Financial Market Functioning and Monetary Policy: Japan's Experience

Naohiko Baba

This paper reviews the financial market functioning under the zero interest rate policy (ZIRP) and the subsequent quantitative monetary easing policy (QMEP) conducted by the Bank of Japan (BOJ). First, the estimation results of the Japanese government bond yield curve using the Black-Gorovoi-Linetsky (BGL) model show that (1) the shadow interest rate has been negative since the late 1990s, turned upward in 2003, and has been on an uptrend since then, and (2) the first-hitting time until the negative shadow interest rate hits zero again under the risk-neutral probability is estimated to be about three months as of the end of February 2006. Second, under the ZIRP and QMEP, the risk premiums for Japanese banks have almost disappeared in short-term money markets such as the market for negotiable certificates of deposit, while they have remained in the credit default swap market and the stock market. This result supports the view that market participants have positively perceived the BOJ's ample liquidity provisions in containing the near-term defaults of banks caused by the liquidity shortage.

Keywords: Bank of Japan; Term structure of interest rates; Zero lower bound; Zero interest rates; Quantitative monetary easing policy; Bank risk premium

JEL Classification: E43, E44, E52, G12

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I. Introduction

This paper aims to review the financial market functioning under the recent monetary policy of the Bank of Japan (BOJ): the zero interest rate policy (ZIRP) and the subsequent quantitative monetary easing policy (QMEP). In doing so, this paper pays particular attention to quantitatively assessing (1) market perceptions about the BOJ's monetary policy from the Japanese government bond (JGB) yield curve; and (2) the effects of the BOJ's monetary policy on the risk premiums for Japanese banks in short-term money markets, as well as long-term credit markets such as the credit default swap (CDS) and stock markets.

Japan has suffered from an economic slump since the bursting of the bubble economy in the early 1990s. During that time, the Tokyo Stock Price Index (TOPIX) fell by about 70 percent from its peak to the low in 2003. Declining asset prices severely hit the financial system, the banking sector in particular. Despite the capital injections of public funds into major banks to address the nonperforming-loan (NPL) problem, the banking sector did not fully recover until quite recently. Business fixed investment continued to suffer from an excess from the late 1980s and the impaired financial system.

In an attempt to find a breakthrough, the BOJ responded with (1) a lowering of the uncollateralized overnight call rate to 0.5 percent after the end of 1995, (2) a further lowering to almost zero percent after February 1999 (ZIRP), and (3) the adoption of the quantitative monetary easing policy (QMEP) after March 2001. As argued in Baba *et al*. (2005) and Ueda (2005), the ZIRP and QMEP have been an attempt to influence expectations about future monetary policy, rather than to change today's policy instrument. In this sense, the ZIRP and QMEP are often called an exercise in expectations management or in shaping expectations.

The QMEP had two pillars: (1) provision of ample liquidity with the outstanding balance of current accounts at the BOJ as its operating policy target; and (2) "a commitment" to maintain the policy until the year-on-year rate of change in the core consumer price index (CPI)—the core CPI inflation rate—registers zero percent or higher on a sustainable basis.[1] To that end, the BOJ has actively used various types of market operations including a purchasing operation for long-term JGBs. Thus, it seems fair to say that the QMEP augmented the ZIRP in terms of both easing effects and expectations management.

Japan's economy finally started recovering in January 2002, and the core CPI inflation rate rose to zero in October 2005, and turned positive the following month. Reacting to these circumstances, the BOJ ended the QMEP in March 2006 and returned to the ZIRP.[2]

Given the above nature of the ZIRP and QMEP, some authors have tried to estimate the effects of the BOJ's attempt to manage expectations on the JGB yield curve. They share a common framework: a macro-finance approach. Bernanke, Reinhart, and Sack (2004) and Oda and Ueda (2005) are such examples. Under the macro-finance

1. The core CPI means the CPI excluding fresh food.
2. The official statement released by the BOJ after the Monetary Policy Meeting on March 9, 2006 was as follows: "[T]he Bank of Japan decided to change the operating target of money market operations from the outstanding balance of current accounts at the Bank to the uncollateralized overnight call rate . . . The Bank of Japan will encourage the uncollateralized overnight call rate to remain at effectively zero percent."

framework, they add a specific macroeconomic structure to the JGB yield curve model. This framework is useful in directly analyzing how some specific macro-factors influence the entire or part of the JGB yield curve. On the other hand, they rely exclusively on the specific macroeconomic structure they choose, which leaves an *ad hoc* inkling. In addition, their models do not seem to closely trace the actual JGB yield curve.[3]

This paper attempts to review the effects of the BOJ's expectations management on the JGB yield curve using a totally different approach from the macro-finance approach: the Black model of interest rates as options. Black (1995) interprets a nominal short-term interest rate as a call option on the "equilibrium" or "shadow" interest rate, where the option is struck at zero percent. Put differently, Black (1995) argues that the nominal short-term interest rate cannot be negative since currency serves as an option, in that if an instrument should have a negative interest rate, investors choose currency instead. Employing this notion enables us to use an underlying (shadow) spot rate process that can take on negative values and simply replace all the negative values of the shadow interest rate with zeros for the observed short-term nominal interest rate.

The Black model has the following advantages over other types of models such as a macro-finance model. First, we do not need to assume any *ad hoc* macroeconomic structure. Second, we can significantly improve the fitting to the actual JGB yield curve. Third, we can directly incorporate the notion of "a zero lower bound on the short-term nominal interest rate" in a more straightforward manner. Fourth, we can directly assess the time period until the negative shadow interest rate first hits zero as the expected duration of the ZIRP, as well as the market expectations about the long-run level of the shadow interest rate.[4,5]

While the basic concept of the Black model is quite robust and is appealing particularly to the recent Japanese situation where short-term interest rates have indeed been zero, the model had the disadvantage in that it was analytically intractable.[6] Quite recently, however, Gorovoi and Linetsky (2004) successfully derive the analytical solutions for zero-coupon bonds using eigenfunction expansions under several specifications for the shadow interest rate process. We follow their solutions, and thus we call the model the Black-Gorovoi-Linetsky (BGL) model in this paper.

Another important task of the BOJ's monetary policy during the QMEP period was to alleviate concerns over the financial-sector problems. As described in Baba *et al*. (2005), many of the BOJ's market operations had the dual role of providing ample liquidity and addressing problems in the financial sector. In the process, the BOJ assumed a certain amount of credit risk. This paper also assesses the market perceptions about this aspect of the BOJ's policy by observing the price developments in various markets, from short-term money markets to the CDS and stock markets. The main objective here is to investigate the time horizons over which the effect of

3. For instance, Bernanke, Reinhart, and Sack (2004) find that the predicted JGB yield curves lie above the actual yield curves after 1999 and the deviation narrows in November 2000 after the end of the ZIRP, and widens again in June 2001 with the adoption of the QMEP. This result implies that their macro-finance model does not closely trace the actual JGB yield curves.
4. Further, we do not even need to assume specific distributions for the timing of the policy change.
5. Black (1995) originally recommends applying his model to the U.S. situation in the 1930s, which was also a period of extremely low interest rates. On the other hand, Gorovoi and Linetsky (2004) and Baz, Prieul, and Toscani (1998) strongly recommend applying the Black model to the recent Japanese situation.
6. See Rogers (1995, 1996) for this line of criticism.

the BOJ's monetary policy extended in calming market perceptions about the credit risk for the Japanese banks.

The rest of the paper is organized as follows. Section II presents an overview of the price developments in the Japanese financial markets under recent monetary easing policy conducted by the BOJ. Section III reviews the effects of the BOJ's monetary policy on the JGB yield curve, paying particular attention to the market perceptions about the BOJ's monetary policy stance. Section IV investigates the influences of the BOJ's monetary policy on the risk premiums for Japanese banks in short-term money markets, as well as the CDS and stock markets. Section V concludes the paper by discussing the policy implications of the findings.

II. Recent Price Developments in the Japanese Financial Markets

A. The BOJ's Monetary Policy and the Interest Rate Environment

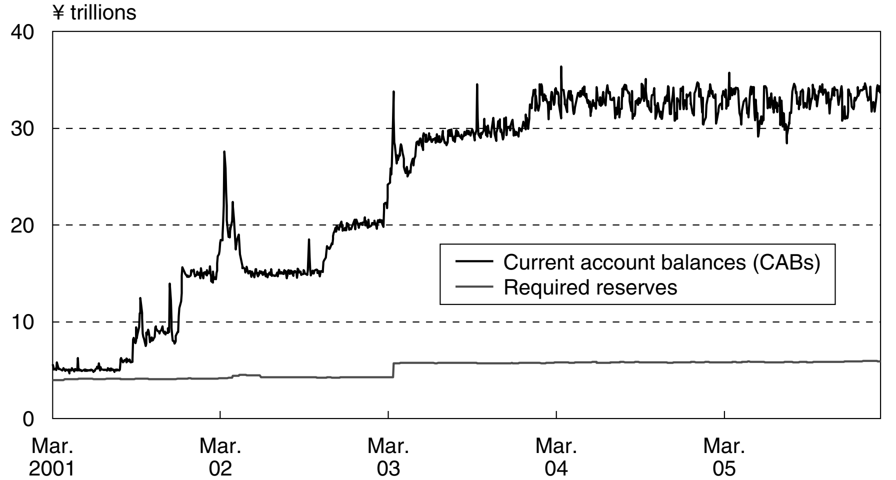
First, let me summarize monetary policy actions by the BOJ since the 1990s. The BOJ started to ease in 1991, then lowered the uncollateralized overnight call rate to 0.5 percent in 1995. This, however, was not enough to counteract deflationary pressures. The BOJ further lowered it to 0.25 percent in 1998, and to effectively zero percent in February 1999, which is the start of the ZIRP. In April 1999, the BOJ promised to maintain the zero interest rates until "the deflationary concerns are dispelled." Then, Japan's economy recovered, growing at 3.3 percent between the third quarter of 1999 and the third quarter of 2000. Consequently, the BOJ abandoned the ZIRP in August 2000. Japan's economy, however, went into a serious recession again, together with other advanced economies, led by worldwide declines in the demand for high-tech goods as an aftermath of the bursting of the "IT bubble."

To cope with the deflationary pressures, the BOJ introduced the QMEP in March 2001. The QMEP consisted of (1) supplying ample liquidity using the current account balances (CABs) held by financial institutions at the BOJ as the operating policy target, and (2) the commitment to maintain ample liquidity provision until the core CPI inflation rate became zero or positive on a sustainable basis. The target for the CABs was raised several times, reaching ¥30–35 trillion in January 2004, which amounts to more than five times the required reserves. Consequently, the actual CABs rose substantially under the QMEP, as shown in Figure 1. To meet the target, the BOJ conducted various purchasing operations for instruments such as bills and CP, in addition to treasury bills (TBs) and long-term JGBs.[7]

The uncollateralized overnight call rate declined to 0.01 percent under the ZIRP, and declined further to 0.001 percent under the QMEP. Medium- and long-term interest rates also declined substantially, as shown in Figure 2. Interest rates in Japan have also been quite low in comparison with other countries such as the United States

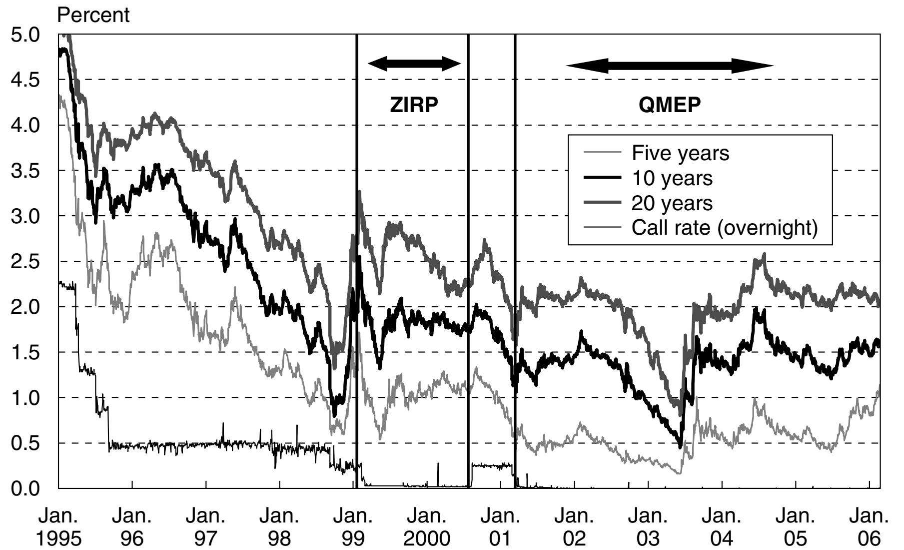
7. The two building blocks of the QMEP, (1) ample liquidity provision and (2) the commitment to maintain ample liquidity provision, as well as (3) the use of various types of market operations, purchasing of long-term JGBs, in particular, roughly correspond to the three policy prescriptions for stimulating the economy without lowering current interest rates, proposed by Bernanke and Reinhart (2004).

Figure 1 Current Account Balances under the QMEP



Source: Bank of Japan.

Figure 2 Interest Rate Environment in Japan



Note: Five-, 10-, and 20-year interest rates are the zero-coupon JGB yields estimated from the prices of coupon bonds using McCulloch's (1971) method. The call rate is the uncollateralized overnight call rate.

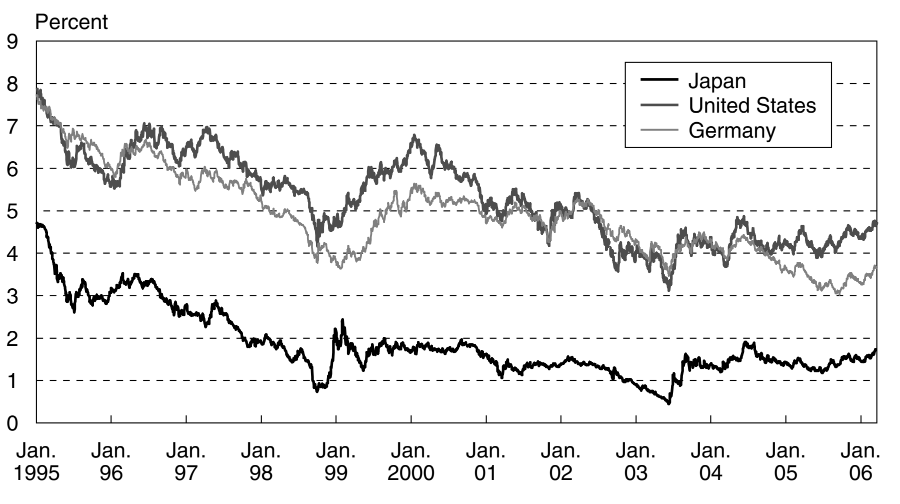
Sources: Japan Securities Dealers Association, Bank of Japan.

and Germany, as shown in Figure 3.[8] The BOJ ended the QMEP on March 9, 2006, and returned to the ZIRP.

