit in the post period is worse than that during the CPI commitment policy. This reflects the obvious fact that the CPI commitment policy was not implemented in the post period although we applied the model of the CPI commitment. Furthermore, the lower performance in the post period suggests that monetary policy was less responsive to CPI inflation, because the BOJ no longer employed the commitment policy that referred to the CPI.

Next, considering that the post period may be very different in macroeconomic circumstances from the period during the CPI commitment policy, we focus on shorter sample periods just before and just after the CPI commitment policy ended. In fact, the post period includes the recent episode of the financial crisis, when GDP dropped, unemployment rose, and financial markets and the financial system were destabilized. Figure 11 demonstrates the interest rate expectations vis-a-vis inflation expectations for differing three sample periods: from December 2005 to February 2006, just before the CPI commitment policy ended, denoted by a blue circle (o); from April 2006 to June 2006, when the CPI commitment policy ended but the zero interest rate policy was maintained, denoted by a red dot ($\cdot$); and from August 2006 to October 2006, just after the Bank of Japan raised their policy rate to 0.25 percent, denoted by a green plus (+). The figure generally shows a positive slope: an increase in interest rate expectations is accompanied with an increase in inflation expectations. The increase in interest rate expectations is distinctly large for 3-months TIBOR, in particular, reflecting the actual rise in the call rate.

We then estimate parameters using the sample periods of December 2005 to February 2006 and August 2006 to October 2006. The interim period from March 2006 to August 2006 is omitted from the sample. Since the sample periods include the periods when the CPI commitment policy was and was not conducted, we need to use two distinct models. For the former period, we estimate the model of the CPI commitment policy given by equation (2.11);

for the latter period, we estimate the model without the CPI commitment policy given by equation (2.14). We denote this approach by 'with commitment'. In estimating the model, we employ a grid-search method with both π^c and π^0 in the range of –1 to 0.5 percent. For each π^c and π^0, we estimate α and β by restricting $\phi = (\beta - \alpha)/(\pi^c - \pi^0)$ from equation (2.16). For comparison, we apply the model without the CPI commitment given by equation (2.14) for the whole sample period. We denote this approach by 'without commitment'.

The results reported in Table 7 confirm our previous results. Parameter estimates β is significantly greater than α. For 2-years government bonds, $\beta - \alpha$ is as much as 0.4 percent point, suggesting that the CPI commitment policy lowered the interest rate by that size. The size is slightly larger than that in the benchmark model. The adjusted R^2 of the model with commitment is higher than the model without commitment. According to the F test, its difference is significant, supporting the validity of the model of the CPI commitment. A slightly dissatisfactory result is the estimate of the threshold inflation rate π^c. It reaches 0.5 percent, the upper bound of grid search. We do not show here, but when we extend the upper bound to 1 percent, the threshold reaches 1 percent.

3.4.2 Inflation Data

We next examine the effect of food and energy price changes. So far, we have focused the CPI excluding perishable, because this is the price index that the BOJ referred to during the QEP. The CPI includes food and energy prices, which are known to be volatile and transitory. One example is from 2007 to 2008, when global food and energy prices increased significantly but soon dropped. In this respect, the CPI excluding food and energy may provide a good indicator for monetary policy guidance. To this end, we construct inflation expectations based on the CPI excluding food and energy and plot interest rate expectations vis-a-vis those inflation expectations. Data on inflation expectations based on the CPI excluding food and energy are not directly available. We thus calculate them by deducting the difference of actual inflation rates between the CPI excluding perishable and the CPI excluding food and energy from the data on inflation expectations.

Figures 12 and 13 plot interest rate expectations vis-a-vis inflation expectations under the CPI commitment policy and after its exit, respectively. Compared with previous Figures 5 and 8, which were based on raw data on inflation expectations, differences are small. Quantitatively, however, Table 8 reveals that the fit of the model worsens for the period of the CPI commitment policy. For example, for 2-years government bonds, adjusted R^2 decreases from 0.41 to 0.18. This result is consistent with the BOJ's announcement during the CPI commitment policy, conditioning their policy on not the CPI excluding food and energy but the CPI excluding perishable. In the post period, changes in the fit of the model are mixed. For 3-months and 2-years maturities, adjusted R^2 increases; for longer maturities, adjusted R^2 increases.

3.4.3 Model Specification

We turn to robustness check to model specification. We estimate four different models: (i) a simple model without a term structure consideration, (ii) a modified Tobit model, (iii) a model with policy inertia, and (iv) a model with the restriction of $\phi = 1.1$. See Appendix B for the details of model specification.

First, we estimate a simpler model than the benchmark by neglecting term structure. In the benchmark regression, we have matched time horizon between the expected interest rate as a dependent variable and the expected inflation rate as an independent variable. To this end, we have constructed inflation expectations for various time horizons by interpolation. In the regression here, we do not match time horizon between the expected interest rate as a dependent variable and the expected inflation rate as an independent variable. For the independent variable, we simply use available survey data on inflation expectations.

Tables 9 reveals that 1-year inflation expectations are a good indicator for interest rate expectations. When using 1-year inflation expectations as an explanatory variable, the results are very close to those we obtained in the benchmark estimation. When using inflation expectations with longer horizon, the goodness of fit worsens. This suggests that when market participants forecast interest rates, they weigh their 1-year inflation expectations rather than longer term inflation expectations.

Second, we estimate a modified Tobit model. A standard Tobit model uses the data that have a clear lower bound, but in our dataset, observed interest rates are not strictly zero due to a term premium. We therefore predetermine a certain positive bound α. When a dependent variable is equal to or lower than α, we judge the data as being constrained by the bound. To see robustness, we try four values of α. A dependent variable is 2-years yields for 3-months forecast horizon, and an independent variable is the inflation expectation over next 1 year.

Tables 10 generally confirms our benchmark results. For α around 0.15 percent, we obtain similar results. The threshold inflation rate is about 0 percent. In other words, if the expected inflation rate is below 0 percent, market participants anticipate that the interest rate continues to be α. If the expected inflation rate is above 0 percent, market participants anticipate that the interest rate goes up above α. For reference, we also report the results when α is zero. Since all the interest rate forecasts are above zero, all the samples are categorized to uncensored. Consequently, the estimation is equivalent to that by the standard OLS method. It clearly creating a bias; for example, the estimated slope ϕ becomes lower.[11]

Third, we consider an inertial monetary policy rule as

$$i_t^* = \rho i_{t-1} + (1-\rho)\{r^* + \pi^* + \phi(\pi_t - \pi^*)\} + \varepsilon_t, \tag{3.1}$$

where ρ represents the degree of inertia.[12] When $\rho = 0$, the policy rule has no inertia, and results are the same as those in the benchmark. For comparison, we construct and estimate models with and without the CPI commitment.

Table 11 supports our previous findings, although some of the results are inconsistent with model prediction. For 2-years government bonds, for example, we obtain very high policy inertia $\rho = 0.92$. The estimated slope ϕ is 1.03, which is above 1 and satisfies the Taylor principle. The threshold inflation rate π^c is -0.21 percent. It is slightly lower than 0.10 percent in the benchmark. An unsatisfactory result is $\alpha > \beta$, suggesting a reduction in policy rates when the CPI commitment policy ends. Even with the restriction of $\alpha = \beta$, which is the estimation of the model without the CPI commitment, we still obtain unsatisfactory results. The threshold inflation rate π^0 is -0.50 percent, which is the minimum in our grid search. Adjusted R^2 is significantly lower according to the F test, suggesting the selection of the model with the CPI commitment.

Fourth, we restrict the benchmark model with $\phi = 1.1$ so that it satisfies the Taylor principle. As Table 12 shows, parameter estimates are similar to those in the benchmark in most cases. β is greater than α for all the maturities; π^c is 0.39 percent for 2-years government bonds, in particular. However, the goodness of fit worsens significantly. For long maturities, adjusted R^2 is even negative, and π^c reaches 0.50, which is the maximum in our grid search.

4 Concluding Remarks

Using the survey on interest rate and inflation expectations, we have evaluated the effect of the BOJ's CPI commitment policy on financial market participants' expectations. This survey is extremely valuable, because otherwise it is difficult to identify whether low interest rate expectations are due to the CPI commitment policy or simply due to low inflation expectations. We have found that for the medium-term interest rates, the CPI commitment policy lowered

[11] We also tried to estimate another Tobit model by taking account of uncertainty regarding a threshold inflation level (see Appendix B). However, we could not find plausible results.

[12] We here assume that the latent nominal interest rate i_t^* depends on the previous actual nominal interest rate i_{t-1}. Alternatively, we may assume that the latent nominal interest rate i_t^* depends on the previous latent nominal interest rate i_{t-1}^* (see Reifschneider and Williams [2000]). We, however, do not adopt the latter rule because it is empirically difficult to calculate i_{t-1}^*. By adopting the former rule, we can continue to focus on π^c as the threshold inflation rate that characterizes the end of the CPI commitment policy.

interest rate expectations by about 0.2 percent points given the same level of inflation expectations. Market participants expected a rise in the interest rates when inflation expectations exceeded a threshold of about 0 percent.

The future work needs its extension in two directions. The first concerns implications for the real economy. We have analyzed the effect of the CPI commitment policy on market participants' expectations, but an important issue relates to its effect on economic activity and inflation. Moreover, because our model is a partial equilibrium model, we have neglected a feedback loop of the expectations to the formation of the commitment policy, unlike Eggertsson and Woodford (2003) and Ueda (2010). If the CPI commitment policy is effective in lowering interest rate expectations and boosting the economy, the recovery of the economy may change the policy response endogenously, urging the central bank to exit from its accommodative policy early.

Second, we need to pay more attention to the central bank's balance sheet. We have focused on interest rates with respect to the ZLB rather than current account balances that were the official target under the QEP. An unanswered important question is the effect of an increase in current account balances on market expectations (see Figure 14). Under the QEP, the BOJ raised the target level of current account balances held by financial institutions at the BOJ. The target level increased step by step from 5 trillion yen at the beginning of the QEP (March 2001) to the band of 30 to 35 trillion yen at the end of the QEP (March 2006). As for the effect of the increase in current account balances, Ugai (2007) reports mixed results. Survey data on interest and inflation expectations, used in this paper, may provide a clue, although data on inflation expectations are limited in that during that time, the target level of current account balances stayed unchanged.

References

[1] Baba, N., S. Nishioka, N. Oda, M. Shirakawa, K. Ueda, and H. Ugai (2005), "Japan's Deflation, Problems in the Financial System and Monetary Policy," *Monetary and Economic Studies*, 23 (1), pp. 47–111.

[2] Eggertsson, G.B. and M. Woodford (2003), "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, 34(1), pp.139–235.

[3] Honore, B.E. (1992), "Trimmed LAD and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects," *Econometrica*, 60(3), pp. 533–565.

[4] Lancaster, T. (2000), "The Incidental Parameter Problem Since 1948," *Journal of Econometrics*, 95(2), pp. 391–413.

[5] Neyman, J. and E.L. Schott (1948), "Consistent Estimates Based on Partially Consistent Observations," *Econometrica*, 16(1), pp. 1–32.

[6] Oda, N. and K. Ueda (2007), "The Effects of the Bank of Japan's Zero Interest Rate Commitment and Quantitative Monetary Easing on the Yield Curve: A Macro-Finance Approach," *Japanese Economic Review*, 58(3), pp. 303–328.

[7] Okina, K. and S. Shiratsuka (2004), "Policy Commitment and Expectation Formation: Japan's Experience under Zero Interest Rates," *North American Journal of Economics and Finance*, 15(1), pp.75–100.

[8] Reifschneider, D., and J.C. Williams (2000). "Three Lessons for Monetary Policy in a Low-Inflation Era." *Journal of Money, Credit and Banking*, 32, pp. 936–966.

[9] Ueda, K. (2010). "A Time-Invariant Duration Policy under the Zero Lower Bound," IMES Discussion Paper Series, Bank of Japan, E-12.

[10] Ugai, H. (2007), "Effects on Monetary Easing Policy: A Survey of Empirical Analyses," *Monetary and Economic Studies*, 25(1), pp.1–47.

A QSS Data

In this Appendix, we report the data in the QSS in more details. We plot the mean, the ratio of the standard deviation to the mean, and the skewness with the CPI inflation rate. A shaded area indicates the period of the QEP (CPI commitment policy).

A.1 Interest Rate Expectations

Figures A-1 to A-5 plot interest rate expectations. As for the mean of interest rate expectations, short- to medium-term bond yields were low and stable under the CPI commitment policy. That supports the effect of the CPI commitment policy for those maturities. Some months before the exit from the policy, those yields picked up gradually. Long-term bond yields were relatively high and unstable.

We next examine the variation of interest rate expectations in view of the ratio of the standard deviation to the mean. We do not look at a simple standard deviation, because the standard deviation obviously decreases due to the decrease in the level of the yield under the CPI commitment policy. According to this measure, the variation of the short- to medium-term bond yields decreased slowly under the CPI commitment policy. That implies that the CPI commitment policy lowered the short- to medium-term bond yields on impact, but stabilized them over time. It may reflect the gradual propagation and credibility enhancement of the CPI commitment policy among market participants. Or it may reflect regained stability of the financial market and the financial system. A few months before the exit from the CPI commitment policy, the variation of 3-months TIBOR yields started to increase.

The skewness of interest rate expectations on short- to medium-term bond yields was positive in most of the periods under the CPI commitment policy. That suggests that some market participants expected very high yields, but the ZLB prevented them from expecting negative yields. On the other hand, the skewness of interest rate expectations on long-term bond yields are nearly zero. That suggests symmetric expectations in those maturities.

