Monetary Policy and the Term Structure of Interest Rates When Short-Term Rates Are Close to Zero

Shigeru Iwata

The zero lower bound on nominal interest rates can affect the effectiveness of monetary policy potentially in two ways. First, it limits the size of a change in the policy interest rate when trying to loosen money. For example, when the nominal rate is 0.5 percent, it obviously cannot be cut by more than 0.5 percent. Second, it may alter the mechanism of how a movement of the policy rate drives market rates of longer maturities. This paper is an attempt to investigate the latter issue, and, in particular, to empirically examine the effect of monetary policy on the term structure of interest rates when nominal short-term rates are close to zero, using Japanese data in the 1990s and early 2000s.

We found that when the policy short rate is already zero but longer rates are still positive in the zero interest rate period, an expansionary monetary policy still works through the conventional interest rate channel by pushing down longer rates, although the effect is much weakened relative to the normal time. When the longer rates are already lowered to some level, however (for example, the 10-year bond rate went down to the level as low as 1.5 percent during the quantitative easing period of 2001–06), a further expansion of the monetary base by increasing excess reserves of banks appears to have little effect in lowering longer-term rates.

Keywords: Zero interest rates; Yield curve; Liquidity trap
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I. Introduction

Nominal interest rates usually cannot go below the floor of zero and can get stuck at zero or in its vicinity, even though the real interest rate may still be higher than the level necessary to ensure stable prices and full employment. The question of how monetary policy should be conducted in a zero interest rate environment has been attracting a great deal of attention recently among economists as well as policymakers.[1]

Such a zero lower bound on nominal interest rates can affect the effectiveness of monetary policy potentially in two ways. First, it limits the size of a change in the policy interest rate when trying to loosen money. For example, when the nominal rate is 0.5 percent, it obviously cannot be cut by more than 0.5 percent. Second, it may alter the mechanism of how a movement of the policy rate drives market rates of longer maturities. This paper is an attempt to investigate the latter issue and, in particular, to empirically examine the effect of monetary policy on the term structure of interest rates when nominal short-term rates are close to zero, using Japanese data in the 1990s and early 2000s.[2]

How interest rates with a variety of maturities move in response to monetary policy is important for several reasons. First, central banks conduct monetary policy by manipulating the short-term rates, but it is mainly the long-term rates that affect consumption and investment decisions of economic agents. Therefore, examining the transmission of a policy shock to medium to long rates is of primary importance (Summers [1991]).

Second, when the short-term rate becomes too low to function as a policy instrument, interest rates on bonds with longer maturities can serve as a measure of policy impact. Estimating the relation between short rates and long rates would be helpful in making a quantitative assessment of the degree to which monetary policy would lose its effectiveness due to the zero bound constraint on the policy rate. Further, it would provide a useful insight into thinking on how the central bank can potentially affect long-term rates when lowering the short-term policy rate is no longer feasible.

Third, the level of the long-term rate is often said to contain information about the market expectation of future inflation (Mishkin [1990]). If we can extract the information about the people's inflation expectation from the current long-term interest rate, we can find out how successful the monetary policy of the central bank is in raising the inflation expectation.

To investigate in what way a monetary policy can move longer-term rates by controlling the short-term policy rate, Evans and Marshall (1998) construct a linear vector autoregression (VAR) system with a block of macroeconomic state variables together with long-term interest rates. Evans and Marshall (2007) extend the same framework to one with shocks identified in an innovative way. In contrast, our empirical approach is based on a nonlinear VAR model with a censored dependent variable. The original

1. The issue of how the zero lower bound constraints may interfere with the conduct of monetary policy is discussed by Fuhrer and Madigan (1997), Orphanides and Wieland (1998), Clouse *et al.* (2000), Reifschneider and Williams (2000), Wolman (1998), and others. The issue of what monetary policy can do when the economy is in the liquidity trap is discussed by Bernanke and Reinhart (2004), Bernanke, Reinhart, and Sack (2004), Buiter and Panigirtzoglou (1999), Eggertsson (2003), Eggertsson and Woodford (2003, 2004), Krugman (1998), McCallum (2000, 2001), Svensson (2001), and others.

