Hitotsubashi Journal of Economics 50 (2009), pp.71-85. © Hitotsubashi University

DOES THE EXPECTATION HYPOTHESIS HOLD AT THE SHORTEST END OF THE TERM STRUCTURE?*

IICHIRO UESUGI**

Institute of Economic Research, Hitotsubashi University
Kunitachi Tokyo 186-8603, Japan
iuesugi@ier.hit-u.ac.jp

AND

GUY M. YAMASHIRO

Department of Economics, California State University
Long Beach CA 90266, USA
gyamashi@csulb.edu

Accepted March 2009

Abstract

This paper examines the predictability smile at the shortest end of the term structure. The existence of a predictability smile has been well documented: spreads between long rates and short rates are able to forecast subsequent movements in interest rates well, provided the horizon is three months or less or two years or more. The predictive power of the spread at the shortest maturities, however, has not been adequately investigated. This is a potential shortcoming of the existing literature as a projection of the predictability smile to the shorter maturities is not a guarantee that the expectations hypothesis holds. In Japan, a positive spread between the forward and the spot rates has insufficient predictive power for the future spot rate innovations, while a negative spread has near-perfect predictive ability. Further, we provide evidence that this result is not unique to Japan, as we find this "asymmetric predictability" to be a feature of the very short-term money markets of the U.S., U.K. and Italy.

Keywords: Term Structure, Predictability, Money Market
JEL Classification: E43, E44, E52

* We thank Jim Hamilton, Wouter den Haan, Marjorie Flavin, Takeo Hoshi, Shigenori Shiratsuka, and Tsutomu Watanabe for many useful comments and discussions. Excellent research assistance by Keiji Saito is gratefully appreciated.
** Corresponding author.

I. *Introduction*

Do long-term interest rates reflect expected future short-term rates? Or, put more precisely, does the implied forward interest rate[1] forecast the future spot interest rate? According to the rational expectations theory of the term structure, the answer is yes. Most empirical investigations of the term structure, however, have rejected this prediction. Because the validity of the expectations hypothesis is fundamental to term structure theory, a large literature has been built around the relatively simple question of whether forward rates, or yield spreads, can forecast future spot rates. One area of research has been to examine how predictability varies across different maturities. The consensus is that yield spreads are able to predict the future spot rate better at shorter (three months or less) and longer (two years or more) horizons than those in between. Moreover, a graph of the slope coefficients, in a regression of realized spot rates on forward rates, displays a smile-shaped pattern referred to in the literature as the predictability smile.

The focus of this paper is to examine the predictive power of the forward interest rate at the shortest end of the term structure, where the forecast horizon is only one or two days. In this case, given the existing empirical findings, we may expect the forward interest rate to easily predict the future spot rate. On the other hand, if market institutions are such that one-time random shocks have large distortional effects, it may be that the predictive ability of the spread worsens. To investigate this issue, we introduce a pair of very short forward interest rates that have not, as of yet, been utilized by researchers: the "tomorrow next" (*TN*) rate and the "spot next" (*SN*) rate. Both have the same maturity as the overnight (*ON*) rate, but their contract terms are predetermined either one day (*TN*) or two days (*SN*) before procurement.

The *ON*, *TN*, and *SN* rates are all found in the Japanese money market. This market is characterized by several specific institutional requirements set by the Bank of Japan (BOJ). First, any financial institution that holds reserves in its BOJ provided current account, is required to have a non-negative reserve balance at end of each day. Second, all depository institutions are required to meet its reserve requirements by the end of the reserve maintenance period. The requirements are "asymmetric" in that financial institutions are penalized only when they are short of their respective reserve requirements. When financial institutions expects a high probability of running negative reserves, not only do they have strong demand for reserves which raises the expected value of the overnight interest rate but also they have strong incentives to secure the reserves amount with forward procurement contracts. These incentives possibly distort the relationship between the *ON*, *TN*, and *SN* rates as implied by the expectations hypothesis.

We find that in the Japanese money market, positive forward-spot rate spreads have insufficient predictive power for a subsequent movement in the future spot rate, while negative spreads have near-perfect predictive ability. This "asymmetric predictability" is consistent with the "asymmetric penalties" for overdrafts, and provides strong evidence that at the very short end of the term structure, institutional constraints can result in a sharp break of the predictability smile. Furthermore, this asymmetry is not unique to Japan, as we find that a negative spread has significantly better predictive power (at times near-perfect predictability)

[1] Throughout the paper, we use the terms "implied forward interest rate" and "forward interest rate" interchangeably.

than a positive spread in the U.S., U.K., and Italian money markets. Even though we have no solid evidence that the relevant institutional structures are identical across these countries the fact that financial institutions are penalized for negative reserve positions in all of them, may explain the asymmetric predictive ability of the spread.

The paper proceeds as follows. In section II, we briefly summarize the existing literature. In section III, we take a closer look at how institutional factors constrain the behavior of participants in the Japanese short-term money market. In section IV, we test the predictive ability of the spread at the shortest maturities in Japan. The estimation results for the U.S., U.K., and Italy are presented in section V. Section VI concludes.

