How the Japanese Government Bond Market Has Responded to the Zero Interest Rate Policy*

Yosuke Takeda and Yasuhide Yajima**

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Abstract

Since February 1999, including a brief intermission, the Bank of Japan has consistently pursued a zero interest rate policy. This paper examines how the Japanese Government Bond (JGB) market—the benchmark indicator of the long-term interest rate—has responded to the zero interest rate policy. We study changes in the JGB market from the perspective of the two goals of the zero interest rate policy—supplying liquidity, and dispelling deflationary concerns.

First, after testing the expectations hypothesis for determination of long-term interest rates, we conduct an empirical analysis of the effect of the zero interest rate policy on the JGB market, focusing on the forward rate. The results are as follows.

1. Overall, the expectations hypothesis holds for the JGB market.

2. At the same time, we confirmed the existence of a liquidity premium over the long term. That is, the term premium is an increasing function of maturity. This means that the liquidity premium hypothesis rejected by Kuroda (1982) has been validated in recent years.

3. During the period of the zero interest rate policy, policy changes toward further easing had the effect of reducing the marginal term premium. In particular, the reinstatement of the zero interest rate policy on March 19, 2001 successfully reduced the marginal premium of government bonds of various maturities by a statistically significant amount. A similar result has been confirmed regarding the BOJ's declared commitment to pursuing the zero interest rate policy (the policy duration effect) by Shiratsuka and

* The authors wish to acknowledge Teruyoshi Suzuki of NLI Research Institute for his assistance in measuring forward rates.
** Y. Takeda is associate professor of economics at Sophia University, and visiting researcher at NLI Research Institute. Y. Yajima is an economist at NLI Research Institute.

Fujiki (2001) in their analysis of money markets.

4. However, as Ueda (2001) points out, after August 14, 2001, when the BOJ decided to increase direct purchases of long-term government bonds, the marginal premium increased, albeit temporarily. This point might suggest that market participants had been anticipating the imminent onset of inflation due to loss of fiscal discipline.

5. Finally, alongside the zero interest rate policy, we must not ignore the effect of JGB credit downgrades on the marginal premium. Moody's downgrades of long-term JGBs have been immediately followed by an increase in the marginal premium. In particular, the Aa2 downgrade on September 8, 2000, and Aa3 downgrade on December 4, 2001 caused statistically significant increases.

From the above empirical results, we assess the zero interest rate policy based on its two goals of supplying liquidity and alleviating deflationary concerns as follows.

1. The zero interest rate policy has been successful in supplying liquidity and thereby offsetting the liquidity premium. In particular, the reinstatement of the zero interest policy was quite effective in this regard.

2. Although the inflation premium cannot be isolated due to the absence of inflation-indexed bonds in Japan (Kitamura, 1997), our findings support Ueda's (2001) concern—that the increase in marginal premium immediately after the BOJ decided to increase direct purchases of long-term JGBs can be construed as an inflation premium. However, the effect of this non-traditional operation is temporary; indeed, we found the effect of the JGB credit downgrading on the premium to be more pronounced. Thus confidence in the central bank—a prerequisite to introducing inflation targeting—is not yet evident in the JGB market.

Introduction

Since February 1999, despite a brief intermission, the Bank of Japan has consistently pursued a zero interest rate policy. This paper examines how the Japanese Government Bond (JGB) market—the benchmark indicator of the long-term interest rate—has responded to the zero interest rate policy. We study changes in the JGB market from the perspective of the two goals of the zero interest rate policy—supplying liquidity, and dispelling deflationary concerns.

Aside from research affiliated with the BOJ, no research has been conducted on the effects of the zero interest rate policy. Shiratsuka and Fujiki (2001) of the BOJ's Institute for Monetary and Economic Studies conducted an empirical analysis of Japanese yen TIBOR data (Tokyo Interbank Offered Rate), and concluded that one component of the zero interest rate policy—the policy duration effect achieved by committing to the zero interest rate policy—flattens the yield curve, and also contributes to reducing the term premium and boosting liquidity. On the other hand, reflecting on the zero interest rate policy overall, Ueda (2001), a member of the BOJ's Policy Board, points out that the quantitative easing move to increase direct purchases of long-term JGBs in August 2001 pushed long-term interest rates upward, and notes that "it is important to recognize this as a risk of purchasing more long-term bonds."

Drawing on the above literature, this paper examines the response of the long-term JGB market (not covered by Shiratsuka and Fujiki, 2001) to monetary policy changes over the entire period of the zero interest rate policy (also not covered)—from the introduction of the zero interest rate policy, to the BOJ's commitment to achieve the policy duration effect, suspension and reinstatement of the policy, and increase in direct purchases of long-term JGBs. The key variable in our analysis is the implied forward rate. Using daily data for each maturity enables us to measure the JGB market's response to changes in the zero interest rate policy on a daily basis.

Part 1 reviews the history of the zero interest rate policy and development of the JGB market. Part 2 discusses the implied forward rate, while Part 3 examines two theories on long-term interest rates, the expectations hypothesis and liquidity premium hypothesis. Part 4 compares specific zero interest rate policy actions against fluctuations in the term premium. Then as pointed out by Ueda (2001), we empirically examine the increase in long-term JGB purchases against fluctuations in the inflation premium. Finally, we present an empirical

analysis of the effect of sovereign credit rating downgrades, which impact not only the JGB market but the wider economy as well.

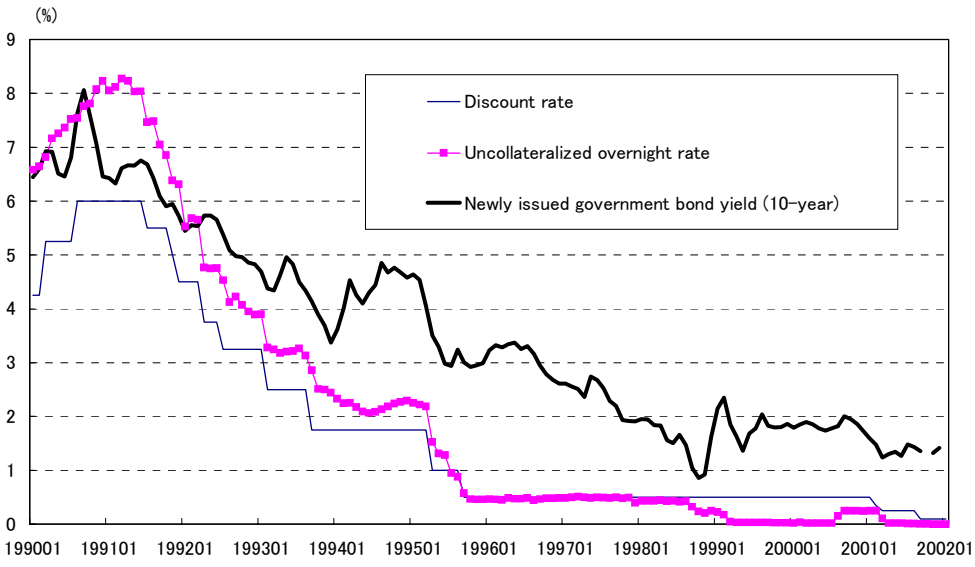
The zero interest rate policy—in practice an inflation targeting policy for a zero inflation rate—represents the BOJ's channel for dialogue with the JGB market, which serves as the "North Star" of the bond market. Our analysis confirms the success of the zero interest rate policy in supplying liquidity (from the perspective of term premium fluctuations), but finds that the inflation premium from the increase in direct purchases of long-term JGBs is temporary in nature. These market reactions demonstrate the central bank's difficulty in gaining market confidence, a prerequisite for the inflation targeting policy now actively being debated (Ito, 2001).

1. History of the Zero Interest Rate Policy and JGB Market Trends

1.1 Introduction of the Zero Interest Rate Policy

Below we briefly describe changes in monetary policy of the late 1990s leading to the zero interest rate policy (Figure 1).

Figure 1 Interest Rate Trends



Source: Bank of Japan

The successive failures of Sanyo Securities, Hokkaido Takushoku Bank, and Yamaichi Securities in November 1997 created a wave of financial insecurity. As a result, liquidity

declined precipitously in the money markets. Sanyo's failure caused an unprecedented default in the call market, triggering a broad-based loss of confidence that led major fund providers such as life insurers and regional banks to restrict funds, thereby reducing the liquidity of the money markets.

This was followed in 1998 by failures of the Long-Term Credit Bank and Nippon Credit Bank, further damaging confidence in the market. Japanese banks were imposed a "Japan premium" by foreign investors. In the domestic money markets, the growing demand for liquidity caused term premiums to rise, while wide disparities appeared in the credit risk of banks.

Monetary easing policies have been pursued ever since the official discount rate was cut from 6% to 5.5% in July 1991. But after being cut from 1.75% to 1% in April 1995, and then to 0.5% in September, little room was left for further discount rate cuts.

According to Ueda (2001), when short-term interest rates are this low, three options are available for further monetary easing. First, if not already at absolute zero, the short-term rate can be brought as close as possible to zero by increasing the monetary base. Second, committing now to continued monetary easing in the future—referred to as the policy duration effect—can shift expectations of the overall economy. Third, the central bank can perform non-traditional operations by purchasing assets other than conventional short-term JGBs—and thereby affect these asset prices.

In practice, given the above domestic conditions, the BOJ has implemented all three options. In February 1999, the zero interest rate was effectively achieved, and two months later in April, the BOJ announced it would retain the zero interest rate policy until deflationary concerns had been dispelled. As for the third option, the BOJ has implemented all available means such as expanding the scope of CP repo operations and adding corporate bonds and asset-backed securities to the list of collateral securities eligible for the BOJ's market operations.

1.2 Suspension of the Zero Interest Rate Policy

In the spring of 1999, Japan's economy began showing signs of recovery. Though initially the result of policy stimuli, a budding recovery emerged led by the corporate sector as economic recovery in Asia and growth in the U.S. caused exports to grow, thereby stimulating production, boosting corporate profits, and encouraging capital investment.

However, views were divided on whether the corporate sector's improvement would spread to the household sector. The BOJ used a dam analogy, arguing that recovery was slower than usual because corporate profits were filling a dam reservoir, but that benefits would eventually flow downstream to the household sector in the form of jobs and income. The government and some private economists countered with a leaky dam analogy, saying that profits would instead be channeled toward restructuring and thus not flow downstream.

Despite opposition from the government, the BOJ ended the zero interest rate policy in August 2000.

1.3 Reinstatement of the Zero Interest Rate Policy and Quantitative Easing

In late 2000, with exports clearly impacted by the U.S. slowdown, Japan's economy deteriorated rapidly. In response, the zero interest policy was reintroduced in February 2001. This was followed in March by a decision to shift the policy target from interest rates (the uncollateralized overnight call rate) to current account balances of financial institutions (reserves held at the BOJ). The initial target level for reserves was set at 5 trillion yen (the average level at the time was 4 trillion yen), and the BOJ announced its intention to conduct open market operations to directly purchase long-term JGBs as necessary, as well as its commitment to pursue these measures until the CPI's year-on-year change (national, excluding fresh foods) stabilized at zero percent or higher.

According to Ueda (2001), although the new policy framework makes the same commitment as the previous one, under the new framework, money market interest rates can rise above zero percent if the demand for liquidity surges.

Entering 2001, the economy took a turn for the worse as the decline in capital investment was accompanied by sluggish consumption due to the deteriorating income and job environment. In August, the target for reserves held at the BOJ was raised to 6 trillion yen, and monthly purchases of long-term JGBs increased from 400 billion yen to 600 billion yen. Moreover, this was followed by successive easing measures. In September, (1) the reserve target was raised to over 6 trillion yen, (2) the official discount rate was cut from 0.15% to 0.10%, and (3) the maximum number of days for supplementary loans was extended. Then in December, (1) the reserve target level was raised further to 10-15 trillion yen, and (2) direct purchases of long-term JGBs were increased.

The important point here is the BOJ's complete turnaround regarding direct purchases of long-term JGBs, which were originally designated as a means of supplying "growth currency"

to meet conventional demand for bank notes. Instead, the BOJ has increased its non-traditional operation of purchasing long-term JGBs from 400 billion yen per month to 600 billion yen (August 14, 2001) and then to 800 billion yen (December 19, 2001). And as of February 2002, the government has been pressing the BOJ to increase this pace to 1 trillion yen per month.

The zero interest rate policy maintains the two goals of supplying liquidity to financial institutions and dispelling deflationary concerns. And as Ueda (2001) says, the three options available in pursuing this policy are to control the monetary base, commit to zero interest rates on a long-term basis, and conduct non-traditional operations. The empirical analysis below examines the success of the zero interest rate policy in meeting its goals by focusing on the supply of liquidity and the inflation premium.