A.2 Inflation Expectations

Figure A-6 plots inflation expectations. As for the mean of inflation expectations, we find four things. First, the inflation expectation of next 1- and 2-years increased steadily from 2004 to the exit from the CPI commitment policy. That movement is correlated with that in the actual CPI. Second, in the 1-year horizon, market participants already expected a positive inflation rate in mid-2005, one year earlier than the exit in March 2006. In the 2-years horizon, inflation expectations were positive when the survey started in mid-2004. Third, 10-years inflation expectations are stable over the entire sample periods. Its mean is 1.1 percent, which is in the range of the understanding of medium- to long-term price stability clarified by the policy board at the BOJ: between 0 to 2 percent with median figure around 1 percent. Fourth, from the end of 2007, inflation expectations rose reflecting the wake of financial crisis and the boom in commodity prices.

The middle panel plots the standard deviation of inflation expectations. Since the mean of inflation expectations fluctuates around zero, unlike previous figures, we do not plot the ratio of the standard deviation to the mean. The standard deviation was stable during the CPI commitment policy. It then increased from 2007.

The skewness of inflation expectations were positive in most of the periods. That suggests that some market participants expected very high inflation rates.

B Robustness

B.1 Simple Model without a Term Structure Consideration

Here we do not match time horizon between the expected interest rate and the expected inflation rate, when regressing the former with the latter. Unlike equation (2.11), we do not use a term structure model and instead consider the following simple model:

$$\begin{aligned} \mathrm{E}_t i_{t+k}^T &= \alpha \left\{1 - I(\mathrm{E}_t \pi_{t+j} - \pi^c)\right\} \\ &+ I(\mathrm{E}_t \pi_{t+j} - \pi^c) \cdot \left\{\beta + \phi(\mathrm{E}_t \pi_{t+j} - \pi^c)\right\}. \end{aligned} \tag{B.1}$$

Here, parameters j, k, and T are arbitrary; the horizons of interest rates and inflation do not match.

B.2 Tobit Model

B.2.1 Simple Tobit Model

We construct a Tobit model. We begin by neglecting additional non-linearity arising from the CPI commitment policy. Regarding the policy rate described as

$$i_t^* = \gamma + \phi \pi_t + \varepsilon_t, \tag{B.2}$$

we assume that $\mathrm{E}_t^j[\varepsilon_{t+k}]$ obeys normal distribution with

$$\mathrm{E}_t\left[\mathrm{E}_t^j[\varepsilon_{t+k}]\right] = 0, \tag{B.3}$$

$$\mathrm{Var}_t\left[\mathrm{E}_t^j[\varepsilon_{t+k}]\right] = \sigma_\varepsilon^2. \tag{B.4}$$

The likelihood that $\mathrm{E}_t^j\left[i_{t+k}\right]$ equals 0 is

$$P(E_t^j\left[i_{t+k}\right]=0) \equiv 1-\left\{1-\Phi\left(\frac{0-\{\gamma+\phi \mathrm{E}_t^j\left[\pi_{t+k}\right]\}}{\sigma_{\varepsilon}}\right)\right\}. \tag{B.5}$$

The likelihood that $\mathrm{E}_t^j\left[i_{t+k}\right]$ has a certain positive value is

$$P(E_t^j\left[i_{t+k}\right], E_t^j\left[i_{t+k}\right]>0) \equiv \frac{1}{\sigma_{\varepsilon}} \phi\left(\frac{E_t^j\left[i_{t+k}\right]-\{\gamma+\phi \mathrm{E}_t^j\left[\pi_{t+k}\right]\}}{\sigma_{\varepsilon}}\right). \tag{B.6}$$

Summing up, log-likelihood is given by

$$LL \equiv \sum_j \log P(E_t^j\left[i_{t+k}\right]=0) P(E_t^j\left[i_{t+k}\right], E_t^j\left[i_{t+k}\right]>0). \tag{B.7}$$

In the presence of the term premium $\alpha>0$, log-likelihood becomes

$$LL \equiv \sum_j \log P(E_t^j\left[i_{t+k}\right]<\alpha) P(E_t^j\left[i_{t+k}\right], E_t^j\left[i_{t+k}\right]>\alpha), \tag{B.8}$$

where the likelihood of $\mathrm{E}_t^j\left[i_{t+k}\right]=0$ is transformed into

$$P(E_t^j\left[i_{t+k}\right]=0) \equiv 1-\left\{1-\Phi\left(\frac{\alpha-\{\gamma+\phi \mathrm{E}_t^j\left[\pi_{t+k}\right]\}}{\sigma_{\varepsilon}}\right)\right\} \tag{B.9}$$

We can find $\{\sigma_{\varepsilon}^2, \gamma, \phi\}$ so as to maximize the above log-likelihood function. Note that the threshold inflation rate is given by $0=\alpha-\{\gamma+\phi \pi^c\}$, that is

$$\pi^c=\frac{\alpha-\gamma}{\phi}. \tag{B.10}$$

B.2.2 Tobit Model with the CPI Commitment

We next introduce non-linearity arising from the CPI commitment policy. We here assume that each market participant has a different view on the CPI threshold of the CPI commitment. That is, a market participant j forms the expectation of

$$\mathrm{E}_t^j\left[i_{t+k}\right]=\begin{cases} 0 & \text{if } \mathrm{E}_t^j\left[i_{t+k}^*\right] \leq 0 \\ 0 & \text{if } \mathrm{E}_t^j\left[\pi_{t+k}\right] \leq \mathrm{E}_t^j[\pi_{t+k}^c] \\ \mathrm{E}_t^j\left[i_{t+k}^*\right] & \text{otherwise} \end{cases}. \tag{B.11}$$

We suppose that $\mathrm{E}_t^j[\varepsilon_{t+k}]$ and $\mathrm{E}_t^j[c_{t+k}]$ obey normal distribution with

$$\mathrm{E}_t\left[\mathrm{E}_t^j[\varepsilon_{t+k}]\right] = 0, \tag{B.12}$$

$$\mathrm{Var}_t\left[\mathrm{E}_t^j[\varepsilon_{t+k}]\right] = \sigma_\varepsilon^2, \tag{B.13}$$

$$\mathrm{E}_t\left[\mathrm{E}_t^j[\pi_{t+k}^c]\right] = c, \tag{B.14}$$

$$\mathrm{Var}_t\left[\mathrm{E}_t^j[\pi_{t+k}^c]\right] = \sigma_c^2, \tag{B.15}$$

$$\mathrm{Cov}_t\left[\mathrm{E}_t^j[\varepsilon_{t+k}], \mathrm{E}_t^j[\pi_{t+k}^c]\right] = 0. \tag{B.16}$$

Higher c implies that the market forecasts a longer ZLB duration. Lower uncertainty σ_c implies stronger credibility.

In the presence of the term premium $\alpha > 0$, the likelihood that $\mathrm{E}_t^j\left[i_{t+k}\right]$ equals α is

$$\begin{aligned} &P(E_t^j\left[i_{t+k}\right] = \alpha) \\ &\quad \equiv 1 - \left\{1 - \Phi\left(\frac{\alpha - \{\gamma + \phi \mathrm{E}_t^j\left[\pi_{t+k}\right]\}}{\sigma_\varepsilon}\right)\right\} \\ &\quad \Phi\left(\frac{\mathrm{E}_t^j\left[\pi_{t+k}\right] - c}{\sigma_c}\right). \end{aligned} \tag{B.17}$$

The likelihood that $\mathrm{E}_t^j\left[i_{t+k}\right]$ has a certain value larger than α is

$$\begin{aligned} &P(E_t^j\left[i_{t+k}\right], E_t^j\left[i_{t+k}\right] > \alpha) \\ &\quad \equiv \frac{1}{\sigma_\varepsilon}\phi\left(\frac{E_t^j\left[i_{t+k}\right] - \{\gamma + \phi \mathrm{E}_t^j\left[\pi_{t+k}\right]\}}{\sigma_\varepsilon}\right) \\ &\quad \Phi\left(\frac{\mathrm{E}_t^j\left[\pi_{t+k}\right] - c}{\sigma_c}\right). \end{aligned} \tag{B.18}$$

Summing up, log-likelihood is given by

$$LL \equiv \sum_j \log P(E_t^j\left[i_{t+k}\right] < \alpha) P(E_t^j\left[i_{t+k}\right], E_t^j\left[i_{t+k}\right] > \alpha). \tag{B.19}$$

We can find $\{\sigma_\varepsilon^2, \sigma_c^2, c, \gamma, \phi\}$ so as to maximize the above log-likelihood function.

B.3 Inertia in a Taylor Rule

We consider a monetary policy rule with inertia as

$$i_t^* = \rho i_{t-1} + (1-\rho)\left\{r^* + \pi^* + \phi(\pi_t - \pi^*)\right\} + \varepsilon_t, \tag{B.20}$$

where ρ represents the degree of inertia. When $\rho = 0$, the policy rule has no inertia, and results are the same as those in the benchmark case.

In a similar way to derive equation (2.11), we can derive the following equation:

$$\begin{aligned} \mathrm{E}_t i_{t+k}^T = & \frac{1}{T} \sum_{j=k}^{T+k-1} \alpha \{1 - I(\mathrm{E}_t \pi_{t+j} - \pi^c)\} \\ & + \frac{1}{T} \sum_{j=k}^{T+k-1} I(\mathrm{E}_t \pi_{t+j} - \pi^c) \\ & \cdot [\beta + \rho \mathrm{E}_t i_{t+j-1} + (1-\rho) \{r^* + \pi^* + \phi(\mathrm{E}_t \pi_{t+j} - \pi^c)\}], \end{aligned} \tag{B.21}$$

where $\beta = \alpha + (1-\rho)\{r^* + \pi^* - \phi(\pi^* - \pi^c)\}$. Due to the assumption of equation (2.5), we require $\beta > \alpha$. Using the expectations of interest rates and inflation rates at the previous period, the above equation is transformed into

$$\begin{aligned} \mathrm{E}_t i_{t+k}^T = & \frac{1}{T} \sum_{j=k}^{T+k-1} \alpha \{1 - I(\mathrm{E}_{t-1} \pi_{t+j} - \pi^c)\} \\ & + \frac{1}{T} \sum_{j=k}^{T+k-1} I(\mathrm{E}_{t-1} \pi_{t+j} - \pi^c) \\ & \cdot \left[\beta + \rho \mathrm{E}_{t-1} i_{t+k-1}^T + (1-\rho) \{r^* + \pi^* + \phi(\mathrm{E}_{t-1} \pi_{t+j} - \pi^c)\}\right] \\ & + \mu_t, \end{aligned} \tag{B.22}$$

where a term μ_t is expressed as $(\mathrm{E}_t - \mathrm{E}_{t-1})$ of endogenous variables. In other words, μ_t represents unexpected changes in interest rates and inflation rates. When regressing the above equation, compared with the benchmark, we additionally use the lagged interest rate expectation, $\mathrm{E}_{t-1} i_{t+k-1}^T$, and replace $\mathrm{E}_t \pi_{t+j}$ by the lagged inflation expectation $\mathrm{E}_{t-1} \pi_{t+j}$. We do not use unobservable μ_t, but estimates are unbiased. This is because other explanatory variables are the expectations at the previous period $t-1$, which are uncorrelated with μ_t that is the surprise component from $t-1$ to t.

For comparison, we also estimate the model without the CPI commitment:

$$\begin{aligned} \mathrm{E}_t i_{t+k}^T = & \frac{1}{T} \sum_{j=k}^{T+k-1} \alpha \left\{1 - I(\mathrm{E}_{t-1} \pi_{t+j} - \pi^0)\right\} \\ & + \frac{1}{T} \sum_{j=k}^{T+k-1} I(\mathrm{E}_{t-1} \pi_{t+j} - \pi^0) \\ & \cdot \left[\alpha + \rho \mathrm{E}_{t-1} i_{t+k-1}^T + (1-\rho) \left\{r^* + \pi^* + \phi(\mathrm{E}_{t-1} \pi_{t+j} - \pi^0)\right\}\right] \\ & + \mu_t. \end{aligned} \tag{B.23}$$

Table 1: BOJ's CPI commitment policy

Date	Policy
Mar. 19, 2001	Committing that the QEP continues to be in place until the CPI (excluding perishables) inflation registers stably a zero percent or an increase year on year.
Oct. 10, 2003	Enhancing monetary policy transparency. BOJ's commitment is underpinned by the following two conditions. 1. it requires not only that the most recently published CPI inflation should register a zero percent or above, but also that such tendency should be confirmed over a few months. 2. the BOJ needs to be convinced that the prospective CPI inflation will not be expected to register below a zero percent. The above conditions are the necessary condition. There may be cases, however, that the BOJ will judge it appropriate to continue with the QEP even if these two conditions are fulfilled.
Mar. 9, 2006	Exit from the QEP by changing the operating target to the uncollateralized overnight call rate. Encouraging the uncollateralized overnight call rate to remain at effectively zero percent.
Jul. 14, 2006	Encouraging the uncollateralized overnight call rate to remain at around 0.25 percent.