II. *Existing Literature*

The relationship between the forward interest rate and the future spot interest rate has produced a large body of literature. The primary focus of the research has been to test the rational expectations hypothesis of the term structure. Under the expectations hypothesis, the forward rate is a combination of a shorter spot interest rate and a longer spot rate with twice the maturity of the shorter one.[2]

Let $i_{1,t}$ be the interest rate on the shorter (one-period) bond and $i_{2,t}$ be the interest rate on the longer (two-period) bond. Under the expectations hypothesis, investors are indifferent between holding the longer maturity bond or a series of shorter maturity bonds. In other words, the current long-term rate is equal to the average of the expected short-term rates over the duration of the bond,

$$f_{t,t+1}=2i_{2,t}-i_{1,t}. \tag{1}$$

Assuming rational expectations,

$$i_{1,t+1}=E_t(i_{1,t+1})+\varepsilon_{t+1}, \tag{2}$$

where ε_{t+1} is the forecast error orthogonal to the time t information set. Subtracting $i_{1,t}$ from both sides of equation (2), and assuming that the forward interest rate, $f_{t,t+1}$, is the unbiased estimator of $i_{1,t+1}$ yields

$$i_{1,t+1}-i_{1,t}=f_{t,t+1}-i_{1,t}+\varepsilon_{t+1}, \tag{3}$$

which provides the testing equation:

$$i_{1,t+1}-i_{1,t}=\alpha+\beta\,[f_{t,t+1}-i_{1,t}]+\varepsilon_{t+1} \tag{4}$$

with null hypotheses, $\alpha=0$ and $\beta=1$. Since the error term, ε_{t+1}, is uncorrelated with the right-hand side regressors, OLS provides consistent coefficient estimates.

β has been estimated over a range of maturities, from two weeks to five years, and for different market instruments,[3] including Treasury bills, Certificates of Deposit (CDs),

[2] The use of these maturities is standard in the literature.

[3] Although U.S. Treasury securities (bills, notes, and bonds) are generally regarded as closest to the theoretical ideal because of their negligible default risk, and no call provisions after 1985, other market instruments have also been used for analysis. In this case, however, we limit our discussion to U.S. dollar denominated assets. See Mishkin (1991),

Eurodollars,[4] and Commercial Paper (CP). Cook and Hahn (1990), and Rudebusch (1995) summarize the main results of the literature as follows:

(i) Estimates of β are significantly less than one for almost all instruments, data sets, and maturities.
(ii) Estimates of β for interest rates of short maturities (from two weeks to two months) are significantly positive.
(iii) Estimates of β for interest rates of medium maturities (from three months to twelve months) are not significantly different from zero.
(iv) Estimates of β for interest rates of long maturities (more than one or two years) appear to be significantly positive.

While the "predictability smile," outlined by points (ii) through (iv), is of great interest to economists,[5] result (i), the failure of the null of $\beta=1$, is the most significant of these results. This implies that the forward rate is a biased estimator of the future spot rate, which is inconsistent with the expectations hypothesis.

In addition to these standard estimations, other studies use long rates with maturities more than twice as long as the maturities of the short rates. In these non-standard estimations, since the errors overlap, the standard error of β must be corrected for serial correlation. Simon (1990), Campbell and Shiller (1991), Campbell (1995), and Roberds and Whiteman (1999) report the results from these estimations, with findings similar to those above. It must be emphasized, however, that none of these studies, standard or nonstandard, test if the expectations hypothesis holds at the shortest maturities.[6]

III. *Institutional Structure of Japan's Very Short-Term Money Market*[7]

In this section, we take a closer look at the organization of Japan's short-term money market. Participants in the very short-term money market are for the most part limited to financial institutions, and, many of them have few, if any, alternatives to short-term money market instruments. While most of the participants are primarily concerned with satisfying monthly reserve requirements, they also worry about maintaining non-negative (end-of-day) reserve levels. Thus, elements affecting the daily flow of funds are closely monitored. These factors include government expenditures, the central bank's market operations, and other market participants' procurement/investment behavior. We begin by documenting the market's

Hardouvelis (1994), and Jorion and Mishkin (1991) for studies of assets denominated in currencies other than U.S. dollars.

[4] See Jegadeesh and Pennacchi (1996).

[5] There have been many attempts to explain the observed pattern. For example, the improved forecasting performance of the spread at the longer horizons may imply some long run predictability arising from business cycle effects. Likewise, the inability of the spread to forecast the future spot rate for medium term securities may be due to the central bank's success, at the three to twelve month horizon, in smoothing interest rates. See Roberds and Whiteman (1999) and Rudebusch (1995) for more details.

[6] The sole exception (that the authors are aware of) is Saito, et al. (2001).

[7] This section is based on interviews conducted with people in charge of money market transactions at money market brokerages, city banks, foreign banks, and the central bank (Bank of Japan).