B. Interest Rates in Short-Term Money Markets

Next, let me look at the interest rates in short-term money markets. First, credit risks of Japanese and non-Japanese banks are expected to be priced in TIBOR and LIBOR, since the majority of referenced banks for TIBOR and LIBOR are Japanese and non-Japanese banks, respectively.[9] Indeed, the so-called "Japan premium," generally defined as the spread between TIBOR and LIBOR (the TL spread), rose sharply to nearly 100 basis points in U.S. dollars and 40 basis points in yen at the height of the Japanese financial crisis in 1997–98.[10] The Japan premium was also considered to reflect non-Japanese major banks' skepticism concerning the opaque Japanese accounting and banking supervision system beyond a simple relative indicator of credit risk, as suggested by Ito and Harada (2004). As shown in Figure 4, the TL spread has fluctuated around zero since the adoption of the ZIRP in 1999. Another noteworthy point here is as follows. Around 2001 to 2002, concerns over the instability of Japanese banks became highlighted again, mainly due to their low earnings and newly emerging NPLs. This time, however, the TL spread did not widen at all. Ito and Harada (2004)

Figure 3 International Comparison of 10-Year Interest Rates

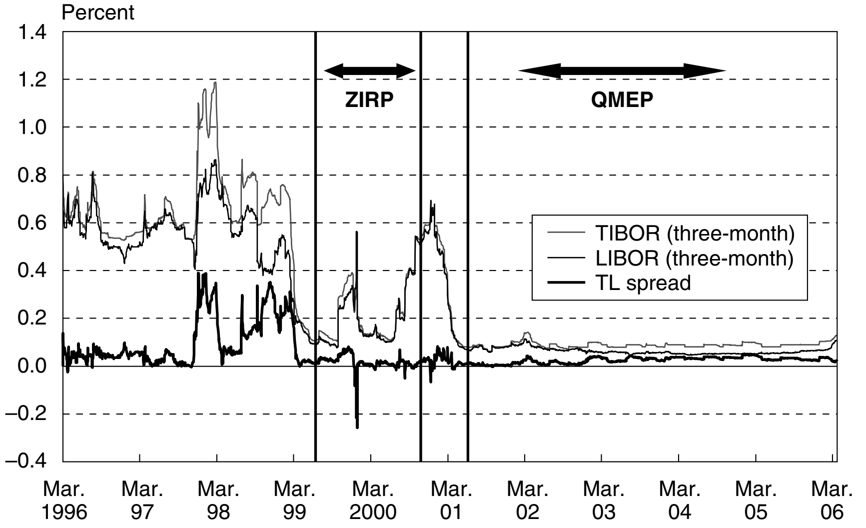


Note: Interest rates are 10-year yields on government bonds in each country.

Source: Bloomberg.

8. As shown in Baba *et al*. (2005), long-term JGB yields in recent years are also lower than long-term U.S. government bond yields in the 1930s.
9. TIBOR and LIBOR are the Tokyo Interbank Offered Rate and London Interbank Offered Rate, respectively. For more details on them, see Baba and Nishioka (2005) and Ito and Harada (2004).
10. The following financial institutions failed in 1997: Sanyo Securities (November 3), Hokkaido Takushoku Bank (November 17), Yamaichi Securities (November 24), and Tokuyo City Bank (November 26). The concern over the financial stability continued until Long-Term Credit Bank of Japan (October 23, 1998) and Nippon Credit Bank (December 12, 1998) were nationalized.

Figure 4 TIBOR/LIBOR and the TL Spread



Note: TIBOR and LIBOR in this figure are denominated in euroyen.

Source: Bloomberg.

assert that the TL spread lost its role as an indicator of the market perceptions about the vulnerability of Japanese banks.

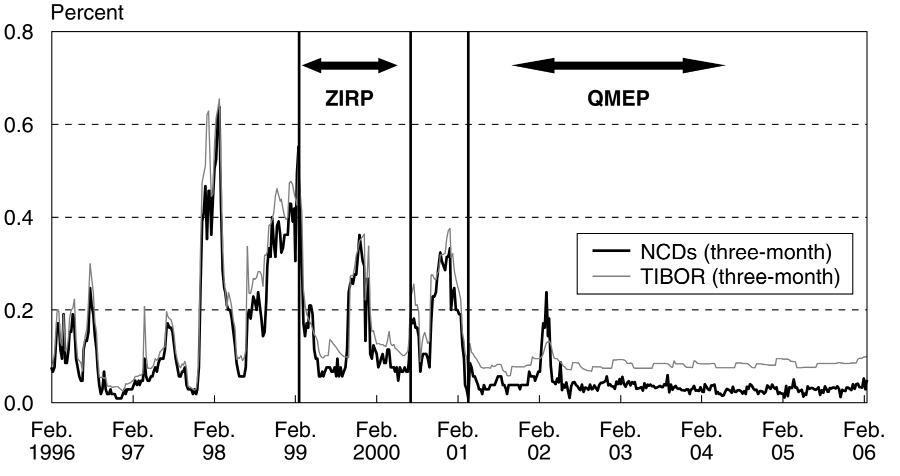
Another important indicator of credit risks for Japanese banks is the interest rates on negotiable certificates of deposit (NCDs). NCDs are debt instruments issued by banks, including city, regional, trust, and foreign banks in Japan. They were the first-ever product with deregulated interest rates in Japan and, since they are uninsured by deposit insurance, NCD interest rates are expected to reflect credit risks for issuing banks.[11] Figure 5 plots the spread of the NCD interest rate over the BOJ's target level of the uncollateralized overnight call rate, together with the TIBOR spread over the same target call rate. Note here that since the adoption of the QMEP, both NCD and TIBOR spreads have remained stable at a very low level with only one temporary spike toward the end of fiscal 2001, despite the reemergence of financial instability around 2001 and 2002.

C. Longer-Term Credit Spreads

Third, let me turn to the long-term credit spreads. As shown in Figure 6, credit spreads of corporate bonds over the JGB yields with the same maturity narrowed following the adoption of the ZIRP. From this figure, we can observe two significant surges in the credit spreads, particularly on BBB-rated bonds. The first surge was from the end of 1997 to 1999, as in the TL and NCD spreads (Figures 4 and 5). The second surge occurred around 2002. This period also corresponds to the period of financial

11. See Baba *et al*. (2006) for more details about the NCD market in Japan.

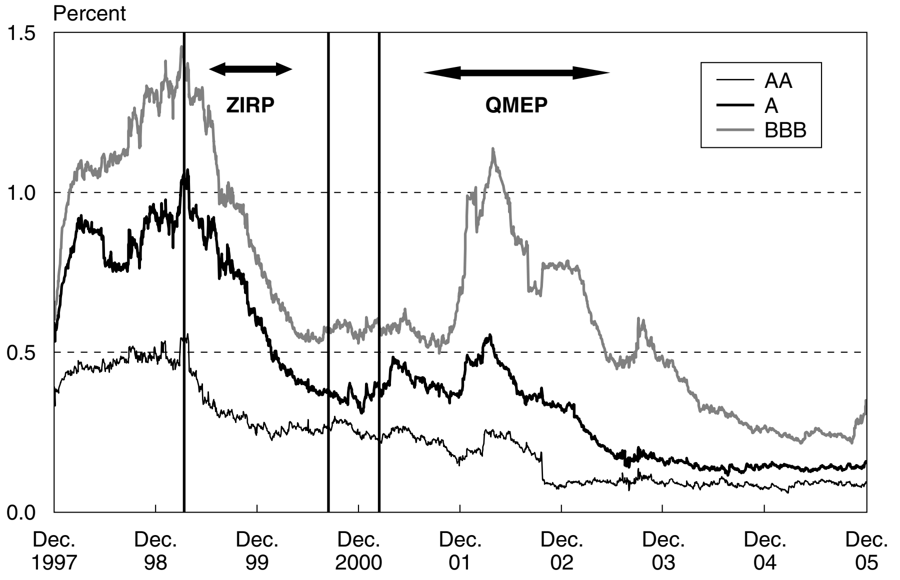
Figure 5 NCDs and TIBOR Spread over the Target Call Rate



Note: Spreads are calculated as NCD interest rate/yen-TIBOR minus the target uncollateralized overnight call rate.

Source: Bloomberg.

Figure 6 Credit Spreads of Corporate Bonds



Note: The spread is defined as the five-year corporate bond interest rate minus the JGB yield with the same maturity. Credit rating is that of Moody's.

Source: Japan Securities Dealers Association.

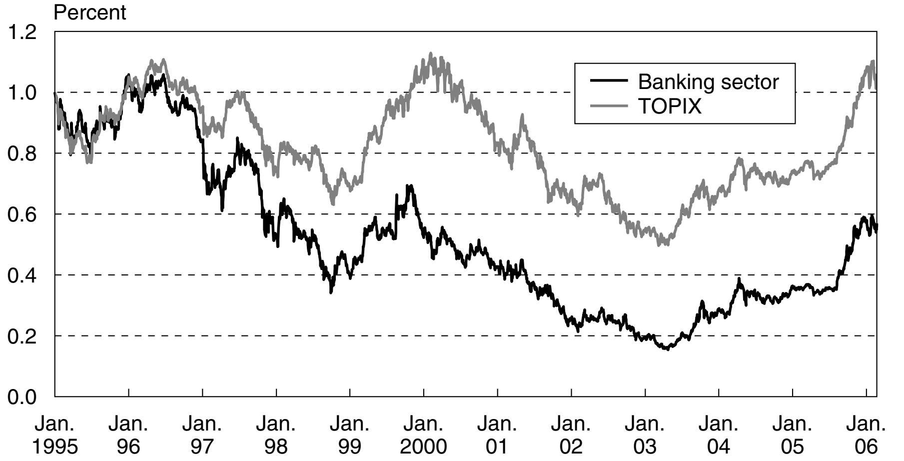
instability, as mentioned above.[12] Since around 2003, credit spreads have substantially narrowed and the narrowing has extended even to corporate bonds with a BBB credit rating. Baba *et al*. (2005) show that credit spreads have barely covered *ex post* default risks for such bonds with relatively lower ratings. Despite such favorable conditions for issuers, the issue amounts of corporate bonds have not increased much.

Wrapping up the developments in short-term money markets, JGB markets, and corporate bond markets, the following observation can be made, as argued by Baba *et al*. (2005). Declines in short-term interest rates forced Japanese investors to look for higher yields by taking various risks in other markets. They first turned to duration risk by investing their funds in longer-term JGBs. Following the decline in long-term JGB yields, however, they began to expect large potential capital losses in the event of a reversal of interest rates. Facing such circumstances, Japanese investors next turned to credit instruments such as corporate bonds. Their active investments in these instruments have substantially narrowed credit spreads even for bonds with relatively low ratings.[13]

D. Stock Prices

Fourth, Figure 7 shows stock price indices: the TOPIX and the stock price index of the banking sector. Both indices have exhibited very similar movement since 1995,

Figure 7 Stock Prices



Note: The stock price index of the banking sector and the TOPIX are both normalized at January 4, 1995 = 1.

Source: Bloomberg.

12. In addition, MYCAL Corporation filed for bankruptcy protection in September 2002, which worsened the sentiments of the overall credit markets.
13. This investment behavior is sometimes called "reaching for yield," investing in assets with returns too low to be justified by rational economic agents. Nishioka and Baba (2004) support the existence of this type of activity by investigating the pricing in the Japanese government and corporate bond markets using the three-factor capital asset pricing model, where mean, variance, and skewness of returns are evaluated in determining the optimal portfolio.

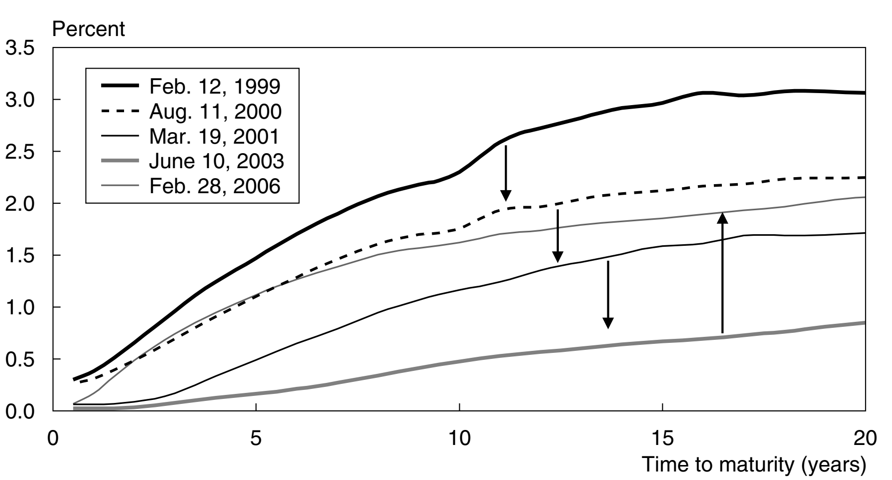
but the bank index experienced much more severe slumps during the financial crisis of the late 1990s and the period of financial instability around 2001 to 2002. The similar movement is due mainly to the large capitalization share of bank stocks in the TOPIX, but we should not overlook the fact that a large decline in stock prices itself triggered the financial instability seen in September 2001, particularly when the TOPIX declined below the 1,000 mark. Not surprisingly, the stock prices of banks with large stockholdings fell substantially in this period. Then, as the disposal of NPLs gradually progressed, the stock prices of banks started to recover from the start of 2003. The TOPIX has returned to almost the same level in January 2006 as in January 1995, but the bank index remains at about 60 percent of the value as of January 1995.[14]

III. The BOJ's Monetary Policy and the JGB Yield Curve

A. JGB Yield Curve

This section reviews the effects of the BOJ's monetary policy on the JGB yield curve, giving particular attention to quantitatively assessing the JGB market perceptions about the BOJ's monetary policy. First, Figure 8 displays the transition of the JGB yield curve since the start of the ZIRP in February 1999. Evidently, the flattening of the JGB yield

Figure 8 Transition of the JGB Yield Curve



Note: Each date corresponds to the following:
- February 12, 1999: start of the ZIRP.
- August 11, 2000: end of the ZIRP.
- March, 19, 2001: start of the QMEP.
- June 10, 2003: peak of the QMEP.
- February 28, 2006: almost at the end of the QMEP (end of sample period).

Source: Japan Securities Dealers Association.

