Policy Duration Effect under the Zero Interest Rate Policy in 1999–2000: Evidence from Japan's Money Market Data

Hiroshi Fujiki and Shigenori Shiratsuka

This paper quantifies the policy duration effect of the zero interest rate policy implemented in Japan from February 1999 to August 2000. Our empirical analysis shows that the policy duration effect observed in Japanese financial markets emerged via the expectations channel on the future course of monetary policy actions, supplemented significantly by liquidity effects in the severe financial conditions. This finding leads to the policy implication that the effectiveness of the zero interest rate policy depends crucially on the financial and economic conditions.

Key words: Zero interest rate policy; Policy duration effect; Liquidity constraint; Forward interest rates

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I. Introduction

The Bank of Japan (BOJ) adopted the so-called zero interest rate policy from February 1999 to August 2000. The BOJ decided to "flexibly provide ample funds and encourage the uncollateralized overnight call rate to move as low as possible" in February 1999 to avoid a possible intensification of deflationary pressure and to ensure that the economic downturn would come to a halt.[1] Subsequently, in April 1999, the BOJ declared its commitment to the zero interest rate "until deflationary concerns are dispelled."[2] This policy was intended to affect market expectations regarding the future course of monetary policy actions, thereby stabilizing interest rates, ranging from overnight to term rates, at a low level. Under this policy, the uncollateralized overnight call rate, which is a direct operational target rate of the BOJ, remained stable at virtually zero percent. On August 11, 2000, the BOJ determined to end the zero interest rate policy to "encourage the uncollateralized overnight call rate to move on average to around 0.25%."

As Fujiki, Okina, and Shiratsuka (2001) have discussed, the most important components of the zero interest rate policy from February 1999 to August 2000 were twofold: (1) guiding the call rate to virtually zero percent (net of the transaction cost in the interbank market), and (2) maintaining a commitment to the zero interest rate policy "until deflationary concerns are dispelled." In other words, two aspects were important for the zero interest rate policy to be effective: the "quantity" of money and the "policy duration."

Of the two aspects of the zero interest rate policy, Yamaguchi (2001), deputy governor of the BOJ, points out the importance of the second one as follows:

> Following the decision on the zero rate on February 12, 1999, Governor Hayami made it clear on April 13 that the BOJ was committed to maintaining the zero rate "until deflationary concerns are dispelled." This statement was received by the financial markets as a signal that the BOJ would continue the zero rate for a considerable period of time. Reflecting such market expectations, interest rates for term instruments declined rapidly, and the yield curve became extremely flat. At this point, we confirmed that the zero rate with future commitment had a powerful automatic easing effect when activity tended to soften.

Furthermore, Yamaguchi (2001) points out that the impact of the zero interest rate policy was strong because of Japan's severe financial conditions at the time:

1. In the announcement of the decisions of the Monetary Policy Meeting (MPM) on February 12, 1999, the following two points were made: (1) "corporate and household sentiments remain cautious and private sector activities stagnant"; and (2) "long-term interest rates have risen considerably, and the yen has been appreciating against the dollar."
2. Governor Masaru Hayami, at a press conference on April 13, 1999, stated that "until we reach a situation in which deflationary concerns are dispelled, we will continue the current policy of providing necessary liquidity to guide the uncollateralized overnight call rate down to virtually zero percent while paying due consideration to maintaining the proper functioning of the market."

> The strength of the zero rate has partly to do with the then-prevailing extreme fragility of Japan's financial system and markets, where liquidity was drying up. The banks with insufficient capital base were facing a serious liquidity shortage. The zero interest rate policy forcefully supplemented the effect of the public injection of capital by its strong liquidity effect.

These two phrases clearly summarize the policymakers' views as to why the zero interest rate policy from February 1999 to August 2000 was effective in Japan. First, the zero interest rate policy accompanied by future commitment affected market expectations with respect to the future course of interest rates, thus bringing longer-term interest rates down to flatten the yield curve. Second, the zero interest rate policy, coupled with the injection of public funds into financial institutions, produced a strong liquidity effect in the fragile Japanese financial markets.

The purpose of this paper is to quantify the "policy duration" effect on the restoration of proper market functioning in the interbank market, with special emphasis on its liquidity effect based on Japan's experience from February 1999 to August 2000.[3] Our empirical analysis reveals that the zero interest policy produced a strong easing effect in two channels. First, it worked through the expectations with respect to the future path of nominal interest rates that were captured by the shape of the yield curve. Second, it produced a significant liquidity effect against the backdrop of the fragile condition of the financial system and the markets, as witnessed by a significant decline in the term spreads of interest rates.

Our findings raise an important policy implication of the zero interest rate policy. The effectiveness of the policy depends crucially on the prevailing financial and economic conditions. Anticipated effects as well as risks or side-effects of policy options considerably depend on economic conditions at the time, and the zero interest rate policy is no exception. We should not excessively generalize Japan's experience of the zero interest rate policy from February 1999 to August 2000 to derive lessons for monetary policy formulation. Depending on the economic situation, the effectiveness of the policy might differ in coping with an economic downturn compared with other policy measures, and, even if it turned out to be an appropriate policy option, the style of a central bank's commitment to the policy could differ.

In addition, a zero interest rate policy in the future could be supplemented by other policy measures that are beyond a central bank's discretion, and could work far better than we have experienced in Japan. It is worth mentioning that the

3. On March 19, 2001, the BOJ decided to adopt "New Procedures for Money Market Operations and Monetary Easing." The major feature of these procedures is to change "the main operating target for money market operations from the uncollateralized overnight call rate to the outstanding balance of the current accounts at the BOJ," and to commit to this "until the consumer price index (excluding perishables, on a nationwide statistics) registers stably a zero percent or an increase year on year." In addition, the BOJ announced, "For the time being, the balance outstanding at the Bank's current accounts be increased to around 5 trillion yen, or 1 trillion yen increase from the average outstanding of 4 trillion yen in February 2001." Although the BOJ did not formally reinstate the zero interest rate policy but chose to make a fundamental change in the operational framework, this policy is expected to have a similar effect in practice to reimposing the zero interest rate policy. However, it is certainly still premature to make any definitive assessment concerning this policy change. For the details of these policy changes, see the BOJ's announcements on its Website (http://www.boj.or.jp/en/seisaku/01/seisaku.htm).

powerful liquidity effects created by the zero interest rate policy were realized, together with the injection of public funds to strengthen commercial banks' capital base. We thus need a better understanding of the relevant structural policy that makes monetary policy sufficiently effective to overcome the lower bound of the nominal interest rate.

This paper is organized as follows. Section II quantifies the policy duration effect from February 1999 to August 2000 based on the theory of term structure of interest rates. In particular, we estimate implied forward interest rates to gauge the effect of the zero interest rate policy and the BOJ's commitment on the future path of the nominal interest rates. Section III investigates the changes in term spreads of interest rates to detect the effect of the zero interest rate policy in mitigating the liquidity constraints that the Japanese banks faced. Section IV discusses the policy implications obtained from our empirical evidence. Section V provides the conclusion. In the appendix, we provide numerical examples of how changes in the parameter values of the generalized Nelson and Siegel (1987) procedure used in Section II affect the shape of the instantaneous forward rate curve.

II. Implied Forward Rates and the Zero Interest Rate Policy

In this section, we examine the effect of the zero interest rate policy from February 1999 to August 2000, with special emphasis on its impact on the flattening of the yield curve.

A. The Policy Duration Effect of the Zero Interest Rate Policy

The "policy duration" effect essentially depends on how long the current abundant provision of funds will last rather than how abundantly the funds are provided.

Based on the classification made by Clouse *et al.* (2000), a zero interest rate policy pursued by using the short-term financial instruments in open market operations would not be a useful way to increase the amount of the monetary base, because short-term financial instruments and the monetary base are essentially perfect substitutes for each other. However, the effect obtained via expectations regarding the future paths of the nominal interest rate, the inflation rate, and asset prices would still be useful. One might also expect that the credit channel would work simultaneously.

For the sake of exploiting the effect obtained via the expectation channel, it is natural to strengthen the power of commitment by explicitly targeting some of the relevant macroeconomic variables, notably the inflation rate. It is possible to say—rather mechanically—that "the central bank will not change the short-term interest rates during any period of time based on the development of certain macroeconomic variables." However, in practice, to make such a commitment in a credible manner, the central bank might consider that the amount of knowledge it requires is too great on a real-time basis. As economic conditions vary, the central bank cannot credibly say it will not change the short-term interest rate during any period of time regardless of economic or price developments. Therefore, in our view, the BOJ could not give a definite time framework contingent on some specific macroeconomic variables, but could only specify that the policy would not be ended "until deflationary concerns are dispelled" on April 13, 1999.[4]

The BOJ's zero interest rate policy with the commitment "until deflationary concerns are dispelled" was highly effective in stabilizing market expectations regarding the future path of short-term interest rates. Guiding the overnight rate to virtually zero worked as an anchor for medium- to long-term interest rates through intermarket arbitrage functioning. As a result, the yield curve flattened and stabilized at a very low level.

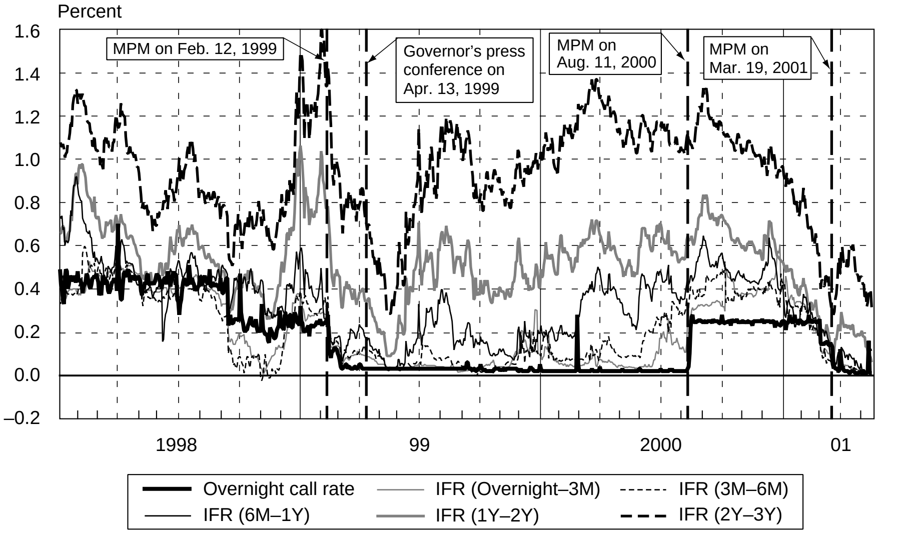
The above mechanism of a "policy duration" effect is underpinned by the expectations hypothesis regarding the term structure of interest rates. The pure expectations theory of the term structure of interest rates tells us that long-term interest rates today should reflect the future course of short-term interest rates.[5] For example, the one-year interest rate is determined by market expectations for overnight interest rates during the subsequent 12-month period. Based on a more practical and general formula, long-term interest rates are the sum of market expectations regarding the future course of short-term interest rates and a term premium (based on risk caused by uncertainty or the preference of market participants). Premiums being constant, fluctuations of interest rates on term instruments reflect changes in expectations.

