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Liquidity Demand and Asset Pricing: Evidence from the Periodic Settlement in Japan

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Abstract

While standard finance theory shows that asset pricing is based on discounted future cash flows with risk premium adjustment, practitioners and even academicians often argue that asset pricing is influenced heavily by current demand for financial assets. One of the most important issues here is when asset pricing is determined primarily by current liquidity conditions, without proper reflection of future cash flows. According to a recent theoretical paper by Holmström and Tirole [2001], when firms anticipate not financing liquidity events on their future revenues, they boost demand for short-term assets, which will mature coincidently with the timing of liquidity events. Such asset demand in preparation for liquidity events may substantially lower short-term rates relative to long-term rates by the order of liquidity premium. This paper empirically examines this implication, using as liquidity events the periodic (quarterly) settlement that prevails as common practice among firms in Japan. We find that, when controlling for the factor of expectations, assets with maturities at the settlement period are indeed more highly priced than assets with maturities beyond the period.

Keywords: Liquidity-based asset pricing model; Periodic settlement; Term structure of interest rates.

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1. Introduction

In this paper, we will empirically analyze the interaction of two extremely important issues, neither of which has been resolved in empirical finance literature. The first issue regards the liquidity impact on asset pricing. While standard finance theory demonstrates that asset pricing is based on discounted future cash flows with risk premium adjustment, practitioners and even academicians often argue that asset pricing is heavily influenced by current demand for financial assets. In other words, a liquidity premium may be reflected in asset prices. Existing literature, however, has not empirically presented any explicit evidence of such liquidity impact on asset prices.[1]

The second issue concerns the empirical relevance of the expectations hypothesis regarding the term structure of interest rates. Much empirical research on the term structure presents findings contrary to the prediction of the expectations hypothesis; neither yield spreads nor forward rates can forecast future spot rates correctly.[2] In some cases, high yield spreads tend to forecast decreasing future spot rates, in sharp contradiction with the expectations hypothesis. Even when considering risk aversion behavior, asset pricing models still fail to offer satisfactory explanation of the term structure.[3] This chronic empirical failure of the expectations hypothesis suggests that the term structure may be affected by factors other than expectations or risk aversion.

This paper explores the possibility that liquidity factors successfully explain how the term structure changes over time. The idea of liquidity impact on the term structure is not new to economists at all. Hicks [1946], Lutz [1940], Modigliani and Sutch [1966], and others argue that bond market supply-demand conditions exercise some effects on the term structure. As Campbell et al. [1997] discuss, however, these authors do not explicitly question the expectations hypothesis.

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[1] With respect to the liquidity effect driven by monetary operations, empirical evidence has accumulated in literature. Using interbank market data, for example, Hamilton [1997] finds that the liquidity effect is stronger towards the end of the reserve maintenance period, while Hayashi [2001] examines the presence of liquidity effects using Japanese intra-day data.

[2] Shiller [1990], Campbell et al. [1990], and others systematically survey empirical literature on the term structure of interest rates, with considerable emphasis on the empirical relevance of the expectations hypothesis.

[3] Singleton [1990], for example, provides a systematic survey on the empirical failure of consumption-based asset pricing models, which explicitly consider risk aversion behavior, in his explanation of bond pricing.

One of the most essential questions we have to raise explicitly in the empirical context is when and how asset pricing is determined primarily by current liquidity conditions, without proper reflection of future spot rates. According to a recent theoretical paper by Holmström and Tirole [2001], when firms anticipate not financing liquidity events or a liquidity shortage on their future revenues due to either enforcement or agency problems, they will boost demand for short-term assets, which will mature coincidently with the timing of liquidity events. Such asset demand in preparation of liquidity events leads to a high evaluation of short-term assets. That is to say, liquidity demand may substantially lower short-term rates relative to long-term rates by the order of liquidity premium.

It is crucial to identify a certain liquidity event in order to test the above implication. This paper examines it empirically, using as liquidity events, the periodic settlement that prevails as common practice among Japanese firms. In Japan, firms have to make quarterly settlements, including the very end of March (the end of the fiscal year), September (the month when private companies announce interim accounts), and December (the end of the calendar year). Firms are quite strict about completing their periodic settlements, because failure to do so often jeopardizes continuation of their business. Given such strict enforcement, firms voluntarily accumulate enough cash prior to settlement by rolling over funds in money markets, partly due to tight credit conditions during settlement months, and partly due to their consideration of their counter-parties' credit risks in settlements.

As described above, firms doing business in Japan consider the periodic settlement as a serious liquidity event. The periodic settlement may force firms to hold assets that mature at the settlement period in exchange for assets that mature beyond the period, in order to avoid interest rate risks at settlement. Such a shift in asset demand may raise prices of short-term assets by the order of liquidity premium.

Using term structure data from money markets such as the call market, the euro yen market, and the GENSAKI market, we empirically examine whether, when controlling the factor of expectations, assets with maturities at the settlement period are indeed priced more highly than assets with maturities beyond the period, before the periodic settlement. More specifically, we statistically test whether current forward rates have a tendency to overestimate future spot rates in comparison with the expectations hypothesis, reflecting low short-term rates relative to long-term rates by the order of liquidity premium. In this context, the current liquidity factor may be responsible for deviation from the expectations hypothesis.

This paper is organized as follows. Section 2 briefly reviews a theoretical model presented by Holmström and Tirole [2001], with emphasis on its empirical implication for the term structure. Section 3 derives a simple empirical specification, and presents estimation results. Section 4 provides a brief conclusion.

2. A Liquidity-Based Asset Pricing Model by Holmström and Tirole

2.1. **A simple version of Holmström and Tirole** This section briefly reviews a simple version of a liquidity-based asset pricing model presented by Holmström and Tirole [2001]. While they develop a more general framework in their paper, the following simple version embodies the essence of their asset pricing model.

There are three periods, $t = 0$, 1, and 2. Consumers are risk neutral with zero time preference. In other words, they make savings and consumption decisions that maximize the expected consumption stream $c_0 + c_1 + c_2$. On the other hand, there are N identical entrepreneurs in this economy. They are also risk neutral with zero time preference. Each of them is endowed with one project, but without any initial fund.

Each project requires investment I as a setup cost at date 0, and y as an interim input at date 1, while the project generates random income x at date 1, and a deterministic income $by - \frac{y^2}{2}$ at date 2. Random income x represents aggregate shocks, and are the same for all entrepreneurs. Suppose that x is continuously distributed with density $g(x)$ on $[0, \infty)$, with $Ex > I$. In this setup, we will use the date-1 reinvestment opportunity that requires y units of liquidity as our potential liquidity event.

Without any constraints or liquidity problems, equilibrium spot rates are zero for all maturities, with reflection of risk neutrality and zero time preference. Then, an entrepreneur pays a setup cost by borrowing I from consumers (equivalently, investors). In addition, the entrepreneur invests $b-1$ as an interim input at date 1 to maximize $by - \frac{y^2}{2} - y$. If revenue realized at date 1 (x) is short of $b-1$, then the entrepreneur finances $b-1-x$ at zero spot rates.

Holmström and Tirole introduce the following constraints for both entrepreneurs and consumers in order to analyze the impact of the above liquidity event (the date-1 reinvestment opportunity) on asset pricing. First, entrepreneurs may not finance interim inputs at date 1. Such a borrowing constraint may be motivated by various factors, including agency costs and enforcement problems. Holmström and Tirole justify the presence of the above constraint by assuming that date-2 revenue $(by - \frac{y^2}{2})$ is a private benefit; accordingly, entrepreneurs cannot finance interim inputs from consumers on their date-2 revenue.

In the presence of the above borrowing constraint, entrepreneurs may demand liquidity at date 0, such that they may not be forced to give up reinvestment on interim inputs at date 1. That is, they may borrow extra cash in addition to setup costs, from consumers at date 0, and roll over funds in money markets up to date 1; such liquidity-holding will serve as a buffer against the disruption of reinvestment at date 1.

Second, Holmström and Tirole assume that the government, as a lender in money markets, issues a fixed quantity of bonds $(\bar{l})$ at date 0, while consumers are not allowed to borrow in money markets at any date. For simplicity, the government issues discount bonds at the price q per contract, and pays one unit of goods per contract, regardless of the realization of x at date 1.

They contend that the difference in the borrowing ability between the government and the household sector is due to either the information advantage derived from the tax authority or the governmental ability to commit to long-run contracts. Because of the above assumption, equilibrium (real) spot rates may be negative given a fixed supply of government bonds at date 0. At negative spot rates or $q > 1$, entrepreneurs still may demand bonds at date 0 due to liquidity needs at date 1, while consumers may have incentives to consume goods instead of holding bonds at date 0.

Given the above setup, entrepreneur i invests I as setup costs, and holds l_i units of bonds by borrowing $I + ql_i$ at date 0, while she/he can reinvest $y(x)$ on an interim input up to $x + l_i$, depending on the realization of x at date 1. That is, the reinvestment policy must satisfy

$$y(x) \leq x + l_i \tag{1}$$

for every realization of x.

With respect to contracts with entrepreneur i, consumers lend $I + ql_i$ at date 0, and receive $x + l_i - y(x)$ at date 1. If consumers competitively lend to entrepreneurs, then they expect a zero rate of return on the above investment, and

$$E_0 \left[x - I - y(x) - (q-1)l_i \right] = 0 \tag{2}$$

obtains, where E_0 is the date-0 expectation with respect to x.

Then, the optimal contract between entrepreneur i and consumers maximizes the surplus generated for entrepreneur i at date 2, or

$$E_0 \left[by(x) - \frac{y(x)^2}{2} \right], \tag{3}$$

with respect to $\{y(x), l_i\}$ subject to equations (1) and (2).

The clearing condition of the government bond market leads to

$$l_i \times N = \bar{l}.$$

Letting μ denote the Lagrange multiplier associated with constraint (2), Holmström and Tirole derive the optimal reinvestment policy as follows:

$$y(x) = \min(y^*, x + l_i),$$

where y^* is the solution of the program without constraint (1), or

$$y^* = b - \mu.$$

In other words, if the realized x is smaller than $y^* - l_i$, then the borrowing constraint (2) is binding ex-post, otherwise it is not binding.

However, the fact that the borrowing constraint may not be binding ex-post, does not imply that the constraint never binds ex-ante. Considering the possibility of borrowing constraints for some states, we can show that $\mu \geq 1$. Consequently, y^* is still smaller than the first best solution $b-1$.

Interestingly enough, the pricing kernel for the date-1 payoff $m(x)$ is derived as

$$m(x) = \left\{ \begin{array}{l} m(x) = \left[\frac{1}{\mu}(b-y(x))-1\right]+1 \text{ for } x < y^* - \frac{\bar{l}}{N} \\ 1 \text{ for } x \geq y^* - \frac{\bar{l}}{N} \end{array} \right\},$$

given a fixed supply of the government bond $\bar{l}$.

Based on the above condition, it can be easily verified that, if date-1 revenue x is smaller than $y^* - \frac{\bar{l}}{N}$, then the marginal private benefit expressed in monetary terms, or $\frac{1}{\mu}(b-y(x))-1$ is positive, consequently, entrepreneurs will highly evaluate date-1 cash flow.

The discount bond with one unit of principal is then priced according to the above pricing kernel as follows:

$$q = E_0\left[m(x) \times 1\right].$$

Furthermore, we can show that

$$q \geq 1.$$

That is, the discount bond is priced highly, and one-period spot rates become negative at equilibrium. This proves that the bond pricing q becomes more expensive as the total bond supply $\bar{l}$ declines.

As the above result clearly indicates, high bond pricing reflects that entrepreneurs demand bonds at date 0 according to their liquidity needs for date-1 reinvestment or the liquidity event. Then, $q-1$ (≥ 0) can be perceived as the order of liquidity premium.

2.2. **Implications for the term structure** In order to arrive at implications for the term structure, Holmström and Tirole introduce another discount bond, issued at price Q at date 0, and repaid by one unit of principal at date 2 instead of date 1. They assume that a fixed supply of the long-term bond amounts to $\overline{L}$. In addition, it is assumed that investors (consumers) may not deal either short positions or interest-rate derivatives.

As a device to finance the date-1 liquidity event, the above long-term bond suffers from the interest-rate-risk caused by the date-1 spot rate movements. More specifically, when the long-term bond is cashed in at date 1, its price θ is continuously distributed with density $h(\theta)$ on $[0, \infty)$, with $E\theta = 1$. As long as $E\theta = 1$ and there are no constraints, both q and Q equal one at equilibrium, and therefore the yield curve is completely flat.