Table 1. Market Participants in Japan's Very Short-Term Money Market

	Procurement		Investment
	Overnight (ON)	Tomorrow next (TN) and later	
Unsecured Call	City banks, foreign banks	City banks, foreign banks	Investment trusts, regional banks, second-tier regional banks, agricultural cooperative banks, life and non-life insurers, trust banks
Euroyen	----------	Japanese banks (overseas branches), foreign banks	Japanese banks (domestic branches)
Forex Swap	----------	Foreign banks, Japanese banks	Japanese banks
Repo	----------	Securities firms, city banks	Investment trusts, foreign banks

Note: Modified from chart 3 in Inaba et al. (2001).

participants, and then discuss how these participants respond to changes in the procurement environment.

We focus our discussion on the period prior to the introduction of the zero interest rate policy (*zirp*) by the Bank of Japan. Following the introduction of *zirp*, money market interest rates, as well as the interest rate spreads were near zero, which makes the examination of the expectations hypothesis almost meaningless.[8]

1. Market Participants

We focus on markets with large amounts of very short-term transactions, namely the unsecured call market, the Euroyen market, the forex swap market, and the repurchase agreement (repo) market. The repo market differs somewhat from the other markets in that funds are invested and raised by putting up collateral. When collateral values are deducted, however, the rate in the repo market, under normal conditions, should be the same as in the other markets. Table 1 summarizes the main players on both the investment and procurement sides of the Japanese very short-term money market.

It is clear that there are few procurers of funds in the market. The main players are limited to city banks, foreign banks, and securities firms needing funds to hold bonds. On the investment side, there is a greater diversity of participants, and, in contrast to the procurement side, players are fixed in particular markets. Investment trusts, for example, invest only at the overnight (*ON*) rate because a portion of their funds must be available within the day due to the nature of their investments. Similarly, agricultural cooperative banks and life and non-life insurers, tend to allocate a great portion of their funds to the *ON* market. If, and when, they do decide to adjust their position, they do not put their funds into the tomorrow next (*TN*) market, but instead move to longer-term markets, such as the one-month and three-month bond markets. The main reason investors participate only in certain markets is that the opportunity cost of being unable to lend is much smaller than the various penalties incurred in the event of an overdraft. Because of this, we focus the remaining discussion on procurers of funds, and outline

[8] Note that the Bank of Japan has abandoned its *zirp* since June 2006. However, we have not examined if the current money market functions as it did prior to the introduction of *zirp*.

their behavior in the *ON* and *TN* markets.

2. Main Players on the Procurement Side of the Market

In order to understand the procurement behavior of securities firms and banks it is important that we make a distinction between the requirements faced by these institutions. There are two types of requirements with respect to the reserve level in Japan: (a) monthly reserve requirements, which are calculated from the deposit amount of each financial institution and must be met within a reserve maintenance period, and (b) positive end-of-day reserve levels. Securities firms need only satisfy (b), while banks must meet both (a) and (b). If institutions do not fulfill the respective requirements, they pay a penalty of the discount rate plus 3.75% (in case of failing to satisfy (a)) or the discount rate plus 6% (in case of failing to satisfy (b)).

(1) Securities Companies

While securities firms are exempt from monthly reserve requirements, they do face possible overdraft penalties if they fail to maintain a non-negative end-of-day reserve balance. Their ability to procure at the *ON* rate is limited for the following reasons. They tend to actively use the repo market, where bonds and cash are traded, and, by custom, settlements are *not* carried out on the day of the transaction, $t+0$, but on the following day, $t+1$, or even later. Securities firms, therefore, rarely turn to the *ON* market if they are in need of very short-term funds, and instead rely heavily on the *TN* or later markets. Because participants on the investment side of the very short-term money market are aware of this, credit lines for securities firms on the *ON* unsecured call market are either non-existent or extremely limited. In addition, concerns over whether clerical procedures[9] for *ON* market procurements will go smoothly, further reduces the incentives for securities firms to raise funds in the *ON* market. Thus, it is generally accepted that securities companies are active participants in the *TN* market, but not the *ON* market.

(2) City Banks and Foreign Banks

In contrast to securities firms, both city banks and foreign banks must satisfy their reserve requirements by the end of the maintenance period, *and* must maintain a non-negative end-of-day reserve balance. Because banks forecast the amount of funds they will need approximately two days in advance, they generally know how much money they will need on a particular day, with a reasonable degree of accuracy. Hence, these banks are in a position to choose the market, *ON* or *TN*, in which to raise funds. As previously discussed, however, players on the investment side of the short-term money market tend to participate in a specific market, usually the *ON* market. For this reason, those in charge of investments at these firms are more concerned with keeping labor costs down than with continually searching for the best returns. As a result, they simply set rates high enough to earn a small positive amount of interest each day. The resultant low rates provide a strong incentive for banks to mainly borrow in the *ON* market.

[9] Clerical procedures include communications through the short-term funds transaction confirmation system and delivery of promissory notes.