The expectations theory indicates that the zero interest rate policy contains an automatic stabilizer element in its easing effect. That is, if the economy is on a downward trend, market participants believe that the termination of the zero interest rate policy will be delayed, thus bringing longer-term interest rates down to flatten the yield curve. On the contrary, if the economy is on an upward trend, market participants believe that the termination will grow closer, thus raising longer-term interest rates to steepen the yield curve, acting as a brake on the easing effect.[6]

Figure 1 plots the implied forward rates (IFRs) calculated from short-term interbank interest rates and short- and medium-term government securities. Casual observation of this figure supports our aforementioned discussion of the policy duration effect. After the introduction of the zero interest rate policy on February 12, 1999, IFRs were on a downward trend. However, from the middle of March 1999, the IFRs, particularly those ranging from one year to two years and from six months to one year, increased. Observe that immediately after the announcement of the commitment on April 13, 1999 "until deflationary concerns are dispelled," those IFRs declined again by June. Although longer-term IFRs subsequently increased again, it is noteworthy that the IFRs ranging from six months to one year remained around 0.1–0.2 percent after the yen's appreciation in summer 1999. On the contrary, in June and July 2000, IFRs for the periods from three to six months and

4. On March 19, 2001, the BOJ committed to the new procedures for money market operations until the consumer price index (excluding perishables, on a nationwide statistics) registers stably a zero percent or an increase year on year.
5. See Goodfriend (1998) for an excellent discussion on the use of the term structure of interest rates for monetary policy analysis.
6. See Ueda (2000a, b). Taking into account the fact that the economy continuously faces structural change, forward-looking monetary policy management is not necessarily the same as automatic policy management using forecasts based on past experience.

Figure 1 Implied Forward Rates



Sources: Bank of Japan, *Economic and Financial Statistics Monthly*; Bloomberg.

from overnight to three months started rising in succession, reflecting growing expectations of a termination of the zero interest rate policy.

Figure 1 provides casual evidence to support our view that information extracted from yield curves helps us gauge market expectations regarding the future course of monetary policy actions, given the assumption that the term premium is negligible or constant. In the following, we will employ a more sophisticated procedure to estimate the instantaneous forward rate to demonstrate the inference that using the IFR will be helpful in understanding the policy duration effect under a zero interest rate policy.[7]

B. The Generalized Model of Nelson and Siegel (1987)

We employ three alternative specifications of instantaneous forward rate curves, all of which are versions of Nelson and Siegel's (1987) model, with simple, parsimonious functional forms, but flexible enough to capture the general property of yield curves for monetary policy purposes.

Our most generalized specification of the instantaneous forward rate with settlement in period m, denoted $r^{GNS}(m)$, is a generalized version of Nelson and Siegel's (1987) model as follows:

$$r^{GNS}(m) = \beta_0 + \beta_1 \cdot \exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \cdot \left(\frac{m}{\tau_2}\right) \cdot \exp\left(-\frac{m}{\tau_2}\right), \quad (1)$$

7. The instantaneous forward rate corresponds to a marginal increase in the total return from a marginal increase in the length of investment. Intuitively, the instantaneous forward rate curve indicates the expected future time path of yields, while the yield curve shows the expected future averages of the yields. See Svensson (1995) for the details about the distinction between the two curves.

where β_0, β_1, β_2, τ_1, and τ_2 are parameters to be estimated from the data.[8] We expect β_0, τ_1, and τ_2 to be positive. Important features of equation (1) are that the limits of forward and spot rates when maturity approaches zero and infinity, respectively, are equal to $\beta_0 + \beta_1$ and β_0.[9]

The instantaneous forward rate curve, shown in equation (1), consists of three components. The first component is a constant, β_0. The second component is an exponential function, $\beta_1 \cdot \exp(-m/\tau_1)$. β_1 generally takes a negative value in our estimation periods, producing an upward-sloping shape for the forward rate curve. A large (small) value of τ_1 means that this exponential effect decays more slowly (quickly). The third component is $\beta_2 \cdot (-m/\tau_2) \cdot \exp(-m/\tau_2)$. This component creates a hump shape when β_2 is positive, while it generates a U-shape when negative. τ_2 controls the speed of convergence of the third term in equation (1), as does τ_1 for the second component.

The second specification, denoted $r^{ONS}(m)$, imposes a restriction of $\tau_1 = \tau_2$ on equation (1), which corresponds to the original version of Nelson and Siegel's (1987) model, as follows:

$$r^{ONS}(m) = \beta_0 + \beta_1 \cdot \exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \cdot \left(\frac{m}{\tau_1}\right) \cdot \exp\left(-\frac{m}{\tau_1}\right). \tag{2}$$

This model implies the equal convergence speeds between the upward/downward-sloping and hump/U-shaped components. The third specification, denoted $r^{EXP}(m)$, imposes a further restriction of $\beta_2 = 0$, which exhibits a simple exponential curve, as follows:

$$r^{EXP}(m) = \beta_0 + \beta_1 \cdot \exp\left(-\frac{m}{\tau_1}\right). \tag{3}$$

To select the most appropriate specification among the three, we conduct two hypothesis tests by applying a likelihood ratio testing procedure: one is the constraint of $\tau_1 = \tau_2$ used to compare the models of $r^{GNS}(m)$ and $r^{ONS}(m)$, and the other is the constraint of $\beta_2 = 0$ to compare the models of $r^{ONS}(m)$ and $r^{EXP}(m)$. Although Nelson and Siegel (1987) point out that the model of $r^{GNS}(m)$ is likely to be over-parameterized, this model is useful in our empirical exercise because the shape of the forward rate curve at the short end shows very volatile movement when some special liquidity events, such as the end of the calendar and fiscal year, approach in 1999 and

8. The model of $r^{GNS}(m)$ can be also interpreted as a special case of the extended Nelson and Siegel (1987) model, proposed by Söderlind and Svensson (1997). Their functional form, denoted $r^{ENS}(m)$, includes two hump-/U-shaped components as follows:

$$r^{ENS}(m) = \beta_0 + \beta_1 \cdot \exp\left(-\frac{m}{\tau_1}\right) + \beta_3 \cdot \left(\frac{m}{\tau_1}\right) \cdot \exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \cdot \left(\frac{m}{\tau_2}\right) \cdot \exp\left(-\frac{m}{\tau_2}\right),$$

and, thus, we can obtain equation (1) by imposing a restriction of $\beta_3 = 0$.

9. Since, as mentioned below, we employ interbank interest rates ranging from overnight to one year, the horizontal asymptote of the function, captured by β_0, does not necessarily imply long forward rates, but the expected forward rate for settlements around one year ahead.

2000.[10] At the same time, the simple exponential curve, expressed by the model of $r^{EXP}(m)$, is sufficient to approximate the forward rate curve when the yield curve is upward sloping and relatively smooth, and thus we can safely ignore the third component of equations (1) and (2).

The spot rate for each specification, denoted $R^i(m)$ (for i = *GNS*, *ONS*, or *EXP*), can in turn be derived by integrating the equations (1), (2), and (3) from zero to m and dividing by m. That is,

$$R^i(m) = \frac{1}{m}\int_{s=0}^{m} r^i(s)\,ds \text{ (for } i = GNS, ONS, \text{ or } EXP),$$

and the specific functional forms employed in estimation are as follows:

$$R^{GNS}(m) = \beta_0 + \beta_1 \cdot \left(\frac{\tau_1}{m}\right) \cdot \left(1 - \exp\left(-\frac{m}{\tau_1}\right)\right) + \beta_2 \cdot \left[\left(\frac{\tau_2}{m}\right) \cdot \left(1 - \exp\left(-\frac{m}{\tau_2}\right)\right) - \exp\left(-\frac{m}{\tau_2}\right)\right], \quad (4)$$

$$R^{ONS}(m) = \beta_0 + \beta_1 \cdot \left(\frac{\tau_1}{m}\right) \cdot \left(1 - \exp\left(-\frac{m}{\tau_1}\right)\right) + \beta_2 \cdot \left[\left(\frac{\tau_1}{m}\right) \cdot \left(1 - \exp\left(-\frac{m}{\tau_1}\right)\right) - \exp\left(-\frac{m}{\tau_1}\right)\right], \quad (5)$$

$$R^{EXP}(m) = \beta_0 + \beta_1 \cdot \left(\frac{\tau_1}{m}\right) \cdot \left(1 - \exp\left(-\frac{m}{\tau_1}\right)\right). \quad (6)$$

C. Estimation of the Instantaneous Forward Rates

We focus our study on Japanese yen Tokyo interbank offered rates (TIBOR), ranging from one- to 12-month contracts, from December 1, 1998 to December 29, 2000 for every business day.[11] This is because the pricing of the Japanese government securities in 1998–2000 was highly distorted due to various problems with regard to market liquidity, including the Y2K problem, given the possible credit premium on Japanese yen TIBORs.

1. Estimation results and their interpretation

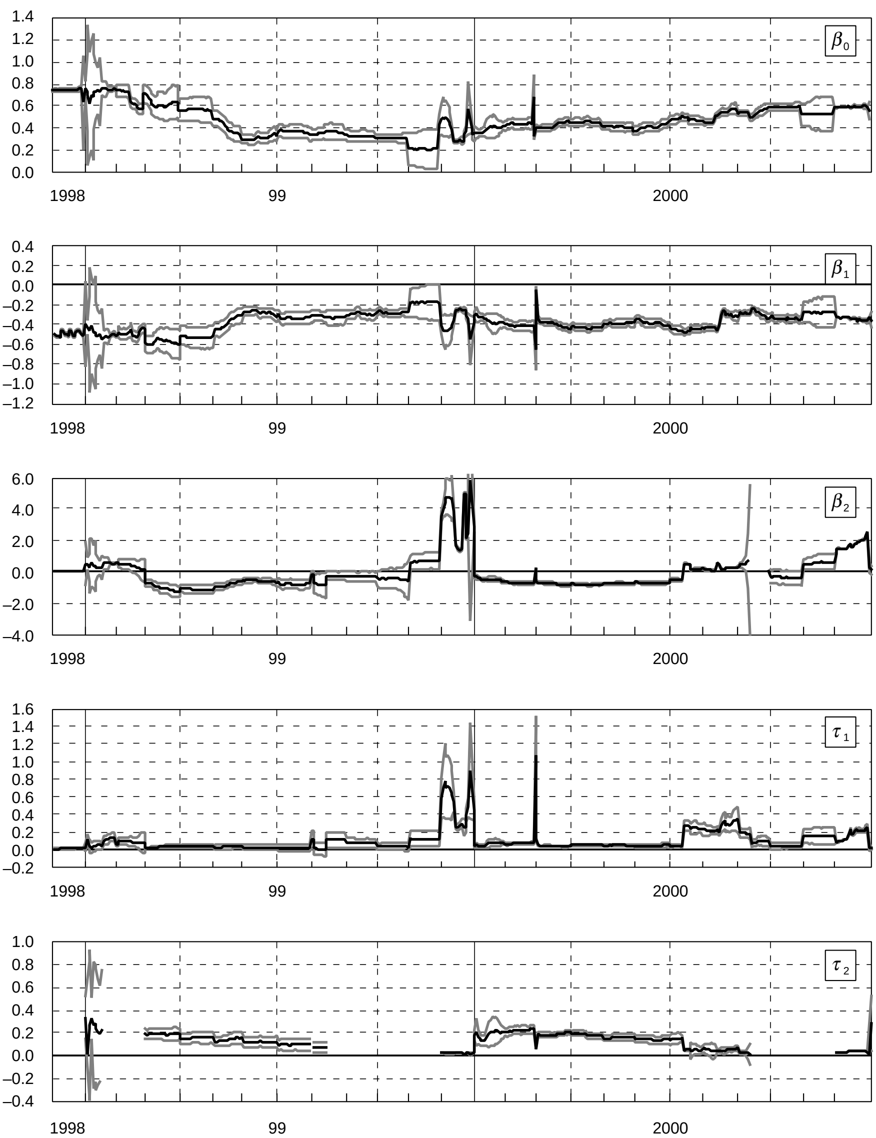
We directly fit equations (4), (5), and (6) to the data on Japanese yen TIBORs, since TIBORs are free (by construction) from coupon effects. We employ the restriction of the overnight call rate being equal to $\beta_0 + \beta_1$, which corresponds to the limit of the spot and forward rates as settlement becomes due and maturity approaches zero. To make the speed of convergence faster, we change the dimension of τ_1 and τ_2, so that

10. Volatile interest rate fluctuations might be avoided by the "Lombard-type" lending facility announced on February 9, 2001.
11. Japanese yen TIBORs are published daily by the Japanese Bankers Association at 12:00 p.m. These TIBORs are based on yen deposit rates quoted by 18 designated banks, by averaging after eliminating the two highest and lowest rates.