Table 2: Questionnaires in the QSS

Item	Time horizon of forecast	Period
TIBOR yield (3 months)	1, 3, 6 months	2000M5 – 2008M11
Newly issued JGB yield (2 years)	1, 3, 6 months	2001M5 – 2008M11
Newly issued JGB yield (5 years)	1, 3, 6 months	2001M5 – 2008M11
Newly issued JGB yield (10 years)	1, 3, 6 months	1998M7 – 2008M11
Newly issued JGB yield (20 years)	1, 3, 6 months	2003M4 – 2008M11
CPI (excluding perishable) inflation	Average of 1, 2, 10 years	2004M7 – 2008M11

Table 3: Basic statistics

Item	1M forecast	3M forecast	6M forecast
TIBOR (3M)	0.303%	0.322%	0.351%
	(0.296)	(0.306)	(0.326)
JGB (2Y)	0.359%	0.387%	0.426%
	(0.334)	(0.356)	(0.386)
JGB (5Y)	0.774%	0.816%	0.871%
	(0.366)	(0.380)	(0.400)
JGB (10Y)	1.503%	1.563%	1.639%
	(0.308)	(0.315)	(0.327)
JGB (20Y)	2.047%	2.099%	2.161%
	(0.282)	(0.280)	(0.282)

Item	1Y average	2Y average	10Y average
CPI (excluding perishable)	0.367%	0.553%	1.131%
inflation	(0.415)	(0.305)	(0.154)

Note: An upper and lower number in parenthesis indicates the means and the standard deviation, respectively.

Table 4: Estimation results (benchmark)

dependent variables		#N	α	S.E.	β	S.E.	ϕ	S.E.	π^c	Adj R^2
	1M	2,566	0.089	0.000	0.092	0.002	0.189	0.018	0.02	0.193
TIBOR	3M	2,566	0.093	0.001	0.095	0.002	0.249	0.013	-0.04	0.256
	6M	2,565	0.100	0.001	0.134	0.003	0.192	0.018	0.01	0.270
	1M	2,915	0.111	0.002	0.255	0.005	0.159	0.020	0.10	0.422
2Y	3M	2,874	0.118	0.003	0.287	0.005	0.153	0.020	0.10	0.413
	6M	2,852	0.137	0.004	0.299	0.006	0.170	0.019	0.10	0.350
	1M	2,952	0.527	0.009	0.683	0.008	0.209	0.018	0.06	0.197
5Y	3M	2,953	0.551	0.009	0.757	0.008	0.206	0.018	0.09	0.232
	6M	2,933	0.622	0.009	0.849	0.009	0.181	0.020	0.15	0.233
	1M	2,964	1.322	0.026	1.434	0.007	0.066	0.009	-0.11	0.035
10Y	3M	2,966	1.447	0.008	1.562	0.008	0.054	0.013	0.29	0.065
	6M	2,947	1.499	0.009	1.666	0.009	0.049	0.015	0.34	0.094
	1M	2,926	1.930	0.045	2.055	0.006	0.026	0.006	-0.20	0.012
20Y	3M	2,925	1.896	0.051	2.104	0.007	0.051	0.006	-0.20	0.035
	6M	2,905	2.168	0.006	2.254	0.008	0.047	0.011	0.50	0.060

Note: #N indicates the number of sample. The sample period is July 2004 to February 2006.

Table 5: Estimation of models with and without the CPI commitment

		α	β	ϕ	π^c	π^0	Adj R^2	F test
TIBOR	benchmark	0.093	0.095	0.249	-0.04	–	0.256	0.342
	w/o commit	0.093	$=\alpha$	0.259	–	-0.04	0.256	
	(S.E.)	0.001	–	0.009	–	–		
2Y	benchmark	0.118	0.287	0.153	0.10	–	0.413	0.000
	w/o commit	0.140	$=\alpha$	0.395	–	-0.05	0.350	
	(S.E.)	0.002	–	0.010	–	–		
5Y	benchmark	0.551	0.757	0.206	0.09	–	0.232	0.000
	w/o commit	0.643	$=\alpha$	0.346	–	0.00	0.198	
	(S.E.)	0.005	–	0.013	–	–		
10Y	benchmark	1.447	1.562	0.054	0.29	–	0.065	0.000
	w/o commit	1.479	$=\alpha$	0.115	–	0.00	0.055	
	(S.E.)	0.006	–	0.009	–	–		
20Y	benchmark	1.896	2.104	0.051	-0.20	–	0.035	0.000
	w/o commit	2.096	$=\alpha$	0.056	–	-0.20	0.030	
	(S.E.)	0.006	–	0.006	–	–		

Note: The sample period is July 2004 to February 2006. Dependent variables are forecasts of 3 months forecast horizon.

Table 6: Changes in parameters for differing samples

	α				β			
	Benchmark	Middle	Latter	Post	Benchmark	Middle	Latter	Post
TIBOR	0.093	0.088	0.108	0.852	0.095	0.092	0.114	0.680
2Y	0.118	0.136	0.194	0.958	0.287	0.197	0.563	0.763
5Y	0.551	0.547	0.666	1.290	0.757	0.623	1.069	1.243
10Y	1.447	1.265	1.428	1.713	1.562	1.465	1.728	1.703
20Y	1.896	1.869	2.099	2.113	2.104	2.086	2.197	2.202
	ϕ				π^c			
	Benchmark	Middle	Latter	Post	Benchmark	Middle	Latter	Post
TIBOR	0.249	0.008	0.478	0.083	-0.040	-0.230	0.090	0.100
2Y	0.153	-0.055	0.440	-0.014	0.100	0.210	0.280	0.400
5Y	0.206	0.101	0.382	-0.105	0.090	-0.200	0.300	0.400
10Y	0.054	0.082	0.124	-0.059	0.290	-0.200	0.400	0.480
20Y	0.051	0.073	0.050	0.012	-0.200	-0.200	0.490	0.220
	Adj R^2							
	Benchmark	Middle	Latter	Post				
TIBOR	0.256	0.013	0.538	0.213				
2Y	0.413	0.043	0.616	0.185				
5Y	0.232	0.042	0.439	0.052				
10Y	0.065	0.039	0.266	0.019				
20Y	0.035	0.049	0.075	0.009				

Note: Dependent variables are forecasts of 3 months forecast horizon.

Table 7: Estimation for the sample periods that include three months just before and after the CPI commitment policy ended

		α	β	ϕ	π^c	π^0	Adj R^2	F test
TIBOR	w commit	0.152	0.302	0.193	0.32	–	0.808	0.000
	(S.E.)	0.005	0.003	–		-0.46		
	w/o commit	0.114	$= \alpha$	0.925	–	0.02	0.518	
	(S.E.)	0.009	–	0.031	–	–		
2Y	w commit	0.349	0.733	0.493	0.50	–	0.608	0.000
	(S.E.)	0.007	0.009	–		-0.49		
	w/o commit	0.438	$= \alpha$	2.663	–	0.20	0.296	
	(S.E.)	0.011	–	0.138	–	–		
5Y	w commit	0.923	1.179	0.328	0.50	–	0.376	0.000
	(S.E.)	0.011	0.011	–		-0.49		
	w/o commit	1.022	$= \alpha$	0.961	–	0.20	0.170	
	(S.E.)	0.011	–	0.073	–	–		
10Y	w commit	1.579	1.707	0.164	0.50	–	0.182	0.000
	(S.E.)	0.011	0.009	–		-0.49		
	w/o commit	1.657	$= \alpha$	0.127	–	0.25	0.079	
	(S.E.)	0.009	–	0.014	–	–		
20Y	w commit	2.116	2.180	0.081	0.50	–	0.080	–
	(S.E.)	0.011	0.007	–		-0.49		
	w/o commit	2.161	$= \alpha$	0.057	–	0.25	0.038	
	(S.E.)	0.008	–	0.009	–	–		

Note: The sample period is December 2005 to February 2006 and August 2006 to October 2006. In the benchmark, we use the model with the CPI commitment policy for the former period and the model without the CPI commitment policy for the latter period. Dependent variables are forecasts of 3 months forecast horizon.

Table 8: Use of inflation expectations excluding food and energy

	α				β			
	Benchmark		Post		Benchmark		Post	
		excl. F&E		excl. F&E		excl. F&E		excl. F&E
TIBOR	0.093	0.101	0.852	0.818	0.095	0.117	0.680	0.707
2Y	0.118	0.163	0.958	0.720	0.287	0.287	0.763	0.910
5Y	0.551	0.675	1.290	1.049	0.757	0.789	1.243	1.309
10Y	1.447	1.512	1.713	1.534	1.562	1.566	1.703	1.796
20Y	1.896	2.123	2.113	2.171	2.104	2.165	2.202	2.230

	ϕ				π^c			
	Benchmark		Post		Benchmark		Post	
		excl. F&E		excl. F&E		excl. F&E.		excl. F&E
TIBOR	0.249	0.024	0.083	0.074	-0.04	-0.20	0.10	-0.22
2Y	0.153	0.074	-0.014	-0.003	0.10	-0.15	0.40	-0.34
5Y	0.206	0.136	-0.105	0.031	0.09	-0.07	0.40	-0.20
10Y	0.054	0.029	-0.059	-0.009	0.29	0.20	0.48	0.00
20Y	0.051	0.023	0.012	0.013	-0.20	0.30	0.22	0.11

	Adj R^2			
	Benchmark		Post	
		excl. F&E		excl. F&E
TIBOR	0.256	0.021	0.213	0.103
2Y	0.413	0.180	0.185	0.173
5Y	0.232	0.102	0.052	0.254
10Y	0.065	0.017	0.019	0.275
20Y	0.035	0.017	0.009	0.050

Note: Dependent variables are forecasts of 3 months forecast horizon.

Table 9: Estimation without term structure consideration

	α	S.E.	β	S.E.	ϕ	S.E.	π^c	Adj R^2
– 1Y π^e as an explanatory variable –								
TIBOR	0.094	0.001	0.121	0.002	0.033	0.009	0.10	0.180
2Y	0.151	0.002	0.219	0.005	0.270	0.018	0.01	0.359
5Y	0.663	0.004	0.765	0.008	0.394	0.030	0.01	0.290
10Y	1.436	0.014	1.463	0.006	0.251	0.016	-0.25	0.089
20Y	2.074	0.013	2.124	0.006	0.094	0.016	-0.25	0.022
– 2Y π^e as an explanatory variable –								
TIBOR	0.062	0.007	0.082	0.002	0.037	0.002	-0.30	0.099
2yrs	0.156	0.003	0.241	0.005	0.063	0.012	0.20	0.216
5yrs	0.668	0.004	0.800	0.008	0.089	0.020	0.20	0.187
10yrs	1.308	0.026	1.455	0.007	0.148	0.010	-0.30	0.083
20yrs	1.951	0.024	2.106	0.006	0.087	0.010	-0.25	0.046
– 10Y π^e as an explanatory variable –								
TIBOR	0.094	0.002	0.100	0.001	0.006	0.001	0.40	0.015
2yrs	0.176	0.004	0.197	0.004	0.025	0.005	0.50	0.033
5yrs	0.689	0.007	0.739	0.007	0.035	0.007	0.50	0.038
10yrs	1.498	0.006	1.534	0.006	0.028	0.007	0.50	0.027
20yrs	2.114	0.005	2.142	0.006	0.031	0.006	0.50	0.029

Note: Dependent variables are forecasts of 3 months forecast horizon.

Table 10: Estimation of the Tobit model using 1Y π^e as an explanatory variable

	α (preset) [#N, #N]	γ	S.E.	ϕ	S.E.	σ_ε	S.E.	$\pi^c=(\alpha-\gamma)/\phi$
2Y	0 [0, 2096]	0.191	0.002	0.299	0.005	0.096	0.001	-0.64
	0.10 [413, 1683]	0.173	0.002	0.353	0.006	0.113	0.001	-0.21
	0.15 [919, 1177]	0.136	0.003	0.453	0.009	0.138	0.002	0.03
	0.20 [1242, 854]	0.100	0.005	0.575	0.017	0.150	0.003	0.17

Note: Two figures in a square bracket [,] indicate the number of samples where the dependent variable is equal or lower than α and higher than α, respectively. When α is 0, the esimation is equivalent to simple linear regression because all the dependent variables are above zero due to a term premium. Dependent variables are forecasts of 3 months forecast horizon.

Table 11: Estimation of models with policy inertia

		α	β	ϕ	ρ	π^c	π^0	Adj R^2	F test
TIBOR	w commit	0.088	0.019	0.288	0.728	-0.24		0.440	0.000
	(S.E.)	0.002	0.002	0.028	0.025				
	w/o commit	0.008	$=\alpha$	0.227	0.717	–	-0.48	0.434	
	(S.E.)	0.002	–	0.021	0.024	–	–		
2Y	w commit	0.111	0.007	1.026	0.922	-0.21		0.702	0.000
	(S.E.)	0.007	0.003	0.184	0.016				
	w/o commit	-0.012	$=\alpha$	0.857	0.913	–	-0.50	0.694	
	(S.E.)	0.004	–	0.135	0.016	–	–		
5Y	w commit	0.570	0.108	0.128	0.891	-0.01		0.642	0.000
	(S.E.)	0.010	0.012	0.110	0.016				
	w/o commit	0.108	$=\alpha$	0.306	0.804	–	-0.50	0.624	
	(S.E.)	0.010	–	0.046	0.014	–	–		
10Y	w commit	1.229	0.595	0.061	0.597	-0.21		0.448	0.000
	(S.E.)	0.035	0.022	0.017	0.014				
	w/o commit	0.658	$=\alpha$	0.058	0.549	–	-0.50	0.420	
	(S.E.)	0.021	–	0.015	0.014	–	–		
20Y	w commit	1.896	0.969	0.012	0.541	-0.21		0.361	0.000
	(S.E.)	0.043	0.032	0.011	0.015				
	w/o commit	1.207	$=\alpha$	0.010	0.430	–	-0.50	0.301	
	(S.E.)	0.029	–	0.009	0.014	–	–		

Note: Dependent variables are forecasts of 3 months forecast horizon.