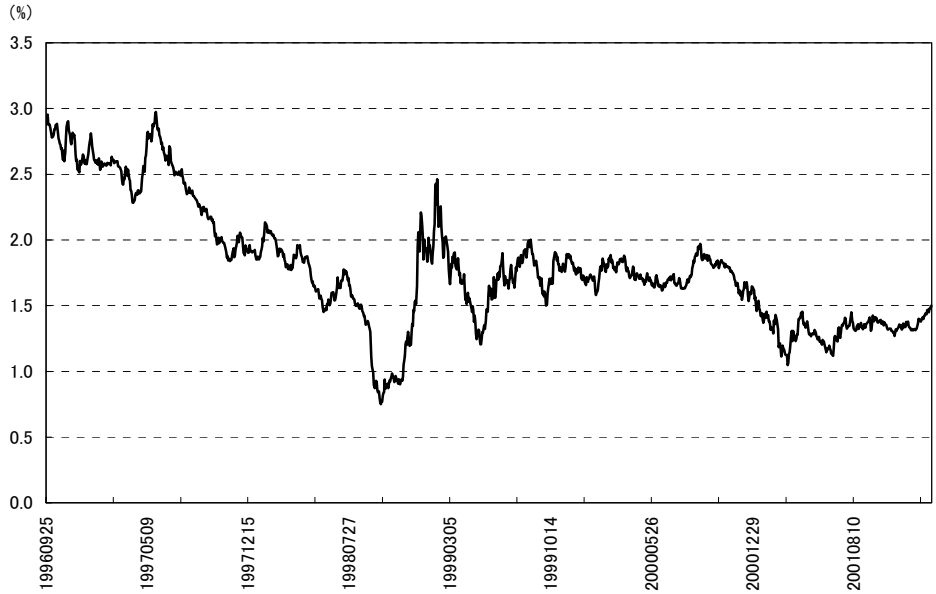
1.4 JGB Market Trends in the Late 1990s

In many countries, the government bond market is an important market comparable in size to the stock market. While the government bond market and the bonds themselves perform many roles including financing government expenditures and determining risk-free interest rates, for market participants and investors, the government bond market is important as a benchmark.

Many measures have been implemented to enhance the efficiency of the government bond market. As Tomita (2001) states, “In the government bond market, a diverse range of participants conduct numerous transactions such that sufficient arbitration occurs. The market interest rates here form the basis for prices in the interest rate futures market and swap market. Indeed, government bond yields are at the core of market interest rates, serving as a North Star to navigate in uncharted seas.” As such, analysis of the government bond market is crucial for revealing the expectations of market participants and investors.

After the collapse of the bubble economy, the long-term interest rate continued to decline, falling below 5% in March 1995 and under 2% in October 1997 (Figure 2). In the second half of 1998, economic uncertainties, growing financial system instability, and the Russian crisis all served to intensify the “flight to quality,” spurring demand for government bonds. Then on October 2, 1998 the long-term interest rate hit an all-time low of 0.740%.

Figure 2 Yield on 10-Year Government Bonds
(OTC Standard Bond Quotations)



Source: Japan Securities Dealers Association

Interest rates later turned upward as a result of emergency economic measures (November 16) and progress in resolving domestic financial problems. In December, when plans for government bond issuance were released and the Trust Fund Bureau announced it would cease government bond purchases, the interest rate surged, reaching 2.5% in February 1999. When the zero interest rate policy was subsequently adopted (February 1999), and the Trust Fund Bureau resumed government bond purchases, the long-term interest rate declined and stayed in the mid 1% range.

In 1999, under the zero interest rate policy, the long-term rate fell to 1.2% in mid May. With expectations of economic recovery and renewed concerns about an excess supply of government bonds, the long-term rate rose to around 1.8% by late August. During this time, the release of a series of upbeat GDP numbers helped spur speculation that the zero interest policy would be suspended.

In September, as the yen's surge dampened market expectations for economic recovery and lifting of the zero interest rate policy, the long-term rate again fell to 1.7%. Then due to rising business sentiment, speculation about lifting the zero interest policy, concerns about deteriorating bond market conditions, and credit downgrading of government bonds, the long-term rate fluctuated mainly in the range of 1.6% to 1.9%.

However, the long-term rate resumed its decline from the autumn of 2000. Due to weak stock markets in Japan and abroad, a plunge in business sentiment, and the market's

unenthusiastic response to new bond issues, the long-term rate continued to decline, reaching around 1.4% in February 2001. With the resumption of the zero interest rate policy, the long-term rate temporarily dropped to 1.0%, but ended the period in the mid 1.3% range due to profit taking.

In fiscal 2001, concerns about the deteriorating government bond market resurfaced and briefly pushed the long-term rate to 1.5%. In June, these concerns diminished amid expectations for the Koizumi administration's fiscal structural reform program, and the long-term rate declined to 1.1%. From August, despite further monetary easing, the long-term rate headed toward 1.5% at yearend due to downgrades of Japan's sovereign credit rating and disappointment over Koizumi's structural reforms (Figure 3).

Figure 3　History of JGB Credit Ratings

		Moody's	S&P
Before:	1998/11/16	Aaa	AAA
	1998/11/17	Aaa→Aa1	
	2000/09/08	Aa1→Aa2	
	2001/02/23		AAA→AA+
	2001/11/28		AA+→AA
	2001/12/04	Aa2→Aa3	

Sources: Moody's, S&P

2. Measurement of the Implied Forward Rate

The forward rate refers to the future spot rate as predicted from the term structure of interest rates. Since the forward rate contains valuable information regarding the market's prediction of the future long-term interest rate, it is carefully followed by monetary policymakers (Saito, 2000; Buttiglione, Del Giovane and Tristani, 1996; Soderlind and Svensson, 1997).

However, a difficulty arises in that the pure expectations hypothesis does not necessarily hold, so that the forward rate does not coincide with the future spot rate. Soderlind and Svensson (1997) attribute the divergence to the term premium. At time *t*, the market's predicted spot rate for term $(T-\tau)$ at time τ in the future is $E_t i(\tau, T)$, defined as

$$E_t i(\tau,T) = f(t,\tau,T) - \varphi^f(t,\tau,T)$$

Here, $f(t,\tau,T)$ is the forward rate, and $\varphi^f(t,\tau,T)$ represents the term premium.

Given nominal interest rate $i(\tau,T)$, real interest rate $r(\tau,T)$, and inflation rate $\pi(\tau,T)$, the expected inflation rate $E_t\pi(\tau,T)$ is defined as

$$E_t\pi(\tau,T) = E_t i(\tau,T) - E_t r(\tau,T) - \varphi^\pi(t,\tau,T)$$

Here, $\varphi^\pi(t,\tau,T)$ represents the inflation premium.

After eliminating $E_t i(\tau,T)$ from the above two equations, we have

$$f(t,\tau,T) = E_t\pi(\tau,T) + g(t,\tau,T) + \left[\varphi^f(t,\tau,T) - \varphi^g(t,\tau,T)\right] + \varphi^\pi(t,\tau,T)$$

The forward rate can thus be defined as consisting of a component determined by the real forward rate and expected inflation rate, to which the term premium and inflation premium are added. Here, $g(t,\tau,T)$ is the real forward rate, and $\varphi^g(t,\tau,T)$ is the real term premium.

In this paper, we estimate the forward rate directly from the market rate, and analyze the effects of the term premium and inflation premium in determining the forward rate. For estimation of the long-term interest rate, we use the Houglet method.[1] While the Houglet method uses a more complex nonlinear equation, it differs from most other estimation methods in that rather than estimating the spot rate, it estimates the forward rate directly.

The analysis below uses 1-year implied forward rates ($T-\tau=1$) estimated with the Houglet method. As for the data, we used closing prices of the Tokyo Stock exchange and standard quotations from the OTC market.

3. Expectations Hypothesis and the Term Premium

[1] See Appendix A for a description of the Houglet method.

In this section, we briefly describe various hypotheses in the current literature regarding determining factors for long-term interest rates, and then test each hypothesis using our measured forward rates. The term premium is zero under the pure expectations hypothesis, and does not exist at time t under the expectations hypothesis. In addition, we can determine whether the liquidity premium arises depending on whether the term premium is an increasing or decreasing function of maturity (McCulloch and Kochin, 2000).

3.1 Expectations Hypothesis and the Time-Varying Term Premium

Based on our definition of the forward rate, for 1-year instruments ($T-\tau=1$) with maturity $m=T-t$、the term premium at time t can be expressed as follows.

$$\varphi^{f}(t,\tau,T)=f(t,\tau,T)-E_t i(\tau,T)$$

According the pure expectations hypothesis, the leading hypothesis on determination of long-term interest rates, the term premium is zero, such that

$$f(t,\tau,T)=E_t i(\tau,T)$$

Let us now consider as a variable the first difference of the forward rate at time (t).

$$\begin{aligned} f(t+\Delta t,\tau,T)-f(t,\tau,T) &= E_{t+\Delta t} i(\tau,T)-E_t i(\tau,T) \\ &= E_{t+\Delta t} i(\tau,T)-E_t\{E_{t+\Delta t} i(\tau,T)\} \\ &\equiv \varepsilon_t(\tau,T) \end{aligned}$$

The final term $\varepsilon_t(\tau,T)$ expresses the predicted error at present of the expected value of the future spot rate, according to the Law of Iterated Expectations, and represents white noise. Thus according to the pure expectations hypothesis, the forward rate conforms with the Martingale process.

In addition, under the expectations hypothesis, the term premium is time-invariant and a function of only maturity $m=T-t$.

$$\varphi^{f}(t,\tau,T)\equiv\varphi^{f}(m)=f(t,\tau,T)-E_t i(\tau,T)$$

According to the Law of Iterated Expectations, the first difference of the forward rate can be

expressed as follows.

$$
\begin{aligned}
f(t+\Delta t,\tau,T)-f(t,\tau,T) &= \varphi^f(t+\Delta t,\tau,T)-\varphi^f(t,\tau,T)+E_{t+\Delta t}i(\tau,T)-E_t i(\tau,T) \\
&= \varphi^f(t+\Delta t,\tau,T)-\varphi^f(t,\tau,T)+E_{t+\Delta t}i(\tau,T)-E_t\{E_{t+\Delta t}i(\tau,T)\} \\
&= \varphi^f(m-\Delta t)-\varphi^f(m)+\varepsilon_t(\tau,T) \\
&= -\{\varphi^f(m)-\varphi^f(m-\Delta t)\}+\varepsilon_t(\tau,T)
\end{aligned}
$$

The right side is equivalent to the marginal change in term premium (marginal term premium) plus the prediction error (white noise). If the term premium is time-invariant and a function of maturity (m), then as with the pure expectations hypothesis, this equation states that the forward rate conforms with the Martingale process.

$$
f(t+\Delta t,m)-f(t,m)=\varepsilon_t(m)
$$

To test whether the forward rate conforms with the Martingale process, we performed a unit root test (Campbell, Lo and MacKinlay, 1997). For this, we used a Phillips-Perron type unit root test, which takes into consideration serial correlation of error terms. Since the marginal term premium may be a function of maturity, we consider three cases: intercept term only, trend and intercept, and neither. We selected eleven different estimation periods prior to December 28, 2001, which are identified by their starting date: February 24, 1993 (rising interest rate phase due to comprehensive economic policies), January 7, 1994 (rising interest rate phase due to reports of open market sales by the Trust Fund Bureau), October 4, 1995 (rising interest rate phase due to prediction of interest rate hikes), April 7, 1997 (rising interest rate phase due to concerns that downward guidance of interest rates would end), October 2, 1998 (rising interest phase due to the so-called Trust Fund Bureau shock), February 12, 1999 (introduction of zero interest rate policy), April 13, 1999 (policy duration effect from the commitment to maintaining a zero interest rate policy), August 11, 2000 (suspension of zero interest rate policy), March 19, 2001 (reinstatement of zero interest rate policy), August 14, 2001 (quantitative easing: increase reserves at BOJ to six trillion yen, and increase monthly purchases of long-term JGBs from 400 million yen to 600 million yen), and September 18, 2001 (quantitative easing: increase reserves at BOJ to above six trillion yen, and cut official discount rate).[2] Unit root test results for forward rate levels are shown by

[2] Takada and Sumitomo (2001) define five rising interest rate phases as follows: February 24, 1993 to May 24, 1994, characterized by the comprehensive economic policies; January 7, 1994 to August 10, 1994, characterized by the report of open market sales by the Trust Fund Bureau, and recovery in business sentiment; October 4, 1995 to February 26, 1996, characterized by the strong yen, rising stock market, and prediction of interest rate hikes; April 7, 1997 to May 28, 1997, characterized by concerns that efforts to guide interest rates lower would end; October 2, 1998 to February 5, 1999, characterized by the so-called Trust Fund Bureau shock.

maturity in Figure 7 (see Appendix B).

In many cases, the null hypothesis that the forward rate conforms to a nonstationary process is not rejected. For no maturity is the null hypothesis rejected at a 10% significance level in all three cases—intercept, trend and intercept, and neither. However, for the October 2, 1998 period in particular, the existence of a unit root is rejected in some cases for maturities of five years or more. Moreover, in the unit root test results for the first difference of the forward rate, the null hypothesis is rejected at a 1% significance level in all cases (Figure 8, at end of paper).

Thus the condition of a time-invariant term premium—necessary for the expectations hypothesis—holds overall. However, this result is not necessarily robust for the sample period. The possibility of a time-varying term premium cannot be rejected. The unit root test results for the first difference of the forward rate shows that the marginal term premium conforms to a stationary process. In what follows, while considering the possibility of a stationary, time-varying term premium, we examine whether the term premium is an increasing or decreasing function of maturity by looking at different periods.