$\tau_1 = \tau_2 = 1$ corresponds to 365 days. Our estimations use the CML procedure in GAUSS 3.5.

Figure 2 summarizes the estimates of parameters β_0, β_1, β_2, τ_1, and τ_2 from the top panel to the bottom. In each panel, a solid line shows the estimated parameters, and shaded lines show the upper and lower bounds of each parameter, created by adding and subtracting two times the standard error of the estimated coefficient.

Figure 2 Estimated Coefficients



Note: Shaded lines indicate the upper and lower bounds, respectively, of the confidence interval (estimated coefficients ± 2・standard errors).

The likelihood ratio test statistics support model $r^{GNS}(m)$ for 337 business days out of 513.[12] Model $r^{ONS}(m)$, the original Nelson-Siegel model, is selected for 145 business days, concentrated in three relatively long periods: from January 18 to February 24 and from August 12 to November 26 in 1999, and from September 28 to November 28 in 2000. Model $r^{EXP}(m)$ is chosen for only 31 business days: from December 1 to December 28 in 1999 and from September 11 to September 27 in 2000. In Figure 2, the model periods $r^{GNS}(m)$, $r^{ONS}(m)$, and $r^{EXP}(m)$ are chosen to correspond to the periods in which the estimates for all the coefficients are reported, those in which the estimates of all the coefficients except for τ_2 are reported, and those in which the estimates of β_2 are not reported, respectively.

The magnitudes and signs of the estimated parameters are consistent with our theoretical predictions. For example, the value of β_0 is typically around the range from 0.2 to 0.8. The value of β_1 is typically around the range from –0.7 to –0.2. β_2 takes an extremely large positive value in November and December 1999, reflecting the upward pressure of the yield curve for approximately one month that extends beyond the end of the calendar year due to the Y2K problem. τ_1 and τ_2 always take positive values, but the value of τ_1 becomes relatively large when the value of τ_2 becomes zero.

The overall performance of our estimations is satisfactory for the sake of our discussion, considering that we experienced extraordinary financial conditions and the zero interest rate policy during the estimation period. Table 1 summarizes the typical values of estimates for parameters β_0, β_1, β_2, τ_1, and τ_2.

Table 1 Typical Parameters for Each Period of Time

Periods	Parameters				
	β_0	β_1	β_2	τ_1	τ_2
Early February 1999	0.75	–0.50	0.46	0.09	—
Early March 1999	0.60	–0.57	–1.00	0.03	0.18
Early April 1999	0.57	–0.54	–1.10	0.03	0.15
June 1999	0.30	–0.27	–0.60	0.02	0.12
July 1999	0.37	–0.34	–0.80	0.02	0.09
September 1999	0.33	–0.30	–0.32	0.07	—
February/March 2000	0.42	–0.40	–0.75	0.04	0.18
May/June 2000	0.42	–0.40	–0.72	0.04	0.14
Late July 2000	0.48	–0.46	0.15	0.22	0.05
Late August/September 2000	0.55	–0.30	0.25	0.33	0.06
October 2000	0.59	–0.34	–0.38	0.04	—

2. An illustration of forward rate curves

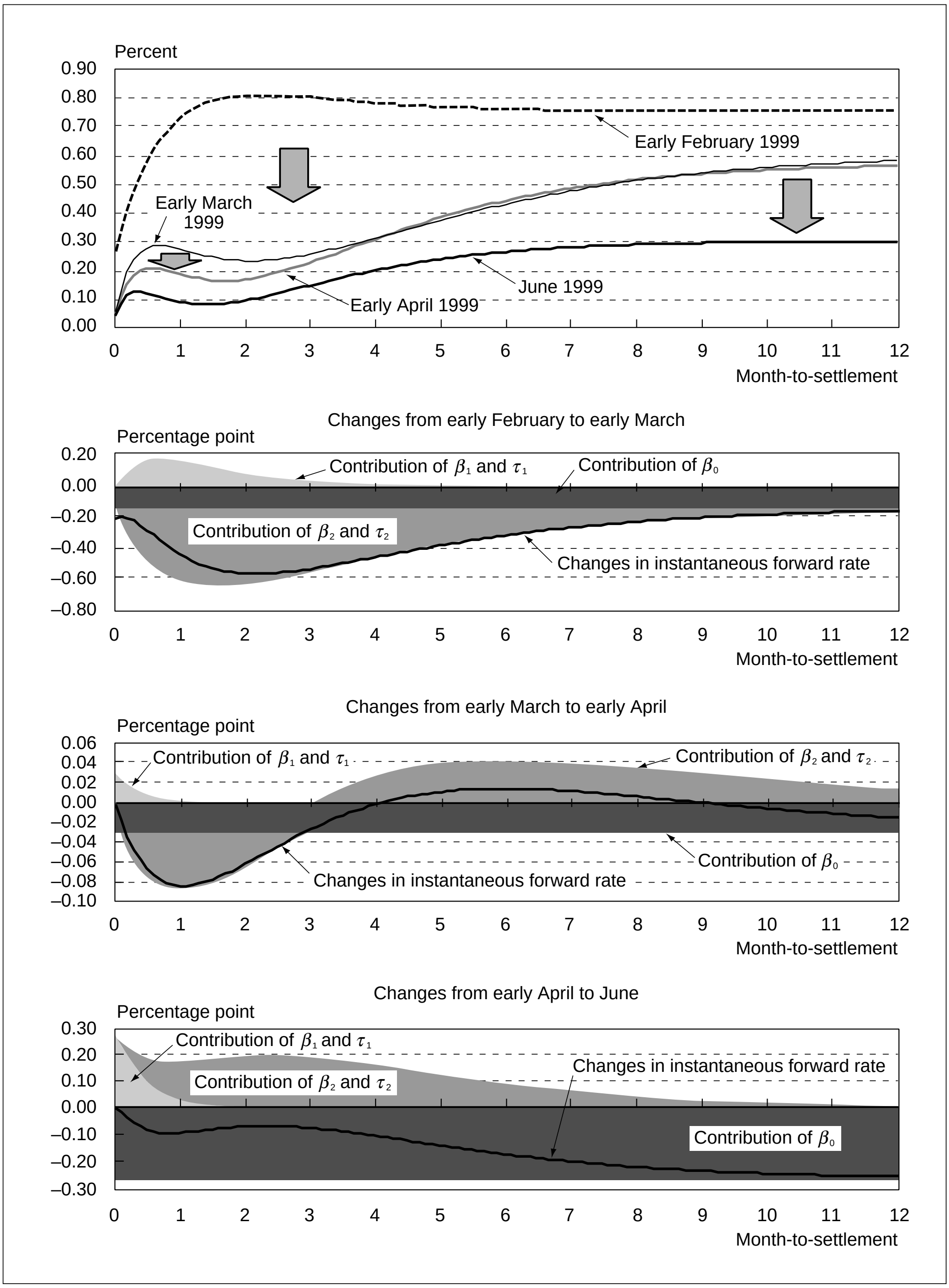
Next, using the parameter values listed in Table 1, we illustrate the typical shape of forward rate curves around the period of policy changes, and examine their implications for the policy duration effect.

12. Although there are 514 business days from December 1, 1998 to December 29, 2000, December 27, 1999 failed to converge, thus total observations are equal to 513.

a. Introduction of the zero interest rate policy (February to June 1999)

First, let us focus on the period around the introduction of the zero interest rate policy in February 1999. The top panel of Figure 3 illustrates typical instantaneous forward rate curves before and after the introduction of the zero interest rate policy.

Figure 3 Simulated Instantaneous Forward Curves (1): Period around the Introduction of the Zero Interest Rate Policy



The horizontal axis in the figure shows the month-to-settlement, and the vertical axis shows the level of instantaneous forward rate curve in percentage terms. After the introduction of the zero interest rate policy, the instantaneous forward rate curve shifted downward from the line labeled "Early February 1999" to that labeled "Early March 1999." The policy change reduced the short-term rate more than the long-term rate, although the instantaneous forward rate curve labeled "Early March 1999" showed a hump shape due to the liquidity concerns extending beyond the end of fiscal 1998, or end-March 1999.

The second to fourth panels of Figure 3 decompose these shifts in instantaneous forward rate curves (solid line labeled "Changes in instantaneous forward rate") into changes explained by the shifts in the values of parameters β_0, $\beta_1 \cdot \exp(-m/\tau_1)$, and $\beta_2 \cdot (-m/\tau_2) \cdot \exp(-m/\tau_2)$.[13]

The second panel shows that the significant downward shift in forward rate curves after the introduction of the zero interest rate policy in February 1999 was explained by the first and second components: a downward parallel shift produced by the decline in β_0 from 0.75 to 0.6 (the component labeled "Contribution of β_0"), as well as a U-shape generated by the decline in β_2 from 0.46 to –1.00 (the component labeled "Contribution of β_2 and τ_2"). However, the smaller negative value of β_1 and the smaller value of τ_1 added a positive exponential curve that decayed quickly (the component labeled "Contribution of β_1 and τ_1"). This component created the hump shape in the instantaneous forward rates labeled "Early March 1999" in the top panel of Figure 3, reflecting the liquidity demand extending beyond the end of fiscal 1998.

The hump shape of the instantaneous forward curve became insignificant in early April, reflecting the disappearance of liquidity demand extending beyond the end of the fiscal year (the line labeled "Early April 1999" in the top panel of Figure 3). The third panel of Figure 3 shows that the upward contribution of the second component labeled "Contribution of β_1 and τ_1" almost disappeared, while the U-shaped components labeled "Contribution of β_2 and τ_2" expanded slightly.

After the BOJ governor's announcement at the press conference on April 13, 1999 to commit to the zero rate "until deflationary concerns are dispelled," the instantaneous forward rate curve shifted further downward, especially the curve ranging from six to 12 months. The bottom panel of Figure 3 shows that the announcement created a parallel downward shift of 30 basis points (the component labeled "Contribution of β_0"). The panel also indicates that this downward impact was offset by the reduced U-shape generated by the third component, labeled "Contribution of β_2 and τ_2." This flattening and stabilizing effect on forward rate curves is deemed consistent with the policy duration effects.