Table 12: Estimation with restriction $\phi = 1.1$

		α	β	π^c	Adj R^2
TIBOR		0.099	0.199	0.14	0.117
	(S.E.)	0.001	0.003		
2Y		0.180	0.433	0.39	0.078
	(S.E.)	0.002	0.009		
5Y		0.704	1.359	0.50	-0.070
	(S.E.)	0.005	0.010		
10Y		1.558	2.695	0.50	-1.095
	(S.E.)	0.008	0.009		
20Y		2.176	3.713	0.50	-4.133
	(S.E.)	0.012	0.010		

Note: Dependent variables are forecasts of 3 months forecast horizon.

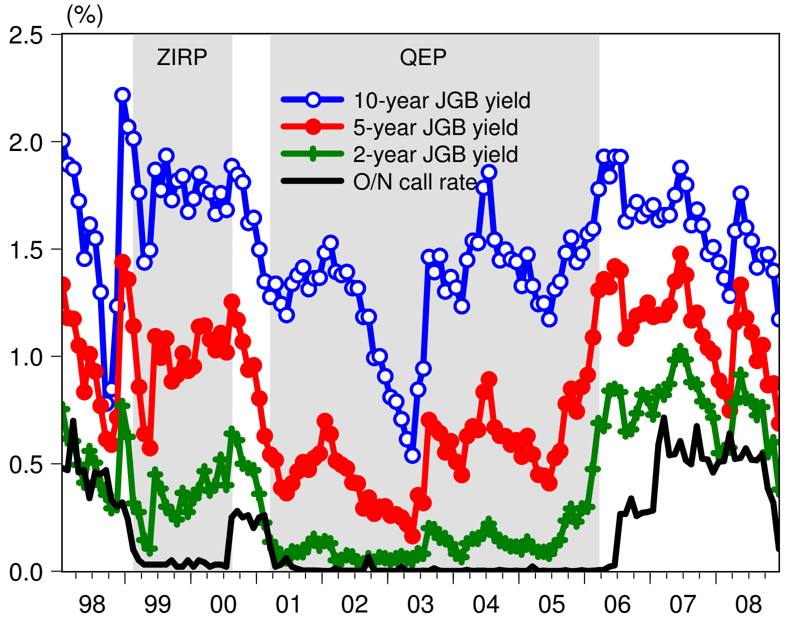

Figure 1: Interest rates. Sources: Bloomberg; Bank of Japan.

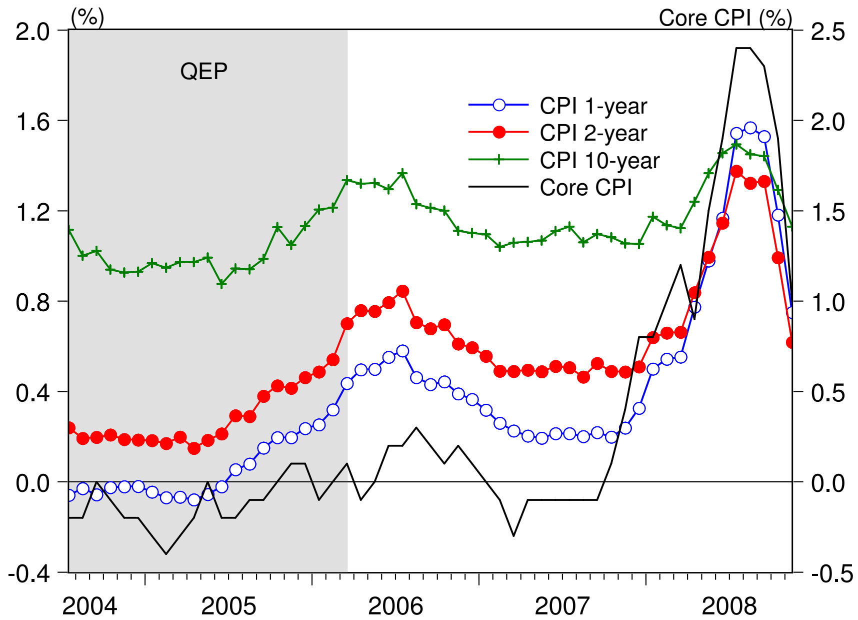

Figure 2: Acutal and expected inflation. Sources: QUICK corporation "QUICK Survey System"; Statistics Bureau.

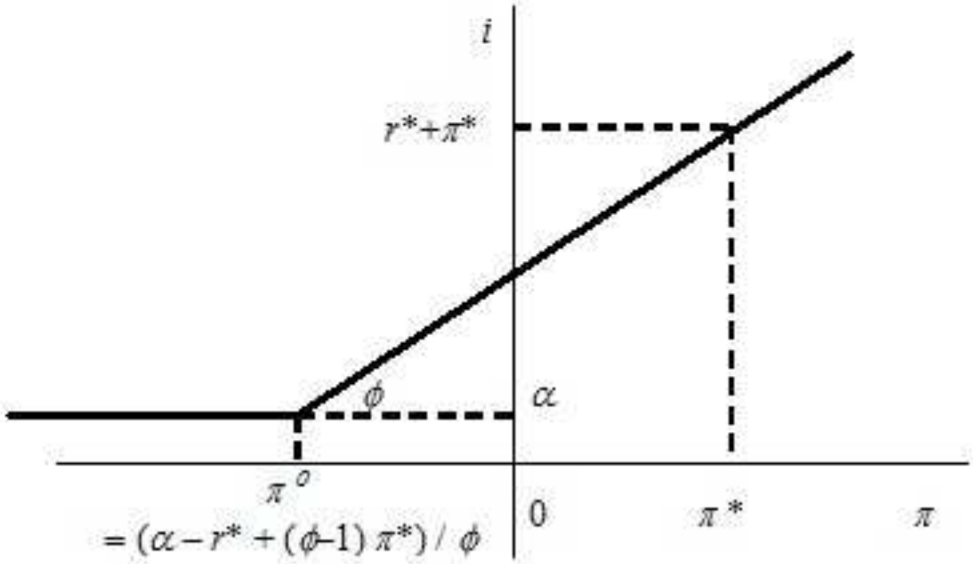

Figure 3: Monetary policy with the ZLB but without the CPI commitment

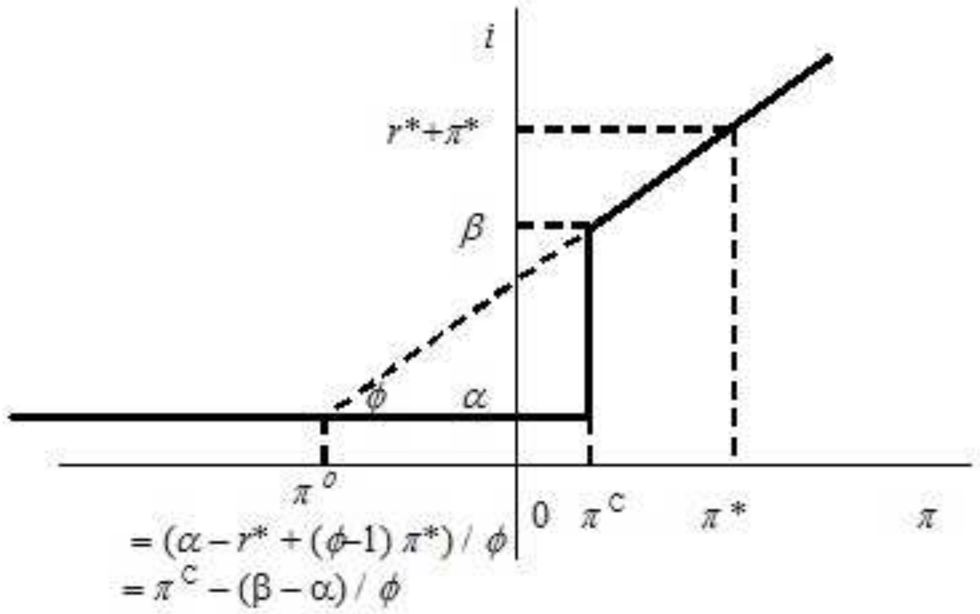

Figure 4: Monetary policy with the CPI commitment (from idea.doc)