14. Ito and Harada (2006) provide a detailed survey of the developments in bank stock prices from the late 1990s.

curve, together with an overall downward shift, sufficiently progressed under the ZIRP and QMEP until the middle of 2003. As a result, conventional yield curve models such as the Vasicek or the Cox, Ingersoll, and Ross (CIR) models no longer successfully trace the changing shape of the JGB yield curve.[15] Extremely low levels of short- and medium-term interest rates reflect the market participants' perceptions about the duration of the ZIRP, which was explicitly committed to by the BOJ to maintain the core CPI inflation rate as a policy guideline by the BOJ under the QMEP. In fact, the thrust of the ZIRP and QMEP lies in "managing expectations," as argued by Baba *et al*. (2005) and Ueda (2005). In what follows, let me review the estimation results from applying the Black model of interest rates as options to the JGB yield curve. The model turned out to be very useful in fitting to the extremely flattened JGB yield curve and quantitatively assessing the duration of the ZIRP expected by the JGB market without adding any *ad hoc* macroeconomic structure to the model.

B. The Black Model of Interest Rates as Options

Black (1995) assumes that there is a shadow instantaneous interest rate that can become negative, while the observed nominal interest rate is a positive part of the shadow interest rate. The rationale for this assumption is quite straightforward. As long as investors can hold currency with zero interest rates, nominal interest rates on other financial instruments must remain non-negative to rule out arbitrage. Specifically, the observed nominal interest rate r_t can be written as

$$r_t = \max[0, r_t^*] = r_t^* + \max[0, -r_t^*], \quad r_0^* = r, \tag{1}$$

where r_t^* is the shadow interest rate. The relationship between r_t and r_t^* is illustrated in Figure 9. In other words, equation (1) shows that the observed nominal interest rate can be viewed as a call option on the shadow interest rate that is struck at zero percent. Also, the second equality in equation (1) tells us that the observed nominal interest rate can be expressed as the sum of the shadow interest rate and an option-like value that provides a lower bound for the nominal interest rate at zero percent when the shadow interest rate is negative. Let me call this option-like value the floor value in this paper, following Bomfim (2003). In other words, the floor has the option to switch investors' bondholdings into currency, if r_t^* falls below zero.

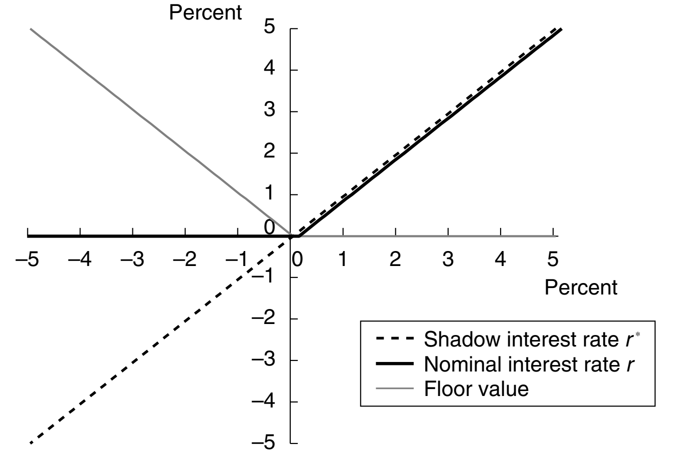
Under normal circumstances, r_t^* is sufficiently above zero so that the floor value in equation (1) can be safely ignored. When short-term nominal interest rates are at zero or near zero, however, long-term interest rates embed more-than-usual term premiums and thus the expectations about the future movements of short-term interest rates.

The slope of the term structure for time to maturity T can be written by

$$R(r, T) - r_0 = \frac{1}{T}\int_{s=0}^{T} f(r, s)ds - \max[0, r], \tag{2}$$

15. See Vasicek (1977) for the Vasicek model, and Cox, Ingersoll, and Ross (1985) for the CIR model.

Figure 9 Shadow and Nominal Interest Rates



where $R(r, T) - r_0$ can thus be interpreted as the value of a portfolio of options since $R(r, T)$, the yield to maturity, is an average of instantaneous forward rates, $f(r, s)$ ($s = 0, \ldots, T$), and each of the forward rates exhibits option properties. More specifically, $f(r, s)$ can be viewed as

$$f(r, s) = \mathrm{E}_r[r_s] + \text{forward premium} + \text{floor value}, \tag{3}$$

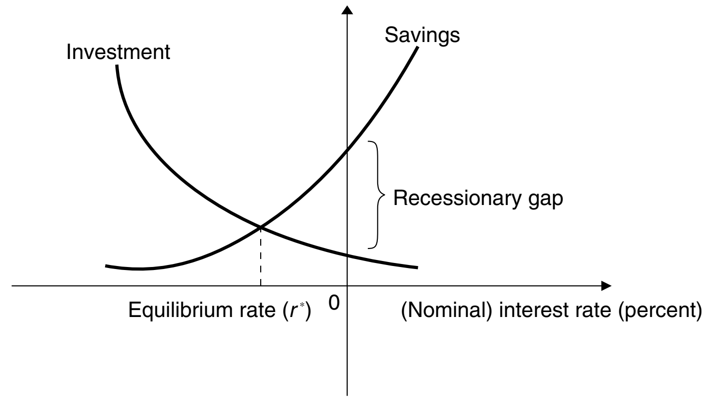
where $\mathrm{E}_r[\bullet] \equiv \mathrm{E}[\bullet | r_0^* = r]$. As discount bond prices are derived from forward rates, the floor value is compounded all over the yield curve, resulting in a steeper yield curve than the curve that could be expected should currency not exist.

How should we interpret the shadow interest rate in the Black model? Let me first present the view of Black (1995) himself.[16] Suppose a situation where the equilibrium nominal interest rate that clears the savings-investment gap is negative. Figure 10 illustrates such a situation for a given rate of expected inflation. This situation is akin to the so-called liquidity trap, where under deflationary pressures very low nominal interest rates cause people to hoard currency. As a result, it neutralizes monetary policy attempts to restore full employment.[17] In Figure 10, savings and investment, or supply and demand of capital, are equal at a negative value of r^*. The prevailing interest rate is zero, however, since currency exists. This leaves the savings-investment gap uncleared. Real-life examples of such situations include the United States during the Great Depression in the 1930s (Black [1995] and Bernanke [2002]), and Japan since the 1990s (Krugman [1998]).

The second interpretation is that the shadow interest rate may give us a clue to the length of time until the short-term interest rate becomes positive again, given that

16. Bomfim (2003) and Baz, Prieul, and Toscani (1998) follow this interpretation.
17. See Keynes (1936), Hicks (1937), and Robertson (1948) for classical debates about the liquidity trap. For Japan's recent case, see Krugman (1998) and Baz, Prieul, and Toscani (1998).

Figure 10 Recessionary Gap and Zero Floor of the Nominal Interest Rate



the current shadow interest rate is negative. In this sense, the expected time for the negative shadow interest rate to become positive again (the first-hitting time) is regarded roughly as the duration of the ZIRP perceived by the JGB market participants. Note here that if the JGB market participants think that the BOJ will continue the ZIRP until Japan's economy breaks out firmly from the liquidity trap, both interpretations coincide with each other. Considering the BOJ's official statement "until deflationary concerns are dispelled" and the BOJ's cautiousness in setting monetary policy, the JGB market participants are likely to think in this manner.

On the other hand, the Black model of interest rates as options had a disadvantage in that it was analytically intractable. In fact, Rogers (1995, 1996) criticizes the Black model for this reason and favors models with a reflecting boundary at the zero interest rate, despite the criticism on economic grounds.[18] Gorovoi and Linetsky (2004), however, show that the Black model is as analytically tractable as the reflecting boundary models, and successfully obtain analytical solutions for zero-coupon bonds under several specifications for the shadow interest rate process. In addition, Linetsky (2004) finds an analytical solution to the first-hitting time until the negative shadow interest rate reaches zero.[19] Thus, let me call the Black model with an analytical solution by Gorovoi and Linetsky (2004) the BGL model and review some results obtained for the JGB yield curves using the BGL model in what follows.

C. Estimation Results of the BGL Model

1. Fixed-parameter BGL model

First, Ichiue and Ueno (2006) estimate the following model with fixed parameters throughout the sample period from January 1995 to December 2005, using end-of-month JGB yields. They assume that under the actual probability P, r_t^* follows a process given by

18. Black (1995) argued that when the zero interest rate is a reflecting boundary, the rate "bounces off" zero, and this seems strange in terms of a real economic process.
19. See Appendix 1 for technical details.

$$dr_t^* = \kappa^P(\theta^P - r_t^*)dt + \sigma dB_t^P, \tag{4}$$

$$\lambda_t = \delta_0 + \delta_1 r_t^*, \tag{5}$$

where θ^P is the long-run level of the shadow interest rate that is likely to reflect the views of market participants about the future state of the real economy, κ^P is the rate of mean reversion toward the long-run level, and σ is the volatility parameter. Also, λ_t denotes the market price of risk, and δ_0 and δ_1 denote the parameters to be estimated. With this choice of market price of risk, r_t^* follows an Ornstein-Uhlenbeck process under both the actual probability P and the risk-neutral probability Q. Specifically, under Q,

$$dr_t^* = \kappa^Q(\theta^Q - r_t^*)dt + \sigma dB_t^Q, \tag{6}$$

where $\kappa^Q = \kappa^P + \delta_1\sigma$ and $\kappa^Q\theta^Q = \kappa^P\theta^P - \delta_0\sigma$. They estimate the parameters using the Kalman filter after linearizing the model.[20] For estimation, they use the JGB yields with 0.5-, two-, five-, and 10-year maturities, as well as the collateralized overnight call rate.[21]

Figure 11 [1] reports the parameter estimates. All of the parameters are estimated with expected signs and are significant, except for δ_1. Next, Figure 11 [2] exhibits the estimated shadow interest rate, together with the core CPI inflation rate, and the corresponding first-hitting time. The noteworthy points here are as follows. First, the shadow interest rate declined and reached zero percent for the first time in late 1995, and fluctuated around zero percent until 1997. Subsequently, it was on a consistent downtrend until the middle of 2003. Then it turned around and has been on an uptrend. If we follow the interpretation by Black (1995), the depth of the negativity of the shadow interest rates implies the degree to which the economy is perceived to be in a liquidity trap by market participants. Second, the shadow interest rate seems to have closely followed the core CPI inflation rate with several-month lags since early 2001.[22] In March 2001, the BOJ introduced the explicit commitment stating that it would continue the QMEP until the core CPI inflation rate became zero or higher on a sustainable basis. A seemingly higher lagged correlation between the shadow interest rate and the CPI inflation rate since early 2001 is likely to capture the commitment effect perceived by the JGB market participants. Third, as of the end of December 2005, the first-hitting time is estimated to be about 11 (10) months under the actual (risk-neutral) probability $P(Q)$.[23] Thus, under both probabilities, the fixed-parameter BGL model implies that the ZIRP will be abandoned within the year 2006, which seems very plausible judging from the current market observations.

20. See Appendix 2 for technical details. Throughout the paper, we use the discount bond yields estimated from the prices of coupon bonds with five-, 10-, and 20-year maturities at issue using McCulloch's (1971) method. The data source is the Japan Securities Dealers Association.
21. The collateralized call rate plays the role of guiding the shadow interest rate when the shadow rate is positive. See Appendix 2 for more details.
22. Note that the release of the CPI data is delayed by approximately two months.
23. Since the market price of risk is estimated to be negative throughout the sample period, the first-hitting time is longer under the actual probability than under the risk-neutral probability, since θ is smaller under the actual probability. The market price of risk is usually negative in the yield curve models.

Figure 11 Estimated Results of Fixed-Parameter BGL Model

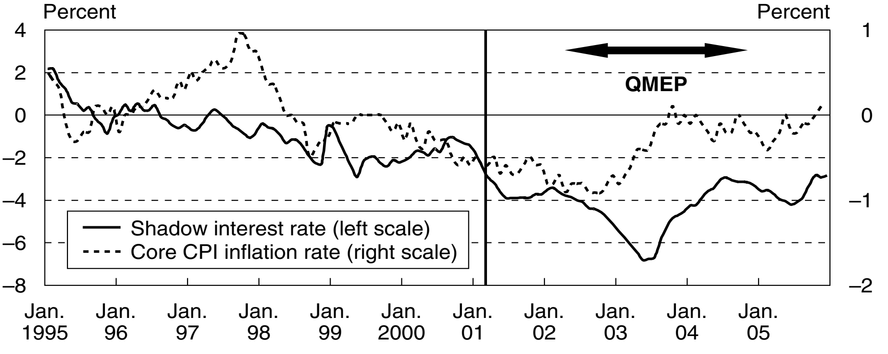
[1] Parameter Estimates

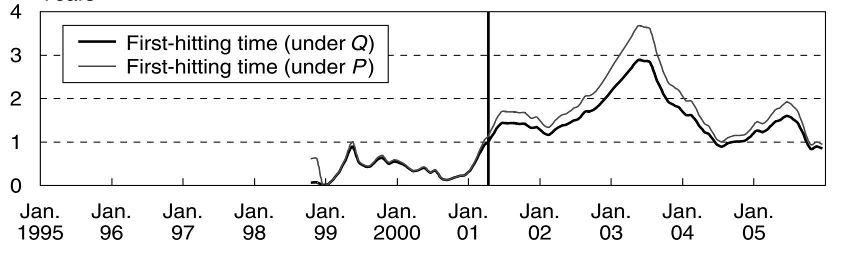
Sample period: Jan. 1995–Dec. 2005 (end of month)
Number of observations: 132

θ^P	0.0145*** (2.36E-04)	σ_ϵ (call)	0.0032*** (3.28E-04)
κ^P	0.2145*** (1.07E-02)	σ_ϵ (0.5-year)	0.0012*** (1.56E-04)
σ	0.0168*** (1.41E-04)	σ_ϵ (two-year)	0.0012*** (6.79E-05)
δ_0	–0.3181*** (1.06E-02)	σ_ϵ (five-year)	0.0027*** (4.45E-04)
δ_1	0.1860 (3.07E-01)	σ_ϵ (10-year)	0.0044*** (7.19E-04)
θ^Q	0.0389		
κ^Q	0.2176	Log-likelihood	27.471

Notes: 1. The numbers in parentheses are standard errors. *** denotes the significance level at the 1 percent level. Log-likelihood is the sample average.
2. Superscript *P* denotes the actual and *Q* denotes the risk-neutral probabilities, respectively.
3. See Appendix 2 for details.

[2] Estimated Shadow Interest Rate, Core CPI Inflation Rate, and First-Hitting Time





Notes: 1. The core CPI excludes fresh food.
2. Superscript *P* denotes the actual and *Q* denotes the risk-neutral probabilities, respectively.