2. Related work includes Braun and Shioji (2006), Ichiue and Ueno (2006), and Nagayasu (2004).

VAR on which our model is based is the one similar to Evans and Marshall (1998, 2007), but unlike in their model, the zero lower bound constraint on the short-term rate is binding during some time period. This makes our VAR model nonlinear and leads to nonstandard dynamic responses of key variables to a monetary policy shock, which are the main focus of our paper.

Recently some macroeconomists have begun using models with no arbitrage restrictions.[3] When the zero bound constraint is binding, however, such models would lose many desirable properties. Specifying stochastic discount factors as a linear function of factors with the zero bound constraint would not lead to the bond yields that are linear in factors and do not even have closed-form expressions. Our main focus is on examining the implications of the zero bound constraint on the monetary policy effect regarding impacts on longer-term rates. To do so, we keep the basic framework unchanged without imposing the no-arbitrage condition. After directly examining the dynamic responses of our nonlinear VAR model, we next investigate the monetary policy impact on long-term rates through the expectations hypothesis (EH) when the policy rate is essentially zero. From the standpoint of monetary policy, the EH of the term structure of interest rates is attractive, because it directly links long-term rates to short-term rates. This gives further insight into evaluating the policy impact on the expected future short rates.[4] Roush (2007) shows that the conditional version of the EH is still useful for investigating the monetary policy effect.

The rest of the paper is organized as follows. Section II describes the data used for our analysis. Section III discusses our model. Section IV presents the empirical results, and Section V concludes.