In this new setup,

$$y(x) \leq x + l_i + \theta L_i \tag{4}$$

replaces constraint (1) for every realization of x, while equation (2) is replaced by

$$E_0 \left[x - I - y(x) - (q-1)l_i - (Q-1)L_i \right] = 0, \tag{5}$$

where consumers hold L_i units of long-term bonds per entrepreneur at date 0. In addition, we have both $l_i \times N = \bar{l}$ and $L_i \times N = \overline{L}$ as the market clearing condition.

Following the same procedure as before, we can derive a new pricing kernel for the date-1 payoff $z(\theta)$ as

$$z(\theta) = \int_0^{y^* - \bar{l}/N - \theta \overline{L}/N} \left[\frac{1}{\mu} (b - y(x)) - 1 \right] g(x) dx + 1.$$

This proves that $z(\theta)$ is decreasing in θ, and that the covariance between θ and $z(\theta)$ is negative. The intuition behind this proof is that an increase in θ leads to a relaxation of borrowing constraint (4), and accordingly to a decline in the marginal private benefit.

The short-term and long-term bonds are then priced according to the above pricing kernel as follows:

$$q = E_0 \left[z(\theta) \times 1 \right]$$

and

$$Q = E_0 \left[z(\theta) \times \theta \right].$$

Given that $E\theta = 1$ and $Cov\,(\theta, z(\theta)) < 0$ as described above, it is easy to show that

$$q > Q.$$

In other words, short-term rates are lower than long-term rates, and the yield curve is now upward sloping. The reason why long-term bonds are priced low is that the embodied interest-rate-risk reduces the benefit of long-term bonds as a device to finance the liquidity event.[4] Because investors (consumers) are willing to purchase long-term bonds as soon as $Q < 1$, Q is bounded at one ($Q \geq 1$).

What is the essential implication for the term structure from the above model? In the current set up, the short-term bond matures when the liquidity event is realized, while the long-term bond matures after the realization. Therefore, in the context of the expectations hypothesis, the current yield spread $(q - Q)$ should correctly reflect the expectation of the future spot rate that will start when the liquidity event is realized $(E(1-\theta))$. That is, $q - Q = E(1-\theta)$ holds exactly under the expectations hypothesis. On the other hand, the above model with embodying liquidity demand demonstrates that the forecast based on the current yield spread tends to overestimate the future spot rate $(q - Q > E(1-\theta))$.

Relaxing the assumption of zero time preference and three periods, and the characterization of θ, we can still define the above implication as the deviation from the expectations hypothesis. Suppose that the economy starts at date t, and that the liquidity event takes place at date $t+i$. Then, $r_{t,i}$ ($r_{t,j}$) denotes the i-period (j-period) spot rate at date t. When $i < j$, then the i-period (j-period) bond corresponds to the short-term (long-term) bond in the above-described context.

The forecast of the $(j-i)$ period spot rate prevailing at date $t+i$ ($r_{t+i,j-i}$) based on the expectations hypothesis corresponds to the i-period-ahead $(j-i)$-period forward rate, or $f_{t,t+i,j-i} = \frac{1}{j-i}\left(j \times r_{t,j} - i \times r_{t,i}\right)$. If the date-$(t+i)$ liquidity event has a significant effect on the term structure, then the forward rate tends to overestimate the future spot rate, or

[4] More rigorously, once there is a possibility that liquidity constraints are binding at date-1, then aversion to interest rate risks, driven by concavity of date-2 private benefit ($by - \frac{y^2}{2}$), is responsible for the liquidity premium $q - Q$.

$$f_{t,t+i,j-i} = \frac{1}{j-i}\left(j \times r_{t,j} - i \times r_{t,i}\right) > E_t r_{t+i,j-i} \tag{6}$$

obtains.[5] We will empirically examine the above inequality (6) in the next section.

3. Empirical Specification and Estimation

3.1. **Periodic settlement as liquidity events** As discussed in the introduction, it is crucial to identify liquidity events for the purpose of testing the implication explored in the previous section. This paper examines it empirically, regarding as liquidity events, the periodic settlement that prevails as practice among Japanese firms. In Japan, firms must make quarterly settlements largely during the last week of either March (corresponding to the end of the fiscal year), September (the month when private firms announce interim accounts), or December (the end of the calendar year). In particular, settlements are extremely intensive between debtors and creditors at the very end of these months.

Firms are quite strict about completion of the periodic settlement, because failure to settle certainly damages their credit, and often jeopardizes continuation of their business. Given such legal and social enforcement, firms voluntarily accumulate enough liquidity in advance of the periodic settlements by rolling over funds in money markets, partly due to tight credit conditions during the settlement month,[6] and partly due to their consideration of counter-parties' credit risks in settlements.

In comparison with the model presented in Section 2, firms' cash accumulation in preparation for the periodic settlement can be considered as liquidity holding for reinvestment in interim inputs at date 1. Firms running business in Japan then perceive periodic settlement as liquidity events. In the presence of the periodic settlement, therefore, firms are expected to hold financial assets maturing at settlement in exchange for assets that mature beyond settlement, in order to avoid interest rate risk at settlement. As the model predicts, such a shift in asset demand may substantially raise prices of shorter-term assets by the order

[5] Following existing empirical research, our specification ignores the effect of Jensen's inequality, that is often assumed to be quite small.

[6] One reason why money markets are seriously tight in March (the end of the fiscal year) is that regional banks, usually major creditors in markets, are reluctant to lend loans because they attempt to reduce the risk capital required by the BIS regulation as much as possible.

of liquidity premium.

Using term structure data from the money market in Japan, this section empirically examines whether assets with maturities at settlement are indeed more highly priced than assets with maturities beyond settlement. More specifically, we statistically test whether the forward rate observed prior to the periodic settlement tends to significantly overestimate the corresponding future spot rate, reflecting low short-term rates relative to long-term rates.

3.2. **Data** Our estimation procedure uses money market rates available from the following three markets: the call market, the euro yen market (the Japan offshore market, or JOM) and the GENSAKI market. Each data set has strong and weak points. The call market is an interbank market, and its rate only reflects liquidity needs from financial institutions. However, because very short-term contracts such as overnight and one week contracts make up a large part of this market, we can focus on the very end of the settlement months as shown in the next subsection.

The euro yen market, like the call market, is also the interbank market, but it is only used by highly rated banks. The market enables Japanese banks to finance from foreign institutions; however, Japanese institutions are unlikely to finance liquidity needs due to domestic settlement practices in the offshore market. In addition, distortion in the term structure, if any, is likely to be arbitrated immediately by creditworthy banks participating in this market. Accordingly, we regard the offshore market as a controlled environment where the market rate is relatively free from liquidity demands motivated by periodic settlement.

In the GENSAKI market, on the other hand, not only financial institutions, but also non-financial firms trade repurchase contracts. The GENSAKI market was the most representative open money market until the repo market was introduced in 1996. Unlike the call market, however, the shortest term is one month in the GENSAKI market.

The frequency of the above data sets is daily, while the sample period is between November, 1988 and November, 1997. We have chosen this sample period for two reasons. First, the domestic money markets were strictly regulated until the mid 1980s;[7] then, market rates were unlikely to reflect the demand-supply condition before the mid 1980s. Second, the Bank of Japan (BOJ) has intervened heavily in domestic money markets since late November, 1997 in response to the liquidity crises.[8]

More specifically, as Saito and Shiratsuka [2001] demonstrate, the BOJ initially attempted to flatten the yield curve through complicated market operations,[9] and later implemented a zero interest rate policy. Accordingly, the term structure had been heavily influenced by such an active monetary policy, rather than the autonomous market mechanism motivated by the periodic settlement. In the terminology of Holmström and Tirole [2001], the BOJ exercised strong effects on the allocation of the government bonds, $\bar{l}$ and $\overline{L}$.

3.3. **Specification and estimation results: the case of overnight rates** The first estimation concerns the forecasting error of the so-called MATSU-SHO rate observed in the call market, the rate that starts on the final day (MATSU in Japanese) of the settlement month, and ends on the first day (SHO) of the next month. Since one-day-ahead one day forward contracts (tomorrow-next) are traded in the call market, the forecasting error can be defined as $f_{t,t+1,1} - r_{t+1,1}$ at time t, where $f_{t,t+1,1}$ is the tomorrow-next rate, and $r_{t+1,1}$ is the corresponding ex-post overnight rate.[10] [11] Unlike other estimation procedures, the sample period starts in May, 1994 because the above forward contract has been traded since the mid 1990s.

The forecasting error defined above is regressed on three types of timing dummy variables. The first dummy, denoted by **DMSD**, takes a value of one at the timing of forecast-

[7] More concretely, money market rates have been completely determined on a market quote basis since November, 1988.

[8] Yamaichi, one of the leading securities companies in Japan, went bankrupt on November 22, 1997.

[9] More concretely, the BOJ implemented the so-called dual operation by both purchases in longer-term markets and sales in shorter-term markets in 1997 and 1998.

[10] As related empirical research, Hayashi [2001] examines the systematic error between the half-a-day-ahead morning forward rate and the corresponding ex-post afternoon rate. In the context of his research, the massive clearance settlement at 1:00 p.m. may be considered as the liquidity event.

[11] Because banks with low ability to finance in the spot call market often make the tomorrow next contract, the forward rate tends to be larger than the corresponding spot rate by the order of credit risk even at ordinary times. What we test in this empirical exercise is not such a credit premium observed throughout time, but a liquidity premium generated at the timing of periodic settlement practices.

ing for the final day of the settlement month, or one day before the end of either March, September, or December, otherwise zero. The second, denoted by **DOTM**, takes a value of one, one day before the end of either January, February, April, May, June, July, August, October, or November, otherwise zero. The third, denoted by **DRR**, takes a value of one, one day before the final day of the reserve maintenance period each month, otherwise zero.

The following explanatory variables are also included to represent the degree of tightness in the money market. **C1WM** denotes a change in one week call rates from "six day" before the final day of the settlement months to "five day" before; when market tightness is expected at the final day, one week rates tend to jump up as soon as the end of the one week contract covers the final day. Similarly, **C1WR** denotes a change in one week call rates from "six day" before the final day of the reserve maintenance period to "five day" before. Finally, **DFS3** denotes the dummy variable that takes a value of one when there is a fund shortage of more than three trillion yen in the cash market due to strong demand from the fiscal and private sectors on the following day. Otherwise its value is zero. The market participants can anticipate such a large-scale cash shortage quite accurately at least one day before; therefore, this dummy variable may be included as an explanatory variable.

In addition, we add a set of dummy variables which indicate the change in the official discount rate, thereby controlling for the impact of the unexpected policy change on the forecasting error. Table 1 reports the estimation results, where the standard error is adjusted for heteroskedasticity and autocorrelation with one day lags based on Newey and West [1987].

As the estimated coefficient on **DMSD** clearly demonstrates, the tomorrow-next rate substantially overestimates the corresponding overnight rate just before the final day of the settlement months. According to the estimated coefficient on **C1WM**, overestimation is even more remarkable as the call market is expected to be more tight. In addition, though less substantial, overestimation takes place just before the final day of the reserve maintenance periods, and on the day when a substantial shortage is expected in the cash market. The above observations are intact even if the sample period starts in September, 1995, when the policy instrument was effectively changed from the official discount rate to the overnight call rate.[12] In addition, estimation results do not change substantially, when the dummy variables of the policy change are included as explanatory variables.

3.4. **Specification and estimation results: the case of weekly rates** The second estimation procedure uses the one week call rate ($r_{t,5}$) as a forecaster, and the rolling rates on the overnight call market ($\{r_{t+i,1}\}_{i=0}^{4}$) as ex-post rates. The forecasting error is thus defined as $r_{t,5} - \frac{1}{5}\sum_{i=0}^{4} r_{t+i,1}$ at time t. The defined forecasting error is regressed on the dummy variables of the last four days before the end of each month (**DMMX**) as well as those of the last four days before the end of the reserve maintenance periods (**DRRX**). In addition, as in the previous procedure, a set of explanatory variables includes the dummy variables of changes in the official discount rates. Table 2 reports estimation results, where the standard error is adjusted for heteroskedasticity and autocorrelation with one week lags.