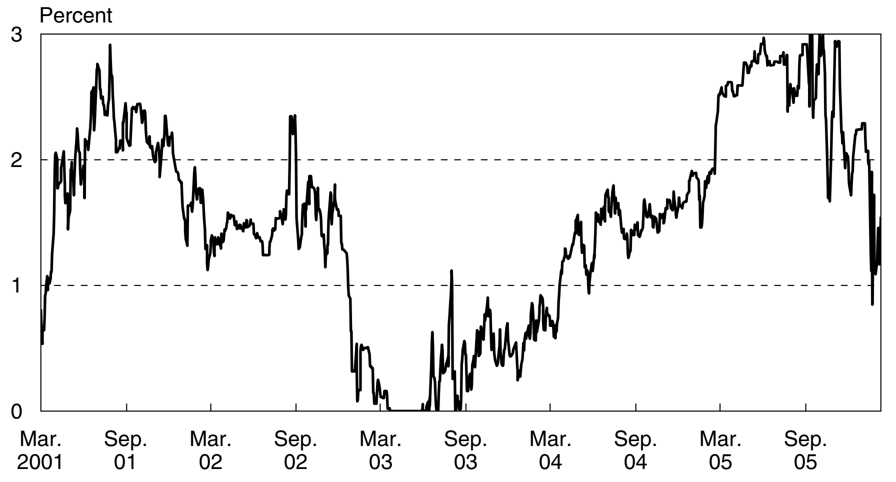
Source: Ichiue and Ueno (2006).

2. Day-to-day calibration results

Next, Ueno, Baba, and Sakurai (2006) calibrate the BGL model to the JGB yield curve on a day-to-day basis from the start of the QMEP through February 28, 2006. This calibration aims to capture a more accurate measure of the first-hitting time by taking account of time-series movement of the BGL model parameters.[24,25] In particular, we are interested in the movement of θ, the long-run level of the shadow interest rate, which is likely to reflect the market perceptions about the long-run real economic activity, together with the long-run target level of the call rate for the BOJ perceived by the JGB market participants.

First, Figure 12 plots the long-run level of the shadow interest rate θ under the risk-neutral probability Q, estimated by the day-to-day calibration of the BGL model to the JGB yield curve. θ seemingly exhibits a mean-reverting movement. From around September 2001, it fell and reached almost zero percent in the middle of 2003, and then bounced back to about 3 percent until the middle of 2005. The overall movement of θ is consistent with the following anecdotal market observations. The

Figure 12 Time-Series Estimates of the Long-Run Level θ by the BGL Model



Notes: 1. θ is estimated by calibrating the BGL model to the JGB yield curve on a day-to-day basis.
2. Sample period is from the start of the QMEP (March 19, 2001) through February 28, 2006.

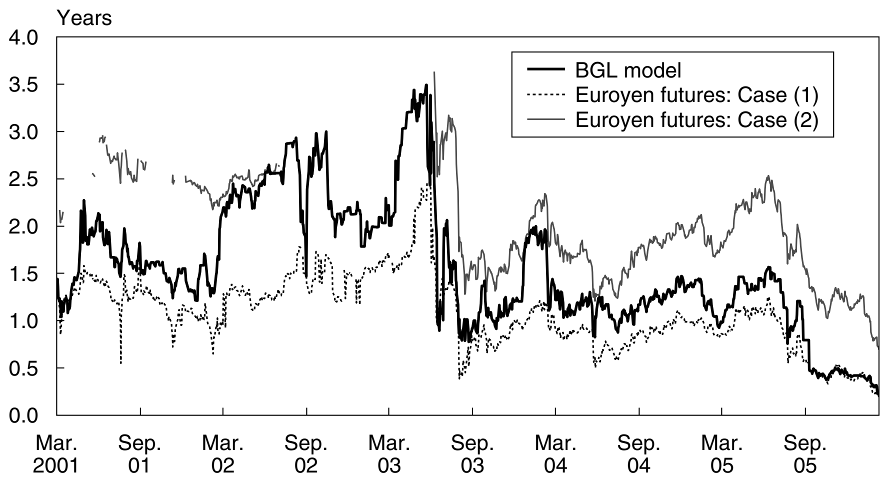
Source: Ueno, Baba, and Sakurai (2006).

24. Maturity grids we use here are 0.5, one, two, three, five, seven, 10, 15, 18, and 20 years, instead of overnight (call rate), 0.5, two, five, and 10 years in the case of the fixed-parameter BGL model. Thus, the day-to-day calibration is expected to provide more accurate estimates of the BGL parameters in this regard, too.
25. In fact, empirical performance of the BGL model is much better than the original Vasicek model. The sample average of squared errors from the BGL model is less than one-third that from the original Vasicek model. Also, quite interestingly, the difference in empirical performance between these models narrows when the first-hitting time derived by the BGL model is less than one year, which corresponds to the periods from the middle to the end of 2003 and from the middle of 2005 onward. See Ueno, Baba, and Sakurai (2006) for more details.

JGB market participants were deeply concerned about falling economic growth until the middle of 2003, and since then they have begun to price in the economic recovery.[26]

Second, Figures 13 and 14 exhibit the first-hitting time and the corresponding ending date of the ZIRP estimated by the BGL model, respectively. For comparison, we also show the first-hitting time implied by the euroyen futures interest rates in Figure 13. The two threshold points in time that we regard as the end of the ZIRP are as follows: (1) when the euroyen futures interest rate exceeds 0.19 percent, which corresponds to the average rate when only the ZIRP was in place (February 1999–August 2000); and (2) when the euroyen futures interest rate exceeds 0.51 percent, which corresponds to the average rate when the target for the uncollateralized overnight call rate was 0.25 percent (August 2000–February 2001). As shown in Figure 13, the first-hitting time estimated by the BGL model is basically within the band between the two first-hitting times implied by the euroyen futures.[27] This result shows the relevance of the BGL model as a tool for monitoring market perceptions about the BOJ's monetary policy. In particular, since around September 2005, the first-hitting time estimated by the BGL model has shown a very close movement

Figure 13 First-Hitting Time Estimated by Day-to-Day Calibration of the BGL Model and Euroyen Futures



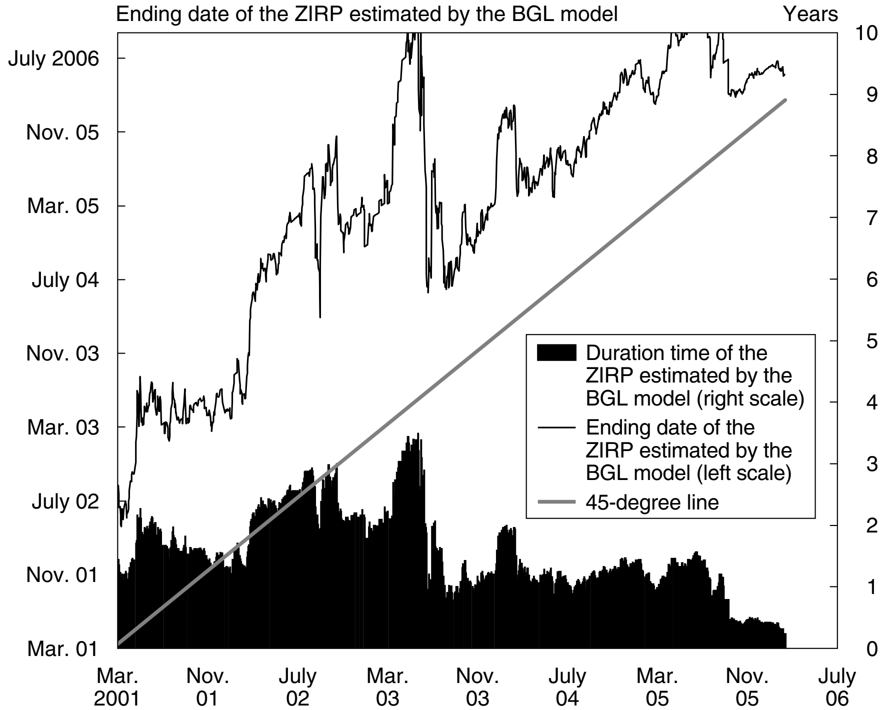
Notes: 1. The thick black line is the first-hitting time estimated by the BGL model. The dashed and thin gray lines are the expected times to end the ZIRP implied by euroyen futures. Case (1): the threshold euroyen futures interest rate is assumed to be 0.19 percent (average of the ZIRP period); case (2): it is assumed to be 0.51 percent (average of the period when the target for uncollateralized overnight call rate was 0.25 percent).
2. Sample period is from the start of the QMEP (March 19, 2001) through February 28, 2006.

Source: Ueno, Baba, and Sakurai (2006).

26. See Nakayama, Baba, and Kurihara (2004) for these anecdotal JGB market observations.

27. Missing values of euroyen futures before fiscal 2003 are due to no transactions occurring.

Figure 14 Ending Date of the ZIRP Estimated by the BGL Model



Note: Sample period is from the start of the QMEP (March 19, 2001) through February 28, 2006.

Source: Ueno, Baba, and Sakurai (2006).

and level to the lower bound of the first-hitting time implied by the euroyen futures. As of February 28, 2006, the first-hitting time estimated by the BGL model is about three months under the risk-neutral probability. This means that the JGB market participants expect that the ZIRP will end around the end of April 2006 at the earliest, as shown in Figure 14.[28]

IV. The BOJ's Monetary Policy and Risk Premiums for Japanese Banks

This section investigates the effects of the BOJ's monetary policy on the risk premiums for Japanese banks in a wide range of financial markets, from short-term money markets to the long-term CDS and stock markets.

28. Note that under the actual probability, the first-hitting time is longer than that under the risk-neutral probability when the market price of risk is negative.

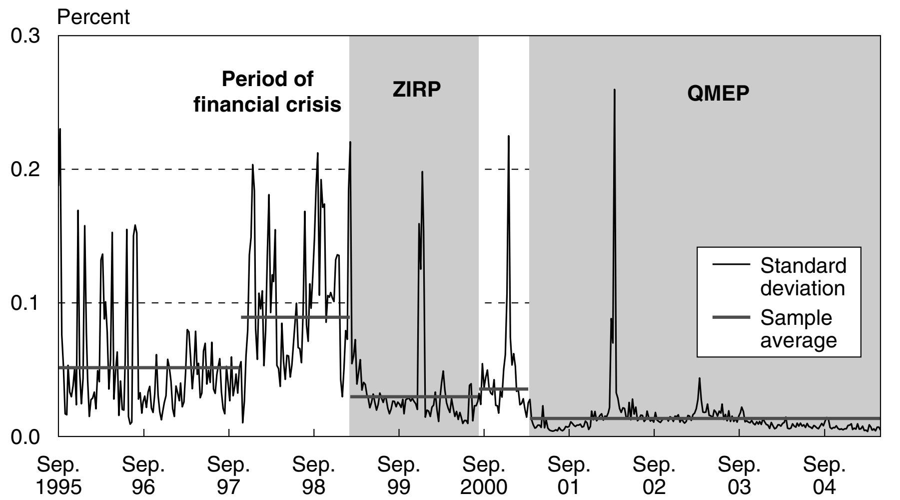
A. NCD Interest Rates

1. Dispersion of NCD interest rates across banks

First, let me review the analysis by Baba *et al*. (2006) that explores the effects of the BOJ's monetary policy on the NCD interest rates. Major Japanese banks recently raise about 30 percent of their total market funding by issuing NCDs. Thus, NCDs can be thought of as one of their principal instruments for meeting liquidity needs.

Interest rates on major banks' newly issued NCDs had served as a main indicator for deregulated interest rates, although their movement had been similar across banks for some time after the first NCDs were issued in May 1979. That is, the NCD interest rates had not reflected differences in bank credit risks. From the 1990s, however, the NCD interest rates started to reflect the credit risk of individual issuing banks, due mostly to the rising concern over the instability of the Japanese financial system. Such concern heightened during the period from late 1997 to 1998. This is shown in Figure 15 by substantial spikes in the dispersion as measured by the standard deviation of the weekly NCD interest rates across issuing banks in November 1997.[29] The standard deviations declined significantly, however, after the adoption of the ZIRP in February 1999 and fell further following the adoption of the QMEP in March 2001.[30]

Figure 15 Dispersion of NCD Interest Rates



Note: NCD interest rates used here are those with maturities less than 30 days.

Source: Baba *et al.* (2006).

29. The standard deviation of the NCD interest rates with maturities less than 30 days is plotted in Figure 15. It is the most liquid maturity zone of the NCDs in Japan. Baba *et al*. (2006) further report a similar result for other maturity zones including less than 60 days and 90 days. Sample banks are 11 city and trust banks for which weekly NCD interest rates are available.
30. In calculating the averages of standard deviations, the following event dates are excluded for institutional reasons: (1) the end of 1999 (Y2K problem); (2) the end of 2000 (preparation for the adoption of real-time gross settlement [RTGS]); and (3) the end of fiscal 2001 (the partial removal of blanket deposit insurance). Evidently, significant spikes are observed on these three dates.

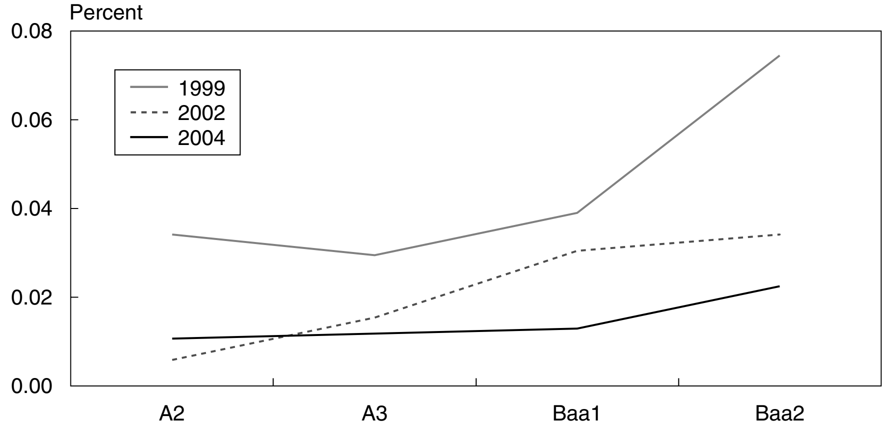
2. Credit curves of NCD spreads

Next, let me look at the credit curves of NCD spreads. Here, the NCD credit spread for a bank is defined as the interest rate on NCDs issued by the bank with maturities less than 30 days minus the weighted average of the uncollateralized overnight call rate. The data frequency is weekly as before. Then, Baba *et al*. (2006) run cross-sectional time-series regressions of the credit spreads on dummy variables corresponding to sample banks' credit ratings for each of the following three years under study: (1) 1999, when the ZIRP was put in place; (2) 2002, one year after the adoption of the QMEP; and (3) 2004, the last year of their sample period. The estimation includes end-of-March, September, and December dummies to control for seasonal market tightness in annual/semiannual book-closing months and the year-end month. The credit spreads for each credit rating category, derived from the coefficients on credit rating dummies along with the constant term, map out the "credit curve" for each year.

Figure 16 demonstrates how the slope of the estimated credit curve became flatter over time.[31] It seems fair to say that the credit curves flattened after the adoption of the ZIRP in 1999, flattened further following the adoption of the QMEP in 2002, and virtually flattened out in 2004.