II. Data and Background

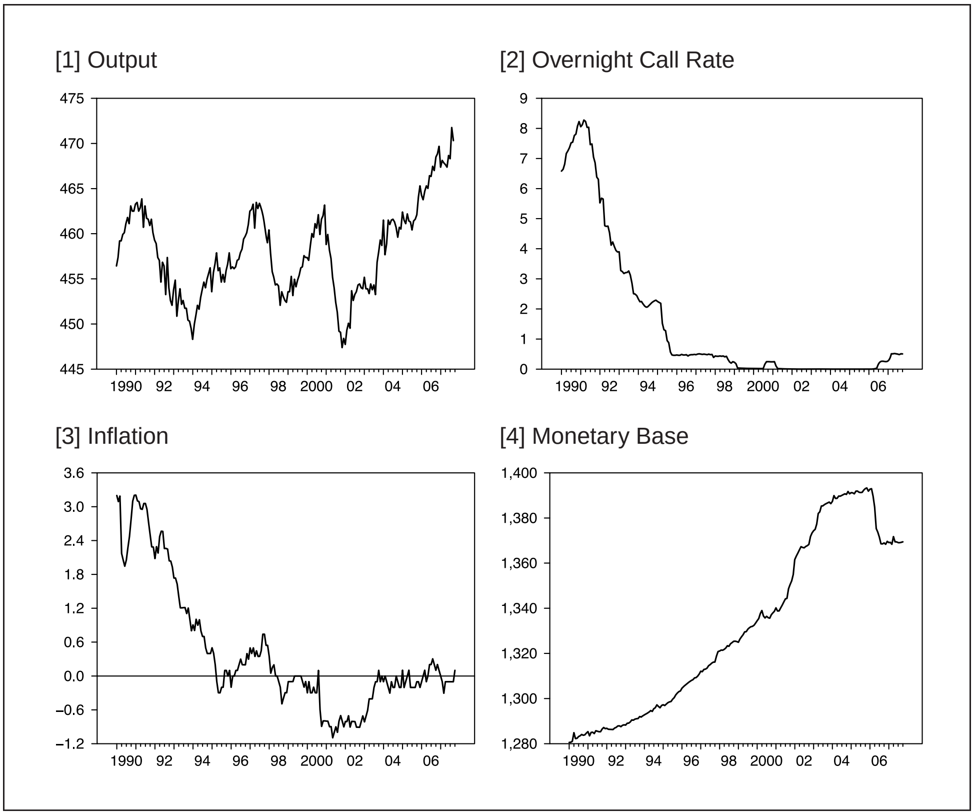
A. Data

In this paper, we use monthly data from 1990 to 2007. The variables include the Japanese consumer price index (CPI), the index of industrial production (IP), the interbank overnight call rate (CAL), the monetary base (MB), and yields on the Japanese government bonds (JGBs) with maturities of 1, 5, 10, and 20 years. Figure 1 displays the output growth, the overnight call rate, inflation, and the monetary base in Japan during the 1990s and early 2000s. Figure 2 displays interest rates ranging from short-term to long-term zero-coupon bonds. Data on the call rate and the monetary base are obtained from the Bank of Japan (BOJ) database. Data on industrial production and the CPI are extracted from the International Financial Statistics database of the International Monetary Fund (IMF). The yields on JGBs are obtained from the Bloomberg database.

3. They explain the latent factors used in the bond pricing models in terms of macroeconomic shocks. Ang and Piazzesi (2003) developed a VAR model describing the joint dynamics of bond yields and macroeconomic variables with no arbitrage restrictions. Rudebusch and Wu (2004) developed a similar term structure model with state variables linked to a simple New Keynesian macro model.

4. Although there is abundant empirical evidence against the EH, the conventional view of the transmission channel of monetary policy rests on the hypothesis that variation in current long rates is driven by variation in current and expected movements of the policy-controlled short rate. According to Kozicki and Tinsley (2005), empirical rejections of the EH reflect incorrect assumptions about expectations formation rather than incorrect assumptions about the theoretical link between long rates and short rates.

Figure 1 Interest Rates and Macro Variables



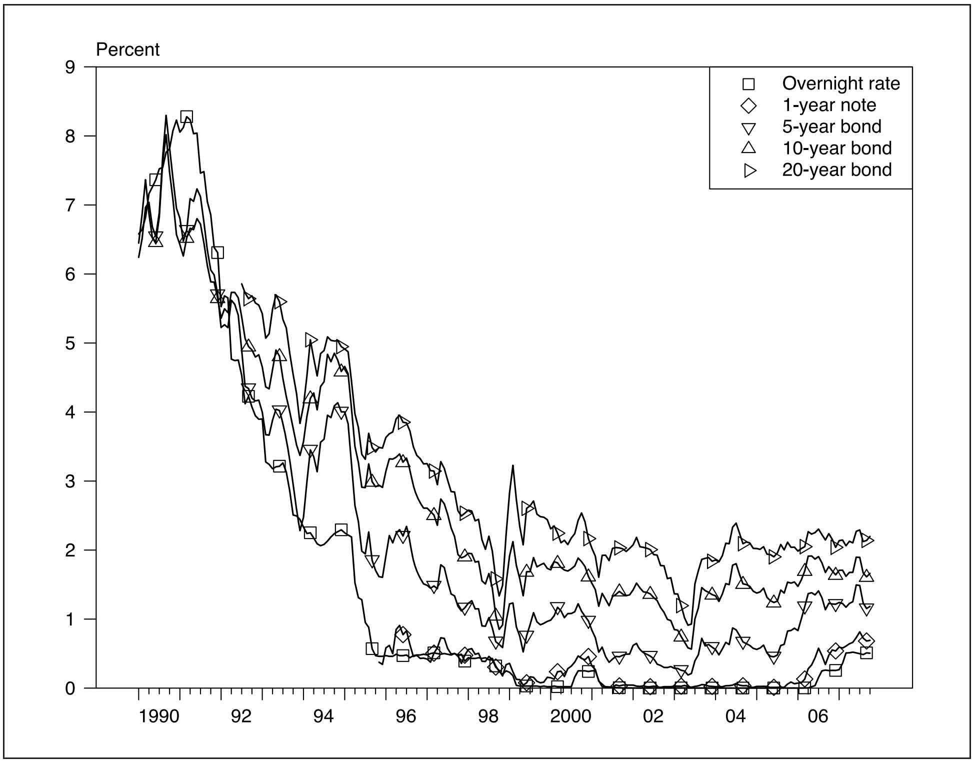
Although the dramatic rise in asset prices starting in the late 1980s had caused the BOJ to focus its policy activities on asset prices, after the bursting of the asset price bubble in 1990, the main concern of the BOJ was to deal with deflation and to revive Japan's domestic economic activity. Therefore, there does not seem to be any major structural change in the BOJ's policy goal during our sample period.[5]