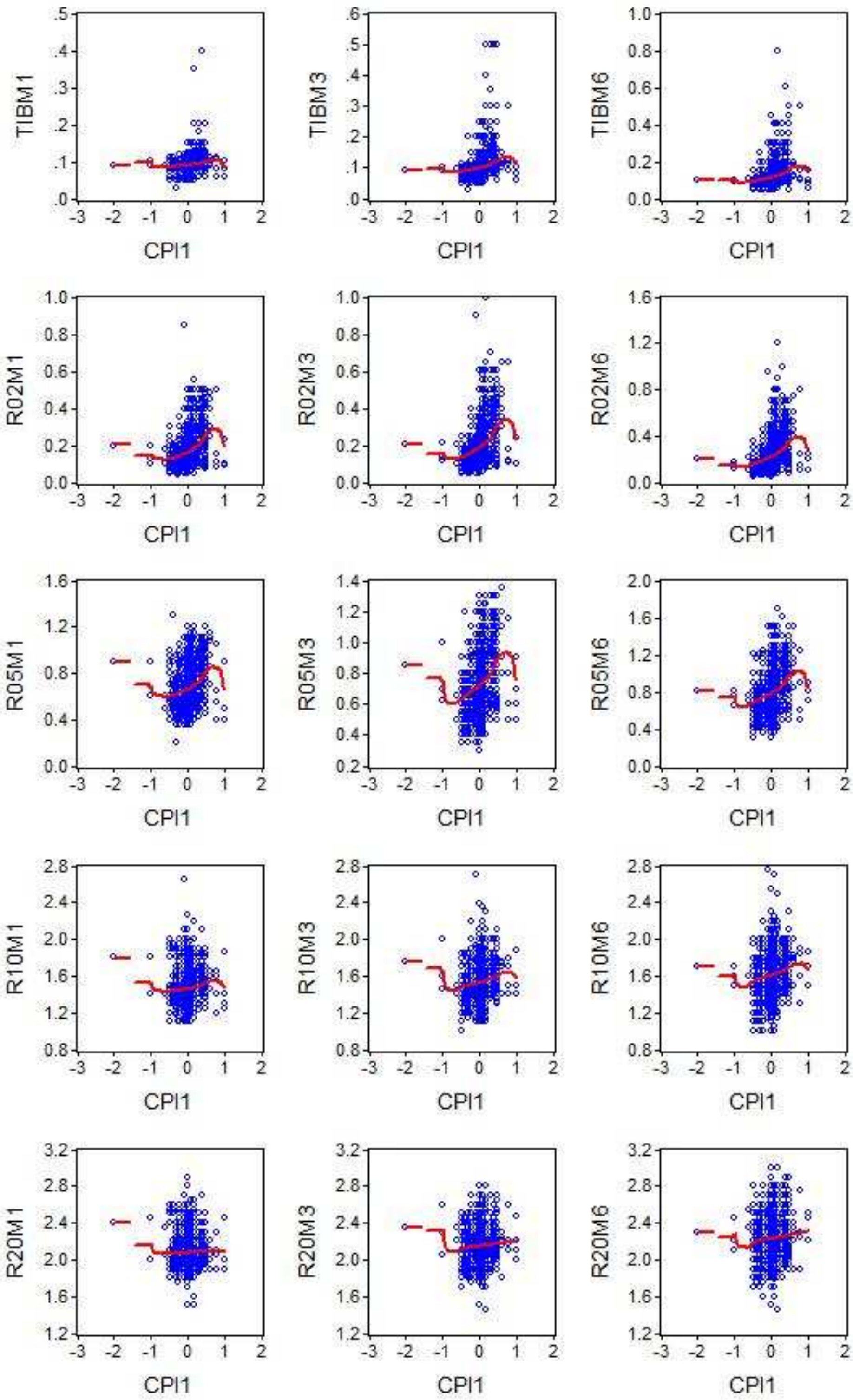

Figure 5: Interest rate expectations vis-a-vis 1-year inflation expectations

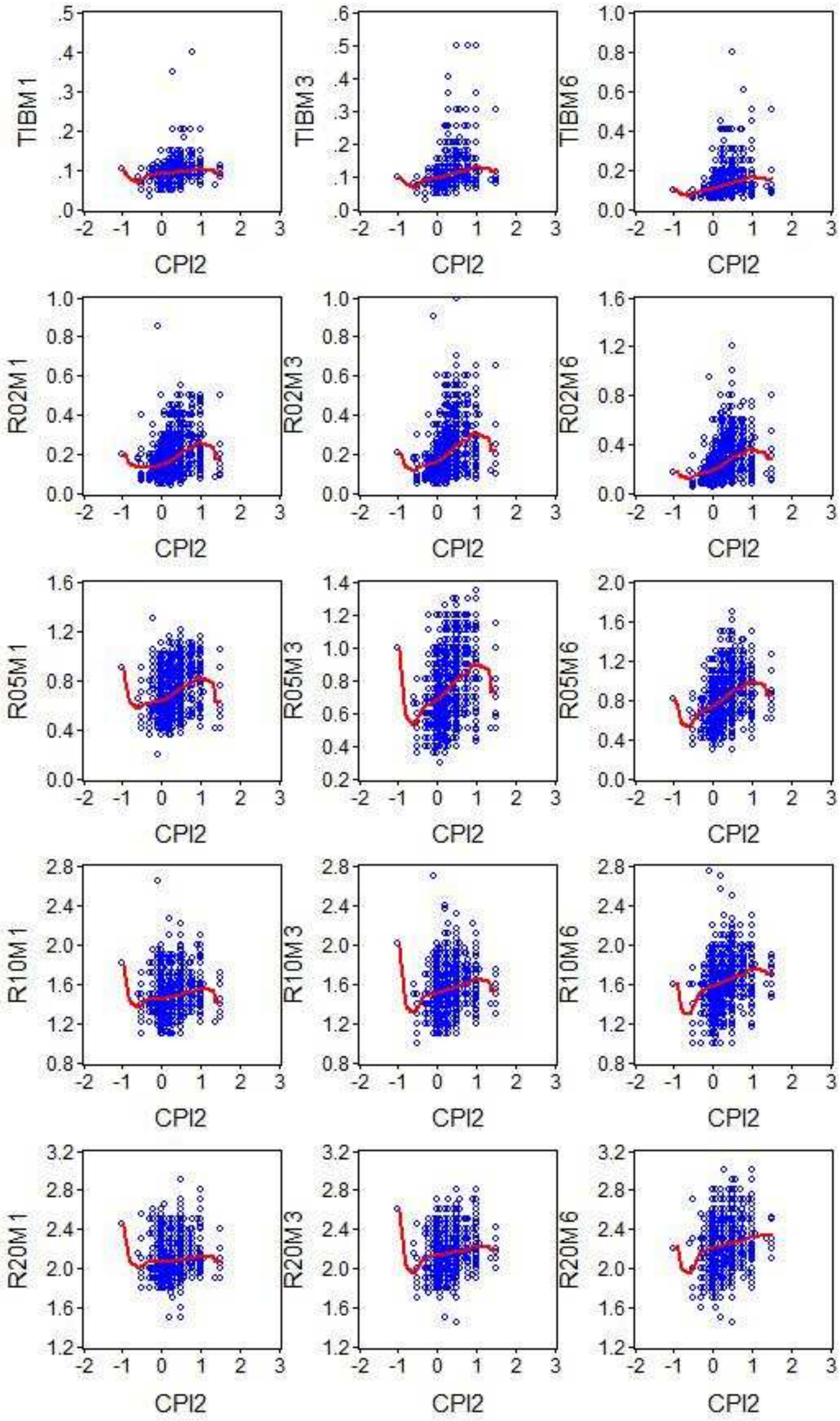

Figure 6: Interest rate expectations vis-a-vis 2-years inflation expectations

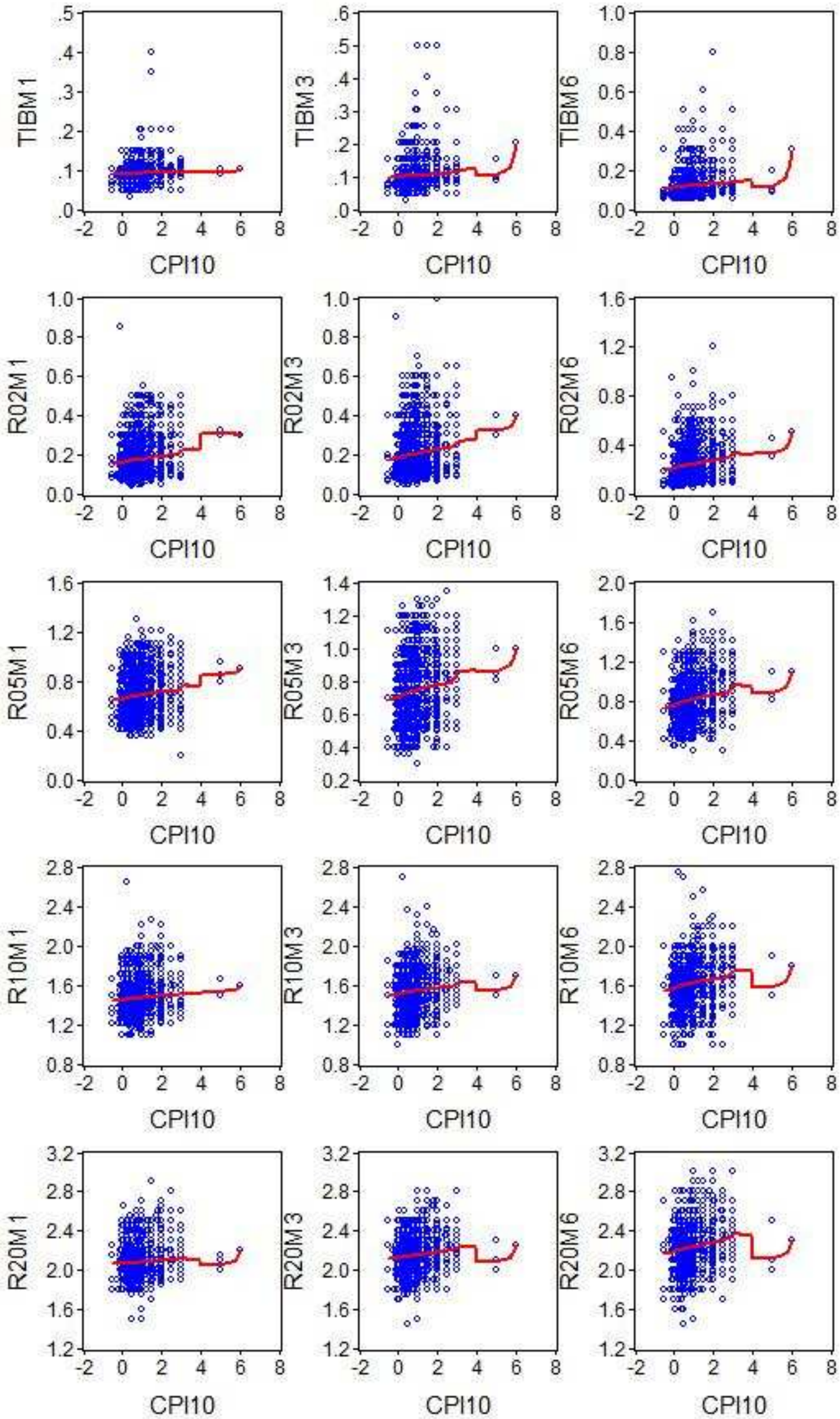

Figure 7: Interest rate expectations vis-a-vis 10-years inflation expectations

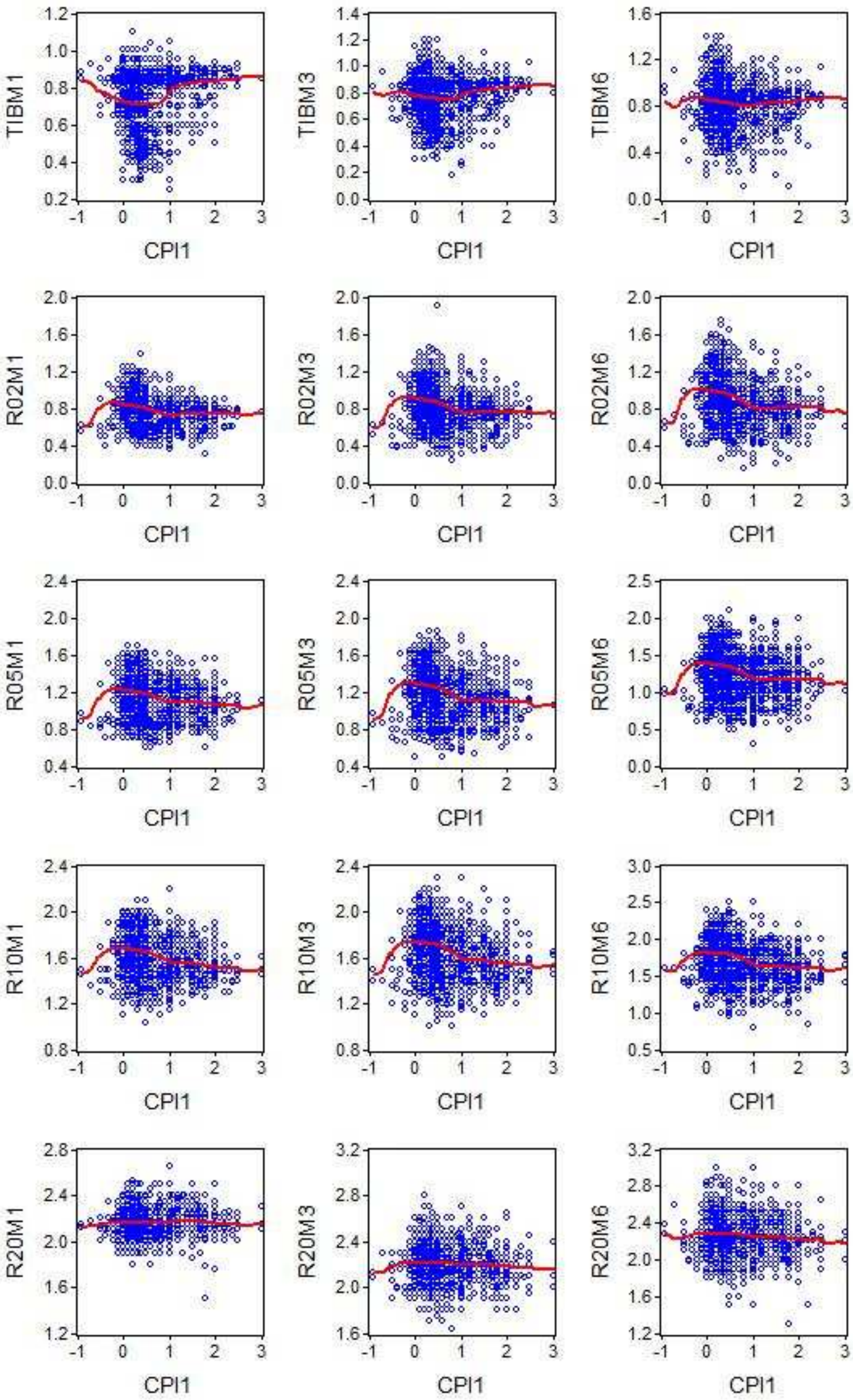

Figure 8: Interest rate expectations vis-a-vis 1-year inflation expectations after the CPI commitment policy ended

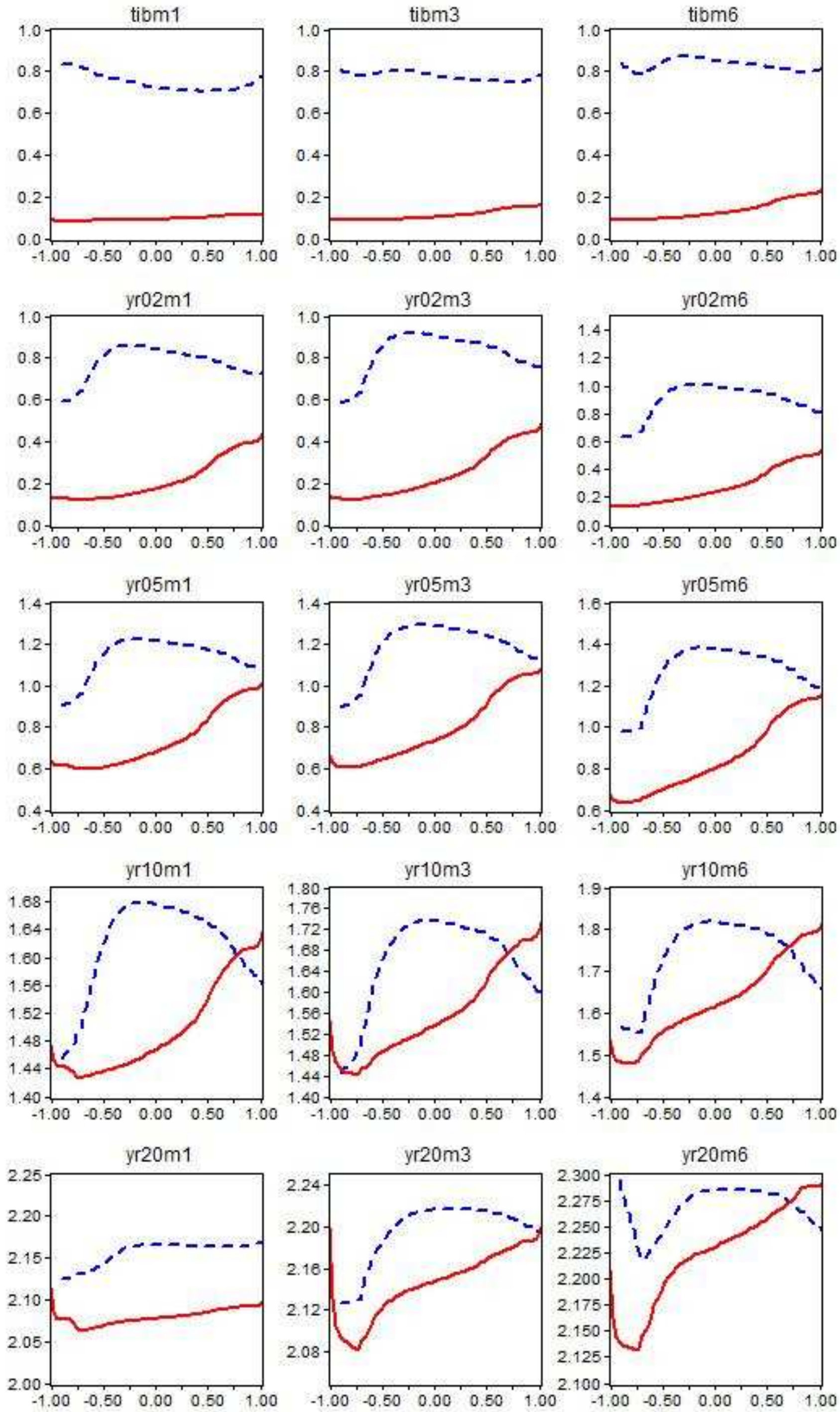

Figure 9: Interest rate expectations vis-a-vis 1-year inflation expectations in two monetary policy regimes.