The estimation result indicates that the credit risk premiums among major banks are recently close to zero, and that the differences in credit ratings among them are now hardly reflected in their fund-raising costs in the money market, such as the NCD market. Therefore, the narrowed dispersion of fund-raising costs among banks, shown in Figure 15, is more likely to be a result of declines in risk premiums across the board in the money market, rather than a result of a lowered dispersion of credit ratings among major banks.

Figure 16 Estimated Credit Curves of NCD Spreads



Note: NCD interest rates are those with maturities less than 30 days. Credit ratings are the long-term ratings of Moody's.

Source: Baba *et al.* (2006).

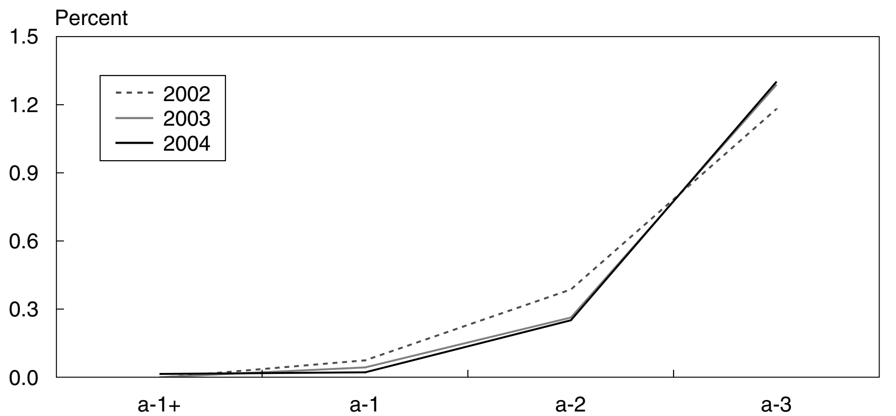
31. Sample banks are the same as in Figure 15.

Figure 17 shows the credit curves of CP spreads with one-month maturity over the uncollateralized overnight call rate as a representative short-term funding measure for nonfinancial corporations.[32] As in the case with NCD spreads, the credit curves have become flatter over time in credit ratings between a-1+ and a-2. There are, however, significant spreads remaining at ratings below a-1.[33] Also, note that the difference in CP spreads between a-2 and a-1 is 10 times as large as the largest one-notch difference in NCD spreads. This result suggests that monetary policy alone cannot create an almost perfectly accommodative environment for corporate finance, unlike for banks, no matter how strong the easing policy that is put in place.

Although it is a formidable task to quantitatively address the role played by the BOJ's monetary policy in the flattening NCD credit curves, Baba *et al*. (2006) assess it using a pooled analysis, allowing the slope of the credit curves to depend on the variables related to the BOJ's monetary policy. Let me briefly summarize their analysis below. The policy variables we include are dummy variables corresponding to the ZIRP and QMEP periods, the level of aggregate CABs, and the average maturity of the BOJ's bill-purchasing operations.[34]

Estimation is done for seven banks for which the long-term bond spread data are available. The result shows that even after controlling for the effect of the long-term bank bond spreads, monetary policy variables, particularly the ZIRP and QMEP dummy variables, as well as the average maturity of the BOJ's bill-purchasing operations,

Figure 17 Estimated Credit Curves of CP Spreads



Note: CP spread is defined as the CP interest rate minus the uncollateralized overnight call rate. Credit ratings are the short-term ratings of Moody's.

Source: Baba *et al.* (2006).

32. Number of observations is 2,327 for 2002, 1,975 for 2003, and 2,006 for 2004, respectively.
33. Another interesting finding is the tightened CP spread between a-1+ and a-1. This is due mainly to the market perception that most of the CP eligible for the fund-supplying operations by the BOJ has a-1 or higher ratings.
34. The rationale behind the inclusion of the average maturity of the BOJ's bill-purchasing operations is as follows. At times of low demand for liquidity by financial institutions, the BOJ had to offer longer-dated operations to meet the target on the CABs. In this sense, the variable may be regarded as a proxy for an *ex ante* "excess supply" of liquidity in the money market.

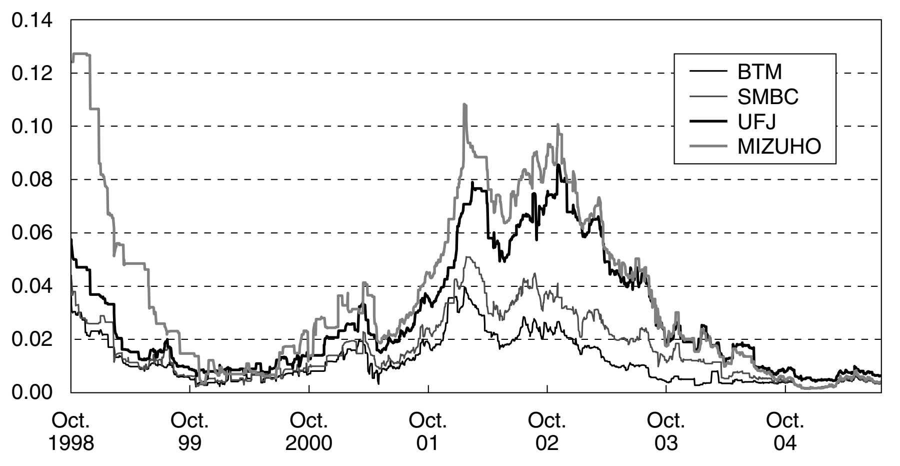
significantly contributed to the decline in risk premiums across the board, as well as the flattening of the credit curves in the NCD market.

B. Risk Premiums for Japanese Banks in the CDS and Stock Markets

Last, let me look at the CDS market as a longer-term market for bank credit risk, as well as the stock market. There has been widespread use of stock prices to assess the default probabilities for corporations using structural models that have their origin in Merton (1974). In addition, as argued by Ito and Harada (2004), due to the recent expansion of CDS trading for Japanese banks, CDS spreads are now regarded as reflecting credit risks of Japanese banks much more sensitively than straight bond spreads and the Japan premium (the TL spread). The typical maturity of CDS contracts for Japanese entities is five years. We can use the so-called reduced-form model to estimate default probabilities from the CDS spreads.

Ueno and Baba (2006a, b) compute the one-year-ahead default probabilities for four Japanese mega-banks, namely, Bank of Tokyo-Mitsubishi (BTM), Sumitomo Mitsui Banking Corporation (SMBC), UFJ Bank (UFJ), and Mizuho Bank (MIZUHO), from CDS spreads and stock prices.[35] Figures 18 and 19 show the results, respectively. Evidently, from late 2001 to 2003, a large and prolonged surge is observed in both

Figure 18 Default Probabilities Implied by CDS Spreads

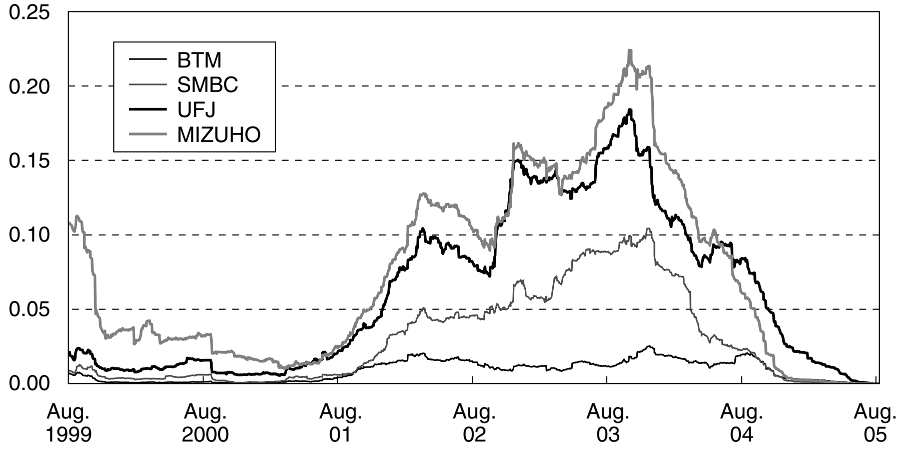


Notes: 1. The time horizon is assumed to be one year. For details, see Appendix 3.
2. BTM: Bank of Tokyo-Mitsubishi; SMBC: Sumitomo Mitsui Banking Corporation; UFJ: UFJ Bank; MIZUHO: Mizuho Bank.
3. SMBC, UFJ, and MIZUHO were established as a result of their respective mergers during the sample period. Before the mergers, we use the data on Sumitomo Bank for SMBC, Sanwa Bank for UFJ, and Fuji Bank for MIZUHO.

Source: Ueno and Baba (2006a).

35. Ueno and Baba (2006b) estimate the default probabilities from the stock prices using the method by Merton (1974). For the reduced-form model used in Ueno and Baba (2006a) to estimate the default probabilities from the CDS spreads, see Appendix 3. Ueno and Baba (2006a) also estimate expected recovery rates, jointly with the default intensities, using both senior and subordinated CDS spreads.

Figure 19 Default Probabilities Implied by Stock Prices



Notes: 1. The time horizon is assumed to be one year. Merton's (1974) model is used.
2. BTM: Bank of Tokyo-Mitsubishi; SMBC: Sumitomo Mitsui Banking Corporation; UFJ: UFJ Bank; MIZUHO: Mizuho Bank.
3. SMBC, UFJ, and MIZUHO were established as a result of their respective mergers during the sample period. Before the mergers, we use the data on Sumitomo Bank for SMBC, Sanwa Bank for UFJ, and Fuji Bank for MIZUHO.

Source: Ueno and Baba (2006b).

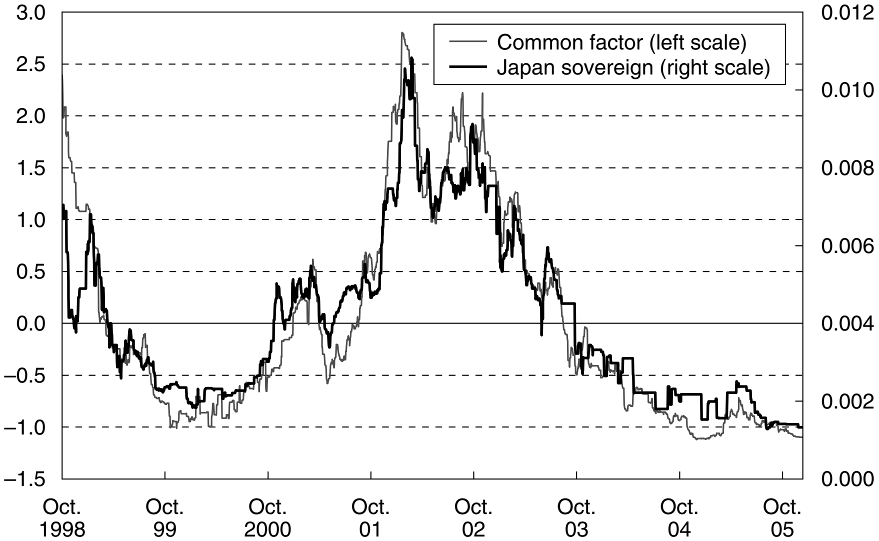
markets, in addition to 1998. This is in sharp contrast to the result of the NCD interest rate and TL spread, shown in Figures 4 and 5. Putting these results together, we can tentatively conclude that there is something distinct in the perceptions for Japanese banks in short-term money markets, compared with other markets including the CDS and stock markets.

Ueno and Baba (2006a) further explore the relationship between the "systemic" nature of Japanese bank credit risk and the government.[36] Specifically, our strategy is to extract a latent common factor from the estimated default intensities for the four banks by factor analysis, and compare the common factor with the default intensity for the Japanese government.[37] The result is displayed in Figure 20. Surprisingly enough, these two default risk indices are almost perfectly correlated with each other, with a correlation coefficient of higher than 0.95. Implications derived from these findings are discussed in the next section.

36. A noteworthy feature of the CDS contracts for Japanese entities is that Japanese sovereign contracts have been traded very actively. As shown by Packer and Suthiphongchai (2003), from 2000 to 2003 the total number of CDS quotes for Japanese sovereign bonds amounts to 2,313, which corresponds to the third largest total, after Brazil and Mexico. This fact, along with successive downgrades of the credit rating on Japanese sovereign bonds, shows investors' deep concern over the financial standing of the Japanese government itself, which faced prolonged deflation after the bursting of the bubble economy in the early 1990s, and the ensuing structural problems, such as the fragile financial system.

37. The estimation result of the factor analysis shows that the first factor whose factor loadings are almost equal across the four banks contributes more than 90 percent of the total variation of the default intensities for the four banks. Thus, it seems quite natural to regard this first factor as the "systemic risk (common) factor."

Figure 20 CDS Spread-Implied Default Intensity for Japan Sovereign and Common Factor Derived from the Four Japanese Mega-Banks' Default Intensities



Notes: 1. The common factor is derived from the four Japanese mega-banks' default intensities estimated from the CDS spreads using factor analysis. The method of principal component is used. The result is the initial solution before a rotation.
2. The common factor is standardized as mean zero and standard deviation one.

Source: Ueno and Baba (2006a).

V. Concluding Remarks

This paper has reviewed the financial market functioning under the ZIRP and the subsequent QMEP conducted by the BOJ. In doing so, particular attention has been given to assessing market perceptions about the duration of the BOJ's monetary policy and its effects on risk premiums for Japanese banks. The main findings are as follows.

First, the estimation results of the JGB yield curve using the BGL model show that (1) the shadow interest rate has been negative since the late 1990s, turned upward in 2003, and has been on an uptrend since then, and (2) the first-hitting time until the negative shadow interest rate hits zero again under the risk-neutral probability is estimated to be about 10 months as of end-December 2005 from the fixed-parameter model, and about three months as of the end of February 2006 from the day-to-day calibration. Second, under the ZIRP and QMEP, the risk premiums for Japanese banks have almost disappeared in short-term money markets, while they have remained in long-term markets such as the CDS and stock markets.

Here, the next question we should address is the following: "why did the short-term money market prices such as the NCD interest rate and TL spread not show a surge in the period of financial instability under the QMEP, unlike the default probabilities derived from the long-term CDS spreads and stock prices?" Let me conclude this paper by raising two hypotheses to address this question and briefly commenting on each.[38]

The first hypothesis is raised by Baba *et al*. (2006). That is, the participants in the Japanese money markets positively perceive the role of the BOJ's ample liquidity provisions under the QMEP in containing the near-term defaults of banks caused by the liquidity shortage. This hypothesis seems to be supported by the findings about NCD credit curves reviewed in this paper. Let me briefly comment on this issue below.

There are two possible effects of the BOJ's monetary policy on bank credit risk. The first effect is that easy monetary policy raises asset prices and lowers risk premiums. This effect is very general. But the second effect is rather specific to the QMEP conducted by the BOJ. The policy package under the QMEP, namely, the strong commitment to maintain a zero interest rate as well as the provision of ample liquidity, substantially contained the risk that banks would fail to meet short-term payment obligations, which likely makes the near-term chance of a default smaller.