Yet, despite all the "certainties" surrounding the market, reserve shocks, or unexpected changes in economic activity affecting the level of bank reserves, are prevalent and result in significant market uncertainty. Reserve shocks are a serious concern for banks because large shocks increase the probability of negative end of day reserve levels, which incurs a stiff penalty from the central bank. Furthermore, at the end of the reserve maintenance period, banks face further penalties if they fall short of their reserve requirements. Under these circumstances, banks increase their demand for reserves. In addition, they prefer to raise a portion of the desired amount of funds on the *TN* market, even if they must pay a higher rate, rather than waiting an additional day to raise funds on the *ON* market. This incentive is even stronger for foreign banks operating in Japan. Foreign banks hold fewer reserves than domestic city banks because of their limited deposits. Thus, even moderate reserve shocks are likely to result in a negative reserve balance for these banks.

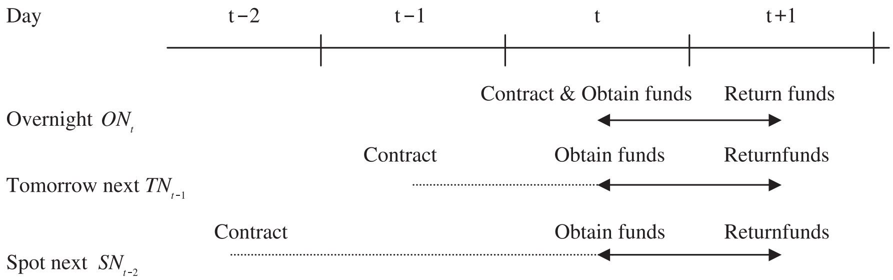
To summarize, city banks and foreign banks generally secure funds on the *ON* market, rather than the *TN* market, because of lower interest rates. Large reserve shocks, however, increase the possibility of an overdraft, and/or the possibility of failing to meet reserve requirements. To avoid the severe penalties associated with these events, banks not only increase their demand for reserves but also prefer to obtain a certain portion of funds in the forward market rather than waiting to participate in the *ON* market.

IV. *Estimation of Predictability: The Case of Japan*

This section implements a series of estimations to measure the predictive ability of the forward-spot spread in Japan. Subsection 1 discusses the details of the data. Subsection 2 contains the results of the standard estimations testing whether the rational expectations hypothesis of the term structure holds in the Japanese very short-term money market. Subsection 3 contains estimation results, which are based on the institutional features of the Japanese money market.

1. Data

To estimate the predictive ability of the forward-spot spread, we rely on the *ON*, *TN*, and *SN* rates from the unsecured call market, which, in terms of amount outstanding, is by far the largest, of the four very short-term money markets. The differences in the contracting options between the *ON*, *TN*, and *SN* are illustrated below:



The markets for these interest rates are considered liquid, although the *ON* market is considerably larger than either the *TN* or *SN* markets.[10] Our estimations rely on the average of the end-of-day bid and ask quotes.[11] The data are from Bloomberg, and are available on a daily basis. The sample begins on 4/11/1996, the date when the database begins providing data, to 2/12/1999, the date of the introduction of *zirp* by the Bank of Japan. The total number of observations is 607. Note, however, that the number of observations is significantly smaller for the *SN* rate possibly because transaction amounts are relatively smaller in this market, and therefore, quotes are often not recorded. Summary statistics are presented in table 2. Notably, the *TN* and *SN* rates appear to be higher than the *ON* rate, on average.

2. Base Estimation

We begin by estimating the standard equation based on the rational expectation hypothesis as discussed in section II. Let ON_t be the interest rate on a one-day maturity spot contract, TN_t be the interest rate on a one-day maturity one-day forward contract, and SN_t be the interest rate on a one-day maturity two-day forward contract. The rational expectations hypothesis predicts,

$$ON_{t+1} - ON_t = \alpha + \beta(TN_t - ON_t) + \gamma' H_t + \varepsilon_{t+1}, \quad (5)$$

$$\left(\frac{ON_{t+1} + ON_{t+2}}{2}\right) - ON_t = \alpha + \beta\left(\frac{TN_t + SN_t}{2} - ON_t\right) + \gamma' H_t + \varepsilon_{t+2}, \quad (6)$$

with null $\alpha = 0$ and $\beta = 1$. Note that both equations include a vector of binary dummy variables, H_t, which contains a series of calendar effects. For example, in the case of (5), if day $t+1$ is the end of a quarter, the dummy variable $dmsd_t = 1$, and zero otherwise.[12] Also included in H_t are dummies indicating the last day of the month, but not the quarter ($doth_t$), the end of the reserve maintenance period (drr_t), the date of a monetary policy change ($d980910_t$), the day preceding a one-day holiday ($dho1p_t$), the day following a one-day holiday ($dho1s_t$), the day preceding a three-day or longer holiday ($dho3p_t$), and the day following a three-day or longer holiday ($dho3s_t$).[13] Estimation results are reported in table 3. To document how the value of β is affected by the inclusion of calendar dummies, the table also includes the "baseline" estimation results, with H_t excluded.