Before introducing our model in detail in the next section, we briefly describe the monetary policy practice of the BOJ during the 1990s, a period when the BOJ explicitly used a short-term nominal interest rate (the overnight interbank call rate) as the policy instrument.[6] Since the collapse of the speculative asset price bubble in early 1990, Japan has suffered prolonged deflation and economic stagnancy. In response to this economic downturn together with the appreciation of the yen, the BOJ aggressively lowered nominal interest rates. The overnight call rate declined from a peak of 8.2 percent in March 1991 to 2.0 percent in March 1995 (Figure 1). By September 1995, it was lowered below 50 basis points and had remained at that low level during the time range of our dataset. More specifically, during the period from 1995 to 2000, the BOJ adopted what it called a

5. The policy goal has not changed, but there are changes in the policy instruments during our sample period, as described later in this paper.

6. Ito and Mishkin (2004) provide an excellent summary of Japanese monetary policy in the 1990s. See also Hetzel (1999), Miyao (2002), Ahearne *et al.* (2002), and Oda and Okina (2001).

Figure 2 Japan Term Structure



zero interest rate policy (ZIRP). The goal of this policy was to avoid further intensifying deflationary pressures and stop the economic downturn. The BOJ's firm commitment to the ZIRP is reflected in the often-cited statement by Governor Masaru Hayami at a press conference on April 13, 1999: "We [the BOJ] will continue the zero interest rate policy until we reach a situation where deflationary concerns are dispelled." In short, the policy undertaken by the BOJ in the late 1990s was to move nominal interest rates down to a level as low as possible by satiating the money market with an excess supply of funds. One important aspect of the ZIRP was that an exogenous monetary easing does not result in any further movement in the interest rate when the rate is already on the zero lower bound. Therefore, while the stance of monetary policy can be directly measured by the interest rate when it is positive, the interest rate at zero is no longer an adequate indicator of the policy stance.

In March 2001, the BOJ adopted the quantitative easing policy (QEP) by switching its instrument from the overnight call rate to the monetary base.[7] The QEP ended in March 2006, when the BOJ returned to the use of the call rate as its instrument. During

7. More accurately, the BOJ used bank reserves (the current account balance in their use of the word) as its policy instrument during the QEP period. The monetary base is simply the sum of bank reserves and the currency in circulation. When changes in the former dominate those in the latter in a given period, the monetary base and bank reserves should both work as a policy indicator. Since bank reserves had rarely been used independently as an operating target before the QEP period, it is found empirically more convenient to work with the monetary base rather than bank reserves.

the QEP period, the BOJ's policy goal did not appear to change, it only switched the instrument to the monetary base, which could be observed even after the nominal rate hit the zero bound.

B. The Interest Rate as a Censored Variable

To model the behavior of the monetary authority in Japan described above, we make the following specification. Let R_t be the short-term nominal interest rate and R_t^* be a latent variable measuring the true stance of monetary policy. R_t^* is in general not observable by an econometrician. However, as long as the central bank uses the short-term interest rate as the operating target, R_t^* is directly linked to R_t through the relation

$$R_t = \begin{cases} R_t^* & \text{if } R_t^* \geq c, \\ c & \text{otherwise}, \end{cases} \tag{1}$$

where c is a lower bound on the nominal interest rate at which R_t is regarded as essentially zero.

The BOJ set the uncollateralized overnight call rate guideline at 0.50 percent for 1995–98 and at 0.25 percent after September 1998. Between February 1999 and July 2000, this lower bound was further pushed down to about 0.02–0.03 percent. Although the actual rate went down to the level as low as 0.01 percent from 2001 to 2005, we regard the rate as being censored, as long as the actual rate R_t is less than 50 basis points.[8] Accordingly, throughout this paper, we choose the lower bound c to be 0.50 percent, and use the terms such as "zero interest rate" or "zero lower bound" even when the actual lower bound is not necessarily exactly equal to zero.