An interesting point to note here is that the default probabilities observed in the long-term CDS and stock markets surged significantly during the period of financial instability even under the QMEP. We also find that the common factor derived from the default intensities of the four Japanese mega-banks is almost perfectly correlated with the default intensity of the Japanese government. This empirical result may suggest the difference in the role between the government and the BOJ in addressing the problem of financial instability around 2001 to 2003: the government played the leading role in addressing the long-term financial standing (solvency) of the Japanese financial institutions, while the BOJ played the role of addressing the short-term liquidity shortage of the Japanese financial institutions.

The second (negative) hypothesis is that the BOJ's QMEP has only paralyzed the functioning of short-term money markets in that banks do not need to raise short-term liquidity from markets and thus do not need to evaluate their counterparties' risk properly. This is because the BOJ provided too much money to meet the target for the CABs. This hypothesis is hard to test. But Baba *et al*. (2005) imply the validity of this hypothesis, saying that as financial institutions have become more and more dependent on the BOJ's fund-supplying market operations, the size of the call market, which had already shrunk under the ZIRP, has contracted further since the adoption of the QMEP.[39]

38. In this regard, Ito and Harada (2004) raise the following two hypotheses. The first is that "Japanese banks have been required to put up cash collaterals to raise dollars in the money markets since around 2000–2001." The second is that "weaker banks have exited from the international money markets." Both of these hypotheses may be the case, but are not necessarily verified. For instance, if the second hypothesis is the case, why did the CDS and equity markets imply high default probabilities for Japanese mega-banks until quite recently?

39. The daily trading volume in the uncollateralized call market was about ¥7.4 trillion before the adoption of the QMEP. Subsequently, it gradually declined, reaching ¥1.3 trillion in April 2004. The amount outstanding also declined from ¥17.9 trillion to ¥5.0 trillion during the same period.

APPENDIX 1: GOROVOI AND LINETSKY'S ANALYTICAL SOLUTION TO THE BLACK MODEL

This appendix briefly describe the analytical solution by Gorovoi and Linetsky (2004) to the Black model of interest rates as options, as well as the framework by Linetsky (2004) to calculate the first-hitting time until the negative shadow interest rate hits zero.

A. Analytical Solution to the Black Model

We adopt the Vasicek model for the shadow interest rate under the risk-neutral probability:

$$dr_t^* = \kappa(\theta - r_t^*)dt + \sigma dB_t, \quad r_0^* = r, \tag{A.1}$$

where θ is the long-run level of the shadow interest rate, κ is the rate of mean reversion toward the long-run level, and σ is the volatility parameter.

Note that the discount bond price can be given by

$$P(r, T) = \mathrm{E}_r\left[\exp\left\{-\int_{s=0}^{T} r_s ds\right\}\right] = \mathrm{E}_r\left[\exp\left\{-\int_{s=0}^{T} \max[0, r_s^*]ds\right\}\right], \tag{A.2}$$

where $\mathrm{E}_r[\bullet] \equiv \mathrm{E}[\bullet | r_0^* = r]$, and T is time to maturity. (A.2) has the form of the Laplace transform of an area functional of the shadow interest rate diffusion:

$$A_t \equiv \int_0^t \max[0, r_s^*]ds, \quad t \geq 0. \tag{A.3}$$

The area functional measures the area below the positive part of a sample path of the interest rate process up to time t. Thus, the discount bond price can be calculated as

$$P(r, T) = \mathrm{E}_r[\exp(-A_T)]. \tag{A.4}$$

To calculate the discount bond price (A.4), the spectral expansion approach is used. The discount bond price $P(r, T)$ as a function of time to maturity T, and the initial shadow interest rate r, solve the fundamental pricing partial differential equation:

$$\frac{1}{2}\sigma^2 P_{rr} + \kappa(\theta - r)P_r - \max[0, r^*]P = P_T, \tag{A.5}$$

subject to the initial condition $P(r, 0) = 1$. The solution has the eigenfunction expansion:

$$P(r, T) = \mathrm{E}_r[\exp(-A_T)] = \sum_{n=0}^{\infty} c_n \exp(-\lambda_n T)\varphi_n(r), \tag{A.6}$$

$$c_n = \int_{-\infty}^{\infty} \varphi(r)\frac{2}{\sigma^2}\exp\left(-\frac{\kappa(\theta - r)}{\sigma^2}\right)dr. \tag{A.7}$$

Here, $\{\lambda_n\}_{n=0}^{\infty}$ are the eigenvalues with $0 < \lambda_0 < \lambda_1 < \ldots, \lim_{n\to\infty} \lambda_n = \infty$, and $\{\varphi_n\}_{n=0}^{\infty}$ are the corresponding eigenfunctions of the associate Sturm-Liouville spectral problem:

$$-\frac{1}{2}\sigma^2 u''(r) - \kappa(\theta - r)u'(r) + \max[0, r^*]u(r) = \lambda u(r). \tag{A.8}$$

Here, we have the following asymptotics for large times to maturities:

$$\lim_{T\to\infty} R(r, T) = \lim_{T\to\infty}\left(-\frac{1}{T}\ln P(r, T)\right) = \lambda_0 > 0. \tag{A.9}$$

As time to maturity increases, the yield curve flattens out and approaches the principal eigenvalue λ_0. Here, the principal eigenvalue is guaranteed to be strictly non-negative.

B. First-Hitting Time until the Negative Shadow Interest Rate Hits Zero
The first-hitting time is defined as

$$\tau_0 \equiv \min[t \geq 0; r_t^* = 0]. \tag{A.10}$$

Linetsky (2004) calculates the probability distribution function (PDF) of the first-hitting time for the Vasicek process using the eigenfunction expansion method. In this paper, we use the mode value of the estimated PDF as the representative value of market perceptions about the first-hitting time τ.

To calculate the PDF of the first-hitting time, Linetsky (2004) uses the eigenfunction expansion approach. Suppose that $r_0^* = r < 0$ and $t > 0$, the PDF of the first-hitting time can be written as

$$f_{\tau 0}(t) = \sum_{n=1}^{\infty} d_n \gamma_n \exp(-\gamma_n t), \quad t \geq 0, \tag{A.11}$$

where $\{\gamma_n\}_{n=0}^{\infty}$ are the eignvalues with $0 < \gamma_0 < \gamma_1 < \ldots < \lim_{n\to\infty} \gamma_n = \infty$. Here, $\{d_n\}_{n=0}^{\infty}$ are explicitly given as

$$d_n = -\frac{H_{\frac{\gamma_n}{n}}\left(\sqrt{\kappa}(\theta - r)/\sigma\right)}{\frac{\gamma_n}{n}\frac{\partial}{\partial\gamma}\left[H_\gamma\left(\sqrt{\kappa}\,\theta/\sigma\right)\right]\Big|_{\gamma=\frac{\gamma_n}{n}}}, \tag{A.12}$$

where $H_\gamma(\bullet)$ denotes the Hermite function.

APPENDIX 2: FIXED-PARAMETER BGL MODEL

This appendix briefly describes the basic setup for the fixed-parameter BGL model used in Ichiue and Ueno (2006). Under the actual probability P, r_t^* is assumed to follow a process given by

$$dr_t^* = \kappa^P(\theta^P - r_t^*)dt + \sigma dB_t^P, \tag{A.13}$$

$$\lambda_t = \delta_0 + \delta_1 r_t^*, \tag{A.14}$$

where λ_t denotes the market price of risk. With this choice of market price of risk, r_t^* follows an Ornstein-Uhlenbeck process under both the actual probability P and the risk-neutral probability Q. Specifically, under Q,

$$dr_t^* = \kappa^Q(\theta^Q - r_t^*)dt + \sigma dB_t^Q, \tag{A.15}$$

where $\kappa^Q = \kappa^P + \delta_1\sigma$ and $\kappa^Q\theta^Q = \kappa^P\theta^P - \delta_0\sigma$.

Discretizing (A.13) gives the following transition equation:

$$r_{t+h}^* = \mu + \Phi r_t^* + \eta_{t+h}, \tag{A.16}$$

$$\mu = \theta^P(1 - \exp(-\kappa^P h)), \tag{A.17}$$

$$\Phi = \exp(-\kappa^P h). \tag{A.18}$$

η_t is assumed to be normally distributed with mean zero and standard deviation σ_η, where

$$\sigma_\eta = \sigma\sqrt{\frac{1 - \exp(-2\kappa^P h)}{2\kappa^P}}. \tag{A.19}$$

Let R_t denote a five-dimensional vector with the observed interest rates at time t. We use the observed JGB yields with 0.5-, two-, five-, and 10-year maturities, as well as the collateralized overnight call rate as R_t. The measurement equation for R_t is then given by

$$R_{t+h} = z(r_{t+h}^*) + e_{t+h}, \quad \text{var}_t(e_{t+h}) = H_t. \tag{A.20}$$

Here, $z(r_{t+h}^*)$ is a function that relates the shadow interest rate to the observed rates, and e_{t+h} is a measurement error vector. The errors are assumed to be normally distributed with mean zero and standard deviation σ_ϵ for each yield, where σ_ϵ is a constant to be estimated. Note that the function $z(r_{t+h}^*)$ is nonlinear due to the use of the BGL model.

As in Duffee (1999), we use a Taylor approximation of this function around the one-period forecast of r_{t+h}^* to linearize the model:

$$R_{t+h}^{ON} = \alpha_{t+h} r_{t+h}^{*} + e_{t+h}^{ON}, \tag{A.21}$$

$$\alpha_{t+h} = \begin{cases} 1, \text{ if } \mu + \Phi r_t^* \geq 0 \\ 0, \text{ otherwise} \end{cases}, \tag{A.22}$$

$$\tilde{R}_{t+h} = (z(\mu + \Phi r_t^*) - \mu - \Phi r_t^*) + z'(\mu + \Phi r_t^*) r_{t+h}^* + \tilde{e}_{t+h}, \tag{A.23}$$

where $\tilde{R}_{t+h}$ is a vector of JGB yields with 0.5-, two-, five-, and 10-year maturities. The likelihood function is constructed following De Jong (2000).

APPENDIX 3: ESTIMATION METHOD OF DEFAULT INTENSITY FROM THE CDS SPREADS

This appendix describes the estimation method of default intensity from the CDS spreads used by Ueno and Baba (2006a). The model setup follows Pan and Singleton (2005). Under the actual measure P, λ_t^Q is assumed to follow a process given by

$$d\lambda_t^Q = \kappa^P(\theta^P - \lambda_t^Q)dt + \sigma^Q \sqrt{\lambda_t^Q} dB_t^P, \tag{A.24}$$

$$\eta_t = \frac{\delta_0}{\sqrt{\lambda_t^Q}} + \delta_1 \sqrt{\lambda_t^Q}. \tag{A.25}$$

With this choice of market price of risk η_t, λ_t^Q follows a square diffusion process under both P and Q. Specifically, under Q,

$$d\lambda_t^Q = \kappa^Q(\theta^Q - \lambda_t^Q)dt + \sigma^Q \sqrt{\lambda_t^Q} dB_t^Q, \tag{A.26}$$

where $\kappa^Q = \kappa^P + \delta_1 \sigma^Q$ and $\kappa^Q \theta^Q = \kappa^P \theta^P - \delta_0 \sigma^Q$. Discretizing the CDS pricing equation[40] gives the following transition equation:

$$\lambda_{t+h}^Q = \mu + \Phi \lambda_t^Q + \psi_{t+h}, \tag{A.27}$$

where $\mu = \theta^P(1 - \exp(-\kappa^P h))$ and $\Phi = \exp(-\kappa^P h)$. ψ_t is assumed to be normally distributed with mean zero and standard deviations σ_η, where

$$\sigma_\psi = \sigma^Q \sqrt{\left(\frac{1 - \exp(-\kappa^P h)}{\kappa^P}\right)\left(\frac{\theta^P(1 - \exp(-\kappa^P h))}{2} + \lambda_t^Q \exp(-\kappa^Q h)\right)}. \tag{A.28}$$

40. The CDS pricing equation equates the present value of the premiums paid by the buyer of CDS protection with the present value of the payment paid by the seller when credit events occur.

Now, let CDS_t denote an N_t-dimensional vector of the observed CDS spreads at time t, where N denotes the maturity of the CDS contract. The measurement equation for CDS_t is then given by

$$CDS_{t+h} = z(\lambda^Q_{t+h}) + e_{t+h}, \quad \text{var}_t(e_{t+h}) = H_t. \tag{A.29}$$

Here, $z(\lambda^Q_{t+h})$ maps the default intensity into CDS spreads in which we attempt to identify between the default intensity and the expected recovery due to the property of fractional recovery of face value, inherent in the CDS contract.[41] We further identify the difference in the expected recovery rate between senior and subordinated CDS contracts by assuming their proportional relation to each other. The function $z(\lambda^Q_{t+h})$ is nonlinear, and e_{t+h} is a measurement error vector. The matrix H_t is an $N_t \times N_t$ diagonal matrix of which the j-th diagonal element is $\sigma_\epsilon |Bid_{j,t} - Ask_{j,t}|$.

As in Duffee (1999), a Taylor approximation of this function around the one-period forecast of λ^Q_t is used to linearize the model and we do not assume that the default intensity processes are stationary. Therefore, we cannot use the unconditional distribution of λ^Q_t to initiate the Kalman filter recursion. Instead, we use a least-squares approach to extract an initial distribution from the first CDS spread observation. Denote this first date as date 0. Then,

$$z(\lambda^Q_0) \approx z(\lambda^Q_0) - Z\theta^Q + Z\lambda^Q_0, \tag{A.30}$$

where Z is the linearization of z around θ^Q:

$$Z = \left.\frac{\partial z(\lambda^Q_0)}{\partial \lambda^Q_0}\right|_{\lambda^Q_0 = \theta^Q}. \tag{A.31}$$

Based on this linearization, we can write the measurement equation for the first date CDS spreads as

$$CDS_0 = z(\theta^Q) - Z\theta^Q + Z\lambda^Q_0 + e_0. \tag{A.32}$$

This equation can be rewritten in terms of λ^Q_0:

$$\lambda^Q_0 = \frac{Z'(CDS_0 - z(\theta^Q) + Z\theta^Q)}{Z'Z} - \frac{Z'e_0}{Z'Z}. \tag{A.33}$$

Thus, the distribution of λ^Q_0 is assumed to have mean $Z'(CDS_0 - z_0(\theta^Q) + Z\theta^Q)/(Z'Z)$ and variance $H_0/(Z'Z)$. Following De Jong (2000), given this initial distribution of unobserved default intensity, the extended Kalman filter recursion proceeds as follows.