3.2 Average Marginal Term Premium and the Liquidity Premium Hypothesis

Below we examine whether the term premium is an increasing function of maturity, decreasing function of maturity, or neither. On average, if the first difference of the forward rate is positive (or negative), we can determine that the term premium is a decreasing (or increasing) function of maturity (McCulloch and Kochin, 2000).

According to Kuroda's (1982, 1988) seminal research on Japan's interest rate term structure, three theories compete with the expectations hypothesis on the determination of long-term interest rates: (1) liquidity premium hypothesis, (2) segmented markets hypothesis, and (3) preferred habitat hypothesis. It is important to ensure that these are not nested hypotheses; that is, that they do not contradict each other. Even if the unit root test results support the expectations hypothesis, this does not necessarily mean that these other hypotheses can be rejected.

One reason cited for the existence of the preferred habitat is the income gain principle of insurance companies. Under article 86 of the old Insurance Business Law, insurance companies must set aside one-time capital gains in a reserve to prepare against asset price declines in the future, and must pay ordinary dividends out of current interest and dividend income. Thus insurance companies preferred to invest in bonds with high coupon rates.

However, with financial deregulation and the adoption of more advanced investment methods, it became more difficult to distinguish capital gains from income gains. In the 1996 revision of the law, the reserve was reconstituted as a reserve for market risk, and the income distribution principle was reviewed. Furthermore, as mark to market accounting became prevalent, the preferred habitat has given way to an emphasis on final yield and compound interest. This explains why the preference for high coupon rates has disappeared.[3]

Thus for our purposes, only the first two hypotheses need to be tested. The segmented markets hypothesis predicts that the term premium is independent of maturity, while the liquidity premium hypothesis predicts that the term premium is an increasing function of maturity.

Below we consider several methods for selecting sample periods in light of the structural changes in the JGB market, and calculate sample averages of the first difference of the forward rate. If the equation above holds, the average of the first difference of the forward rate will be equivalent to the negative of the average marginal term premium. Figure 4 shows the results of average first difference of forward rates for nine sample periods.

For the February 24, 1993 period, which has the largest sample size, the sample average is negative for all maturities. Averages are also negative for the sample periods starting on January 7, 1994, October 4, 1995, and April 7, 1997. From these results, the overall average term premium appears to be an increasing function of maturity. That is, with regard to the determination of interest rates in the JGB market over the long term, the results support the liquidity premium hypothesis.

However, shortening the sample periods can produce positive term premium averages for certain maturities. Specifically, the term premium is a declining function of maturity—in other words, a solidity premium (McCulloch and Kochin, 2000)—in maturities of three or more years for the October 2, 1998 sample period, seven or eight years for the April 13, 1999 period, eight or nine years for the August 11, 2000 period, and at least one year for the March 19, 2001 period.

With regard to samples after the zero interest rate policy took effect on February 12, 1999, we found that the liquidity premium is a uniformly increasing function of maturity. However, as the zero interest rate policy was continued, then cancelled and resumed, and as large

[3] Okina (1990) points out that the preference for income gains among life insurers was already waning in the 1980s, prior to revision of the Insurance Business Law. This was because under article 86 of the old law, from September 1985, capital gains from a designated money trust scheme could be converted to income gains, while variable insurance sold from November 1986 was not subject to article 86.

infusions of liquidity were made to prevent financial failures, the liquidity premium of some matured government bonds declined. This point is analyzed in the next section, which looks not at sample averages, but at the first difference of the forward rate in the vicinity of policy action dates.

Figure 4　Forward Rate by Term (Average First Difference)

Average from:	0	1	2	3	4	5	6	7	8	9	10
1993/2/24	−0.000014	−0.000014	−0.000014	−0.000014	−0.000015	−0.000015	−0.000013	−0.000011	−0.000008	−0.000010	−0.000016
1994/1/7	−0.000008	−0.000008	−0.000009	−0.000010	−0.000010	−0.000014	−0.000016	−0.000012	−0.000008	−0.000009	−0.000013
1995/10/4	−0.000002	−0.000004	−0.000007	−0.000013	−0.000017	−0.000017	−0.000014	−0.000009	−0.000007	−0.000007	−0.000009
1997/4/7	−0.000004	−0.000006	−0.000009	−0.000012	−0.000013	−0.000011	−0.000010	−0.000007	−0.000005	−0.000005	−0.000009
1998/10/2	−0.000004	−0.000004	−0.000002	0.000000	0.000004	0.000010	0.000016	0.000021	0.000021	0.000017	0.000014
1999/2/12	−0.000005	−0.000010	−0.000015	−0.000017	−0.000017	−0.000016	−0.000014	−0.000009	−0.000006	−0.000015	−0.000024
1999/4/13	−0.000002	−0.000003	−0.000005	−0.000007	−0.000008	−0.000007	−0.000005	0.000000	0.000002	−0.000006	−0.000014
2000/8/11	−0.000008	−0.000014	−0.000018	−0.000020	−0.000020	−0.000016	−0.000011	−0.000002	0.000007	0.000002	−0.000006
2001/3/19	−0.000001	0.000003	0.000006	0.000001	0.000001	0.000014	0.000022	0.000026	0.000029	0.000029	0.000035

Notes: All forward rates are 1-year interest rates. Term refers to the start date of the forward rate. Term 0 refers to the spot rate. The forward rate first difference F(t+1) - F(t) is daily.

4. Zero Interest Rate Policy and the Liquidity Premium

To see how the JGB market has responded to the zero interest rate policy from its inception to suspension and reinstatement, we look at changes in the liquidity premium, as seen in the term premium.

4.1 Fluctuations Around Policy Action Dates

We focus on six key policy action dates: (1) initiation of the zero interest rate policy on February 12, 1999, (2) commitment to maintaining the zero interest rate policy on April 13, 1999, (3) suspension of the zero interest rate policy on August 11, 2000, (4) resumption of the policy on March 19, 2001, (5) increase in monthly purchases of long-term JGBs from 400 million yen to 600 million yen on August 14, 2001, and (6) extension of the maximum Lombard style loan period from five business days to ten on September 18, 2001.

Figure 5 shows the average first differences of the forward rate for the ten (or twenty) business days before and after policy action dates. We test the null hypothesis that averages for the ten days (or twenty days) before and after the policy actions are the same.

Figure 5　Forward Rate Before and After Policy Change (First Difference)

		0	1	2	3	4	5	6	7	8	9	10
02/12/99	(Business days)											
	10 days before	−0.000035	0.000012	0.000058	0.000062	0.000104	0.000152	0.000222	0.000461	0.000452	0.000316	0.000215
	10 days after	−0.000179	−0.000349	−0.000407	−0.000265	−0.000105	−0.000109	−0.000128	−0.000153	−0.000105	−0.000109	−0.000203
	Difference	0.000144	0.000361 *	0.000465	0.000326	0.000210	0.000261	0.000349	0.000614	0.000558	0.000425	0.000418
04/13/99												
	10 days before	−0.000017	−0.000031	−0.000093	−0.000155	−0.000226	−0.000357	−0.000476	−0.000508	−0.000376	−0.000400	−0.000455
	10 days after	−0.000056	−0.000164	−0.000269	−0.000280	−0.000232	−0.000232	−0.000235	−0.000190	−0.000130	−0.000077	−0.000061
	Difference	0.000040 *	0.000133 *	0.000176	0.000125	0.000007	−0.000125	−0.000241	−0.000319	−0.000247	−0.000324	−0.000395
08/11/00												
	10 days before	0.000078	0.000099	0.000072	−0.000002	−0.000027	0.000033	0.000064	0.000033	0.000005	−0.000040	−0.000135
	10 days after	0.000106	0.000100	0.000127	0.000188	0.000231	0.000248	0.000212	0.000094	0.000076	0.000281	0.000333
	Difference	−0.000029	0.000000	−0.000055	−0.000190 *	−0.000257 *	−0.000215 *	−0.000147	−0.000060	−0.000071	−0.000321 *	−0.000468 *
03/19/01												
	10 days before	−0.000077	−0.000091	−0.000108	−0.000129	−0.000126	−0.000088	−0.000033	−0.000004	0.000014	0.000081	0.000148
	10 days after	0.000014	0.000126	0.000213	0.000147	0.000114	0.000202	0.000208	0.000160	0.000145	0.000275	0.000488
	Difference	−0.000091 *	−0.000217 *	−0.000321 *	−0.000276	−0.000240	−0.000290	−0.000241	−0.000164	−0.000131	−0.000194	−0.000340
08/14/01												
	10 days before	0.000017	−0.000003	−0.000036	−0.000048	−0.000056	−0.000072	−0.000036	0.000069	0.000062	0.000020	0.000028
	10 days after	−0.000008	0.000013	0.000088	0.000156	0.000134	0.000092	0.000060	−0.000021	−0.000023	0.000068	0.000075
	Difference	0.000025	−0.000016	−0.000124	−0.000204	−0.000190	−0.000165	−0.000096	0.000089	0.000085	−0.000048	−0.000047
09/18/01												
	10 days before	−0.000013	−0.000061	−0.000150	−0.000186	−0.000166	−0.000124	−0.000003	0.000144	0.000143	0.000004	−0.000045
	10 days after	0.000011	0.000039	0.000050	0.000040	0.000053	0.000057	0.000020	−0.000033	−0.000028	0.000062	0.000113
	Difference	−0.000024 *	−0.000100 *	−0.000200 *	−0.000226 *	−0.000219	−0.000182	−0.000023	0.000177	0.000171	−0.000058	−0.000159
02/12/99												
	20 days before	−0.000035	−0.000005	0.000051	0.000071	0.000083	0.000100	0.000156	0.000288	0.000343	0.000308	0.000235
	20 days after	−0.000110	−0.000220	−0.000302	−0.000272	−0.000194	−0.000138	−0.000079	−0.000121	−0.000115	−0.000058	−0.000147
	Difference	0.000075	0.000215	0.000353 *	0.000343	0.000278	0.000238	0.000235	0.000409	0.000458 *	0.000365	0.000382
04/13/99												
	20 days before	−0.000026	−0.000044	−0.000094	−0.000139	−0.000181	−0.000239	−0.000259	−0.000226	−0.000181	−0.000284	−0.000298
	20 days after	−0.000054	−0.000141	−0.000214	−0.000228	−0.000203	−0.000206	−0.000240	−0.000192	−0.000135	−0.000196	−0.000253
	Difference	0.000027	0.000096	0.000120	0.000089	0.000022	−0.000033	−0.000019	−0.000034	−0.000046	−0.000088	−0.000044
08/11/00												
	20 days before	0.000006	−0.000008	−0.000025	−0.000044	−0.000052	−0.000048	−0.000035	0.000009	0.000026	−0.000006	−0.000093
	20 days after	0.000058	0.000049	0.000051	0.000094	0.000135	0.000108	0.000086	0.000056	0.000046	0.000119	0.000089
	Difference	−0.000052	−0.000057	−0.000076	−0.000138 *	−0.000187 *	−0.000156	−0.000122	−0.000047	−0.000020	−0.000125	−0.000181
03/19/01												
	20 days before	−0.000095	−0.000125	−0.000157	−0.000145	−0.000120	−0.000119	−0.000105	−0.000118	−0.000095	−0.000096	−0.000134
	20 days after	−0.000004	0.000044	0.000105	0.000114	0.000149	0.000228	0.000235	0.000199	0.000194	0.000296	0.000436
	Difference	−0.000091 *	−0.000169 *	−0.000261 *	−0.000259 *	−0.000269 *	−0.000347 *	−0.000340 *	−0.000317 *	−0.000289	−0.000392	−0.000570 *
08/14/01												
	20 days before	0.000014	0.000009	−0.000014	−0.000026	−0.000020	−0.000029	0.000007	0.000079	0.000066	0.000014	−0.000014
	20 days after	−0.000009	−0.000004	0.000045	0.000102	0.000121	0.000135	0.000121	0.000024	−0.000022	0.000033	0.000054
	Difference	0.000023 *	0.000013	−0.000059	−0.000128	−0.000141	−0.000164	−0.000114	0.000055	0.000088	−0.000019	−0.000068
09/18/01												
	20 days before	−0.000007	−0.000021	−0.000037	−0.000028	−0.000010	0.000007	0.000038	0.000025	−0.000026	−0.000041	−0.000027
	20 days after	0.000006	0.000030	0.000045	0.000020	−0.000002	−0.000020	−0.000028	−0.000032	−0.000002	0.000054	0.000093
	Difference	−0.000013 *	−0.000051 *	−0.000082	−0.000048	−0.000008	0.000027	0.000066	0.000057	−0.000023	−0.000095	−0.000120

Notes:　Shows average forward rate spread (F(t+1)-F(t)).
　　* Indicates rejection of null hypothesis at 10% critical value.

Overall, the zero interest rate policy actions—including its suspension—have been successful in reducing the liquidity premium. A typical example is the reinstatement of the zero interest rate policy on March 19, 2001. The marginal term premium, which was negative in the 20-day period before this date for all maturities, turned positive in the period after with the exception of the spot rate. In other words, the reinstatement caused the term premium to switch from being an increasing function of maturity to a decreasing function. The same change is seen regarding the suspension of the policy.