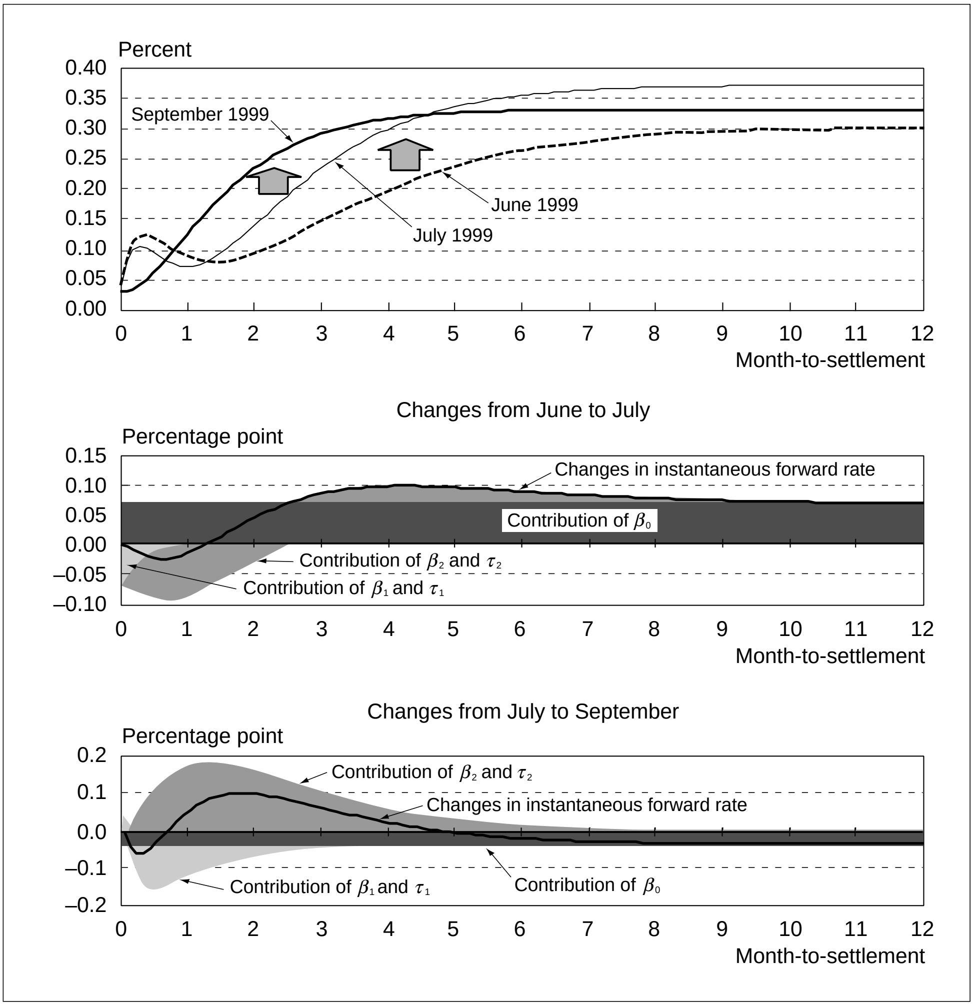
b. Commitment to the zero interest rate policy (June to September 1999)

Second, let us focus on the period from June to September 1999, shown in the top panel of Figure 4.

During this period, although the instantaneous forward rate curves were stabilized at a very low level, especially ranging further than six months ahead, forward rates

13. Numerical examples regarding the shifts in each parameter value and their effect on the shape of the instantaneous forward rate curve are summarized in the appendix.

Figure 4 Simulated Instantaneous Forward Curves (2): Period after the Commitment to the Zero Interest Rate Policy



from one to six months ahead started rising in July. This change is attributable partly to the recovery in public sentiment, evidenced by the increase in stock prices. However, major upward pressure was created by increased concerns over the Y2K problem.

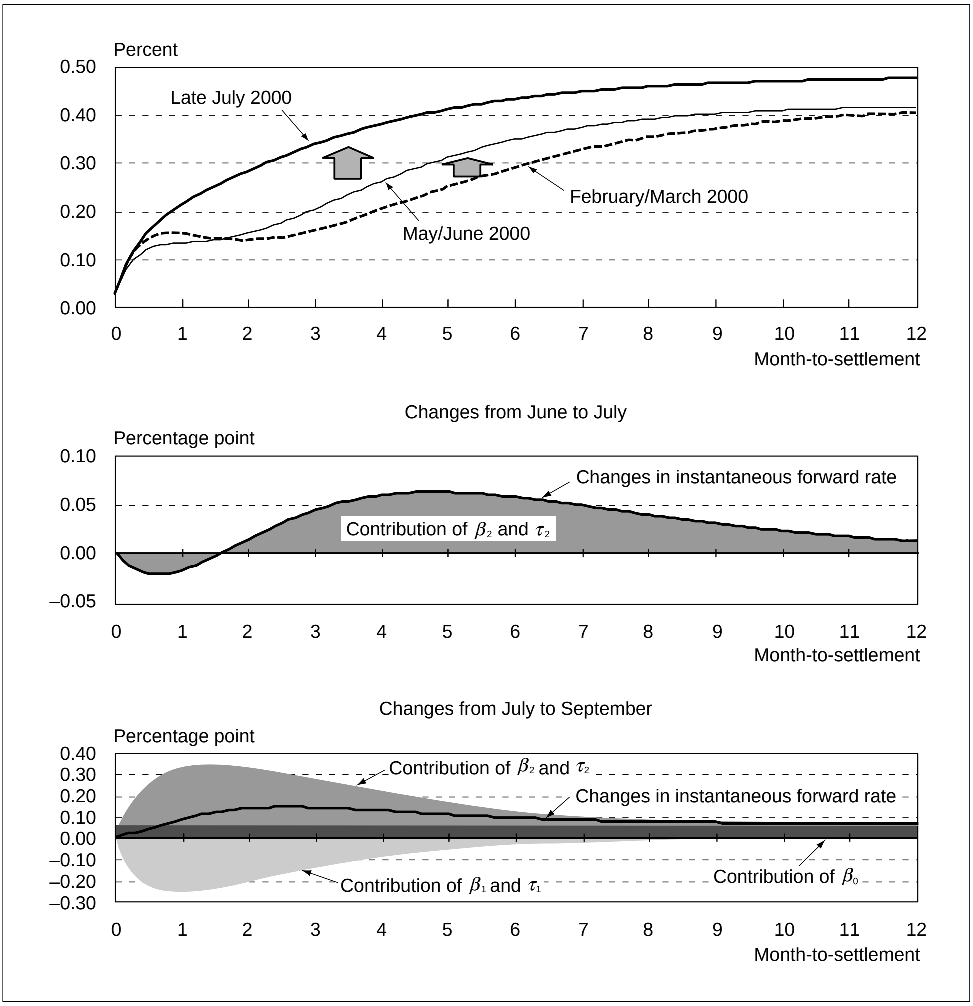
These interpretations are consistent with the bottom panel of Figure 4, because the component labeled "Contribution of β_2 and τ_2" created a large hump shape for medium-term instantaneous forward rates, while the short-term instantaneous forward rates were reduced by the component labeled "Contribution of β_1 and τ_1."

c. Growing expectations of a termination of the zero interest rate policy (February to July 2000)

Third, let us turn to the changes in the shape of instantaneous forward rate curves from February to July 2000, which corresponds to the period during which market expectations of a termination of the zero interest rate policy were growing.

From February 2000 to March 2000, financial markets recovered their stability from the Y2K problem around the turn of the year (the line labeled "February/March 2000" in the top panel of Figure 5). However, as the expectations of a termination of the zero interest rate grew, the instantaneous forward rate curve started shifting upward gradually (the line labeled "May/June 2000" in the top panel of Figure 5), especially ranging from three months to one year ahead (the middle panel of Figure 5).

Figure 5 Simulated Instantaneous Forward Curves (3): Period of Growing Expectations of a Termination of the Zero Interest Rate Policy



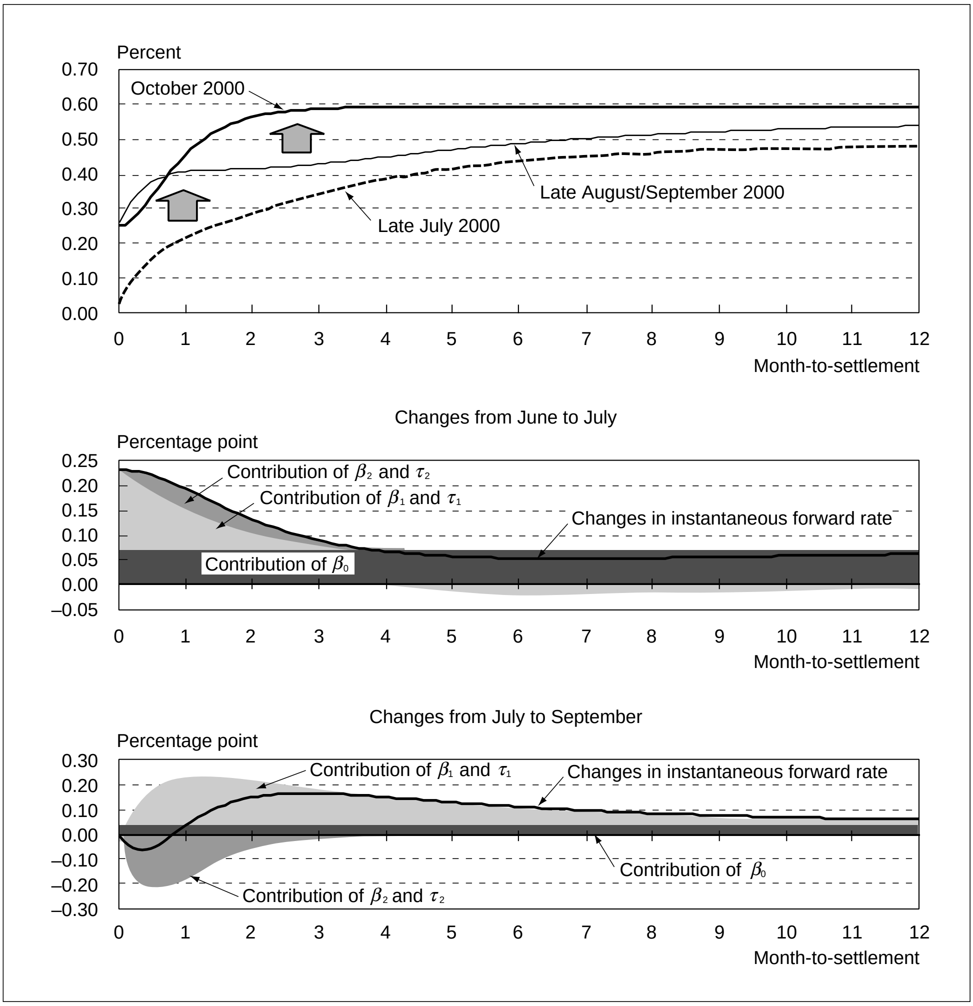
Upward shifts of the instantaneous forward rate curve became more apparent at the short end, ranging from zero to three months, by July (the line labeled "Late July 2000" in the top panel of Figure 5). The zero interest rate policy still kept the very short-term rates close to zero, however, so the entire shape of the yield curve became upward sloping and the short end of the instantaneous forward rate curve swelled upward, as shown in the bottom panel. Observations that upward pressure on the instantaneous forward rate curves began in the relatively long-term rates and then penetrated to the short-term rates are consistent with the policy duration effects detected before the end of the zero interest rate policy.

d. Termination of the zero interest rate policy (July to October 2000)

Finally, let us consider the shifts in the parameter values from July to October 2000 to understand the effects of the termination of the zero interest rate policy on August 11, 2000.

The top panel of Figure 6 illustrates the changes in the shape of the instantaneous forward rate curves before and after the termination of the zero interest rate policy. The upward shift was evident at the very short end of the forward rate curve soon after the termination of the zero interest rate policy, while the instantaneous forward rate curve shifted further upward in the range of two to three months ahead in October.