41. For fractional recovery of face value, see Duffie and Singleton (2003) for details.

Model:

$$CDS_{t+h} = A(\lambda_t^Q) + B(\lambda_t^Q)\lambda_{t+h}^Q + e_{t+h}, \quad \mathrm{var}(e_{t+h}) = H_t, \tag{A.34}$$

$$A(\lambda_t^Q) = z(\mu + \Phi\lambda_t^Q) - B(\lambda_t^Q)(\mu + \Phi\lambda_t^Q), \tag{A.35}$$

$$B(\lambda_t^Q) = \left.\frac{\partial z(\lambda_{t+h}^Q)}{\partial \lambda_{t+h}^Q}\right|_{\lambda_{t+h}^Q = \mu + \Phi\lambda_t^Q}, \tag{A.36}$$

$$\lambda_{t+h}^Q = \mu + \Phi\lambda_t^Q + \eta_{t+h}. \tag{A.37}$$

Initial conditions:

$$\hat{\lambda}_0^Q = Z'(CDS_0 - z(\theta^Q) + Z\theta^Q)/(Z'Z), \tag{A.38}$$

$$\hat{q}_0 = H_0/(Z'Z). \tag{A.39}$$

Prediction:

$$\lambda_{t|t-h}^Q = \mu + \Phi\hat{\lambda}_{t-h}^Q, \tag{A.40}$$

$$q_{t|t-h} = \Phi^2\hat{q}_{t-h} + \sigma_\psi^2. \tag{A.41}$$

Likelihood contributions:

$$u_t = CDS_t - A(\hat{\lambda}_{t-h}^Q) - B(\hat{\lambda}_{t-h}^Q)\lambda_{t|t-h}, \tag{A.42}$$

$$V_t = B(\hat{\lambda}_{t|t-h}^Q)q_{t|t-h}B(\hat{\lambda}_{t-h}^Q) + H_t, \tag{A.43}$$

$$-2\ln L_t = \ln|V_t| + u_t' V_t^{-1} u_t. \tag{A.44}$$

Updating:

$$K_t = q_{t|t-h}B(\hat{\lambda}_{t-h}^Q)' V_t^{-1}, \tag{A.45}$$

$$L_t = I - K_t B(\hat{\lambda}_{t-h}^Q), \tag{A.46}$$

$$\hat{\lambda}_t^Q = \lambda_{t|t-h} + K_t u_t, \tag{A.47}$$

$$\hat{q}_t = L_t q_{t|t-h}. \tag{A.48}$$

The survival and default probabilities are calculated following Longstaff, Mithal, and Neis (2005).

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Comment

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I. Introduction

In his interesting paper, Naohiko Baba covers two main subjects. The first is expectations about interest rates rising above the zero bound. The second is risk premiums for Japanese banks during the period of the zero interest rate policy (ZIRP) and the quantitative monetary easing policy (QMEP). The paper is very useful in providing us with a summary of the extensive work that has been done at the Bank of Japan (BOJ) by the author and various co-authors on related topics over the past three years.

I would like to focus on four topics:

- What we can learn from this paper about yield curve indicators and how financial markets work at the zero lower bound on nominal interest rates.
- What we can learn from this paper about the behavior of credit risk premiums for banks under the ZIRP and QMEP.

42. The views expressed in this comment are solely those of the author. No responsibility for them should be attributed to the Bank of Canada.

- What we can learn about monetary policy at the zero bound.
- What some of the extensions to the analysis in this paper are that would help us to learn more about monetary policy and the behavior of financial markets at the zero bound. I will talk about such extensions throughout my remarks.

However, before getting into these topics, I would like to step back and suggest how, in general, I see the influences on financial markets.

First, it is clear that behavior in financial markets is affected by the monetary policy that is in place. In the present paper, this means the ZIRP and QMEP. Moreover, it is not merely the policy itself, but the market's perceptions of what that policy means in practice. In particular, the market will be influenced by publications and statements of officials from the BOJ, as well as statements from government spokespeople. In addition, the market's response to data will depend on how it perceives the monetary policy regime.

Second, the market's perception of the credit risk it faces in lending to banks will depend on its perception of the regulatory and supervisory system in place. In the period in question in Japan, this includes beliefs about the degree of forbearance of deficient capital positions by the supervisor and the government.

Third, changes in risk perception and risk aversion can also lead to changes in financial market prices.

Given that all three factors above will always be at play, developing a completely "causal" story for the behavior of interest rates may be somewhat complicated. As well, some of the influences may emanate from abroad. To take two examples, changes in risk aversion or risk appetite may be international in scope and some of the data relevant to future policy interest rate developments in Japan may be data on foreign demand or output, because that will ultimately be reflected in foreign demand for Japanese products. As evidence that the former may have been important, one can point to the general decline in credit spreads across countries in recent years. As evidence of the latter, one can point to the high correlation between Japanese and U.S. or German 10-year bond yields over the past five or six years, as shown in Figure 3 in the paper.

II. Financial Markets at the Zero Bound: The Yield Curve

In the first part of the paper, the author uses the Black-Gorovoi-Linetsky (BGL) model to examine yield curve behavior when short-term interest rates are essentially zero. He finds that over most of the period, the BOJ was not expected to exit the ZIRP or QMEP very soon. Anthony Richards, the other discussant for this paper, discusses the BGL model in more detail. What I will do is to raise two questions and talk about possible extensions.

The first question is a technical one. If one is interested in developing precise estimates of the horizon to leave the zero bound—the "first-hitting time" in the expression used by the author—would it help to include more points along the short part of the yield curve, say, by adding the three-month, nine-month, 1.5-year, and 2.5-year rates?

The second question is about the interpretation of the results. As I read the results in Figure 13, the market has almost always *underestimated* the amount of time it would take for interest rates in Japan to rise above zero. If one assumes that this rise will occur in the second half of 2006, there are basically only two periods in which the market has *not* underestimated the amount of time. The first was in mid-2003, when the market thought it would take some three to 3.5 years for rates to rise above zero. The second was in mid-2005, when the market thought it would take one to 1.5 years.

There are two extensions to this part of the paper that I would find useful.

The first would be very easy to do. It is to calculate the expectation of the increase in interest rates over the course of the first year following the first-hitting time. This could be presented either as the expected one-year rate at the first-hitting time or the expected overnight rate one year after the first-hitting time. Either would represent a measure of the market's view of how steep or shallow the increase in interest rates would be in the period just after the BOJ exits zero interest rates.

The second would be to examine what macro variables and announcements are driving the yield curve, especially the "shadow interest rate" and the first-hitting time. The author notes that "the shadow interest rate seems to have closely followed the core CPI inflation rate with several-month lags since early 2001" (Section III.C.1) and that "the release of the CPI data is delayed by approximately two months" (Footnote 22). The relationship between the shadow interest rate and core CPI inflation is displayed graphically in Figure 11 (2) of his paper. A beginning to a further examination would be to explore more fully, in a regression context, the relationship between the shadow interest rate and lags on the core CPI inflation rate. To this relationship could be added information on real growth rates in Japan, announcements and speeches by the BOJ and government officials on monetary policy (going beyond the announcements of the beginning of the ZIRP and QMEP), any important announcements on the health of the banking system, and possible foreign economic data as well, because of its effect on the demand for Japanese goods and services. An alternative to this line of exploration would be to explore the relationship between the first-hitting time and the variables that I have mentioned. I will come back to this general issue later, in the context of using estimated macro-finance models to better understand the implications for monetary policy at the zero bound.

III. Financial Markets at the Zero Bound: Credit Risk Premiums

In the second part of his paper, the author turns his attention to the credit risk premiums paid by banks. His results are not unexpected. To summarize, bank short-term risk premiums have almost disappeared, but long-term risk premiums have remained, although they are now much lower than in the 2001–03 period. The author notes (Section IV.A.2) that he and co-authors have found that "even after controlling for the effect of the long-term bank bond spreads, monetary policy variables . . . significantly contributed to the decline in risk premiums across the board, as well as the flattening of the credit curves in the NCD [negotiable certificates of deposit] market." What is not controlled for, however, is the policy of the banking supervisor and the government toward the operations of Japanese banks with capital deficiencies.

To the extent that there is regulatory forbearance, it may be regulatory policy as much as monetary policy that is leading to low credit risk premiums. Not being an expert on the timing of various regulatory initiatives in Japan, I am unable to say how relevant this has been over the past few years. But it certainly has had relevance over some of the last 15 years in Japan. What we do know is that the provision of liquidity by a central bank cannot by itself make an insolvent bank solvent. Short-term credit risk premiums presumably are more related to the expected probability of insolvency than to liquidity, although—admittedly—excess liquidity may hide solvency problems from the market to some extent. Overall, it would be useful for the author to spend some time to see whether the analysis is robust to an examination of the attitude of the supervisor and the government toward capital deficiencies in Japanese banks over the period in question.

IV. Monetary Policy at the Zero Bound

I would now like to turn my attention to the question of how monetary policy can and has worked at the zero bound for nominal interest rates.

From a theoretical point of view, there are various channels through which monetary policy can work at the zero bound. The first channel is engendering expectations that rates will stay at zero for a long time, or until some condition is fulfilled, such as the "commitment" under the QMEP "to maintain the policy until the year-on-year rate of change in the core CPI . . . registers zero percent or higher on a sustainable basis." This first channel is, in essence, the topic of the first half of the paper. The second channel is working through quantities, such as under the QMEP, assuming that money and other financial assets are imperfect substitutes. The QMEP presumably was expected to reduce risk premiums of various sorts, the topic of the second half of the paper, and to raise asset prices and thus wealth. Other quantitative policies include the use of foreign exchange market intervention to affect foreign exchange rates. The third channel is by working in conjunction with fiscal policy, such that an increase in fiscal spending is financed by printing money. (Some of these topics were dealt with by Bennett T. McCallum earlier in the conference.)

The paper clearly shows that the first channel has been an important one in the case of Japan—expectations of a significant period of zero interest rates were indeed engendered and long-term rates came down significantly as a result. As mentioned earlier, however, the expected period over which interest rates would remain at zero was, with two brief exceptions, shorter than the actual period over which interest rates have remained at zero. And so the question remains, is this because the BOJ underestimated the depth of the deflationary problem, or because the market misunderstood how long the BOJ would indeed have to keep interest rates at zero?

To understand more fully what was driving changes in the market's expectation of the time that interest rates would be at zero, it is imperative to use models that relate the macroeconomy to the yield curve. As the author would be the first to argue, such work needs to explicitly take into account the existence of the zero bound. The author is critical of earlier work by Bernanke, Reinhart, and Sack (2004) and Oda and Ueda (2005) because it relies on specific macroeconomic structures and does not closely trace the actual Japanese government bond yield curve. While the macro-finance framework, in which a macro-model structure is added to a yield curve model, is still in its infancy, I would argue that something like it is needed to understand the effects of a monetary policy framework on the yield curve, as well as how macroeconomic shocks and "news" affect the yield curve. Indeed, as one who grew up as a macroeconomist, I found it somewhat strange how yield curve analysis in finance was completely divorced from monetary policy and macroeconomic models. But now progress is being made on integration of the two fields, and it is all to the good.

Since the work by Bernanke, Reinhart, and Sack (2004) and Oda and Ueda (2005), there have been a number of developments. First, more data on the Japanese economy under the QMEP have become available. Second, more work on what drives the yield curve in other economies has become available, including that of Bikbov and Chernov (2006) for the U.S. economy and that of Chabi-Yo and Yang (2006) for Canada. Third, more economists, such as Naohiko Baba, who can incorporate the nonlinear complications posed by the existence of the zero lower bound into the other new developments in the literature, have been entering the field everyday. Thus, I would call for more work in the macro-finance area for Japan.

The paper clearly shows the credit risk premiums paid by the banks on short-term NCDs were clearly squeezed. To determine the effect of this channel of monetary policy on the real economy and economic activity, one needs to answer a few questions. First, how much was actually transacted at these rates, say, as a percentage of bank loans outstanding? Second, what is the evidence that more loans were made because of lower funding costs? For example, did interest rates on bank loans decline in the QMEP period relative to the ZIRP period? Third, what is the overall judgment as to whether this had an appreciable effect on the cost of capital for firms, and thus led to more business fixed investment than would otherwise have been the case? As mentioned earlier, there is the question of how much of the decline in NCD rates arose because of the QMEP and how much because of regulatory forbearance by supervisors or the government.

I would add that the whole question of the interaction of monetary and bank regulatory policies in the ZIRP and QMEP periods is one of great interest in terms of the policy lessons to be drawn from these periods.

V. Conclusion

The author is to be congratulated for introducing a number of tools to describe the behavior of financial markets under the ZIRP and QMEP. In this paper, we learn much about the channels through which monetary policy has worked in a very low interest rate environment. At the same time, I would make a plea for extensions to this work. Chief among the extensions would be to relate the changes in the Japanese yield curve and the bank credit risk premiums to news arising from economic data, information about monetary policy, and information about regulatory forbearance. Some of this work needs to be carried out in well-developed macro-finance models.

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Comment

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Reserve Bank of Australia

The paper by Naohiko Baba covers a wide range of material on recent developments in Japanese financial markets and provides some excellent background for this conference. Given the current policy juncture in Japan, the paper is very timely. And I found the results of the paper to be quite plausible. These comments will focus on Section III, which is the novel part of the paper, and is about modeling interest rates when you are at the zero lower bound. This topic is highly relevant, given that interest rates have been at or near zero in Japan for more than 10 years (i.e., since the target for the policy rate was lowered to 0.5 percent in 1995) but as of the time of the conference were widely expected to rise shortly. Then I will touch briefly on some of the material in Section IV on some broader developments in Japanese financial markets.

In contrast with earlier work by the Bank of Japan (BOJ) on the term structure, the analysis of the zero lower bound in the current paper does not start from a macroeconomic model. Instead, it relies on continuous-time interest rate modeling, where the results are all derived from the level, shape, and volatility of the yield curve, and the assumed stochastic model. This presumably has both pluses and minuses. If we simply want to fit the yield curve, it may be best to do so without the constraints that macroeconomics might add. But if we are looking for an economic interpretation of the results, we have to look outside the pure modeling exercise.

The results suggest that, as of late 2005, an increase in official interest rates was expected within a year. And as of February 2006, the likely date for this had moved forward somewhat. As far as the zero interest rate policy (ZIRP) is concerned, the results suggest that the end is nigh. Market commentary around the time of the conference would not suggest any reason to question this view.

To obtain the key results, the paper uses a complex continuous-time model, which takes account of the fact that currency represents an option that prevents interest rates from going negative. One obvious question would be whether one could get similar results using a simpler framework. After all, the expectations model of the term structure still holds even when interest rates are at the zero lower bound.