4.2 Effect of Increased Purchases of Long-term JGBs

However, with regard to the increase in long-term JGB purchases on August 14, 2001 and subsequent policy actions, one effect cannot be ignored. For the 10-day and 20-day periods before August 14, we found a negative marginal term premium for maturities of at least six years, but did confirm a liquidity premium overall. Prior to this date, we found a decline in the liquidity premium after the policy shift toward quantitative easing. However, while not statistically significant, the premium increases in the 10-day averages for seven and eight year maturities, and in the 20-day averages for the eight-year maturity. Similarly, with the further quantitative easing on September 18, the premium rose for seven and eight-year maturities in the 10-day averages, and for four to eight year maturities in the 20-day averages.

As pointed out by Ueda (2001), some zero interest rate policy effects cannot be accounted for by fluctuations in the liquidity premium. The market may have predicted that BOJ purchases of long-term JGBs would lead to loss of fiscal discipline, thus fermenting inflationary expectations. In other words, this implies that the BOJ will need to take into account fluctuations in the inflation premium in addition to the term premium.

5. Inflation Premium

Below we add the inflation premium $\varphi^{\pi}(t,\tau,T)$ to our expression of the forward rate.

$$f(t,\tau,T) = E_t\pi(\tau,T) + g(t,\tau,T) + \left[\varphi^{f}(t,\tau,T) - \varphi^{g}(t,\tau,T)\right] + \varphi^{\pi}(t,\tau,T)$$

In countries with inflation-indexed bonds such as the U.S. and U.K., real bonds exist alongside nominal bonds, making it technically possible to extract the expected inflation rate and inflation premium (Soderlind and Svensson, 1997; Bar and Campbell, 1997). For Japan, it is impossible even after invoking theoretical assumptions to isolate the expected inflation rate and inflation premium (Kitamura, 1997). Thus similar to the term premium, we assume the inflation premium to be constant over time (t), and instead observe changes in the marginal inflation premium.

5.1 The Forward Rate and Marginal Inflation Premium

As with the term premium, we assume that the inflation premium $\varphi^{\pi}(t,\tau,T)$ is constant over time (t). Even more importantly, we assume that the real forward rate $g(t,\tau,T)$ and real term premium $\varphi^{g}(t,\tau,T)$ are constant with respect to time (t) and maturity $m = T - t$.

The assumption of a constant real forward rate, according to empirical research on inflation-indexed bonds in the U.K. (Soderlind and Svensson, 1997), is a suitable approximation. In this case, the average first difference of the forward rate is the sum of the marginal first premium and marginal inflation premium.

$$
\begin{aligned}
& f(t+\Delta t,\tau,T) - f(t,\tau,T) \\
&= E_{t+\Delta t}\pi(\tau,T) - E_t E_{t+\Delta t}\pi(\tau,T) + \left[\varphi^{f}(t+\Delta t,\tau,T) - \varphi^{f}(t,\tau,T)\right] + \left[\varphi^{\pi}(t+\Delta t,\tau,T) - \varphi^{\pi}(t,\tau,T)\right] \\
&= -\left[\left\{\varphi^{f}(m) - \varphi^{f}(m-\Delta t)\right\} + \left\{\varphi^{\pi}(m) - \varphi^{\pi}(m-\Delta t)\right\}\right] + \varepsilon_t(\tau,T)
\end{aligned}
$$

5.2 JGB Purchases and the Marginal Inflation Premium

Below we examine how the first difference of the forward rate responded to the Policy Board Meeting on August 14, when the BOJ initiated quantitative easing by increasing the monthly purchase of long-term JGBs from 400 million to 600 million yen. Figure 9 shows a 5-day moving average (five business days before) of the first difference, by maturity. Figure 10 shows a 10-day moving average of the same (see Appendix B).

A negative first difference indicates that the inflation premium and other premiums have a positive marginal tendency. If the inflation premium for a bond with maturity m has a positive marginal tendency, it means that market participants are predicting inflation m years ahead.

The measured results confirm Ueda's (2001) concerns: the increase in inflation premium following the August 14 meeting lasted one week at most. Looking at the 10-day average, by August 22, the first difference of the forward rate had turned negative for all maturities, indicating that the marginal premium had risen. This suggests that the increase in JGB purchases had a positive impact on the inflation premium of market participants.

However, the temporary nature of this impact becomes clear from subsequent developments. In Figures 9 and 10, the marginal premium turns positive for all maturities occurs twice—in early September and early December. This timing coincides perfectly with the downgrade

issued by Moody's for Japan's sovereign credit rating. On September 6, 2001 Moody's announced a review of Japan's sovereign credit rating and possible downgrade from Aa2 to Aa3. The actual downgrade occurred on December 4, 2001. The impact of this news on the JGB market is described below.

5.3 Impact of Credit Downgrade

For each of Moody's reviews and downgrades of long-term JGBs during the zero interest rate policy period, we measured the average first difference of the forward rate 10 and 20 business days before and after the events, and noted the change. Moody's announced the first review for possible downgrade from Aa1 on February 17, 2000, and carried out the downgrade to Aa2 on September 8, 2000. The second downgrade review was announced on September 6, 2001, and the downgrade to Aa3 was carried out on December 4, 2001 (Figure 6).

Figure 6 Effect of JGB Credit Downgrades by Moody's

		0-1	1	2	3	4	5	6	7	8	9	10
2000/2/17	(Business days)											
Review downgrade	10 days before	−0.000019	−0.000009	0.000058	0.000110	0.000135	0.000189	0.000163	0.000003	−0.000078	0.000006	0.000037
from Aa1	10 days after	0.000003	−0.000003	−0.000020	−0.000052	−0.000077	−0.000084	−0.000115	−0.000119	−0.000055	−0.000081	−0.000288
	Difference	−0.000022	−0.000006	0.000078	0.000162	0.000212	0.000273	0.000278	0.000122	−0.000023	0.000087	0.000325
2000/9/8												
Downgrade to Aa2	10 days before	0.000051	0.000077	0.000093	0.000132	0.000189	0.000161	0.000132	0.000101	0.000074	0.000098	0.000021
	10 days after	0.000023	−0.000041	−0.000083	−0.000078	−0.000067	0.000009	0.000051	0.000031	0.000073	0.000180	0.000291
	Difference	0.000028	0.000118	0.000176	0.000210	0.000257	0.000152	0.000081	0.000070	0.000002	−0.000083	−0.000271
			*	*	*	*						
2001/9/6												
Review downgrade	10 days before	−0.000008	−0.000005	0.000043	0.000083	0.000102	0.000118	0.000106	−0.000023	−0.000115	−0.000039	0.000033
from Aa2	10 days after	−0.000001	0.000008	0.000002	−0.000021	−0.000012	0.000000	0.000027	0.000113	0.000150	0.000069	−0.000005
	Difference	−0.000006	−0.000013	0.000041	0.000104	0.000114	0.000118	0.000080	−0.000136	−0.000265	−0.000108	0.000038
										*		
2001/12/4												
Downgrade to Aa3	10 days before	0.000014	0.000065	0.000103	0.000056	0.000042	0.000103	0.000083	−0.000010	−0.000056	−0.000047	−0.000014
	10 days after	−0.000001	−0.000039	−0.000078	−0.000072	−0.000077	−0.000161	−0.000147	−0.000017	0.000017	−0.000077	−0.000165
	Difference	0.000015	0.000103	0.000181	0.000129	0.000119	0.000263	0.000230	0.000007	−0.000073	0.000031	0.000151
			*	*			*	*				
2000/2/17												
Review downgrade	20 days before	−0.000007	0.000011	0.000031	0.000036	0.000047	0.000067	0.000047	0.000015	−0.000018	−0.000019	0.000028
from Aa1	20 days after	0.000030	0.000053	0.000055	0.000033	0.000007	−0.000025	−0.000041	−0.000058	−0.000036	0.000016	−0.000103
	Difference	−0.000036	−0.000041	−0.000024	0.000003	0.000041	0.000092	0.000088	0.000073	0.000018	−0.000035	0.000131
2000/9/8												
Downgrade to Aa2	20 days before	0.000065	0.000062	0.000073	0.000122	0.000171	0.000156	0.000133	0.000078	0.000058	0.000151	0.000131
	20 days after	0.000007	−0.000029	−0.000052	−0.000066	−0.000077	−0.000062	−0.000027	0.000024	0.000066	0.000091	0.000159
	Difference	0.000059	0.000091	0.000125	0.000188	0.000248	0.000218	0.000160	0.000054	−0.000008	0.000060	−0.000028
		*	*	*	*	*	*	*				
2001/9/6												
Review downgrade	20 days before	−0.000012	−0.000043	−0.000026	0.000009	−0.000003	−0.000015	0.000002	0.000009	0.000016	0.000052	0.000051
from Aa2	20 days after	0.000002	0.000010	−0.000007	−0.000038	−0.000039	−0.000032	−0.000009	0.000025	0.000039	0.000020	0.000006
	Difference	−0.000015	−0.000052	−0.000019	0.000047	0.000035	0.000017	0.000011	−0.000016	−0.000022	0.000032	0.000045
		*	*									
2001/12/4												
Downgrade to Aa3	20 days before	0.000007	0.000032	0.000063	0.000067	0.000081	0.000123	0.000119	0.000049	−0.000006	−0.000014	−0.000013
	20 days after	−0.000004	−0.000034	−0.000039	−0.000010	0.000005	−0.000019	−0.000031	0.000006	0.000001	−0.000066	−0.000097
	Difference	0.000012	0.000066	0.000102	0.000076	0.000076	0.000142	0.000149	0.000043	−0.000007	0.000052	0.000085

Notes: Shows average first difference of forward rate (F(t+1)-F(t)). * Indicates rejection of null hypothesis at 10% critical value. For 2001/12/4, 20-day average is for 12/4 to 12/28.

The 10-day results show that the downgrade on September 8, 2000 had a statistically significant positive effect on the marginal premium. This can also be confirmed from the 20-day results. Moreover, the 10-day results indicate that the downgrade on December 4,

2001 also raised the marginal premium.

The impact of the JGB credit downgrades on the marginal premium can also be interpreted as the manifestation of credit risk. This insight, which is beyond the scope of our paper, warrants further research.

6. Conclusion

In this paper, we tested the expectations hypothesis for determining long-term interest rates, and performed an empirical analysis of the zero interest rate policy's effect on the JGB market by focusing on the forward rate. To see how the zero interest rate policy has contributed to marginal changes in the term premium and inflation premium—which correspond to the policy's twin objectives of supplying liquidity and dispelling deflationary concerns—we tracked premium movements against specific policy actions. Our findings are as follows.

1. Overall, the expectations hypothesis holds for the JGB market.

2. At the same time, we confirmed the existence of the liquidity premium over the long term; the term premium is an increasing function of maturity. This result implies that the liquidity premium hypothesis, rejected by Kuroda (1982), has become viable in recent years.

3. Over the duration of the zero interest rate policy, further monetary easing actions have worked to reduce the marginal premium. In particular, the reinstatement of the zero interest rate policy on March 19, 2001 caused a statistically significant reduction in the marginal premium for government bonds of various maturities. On this point, we agree with Shiratsuka and Fujiki (2001) that the zero interest rate policy has been successful in influencing money markets.

4. However, as Ueda (2001) points out, the marginal premium did rise, albeit temporarily, after, the August 14, 2001 decision to increase purchases of long-term JGBs. This suggests that market participants, sensing a loss of fiscal discipline, predicted inflation in the near future.

5. Finally, in addition to the zero interest rate policy, we must not ignore the effect of JGB credit downgrades. Immediately after Moody's has downgraded long-term JGBs, the

marginal premium has risen. In particular, the Aa2 downgrade on September 8, 2000, and Aa3 downgrade on December 4, 2001 caused statistically significant increases.

From the above empirical results, we assess the zero interest rate policy on its two goals of supplying liquidity and dispelling deflationary concerns as follows.

1. The zero interest rate policy has been successful in supplying liquidity and reducing the liquidity premium. In particular, the effect of the reinstatement of the zero interest rate policy was substantial.

2. As for the inflation premium, although complete isolation is impossible in the absence of inflation-indexed government bonds (Kitamura, 1997), the marginal premium increase that immediately followed the decision to purchase more long-term JGBs could be interpreted as the inflation premium, as Ueda states (2001). However, the effect of this type of non-traditional operation is only temporary; in fact, the premium is affected by JGB credit downgrades in a much more pronounced way. In this sense, confidence in the central bank—a prerequisite for inflation targeting—is not visible in the JGB market.

Appendix A—The Houglet Method

Despite the complexity of its nonlinear equation, the Houglet method is useful in being able to directly estimate the forward rate without using the Spline assumption. The following explanation is derived from Inui and Muromachi (2000).