The estimated coefficients on **DMMX** demonstrate that overestimation takes place as soon as the end of the one week contract covers the MATSU-SHO rate in the settlement months, March, September, and December. Overestimation is most serious in the March settlement. During the last four days in each settlement, on the other hand, overestimation is a little weaker on the day immediately before the end of the month as opposed to the preceding three days. The latter finding suggests that the liquidity premium decreases as uncertainty about the periodic settlement is resolved to a great extent just before the final day of the settlement months. The above findings are intact even if the sample period is split in 1995.

3.5. **Specification and estimation results: the case of monthly euro yen rates** Three kinds of implied forward rates, one-month-ahead one-month forward rates ($f_{t,1,1}$), one-month-ahead two-month forward rates ($f_{t,1,2}$), and two-month-ahead one-month forward rates ($f_{t,2,1}$) can be constructed from one-month, two-month, and three month rates available from the euro yen market. As a result, the forecast error can be defined as

[12] More specifically, the BOJ first changed the policy instrument from the official discount to the overnight call rate in March, 1995. The market participants, however, did not recognize the change in policy instruments very well. When the BOJ announced the call rate as targets again in September, 1995, they started to pay serious attention to the change.

the difference between the implied forward rate and the corresponding ex-post rate, or $f_{t,i,j} - r_{t+i,j}$.

In order to examine the presence of systematic forecasting errors, we regress the above forecast error on the timing dummies that are constructed as follows. First, each month is divided into four periods, (i) the period of the first week, (ii) the period after the first week until the last day of the reserve maintenance period, (iii) the period after the last day before the last week, and (iv) the period of the last week. Second, a dummy variable $m_{t,i,j}$ is constructed for the jth period of month i at time t. The empirical specification is thus defined as follows:

$$f_{t,i,j} - r_{t+i,j} = \sum_{i=1}^{12} \sum_{j=1}^{4} \beta_{i,j} m_{t,i,j}$$

The above specification excludes constant terms to avoid liner dependence.

If the implied forward rate overestimates the future spot rate in a particular timing, then the corresponding coefficient on a monthly dummy $\beta_{i,j}$ is significantly large. As in the previous estimation procedures, explanatory variables include the dummy variables of changes in the official discount rates. Tables 3-1 through 3-3 report estimation results, where the standard error is adjusted for heteroskedasticity and serial correlation with lags of either one or two months.

Considering that settlements are concentrated during the last week of each settlement month, $\{\beta_{i-1,j}\}_{j=1,2,3,4}$, $\beta_{i-1,4}$ in particular should be large relative to other coefficients for settlement month i in the case of one-month-ahead rates (Table 3-1 and 3-2). $\{\beta_{i-2,j}\}_{j=1,2,3,4}$ should be large for settlement month i in the case of two-month-ahead rates (Table 3-3).

According to the tables, however, the evidence for this prediction is not as strong as in the previous subsections. In Table 3-1, $\{\beta_{8,j}\}_{j=1,2,4}$ and $\{\beta_{11,j}\}_{j=2,3}$ are indeed significantly positive in cases using the policy dummy variables, but $\{\beta_{2,j}\}_{j=1,2,3,4}$ tend to be small contrary to the prediction. The estimation results of both Tables 3-2 and Table 3-3 basically follow the pattern demonstrated in Table 3-1.

As suggested before, however, the above finding or the absence of strong liquidity impact is fairly reasonable in that participating financial institutions, often highly-rated, are unlikely to finance liquidity demands due to domestic settlement practices in the euro market. In addition, any distortion in the term structure is likely to be arbitrated by creditworthy banks participating in the offshore market; consequently, it would be difficult to observe distortion motivated by settlement practices in this market.

3.6. Specification and estimation results: the case of monthly GENSAKI rates

We apply the same empirical framework as above to the monthly rate available from the GENSAKI market. Tables 4-1 through 4-3 report estimation results, where the standard error is adjusted for heteroskedasticity and serial correlation with lags of either one or two months.

The estimated parameters are not necessarily consistent with predictions in cases without any policy dummy variables. However, once policy dummies are included as explanatory variables, and surprises about monetary operation are controlled, then the estimated coefficients on $m_{t,i,j}$ yield a pattern consistent with the theoretical prediction in the case of one-month-ahead one month rates (the third column of Table 4-1). As shown in Figure 1, the coefficients associated with February, August, and November are large relative to those with adjoining months, thereby implying that assets with maturities at settlement months are priced more highly than assets with maturities beyond it. As shown in Tables 4-2 and 4-3, the case of one-month-ahead two month rates follows the same pattern as above, while the case of two-month-ahead one month rates does not generate any consistent pattern even after controlling for unexpected policy changes.

Compared with the previous subsection, the liquidity impact is much stronger in the GENSAKI market than in the euro yen market. It thus follows that, in the open domestic market where financial institutions as well as non-financial institutions take part, accordingly, the term structure of interest rates is substantially distorted by liquidity demands due to domestic settlement practices.

4. Conclusion

This paper has explored the theoretical possibility that asset pricing is heavily influenced by current demand for financial assets based on Holmström and Tirole [2001]; one of the basic messages from their model is that asset demand in preparation for liquidity events may assess highly short-term assets with maturities at a liquidity event relative to longer-term assets. Then, we empirically examined this implication, regarding the periodic settlement that prevails among Japanese firms as liquidity events.

In terms of the overnight and one-week forecasting in the call market, we find that assets with maturities at the end of the settlement months, March, September, and December, are indeed priced more highly than assets with maturities beyond the last day of these months. Such findings are quite robust with respect to alternative specifications and sample periods.

With regard to the one-month-ahead forecasting in the GENSAKI market, estimation results also present evidence of liquidity impact of the periodic settlement on the term structure of interest rates. In contrast, there is no clear evidence in the euro yen market (the offshore market), where the money rate is expected to be free from liquidity demands due to domestic settlement practices.

The periodic settlement practice may be justified as a device to economize liquidity uses by concentrating settlements at a particular timing. Our overall estimation results, however, indicate that the settlement practice results in not liquidity savings, but additional liquidity demands. In other words, this practice makes money markets carry a heavy load, thereby yielding a liquidity premium in the term structure of interest rates.

Our findings suggest that liquidity demand matters in yielding deviation from the expectations hypothesis of the term structure. While the periodic settlement, regarded as a repeated liquidity event in this paper, is specific to Japanese practice, once any liquidity event is properly identified in bond or money markets of other countries, then we will have an opportunity to examine whether liquidity demand has any effect on the term structure of interest rates as predicted by the liquidity-based asset pricing model.

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Table 1: Biases in Forecasting Errors

forecasting one-day-ahead overnight rates based on the tomorrow-next transaction

	From May 16, 1994 to Nov. 21, 1997								From Sep. 12, 1995 to Nov. 21, 1997			
	W/O policy change dummy		With policy change dummy		W/O policy change dummy		With policy change dummy					
Constant	1.249	(0.116 ***)	1.168	(0.098 ***)	1.246	(0.117 ***)	1.169	(0.098 ***)	0.996	(0.102 ***)	0.991	(0.102 ***)
DMSD	25.676	(12.464 **)	7.488	(3.814 **)	14.878	(10.513 *)	3.866	(2.918 *)	8.004	(4.343 **)	3.787	(3.441)
DOTM	0.110	(0.324)	0.191	(0.318)	-0.662	(0.894)	-0.104	(0.365)	0.425	(0.349)	0.060	(0.403)
DRR	1.903	(1.012 **)	1.222	(0.711 **)	1.766	(1.020 **)	1.065	(0.704 *)	1.856	(0.495 ***)	1.874	(0.489 ***)
C1WM	---	(---)	---	(---)	1.771	(1.726)	0.674	(0.255 ***)	---	(---)	0.704	(0.273 ***)
C1WR	---	(---)	---	(---)	-0.164	(0.038 ***)	-0.179	(0.036 ***)	---	(---)	0.352	(0.349)
DFS3	0.983	(0.653 *)	1.063	(0.650 *)	0.985	(0.653 *)	1.063	(0.650 *)	1.793	(0.803 **)	1.799	(0.803 **)
D940929	---	(---)	66.344	(3.813 ***)	---	(---)	69.966	(2.918 ***)	---	(---)	---	(---)
D950330	---	(---)	116.344	(3.813 ***)	---	(---)	107.837	(5.256 ***)	---	(---)	---	(---)
D950413	---	(---)	31.985	(0.707 ***)	---	(---)	32.141	(0.701 ***)	---	(---)	---	(---)
D950414	---	(---)	23.832	(0.098 ***)	---	(---)	23.831	(0.098 ***)	---	(---)	---	(---)
D950907	---	(---)	37.832	(0.098 ***)	---	(---)	37.831	(0.098 ***)	---	(---)	---	(---)
Sample	875		875		875		875		542		542	
$\bar{R}^2$	0.209		0.775		0.288		0.785		0.142		0.214	

Notes:

1. DMSD denotes the dummy variable that takes a value of one at the timing of forecasting for the final day of the settlement month, or one day before the end of either March, September, or December, otherwise zero.
2. DOTM denotes the dummy variable that takes a value of one, one day before the end of either January, February, April, May, June, July, August, October, or November, otherwise zero.
3. DRR denotes the dummy variable that takes a value of one, one day before the final day of the reserve maintenance period each month, otherwise zero.
4. C1WM denotes a change in one week call rates from “six day” before the final day of the settlement month (March, September, or December) to “five day” before, implying tightness in the call market at the final settlement date.
5. C1WR denotes a change in one week call rates from “six day” before the final day of the reserve maintenance period to “five day” before, implying tightness in the call market at the final reserve maintenance day.
6. DFS3 denotes the dummy variables that takes a value of one when there is a fund shortage of more than three trillion yen in the reserve market due to demand for banknotes and the treasury fund transaction on the following day, otherwise zero, implying the tightness of the cash market.
7. DYYMMDD denotes the dummy variable that takes a value of one when the official discount rate is changed on DD/MM/YY, otherwise zero.
8. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one day lags based on Newey and West [1987].
9. ***, **, and * denote significance levels of 1%, 5%, and 10% respectively.