The first thing to notice is that the βs are significantly different from both zero and one at the 1% level. For equations (5) and (6), the coefficients range between 0.12 and 0.16. These results are not consistent with the existing literature on the predictability smile, as an extrapolation of the existing smile toward the shortest end of the term structure would predict much higher predictability. This is clearly not true in the Japanese money market. It should also be noted that the null of $\alpha = 0$ is rejected at the 1% level.

---

[10] One market participant interviewed believed the *ON* market to be about ten times larger than the *TN* market.

[11] We also obtained daily averages of the *ON* and *TN* rates from the Fund Brokers Association. We do not present estimation results based on these data, however, partly because we lack similar information for the *SN* rate, and because we obtain qualitatively similar results to what is presented in the paper.

[12] In the case of (6), the dummies indicate day *t+1 or t+2*.

[13] Other calendar effect dummies such as those for day of week are not included in our estimation. Previous studies on the development of the call rate in Japan, including Uesugi (2002), do not find that they are significant.

TABLE 2. SUMMARY STATISTICS

Variables	# of Obs.	Mean	Std. Dev.	Min	Max
ON_t	607	0.426	0.096	0.15	0.72
TN_t	607	0.464	0.093	0.21	0.78
SN_t	346	0.460	0.118	0.21	1.18
$ON_{t+1}-ON_t$	607	0.000	0.035	−0.23	0.21
$(ON_{t+1}+ON_{t+2})/2-ON_t$	346	0.000	0.039	−0.23	0.14
TN_t-ON_t	607	0.038	0.053	−0.16	0.41
$(TN_t+SN_t)/2-ON_t$	346	0.050	0.059	−0.16	0.35

Note: Figures are percentages.

TABLE 3. BASE ESTIMATION (ESTIMATIONS (5) AND (6))

Regressor	Dependent variable			
	$ON_{t+1}-ON_t$		$(ON_{t+1}+ON_{t+2})/2-ON_t$	
TN_t-ON_t	0.118***	0.157***		
	(0.025)	(0.026)		
$(TN_t+SN_t)/2-ON_t$			0.130***	0.147***
			(0.035)	(0.035)
dmsd	0.059***		0.018	
	(0.012)		(0.012)	
doth	0.023***		0.014**	
	(0.007)		(0.007)	
drr	0.011*		0.012**	
	(0.006)		(0.006)	
d980910	−0.228***		−0.210***	
	(0.032)		(0.036)	
dholp	0.004		0.020*	
	(0.009)		(0.010)	
dholf	−0.001		0.003	
	(0.009)		(0.011)	
dho3p	−0.020**		−0.009	
	(0.009)		(0.008)	
dho3f	0.012		0.010	
	(0.008)		(0.009)	
constant	−0.006***	−0.006***	−0.010***	−0.007***
	(0.002)	(0.002)	(0.003)	(0.003)
# of observations	607	607	346	346
$\overline{R}^2$	0.1829	0.0557	0.1500	0.0465
Prob. coefficient for spread = 1	0.0000	0.0000	0.0000	0.0000

Note: Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

3. Asymmetric Predictability Estimation

The institutional structure of the Japanese money market presented in section III implies a different set of specifications from the standard ones in (5) and (6). Because penalties are only incurred for daily negative reserves, and not for non-negative reserves, we expect there to be an asymmetry in the predictive ability of the interest rate spread. Sizeable shocks to the market

Table 4. Asymmetric Predictability Estimation with Split Dummies (Estimations (7) and (8))

Regressor	Dependent variable	
	$ON_{t+1}-ON_t$	$(ON_{t+1}+ON_{t+2})/2-ON_t$
$(TN_t-ON_t)\,I(\bullet>0)$	0.063**	
	(0.026)	
$(TN_t-ON_t)\,I(\bullet\leq 0)$	1.023***	
	(0.130)	
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet>0)$		0.072**
		(0.036)
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet\leq 0)$		1.183***
		(0.198)
dmsd	0.065***	0.024**
	(0.011)	(0.011)
doth	0.023***	0.013*
	(0.007)	(0.007)
drr	0.011*	0.013**
	(0.006)	(0.006)
d980910	− 0.230***	− 0.213***
	(0.030)	(0.034)
dholp	0.003	0.019*
	(0.008)	(0.010)
dholf	0.000	− 0.005
	(0.008)	(0.010)
dho3p	− 0.020**	− 0.011
	(0.008)	(0.008)
dho3f	0.011	0.009
	(0.007)	(0.008)
constant	− 0.003	− 0.005*
	(0.002)	(0.003)
# of observations	607	346
$\bar{R}^2$	0.2333	0.2155
Prob. coefficient for spread $*I(\bullet>0)=1$	0.0000	0.0000
Prob. coefficient for spread $*I(\bullet\leq 0)=1$	0.8626	0.3568

Note: Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

raise the probability for each bank to end the day with negative reserves. Fearing a negative reserve balance, banks increase their demand for reserves, which possibly raises the expected value of the overnight interest rate of ON_{t+1}. Furthermore, banks prefer to secure funds immediately, at the TN_t rate, rather than waiting an additional day and paying the ON_{t+1} rate. This behavior biases the TN_t rate upward, which violates the rational expectations hypothesis. In contrast, when market participants are less concerned about the negative reserve level at the end of day, in which case the expected rate of ON_{t+1} tends to decrease, the procurement behavior will not bias the relationship between the *TN* and the *ON* rate.