From N bonds with market prices $p_k^m (k = 1,...., N)$, we use the Houglet method to estimate the interest rate term structure for term $[0, T]$. However, we assume the maturity of bond k to be T_K, and $T \geq \max_k T_k$. If coupon payments occur at $t_i (i = 0,1,..., M; t_0 = 0, t_M = T)$, and the forward rate at $[t_{i-1}, t_i)$ is f_i, the discount rate $d(t)$ at random time $t \in [t_{j-1}, t_j)$ is expressed as follows.

$$d(t)=\exp\left\{-\sum_{i=1}^{j-1} f_i(t_i-t_{i-1})-f_j(t-t_{j-1})\right\} \qquad \text{———①}$$

For bond k, which has coupons C_k, interest payment dates $t_{k,l}(l=1,...,n(k)-1)$, and maturity date $t_{k,n(k)}$, the theoretical price p_k^m is

$$p_k^m = d(t_{k,n(k)})+C_k\sum_{l=1}^{n(k)} d(t_{k,l}) \qquad \text{————②}$$

For the N bonds, the market price vector is $\mathrm{P}^m=(p_k^t-p_N^m)'$, the theoretical price vector is $\mathrm{P}^t=(p_1^t-p_N^t)'$, the residual is $e_k=p_k^t-p_k^m$, and the residual vector is $e=(e_1,....e_N)'$. Thus from ① and ②, the sum of squared residuals is expressed as follows.

$$\varepsilon_R^2=e'e=(\mathrm{P}^t-\mathrm{P}^m)=\sum_{k=1}^{N}(p_k^t-p_k^m)^2 \qquad \text{————③}$$

This is a nonlinear function containing f_i, which has M unknown values. Usually, we can obtain $f=(f_1,...,f_M)'$ to minimize the sum of squared residuals ε_R^2 using the nonlinear least squares method.

However, the original parameter estimation method proposed by Houglet takes into consideration both the sum of squared residuals and variance. That is, it uses the nonlinear least squares method to obtain an $f=(f_1,...,f_M)'$ that minimizes

$$\varepsilon^2=\varepsilon_R^2+\frac{1}{V}\varepsilon_J^2=\sum_{k=1}^{N}(p_k^t-p_k^m)^2+\frac{1}{V}\sum_{i=1}^{M-1}(f_{i+1}-f_i)^2$$

Appendix B—Test Results

Figure 7　Unit Root Test (Level)

Start date	Term	0	1	2	3	4	5	6	7	8	9	10	Lagged diff.
02/24/93	Intercept	−1.97	−1.56	−1.24	−0.95	−0.88	−0.99	−1.13	−1.29	−1.42	−1.81	−1.76	
	Trend and intercept	−1.61	−2.11	−2.44	−2.71	−2.67	−2.92	−3.20	−2.44	−2.46	−3.56 **	−3.33 *	7
	None	−2.74 ***	−2.03 **	−1.57	−1.38	−1.40	−1.32	−1.20 *	−1.29	−1.10	−1.12	−1.40	
01/07/94	Intercept	−1.11	−1.04	−0.95	−0.74	−0.63	−0.93	−1.52	−1.46	−1.42	−1.72	−1.74	
	Trend and intercept	−1.42	−2.20	−2.71	−3.17 *	−3.41 *	−2.81	−2.55	−2.11	−2.27	−3.19 *	−3.24 *	7
	None	−1.59	−1.25	−1.08	−1.02	−0.96	−1.23	−1.60	−1.36	−0.98	−1.00	−1.17	
10/04/95	Intercept	−1.75	−1.61	−1.33	−1.13	−1.38	−1.63	−1.65	−1.47	−1.67	−2.01	−1.96	
	Trend and intercept	−3.30 *	−3.33 *	−3.01	−2.27	−2.10	−2.29	−2.13	−1.74	−1.82	−2.78	−3.00	7
	None	−1.28	−1.17	−1.13	−1.44	−1.73 *	−1.61	−1.36	−1.05	−0.93	−0.82	−0.85	
04/07/97	Intercept	−1.52	−1.93	−1.95	−1.81	−1.91	−2.14	−2.25	−2.32	−2.48	−2.72	−2.45	
	Trend and intercept	−2.43	−3.05	−2.87	−2.43	−2.44	−2.54	−2.34	−2.22	−2.35	−2.78 *	−2.66	6
	None	−1.47	−1.42	−1.35	−1.39	−1.32	−1.13	−1.01	−0.91	−0.78	−0.74	−0.84	
10/02/98	Intercept	−1.61	−1.91	−1.87	−1.80	−2.17	−2.69 *	−3.20 **	−4.01 ***	−4.18 ***	−3.47 ***	−2.53	
	Trend and intercept	−1.74	−2.51	−2.71	−2.80	−3.25 *	−3.60 **	−3.78 **	−3.96 **	−3.92 **	−3.83 **	−3.90 **	6
	None	−1.44	−1.15	−0.80	−0.53	−0.35	−0.20	0.03	0.37	0.48	0.12	−0.11	
02/12/99	Intercept	−1.76	−2.37	−2.20	−1.69	−1.60	−1.89	−2.08	−2.81 *	−3.58 ***	−3.04 **	−2.08	
	Trend and intercept	−1.71	−2.40	−2.34	−2.08	−2.36	−2.83	−2.94	−3.10	−3.48 **	−3.37 *	−3.05	6
	None	−1.82 *	−1.90 *	−1.66 *	−1.41	−1.20	−1.05	−0.90	−0.75	−0.61	−0.95	−1.10	
04/13/99	Intercept	−1.04	−1.40	−1.34	−1.10	−1.18	−1.52	−1.74	−2.30	−3.15 **	−2.74 *	−1.72	
	Trend and intercept	−1.20	−1.96	−2.17	−2.28	−2.61	−2.97	−3.01	−2.98	−3.14 *	−3.18 *	−2.95	6
	None	−1.20	−0.91	−0.74	−0.68	−0.67	−0.59	−0.48	−0.17	−0.09	−0.52	−0.71	
08/11/00	Intercept	−0.63	−1.33	−1.59	−1.40	−1.38	−1.71	−1.71	−1.70	−2.06	−2.30	−2.00	
	Trend and intercept	−1.04	−1.04	−1.33	−1.44	−1.66	−1.77	−1.57	−1.63	−2.20	−2.30	−2.00	5
	None	−1.44	−1.95 **	−1.74 *	−1.53	−1.27	−0.97	−0.71	−0.27	0.11	−0.18	−0.42	
03/19/01	Intercept	−2.19	−2.89 **	−3.14 **	−2.85 *	−2.67 *	−2.99 **	−2.66 *	−2.24	−2.49	−3.03 **	−3.63 ***	
	Trend and intercept	−2.19	−2.93 **	−3.15 **	−2.87 *	−2.69 *	−2.99 **	−2.93 *	−2.65	−2.63	−3.53 **	−4.02 ***	4
	None	−1.48	−0.44	−0.15 *	−0.24	−0.19	0.16	0.49	0.76	0.68	0.38	0.38	
08/14/01	Intercept	−2.11	−1.73	−2.04	−2.70 *	−2.78 *	−2.75 *	−2.49	−2.36	−2.38	−3.20 **	−2.77 *	
	Trend and intercept	−3.84 **	−2.84	−3.00	−2.84	−2.77	−2.74	−2.46	−2.48	−3.41	−4.11 ***	−2.55	3
	None	−0.67	−0.11	0.36	0.45	0.42	0.42	0.42	0.09	−0.16 *	0.01	0.14	
09/18/01	Intercept	−2.32	−2.98 **	−2.86 *	−2.61 *	−2.41	−2.19	−1.94	−2.09	−1.87	−1.52	−1.60	
	Trend and intercept	−2.82	−2.61	−3.04	−2.92	−2.52	−2.21	−1.88	−2.00	−3.01	−3.72 **	−2.09	3
	None	0.84	0.38	0.68	0.71	0.58	0.44	0.12	−0.49	−0.75	−0.58	−0.24	

Notes: (1) All forward rates are for 1-year instruments. Term refers to when the 1-year forward rate applies. Term 0 refers to the spot rate.

(2) Unit root test is the Phillips-Perron test.

(3) MacKinnon critical values for rejection of hypothesis of a unit root: *** = 1%, ** = 5%, * = 10%.

Figure 8　Unit Root Test (First Difference)

Start date	Term	0	1	2	3	4	5	6	7	8	9	10	Lagged diff.
02/24/93	Intercept	−39.35 ***	−40.59 ***	−41.86 ***	−42.92 ***	−44.03 ***	−45.12 ***	−45.98 ***	−40.97 ***	−37.67 ***	−40.55 ***	−38.75 ***	7
	Trend+intercpt.	−39.37 ***	−40.59 ***	−41.85 ***	−42.91 ***	−44.02 ***	−45.11 ***	−45.97 ***	−40.96 ***	−37.66 ***	−40.54 ***	−38.75 ***	
	None	−39.31 ***	−40.57 ***	−41.85 ***	−42.91 ***	−44.01 ***	−45.11 ***	−45.97 ***	−40.96 ***	−37.67 ***	−40.55 ***	−38.75 ***	
01/07/94	Intercept	−37.84 ***	−38.88 ***	−40.30 ***	−41.65 ***	−42.60 ***	−43.51 ***	−43.23 ***	−38.13 ***	−36.02 ***	−37.58 ***	−36.23 ***	7
	Trend+intercpt.	−37.83 ***	−38.87 ***	−40.29 ***	−41.65 ***	−42.60 ***	−43.50 ***	−43.23 ***	−38.13 ***	−36.01 ***	−37.57 ***	−36.22 ***	
	None	−37.83 ***	−38.88 ***	−40.30 ***	−41.65 ***	−42.60 ***	−43.50 ***	−43.22 ***	−38.13 ***	−36.02 ***	−37.58 ***	−36.23 ***	
10/04/95	Intercept	−34.77 ***	−34.56 ***	−36.68 ***	−38.32 ***	−38.81 ***	−38.37 ***	−36.88 ***	−33.09 ***	−32.65 ***	−32.92 ***	−32.66 ***	7
	Trend+intercpt.	−34.76 ***	−34.55 ***	−36.67 ***	−38.31 ***	−38.80 ***	−38.37 ***	−36.88 ***	−33.08 ***	−32.65 ***	−32.91 ***	−32.65 ***	
	None	−34.77 ***	−34.57 ***	−36.68 ***	−38.30 ***	−38.77 ***	−38.36 ***	−36.88 ***	−33.10 ***	−32.66 ***	−32.93 ***	−32.67 ***	
04/07/97	Intercept	−32.41 ***	−31.15 ***	−32.13 ***	−33.03 ***	−33.76 ***	−33.73 ***	−32.05 ***	−28.86 ***	−28.66 ***	−29.15 ***	−28.83 ***	6
	Trend+intercpt.	−32.40 ***	−31.13 ***	−32.12 ***	−33.02 ***	−33.75 ***	−33.72 ***	−32.04 ***	−28.86 ***	−28.66 ***	−29.14 ***	−28.82 ***	
	None	−32.41 ***	−31.15 ***	−32.13 ***	−33.03 ***	−33.75 ***	−33.73 ***	−32.06 ***	−28.87 ***	−28.67 ***	−29.16 ***	−28.84 ***	
10/02/98	Intercept	−24.37 ***	−24.58 ***	−25.49 ***	−26.46 ***	−27.46 ***	−27.56 ***	−26.38 ***	−24.97 ***	−24.91 ***	−25.05 ***	−24.42 ***	6
	Trend+intercpt.	−24.36 ***	−24.57 ***	−25.49 ***	−26.49 ***	−27.51 ***	−27.61 ***	−26.45 ***	−25.05 ***	−24.96 ***	−25.08 ***	−24.45 ***	
	None	−24.38 ***	−24.60 ***	−25.51 ***	−26.48 ***	−27.47 ***	−27.57 ***	−26.38 ***	−24.96 ***	−24.89 ***	−25.05 ***	−24.43 ***	
02/12/99	Intercept	−22.08 ***	−22.83 ***	−23.96 ***	−25.24 ***	−26.53 ***	−26.62 ***	−25.07 ***	−23.03 ***	−22.92 ***	−23.17 ***	−22.18 ***	6
	Trend+intercpt.	−22.07 ***	−22.82 ***	−23.95 ***	−25.22 ***	−26.50 ***	−26.60 ***	−25.05 ***	−23.02 ***	−22.92 ***	−23.16 ***	−22.16 ***	
	None	−22.06 ***	−22.82 ***	−23.95 ***	−25.22 ***	−26.51 ***	−26.62 ***	−25.07 ***	−23.04 ***	−22.93 ***	−23.17 ***	−22.18 ***	
04/13/99	Intercept	−22.77 ***	−23.37 ***	−24.28 ***	−25.31 ***	−26.20 ***	−25.86 ***	−24.32 ***	−22.32 ***	−21.72 ***	−22.20 ***	−21.38 ***	6
	Trend+intercpt.	−22.77 ***	−23.37 ***	−24.28 ***	−25.33 ***	−26.20 ***	−25.85 ***	−24.30 ***	−22.30 ***	−21.70 ***	−22.18 ***	−21.36 ***	
	None	−22.78 ***	−23.39 ***	−24.30 ***	−25.33 ***	−26.21 ***	−25.88 ***	−24.33 ***	−22.33 ***	−21.74 ***	−22.21 ***	−21.40 ***	
08/11/00	Intercept	−14.65 ***	−15.69 ***	−16.53 ***	−17.22 ***	−18.16 ***	−18.62 ***	−17.87 ***	−16.03 ***	−15.36 ***	−15.72 ***	−14.79 ***	5
	Trend+intercpt.	−14.63 ***	−15.71 ***	−16.55 ***	−17.23 ***	−18.16 ***	−18.62 ***	−17.87 ***	−16.01 ***	−15.33 ***	−15.69 ***	−14.77 ***	
	None	−14.58 ***	−15.62 ***	−16.49 ***	−17.19 ***	−18.14 ***	−18.62 ***	−17.88 ***	−16.06 ***	−15.38 ***	−15.74 ***	−14.81 ***	
03/19/01	Intercept	−12.61 ***	−10.99 ***	−11.69 ***	−12.45 ***	−13.15 ***	−13.23 ***	−12.99 ***	−12.24 ***	−11.43 ***	−10.79 ***	−9.73 ***	4
	Trend+intercpt.	−12.65 ***	−10.96 ***	−11.66 ***	−12.42 ***	−13.12 ***	−13.19 ***	−12.97 ***	−12.24 ***	−11.46 ***	−10.80 ***	−9.76 ***	
	None	−12.63 ***	−11.01 ***	−11.72 ***	−12.48 ***	−13.18 ***	−13.26 ***	−13.00 ***	−12.23 ***	−11.43 ***	−10.80 ***	−9.74 ***	
08/14/01	Intercept	−8.40 ***	−7.63 ***	−8.03 ***	−8.84 ***	−9.84 ***	−9.89 ***	−9.87 ***	−9.21 ***	−9.00 ***	−9.81 ***	−8.90 ***	3
	Trend+intercpt.	−8.52 ***	−7.59 ***	−7.98 ***	−8.79 ***	−9.78 ***	−9.83 ***	−9.82 ***	−9.15 ***	−8.99 ***	−10.04 ***	−9.11 ***	
	None	−8.43 ***	−7.67 ***	−8.04 ***	−8.85 ***	−9.87 ***	−9.92 ***	−9.90 ***	−9.26 ***	−9.06 ***	−9.87 ***	−8.95 ***	
09/18/01	Intercept	−9.66 ***	−7.21 ***	−7.74 ***	−9.05 ***	−10.13 ***	−10.00 ***	−10.27 ***	−8.84 ***	−8.57 ***	−8.91 ***	−7.73 ***	3
	Trend+intercpt.	−9.85 ***	−7.45 ***	−7.82 ***	−8.99 ***	−10.05 ***	−9.92 ***	−10.20 ***	−8.83 ***	−8.50 ***	−8.97 ***	−7.89 ***	
	None	−9.48 ***	−7.16 ***	−7.67 ***	−9.04 ***	−10.18 ***	−10.06 ***	−10.37 ***	−8.89 ***	−8.58 ***	−8.94 ***	−7.79 ***	