Table 2: Biases in Forecasting Errors

forecasting one week rolling call rates based on one week call rates

	From Nov. 1, 1988 to Nov. 21, 1997		From Nov. 1, 1988 to Dec. 30, 1994		From Sep. 12, 1995 to Nov. 21, 1997
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy	
Constant	3.296 (0.391***)	2.989 (0.370***)	3.092 (0.543***)	2.861 (0.530***)	3.651 (0.315***)
DJAN4	1.443 (2.766)	1.750 (2.761)	3.058 (4.016)	3.289 (4.011)	-1.222 (0.315***)
DJAN3	0.386 (2.813)	0.693 (2.803)	1.498 (4.155)	1.730 (4.142)	-1.079 (0.332***)
DJAN2	2.131 (2.734)	2.438 (2.721)	3.833 (3.913)	4.064 (3.893)	-0.008 (1.014)
DJAN1	4.138 (2.698*)	4.611 (2.993*)	6.478 (3.551**)	7.353 (4.077**)	-0.222 (0.844)
DFEB4	-2.439 (1.180**)	-2.132 (1.173**)	-3.212 (1.592**)	-2.980 (1.587**)	-0.222 (0.437)
DFEB3	-2.489 (1.277**)	-2.181 (1.271**)	-3.307 (1.753**)	-3.075 (1.748**)	-0.436 (0.349)
DFEB2	-0.392 (1.523)	-0.085 (1.518)	-0.492 (2.232)	-0.261 (2.228)	0.778 (0.374**)
DFEB1	2.300 (1.539*)	2.607 (1.533**)	3.551 (2.219*)	3.782 (2.215**)	1.385 (0.630**)
DMAR4	70.056 (14.499***)	82.418 (15.893***)	84.463 (18.626***)	97.652 (17.342***)	43.992 (14.740***)
DMAR3	86.053 (16.773***)	93.088 (19.965***)	109.693 (17.914***)	113.275 (21.179***)	42.278 (17.887***)
DMAR2	80.758 (16.717***)	74.746 (18.256***)	104.212 (18.538***)	97.243 (20.778***)	32.992 (11.438***)
DMAR1	24.348 (10.221***)	20.443 (10.961**)	30.794 (14.226**)	24.665 (15.419*)	1.849 (1.161*)
DAPR4	1.852 (1.012**)	2.159 (1.004**)	2.094 (1.339*)	2.325 (1.334**)	1.635 (2.043)
DAPR3	2.978 (2.066*)	3.286 (2.062*)	4.450 (2.951*)	4.681 (2.948*)	0.135 (0.555)
DAPR2	3.237 (2.849)	3.545 (2.846)	4.364 (4.185)	4.595 (4.183)	0.094 (1.030)
DAPR1	3.357 (2.373*)	3.665 (2.370*)	3.906 (3.401)	4.137 (3.399)	2.064 (0.600***)
DMAY4	2.182 (3.222)	-0.844 (0.855)	3.220 (4.787)	-1.715 (1.094*)	-0.151 (0.709)
DMAY3	1.990 (2.831)	-0.629 (0.747)	3.742 (4.083)	-0.399 (1.089)	-0.651 (0.425*)
DMAY2	1.537 (2.030)	-0.477 (1.048)	3.062 (2.739)	-0.096 (1.191)	0.278 (1.780)
DMAY1	1.898 (1.651)	1.045 (1.096)	3.497 (2.161*)	2.033 (1.366*)	0.171 (1.358)
DJUN4	-2.089 (1.426*)	-0.961 (1.330)	-2.282 (1.995)	-0.817 (1.946)	-0.008 (0.622)
DJUN3	-0.567 (1.188)	-0.350 (1.312)	-0.666 (1.534)	-0.639 (1.790)	1.564 (1.186*)
DJUN2	0.923 (1.633)	0.434 (1.612)	0.950 (2.091)	-0.128 (2.025)	2.992 (2.777)
DJUN1	3.342 (2.326*)	1.442 (1.312)	4.639 (3.237*)	1.556 (1.688)	2.349 (2.481)
DJUL4	0.242 (1.082)	0.549 (1.075)	-0.215 (1.496)	0.017 (1.494)	1.635 (1.023*)
DJUL3	-1.445 (1.229)	-1.138 (1.219)	-2.125 (1.674)	-1.894 (1.666)	0.849 (0.703)
DJUL2	-0.640 (1.474)	-0.333 (1.466)	-1.180 (1.798)	-0.948 (1.791)	3.349 (0.325***)
DJUL1	-1.201 (1.198)	-0.894 (1.191)	-1.355 (1.597)	-1.123 (1.593)	1.135 (0.358***)
DAUG4	-2.849 (1.281**)	-2.836 (1.388**)	-4.016 (1.564***)	-4.531 (1.653***)	0.564 (0.903)
DAUG3	-3.061 (1.211***)	-2.637 (1.289**)	-3.740 (1.594***)	-3.499 (1.817**)	-0.365 (0.691)
DAUG2	-3.200 (1.197***)	-2.776 (1.314**)	-3.877 (1.612***)	-3.636 (1.841**)	-0.793 (0.507*)
DAUG1	-0.475 (0.910)	-0.168 (0.891)	0.389 (1.170)	0.620 (1.163)	-1.151 (0.787*)
DSEP4	36.484 (10.668***)	36.792 (10.667***)	51.340 (12.123***)	51.571 (12.120***)	6.826 (3.105**)
DSEP3	35.248 (11.495***)	35.555 (11.495***)	49.033 (14.177***)	49.265 (14.177***)	7.730 (4.259**)
DSEP2	37.611 (11.960***)	37.919 (11.959***)	52.864 (14.330***)	53.095 (14.330***)	7.159 (3.787**)
DSEP1	8.342 (5.014**)	8.649 (5.013**)	12.089 (7.474*)	12.320 (7.475**)	1.492 (1.291)
DOCT4	1.035 (1.631)	1.343 (1.627)	1.446 (2.240)	1.678 (2.238)	0.266 (1.913)
DOCT3	2.753 (2.624)	3.060 (2.622)	4.162 (3.708)	4.393 (3.706)	-0.014 (1.974)
DOCT2	2.730 (2.247)	3.038 (2.243*)	4.085 (3.230)	4.316 (3.227*)	0.073 (0.953)
DOCT1	2.069 (1.712)	2.376 (1.708*)	2.777 (2.381)	3.008 (2.378)	0.707 (1.765)
DNOV4	2.299 (2.456)	2.607 (2.453)	3.510 (3.051)	3.741 (3.048)	-1.579 (0.894**)
DNOV3	3.140 (3.155)	3.448 (3.152)	4.367 (3.959)	4.598 (3.957)	-0.793 (1.333)
DNOV2	5.568 (4.261*)	5.875 (4.259*)	7.181 (5.346*)	7.413 (5.344*)	0.278 (1.481)
DNOV1	11.159 (7.685*)	11.466 (7.684*)	14.332 (9.306*)	14.563 (9.305*)	-0.329 (2.153)
DDEC4	22.318 (8.308***)	19.579 (8.765**)	28.077 (9.710***)	25.171 (10.804***)	2.522 (0.395***)
DDEC3	20.534 (8.216***)	17.148 (8.366**)	25.836 (9.741***)	21.993 (10.470**)	2.336 (0.321***)
DDEC2	22.960 (10.484**)	18.995 (10.883**)	28.743 (12.714**)	24.208 (13.904**)	3.077 (0.369***)
DDEC1	12.952 (10.090*)	13.259 (10.088*)	16.611 (12.332*)	16.842 (12.329*)	-0.361 (0.504)
DRR4	-0.901 (0.884)	-0.843 (0.770)	-1.742 (1.141*)	-1.290 (1.073)	1.158 (0.524**)
DRR3	-0.291 (0.875)	0.134 (0.819)	-0.358 (1.221)	0.233 (1.165)	0.844 (0.605*)
DRR2	0.684 (0.768)	0.819 (0.730)	0.760 (1.052)	1.090 (1.047)	0.897 (0.481**)
DRR1	-0.118 (0.586)	0.140 (0.541)	-0.124 (0.787)	0.223 (0.771)	0.029 (0.408)
D890531-4	--- (---)	23.476 (0.370***)	--- (---)	23.603 (0.530***)	--- (---)
D890531-3	--- (---)	29.998 (0.783***)	--- (---)	30.996 (0.973***)	--- (---)
D890531-2	--- (---)	26.336 (0.659***)	--- (---)	26.235 (0.967***)	--- (---)
D890531-1	--- (---)	20.897 (1.285***)	--- (---)	20.340 (1.344***)	--- (---)
D891011-4	--- (---)	-9.685 (0.370***)	--- (---)	-9.558 (0.530***)	--- (---)
D891011-3	--- (---)	-17.596 (0.370***)	--- (---)	-17.468 (0.530***)	--- (---)
D891011-2	--- (---)	-22.310 (0.370***)	--- (---)	-22.183 (0.530***)	--- (---)
D891011-1	--- (---)	-31.938 (0.712***)	--- (---)	-31.636 (1.002***)	--- (---)
D891225-4	--- (---)	-18.364 (0.370***)	--- (---)	-18.236 (0.530***)	--- (---)
D891225-3	--- (---)	-7.399 (0.370***)	--- (---)	-7.272 (0.530***)	--- (---)
D891225-2	--- (---)	-6.953 (0.370***)	--- (---)	-6.825 (0.530***)	--- (---)
D891225-1	--- (---)	1.663 (0.841**)	--- (---)	1.791 (0.922**)	--- (---)

Table 2 (continued)

	From Nov. 1, 1988 to Nov. 21, 1997				From Nov. 1, 1988 to Dec. 30, 1994				From Sep. 12, 1995 to Nov. 21, 1997	
	W/O policy change dummy		With policy change dummy		W/O policy change dummy		With policy change dummy			
D900320-4	---	(---)	-12.218	(0.656***)	---	(---)	-12.362	(0.941***)	---	(---)
D900320-3	---	(---)	-8.348	(0.444***)	---	(---)	-8.302	(0.633***)	---	(---)
D900320-2	---	(---)	-5.361	(0.444***)	---	(---)	-5.316	(0.633***)	---	(---)
D900320-1	---	(---)	19.136	(3.578***)	---	(---)	19.264	(3.592***)	---	(---)
D900830-4	---	(---)	1.083	(0.370***)	---	(---)	1.210	(0.530**)	---	(---)
D900830-3	---	(---)	1.851	(0.370***)	---	(---)	1.978	(0.530***)	---	(---)
D900830-2	---	(---)	2.651	(1.344**)	---	(---)	4.473	(1.577***)	---	(---)
D900830-1	---	(---)	-1.050	(1.253)	---	(---)	-0.062	(1.692)	---	(---)
D910701-4	---	(---)	-7.385	(1.296***)	---	(---)	-7.401	(1.899***)	---	(---)
D910701-3	---	(---)	0.807	(1.273)	---	(---)	1.224	(1.729)	---	(---)
D910701-2	---	(---)	7.167	(1.580***)	---	(---)	7.856	(1.969***)	---	(---)
D910701-1	---	(---)	19.873	(1.637***)	---	(---)	19.887	(1.919***)	---	(---)
D911114-4	---	(---)	4.797	(0.370***)	---	(---)	4.925	(0.530***)	---	(---)
D911114-3	---	(---)	7.476	(0.370***)	---	(---)	7.603	(0.530***)	---	(---)
D911114-2	---	(---)	14.693	(0.756***)	---	(---)	15.268	(1.044***)	---	(---)
D911114-1	---	(---)	5.106	(1.318***)	---	(---)	5.049	(1.499***)	---	(---)
D911230-4	---	(---)	-0.685	(0.370**)	---	(---)	-0.558	(0.530)	---	(---)
D911230-3	---	(---)	27.422	(8.820***)	---	(---)	21.957	(10.880**)	---	(---)
D911230-2	---	(---)	33.238	(8.409***)	---	(---)	28.521	(10.530***)	---	(---)
D911230-1	---	(---)	38.454	(10.924***)	---	(---)	33.369	(13.961***)	---	(---)
D920401-4	---	(---)	-62.639	(15.892***)	---	(---)	-77.745	(17.327***)	---	(---)
D920401-3	---	(---)	-0.041	(19.946)	---	(---)	-20.100	(21.134)	---	(---)
D920401-2	---	(---)	65.569	(18.240***)	---	(---)	43.199	(20.744**)	---	(---)
D920401-1	---	(---)	42.255	(18.451**)	---	(---)	38.162	(21.392**)	---	(---)
D920727-4	---	(---)	0.190	(0.370)	---	(---)	0.317	(0.530)	---	(---)
D920727-3	---	(---)	7.333	(0.370***)	---	(---)	7.460	(0.530***)	---	(---)
D920727-2	---	(---)	10.476	(0.370***)	---	(---)	10.603	(0.530***)	---	(---)
D920727-1	---	(---)	21.190	(1.096***)	---	(---)	21.317	(1.160***)	---	(---)
D930204-4	---	(---)	-4.916	(2.985**)	---	(---)	-7.530	(4.069**)	---	(---)
D930204-3	---	(---)	1.775	(2.985)	---	(---)	-0.839	(4.069)	---	(---)
D930204-2	---	(---)	38.529	(0.370***)	---	(---)	38.657	(0.530***)	---	(---)
D930204-1	---	(---)	27.368	(6.584***)	---	(---)	27.496	(6.595***)	---	(---)
D930921-4	---	(---)	-2.236	(0.444***)	---	(---)	-2.191	(0.633***)	---	(---)
D930921-3	---	(---)	14.199	(0.370***)	---	(---)	14.326	(0.530***)	---	(---)
D930921-2	---	(---)	10.404	(0.370***)	---	(---)	10.532	(0.530***)	---	(---)
D930921-1	---	(---)	7.284	(0.370***)	---	(---)	7.412	(0.530***)	---	(---)
D950331-4	---	(---)	-0.185	(0.370)	---	(---)	---	(---)	---	(---)
D950331-3	---	(---)	-45.853	(15.892***)	---	(---)	---	(---)	---	(---)
D950331-2	---	(---)	-60.505	(19.946***)	---	(---)	---	(---)	---	(---)
D950331-1	---	(---)	-8.690	(15.423)	---	(---)	---	(---)	---	(---)
D950414-4	---	(---)	-4.221	(0.370***)	---	(---)	---	(---)	---	(---)
D950414-3	---	(---)	7.336	(0.756***)	---	(---)	---	(---)	---	(---)
D950414-2	---	(---)	14.056	(0.769***)	---	(---)	---	(---)	---	(---)
D950414-1	---	(---)	25.925	(1.359***)	---	(---)	---	(---)	---	(---)
D950707-4	---	(---)	7.297	(0.370***)	---	(---)	---	(---)	---	(---)
D950707-3	---	(---)	13.440	(0.370***)	---	(---)	---	(---)	---	(---)
D950707-2	---	(---)	18.440	(0.370***)	---	(---)	---	(---)	---	(---)
D950707-1	---	(---)	23.297	(0.496***)	---	(---)	---	(---)	---	(---)
D950908-4	---	(---)	14.154	(0.370***)	---	(---)	---	(---)	---	(---)
D950908-3	---	(---)	21.297	(0.370***)	---	(---)	---	(---)	---	(---)
D950908-2	---	(---)	26.868	(0.370***)	---	(---)	---	(---)	---	(---)
D950908-1	---	(---)	37.104	(1.227***)	---	(---)	---	(---)	---	(---)
Sample	2,248		2,248		1,532		1,532		542	
$\bar{R}^2$	0.402		0.458		0.477		0.510		0.489	