Hence, we present a set of modified specifications, specifications with two split dummy variables:

Table 5. Asymmetric Predictability Estimation with Split Dummies and Split Dummies for Reserve Maintenance Effect (Estimations (9) and (10))

Regressor	Dependent variable $ON_{t+1}-ON_t$	Dependent variable $(ON_{t+1}+ON_{t+2})/2-ON_t$
$(TN_t-ON_t)I(\bullet>0)$	0.056**	
	(0.027)	
$(TN_t-ON_t)I(\bullet>0)drr_t$	0.089	
	(0.102)	
$(TN_t-ON_t)I(\bullet\leq 0)$	1.013***	
	(0.130)	
$(TN_t-ON_t)I(\bullet\leq 0)drr_t$	1.140	
	(1.343)	
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet>0)$		0.062*
		(0.037)
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet>0)drr_t$		0.133
		(0.136)
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet\leq 0)$		1.177***
		(0.205)
$\left[\frac{TN_t+SN_t}{2}-ON_t\right]I(\bullet\leq 0)drr_t$		−0.060
		(0.813)
# of observations	607	346
$\bar{R}^2$	0.2483	0.2406
Prob. coefficient for spread $*I(\bullet>0)=1$	0.0000	0.0000
Prob. coefficient for spread $*I(\bullet\leq 0)=1$	0.9191	0.3884

Note: Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Coefficients for other dummy variables and constant are not shown in the table.

$$ON_{t+1}-ON_t=\alpha_1+\beta_1(TN_t-ON_t)\,I\,(TN_t-ON_t>0)\\+\beta_2(TN_t-ON_t)\,I\,(TN_t-ON_t\leq 0)+\gamma'\,H_t+\varepsilon_{t+1} \tag{7}$$

$$\frac{ON_{t+1}+ON_{t+2}}{2}-ON_t=\alpha_1+\beta_1\left(\frac{TN_t+SN_t}{2}-ON_t\right)I\left(\frac{TN_t+SN_t}{2}-ON_t>0\right)\\+\beta_2\left(\frac{TN_t+SN_t}{2}-ON_t\right)I\left(\frac{TN_t+SN_t}{2}-ON_t\leq 0\right)+\gamma'\,H_t+\varepsilon_{t+2} \tag{8}$$

where $I(\bullet)$ is a dummy variable equal to one when the equation is satisfied and zero otherwise. The null hypotheses are $\beta_1<1$ and $\beta_2=1$. $\beta_1<1$ implies that financial institutions deviate from the rational expectations hypothesis due to end-of-day overdraft penalty. The estimation results are presented in table 4. The table indicates that β_1 in both equations (7) and (8) is significantly different not only from zero, but also from one, while β_2 is not significantly different from one. We are, therefore, unable to reject the null in this case. The estimate of β_2 in (8) is slightly larger than the one in (7).

In addition to the effect of the penalty for end-of-day overdrafts, we examine the effect of the penalty for failing to satisfy monthly reserve requirements. One day before the final day of the reserve maintenance period, depository institutions have an additional incentive to avoid penalties incurred by the failure to satisfy the monthly reserve requirement, which further deviate these institutions from the rational expectations hypothesis. Therefore, we introduce another set of variables with which to examine the effect:

$$ON_{t+1}-ON_t=\alpha_1+\beta_1(TN_t-ON_t)\,I(\bullet>0)+\beta_{11}(TN_t-ON_t)\,I(\bullet>0)drr_t$$
$$+\beta_2(TN_t-ON_t)\,I(\bullet\leq 0)+\beta_{21}(TN_t-ON_t)\,I(\bullet\leq 0)drr_t+\gamma' H_t+\varepsilon_{t+1} \quad (9)$$

$$\frac{ON_{t+1}-ON_{t+2}}{2}-ON_t=\alpha_1+\beta_1(\frac{TN_t+SN_t}{2}-ON_t)\,I(\bullet>0)$$
$$+\beta_{11}(\frac{TN_t+SN_t}{2}-ON_t)\,I(\bullet>0)drr_t$$
$$+\beta_2(\frac{TN_t+SN_t}{2}-ON_t)\,I(\bullet\leq 0)$$
$$+\beta_{21}(\frac{TN_t+SN_t}{2}-ON_t)\,I(\bullet\leq 0)drr_t+\gamma' H_t+\varepsilon_{t+2} \quad (10)$$

The estimation results are presented in table 5. The null hypotheses are $\beta_1<1$, $\beta_2=1$, $\beta_{11}<0$, and $\beta_{21}=0$. We expect the largest deviation from the rational expectation hypothesis to occur when $drr_t=1$, in which case we have $\beta_1+\beta_{11}<\beta_1<1$. As in table 4, β_1 in both equations (9) and (10) are significantly different not only from zero, but also from unity, while β_2 is *not* significantly different from unity. Note, however, that both β_{11} and β_{21} are not significantly different from zero. Hence, penalties for not satisfying the monthly reserve requirement do not significantly contribute to the deviation from the rational expectations hypothesis.