Note: Red solid lines and blue dashed lines represent the means during and after the CPI commitment policy, respectively.

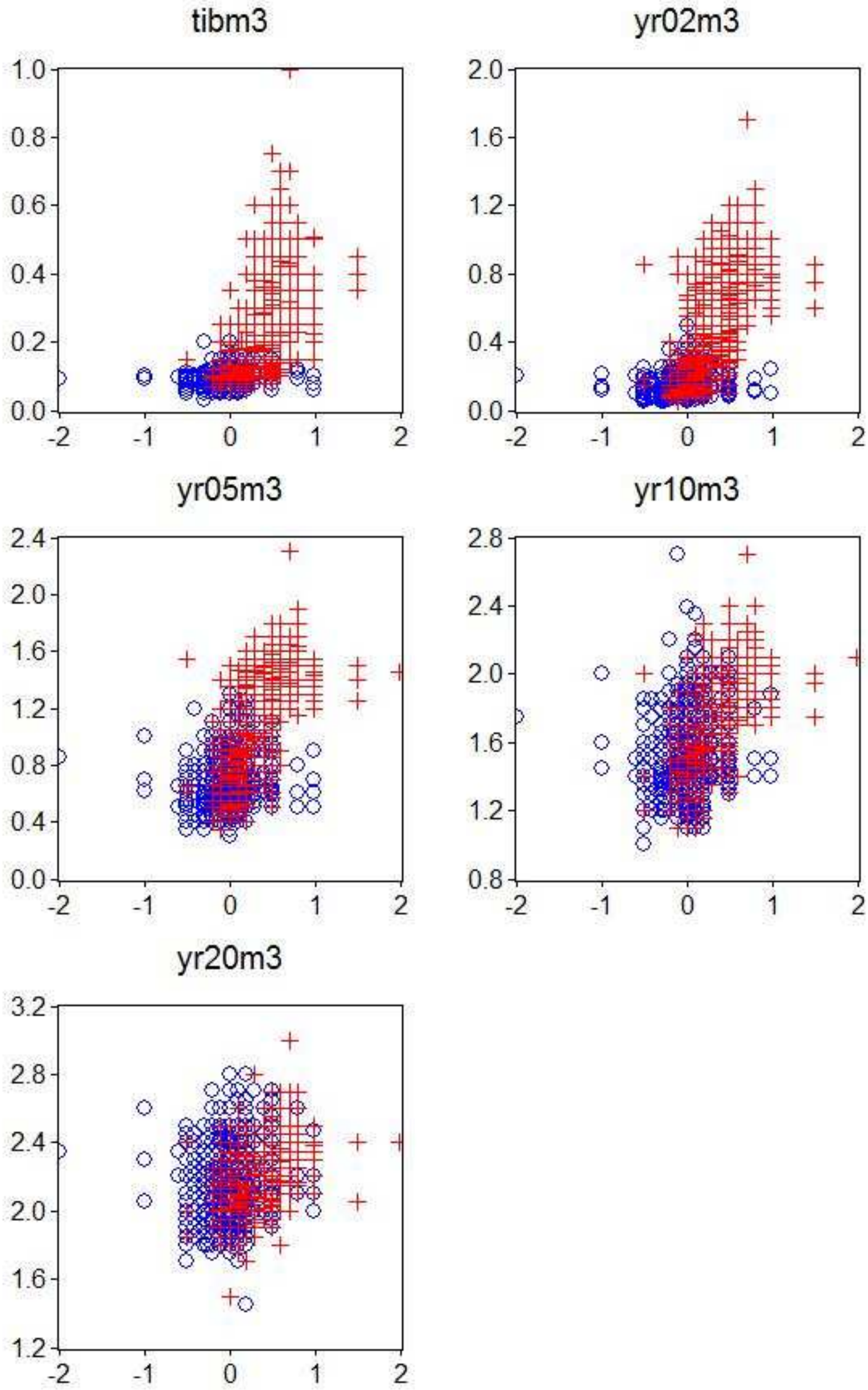

Figure 10: Interest rate expectations vis-a-vis 1-year inflation expectations in the middle and latter period of the CPI commitment policy

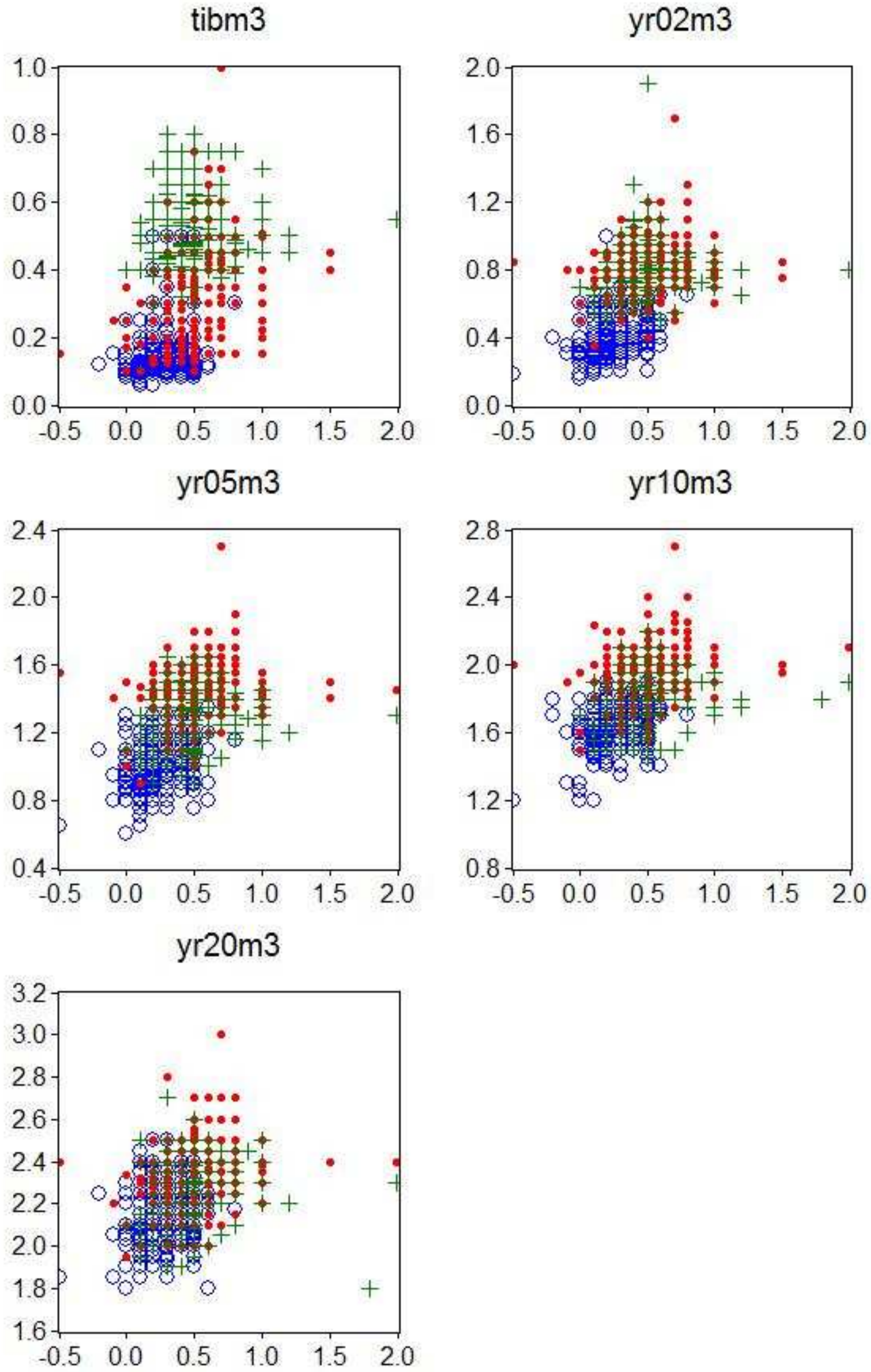

Figure 11: Interest rate expectations vis-a-vis 1-year inflation expectations in the short period just before and just after the CPI commitment policy ended

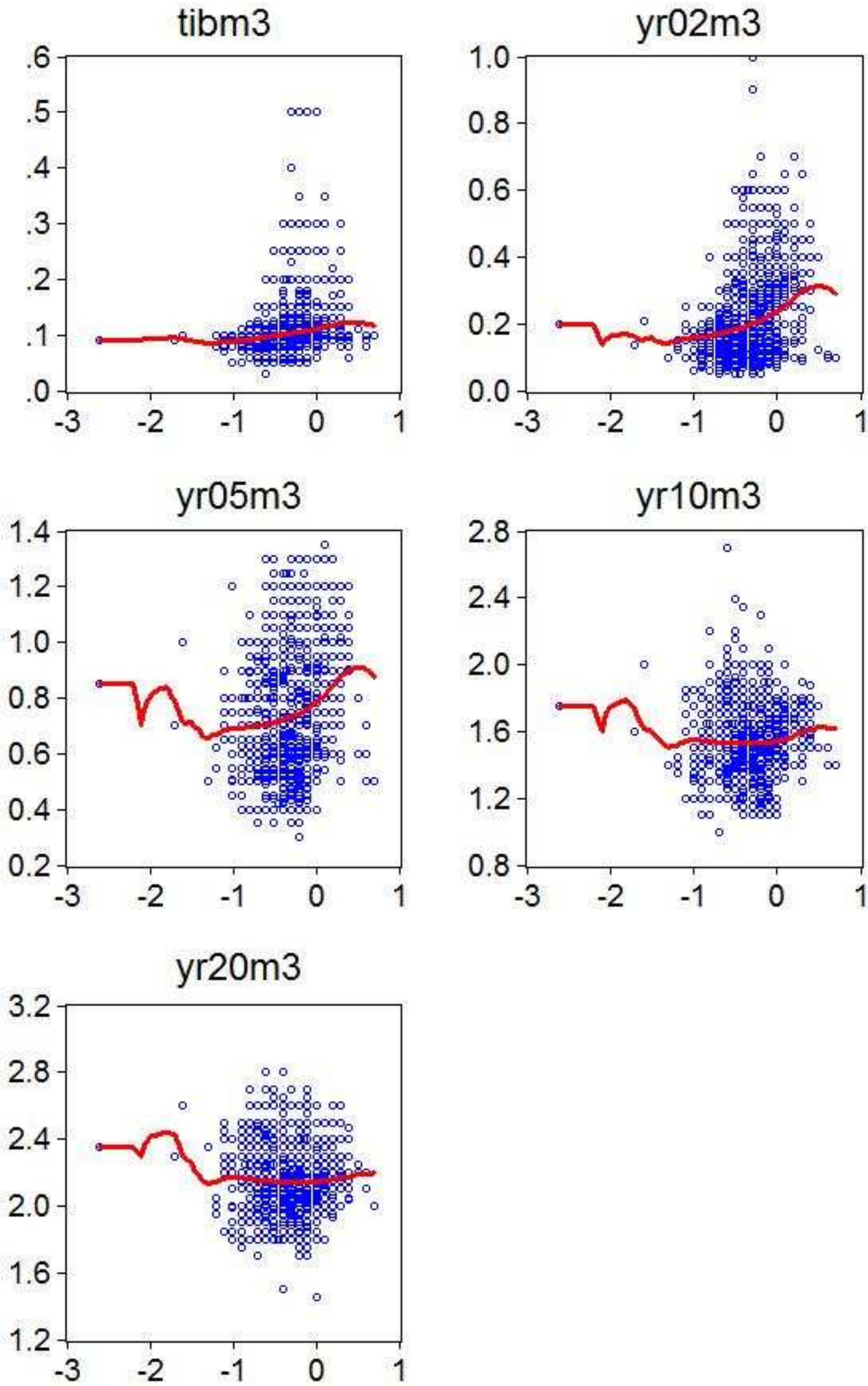

Figure 12: Interest rate expectations vis-a-vis 1-year inflation expectations excluding food and energy during the CPI commitment policy

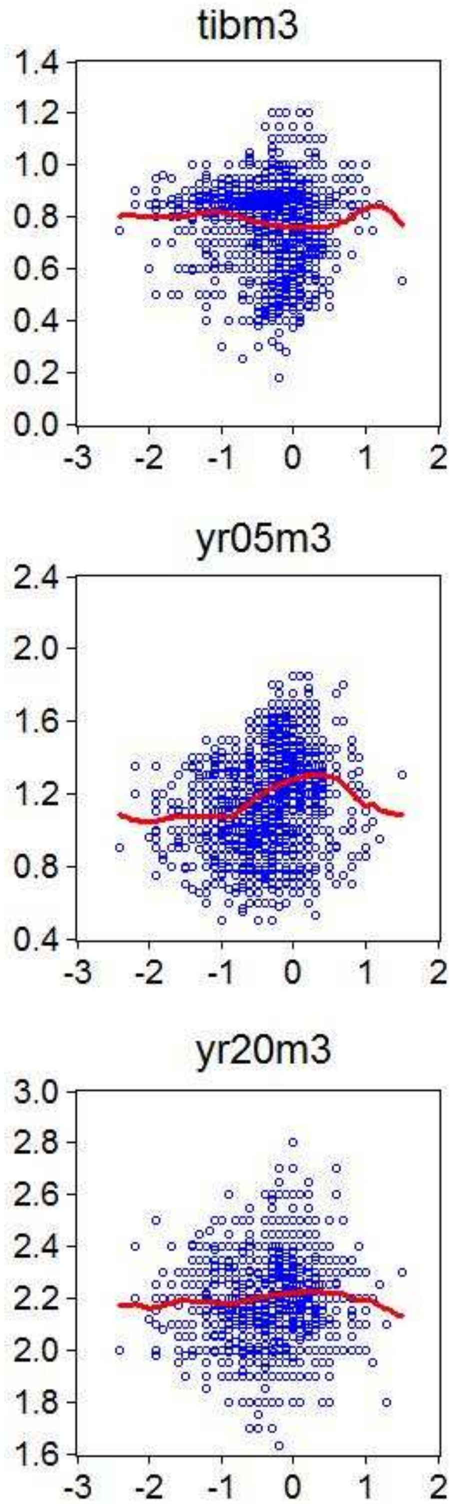

Figure 13: Interest rate expectations vis-a-vis 1-year inflation expectations excluding food and energy after the CPI commitment policy ended