Figure 6 Simulated Instantaneous Forward Curves (4): Before and After the Termination of the Zero Interest Rate Policy



The middle panel of Figure 6 clearly shows that the initial impact of the termination of the zero interest rate policy on the shape of the forward rate curve was concentrated at the short end. This mainly reflects the increase in the BOJ's target overnight rate from virtually zero to 0.25 percent. At the same time, longer-term interest rates exceeding one year seemed to increase slightly.

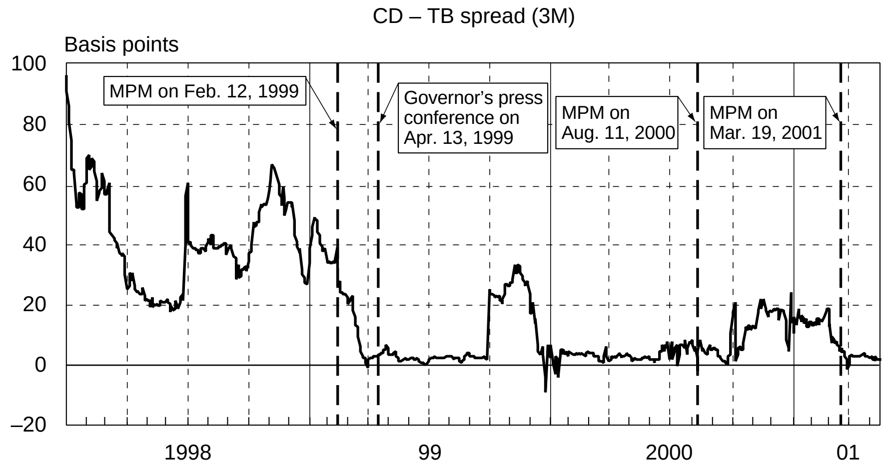
In October, the instantaneous forward rate curve shifted further upward in the range of two to three months ahead, reflecting the increased liquidity demand extending beyond the end of the calendar year due to growing concerns over the introduction of the real-time gross settlement (RTGS) system at the beginning of 2001. However, expectations regarding the continuation of a low interest rate policy itself seemed to have persisted, because we see only a small increase in the instantaneous forward rate around 12 months.

3. Reservations

Let us emphasize again that the inferences regarding the policy duration effect based on the instantaneous forward rate curves are valid only under the assumption that the forward term premium is negligible, or constant. Therefore, if the BOJ's commitment on April 13, 1999 to maintaining the zero rate "until deflationary concerns are dispelled" was somewhat effective in removing the liquidity constraints Japanese banks faced at that time, we might overstate the policy duration effect observed by the changes in forward rate curves.

To understand the effectiveness of the zero interest rate policy and its policy duration effect, it is necessary to investigate the liquidity constraints operating on Japanese banks, if any. Indeed, as shown in Figure 7, the credit spread for financial institutions, measured as the difference between the CD rate and the TB rate in three-month contracts, seems to have declined remarkably soon after the introduction of the zero interest rate policy, indicating a significant reduction in the external

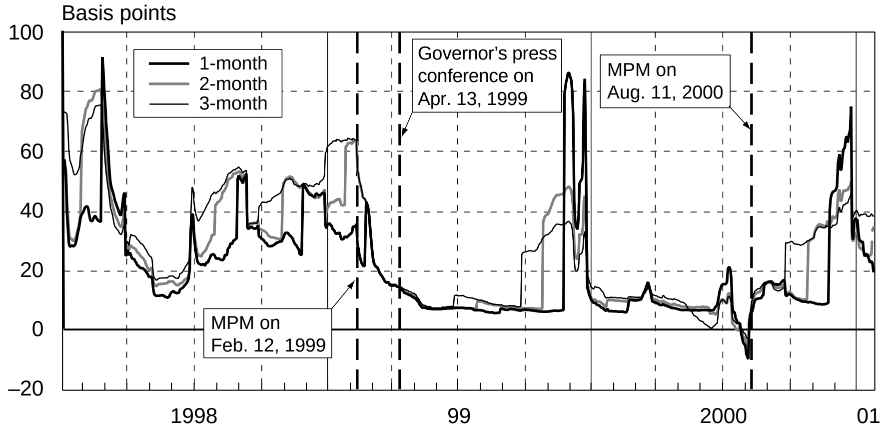
Figure 7 Credit Spread



Sources: Bank of Japan, *Economic and Financial Statistics Monthly*; Bloomberg.

financing premium for financial institutions. At the same time, the term spread, defined as the difference between the term contracts of Japanese yen TIBOR and the average overnight call rate for the corresponding period, seems to have been reduced substantially, as can be seen in Figure 8.

Figure 8 Term Spreads



Sources: Bank of Japan, *Economic and Financial Statistics Monthly*; Bloomberg.

The above casual observations suggest that, during the period before the introduction of the zero interest rate policy in February 1999, Japanese financial institutions as a whole were faced with severe credit constraints, and a significant liquidity event occurred almost every business day. Since financial institutions require continuous money-financing to maintain their investment activities, the liquidity constraint has a negative impact on not only financial market transactions but also loan activities. The next section considers this point empirically in detail.[14]

III. Liquidity Constraints and the Zero Interest Rate Policy

In this section, we examine empirically the effectiveness of the policy duration effect under the zero interest rate policy, by focusing on its impact in the form of mitigating liquidity constraints upon financial institutions.

A. Monetary Easing Effects through Mitigating Liquidity Constraints

As Saito and Shiratsuka (2001) point out, the forecasting power of future interest rates is a good indicator by which to detect the liquidity constraints operating upon financial institutions.

14. In this sense, it cannot be denied that the decline in the term spreads is likely to cause a decline in the estimated value of β_0.

More precisely, Holmström and Tirole (2001) demonstrate that, given the possibility of liquidity constraints in the near future, agents have a stronger incentive to hold short-term bonds to the extent that liquidity demands. Consequently, the price of short-term bonds rises and the short-term return is therefore low relative to the long-term return. In other words, the future possibility of liquidity constraints makes the yield curve rather steeper. This implies that even if agents are risk-neutral, the standard expectations hypothesis of the term structure fails to hold in the presence of liquidity demand, and the term spread at time $t(TS_t)$, defined in the following equation (7), shows a positive value:

$$TS_t = Y_t(n) - CALL_t(n) > 0, \tag{7}$$

where $Y_t(n)$ is the n-period term rate observed at time t, and $CALL_t(n)$ is the average overnight rate from time t to $t + n - 1$.

Equation (7) implies that current term rates tend to overestimate future overnight rates because of strong liquidity demand for shorter-term bonds in preparation for a liquidity event during the period from time t to $t + n - 1$. The more likely liquidity constraints will be binding, the more seriously current yield spreads overestimate future yields. Not only current liquidity constraints but also the future possibility of liquidity constraints may have an important impact on asset pricing through their effect on liquidity demand.[15]

In the following two subsections, we examine the impact of the zero interest rate policy on the term spread in two ways. First, we employ a rolling estimation procedure to estimate the changes in the term spread over the period from 1998 to 2000. Second, we conduct an event study analysis by focusing on the adoption and termination of the zero interest rate policy in February 1999 and August 2000, respectively. In these exercises, the term spread we employ is computed as the difference between the Japanese yen TIBOR for one-, two-, and three-month contracts and the average overnight call rates for their corresponding periods.

B. Impacts on Term Spreads (1): Rolling Regression Analysis

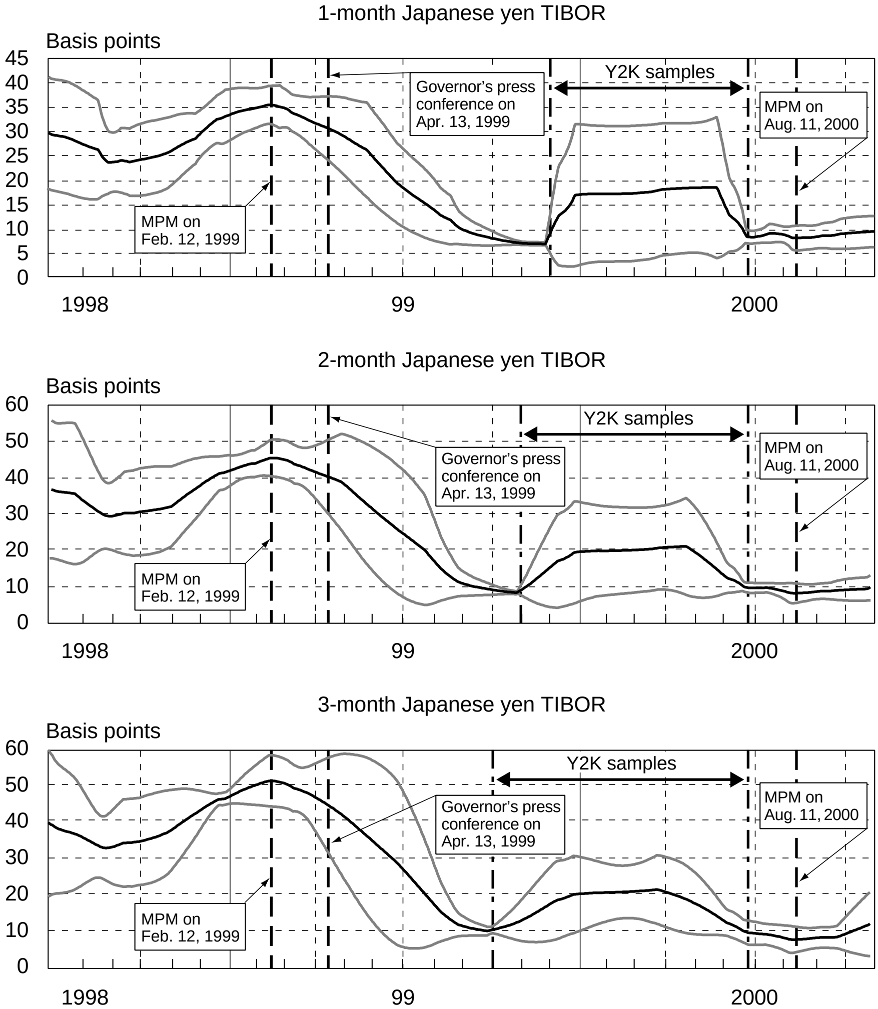
First, we estimated the following equation (8) by using rolling regressions with subsamples of 120 business days:[16]

$$TS_t = \alpha + \varepsilon_t, \tag{8}$$

15. The key assumption in Holmström and Tirole (2001) is a significant liquidity constraint at the time of a liquidity event. This assumption is plausible in a financially stressed situation where most financial institutions are faced with a significant liquidity constraint simultaneously. Under such a circumstance, both market participants' expectations regarding the future course of monetary policy and their concerns over the availability of liquidity might affect the term spread. In our view, it is difficult to identify those two factors separately. Moreover, we do not exclude the possibility that other factors, such as a time-varying risk premium, may reject pure expectation theory.
16. We employ the procedure proposed by Newey and West (1987) with a Bartlett window and a bandwidth of 21, 42, and 63 for one-, two-, and three-month contracts, respectively, to adjust for the heteroskedasticity and autocorrelation of error terms. Bandwidth approximately corresponds to the average number of business days in the subsample periods.

where α, and ε_t denote a constant term and an error term, respectively. Based on this estimation, Figure 9 plots the estimated values of α (solid line) with the upper and lower bounds of the 95 percent confidence interval created by adding and subtracting $t_{0.025}$ times standard error of α (shaded lines). Each date on the horizontal axis denotes the end of the 120 business days used in the above rolling regression.