Notes: (1) All forward rates are for 1-year instruments. Term refers to when the forward rate starts. Term 0 refers to the spot rate.
(2) Unit root test is the Phillips-Perron test of the first difference series of each forward rate.
(3) MacKinnon critical values for rejection of hypothesis of a unit root: *** = 1%, ** = 5%、* = 10%.

Figure 9　Average First Difference of Forward Rate (5 Business Days)

	0	1	2	3	4	5	6	7	8	9	10
2001/08/01	0.00003	0.00007	0.00005	−0.00001	−0.00004	−0.00009	−0.00008	−0.00004	−0.00008	−0.00012	−0.00012
2001/08/02	0.00002	0.00005	0.00003	−0.00002	−0.00004	−0.00006	−0.00005	−0.00003	−0.00008	−0.00007	−0.00004
2001/08/03	0.00002	0.00002	−0.00001	−0.00004	−0.00006	−0.00007	−0.00004	0.00003	0.00001	0.00001	0.00004
2001/08/06	0.00002	0.00000	−0.00003	−0.00005	−0.00005	−0.00006	−0.00002	0.00008	0.00008	0.00006	0.00007
2001/08/07	0.00001	−0.00002	−0.00006	−0.00007	−0.00008	−0.00009	−0.00004	0.00009	0.00011	0.00006	0.00006
2001/08/08	0.00000	−0.00005	−0.00010	−0.00009	−0.00009	−0.00008	−0.00003	0.00008	0.00011	0.00009	0.00009
2001/08/09	−0.00001	−0.00005	−0.00008	−0.00006	−0.00004	−0.00003	−0.00001	0.00002	0.00005	0.00004	0.00005
2001/08/10	−0.00001	−0.00005	−0.00005	−0.00002	−0.00002	−0.00001	−0.00001	0.00005	0.00009	0.00004	0.00001
2001/08/13	−0.00001	−0.00006	−0.00007	−0.00003	−0.00006	−0.00007	−0.00004	0.00007	0.00013	0.00007	0.00001
2001/08/14	−0.00001	−0.00007	−0.00008	−0.00005	−0.00008	−0.00012	−0.00007	0.00006	0.00013	0.00006	−0.00002
2001/08/15	−0.00002	−0.00010	−0.00014	−0.00013	−0.00019	−0.00024	−0.00017	−0.00001	0.00007	0.00002	−0.00006
2001/08/16	−0.00002	−0.00007	−0.00007	−0.00002	−0.00004	−0.00006	−0.00004	0.00004	0.00013	0.00017	0.00011
2001/08/17	−0.00002	−0.00006	−0.00006	−0.00001	−0.00003	−0.00006	−0.00004	0.00005	0.00014	0.00018	0.00012
2001/08/20	−0.00001	−0.00002	0.00003	0.00011	0.00010	0.00007	0.00007	0.00007	0.00012	0.00019	0.00015
2001/08/21	−0.00001	−0.00001	0.00005	0.00012	0.00010	0.00006	0.00004	0.00001	0.00003	0.00011	0.00010
2001/08/22	−0.00001	0.00001	0.00008	0.00014	0.00012	0.00009	0.00007	−0.00002	−0.00003	0.00005	0.00005
2001/08/23	0.00000	0.00004	0.00011	0.00016	0.00012	0.00008	0.00003	−0.00007	−0.00011	−0.00004	−0.00002
2001/08/24	0.00000	0.00003	0.00009	0.00013	0.00011	0.00008	0.00006	−0.00002	−0.00008	−0.00001	0.00000
2001/08/27	0.00000	0.00002	0.00009	0.00014	0.00014	0.00013	0.00009	−0.00004	−0.00013	−0.00003	0.00002
2001/08/28	0.00000	0.00001	0.00006	0.00010	0.00011	0.00010	0.00005	−0.00009	−0.00018	−0.00010	−0.00003
2001/08/29	−0.00001	−0.00001	0.00003	0.00005	0.00006	0.00006	0.00004	−0.00008	−0.00017	−0.00010	−0.00002
2001/08/30	−0.00001	−0.00001	0.00003	0.00008	0.00012	0.00016	0.00016	0.00003	−0.00005	0.00002	0.00009
2001/08/31	−0.00001	−0.00002	0.00001	0.00005	0.00007	0.00010	0.00013	0.00006	−0.00004	−0.00002	0.00003
2001/09/03	−0.00001	−0.00001	0.00002	0.00006	0.00008	0.00011	0.00013	0.00007	−0.00002	−0.00002	0.00001
2001/09/04	−0.00001	−0.00002	0.00000	0.00003	0.00007	0.00011	0.00011	0.00004	−0.00006	−0.00007	−0.00003
2001/09/05	−0.00001	−0.00003	−0.00002	0.00003	0.00010	0.00018	0.00020	0.00012	0.00003	0.00004	0.00006
2001/09/06	−0.00001	−0.00003	−0.00003	0.00001	0.00009	0.00018	0.00022	0.00018	0.00011	0.00010	0.00012
2001/09/07	−0.00001	−0.00004	−0.00007	−0.00004	0.00004	0.00013	0.00020	0.00021	0.00016	0.00009	0.00007
2001/09/10	−0.00001	−0.00005	−0.00011	−0.00012	−0.00009	−0.00004	0.00004	0.00013	0.00013	0.00002	−0.00001
2001/09/11	−0.00001	−0.00005	−0.00012	−0.00015	−0.00014	−0.00010	0.00001	0.00015	0.00015	0.00001	−0.00005
2001/09/12	−0.00001	−0.00003	−0.00006	−0.00007	−0.00006	−0.00002	0.00007	0.00019	0.00020	0.00008	0.00001
2001/09/13	0.00000	0.00000	0.00000	−0.00001	0.00002	0.00006	0.00009	0.00015	0.00019	0.00012	0.00005
2001/09/14	0.00000	0.00001	0.00000	−0.00003	−0.00004	−0.00004	−0.00002	0.00004	0.00006	0.00000	−0.00004
2001/09/17	0.00000	0.00002	0.00001	−0.00005	−0.00006	−0.00005	−0.00005	0.00001	0.00005	−0.00001	−0.00007
2001/09/18	0.00001	0.00003	0.00002	−0.00003	−0.00004	−0.00001	0.00000	0.00004	0.00007	0.00002	−0.00002
2001/09/19	0.00001	0.00003	0.00001	−0.00007	−0.00011	−0.00010	−0.00006	0.00004	0.00010	0.00003	−0.00003
2001/09/20	0.00001	0.00005	0.00004	−0.00004	−0.00009	−0.00009	−0.00008	0.00000	0.00006	0.00001	−0.00004
2001/09/21	0.00001	0.00004	0.00001	−0.00008	−0.00011	−0.00013	−0.00013	−0.00005	−0.00001	−0.00006	−0.00010
2001/09/25	0.00001	0.00004	0.00002	−0.00004	−0.00008	−0.00010	−0.00011	−0.00007	−0.00003	−0.00003	−0.00003
2001/09/26	0.00001	0.00004	0.00006	0.00006	0.00006	0.00006	0.00003	−0.00002	0.00000	0.00006	0.00009
2001/09/27	0.00001	0.00004	0.00007	0.00006	0.00006	0.00005	0.00001	−0.00007	−0.00007	0.00004	0.00011
2001/09/28	0.00001	0.00003	0.00002	−0.00001	0.00000	0.00000	−0.00003	−0.00009	−0.00009	0.00000	0.00005
2001/10/01	0.00000	0.00002	0.00000	−0.00004	−0.00005	−0.00005	−0.00003	−0.00004	−0.00006	−0.00001	0.00005
2001/10/02	0.00000	0.00002	0.00001	−0.00003	−0.00002	0.00000	0.00002	0.00001	0.00000	0.00003	0.00008
2001/10/03	0.00000	0.00001	−0.00001	−0.00004	−0.00004	−0.00003	0.00000	−0.00001	−0.00002	0.00003	0.00010
2001/10/04	0.00000	0.00000	−0.00001	−0.00004	−0.00005	−0.00006	−0.00003	−0.00002	−0.00001	0.00007	0.00014
2001/10/05	0.00000	0.00000	0.00000	−0.00002	−0.00003	−0.00004	−0.00001	−0.00001	0.00001	0.00010	0.00018
2001/10/09	0.00000	0.00000	−0.00002	−0.00006	−0.00010	−0.00013	−0.00008	−0.00004	−0.00001	0.00005	0.00012
2001/10/10	0.00000	0.00001	0.00003	0.00001	−0.00003	−0.00007	−0.00005	−0.00003	0.00001	0.00009	0.00016
2001/10/11	0.00000	0.00002	0.00004	0.00002	−0.00003	−0.00008	−0.00006	−0.00004	0.00001	0.00008	0.00013
2001/10/12	0.00000	0.00002	0.00005	0.00002	−0.00004	−0.00007	−0.00007	−0.00006	−0.00002	0.00002	0.00007
2001/10/15	0.00000	0.00002	0.00004	0.00000	−0.00005	−0.00006	−0.00006	−0.00004	−0.00001	0.00001	0.00005
2001/10/16	0.00000	0.00002	0.00003	0.00000	−0.00006	−0.00009	−0.00011	−0.00012	−0.00012	−0.00006	0.00003
2001/10/17	0.00000	0.00001	0.00001	−0.00003	−0.00008	−0.00011	−0.00012	−0.00012	−0.00011	−0.00008	−0.00002
2001/10/18	0.00000	0.00001	0.00000	−0.00005	−0.00010	−0.00012	−0.00013	−0.00010	−0.00006	−0.00002	0.00002
2001/10/19	0.00000	0.00001	0.00001	−0.00002	−0.00005	−0.00007	−0.00010	−0.00007	−0.00002	0.00002	0.00005
2001/10/22	0.00000	0.00001	0.00000	−0.00003	−0.00007	−0.00009	−0.00013	−0.00010	−0.00006	−0.00003	0.00001
2001/10/23	0.00000	0.00001	0.00002	−0.00001	−0.00004	−0.00007	−0.00012	−0.00012	−0.00010	−0.00005	0.00001
2001/10/24	0.00000	0.00002	0.00004	0.00003	0.00000	−0.00003	−0.00010	−0.00014	−0.00013	−0.00003	0.00004
2001/10/25	0.00000	0.00002	0.00002	−0.00001	−0.00005	−0.00007	−0.00012	−0.00014	−0.00013	−0.00007	−0.00002
2001/10/26	0.00000	0.00002	0.00003	0.00000	−0.00001	−0.00001	−0.00007	−0.00013	−0.00015	−0.00011	−0.00007
2001/10/29	0.00000	0.00001	0.00001	−0.00003	−0.00003	−0.00003	−0.00008	−0.00012	−0.00013	−0.00011	−0.00010
2001/10/30	0.00000	0.00001	0.00000	−0.00003	−0.00003	−0.00002	−0.00006	−0.00009	−0.00011	−0.00010	−0.00008
2001/10/31	0.00000	0.00000	−0.00002	−0.00005	−0.00005	−0.00004	−0.00004	−0.00004	−0.00007	−0.00005	−0.00004
2001/11/01	0.00000	0.00000	−0.00001	−0.00001	0.00000	0.00001	0.00002	0.00000	−0.00001	0.00004	0.00005
2001/11/02	0.00000	0.00001	0.00002	0.00004	0.00005	0.00005	0.00003	0.00000	−0.00002	0.00002	0.00003
2001/11/05	0.00000	0.00000	0.00001	0.00003	0.00004	0.00002	0.00001	−0.00002	−0.00004	−0.00002	−0.00002
2001/11/06	0.00000	0.00000	0.00001	0.00003	0.00005	0.00004	0.00002	−0.00001	−0.00003	−0.00003	−0.00005
2001/11/07	0.00000	0.00000	0.00000	0.00001	0.00005	0.00005	0.00005	0.00003	0.00001	−0.00002	−0.00007
2001/11/08	0.00000	0.00000	0.00000	0.00003	0.00008	0.00012	0.00012	0.00008	0.00003	−0.00003	−0.00009
2001/11/09	0.00000	0.00000	0.00002	0.00007	0.00011	0.00014	0.00014	0.00009	0.00002	−0.00002	−0.00006