If one does some simple figuring based on the term structure, one obtains estimates that are reasonably consistent with expectations from surveys of economists.[43] Furthermore, Figure 13 of the paper shows a comparison of the expected length of the ZIRP derived from the model, and two estimates derived from the euroyen futures strip. The latter two estimates can be viewed as differing in terms of the assumptions about the size of the first BOJ move and the various risk premiums in the futures strip. There is a fairly high correlation between the movements (but not necessarily the levels) of the estimates from the simple approach and the estimate derived from the more complex model. This is not surprising given that the input data for the two different methodologies are quite similar.

So why use a more complex model? One reason is that euroyen futures only go out about two or three years. Another reason is that the standard approach does not really allow simulations. So the simple approach may be all a BOJ watcher needs, but the more complex approach may be useful for a range of modeling exercises, including pricing interest rate derivatives.

The current paper uses an insight from Fischer Black's last paper (Black [1995]). In a liquidity trap, the equilibrium nominal interest rate that would equate savings and investment would be negative. However, assuming that currency exists (and that it cannot be taxed so that it yields a negative nominal rate of return), the zero nominal return on currency will dominate the negative rate that would be earned on loans. So people will not lend money at negative rates, and we will not observe them. Black used the term "shadow" interest rate for the interest rate that would clear the market. When interest rates are positive, the shadow and actual rates are one and the same thing. But when the shadow rate is negative, we do not observe it. Instead, we just observe a zero actual rate.

Standard theoretical interest rate models have a great deal of trouble with the zero lower bound. Such models typically assume a mean-reverting component (which in this case would tend to pull the interest rate upward), plus a stochastic component (that could take rates either up or down). But with interest rates at zero, the possibility of downward movements is hard to deal with. Indeed, the paper notes that in practice standard models do not do a very good job—by themselves—of tracing the changing shape of the Japanese government bond yield curve. However, the results of the paper suggest that when you instead assume that such stochastic models apply to the *shadow* interest rate, and that the *observed* interest rate is the maximum of zero and the shadow rate, then you can explain the Japanese data pretty well.

The results suggest that the shadow interest rate was at its lowest around the second quarter of 2003. Similarly, the "first-hitting time" (which is the estimated time until

43. This would involve taking the euroyen futures strip (or implied forward rates from any fitted yield curve). Then one makes some assumptions about the credit and term risk premiums (which are presumably small) incorporated in the futures strip. This yields an expectation about the future level of the policy rate. Then, with assumptions about the size of the possible move that the BOJ might undertake, one can come up with estimates of when the BOJ might increase its policy rate from zero.

the shadow rate turns positive) was at its longest around that time. Not surprisingly, this was when market yields were at their lowest levels. It was also around the time that inflation was at its lowest point. Then, as core inflation began to rise and the economic recovery became more entrenched, expectations about the duration of the ZIRP were gradually wound back. These results are not surprising given that the BOJ's intentions about future policy have been mostly expressed in terms of the level and outlook for core inflation.

Overall, the modeling results seem quite plausible. Now, at the risk of focusing on them more than might have been intended, I will ask how one should think about the estimates of the shadow interest rate. Perhaps one should not focus too much on any particular numerical estimates, but it certainly is tempting, given that it is something that comes out of the current model, and I am not aware of any other work that addresses this question.

Figure 11 suggests that, as of mid-2003, the shadow interest rate had gotten as low as –6 or –7 percent.[44] At that time, the model suggests that the ZIRP was expected to last a further three years or so. This may actually turn out to have been very close to the mark!

The first thing to point out is that there is no macroeconomic analysis involved in the estimate of the shadow interest rate (or the first-hitting time). Instead, it is based purely on the data for the yield curve and the stochastic model assumed for the shadow rate.

Now without being an expert in continuous-time finance, it is hard to be certain exactly how the model generates this shadow rate, but here is my guess. As was noted earlier, the model's shadow interest is assumed to show some tendency to revert back to a long-run level (plus there is also a stochastic component). In the current case, the fixed-parameter model results in Figure 11 tell us that the short rate is reverting to a long-run level of 3.9 percent (although the day-to-day calibration exercise suggests a somewhat lower rate).

Now in most countries, the shadow short rate is also the actual short rate and it will typically not be more than a few percentage points away from its long-run level. But in the case of Japan, the shadow rate might conceivably have gotten a lot further from its long-run level.

And back in mid-2003, the term structure of the yield curve implied that the shadow rate would remain negative for about three years. If the shadow rate had a tendency to revert to a mean of about 4 percent, and if it was expected to take so long for the shadow rate to rise to zero, it must have been starting a long way below zero. So based on the yield curve of that time and the estimated parameters, the model is apparently telling us that the only way the mean-reverting shadow rate could have remained negative for three years was if it started off at –6 or –7 percent. So if one thought that this was too low, one would have to find some way to dampen the effect of the mean reversion term.

How plausible are these estimates of the shadow rate? Perhaps a Taylor rule-type calculation could shed some light on this, subject to the assumption that this type of

44. Indeed, in Ueno, Baba, and Sakurai (2006) the shadow rate appears to get even lower.

calculation remains appropriate even in extreme situations like the Japanese case.

The original Taylor (1993) rule suggested that the nominal policy rate might be set equal to the long-run equilibrium real interest rate plus the rate of inflation (either current or expected), and a response coefficient to the extent that output differs from potential or inflation deviates from the target rate, with Taylor originally suggesting equal response coefficients of 0.5 on each gap (based on U.S. data). Suppose that the long-run equilibrium real interest rate for Japan is around 2 percent and that the implicit longer-term inflation target was 1 percent. The output gap is notoriously hard to measure, but based on the BOJ's recent work it might be plausible to assume that it was something like –3 or –4 percent in mid-2003.[45] And core inflation was running at around –0.5 percent at that time. If we take Taylor's original coefficients, we can simply add the two gaps together (say, a total of –5 percentage points) and apply a coefficient of 0.5, and add this to 0.5 percent. The result, –2 percent, falls far short of the estimated shadow policy rate of –6 or –7 percent. However, if one instead took larger response coefficients, say, as high as 2, then one could indeed generate the large negative shadow rate derived in the current paper.[46]

So although my initial reaction was that a shadow rate of –6 or –7 percent seemed a bit large, one has to say that it is very hard to know how to assess something like this. How can we know what the interest rate would have been in a world so different from ours? Perhaps it would have been necessary to have both nominal *and* real interest rates very significantly negative to have induced Japanese consumers and firms to spend and borrow more.

Returning to the current situation, I wonder if the concept of the shadow interest rate might not have a corollary in the problems that the BOJ may have faced in managing market expectations. Usually the central bank can set the short rate at the level it thinks is appropriate for the economy. Indeed, some of the models assessing central bank transparency assume that one of the ways that the market infers the central bank's reading of the economy is from its setting of the short rate. However, in a case like the Japanese one, the zero lower bound constrains the central bank from setting the policy rate at the level it thinks is appropriate, so markets are unable to infer anything from the level of the policy rate.

Of course, the BOJ can rely on other channels of communication. Its targets for quantitative variables (such the level of current account balances or open market purchases) might be able to replicate much of the information usually provided via a policy rate. And it also has the standard tools of speeches, policy statements, and so on to signal its views on the economy and the policy outlook. So I suspect that the unobservability of the shadow rate has not been a major constraint on its ability to communicate with markets and the public. Of course, given that central bank watchers always want more information from the central bank, I am sure

45. The relevant output gap is in relation to normal levels of resource. This is consistent with the BOJ's recent work, rather than maximum levels as was the case in earlier BOJ estimates of the output gap.

46. However, it is noteworthy that a Taylor-type calculation would suggest that the shadow rate should have been at its lowest point about a year earlier than implied by the financial market pricing. Core inflation and GDP growth were both significantly weaker in mid-2002 than in mid-2003: this was true for both the actual year-end data and for forward-looking expectations from Consensus Forecasts.

they would have been happy to also have had estimates of the shadow rate as an additional guidepost.

I am now going to touch briefly on the results in Section IV. These results suggest that markets are not discriminating much between assets of different levels of risk. This is based on a range of evidence, including on the pricing of certificates of deposit (CDs) issued by a sample of 11 city and trust banks that shows although lower-rated banks do pay a premium (Figure 15), it is now very small and lower than in earlier years (Figure 16). There is more evidence of differentiation in the pricing of risk for lower-rated corporate borrowers in the CP market (Figure 17). There is also evidence of greater longer-term credit risk for banks implicit in the pricing of credit default swaps and bank equities (Figures 18–20). However, the extent of greater pricing of risk should not be overstated, given that Figure 6 shows that the spread on BBB-rated bonds has recently been only about 25 basis points, which is well below equivalent spreads in other countries.

The paper tentatively suggests that one factor behind these results could be that the market treats the quantitative monetary easing policy (QMEP) as having more or less guaranteed the ability of large banks to meet their short-term obligations. Another proposed explanation—and these are not mutually exclusive—is that under the QMEP, banks have not really had to go to the market to raise funds, so the CD market (and the money market more broadly) have atrophied and no longer really price risk.

One could be disapproving of these developments. However, I am not sure one should criticize the BOJ if indeed this is what has happened. Over the past several years, its most important task was presumably to get the macroeconomy going, *at almost any cost*. As the paper notes (Section I), an important element of monetary policy has been "to alleviate concerns over the financial-sector problems . . . [M]any of the BOJ's market operations had the dual role of providing ample liquidity and addressing problems in the financial sector. In the process, the BOJ assumed a certain amount of credit risk."

While the monetary and financial policies that have been followed have presumably ensured a more rapid recovery for the Japanese economy, they might not have done much for financial market development. No doubt in the period ahead, with the macroeconomic situation much improved, it will become more important to worry (again) about these more micro factors.

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General Discussion

Naohiko Baba responded first to discussants' comments about the relationship between the Bank of Japan's (BOJ's) monetary policy and the Japanese government bond (JGB) yield curve. Regarding the underestimation of the first-hitting time by the JGB market, he emphasized the role of a central bank's communication with financial markets, based on his experience of JGB market monitoring. He claimed that the JGB market had always been testing the BOJ by reacting to news about macroeconomic conditions to learn the BOJ's intent and judgment about the timing of the zero interest rate policy (ZIRP) termination. In such a process, the duration of the ZIRP might be expected by the JGB market to be shorter than the actual duration. Regarding the comment about macroeconomic implications, he agreed that it would be very promising to investigate the relationship between the shadow interest rate or first-hitting time implied by the Black-Gorovoi-Linetsky (BGL) model and macroeconomic news. As for the choice of the complicated BGL model instead of simple methods using euroyen futures interest rates, he pointed out some advantages of the BGL model over the simple model. He argued that the euroyen futures interest rate might not properly reflect market views about the future state of the real economy due to its relatively short maturities and it therefore became very volatile due to speculative trading activities.

Second, regarding the risk premiums for banks, Baba argued that not only the BOJ's policy but also the government's policy was very important in lowering the risk premiums for banks during the ZIRP and quantitative monetary easing policy (QMEP) periods. He noted, however, that the government had played a leading role in addressing the long-term financial standing—that is, solvency problems of banks—mainly through the injections of capital into banks. On the other hand, the BOJ has played a leading role in addressing the short-term liquidity shortage problem of banks by supplying ample liquidity under the QMEP. He further argued that regulatory forbearance by the government also played a role in addressing the liquidity problem, particularly by postponing lifting of the full protection of bank deposits that had been planned to be in place by March 2001. Regarding whether or not the benefits of lowered risk premiums for banks were passed on to borrowers, he argued that the benefit from the lowered short-term fund-raising cost was surely passed on by the lowered lending interest rates, while one had to wait until quite recently to see a rise in the amount of loans.

There were several comments from participants regarding the relationship between the options approach adopted by Baba and the macroeconomic approach including the macro-finance approach. Jan Marc Berk (De Nederlandsche Bank) claimed a possible inconsistency between these two approaches when what Baba used in his approach to the macro level is aggregated. Kiyohiko G. Nishimura (Bank of Japan) pointed out the usefulness of exploring the magnitude of the differences in the estimation errors both in-sample and out-of-sample between the options approach and the macro-finance approach. Glenn D. Rudebusch (Federal Reserve Bank of San Francisco) emphasized the role of interest rate expectations, given output and inflation forecasts under the old regime versus the new regime such as the ZIRP and QMEP, in the context of the Taylor rule, for instance. Maurice Obstfeld (University of California at Berkeley) pointed out that we should look at the real interest rate in thinking about the relationship between savings and investment. Tao Wu (Federal Reserve Bank of Dallas) mentioned that it would be useful to extend the model by adding macroeconomic variables or a two-factor setting. Kazumasa Iwata (Bank of Japan) paid particular attention to the meaning of the estimated long-run mean of the shadow interest rate because of the implication for the role of the commitment under the QMEP.

Baba responded to these comments by stressing the distinct features of the JGB yield curve, in that the short end of the JGB yield curve has been zero for several years and the shape of the yield curve was extremely flattened over the short-term and medium-term maturity zones. Given this situation, the options approach would be very useful for tracing the real-life shape of the yield curve and gauging the duration of the ZIRP expected by the market using high-frequency data such as a daily basis. In particular, conventional macro-finance models cannot address the latter issue. He also argued that Fischer Black's own interpretation of the negative shadow interest rate, the liquidity trap, might have confused macroeconomists. This was because macroeconomists think about the liquidity trap in terms of the real interest rate in relation to the investment-savings (IS) gap, while Black thought about it in terms of the nominal interest rate. He claimed that this was the reason why he adopted his own interpretation: as long as the shadow interest rate was negative, JGB market participants would expect the zero nominal interest rates to continue. In this regard, he agreed with the usefulness of rigorously analyzing the relationship between macroeconomic variables such as the output gap and the shadow interest rate in real terms, explicitly taking account of the consumer price index (CPI) inflation process. Lastly, he mentioned that the extension of the BGL model into a multifactor setting would be useful, while one would have to overcome some technical problems due to the lack of analytical solutions for such extensions.

There were some comments regarding the banking sector and the financial market. Andrew Filardo (Bank for International Settlements) asked about the nature of the distortions that might have arisen in these short-run funding markets as risk premiums were squeezed in recent years in the zero interest rate environment. Hiroshi Fujiki (Bank of Japan) pointed out that we should have a better understanding about how and why bank lending did not work as a significant channel for economic recovery. Stefan Ingves (Sveriges Riksbank) argued that we should consider carefully how we could combine the liquidity issues managed by a central bank with the solvency issues normally handled by a deposit insurance agency or the ministry of finance. Hung Tran (International Monetary Fund) argued that to gauge the change in market perception of credit risk for banks under the QMEP, the focus should be on using a credit default swap (CDS) spread, which would be a pure, and thus more reliable, reflection of market perception of credit risk.

The chairperson, Hiroshi Nakaso (Bank of Japan), concluded the session by mentioning that the issues Baba discussed consist of an area where research exercises were of immediate and useful input to policy considerations, and Japan's experience under the ZIRP and QMEP would provide a rich research agenda for bridging macroeconomic and financial research going forward.