Figure 9 Rolling Regression Analysis on the Term Premium



Notes: 1. Rolling regressions on the following regression equation are conducted with subsamples of 120 business days ending at each date on the horizontal axis.
2. Shaded lines indicate the upper and lower bounds, respectively, of the confidence interval (estimated coefficients ± $t_{0.025}\cdot$ standard errors). Standard errors are autocorrelation and heteroskedasticity robust estimators using Newey and West's (1987) procedure. Bandwidths are 21, 42, and 63 for one-, two-, and three-month contracts, respectively, which approximately correspond to the average business day in subsample periods.

The figure clearly demonstrates that the term spread declined significantly after the adoption of the zero interest rate policy, especially after Governor Hayami's announcement of the commitment to the zero rate "until deflationary concerns are dispelled" on April 13, 1999. Although the term spread temporarily increased during the subsample periods including December 1999 due to the Y2K problem, it stayed fairly stable even after the termination of the zero interest rate policy on August 11, 2000.

The above result shows that the liquidity constraints operating upon Japanese financial institutions were mitigated substantially by the introduction of the zero interest rate policy. Furthermore, Japanese financial institutions were not faced with serious liquidity constraints after the termination of the zero interest rate policy.

C. Impacts on Term Spreads (2): Case Study Analysis on Policy Changes

Next, we employ a case study analysis to detect the impacts of changes in monetary policy on the term spreads obtained in equation (8).

1. Adoption of the zero interest rate policy

First, we focus on the period before and after the adoption of the zero interest rate policy, and detect the impacts of the policy announcements on February 12 and April 13 on the term spreads for interbank transactions of term instruments.

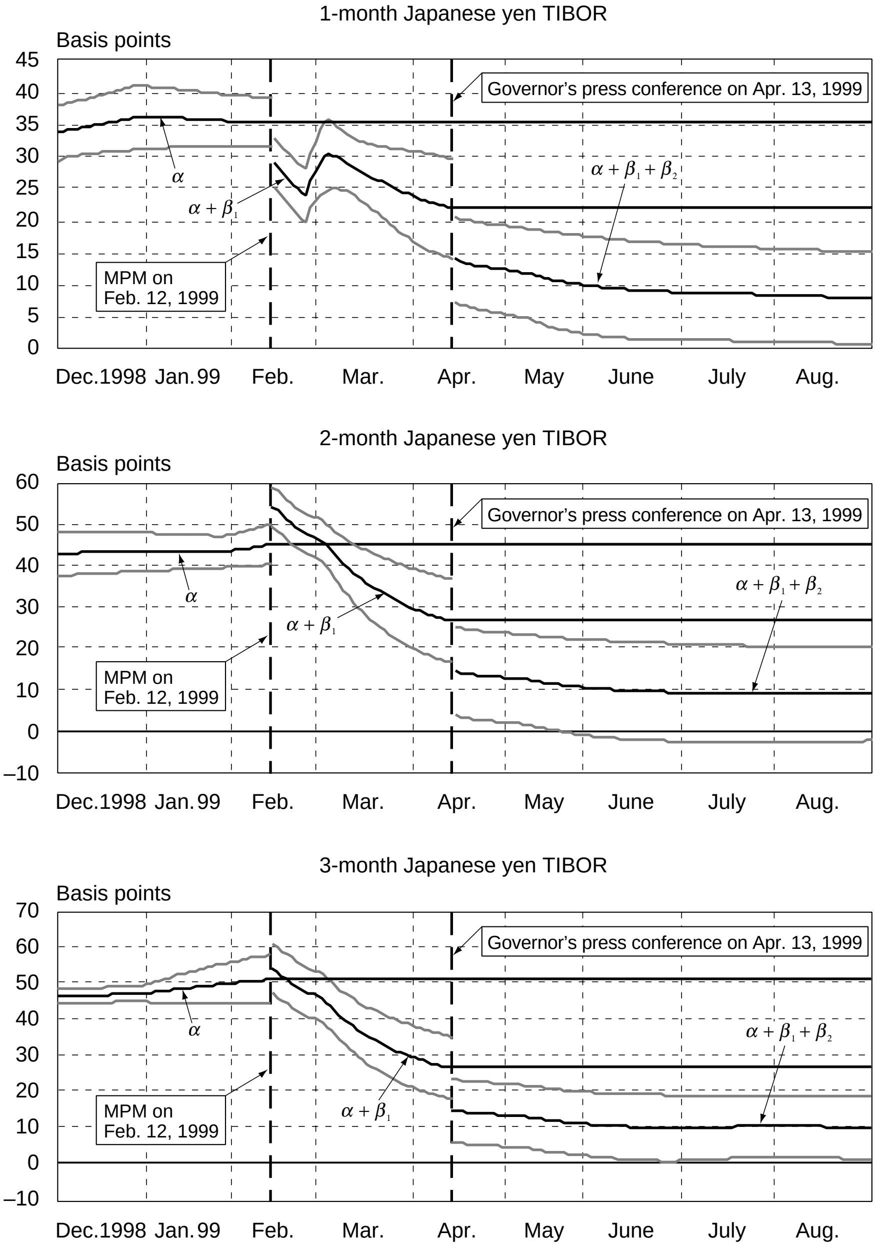
To this end, we estimated the following equation (9) repeatedly by extending the sample period day by day from the initial sample period from August 17 to December 1, 1998, to the final sample period until July 31, 1999:

$$TS_t = \alpha + \beta_1 D1_t + \beta_2 D2_t + \varepsilon_t, \tag{9}$$

where $D1_t$ and $D2_t$ are the dummy variables for the adoption of the zero interest rate policy ($D1_t$ = 0 before and on February 12, 1999, and $D1_t$ = 1 thereafter), and the BOJ governor's announcement ($D2_t$ = 0 before and on April 13, 1999, and $D2_t$ = 1 thereafter), respectively. Figure 10 displays the estimated parameter values for α, β_1, and β_2 with 95 percent confidence intervals for β_1, and β_2 for one, two, and three-month Japanese yen TIBOR.

Observe that in Figure 10, the term premia for two- and three-month contracts declined gradually soon after the adoption of the zero interest rate policy. However, the term premium for the one-month contract increased at the beginning of March, reflecting concerns over the liquidity shortage extending beyond the end of fiscal 1998, i.e., end-March 1999. Furthermore, the figure shows that term premia declined further for all one-, two-, and three-month contracts after Governor Hayami's announcement that the BOJ would commit to the zero rate "until deflationary concerns are dispelled." In this period, the lower bounds of the estimated term premia were close to zero for one- and three-month contracts, and less than zero for two-month contracts, indicating that liquidity concerns on the part of financial institutions were nearly eliminated.

Figure 10 Event Study Analysis on the Term Premium (1): Adoption of the Zero Interest Rate Policy



Note: Shaded lines indicate the upper and lower bounds, respectively, of the confidence interval (estimated coefficients ± $t_{0.025}$ · standard errors). Standard errors are autocorrelation and heteroskedasticity robust estimators using Newey and West's (1987) procedure. Bandwidths are 21, 42, and 63 for one-, two-, and three-month contracts, respectively, which approximately correspond to the average business day in subsample periods.

2. Termination of the zero interest rate policy

Next, we turn to the period before and after the termination of the zero interest rate policy.

For the period before and on August 11, 2000, we repeatedly estimated the following equation (10) by fixing the sample period from February 1 to August 11, 2000, while shortening the period for setting the dummy variable for the termination of the zero interest rate policy ($D3_t$) to one day:

$$TS_t = \alpha + \beta_3 D3_t + \varepsilon_t. \tag{10}$$

Similarly, for the period after August 11, 2000, we estimated the following equation (11) repeatedly by extending the sample period day by day from the initial sample period from February 1 to August 12, 2000, to the final sample period ending on October 31, 2000:

$$TS_t = \alpha + \beta_4 D4_t + \varepsilon_t, \tag{11}$$

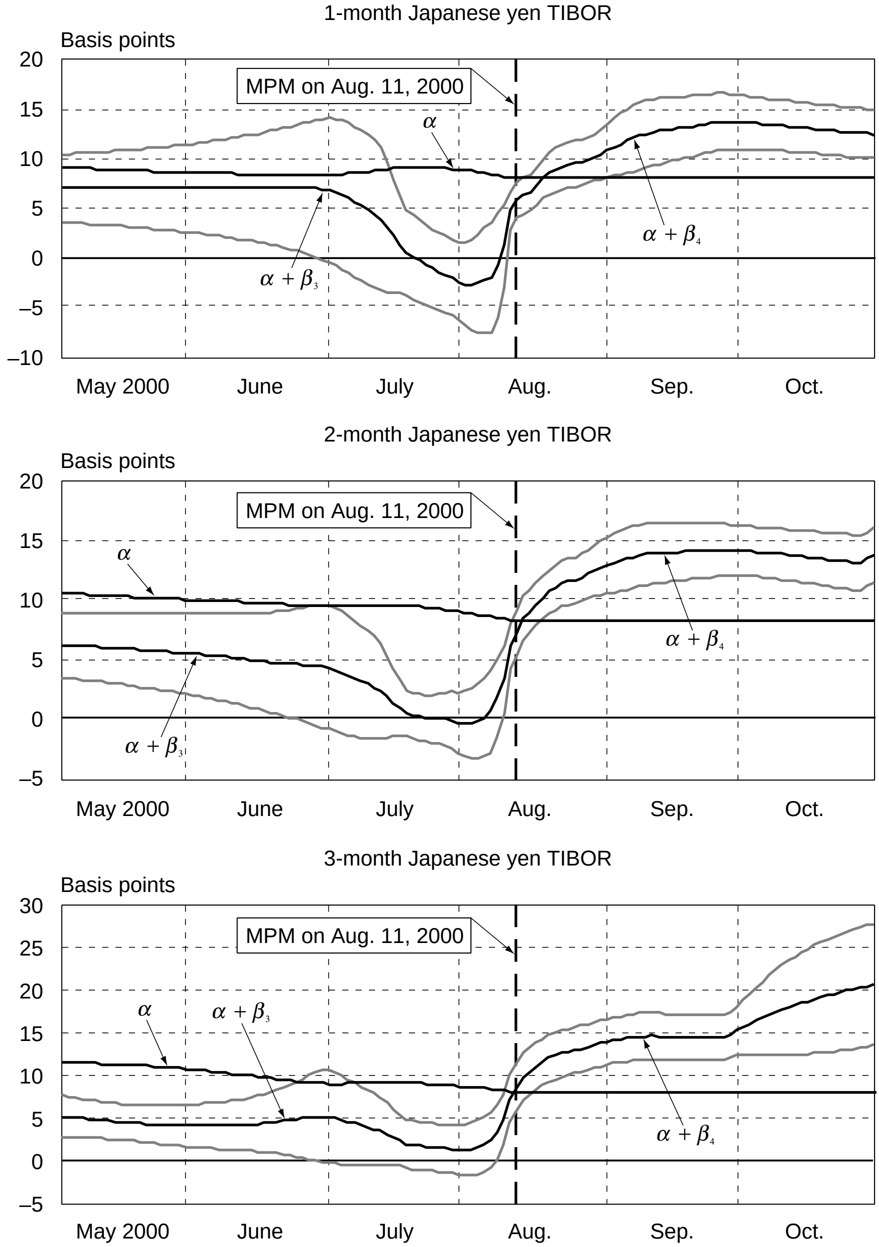
where $D4_t$ is the dummy variable for the termination of the zero interest rate policy ($D4_t = 0$ before and on August 11, 2000, and $D4_t = 1$ thereafter).