V. *Estimation of Predictability: U.S., U.K., and Italy*

In this section, we provide estimates of the predictive ability of the forward-spot rate spread in the money markets of a few other developed countries. Due to the availability of the data, our investigation is limited to the U.S. Euro Dollar, U.K. Euro Sterling, and Italian Domestic Lire markets. Summary statistics for each of these currencies are provided in table 6. For these currencies, estimation results of asymmetric predictability under the split dummy specification are presented in table 7.

It is clear that there exists a significant difference between β_1 and β_2 across all the markets. Moreover, β_1 is always smaller than β_2. A negative spread between the forward and the spot rates has significantly better predictive power than a positive spread. When we consider the U.K. Euro Sterling, β_2 is not significantly different from one, which implies that the negative forward-spot rate spread has near-perfect predictive ability. Furthermore, the β_2 estimates for Italian Domestic Lire are close to one and, at times, not significantly different from one at the 1% significance level. Finally, only the β_2 estimates in the U.S. Euro Dollar market are always significantly less than one.

VI. *Conclusion*

This paper reviews the relationship between the forward interest rate and the spot interest rate at the shortest maturities. Our analysis is centered upon the Japanese very short-term

Table 6. Summary Statistics for Other Currencies

US Euro Dollar

Variables	# of Obs.	Mean	Std. Dev.	Min	Max
ON_t	1250	5.445	0.321	4.66	7.06
TN_t	1250	5.426	0.340	4.34	8.00
SN_t	1249	5.416	0.346	4.56	6.91
$ON_{t+1} - ON_t$	1250	0.000	0.122	− 1.34	1.53
$(ON_{t+1} + ON_{t+2})/2 - ON_t$	1249	0.000	0.125	− 1.39	0.91
$TN_t - ON_t$	1250	− 0.019	0.186	− 1.50	2.47
$(TN_t + SN_t)/2 - ON_t$	1250	− 0.024	0.172	− 1.53	1.22

Note: Figures are percentages. The sample period is from 1/9/1995 to 12/29/1999.

UK Euro Strerling

Variables	# of Obs.	Mean	Std. Dev.	Min	Max
ON_t	1910	5.865	1.356	2.41	39.88
TN_t	1910	5.877	1.015	3.13	8.34
SN_t	1909	5.890	0.996	3.38	8.28
$ON_{t+1} - ON_t$	1910	− 0.001	1.245	− 33.69	34.13
$(ON_{t+1} + ON_{t+2})/2 - ON_t$	1909	− 0.001	1.095	− 33.69	17.28
$TN_t - ON_t$	1910	0.012	0.924	− 33.94	3.03
$(TN_t + SN_t)/2 - ON_t$	1909	0.018	0.922	− 33.94	3.05

Note: Figures are percentages. The sample period is from 1/20/1995 to 8/8/2002.

Italy Domestic Lire

Variables	# of Obs.	Mean	Std. Dev.	Min	Max
ON_t	2714	9.655	3.270	0.75	36.60
TN_t	2714	10.057	3.020	1.69	36.81
SN_t	2713	10.079	2.964	2.25	38.78
$ON_{t+1} - ON_t$	2714	− 0.001	1.985	− 14.06	18.41
$(ON_{t+1} + ON_{t+2})/2 - ON_t$	2713	− 0.002	2.042	− 13.53	14.45
$TN_t - ON_t$	2714	0.402	1.768	− 10.19	12.88
$(TN_t + SN_t)/2 - ON_t$	2713	0.411	1.820	− 8.75	12.50

Note: Figures are percentages. The sample period is from 4/5/1988 to 12/30/1998. We omit the sample period when Euro has been introduced.

money market. The primary reason for this is that, based on extensive interviews with market participants, we have a clear picture of the institutional set-up of the market. We find that in the Japanese money market, a positive spread between the forward and spot rates has insufficient predictive power for future spot rate innovations, while a negative spread has near perfect predictive power. In other words, when the forward rate minus the current spot rate is negative the rational expectations hypothesis holds, and when it is positive the expectations hypothesis fails. We posit that the structure of the Japanese short-term money market may explain this "asymmetric predictability." Penalties for negative end-of-day reserves limit the ability of market participants to behave according to the rational expectations hypothesis, while penalties for failing to satisfy monthly reserve requirements do not have any additional impact.