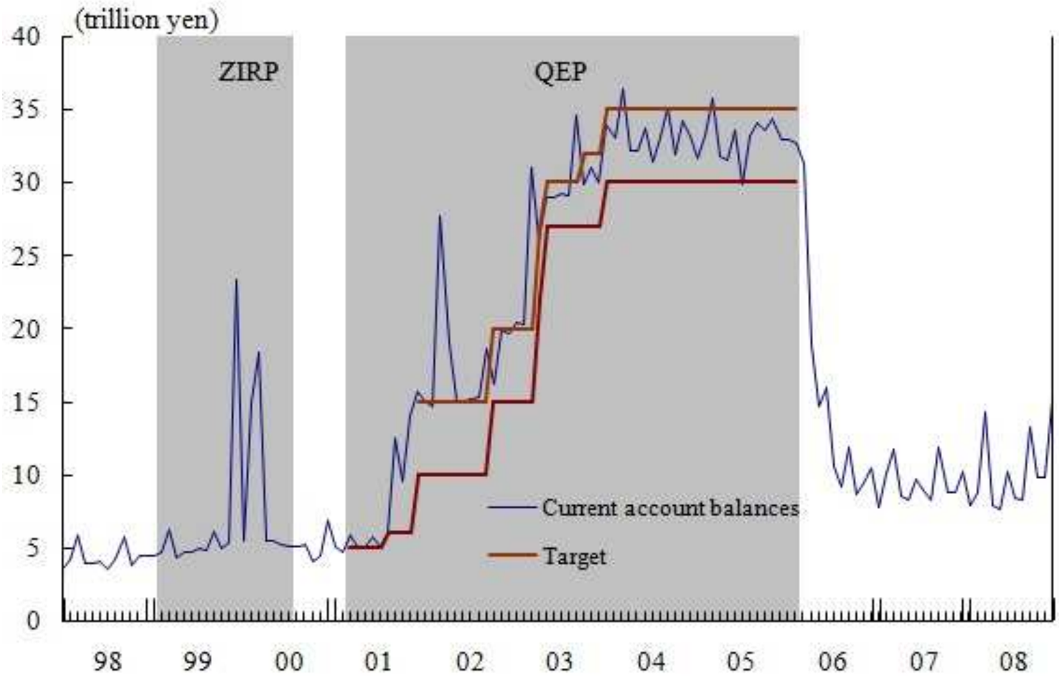

Figure 14: Current account balances

Source: Bank of Japan.

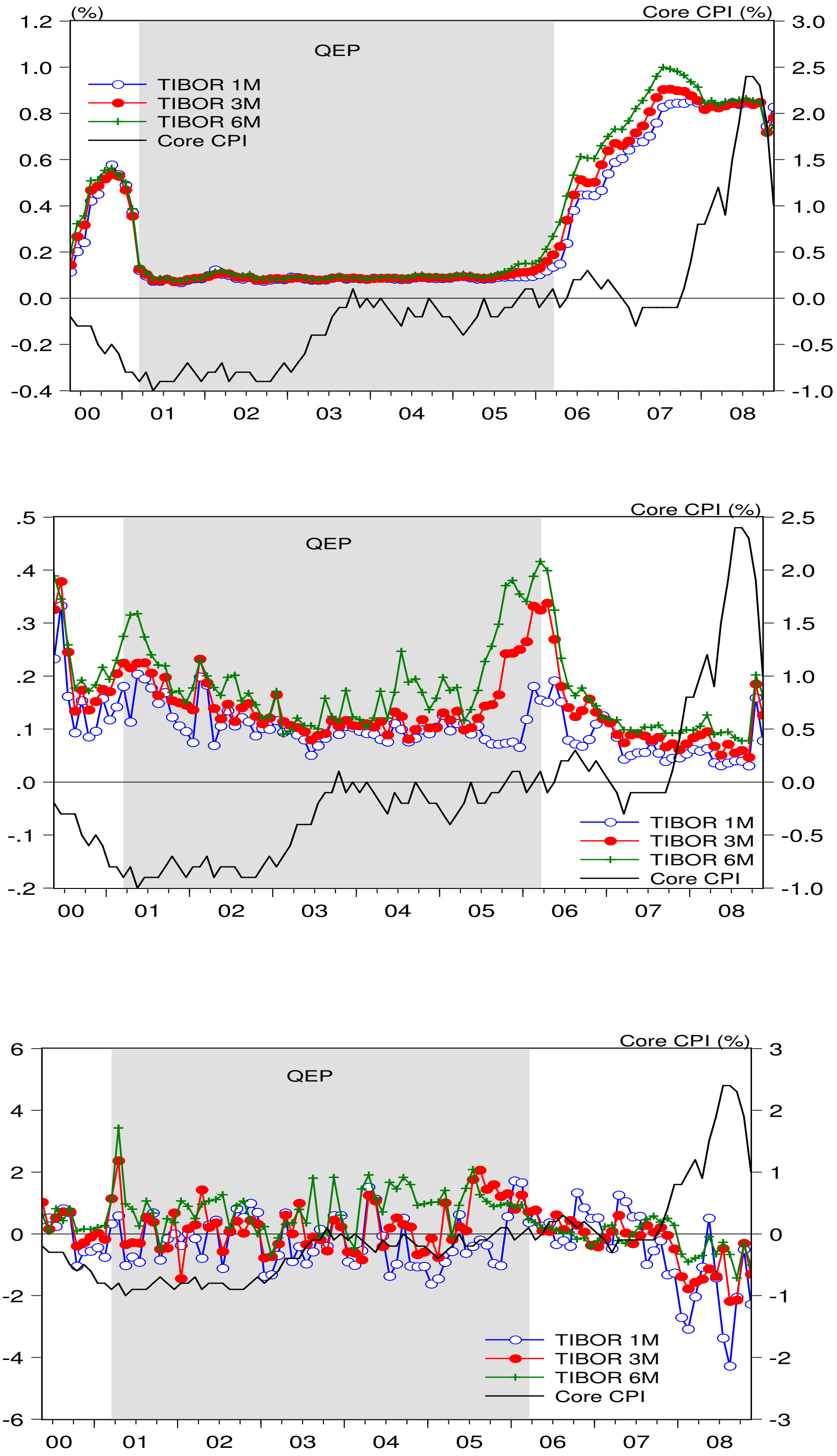

Figure A-1: 3-months TIBOR yields expectations (top: means; middle: standard deviations / means; bottom: skewness)

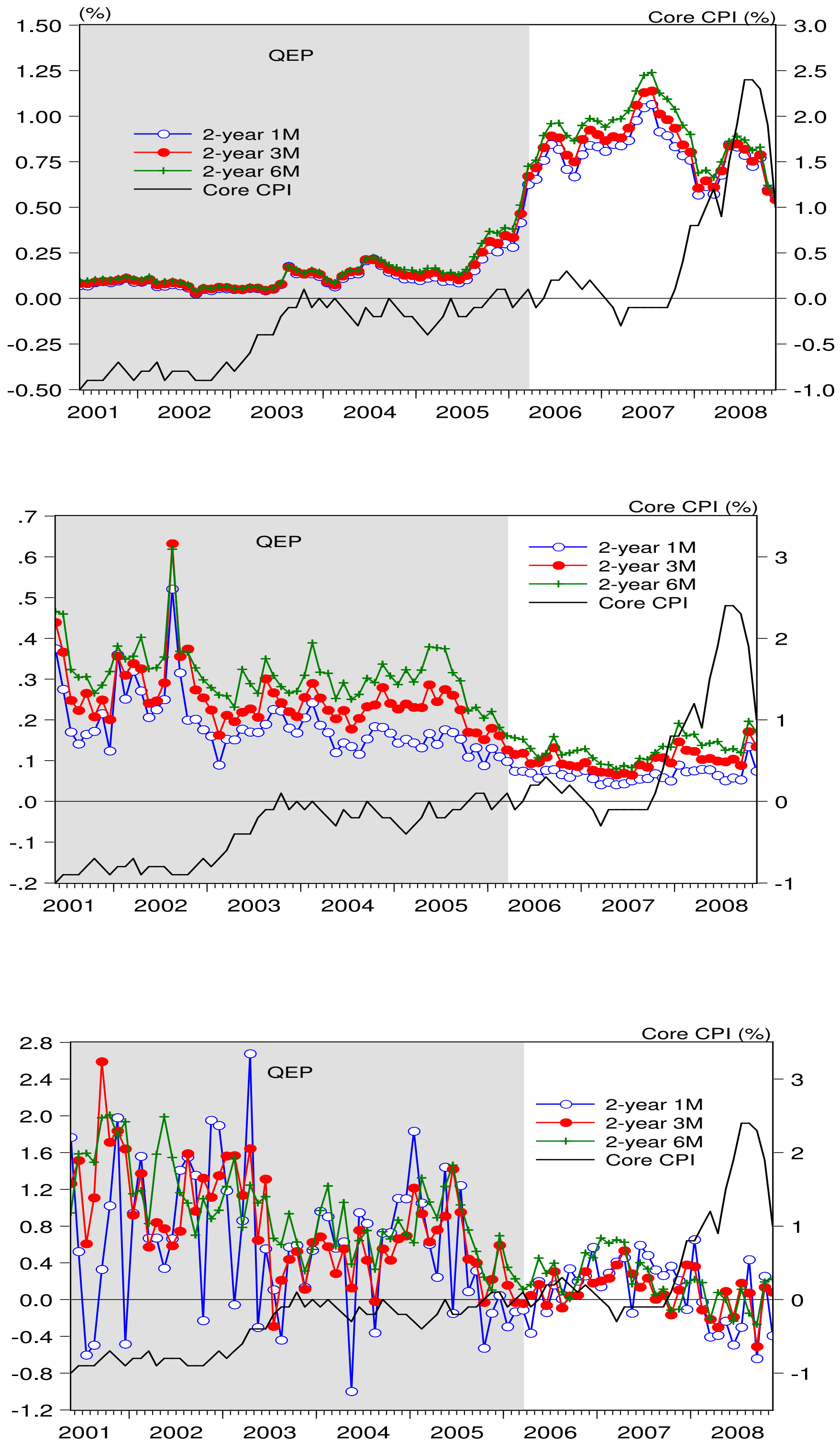

Figure A-2: 2-years JGB yields expectations (top: means; middle: standard deviations / means; bottom: skewness)

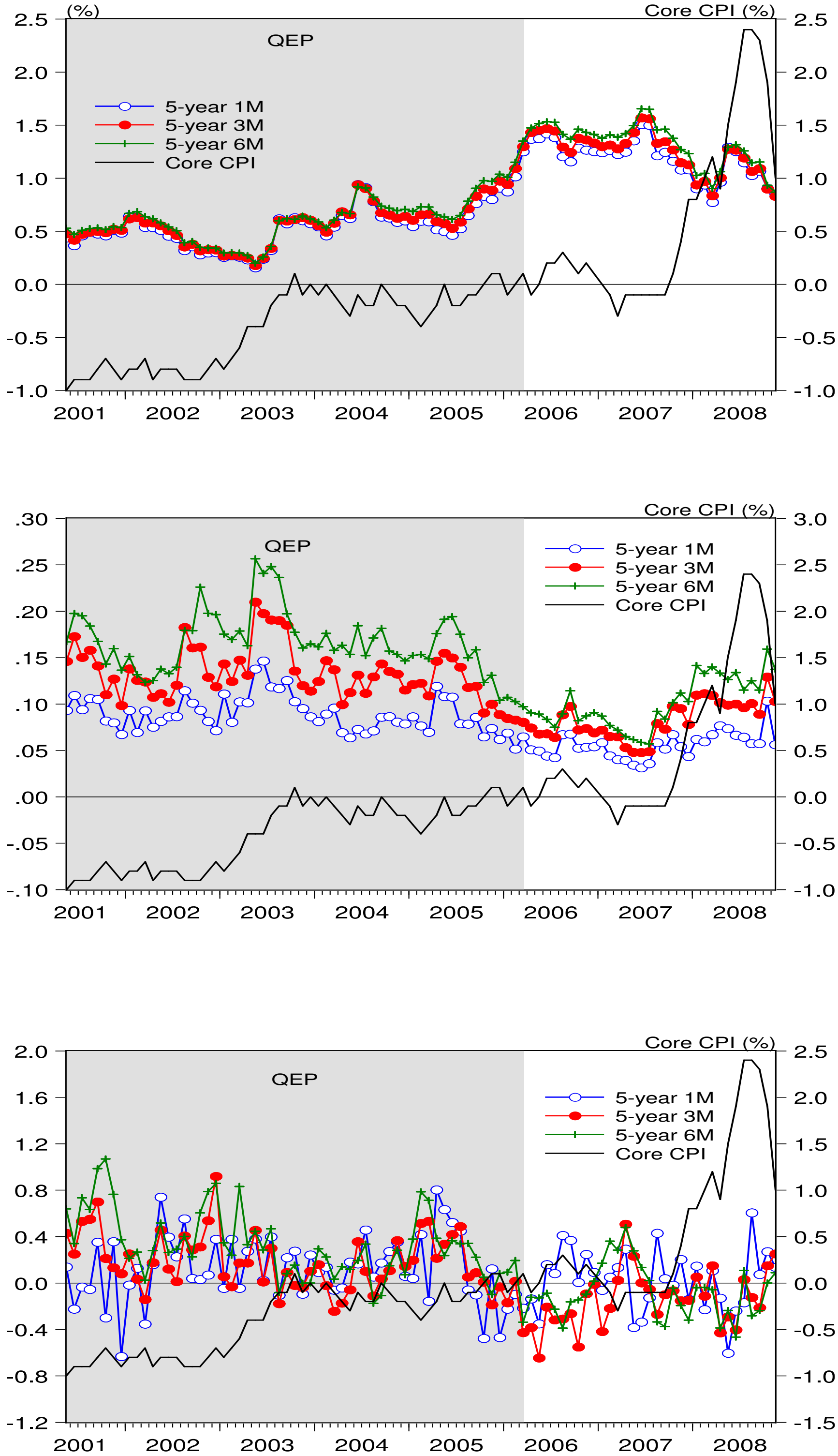

Figure A-3: 5-years JGB yields expectations (top: means; middle: standard deviations / means; bottom: skewness)