Figure 11 summarizes the trends of estimated parameter values and their 95 percent statistical confidence intervals in the same manner as Figure 10. Although the term spread increased slightly after the termination of the zero interest rate policy, it remained low by comparison with the period before February 1999. This implies that liquidity constraints operating upon financial institutions are not so serious as they were during the fragile financial conditions that prevailed shortly before the adoption of the zero interest rate policy.

One may wonder why the term spread declined significantly, and became insignificantly different from zero for all contracts from end-June to mid-August. This was particularly evident for one-month contracts, for which the estimated term spread turned negative from July 19 to August 8. This phenomenon implies that participants in the Japanese interbank market did not definitely expect the termination of the zero interest rate policy until shortly before the MPM on August 11. In retrospect, it cannot be denied that the BOJ's explanation after the MPM on July 17, 2000 appears to have misled market participants into believing that the zero interest rate policy would not be terminated for a considerable period of time.[17]

17. The implied overnight rates extracted from the overnight index swap (OIS), which employ the uncollateralized overnight call rate as the floating rate in the interest rate swap agreement, are also consistent with our view. The implied overnight rates predicted the policy changes on July 17 before the MPM. However, after the decision of no policy change on July 17, the implied overnight rates declined substantially, and did not predict the policy changes on August 11 immediately before the meeting.

Figure 11 Event Study Analysis on the Term Premium (2): Termination of the Zero Interest Rate Policy



Note: Shaded lines indicate the upper and lower bounds, respectively, of the confidence interval (estimated coefficients ± $t_{0.025}$ · standard errors). Standard errors are autocorrelation and heteroskedasticity robust estimators using Newey and West's (1987) procedure. Bandwidths are 21, 42, and 63 for one-, two-, and three-month contracts, respectively, which approximately correspond to the average business day in subsample periods.

IV. Lessons from Japan's Zero Interest Rate Policy of 1999–2000

In this section, we discuss several policy implications extracted from the empirical evidence presented in the preceding sections.

A. Interpretation of the Zero Interest Rate Policy of 1999–2000

As Taylor (2001) points out, it is useful to distinguish between two interpretations of the zero interest rate policy from February 1999 to August 2000. One is to regard the policy as an extension of a conventional monetary policy in which a central bank lowers interest rates as inflation decreases or as the output gap narrows. This emphasizes the role of the central bank's commitment to the zero rate in affecting market expectations regarding the future course of monetary policy actions, and in flattening the yield curve and stabilizing it at a very low level. The other interpretation regards the policy as a kind of emergency measure to deal with the crisis situation in the banking sector since 1997. It pays considerable attention to the impact of providing ample liquidity to the financial system, thus mitigating liquidity constraints on the part of private financial institutions.

Our empirical evidence shown in the previous sections suggests that both effects occurred. However, in our view, the zero interest rate policy is more consistent with the latter interpretation, considering that the easing effects of the zero interest rate policy were limited mainly to mitigating the liquidity constraints at the financial institutions. The latter interpretation, based on Holmström and Tirole (2001), offers various insights regarding the Japanese experience of the zero interest rate policy as an effective measure that can be used to address a liquidity crunch.[18] The large amount of reserves accumulated beyond the legal requirement during the period of the zero interest rate policy might have played a role as collateral as described by Holmström and Tirole (2001) for banks. This view is also consistent with empirical observations of declining term spreads and the so-called Japan premium.[19]

Thus, it is deemed more appropriate to regard the zero interest rate policy in 1999–2000 as a measure to provide ample liquidity at a time of financial crisis. We can also say that it was an extension of the "dual operation" during the period of the financial crises in 1997 and 1998, rather than an extension of conventional monetary policy operations. However, to make an overall evaluation as to whether the zero interest rate policy was successful in coping with the financial crises, we should take

18. Let us recall the role of collateral emphasized by Holmström and Tirole (2001). An essential idea in their paper is that it is very difficult to tax the general public to help financially distressed firms and banks that are hit by an aggregate shock. Therefore, banks and firms try to help themselves by amassing collateral well in advance, which can be reasonably counted on in a distressed situation. In the Japanese interbank market, banks have a strong incentive to hold short-term bonds as liquidity demands when they fear that they will later face a liquidity constraint. Such an incentive must have created a strong demand for short-term assets relative to long-term bonds. In other words, a possibility of future liquidity constraints makes the yield curve rather steeper, or term spreads higher, in the Japanese interbank market.

19. Note that introduction of the zero interest rate policy was not the first time that the BOJ showed strong concerns about the allocation of liquidity over time. For example, the BOJ conducted a "dual operation" during the period of the financial crises in 1997 and 1998. See Saito and Shiratsuka (2001) for their evaluation of the "dual operation" the BOJ employed in 1997–98.

account of complementary policy measures taken during that period, notably the injection of public funds into major Japanese banks.[20] Such a consideration is necessary because restoration of Japan's banking system might not have been achieved merely by supplying ample funds to the banking system.

B. The Role of Commitment to the Zero Interest Rate

The above interpretation of Japan's experience of the zero interest rate policy from February 1999 to August 2000 leads to a different view regarding the role of the central bank's commitment to the zero interest rate.

Since a central bank generally attempts to control a short-term interest rate by guiding market participants' expectations through daily open market operations, the zero interest rate policy is viewed as an extension of conventional monetary policy operations. Reifschneider and Williams (2000), for example, propose an alternative to the Taylor rule in light of the zero bound in nominal interest rates, which maintains the zero rate for a longer period than the Taylor rule indicates. This rule aims to compensate for the central bank's inability to lower the rate below zero by altering the expected future course of monetary policy actions.

However, given that the liquidity effect was the major easing effect under the zero interest rate policy, the interest rate channel was not so important as assumed in Reifschneider and Williams (2000). In practice, a mere 20-basis-point reduction in the overnight call rate *per se* could not be significant. Rather, most of the significant impact on the economy, if any, could have originated from the fact that the commitment amplified the quantitative easing effects to mitigate the deflationary pressures generated by the financial system. Since the zero interest rate cannot be maintained without providing substantial excess reserves, it is effectively a commitment to the future provision of ample liquidity.

Note that the above argument does not mean that the points made by Reifschneider and Williams (2000) are not useful. They tell us that appropriate timing of turning the bias of monetary policy from a very easy stance toward a neutral one should be judged somewhat conservatively compared with the pace of economic recovery. Thus, the BOJ might wish to make some kind of commitment to a specific small but positive target nominal interest rate.

C. The Nature of Adverse Shocks

Our empirical evidence also suggests that the strength of the zero interest rate policy depends crucially on the financial conditions at the time when such a policy measure is employed. Since the initial environment of the economy is not always the same, a zero interest rate policy cannot be guaranteed to have the same effects compared with the BOJ's recent experience.

20. It seems quite difficult to separate the effect of the zero interest rate policy from the injection of public funds into major Japanese banks. Before adopting the zero interest rate policy, several laws to stipulate the basic framework of public funds injection were enacted in October 1998, and the troubled Long-Term Credit Bank of Japan and Nippon Credit Bank were placed under special public administration in October and December 1998, respectively. After adoption of the zero interest rate policy, the injection of public funds of about ¥7.5 trillion in total was approved in March 1999. See Mori, Shiratsuka, and Taguchi (2001) for the detailed chronology of policy response designed to stabilize the financial system.

For example, supposing that a negative shock is large enough to make a target overnight rate negative based on the Taylor rule, what can the central bank do? If the BOJ followed the advice of Reifschneider and Williams (2000), the worse the current economic downturn, the longer may be the period over which nominal short-term interest rates are at zero (Clouse *et al.* [2000]). That is, to deal with an extraordinary negative shock, the central bank might commit to the zero interest rate policy for, say, three to four years.[21]

Furthermore, let us consider a permanent supply shock that reduces the potential growth rate. It is true that the zero interest rate policy reduces the burden of transition to the new steady state by temporarily stimulating aggregate demand, but monetary policy alone cannot push the economy back to the original steady state. In this case, it would be necessary to implement a policy that directly addresses structural impediments.

Note that the discussion in Reifschneider and Williams (2000) assumes that a steady state remains unchanged, and that the impact of an adverse shock gradually decays. This implies that the optimal monetary policy response in their framework should be understood as the most effective way to offset the adverse shocks, given that supplementary policies to address the structural problems directly would be carried out in advance. Thus, a zero interest rate policy should not be regarded as the measure to cope with a permanent productivity shock without structural policy. However, in practice, it is not easy to distinguish the nature of a shock on a real-time basis, given the limited knowledge about the economic structures.

To sum up, the effectiveness of the zero interest rate along with a central bank's commitment will vary depending on the nature of adverse shocks as well as on the then-prevailing conditions. Moreover, such a policy should not be regarded as a panacea that will solve all problems in the economy. We should not, therefore, excessively generalize Japan's experience of the zero interest rate policy from February 1999 to August 2000 to derive lessons for monetary policy formulation. For example, the introduction of a standby lending facility at the official discount rate announced on February 9, 2001 could be used to deal with the potential risks of liquidity shortage in a limited part of the financial system, once the system-wide crisis is over.[22] In some cases, the liquidity provision may not be helpful in enhancing the risk-taking ability of banks, so the BOJ should address itself to formulating a relevant structural policy that makes monetary policy more effective.[23]

21. See Jung, Teranishi, and Watanabe (2001), and Watanabe (2000) for an analysis of the relationship between the magnitude of shocks and the length of commitment to the zero rate.
22. See "Improvements in the Way of Liquidity Provision and Reduction in the Official Discount Rate," available at http://www.boj.or.jp/en/seisaku/01/pb/k010209b.htm for details.
23. See the speech made by Governor Hayami on March 7, 2001, available at http://www.boj.or.jp/en/press/koen066.htm, which express his views on necessary structural reforms in the Japanese economy.

V. Conclusion

In this paper, we have examined the effects of Japan's zero interest rate policy implemented from February 1999 to August 2000 with special emphasis on the "policy duration" effect.

We have shown that a powerful easing effect of the zero interest rate policy along with the future commitment was created as a result of two factors. One factor was the effect on market expectations regarding the future course of monetary policy actions, thereby flattening and stabilizing the yield curve at a very low level. The other was a significant reduction of term spreads achieved by mitigating the liquidity constraints of financial institutions. However, such easing effects were not transmitted outside of the financial system, since the transmission channel linking the financial and nonfinancial sectors remained blocked.

Our empirical evidence is consistent with the interpretation of the zero interest rate policy as a measure to deal with a crisis situation in the Japanese financial system and financial markets since 1997. This interpretation leads to quite different implications from those extracted from the standard interpretation, which regards the policy as an extension of a conventional policy, in which a central bank lowers interest rates as inflation decreases or as the output gap narrows.

As Fujiki, Okina, and Shiratsuka (2001) discuss, given Japan's current economic situation, powerful quantitative easing under the zero interest rate policy would probably leave behind future burdens on fiscal policy.[24] For the sake of making the zero interest rate policy more effective, if it is used again, we need a better understanding of the structural problems in the Japanese economy, and we should identify issues that must be adequately addressed by measures other than the zero interest rate policy.