Notes:

1. DMMMX denotes the dummy variable that takes a value of one, X day before the end of month MMM, otherwise zero.
2. DRRX denotes the dummy variable that takes a value of one, X day before the final day of the reserve maintenance period each month, otherwise zero.
3. DYYMMDD-X denotes the dummy variable that takes a value of one when the official discount rate is changed on DD/MM/YY, otherwise zero. X implies the X days before the policy change.
4. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one week lags based on Newey and West [1987].
5. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Table 3-1: Biases in Forecasting Errors

forecasting one-month-ahead one month rates based on euro yen TIBOR

	From Jan. 4, 1990 to Nov. 21, 1997				From Jan. 4, 1990 to Dec. 30, 1994			
	W/O policy change dummy		With policy change dummy		W/O policy change dummy		With policy change dummy	
mJAN1	5.475	(7.509)	0.023	(5.104)	6.839	(11.924)	-2.264	(8.356)
mJAN2	7.502	(9.320)	-2.564	(4.629)	10.551	(13.633)	-5.380	(7.348)
mJAN3	-0.087	(6.303)	-3.136	(4.874)	-1.257	(10.142)	-6.502	(7.622)
mJAN4	-12.628	(5.703**)	-12.628	(5.703**)	-16.311	(8.212**)	-16.311	(8.212**)
mFEB1	-3.711	(3.172)	-3.711	(3.172)	-5.914	(4.329*)	-5.914	(4.329*)
mFEB2	-2.468	(4.281)	-4.374	(4.219)	-9.109	(4.708**)	-9.109	(4.708**)
mFEB3	-2.718	(5.174)	-5.138	(5.981)	-10.811	(6.447**)	-14.292	(5.882***)
mFEB4	-7.237	(5.212*)	-11.950	(7.109**)	-17.295	(3.116***)	-23.297	(2.727***)
mMAR1	9.989	(5.557**)	2.121	(3.222)	6.637	(5.063*)	0.019	(2.791)
mMAR2	9.056	(6.904*)	-2.235	(1.649*)	3.327	(5.071)	-3.632	(1.943**)
mMAR3	11.723	(9.407)	1.719	(5.143)	2.177	(6.193)	1.613	(6.942)
mMAR4	8.128	(8.641)	8.128	(8.641)	-0.216	(8.930)	-0.216	(8.930)
mAPR1	2.319	(5.831)	2.319	(5.831)	-4.123	(6.836)	-4.123	(6.836)
mAPR2	4.239	(3.622)	4.239	(3.622)	0.432	(4.236)	0.432	(4.236)
mAPR3	3.210	(2.513)	3.210	(2.513)	2.025	(3.600)	2.025	(3.600)
mAPR4	6.246	(3.238**)	6.246	(3.238**)	4.656	(4.631)	4.656	(4.631)
mMAY1	6.837	(3.023**)	6.837	(3.023**)	3.825	(3.368)	3.825	(3.368)
mMAY2	5.224	(3.588*)	5.224	(3.588*)	0.187	(3.744)	0.187	(3.744)
mMAY3	1.802	(3.055)	2.208	(2.825)	-0.949	(4.424)	-0.276	(3.890)
mMAY4	-1.976	(4.207)	-0.693	(3.785)	-3.916	(6.577)	-1.763	(5.589)
mJUN1	3.904	(2.999*)	4.313	(4.349)	6.146	(4.394*)	8.300	(6.006*)
mJUN2	7.951	(5.196*)	1.471	(3.393)	4.643	(6.409)	-1.319	(4.440)
mJUN3	8.365	(6.085*)	1.589	(5.261)	5.434	(8.071)	-5.663	(6.010)
mJUN4	15.308	(6.846**)	13.369	(6.639**)	15.848	(9.849*)	11.533	(9.141)
mJUL1	8.808	(4.748**)	5.324	(4.078*)	6.639	(6.530)	-0.001	(3.958)
mJUL2	4.600	(3.150*)	1.529	(1.849)	5.181	(4.657)	-0.009	(1.955)
mJUL3	6.313	(3.979*)	7.399	(3.914**)	5.604	(4.911)	5.604	(4.911)
mJUL4	-0.148	(5.688)	5.827	(4.925)	-4.734	(7.148)	0.557	(5.713)
mAUG1	5.145	(6.987)	11.501	(6.691**)	1.824	(8.877)	8.438	(8.887)
mAUG2	14.353	(9.780*)	16.611	(9.877**)	10.015	(15.579)	14.301	(15.881)
mAUG3	12.769	(7.273**)	10.278	(9.332)	8.194	(10.142)	5.172	(15.211)
mAUG4	16.014	(8.570**)	14.399	(9.570*)	16.301	(12.986)	13.132	(15.713)
mSEP1	10.279	(6.411*)	9.793	(7.102*)	10.024	(9.326)	9.104	(11.058)
mSEP2	2.588	(6.429)	2.588	(6.429)	3.119	(10.221)	3.119	(10.221)
mSEP3	1.455	(5.351)	1.455	(5.351)	4.183	(8.105)	4.183	(8.105)
mSEP4	4.537	(4.420)	4.537	(4.420)	8.626	(6.390*)	8.626	(6.390*)
mOCT1	3.663	(1.872**)	3.429	(1.726**)	5.380	(2.730**)	4.961	(2.498**)
mOCT2	2.291	(2.347)	1.094	(1.768)	2.495	(3.646)	0.399	(2.777)
mOCT3	-1.563	(1.867)	-2.007	(2.096)	-2.988	(2.937)	-4.133	(3.497)
mOCT4	-2.958	(3.751)	-1.754	(3.966)	-7.177	(4.901*)	-5.920	(5.659)
mNOV1	2.919	(3.462)	3.556	(3.665)	0.155	(4.021)	0.641	(4.637)
mNOV2	4.293	(2.507**)	4.293	(2.507**)	3.044	(3.093)	3.044	(3.093)
mNOV3	5.973	(3.619**)	4.978	(3.792*)	4.604	(4.234)	3.105	(4.505)
mNOV4	6.007	(4.206*)	1.779	(4.748)	6.572	(6.522)	-0.621	(7.886)
mDEC1	2.397	(9.658)	-3.632	(6.459)	3.374	(13.499)	-5.523	(9.159)
mDEC2	3.689	(10.385)	-5.842	(5.480)	4.806	(14.463)	-8.933	(7.517)
mDEC3	7.131	(9.785)	-2.642	(4.426)	9.630	(13.115)	-3.900	(6.445)
mDEC4	6.543	(5.727)	5.566	(6.355)	8.562	(7.839)	7.213	(9.197)
D900320-1	---	(---)	2.549	(6.317)	---	(---)	13.073	(2.838***)
D900320-2	---	(---)	17.050	(3.408***)	---	(---)	19.153	(3.006***)
D900320-3	---	(---)	26.201	(1.679***)	---	(---)	27.598	(1.971***)
D900830-1	---	(---)	-36.679	(5.926***)	---	(---)	-33.068	(8.265***)
D900830-2	---	(---)	-42.772	(9.319***)	---	(---)	-39.343	(15.029***)
D900830-3	---	(---)	-1.771	(9.985)	---	(---)	2.695	(15.393)

Table 3-1 (continued)

	From Jan. 4, 1990 to Nov. 21, 1997		From Jan. 4, 1990 to Dec. 30, 1994	
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy
D910701-1	--- (---)	-9.967 (6.667*)	--- (---)	-10.768 (6.407**)
D910701-2	--- (---)	30.597 (3.531***)	--- (---)	33.387 (4.542***)
D910701-3	--- (---)	41.347 (5.105***)	--- (---)	47.697 (5.919***)
D911114-1	--- (---)	9.338 (2.823***)	--- (---)	10.480 (3.269***)
D911114-2	--- (---)	-11.803 (3.026***)	--- (---)	-8.453 (4.310**)
D911114-3	--- (---)	-6.368 (3.593**)	--- (---)	-3.036 (4.775)
D911230-1	--- (---)	33.823 (8.925***)	--- (---)	35.967 (10.440***)
D911230-2	--- (---)	75.727 (5.575***)	--- (---)	78.577 (7.642***)
D911230-3	--- (---)	68.808 (4.376***)	--- (---)	70.371 (6.310***)
D920401-1	--- (---)	8.802 (5.994*)	--- (---)	16.936 (3.106***)
D920401-2	--- (---)	7.764 (2.205***)	--- (---)	9.443 (2.098***)
D920401-3	--- (---)	3.410 (4.004)	--- (---)	3.947 (5.138)
D920727-1	--- (---)	7.248 (6.617)	--- (---)	12.038 (7.140**)
D920727-2	--- (---)	27.871 (4.246***)	--- (---)	33.196 (4.131***)
D920727-3	--- (---)	23.544 (1.849***)	--- (---)	25.081 (1.955***)
D930204-1	--- (---)	6.837 (5.857)	--- (---)	6.746 (7.697)
D930204-2	--- (---)	52.811 (4.895***)	--- (---)	55.204 (7.954***)
D930204-3	--- (---)	52.854 (4.466***)	--- (---)	55.945 (7.053***)
D930921-1	--- (---)	20.450 (9.428**)	--- (---)	24.313 (14.933*)
D930921-2	--- (---)	18.875 (9.004**)	--- (---)	21.677 (14.851*)
D930921-3	--- (---)	4.867 (7.364)	--- (---)	5.749 (11.609)
D950331-1	--- (---)	14.869 (4.934***)	--- (---)	--- (---)
D950331-2	--- (---)	-2.990 (11.407)	--- (---)	--- (---)
D950331-3	--- (---)	15.417 (10.257*)	--- (---)	--- (---)
D950414-1	--- (---)	25.774 (11.754**)	--- (---)	--- (---)
D950414-2	--- (---)	55.091 (3.954***)	--- (---)	--- (---)
D950414-3	--- (---)	69.421 (5.149***)	--- (---)	--- (---)
D950707-1	--- (---)	-0.300 (3.518)	--- (---)	--- (---)
D950707-2	--- (---)	11.357 (5.462**)	--- (---)	--- (---)
D950707-3	--- (---)	27.353 (3.534***)	--- (---)	--- (---)
D950908-1	--- (---)	-18.462 (4.653***)	--- (---)	--- (---)
D950908-2	--- (---)	2.998 (9.447)	--- (---)	--- (---)
D950908-3	--- (---)	20.368 (9.064**)	--- (---)	--- (---)
Sample	1,950	1,950	1,234	1,234
$\bar{R}^2$	0.066	0.353	0.072	0.347

Notes:

1. In this table, the first period, the second, the third, and the fourth, denoted by the Xth period, respectively imply the period of the first five business days in each month, sixth business day to the last day of the reserve maintenance period, the first day of the reserve maintenance period to the sixth business day from the end of the month, and the last five days.
2. mMMMX denotes the dummy variable that takes a value of one during the Xth period of month MMM, otherwise zero.
3. DYYMMDD-Z denotes the dummy variable that takes a value of one during the first two weeks (Z=1), the next one week (Z=2), or the last week (Z=3) of the month when the official discount rate is changed on DD/MM/YY, otherwise zero.
4. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one-month lags based on Newey and West [1987].
5. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Table 3-2: Biases in Forecasting Errors
forecasting one-month-ahead two month rates based on euro yen TIBOR