Figure 9 (Continued)

	0	1	2	3	4	5	6	7	8	9	10
2001/11/12	0.00000	0.00000	0.00002	0.00006	0.00008	0.00010	0.00011	0.00008	0.00002	−0.00001	−0.00004
2001/11/13	0.00000	0.00000	0.00004	0.00010	0.00010	0.00011	0.00013	0.00011	0.00005	0.00002	0.00001
2001/11/14	0.00000	0.00000	0.00005	0.00010	0.00008	0.00006	0.00007	0.00006	0.00002	0.00000	0.00001
2001/11/15	0.00000	0.00001	0.00006	0.00011	0.00010	0.00008	0.00008	0.00007	0.00004	0.00003	0.00003
2001/11/16	0.00000	0.00003	0.00009	0.00013	0.00010	0.00010	0.00008	0.00004	−0.00002	−0.00004	−0.00002
2001/11/19	0.00000	0.00004	0.00011	0.00013	0.00011	0.00014	0.00012	0.00005	−0.00004	−0.00006	−0.00001
2001/11/20	0.00000	0.00004	0.00010	0.00009	0.00007	0.00009	0.00010	0.00004	−0.00005	−0.00009	−0.00006
2001/11/21	0.00001	0.00008	0.00015	0.00012	0.00008	0.00008	0.00009	0.00003	−0.00005	−0.00007	−0.00004
2001/11/22	0.00001	0.00006	0.00011	0.00008	0.00004	0.00007	0.00006	−0.00003	−0.00010	−0.00010	−0.00007
2001/11/26	0.00001	0.00006	0.00011	0.00008	0.00006	0.00010	0.00010	0.00001	−0.00004	−0.00003	−0.00001
2001/11/27	0.00001	0.00005	0.00008	0.00005	0.00003	0.00008	0.00006	−0.00002	−0.00006	−0.00003	0.00002
2001/11/28	0.00001	0.00002	0.00005	0.00005	0.00006	0.00009	0.00007	0.00000	−0.00003	0.00001	0.00006
2001/11/29	0.00001	0.00002	0.00005	0.00005	0.00008	0.00012	0.00010	0.00004	−0.00001	0.00001	0.00003
2001/11/30	0.00001	0.00002	0.00003	0.00002	0.00005	0.00009	0.00009	0.00006	0.00001	−0.00003	−0.00004
2001/12/03	0.00001	0.00001	0.00001	0.00000	0.00003	0.00006	0.00007	0.00008	0.00004	−0.00004	−0.00007
2001/12/04	0.00001	−0.00002	−0.00005	−0.00006	−0.00005	−0.00004	0.00001	0.00011	0.00011	−0.00001	−0.00010
2001/12/05	0.00000	−0.00004	−0.00010	−0.00011	−0.00009	−0.00011	−0.00006	0.00006	0.00008	−0.00002	−0.00011
2001/12/06	0.00001	−0.00004	−0.00009	−0.00008	−0.00006	−0.00008	−0.00005	0.00006	0.00010	0.00003	−0.00005
2001/12/07	0.00000	−0.00007	−0.00012	−0.00009	−0.00005	−0.00008	−0.00007	0.00003	0.00007	0.00000	−0.00008
2001/12/10	0.00000	−0.00005	−0.00008	−0.00004	−0.00002	−0.00008	−0.00007	0.00002	0.00005	0.00000	−0.00007
2001/12/11	0.00000	−0.00005	−0.00008	−0.00007	−0.00008	−0.00016	−0.00015	−0.00003	0.00001	−0.00006	−0.00012
2001/12/12	0.00000	−0.00004	−0.00007	−0.00006	−0.00006	−0.00014	−0.00013	0.00000	0.00003	−0.00007	−0.00016
2001/12/13	0.00000	−0.00002	−0.00004	−0.00006	−0.00008	−0.00015	−0.00014	−0.00003	0.00000	−0.00012	−0.00018
2001/12/14	0.00000	−0.00003	−0.00007	−0.00010	−0.00013	−0.00019	−0.00018	−0.00007	−0.00002	−0.00011	−0.00017
2001/12/17	0.00000	−0.00003	−0.00005	−0.00007	−0.00007	−0.00011	−0.00011	−0.00005	0.00000	−0.00004	−0.00010
2001/12/18	0.00000	−0.00003	−0.00004	−0.00004	−0.00003	−0.00004	−0.00007	−0.00006	−0.00002	−0.00003	−0.00007
2001/12/19	0.00000	−0.00001	0.00000	0.00001	0.00005	0.00007	0.00000	−0.00009	−0.00009	−0.00008	−0.00006
2001/12/20	0.00000	0.00000	0.00003	0.00006	0.00009	0.00010	0.00003	−0.00006	−0.00008	−0.00009	−0.00008
2001/12/21	0.00000	0.00000	0.00005	0.00009	0.00012	0.00014	0.00007	−0.00004	−0.00009	−0.00010	−0.00008
2001/12/25	−0.00001	−0.00001	0.00002	0.00006	0.00009	0.00014	0.00010	−0.00001	−0.00009	−0.00010	−0.00007
2001/12/26	−0.00001	−0.00002	0.00002	0.00007	0.00010	0.00016	0.00012	0.00003	−0.00003	−0.00006	−0.00003
2001/12/27	−0.00001	−0.00003	0.00002	0.00008	0.00012	0.00018	0.00014	0.00004	−0.00002	−0.00005	0.00000
2001/12/28	−0.00001	−0.00003	0.00001	0.00008	0.00013	0.00021	0.00016	0.00002	−0.00006	−0.00006	0.00003

Figure 10 Average First Difference of Forward Rate (10 Business Days)

	0–1.0	1	2	3	4	5	6	7	8	9	10
08/01/01	0.00001	−0.00001	−0.00005	−0.00007	−0.00008	−0.00009	−0.00004	0.00007	0.00010	0.00006	0.00003
08/02/01	0.00001	−0.00001	−0.00005	−0.00007	−0.00008	−0.00009	−0.00005	0.00004	0.00006	0.00004	0.00001
08/03/01	0.00000	−0.00001	−0.00003	−0.00004	−0.00005	−0.00006	−0.00003	0.00005	0.00008	0.00005	0.00001
08/06/01	0.00001	0.00000	−0.00002	−0.00004	−0.00006	−0.00008	−0.00004	0.00006	0.00009	0.00006	0.00000
08/07/01	0.00001	0.00000	−0.00001	−0.00001	−0.00003	−0.00006	−0.00004	0.00005	0.00008	0.00005	0.00000
08/08/01	0.00001	0.00000	−0.00002	−0.00004	−0.00007	−0.00012	−0.00009	0.00000	0.00003	0.00001	−0.00003
08/09/01	0.00001	0.00000	−0.00001	−0.00001	−0.00004	−0.00006	−0.00005	0.00001	0.00004	0.00006	0.00005
08/10/01	0.00000	0.00000	0.00000	0.00001	−0.00001	−0.00002	0.00000	0.00004	0.00006	0.00010	0.00008
08/13/01	0.00000	0.00000	0.00001	0.00004	0.00004	0.00003	0.00004	0.00006	0.00008	0.00012	0.00012
08/14/01	0.00000	−0.00001	0.00001	0.00004	0.00002	0.00000	0.00001	0.00004	0.00005	0.00007	0.00007
08/15/01	0.00000	−0.00001	0.00001	0.00004	0.00003	0.00001	0.00001	0.00002	0.00002	0.00003	0.00003
08/16/01	0.00000	−0.00001	0.00000	0.00004	0.00003	0.00001	0.00001	−0.00001	−0.00002	0.00001	0.00002
08/17/01	0.00000	−0.00002	0.00000	0.00004	0.00003	0.00002	0.00002	0.00000	−0.00002	0.00000	0.00000
08/20/01	−0.00001	−0.00002	0.00000	0.00004	0.00004	0.00003	0.00002	−0.00001	−0.00002	0.00000	0.00000
08/21/01	−0.00001	−0.00004	−0.00002	0.00001	0.00000	−0.00002	−0.00001	−0.00001	−0.00002	−0.00001	−0.00002
08/22/01	−0.00002	−0.00005	−0.00005	−0.00003	−0.00005	−0.00007	−0.00004	−0.00002	−0.00002	−0.00001	−0.00001
08/23/01	−0.00001	−0.00004	−0.00003	0.00001	0.00001	0.00002	0.00003	0.00003	0.00004	0.00008	0.00008
08/24/01	−0.00001	−0.00004	−0.00002	0.00003	0.00002	0.00002	0.00004	0.00005	0.00006	0.00009	0.00008
08/27/01	−0.00001	−0.00002	0.00001	0.00006	0.00006	0.00007	0.00008	0.00006	0.00005	0.00008	0.00007
08/28/01	−0.00001	−0.00001	0.00003	0.00008	0.00010	0.00012	0.00011	0.00004	0.00001	0.00005	0.00007
08/29/01	−0.00001	−0.00001	0.00003	0.00009	0.00011	0.00014	0.00014	0.00005	0.00001	0.00005	0.00007
08/30/01	−0.00001	0.00000	0.00004	0.00010	0.00012	0.00014	0.00014	0.00007	0.00002	0.00003	0.00004
08/31/01	0.00000	−0.00001	0.00001	0.00005	0.00007	0.00010	0.00012	0.00009	0.00004	0.00003	0.00002
09/03/01	−0.00001	−0.00002	−0.00003	−0.00001	0.00000	0.00001	0.00005	0.00005	0.00000	−0.00001	−0.00001
09/04/01	−0.00001	−0.00002	−0.00003	−0.00002	0.00000	0.00001	0.00004	0.00003	−0.00001	−0.00003	−0.00003
09/05/01	−0.00001	−0.00001	−0.00001	0.00000	0.00001	0.00003	0.00006	0.00005	0.00002	0.00000	0.00000
09/06/01	−0.00001	0.00000	0.00002	0.00003	0.00006	0.00009	0.00010	0.00007	0.00005	0.00005	0.00004
09/07/01	−0.00001	0.00000	0.00001	0.00001	0.00001	0.00003	0.00005	0.00003	0.00001	−0.00001	0.00000
09/10/01	0.00000	0.00000	0.00002	0.00001	0.00001	0.00002	0.00003	0.00003	0.00001	−0.00001	−0.00002
09/11/01	0.00000	0.00001	0.00001	−0.00001	−0.00001	0.00002	0.00004	0.00004	0.00002	−0.00001	−0.00002
09/12/01	0.00000	0.00001	0.00001	−0.00001	−0.00001	0.00003	0.00006	0.00005	0.00004	0.00001	0.00000
09/13/01	0.00000	0.00001	0.00001	−0.00001	0.00000	0.00004	0.00006	0.00006	0.00006	0.00003	0.00002
09/14/01	0.00000	0.00000	−0.00001	−0.00002	0.00000	0.00004	0.00006	0.00008	0.00007	0.00003	0.00000

Figure 10 (Continued)