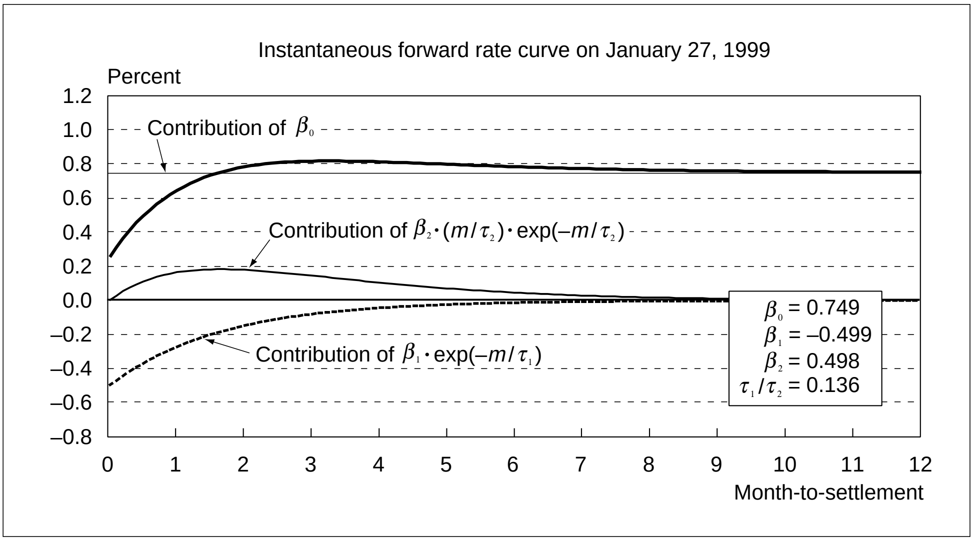
It should be noted that the reservations about the power of the zero interest rate policy we presented in the body of this paper do not mean that the BOJ should do nothing beyond the zero interest rate policy. Rather, we argue that to make monetary policy sufficiently effective to overcome the lower bound of nominal interest rates, we might need to consider a new, tailor-made economic policy package with adequate authority and responsibilities allocated to those concerned.

24. For the effects and costs of the further monetary easing policies, see also Okina (1999) and Oda and Okina (2001).

APPENDIX: ILLUSTRATIONS OF CHANGES IN THE PARAMETERS IN THE GENERALIZED VERSION OF NELSON AND SIEGEL'S (1987) MODEL

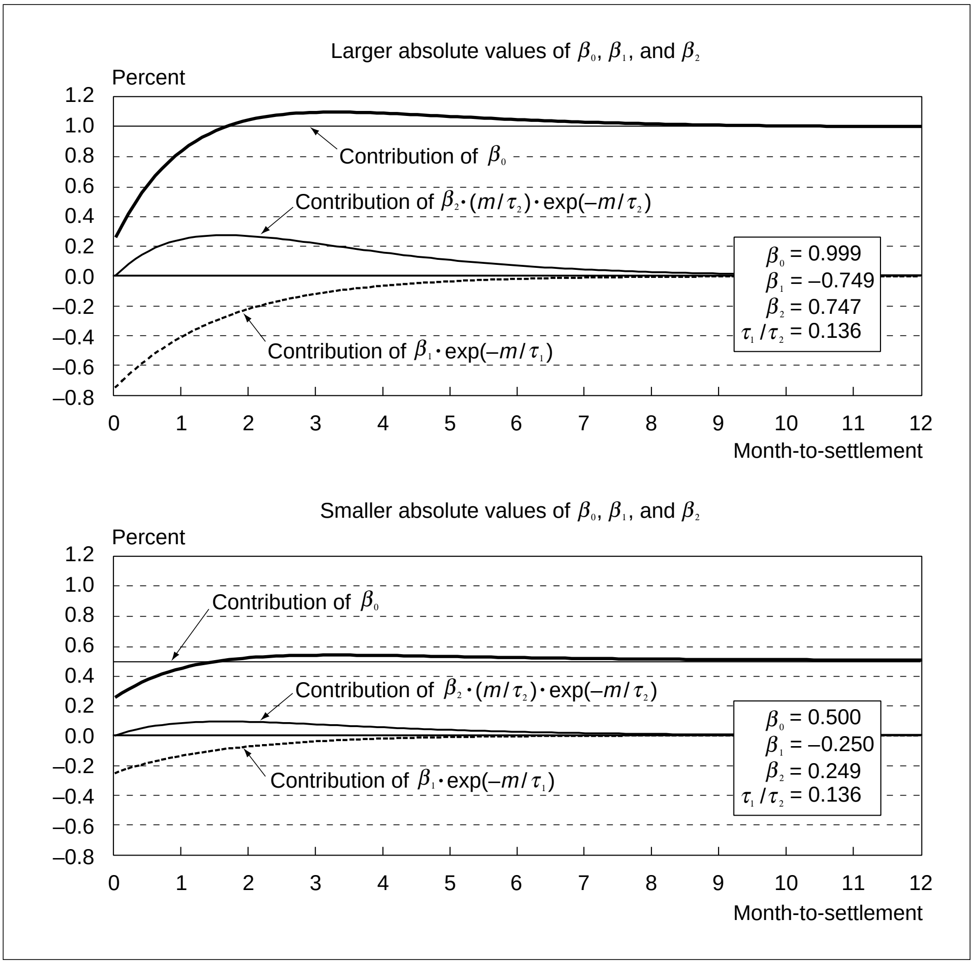
We illustrate the impacts of changes in parameters in the generalized version of Nelson and Siegel's (1987) model by using the example of the estimated forward rate curve on January 27, 1999. The estimates of parameter values are as follows; β_0 = 0.749 (s.e. = 0.011), β_1 = –0.499 (s.e. = 0.011), β_2 = 0.498 (s.e. = 0.011), and $\tau_1 = \tau_2$ = 0.136 (s.e. = 0.026). Appendix Figure 1 decomposes the instantaneous forward rate curve into three components; β_0, $\beta_1 \cdot \exp(-m/\tau_1)$, and $\beta_2 \cdot (-m/\tau_2) \cdot \exp(-m/\tau_2)$. The first component, β_0, is constant over the whole range of time-to-settlement. The second component, $\beta_1 \cdot \exp(-m/\tau_1)$, is an exponential function. Because β_1 is negative, this component is a monotonic increase in m, and this impact decays gradually (quickly) as τ_1 becomes larger (smaller). The third component, $\beta_2 \cdot (-m/\tau_2) \cdot \exp(-m/\tau_2)$, adds a hump shape or U-shape to the instantaneous forward rate curves. This term creates a hump shape when β_2 is positive, while it generates a U-shape when β_2 is negative, thus allowing a non-monotonic increase in the instantaneous forward curve. A large (small) value of τ_2 means that the effects decay more slowly (quickly), and the instantaneous forward rates tend to converge to the long-run interest rate more slowly (quickly).

Appendix Figure 1 Decomposition of Instantaneous Forward Rate Curve



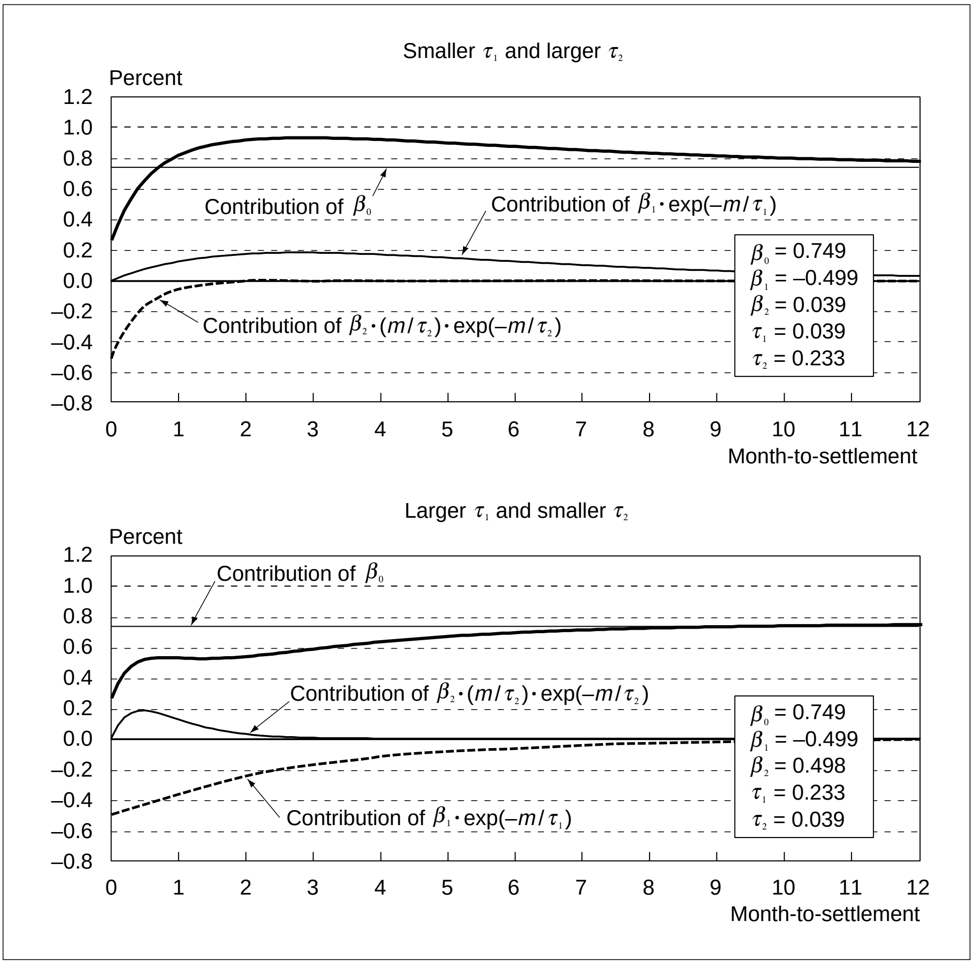
Let us consider the changes that occur in the absolute value of parameters β_0, β_1, and β_2 while keeping the values of τ_1 and τ_2 unchanged, as illustrated in Appendix Figure 2. The top and bottom panels of the figure correspond to the larger and smaller absolute values of parameters β_0, β_1, and β_2, respectively. These panels illustrate the proposition that an increase in the value of β_0 means a parallel upward shift of the instantaneous forward curve, and an increase in the absolute values of β_1 and β_2 amplifies the effects of second and third components. Since the instantaneous forward rate curve is a linear function of these parameters, the effects of the decrease in the absolute value of those parameters on the shape of the instantaneous forward rate curve are symmetric, as long as the signs of both β_1 and β_2 are preserved.

Appendix Figure 2 Impacts of Changes in the Parameter Values (1): β_0, β_1, and β_2



Appendix Figure 3 examines the effects of the changes in the parameter values of τ_1 and τ_2 while holding the values of β_0, β_1, and β_2 unchanged. When the generalized version of the Nelson and Siegel (1987) model is selected, either τ_1 or τ_2 takes a larger value of around 0.2, and the other takes a smaller value of around 0.05. The upper and lower panels of Appendix Figure 3 show the fitted instantaneous forward rate curve for a combination of smaller τ_1 (0.136 $\rightarrow$ 0.039) and larger τ_2 (0.136 $\rightarrow$ 0.233), and that of larger τ_1 and smaller τ_2, respectively. These panels illustrate that a larger (smaller) value of τ_1 makes the upward-sloping gradual (steep), while a larger (smaller) value of τ_2 slows down (speeds up) the convergence of the hump shape when β_2 is positive, as shown in the figure. If β_2 takes a negative value, the third component creates a U-shape, instead of a hump shape, and a larger (smaller) value of τ_2 similarly slows down (speeds up) the convergence of the hump shape.

Appendix Figure 3 Impacts of Changes in the Parameter Values (2): τ_1 and τ_2



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