	From Jan. 4, 1990 to Nov. 21, 1997		From Jan. 4, 1990 to Dec. 30, 1994	
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy
mJAN1	2.388 (6.658)	-2.296 (4.697)	0.585 (10.517)	-7.792 (6.555)
mJAN2	5.426 (7.571)	-2.637 (4.596)	6.360 (11.272)	-7.008 (6.578)
mJAN3	-2.463 (5.907)	-4.842 (4.985)	-4.589 (9.217)	-8.848 (7.375)
mJAN4	-7.811 (5.709*)	-7.811 (5.709*)	-10.248 (8.447)	-10.248 (8.447)
mFEB1	-6.534 (2.635***)	-6.534 (2.635***)	-10.296 (2.726***)	-10.296 (2.726***)
mFEB2	-5.938 (5.901)	-8.409 (5.778*)	-14.254 (7.080**)	-14.254 (7.080**)
mFEB3	-4.127 (5.007)	-6.387 (5.433)	-11.985 (6.175**)	-13.706 (6.186**)
mFEB4	-3.635 (4.007)	-7.618 (5.104*)	-11.723 (1.720***)	-14.921 (2.377***)
mMAR1	9.792 (5.818**)	1.569 (2.261)	4.273 (3.838)	-1.726 (1.033**)
mMAR2	8.394 (7.215)	-3.094 (1.510**)	1.996 (5.339)	-4.981 (1.483***)
mMAR3	13.507 (8.686*)	4.114 (4.266)	5.224 (5.138)	4.793 (5.718)
mMAR4	7.592 (7.577)	7.592 (7.577)	0.158 (7.321)	0.158 (7.321)
mAPR1	2.773 (5.640)	2.773 (5.640)	-1.142 (7.166)	-1.142 (7.166)
mAPR2	3.459 (3.853)	3.459 (3.853)	1.190 (5.278)	1.190 (5.278)
mAPR3	5.183 (2.926**)	5.183 (2.926**)	4.972 (4.513)	4.972 (4.513)
mAPR4	6.823 (3.420**)	6.823 (3.420**)	4.730 (4.566)	4.730 (4.566)
mMAY1	8.295 (3.418***)	8.295 (3.418***)	4.059 (2.857*)	4.059 (2.857*)
mMAY2	5.535 (4.619)	5.535 (4.619)	-1.407 (4.550)	-1.407 (4.550)
mMAY3	2.547 (3.194)	2.867 (2.819)	-0.903 (4.273)	-0.146 (3.642)
mMAY4	-1.861 (4.391)	-0.598 (3.900)	-5.015 (6.652)	-2.593 (5.730)
mJUN1	3.307 (3.155)	4.254 (4.514)	5.568 (4.537)	7.991 (6.181*)
mJUN2	5.440 (4.622)	0.618 (4.018)	2.480 (5.965)	-1.861 (5.553)
mJUN3	5.684 (5.254)	0.053 (5.297)	3.150 (6.596)	-6.338 (6.532)
mJUN4	14.342 (6.549**)	12.446 (6.494**)	13.803 (9.630*)	9.578 (9.261)
mJUL1	6.614 (5.347)	4.094 (5.537)	2.694 (6.825)	-2.697 (6.265)
mJUL2	4.693 (4.397)	1.704 (4.055)	2.900 (6.613)	-2.766 (5.789)
mJUL3	8.342 (5.941*)	9.544 (5.957*)	5.198 (7.776)	5.198 (7.776)
mJUL4	-1.503 (7.520)	5.879 (5.975)	-8.148 (9.488)	-0.699 (6.575)
mAUG1	4.594 (7.627)	12.682 (6.483**)	3.778 (10.606)	13.088 (8.801*)
mAUG2	11.769 (9.845)	15.513 (9.507*)	9.596 (15.777)	16.718 (15.058)
mAUG3	8.417 (8.409)	6.848 (10.561)	3.056 (11.628)	2.182 (17.196)
mAUG4	9.389 (8.756)	8.070 (9.961)	8.554 (13.548)	5.861 (16.803)
mSEP1	9.817 (6.419*)	9.283 (7.120*)	10.755 (9.731)	9.843 (11.625)
mSEP2	2.468 (6.202)	2.468 (6.202)	3.023 (9.894)	3.023 (9.894)
mSEP3	2.836 (4.331)	2.836 (4.331)	4.823 (6.800)	4.823 (6.800)
mSEP4	4.556 (4.719)	4.556 (4.719)	8.549 (6.829)	8.549 (6.829)
mOCT1	3.316 (3.702)	3.182 (3.686)	7.444 (4.597*)	7.266 (4.604*)
mOCT2	2.223 (1.934)	1.536 (1.739)	4.086 (2.614*)	3.197 (2.505)
mOCT3	-2.632 (1.591**)	-2.711 (1.722*)	-3.092 (2.261*)	-3.196 (2.628)
mOCT4	-2.028 (2.808)	-0.862 (2.885)	-5.075 (3.760*)	-3.561 (4.269)
mNOV1	2.373 (2.185)	3.008 (2.248*)	1.096 (2.769)	1.844 (3.061)
mNOV2	3.336 (2.359*)	3.336 (2.359*)	3.489 (3.569)	3.489 (3.569)
mNOV3	3.643 (3.156)	2.829 (3.330)	3.306 (4.273)	2.106 (4.570)
mNOV4	3.731 (3.146)	0.272 (3.517)	4.859 (4.933)	-0.900 (6.027)
mDEC1	2.700 (8.025)	-2.425 (5.539)	3.879 (11.196)	-3.590 (7.969)
mDEC2	2.127 (10.070)	-6.470 (5.986)	2.740 (14.032)	-9.696 (8.222)
mDEC3	6.034 (9.050)	-2.447 (4.580)	8.153 (12.154)	-3.795 (6.751)
mDEC4	5.735 (6.963)	5.018 (7.768)	6.413 (9.706)	5.211 (11.383)
Sample	1,950	1,950	1,234	1,234
$\bar{R}^2$	0.051	0.332	0.055	0.313

Notes:
1. Estimated coefficients for the policy change dummies are not reported in this table.
2. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one-month lags based on Newey and West [1987].
3. See the footnotes of Table 3-1.

Table 3-3: Biases in Forecasting Errors

forecasting two-month-ahead one month rates based on euro yen TIBOR

	From Jan. 4, 1990 to Nov. 21, 1997		From Jan. 4, 1990 to Dec. 30, 1994	
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy
mJAN1	-1.834 (7.457)	-5.450 (7.047)	-8.701 (10.582)	-17.094 (7.553**)
mJAN2	0.242 (8.313)	-5.269 (8.510)	-5.875 (11.012)	-17.865 (8.463**)
mJAN3	-8.586 (6.991)	-10.839 (7.538*)	-19.780 (7.663***)	-26.762 (5.834***)
mJAN4	-7.350 (6.196)	-10.234 (6.851*)	-16.858 (6.905***)	-24.150 (8.184***)
mFEB1	1.322 (7.507)	-8.780 (6.096*)	-9.123 (5.311**)	-18.842 (5.844***)
mFEB2	2.220 (13.252)	-11.005 (10.017)	-15.254 (11.563*)	-22.659 (12.486**)
mFEB3	4.643 (11.805)	-10.146 (8.742)	-11.915 (9.025*)	-23.050 (10.540**)
mFEB4	9.192 (12.777)	-8.275 (9.838)	-7.144 (10.838)	-20.102 (11.927**)
mMAR1	11.405 (11.927)	-3.716 (5.909)	-2.207 (8.519)	-11.073 (6.801*)
mMAR2	11.821 (10.714)	-4.457 (4.052)	2.249 (9.658)	-7.442 (4.485**)
mMAR3	18.631 (8.844**)	7.804 (3.967**)	10.805 (5.767**)	7.316 (4.995*)
mMAR4	13.198 (7.601**)	7.073 (5.343*)	5.290 (5.486)	6.276 (6.764)
mAPR1	8.896 (7.078)	4.863 (6.815)	4.255 (9.585)	4.255 (9.585)
mAPR2	8.460 (6.195*)	6.287 (6.323)	4.079 (8.835)	4.079 (8.835)
mAPR3	10.188 (5.245**)	10.188 (5.245**)	8.975 (8.168)	8.975 (8.168)
mAPR4	7.107 (4.922*)	7.107 (4.922*)	2.645 (6.304)	2.645 (6.304)
mMAY1	14.712 (4.932***)	10.647 (4.742**)	8.242 (3.489***)	4.892 (4.452)
mMAY2	13.402 (6.914**)	7.793 (6.840)	2.480 (6.628)	-1.987 (7.447)
mMAY3	12.511 (6.054**)	6.217 (4.016*)	5.819 (5.615)	2.155 (4.520)
mMAY4	14.348 (7.377**)	3.490 (5.221)	11.625 (10.713)	-0.696 (7.175)
mJUN1	10.834 (6.534**)	-0.760 (4.942)	10.384 (10.294)	-3.530 (6.125)
mJUN2	7.480 (6.440)	-2.880 (5.667)	5.286 (9.884)	-8.740 (6.776*)
mJUN3	10.226 (5.246**)	0.329 (6.409)	9.055 (8.099)	-5.047 (9.956)
mJUN4	14.166 (6.746**)	9.428 (8.643)	10.268 (10.172)	2.431 (12.007)
mJUL1	7.223 (9.760)	15.644 (10.682*)	-0.947 (14.448)	11.759 (17.512)
mJUL2	17.236 (13.331*)	25.908 (13.704**)	9.270 (20.427)	21.531 (22.782)
mJUL3	22.038 (13.432*)	33.727 (12.262***)	13.224 (19.712)	29.727 (20.327*)
mJUL4	13.489 (11.601)	17.532 (11.568*)	5.638 (17.163)	10.404 (16.899)
mAUG1	13.879 (8.398**)	10.561 (9.329)	11.810 (12.896)	4.984 (13.844)
mAUG2	12.602 (7.172**)	6.900 (9.237)	11.072 (11.462)	5.224 (14.034)
mAUG3	8.562 (9.329)	-1.514 (12.173)	3.037 (13.223)	-9.618 (18.167)
mAUG4	7.304 (9.231)	0.963 (12.786)	7.783 (14.681)	-0.758 (20.281)
mSEP1	12.551 (8.411*)	10.790 (10.947)	16.413 (12.980)	14.490 (16.077)
mSEP2	3.910 (6.086)	2.961 (6.812)	5.614 (9.635)	4.545 (11.662)
mSEP3	1.137 (2.647)	0.756 (3.365)	2.835 (3.848)	3.005 (6.130)
mSEP4	2.664 (4.443)	3.454 (4.629)	3.497 (7.040)	5.362 (7.672)
mOCT1	6.237 (5.829)	7.027 (6.377)	9.817 (8.877)	11.683 (10.262)
mOCT2	5.084 (5.003)	5.969 (5.589)	7.179 (7.729)	9.059 (9.246)
mOCT3	2.693 (4.259)	3.937 (4.731)	3.273 (7.107)	5.460 (8.607)
mOCT4	5.286 (5.973)	0.630 (5.811)	4.791 (9.214)	-2.936 (9.388)
mNOV1	5.241 (8.381)	-2.166 (4.528)	7.293 (13.319)	-5.125 (7.505)
mNOV2	7.461 (9.346)	-1.407 (5.222)	11.160 (14.482)	-3.245 (8.821)
mNOV3	8.006 (10.075)	-0.455 (5.510)	11.413 (14.009)	-0.769 (8.257)
mNOV4	8.442 (6.707)	1.250 (3.553)	12.966 (10.225)	1.271 (6.165)
mDEC1	8.027 (8.530)	0.479 (8.731)	10.844 (11.714)	-0.583 (13.523)
mDEC2	4.769 (10.722)	-6.298 (10.221)	6.409 (14.890)	-10.495 (15.625)
mDEC3	5.454 (9.773)	-6.008 (8.227)	7.346 (13.163)	-10.220 (12.362)
mDEC4	-6.542 (8.212)	-15.751 (8.459**)	-8.239 (11.308)	-22.760 (11.848**)
Sample	1,950	1,950	1,234	1,234
$\bar{R}^2$	0.039	0.482	0.056	0.419

Notes:

1. Estimated coefficients for the policy change dummies are not reported in this table.
2. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with two-month lags based on Newey and West [1987].
3. See the footnotes of Table 3-1.