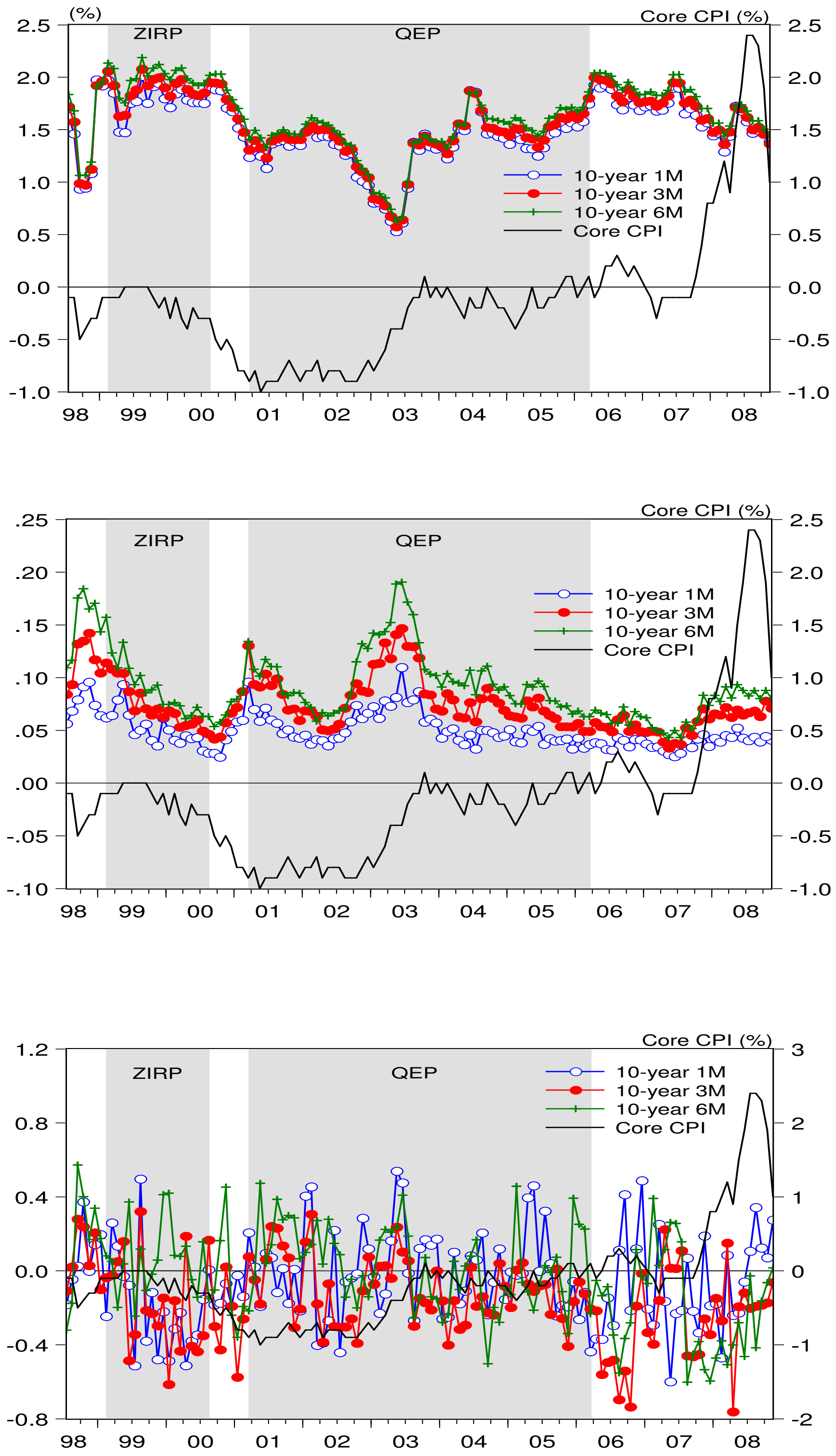

Figure A-4: 10-years JGB yields expectations (top: means; middle: standard deviations / means; bottom: skewness)

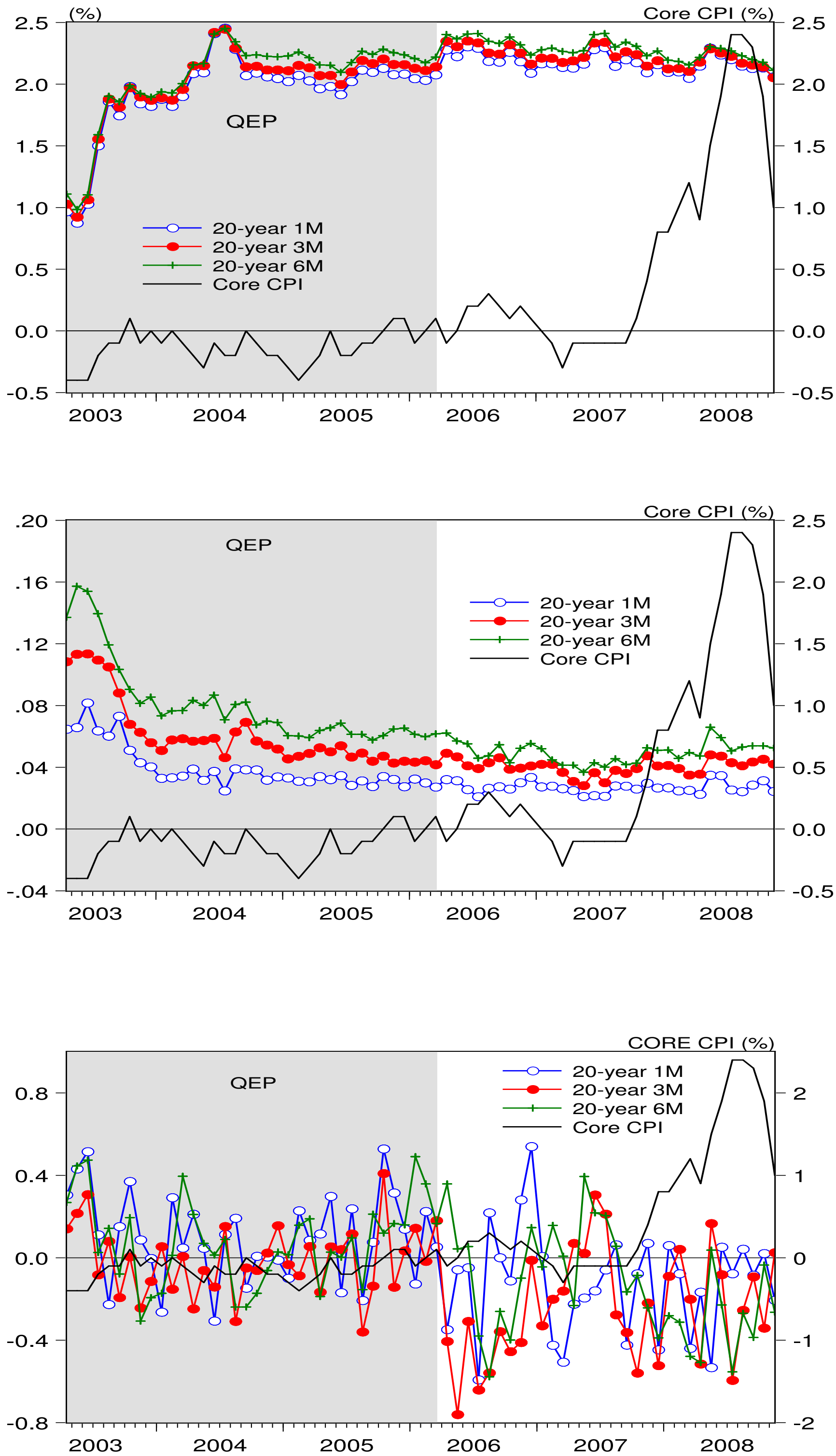

Figure A-5: 20-years JGB yields expectations (top: means; middle: standard deviations / means; bottom: skewness)

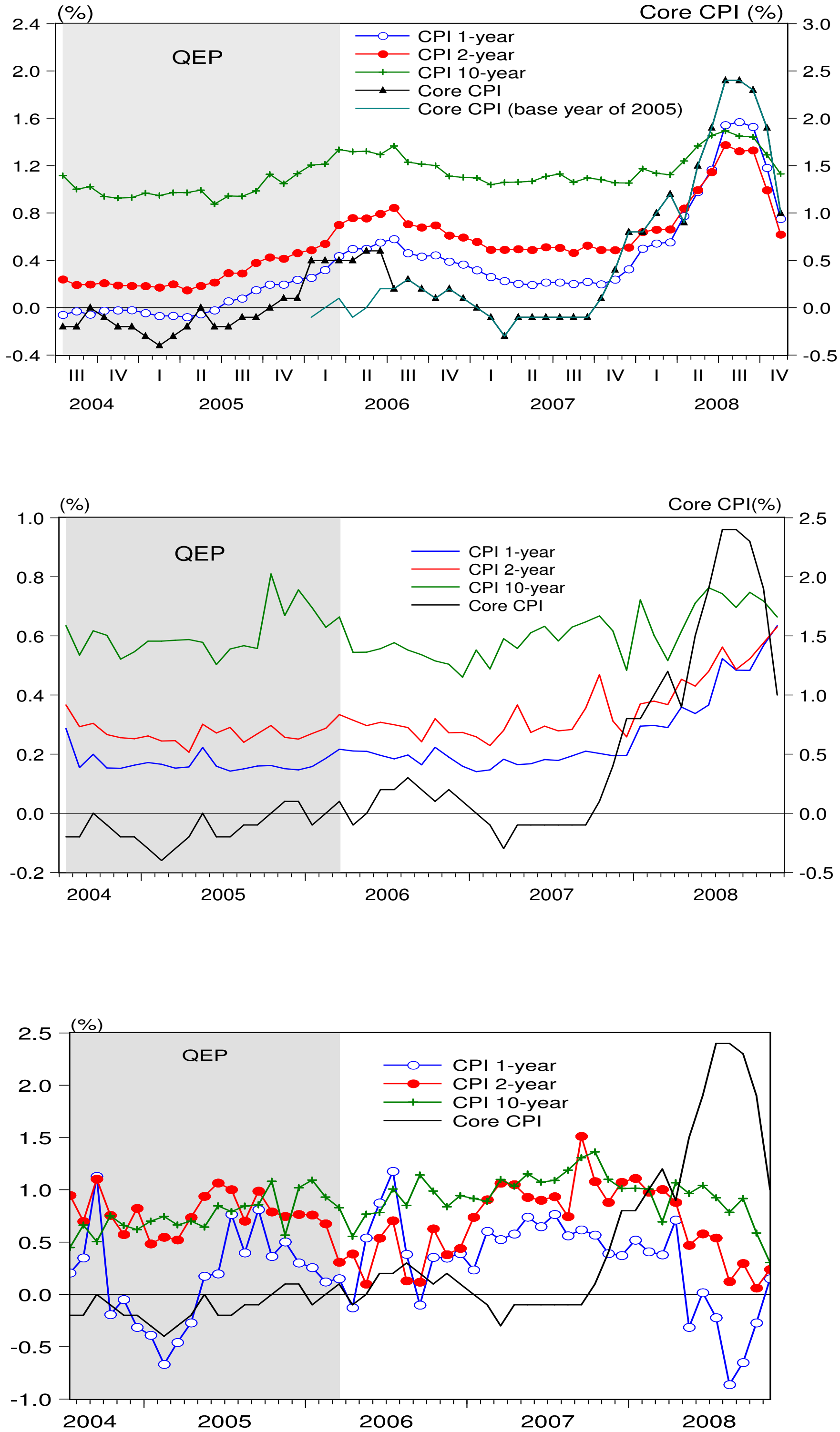

Figure A-6: Inflation expectations (top: means; middle: standard deviations; bottom: skewness)