Furthermore, we obtain similar estimation results using other currencies: U.S. Euro Dollar, U.K. Euro Sterling, and Italian Domestic Lire. In all of these markets, the predictive power of a negative forward-spot spread is significantly higher than a positive spread. For the U.K. Euro

TABLE 7. CROSS-COUNTRY COMPARISON IN ASYMMETRIC PREDICTABILITY

	Japan	US	UK	Italy
Equation (4.3)				
$(TN_t - ON_t)\ I\ (\bullet > 0)$	0.063**	−0.048	0.517***	0.631***
	(0.026)	(0.035)	(0.067)	(0.018)
$(TN_t - ON_t)\ I\ (\bullet \leq 0)$	1.023***	0.292***	0.971***	1.116***
	(0.130)	(0.024)	(0.026)	(0.059)
# of observations	607	1250	1910	2714
$\bar{R}^2$	0.2333	0.1458	0.4502	0.374
Prob. coefficient for spread *$I\ (\bullet > 0)$=1	0.0000	0.0000	0.0000	0.0000
Prob. coefficient for spread *$I\ (\bullet \leq 0)$=1	0.8626	0.0000	0.2549	0.048
Equation (4.4)				
$[(TN_t + SN_t)/2 - ON_t]\ I\ (\bullet > 0)$	0.072**	−0.038	0.600***	0.698***
	(0.036)	(0.041)	(0.052)	(0.017)
$[(TN_t + SN_t)/2 - ON_t]\ I\ (\bullet \leq 0)$	1.183***	0.351***	0.983***	1.298***
	(0.198)	(0.024)	(0.019)	(0.058)
# of observations	346	1249	1909	2713
$\bar{R}^2$	0.2155	0.1868	0.6114	0.469
Prob. coefficient for spread *$I\ (\bullet > 0)$=1	0.0000	0.0000	0.0000	0.0000
Prob. coefficient for spread *$I\ (\bullet \leq 0)$=1	0.3568	0.0000	0.3830	0.0000

Note: Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Sterling in particular, the predictability coefficients are not significantly different from one when the forward-spot spread is negative. What is common to all of these countries, Japan, the U.S., the U.K., and Italy, is that financial institutions are penalized for end of day overdrafts.[14] Even though we have not collected additional evidence of institutional similarities across money markets in these countries, we expect that this overdraft penalty is a contributing factor to the observed asymmetry.

REFERENCES

Borio, C. E. V. (1997), "The Implementation of Monetary Policy in Industrial Countries: A Survey," *BIS Economic Papers* No.47.

Campbell, J.Y. (1995), "Some Lessons from the Yield Curve," *Journal of Economic Perspectives* 9, pp.129-152.

Campbell, J.Y. and R.J. Shiller (1991), "Yield Spreads and Interest Rate Movements: A Bird's Eye View," *Review of Economic Studies* 58, pp.495-514.

Cook, T. and T. Hahn (1990), "Interest Rate Expectations and the Slope of the Money Market Yield Curve," *Federal Reserve Bank of Richmond Economic Review* 76, pp.3-26.

Dufey, G. and I. Giddy (1994), *International Money Market*, 2nd edition, Prentice-Hall: Upper

[14] See Borio (1997).

Saddle River.

Hardouvelis, G.A. (1994), "The Term Structure Spread and Future Changes in Long and Short Rates in the G7 Countries: Is there a Puzzle?" *Journal of Monetary Economics* 33, pp.255-283.

Inaba, K., S. Konno, N. Fukunaga, and T. Shimizu (2001), "The Structure of and Recent Development in the Short-Term Yen Money Markets," *Bank of Japan Market Review*.

Jegadeesh, N. and G.G. Pennacchi (1996), "The Behavior of Interest Rates Implied by the Term Structure of Eurodollar Futures," *Journal of Money, Credit, and Banking* 13, pp.31-43.

Jorion, P. and F. Mishkin (1991), "A Multi-Country Comparison of Term Structure Forecasts at Long Horizons," *Journal of Financial Economics* 29, pp.59-80.

Mishkin, F.S. (1991), A Multi-Country Study of the Information in the Term Structure about Future Inflation," *Journal of International Money and Finance* 10, pp.2-22.

Roberds, W. and C.H. Whiteman (1999), "Endogenous Term Premia and Anomalies in the Term Structure of Interest Rates: Explaining the Predictability Smile," *Journal of Monetary Economics* 44, pp.555-580.

Rudebusch, G.R. (1995), "Federal Reserve Interest Rate Targeting, Rational Expectations and the Term Structure," *Journal of Monetary Economics* 35, pp.245-274.

Saito, M., S. Shiratsuka, T. Watanabe and N. Yanagawa (2001), "Liquidity Demand and Asset Pricing: Evidence from the Periodic Settlement in Japan, Institute for Monetary and Economic Studies, *Bank of Japan Discussion Paper Series* 2001-E-21.

Simon, D.P. (1990), "Expectations and the Treasury Bill-Federal Funds Rate Spread Over Recent Monetary Policy Regimes," *Journal of Finance* 45, pp.467-477.

Stigum, M. (1990), *The Money Market*, 3rd edition, McGraw-Hill: New York.

Totan Research (2002), *The Tokyo Money Market: Revised Edition*, Yuhikaku: Tokyo. In Japanese.

Uesugi, I. (2002), "Measuring the Liquidity Effect: The Case of Japan," *Journal of the Japanese and International Economies* 16, pp.289-316