Table 4-1: Biases in Forecasting Errors

forecasting one-month-ahead one month rates based on Gensaki rates

	From Nov. 1, 1988 to Nov. 21, 1997		From Nov. 1, 1988 to Dec. 28, 1994	
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy
mJAN1	0.682 (4.926)	-3.914 (3.904)	1.189 (7.375)	-6.052 (6.068)
mJAN2	4.177 (9.450)	-4.096 (5.540)	5.659 (12.787)	-6.190 (7.745)
mJAN3	0.134 (5.104)	-3.779 (3.554)	0.507 (7.789)	-5.705 (5.471)
mJAN4	2.230 (5.669)	-2.332 (3.784)	3.432 (8.452)	-3.560 (5.877)
mFEB1	2.150 (3.977)	-0.276 (3.121)	3.855 (5.839)	0.177 (4.819)
mFEB2	1.410 (2.396)	1.410 (2.396)	2.212 (3.451)	2.212 (3.451)
mFEB3	-0.531 (1.903)	-0.332 (2.005)	-0.611 (2.823)	-0.326 (3.015)
mFEB4	-2.400 (2.478)	-1.562 (2.638)	-3.651 (3.500)	-2.508 (3.974)
mMAR1	2.287 (5.827)	-5.367 (2.469**)	-1.910 (6.240)	-5.782 (3.571*)
mMAR2	3.085 (7.194)	-5.010 (2.445**)	-2.960 (5.898)	-5.208 (3.527*)
mMAR3	4.512 (9.351)	-7.809 (2.935***)	-4.353 (5.834)	-8.399 (3.976**)
mMAR4	1.615 (7.878)	-8.388 (2.822***)	-6.194 (4.116*)	-9.007 (3.978**)
mAPR1	-0.459 (4.313)	-4.641 (1.973***)	-4.215 (2.604*)	-4.215 (2.604*)
mAPR2	-1.493 (2.856)	-3.869 (1.665**)	-3.843 (2.215**)	-3.843 (2.215**)
mAPR3	-3.422 (1.864**)	-3.422 (1.864**)	-4.023 (2.709*)	-4.023 (2.709*)
mAPR4	-3.615 (1.247***)	-3.615 (1.247***)	-4.485 (1.704***)	-4.485 (1.704***)
mMAY1	-1.953 (1.768)	-0.430 (1.462)	-3.975 (1.712**)	-1.963 (1.001**)
mMAY2	-0.706 (1.865)	0.620 (1.414)	-2.715 (2.158)	-0.809 (0.911)
mMAY3	-0.996 (2.186)	0.702 (1.671)	-3.666 (2.199**)	-1.457 (1.127*)
mMAY4	-0.599 (1.636)	-1.277 (1.711)	-1.866 (1.929)	-3.262 (1.909**)
mJUN1	0.665 (2.820)	-1.980 (1.642)	1.817 (4.113)	-2.231 (2.479)
mJUN2	5.522 (5.331)	-1.566 (3.029)	2.677 (5.699)	-1.238 (4.036)
mJUN3	5.540 (5.437)	-2.482 (3.122)	2.998 (6.023)	-2.401 (4.353)
mJUN4	7.832 (6.624)	-5.003 (2.519**)	6.301 (8.555)	-6.549 (3.352**)
mJUL1	7.152 (6.468)	-2.508 (3.333)	4.661 (7.987)	-3.118 (4.616)
mJUL2	2.691 (4.413)	-2.325 (1.710*)	4.151 (6.527)	-3.555 (2.617*)
mJUL3	3.445 (4.814)	-1.842 (1.424*)	5.978 (6.932)	-2.004 (2.079)
mJUL4	-0.139 (2.402)	0.959 (2.126)	0.645 (3.358)	2.431 (2.831)
mAUG1	1.068 (3.421)	3.813 (2.923*)	1.222 (5.038)	5.688 (4.386*)
mAUG2	6.336 (5.960)	7.048 (5.893)	4.870 (8.748)	9.601 (8.267)
mAUG3	7.287 (7.478)	6.139 (7.507)	3.923 (9.778)	6.271 (10.331)
mAUG4	8.536 (7.953)	2.177 (8.346)	6.377 (11.071)	2.175 (11.950)
mSEP1	7.395 (7.615)	0.437 (7.639)	5.926 (10.720)	0.090 (10.748)
mSEP2	-1.188 (4.778)	-2.119 (3.983)	-3.272 (6.925)	-4.283 (6.151)
mSEP3	-5.928 (4.508*)	-3.206 (3.026)	-9.367 (6.235*)	-5.977 (4.587*)
mSEP4	-5.439 (4.132*)	-1.067 (2.090)	-8.602 (5.790*)	-2.269 (3.154)
mOCT1	-5.107 (5.797)	0.464 (2.502)	-8.377 (8.378)	-0.193 (3.872)
mOCT2	-2.496 (4.860)	-1.229 (2.728)	-4.514 (7.106)	-2.955 (4.017)
mOCT3	-1.238 (4.882)	-4.218 (4.492)	-3.078 (7.477)	-8.369 (6.775)
mOCT4	-1.255 (3.932)	-2.790 (3.916)	-3.583 (5.626)	-6.393 (5.531)
mNOV1	3.840 (3.227)	4.115 (3.457)	2.648 (4.494)	2.820 (5.020)
mNOV2	4.213 (3.286*)	4.760 (3.343*)	3.779 (4.607)	4.484 (4.822)
mNOV3	2.330 (2.939)	2.330 (2.939)	2.240 (3.997)	2.240 (3.997)
mNOV4	5.213 (4.126)	2.355 (3.390)	7.155 (5.301*)	3.399 (4.585)
mDEC1	3.682 (7.271)	-4.055 (2.382**)	5.774 (9.197)	-4.075 (3.264)
mDEC2	0.268 (7.202)	-5.440 (3.162**)	1.784 (9.126)	-5.521 (4.283*)
mDEC3	1.362 (7.649)	-5.596 (2.875**)	3.058 (9.906)	-6.174 (4.017*)
mDEC4	1.412 (7.067)	-5.744 (2.495**)	3.118 (8.990)	-6.159 (3.343**)
P890531-1	--- (---)	-13.699 (1.524***)	--- (---)	-12.073 (1.001***)
P890531-2	--- (---)	-14.560 (1.672***)	--- (---)	-12.401 (1.128***)
P890531-3	--- (---)	-8.182 (1.757***)	--- (---)	-6.197 (1.954***)
P891011-1	--- (---)	-31.659 (3.114***)	--- (---)	-29.265 (4.748***)
P891011-2	--- (---)	-41.277 (2.317***)	--- (---)	-40.184 (3.330***)
P891011-3	--- (---)	-52.348 (2.376***)	--- (---)	-51.335 (3.622***)

Table 4-1(continued)

	From Nov. 1, 1988 to Nov. 21, 1997		From Nov. 1, 1988 to Dec. 28, 1994	
	W/O policy change dummy	With policy change dummy	W/O policy change dummy	With policy change dummy
D891225-1	--- (---)	-1.634 (2.603)	--- (---)	-2.146 (3.571)
D891225-2	--- (---)	-10.100 (3.203***)	--- (---)	-10.019 (4.311**)
D891225-3	--- (---)	-8.472 (2.734***)	--- (---)	-8.004 (3.772**)
D900320-1	--- (---)	-7.549 (2.659***)	--- (---)	-6.854 (3.681**)
D900320-2	--- (---)	-14.232 (2.359***)	--- (---)	-13.904 (3.437***)
D900320-3	--- (---)	-16.603 (2.405***)	--- (---)	-16.274 (3.404***)
D900830-1	--- (---)	-24.708 (3.768***)	--- (---)	-26.798 (5.371***)
D900830-2	--- (---)	-26.258 (7.009***)	--- (---)	-26.874 (9.627***)
D900830-3	--- (---)	-20.404 (7.535***)	--- (---)	-20.469 (10.636**)
D910701-1	--- (---)	23.801 (3.080***)	--- (---)	24.293 (3.337***)
D910701-2	--- (---)	36.080 (3.013***)	--- (---)	35.950 (4.143***)
D910701-3	--- (---)	38.484 (2.514***)	--- (---)	39.759 (3.385***)
D911114-1	--- (---)	25.111 (3.954***)	--- (---)	28.722 (5.767***)
D911114-2	--- (---)	6.275 (3.692**)	--- (---)	8.955 (4.901**)
D911114-3	--- (---)	-8.765 (3.206***)	--- (---)	-7.979 (4.662**)
D911230-1	--- (---)	71.264 (2.370***)	--- (---)	71.090 (3.241***)
D911230-2	--- (---)	68.125 (2.873***)	--- (---)	68.504 (3.961***)
D911230-3	--- (---)	66.098 (2.461***)	--- (---)	66.540 (3.329***)
D920401-1	--- (---)	34.010 (2.354***)	--- (---)	34.316 (3.431***)
D920401-2	--- (---)	30.058 (2.973***)	--- (---)	30.648 (4.004***)
D920401-3	--- (---)	16.268 (2.774***)	--- (---)	16.882 (3.870***)
D920727-1	--- (---)	45.611 (2.686***)	--- (---)	46.675 (3.455***)
D920727-2	--- (---)	41.152 (1.535***)	--- (---)	42.169 (2.352***)
D920727-3	--- (---)	43.362 (1.444***)	--- (---)	43.525 (2.093***)
D930204-1	--- (---)	41.367 (4.435***)	--- (---)	43.449 (6.283***)
D930204-2	--- (---)	48.065 (3.426***)	--- (---)	49.712 (5.297***)
D930204-3	--- (---)	36.392 (3.761***)	--- (---)	36.779 (5.523***)
D930921-1	--- (---)	37.444 (7.468***)	--- (---)	37.494 (10.636***)
D930921-2	--- (---)	32.290 (5.951***)	--- (---)	33.364 (8.556***)
D930921-3	--- (---)	14.665 (3.460***)	--- (---)	17.133 (5.256***)
D950331-1	--- (---)	46.431 (2.936***)	--- (---)	--- (---)
D950331-2	--- (---)	41.651 (8.689***)	--- (---)	--- (---)
D950331-3	--- (---)	43.959 (8.863***)	--- (---)	--- (---)
D950414-1	--- (---)	35.978 (9.133***)	--- (---)	--- (---)
D950414-2	--- (---)	42.529 (2.775***)	--- (---)	--- (---)
D950414-3	--- (---)	30.294 (1.763***)	--- (---)	--- (---)
D950707-1	--- (---)	37.192 (2.932***)	--- (---)	--- (---)
D950707-2	--- (---)	40.339 (2.508***)	--- (---)	--- (---)
D950707-3	--- (---)	41.324 (3.018***)	--- (---)	--- (---)
D950908-1	--- (---)	22.557 (6.831***)	--- (---)	--- (---)
D950908-2	--- (---)	32.023 (8.347***)	--- (---)	--- (---)
D950908-3	--- (---)	28.273 (6.917***)	--- (---)	--- (---)
Sample	2,218	2,218	1,507	1,507
$\bar{R}^2$	0.024	0.666	0.029	0.591

Notes:

1. In this table, the first period, the second, the third, and the fourth, denoted by the Xth period, imply respectively the period of the first five business days in a month, sixth business day to the last day of the reserve maintenance period, the first day of the reserve maintenance period to the sixth business day from the end of the month, and the last five days.
2. mMMMX denotes the dummy variable that takes a value of one during the Xth period of month MMM, otherwise zero.
3. DYYMMDD-Z denotes the dummy variable that takes a value of one during the first two weeks (Z=1), the next one week (Z=2), or the last week (Z=3) of the month when the official discount rate is changed on DD/MM/YY, otherwise zero.
4. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one-month lags based on Newey and West [1987].
5. ***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.