	0-1.0	1	2	3	4	5	6	7	8	9	10
09/17/01	0.00000	0.00000	-0.00003	-0.00004	-0.00002	0.00000	0.00003	0.00007	0.00007	0.00002	0.00001
09/18/01	0.00000	-0.00001	-0.00004	-0.00006	-0.00005	-0.00003	0.00001	0.00006	0.00007	0.00004	0.00003
09/19/01	0.00000	0.00000	-0.00002	-0.00004	-0.00003	-0.00001	0.00002	0.00004	0.00004	0.00004	0.00004
09/20/01	0.00000	0.00001	-0.00001	-0.00003	-0.00002	0.00000	0.00002	0.00005	0.00006	0.00005	0.00003
09/21/01	0.00000	0.00001	0.00000	-0.00003	-0.00003	-0.00003	0.00000	0.00003	0.00004	0.00003	0.00003
09/25/01	0.00000	0.00002	0.00001	-0.00003	-0.00003	-0.00002	-0.00001	0.00001	0.00002	0.00002	0.00002
09/26/01	0.00001	0.00002	0.00000	-0.00005	-0.00005	-0.00005	-0.00003	-0.00001	0.00001	0.00002	0.00003
09/27/01	0.00000	0.00002	0.00000	-0.00005	-0.00007	-0.00006	-0.00003	0.00001	0.00005	0.00006	0.00007
09/28/01	0.00001	0.00003	0.00002	-0.00004	-0.00007	-0.00008	-0.00006	-0.00001	0.00003	0.00004	0.00006
10/01/01	0.00001	0.00002	0.00001	-0.00005	-0.00010	-0.00012	-0.00010	-0.00005	-0.00001	0.00000	0.00002
10/02/01	0.00001	0.00003	0.00004	0.00000	-0.00004	-0.00007	-0.00007	-0.00004	-0.00001	0.00003	0.00005
10/03/01	0.00001	0.00003	0.00005	0.00003	0.00000	-0.00001	-0.00002	-0.00002	0.00001	0.00006	0.00008
10/04/01	0.00001	0.00003	0.00005	0.00003	0.00001	-0.00001	-0.00003	-0.00005	-0.00002	0.00004	0.00009
10/05/01	0.00001	0.00003	0.00003	0.00000	-0.00002	-0.00003	-0.00005	-0.00008	-0.00007	0.00000	0.00007
10/09/01	0.00000	0.00002	0.00001	-0.00003	-0.00006	-0.00008	-0.00008	-0.00009	-0.00010	-0.00005	0.00002
10/10/01	0.00000	0.00002	0.00001	-0.00003	-0.00006	-0.00006	-0.00006	-0.00005	-0.00005	-0.00001	0.00004
10/11/01	0.00000	0.00001	0.00000	-0.00003	-0.00005	-0.00006	-0.00005	-0.00005	-0.00003	0.00001	0.00007
10/12/01	0.00000	0.00001	-0.00001	-0.00004	-0.00006	-0.00008	-0.00008	-0.00007	-0.00004	0.00001	0.00007
10/15/01	0.00000	0.00001	0.00000	-0.00003	-0.00005	-0.00006	-0.00007	-0.00006	-0.00004	0.00003	0.00009
10/16/01	0.00000	0.00001	0.00001	-0.00002	-0.00005	-0.00007	-0.00007	-0.00007	-0.00005	0.00002	0.00009
10/17/01	0.00000	0.00002	0.00003	0.00001	-0.00004	-0.00007	-0.00009	-0.00010	-0.00007	0.00002	0.00009
10/18/01	0.00000	0.00002	0.00004	0.00001	-0.00002	-0.00005	-0.00007	-0.00008	-0.00006	0.00001	0.00006
10/19/01	0.00000	0.00002	0.00003	0.00000	-0.00003	-0.00005	-0.00008	-0.00008	-0.00007	-0.00003	0.00000
10/22/01	0.00000	0.00002	0.00002	-0.00002	-0.00004	-0.00005	-0.00008	-0.00007	-0.00006	-0.00004	-0.00002
10/23/01	0.00000	0.00002	0.00001	-0.00002	-0.00004	-0.00005	-0.00006	-0.00008	-0.00008	-0.00005	-0.00001
10/24/01	0.00000	0.00001	0.00000	-0.00003	-0.00006	-0.00007	-0.00008	-0.00009	-0.00010	-0.00007	-0.00003
10/25/01	0.00000	0.00000	0.00000	-0.00002	-0.00005	-0.00006	-0.00006	-0.00006	-0.00005	-0.00001	0.00002
10/26/01	0.00000	0.00001	0.00002	0.00001	0.00000	-0.00002	-0.00004	-0.00004	-0.00003	0.00001	0.00003
10/29/01	0.00000	0.00001	0.00001	0.00000	-0.00002	-0.00004	-0.00006	-0.00007	-0.00005	-0.00003	-0.00001
10/30/01	0.00000	0.00001	0.00001	0.00000	-0.00001	-0.00002	-0.00005	-0.00006	-0.00006	-0.00003	-0.00002
10/31/01	0.00000	0.00001	0.00001	0.00002	0.00003	0.00003	-0.00001	-0.00004	-0.00004	-0.00002	-0.00001
11/01/01	0.00000	0.00001	0.00001	0.00001	0.00002	0.00003	0.00000	-0.00004	-0.00006	-0.00005	-0.00004
11/02/01	0.00000	0.00001	0.00003	0.00004	0.00005	0.00006	0.00003	-0.00002	-0.00006	-0.00005	-0.00004
11/05/01	0.00000	0.00001	0.00002	0.00003	0.00003	0.00003	0.00002	-0.00001	-0.00004	-0.00005	-0.00006
11/06/01	0.00000	0.00001	0.00002	0.00003	0.00003	0.00003	0.00003	0.00001	-0.00002	-0.00004	-0.00004
11/07/01	0.00000	0.00001	0.00002	0.00004	0.00003	0.00003	0.00003	0.00002	-0.00001	-0.00001	-0.00001
11/08/01	0.00000	0.00001	0.00003	0.00004	0.00004	0.00003	0.00003	0.00001	-0.00002	-0.00001	0.00000
11/09/01	0.00000	0.00002	0.00005	0.00007	0.00006	0.00006	0.00005	0.00001	-0.00003	-0.00001	0.00000
11/12/01	0.00000	0.00002	0.00007	0.00009	0.00008	0.00009	0.00008	0.00002	-0.00004	-0.00003	-0.00001
11/13/01	0.00000	0.00002	0.00006	0.00006	0.00005	0.00006	0.00005	0.00001	-0.00005	-0.00006	-0.00005
11/14/01	0.00001	0.00004	0.00008	0.00007	0.00006	0.00006	0.00006	0.00002	-0.00003	-0.00005	-0.00005
11/15/01	0.00001	0.00003	0.00005	0.00004	0.00005	0.00008	0.00007	0.00002	-0.00003	-0.00006	-0.00007
11/16/01	0.00001	0.00003	0.00006	0.00006	0.00008	0.00012	0.00012	0.00004	-0.00002	-0.00003	-0.00004
11/19/01	0.00001	0.00003	0.00005	0.00006	0.00007	0.00011	0.00011	0.00004	-0.00001	-0.00001	0.00000
11/20/01	0.00000	0.00001	0.00004	0.00007	0.00008	0.00010	0.00010	0.00005	0.00001	0.00001	0.00003
11/21/01	0.00000	0.00001	0.00005	0.00008	0.00009	0.00011	0.00011	0.00007	0.00003	0.00002	0.00002
11/22/01	0.00000	0.00001	0.00005	0.00007	0.00008	0.00010	0.00010	0.00007	0.00003	0.00000	-0.00002
11/26/01	0.00000	0.00001	0.00003	0.00005	0.00005	0.00005	0.00006	0.00005	0.00001	-0.00005	-0.00007
11/27/01	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00004	0.00007	0.00004	-0.00003	-0.00006
11/28/01	0.00000	0.00000	0.00001	0.00002	0.00001	0.00002	0.00005	0.00007	0.00003	-0.00003	-0.00006
11/29/01	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00004	0.00002	-0.00003	-0.00005
11/30/01	0.00000	0.00001	0.00002	0.00002	0.00001	-0.00001	-0.00001	0.00001	0.00000	-0.00004	-0.00006
12/03/01	0.00000	0.00001	0.00001	0.00001	-0.00001	-0.00003	-0.00003	0.00000	-0.00001	-0.00004	-0.00006
12/04/01	0.00001	0.00001	0.00001	-0.00001	-0.00002	-0.00004	-0.00004	-0.00002	-0.00002	-0.00005	-0.00007
12/05/01	0.00001	0.00001	0.00001	0.00000	0.00000	-0.00002	-0.00002	0.00000	-0.00001	-0.00004	-0.00006
12/06/01	0.00000	0.00000	0.00000	-0.00002	-0.00002	-0.00003	-0.00004	-0.00002	-0.00002	-0.00006	-0.00007
12/07/01	0.00000	-0.00001	-0.00001	-0.00003	-0.00002	-0.00002	-0.00002	0.00001	0.00001	-0.00004	-0.00007
12/10/01	0.00000	-0.00001	-0.00002	-0.00002	-0.00001	0.00000	-0.00001	0.00001	0.00001	-0.00004	-0.00008
12/11/01	0.00000	-0.00002	-0.00003	-0.00004	-0.00002	-0.00002	-0.00002	0.00000	0.00001	-0.00005	-0.00009
12/12/01	0.00000	-0.00002	-0.00005	-0.00005	-0.00003	-0.00003	-0.00003	0.00000	0.00001	-0.00004	-0.00008
12/13/01	0.00000	-0.00002	-0.00003	0.00000	0.00002	0.00003	0.00001	0.00001	0.00001	-0.00003	-0.00006
12/14/01	0.00000	-0.00004	-0.00005	-0.00002	0.00001	0.00002	0.00001	0.00001	0.00000	-0.00005	-0.00007
12/17/01	0.00000	-0.00004	-0.00004	0.00000	0.00003	0.00002	0.00001	0.00003	0.00002	-0.00003	-0.00005
12/18/01	-0.00001	-0.00004	-0.00004	-0.00001	0.00000	-0.00003	-0.00004	0.00000	0.00000	-0.00005	-0.00007
12/19/01	0.00000	-0.00003	-0.00004	-0.00001	0.00000	-0.00002	-0.00003	0.00001	0.00000	-0.00007	-0.00010
12/20/01	0.00000	-0.00002	-0.00002	-0.00001	0.00000	-0.00001	-0.00002	0.00000	-0.00001	-0.00008	-0.00011
12/21/01	0.00000	-0.00002	-0.00003	-0.00002	-0.00002	-0.00003	-0.00005	-0.00003	-0.00003	-0.00009	-0.00011
12/25/01	0.00000	-0.00002	-0.00002	0.00000	0.00002	0.00001	-0.00002	-0.00002	-0.00001	-0.00004	-0.00007
12/26/01	0.00000	-0.00001	0.00000	0.00002	0.00005	0.00005	0.00000	-0.00003	-0.00003	-0.00005	-0.00006
12/27/01	0.00000	0.00000	0.00002	0.00005	0.00009	0.00010	0.00002	-0.00008	-0.00010	-0.00010	-0.00008
12/28/01	0.00000	0.00000	0.00003	0.00006	0.00009	0.00010	0.00003	-0.00006	-0.00008	-0.00009	-0.00008

References

(In Japanese)

[1] Ito, Takatoshi. 2001. *Inflation Targeting—Numerical Targets for Price Stability,* Nihon Keizai Shinbunsha.

[2] Inui, Koji, Yukio Muromachi. 2000. *Estimation and Optimization in Financial Models*, Asakura Shoten.

[3] Ueda, Kazuo. 2001. "The Liquidity Trap and Monetary Policy," speech at the Japan Society of Monetary Economics, Fukushima University, September 29, 2001. Available in Japanese at www.boj.or.jp/press/koen133.htm and in English at www.boj.or.jp/en/press/koen072.htm.

[4] Okina, Kunio. 1990. "Foreign Bond Investment Activity of Institutional Investors in the 1980s," in Yoshiro Miwa and Kiyohiko Nishimura, eds., *Stock Prices and Land Prices of Japan*.

[5] Kuroda, Akio. 1982. *Japan's Interest Rate Structure*. Toyo Keizai Shinposha.

[6] Kuroda, Akio. 1988. *Japan's Financial Markets—Transmission Mechanisms of Monetary Policy*, Toyo Keizai Shinposha.

[7] Saito, Makoto. 2000. *Economic Analysis of Risk and Liquidity—Approaches and Uses of Financial Technology*, Yuhikaku.

[8] Shiratsuka, Shigenori, Hiroshi Fujiki. 2001. "Effect of the Commitment to the Zero Interest Rate Policy: A Test Using Money Market Data for 1999-2000," Bank of Japan IMES Discussion Paper Series No. 2001-J-20.

[9] Insurance Accounting Committee, Ministry of Finance Insurance Council. 1991. "On the Review of Insurance Accounting Practices and Preparation of Disclosure."

[10] Takada, Hajime, Kenichi Sumitomo. 2001. *The Freefall of Government Bonds*, Chuko Shinsho.

[11] Tomita, Toshiki. 2001. *Research on Japanese Government Bonds*, Toyo Keizai Shinposha.

(In English)

[12] Barr, G. David, and John Y. Campbell. 1997. "Inflation, Real Interest Rates, and the Bond Market: A Study of U.K. Nominal and Index-Linked Government Bond Prices," *Journal of Monetary Economics*, 39, pp. 361-83.

[13] Buttiglione, Luigi, Paolo Del Giovane, and Oreste Tristani. 1996. "Monetary Policy Actions and the Term Structure of Interest Rates: A Cross-Country Analysis," in *Monetary Policy and the Term Structure of Interest Rates*.

[14] Campbell, Y. John, Andrew W. Lo, and A Craig MacKinlay. 1997. *The Econometrics of*

Financial Markets, Princeton University Press.

[15] Kitamura, Yukinobu. 1997. “Indexed Bonds and Monetary Policy: The Real Interest Rate and the Expected Rate of Inflation,” *Bank of Japan Monetary and Economic Studies*, May.

[16] McCulloch, J. Huston, and Levis A. Kochin. 2000. “The Inflation Premium Implicit in the US Real and Nominal Term Structures of Interest Rates,” Ohio State University Economics Department Working Paper #98-12.

[17] Soderlind, Pail, and Lars Svensson. 1997. “New Techniques to Extract Market Expectations from Financial Instruments,” *Journal of Monetary Economics*, 40, pp. 383-429.