Table 4-2: Biases in Forecasting Errors
forecasting one-month-ahead two month rates based on Gensaki rates

	From Nov. 1, 1988 to Nov. 21, 1997				From Nov. 1, 1988 to Dec. 28, 1994			
	W/O policy change dummy		With policy change dummy		W/O policy change dummy		With policy change dummy	
mJAN1	0.261	(4.651)	-4.165	(3.491)	0.035	(6.967)	-7.062	(5.215*)
mJAN2	3.428	(8.784)	-4.540	(4.884)	4.265	(11.931)	-7.349	(6.530)
mJAN3	0.677	(4.368)	-3.071	(2.518)	0.674	(6.657)	-5.337	(3.658*)
mJAN4	2.587	(4.930)	-1.809	(2.758)	3.751	(7.334)	-3.023	(4.211)
mFEB1	1.977	(3.670)	-0.378	(2.435)	3.291	(5.424)	-0.299	(3.749)
mFEB2	1.026	(2.000)	1.026	(2.000)	1.245	(2.914)	1.245	(2.914)
mFEB3	-0.410	(1.676)	-0.273	(1.742)	-1.076	(2.462)	-0.899	(2.593)
mFEB4	-1.534	(2.261)	-0.958	(2.449)	-2.773	(3.172)	-2.065	(3.639)
mMAR1	2.374	(5.565)	-4.911	(2.100***)	-2.551	(5.109)	-5.588	(2.979**)
mMAR2	2.909	(7.158)	-4.839	(2.242**)	-3.759	(5.326)	-5.285	(3.236*)
mMAR3	4.697	(9.310)	-7.287	(2.577***)	-4.679	(5.197)	-8.207	(3.456***)
mMAR4	2.288	(7.673)	-7.843	(2.131***)	-5.516	(3.588*)	-8.604	(2.964***)
mAPR1	0.151	(4.142)	-3.987	(1.653***)	-3.690	(2.165**)	-3.690	(2.165**)
mAPR2	-1.384	(2.829)	-3.845	(1.381***)	-4.027	(1.793**)	-4.027	(1.793**)
mAPR3	-3.309	(1.330***)	-3.309	(1.330***)	-4.038	(1.761**)	-4.038	(1.761**)
mAPR4	-3.215	(1.166***)	-3.215	(1.166***)	-4.157	(1.497***)	-4.157	(1.497***)
mMAY1	-1.279	(2.220)	0.830	(1.520)	-3.472	(2.472*)	-0.499	(1.022)
mMAY2	0.423	(2.429)	2.260	(1.751*)	-1.217	(3.283)	1.600	(1.740)
mMAY3	0.043	(2.881)	2.373	(2.158)	-2.311	(3.607)	0.977	(2.556)
mMAY4	-0.242	(2.312)	0.237	(2.591)	-1.545	(2.955)	-1.005	(3.589)
mJUN1	1.578	(2.419)	0.067	(1.998)	2.771	(3.446)	0.550	(2.986)
mJUN2	6.727	(5.252)	0.560	(3.576)	4.139	(5.347)	1.727	(4.736)
mJUN3	6.597	(5.438)	-0.856	(3.600)	4.286	(5.772)	-0.089	(4.970)
mJUN4	8.922	(6.597*)	-3.468	(2.633*)	7.620	(8.255)	-4.159	(3.767)
mJUL1	9.350	(6.301*)	-0.313	(2.894)	7.740	(7.641)	0.075	(4.035)
mJUL2	4.460	(4.330)	-0.443	(1.806)	6.590	(6.292)	-0.777	(2.819)
mJUL3	5.976	(5.035)	0.499	(1.729)	9.671	(7.046*)	1.634	(2.544)
mJUL4	2.582	(2.905)	3.814	(2.587*)	4.473	(4.045)	6.565	(3.303**)
mAUG1	3.731	(3.897)	6.811	(3.314**)	5.044	(5.722)	10.274	(4.687**)
mAUG2	9.276	(6.346*)	10.610	(6.289**)	9.267	(9.416)	14.838	(8.604**)
mAUG3	9.541	(7.494)	9.339	(7.317)	6.951	(9.887)	10.428	(9.952)
mAUG4	9.462	(7.576)	3.875	(7.805)	7.779	(10.519)	4.601	(11.173)
mSEP1	7.934	(7.470)	1.133	(7.533)	6.661	(10.508)	0.999	(10.592)
mSEP2	0.328	(5.102)	-0.500	(4.142)	-1.342	(7.451)	-2.112	(6.440)
mSEP3	-3.956	(4.561)	-1.021	(2.692)	-7.198	(6.325)	-3.360	(4.009)
mSEP4	-4.288	(4.178)	0.290	(2.069)	-7.611	(5.767*)	-0.969	(2.940)
mOCT1	-4.935	(6.122)	0.974	(2.475)	-8.600	(8.791)	0.040	(3.747)
mOCT2	-3.171	(4.875)	-1.521	(2.757)	-5.858	(7.027)	-3.777	(3.933)
mOCT3	-1.237	(4.457)	-3.636	(4.285)	-3.612	(6.732)	-8.064	(6.313)
mOCT4	-1.433	(3.774)	-2.472	(3.954)	-4.349	(5.272)	-6.448	(5.527)
mNOV1	4.895	(3.219*)	5.250	(3.444*)	3.959	(4.517)	4.266	(5.053)
mNOV2	5.501	(3.357*)	5.959	(3.480**)	5.362	(4.718)	5.965	(5.020)
mNOV3	3.463	(3.300)	3.463	(3.300)	3.333	(4.504)	3.333	(4.504)
mNOV4	2.364	(3.430)	0.905	(4.215)	2.866	(4.523)	0.947	(5.755)
mDEC1	3.072	(6.370)	-1.774	(2.332)	4.743	(8.070)	-1.428	(3.115)
mDEC2	0.187	(6.536)	-3.912	(2.269**)	1.438	(8.283)	-3.801	(3.016)
mDEC3	1.458	(7.315)	-5.137	(2.001***)	2.814	(9.490)	-6.005	(2.672**)
mDEC4	1.410	(7.197)	-5.920	(1.947***)	2.793	(9.192)	-6.774	(2.529***)
Sample	2,218		2,218		1,507		1,507	
$\bar{R}^2$	0.035		0.660		0.049		0.583	

Notes:
1. Estimated coefficients for the policy change dummies are not reported in this table.
2. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with one-month lags based on Newey and West [1987].
3. See the footnotes of Table 4-1.

Table 4-3: Biases in Forecasting Errors
forecasting two-month-ahead one month rates based on Gensaki rates

	From Nov. 1, 1988 to Nov. 21, 1997				From Nov. 1, 1988 to Dec. 28, 1994			
	W/O policy change dummy		With policy change dummy		W/O policy change dummy		With policy change dummy	
mJAN1	1.185	(6.335)	-3.700	(4.714)	1.265	(9.467)	-6.572	(7.136)
mJAN2	3.147	(9.854)	-5.648	(7.110)	3.337	(13.416)	-9.486	(9.631)
mJAN3	0.568	(4.549)	-1.951	(3.860)	-0.036	(6.853)	-4.242	(6.057)
mJAN4	0.801	(4.599)	-1.719	(4.213)	0.021	(6.755)	-2.547	(6.825)
mFEB1	4.085	(6.063)	-4.354	(3.760)	0.784	(6.790)	-4.599	(5.856)
mFEB2	4.583	(8.500)	-4.441	(3.475)	-3.010	(6.273)	-4.937	(5.082)
mFEB3	2.662	(9.512)	-8.855	(3.183***)	-5.760	(7.837)	-9.873	(5.019**)
mFEB4	2.064	(10.167)	-8.972	(3.426***)	-7.820	(6.733)	-10.242	(5.034**)
mMAR1	2.444	(10.068)	-7.832	(3.389**)	-7.304	(6.472)	-8.245	(5.036*)
mMAR2	1.536	(10.302)	-8.295	(3.487***)	-8.510	(6.766)	-7.998	(5.046*)
mMAR3	1.738	(10.578)	-10.369	(4.056***)	-8.983	(6.369*)	-11.327	(5.439**)
mMAR4	-0.544	(8.734)	-10.946	(3.367***)	-9.720	(4.637**)	-12.417	(4.629***)
mAPR1	-1.687	(5.310)	-5.379	(2.155***)	-7.484	(2.878***)	-5.369	(2.938**)
mAPR2	-2.369	(4.349)	-4.367	(1.740***)	-7.303	(2.750***)	-5.437	(2.231***)
mAPR3	-4.098	(2.910*)	-2.475	(2.357)	-7.494	(2.724***)	-5.306	(1.563***)
mAPR4	-3.916	(2.646*)	-2.329	(2.070)	-6.958	(2.541***)	-4.843	(1.317***)
mMAY1	2.544	(5.766)	-0.206	(2.478)	-1.031	(6.500)	0.385	(3.547)
mMAY2	7.309	(7.108)	2.100	(3.169)	5.461	(8.661)	5.431	(3.914*)
mMAY3	6.608	(7.866)	1.824	(2.808)	1.932	(8.744)	4.302	(3.841)
mMAY4	9.618	(8.396)	-3.342	(2.474*)	7.384	(10.438)	-4.162	(3.837)
mJUN1	9.397	(8.416)	-6.854	(2.723***)	8.009	(10.892)	-8.553	(4.015**)
mJUN2	10.324	(8.746)	-5.798	(2.646**)	9.135	(11.463)	-7.419	(3.460**)
mJUN3	10.357	(8.537)	-5.436	(3.102**)	10.688	(11.740)	-5.930	(4.371*)
mJUN4	11.087	(8.241*)	-3.182	(3.731)	11.597	(11.418)	-3.692	(5.569)
mJUL1	12.107	(8.052*)	5.681	(5.816)	11.357	(11.018)	8.226	(8.817)
mJUL2	13.324	(7.955**)	10.065	(8.620)	14.968	(11.393*)	13.952	(12.562)
mJUL3	16.220	(8.898**)	13.023	(9.961*)	18.420	(12.728*)	18.499	(14.794)
mJUL4	13.352	(8.770*)	9.684	(8.919)	13.988	(12.689)	12.778	(13.235)
mAUG1	13.324	(9.837*)	9.580	(10.198)	14.230	(14.384)	12.904	(15.506)
mAUG2	11.212	(9.885)	10.816	(11.060)	10.527	(14.628)	15.788	(17.037)
mAUG3	6.632	(10.162)	6.806	(11.632)	2.018	(13.473)	8.072	(17.751)
mAUG4	4.918	(9.724)	4.111	(11.061)	0.573	(13.501)	5.355	(17.247)
mSEP1	3.052	(11.804)	1.064	(11.255)	-1.406	(16.842)	1.176	(16.777)
mSEP2	-1.609	(10.451)	2.666	(7.502)	-5.198	(15.341)	1.749	(12.065)
mSEP3	-4.000	(9.279)	1.464	(4.383)	-8.876	(13.322)	-2.003	(6.580)
mSEP4	-4.385	(8.378)	1.191	(3.546)	-9.728	(11.985)	-2.758	(5.065)
mOCT1	-2.231	(7.818)	2.239	(4.881)	-8.053	(10.970)	-2.953	(7.532)
mOCT2	-1.410	(6.352)	-0.585	(5.828)	-6.322	(8.783)	-6.268	(8.611)
mOCT3	0.031	(4.961)	-0.310	(5.025)	-3.883	(7.134)	-5.350	(7.596)
mOCT4	-1.252	(5.630)	-0.138	(5.767)	-4.424	(8.082)	-3.408	(9.276)
mNOV1	8.797	(7.108)	6.159	(5.001)	10.612	(10.030)	6.678	(7.749)
mNOV2	8.118	(7.364)	4.464	(4.159)	10.352	(10.204)	5.158	(6.381)
mNOV3	5.323	(7.186)	1.851	(4.296)	6.812	(9.762)	2.025	(6.378)
mNOV4	4.707	(7.795)	1.573	(3.530)	6.878	(10.295)	2.879	(4.809)
mDEC1	2.389	(7.670)	-1.977	(3.106)	4.032	(9.738)	-1.438	(4.152)
mDEC2	1.353	(7.994)	-5.537	(4.592)	2.758	(10.123)	-6.341	(6.556)
mDEC3	2.696	(8.398)	-5.257	(4.650)	4.464	(10.865)	-6.449	(6.845)
mDEC4	3.074	(7.597)	-6.283	(4.557*)	4.661	(9.676)	-7.753	(6.293)
Sample	2,218		2,218		1,507		1,507	
$\bar{R}^2$	0.025		0.723		0.058		0.658	

Notes:
1. Estimated coefficients for the policy change dummies are not reported in this table.
2. Figures in parentheses are standard errors adjusted for heteroskedasticity and autocorrelation with two-month lags based on Newey and West [1987].
3. See the footnotes of Table 4-1.

Figure 1: Biases in Forecasting Errors for one-month ahead one-month rate in GENSAKI

Notes:

1. Figures are estimated parameters for time dummies in the estimation using the sample period from November 1988 to November 1997, including policy change dummies, in Table 4-1.
2. Shaded lines correspond to figures derived from adding and subtracting two times the standard errors for estimated parameters.