Equation (1) treats R_t as a censored variable.[9] It implies that, when used by the monetary authority as the policy instrument, the short-term interest rate provides a direct measure of the stance of monetary policy. However, if the monetary policy drives the interest rate down to zero, a further monetary easing will not affect the interest rate. The latent rate R_t^* can be thought of as the level of the interest rate the monetary authority would have set according to its policy rule if there were no zero lower bound on the interest rate. Figure 3 displays the estimated R_t^* along with the actual rate R_t.

C. Three Regimes in Monetary Policy

To connect the above scheme to the macroeconomic shocks, consider a standard money market model. When the interest rate is the operating target, we can describe the determination of the interest rate and the monetary base in terms of fundamental macroeconomic shocks by the following (we abstract from all the lagged variables that may also enter the equations):

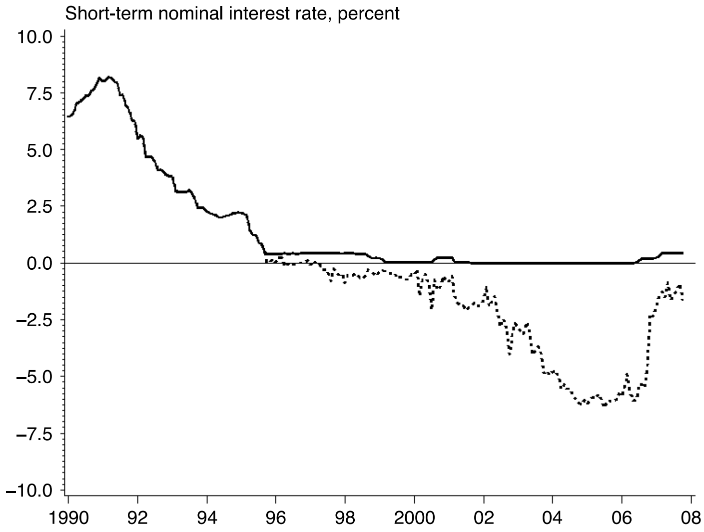
$$R_t^* = \beta_1' \varepsilon_t^Y + \beta_2 \varepsilon_t^{MS}, \tag{2a}$$

$$MB_t = \alpha_1' \varepsilon_t^Y - \alpha_2 \varepsilon_t^{MS} + \alpha_3 \varepsilon_t^{MD}, \tag{2b}$$

8. A visual examination of the plot of the call rate in Figure 1 gives support for such a specification. Moreover, it is also supported by Krugman (1998), which argues that at a nominal rate of 0.43 percent "the economy is clearly in a very good approximation to liquidity trap conditions."

9. The censored model as in (1) was first proposed by Tobin (1958) in the regression context and is applied to the case of the zero bound on interest rates by Wolman (1998), Iwata and Wu (2006), and others.

Figure 3 Observed Call Rate and Latent Rate



Note: The solid line indicates the observed call rate, and the dotted line indicates the latent rate estimated using our model.

where MB_t is the monetary base at time t. Note that the short-term interest rate R_t is determined jointly by (1) and (2a). We use the monetary base here instead of bank reserves, which are a direct operating target of the BOJ under the QEP regime, for two reasons. First, the monetary base appears to be a more appropriate measure of the quantity side of the money market. Second, the monetary base is simply the sum of (1) bank reserves and (2) banknotes and coins in circulation, and the two usually co-move.

Equation (2a) represents the monetary policy reaction function (or policy rule), where ε_t^Y is a vector of innovations to the macroeconomic variables to which the central bank responds contemporaneously when setting the short-term interest rate. ε_t^{MS} is an exogenous monetary policy shock due to any discretionary actions that are not captured by the systematic monetary policy rule, and ε_t^{MD} in equation (2b) stands for an exogenous money demand shock. When the interest rate is the policy instrument, the monetary authority fully accommodates money demand shocks so that ε_t^{MD} only affects the monetary base without having any immediate effect on the interest rate. On the other hand, the exogenous monetary policy shock ε_t^{MS} affects both the interest rate and the monetary base.

More specifically, equations (1) and (2) together imply that, when the interest rate is positive, an expansionary policy shock ($\varepsilon_t^{MS} < 0$) lowers the interest rate and raises the monetary base. When the interest rate is initially on the zero bound, however, an expansionary policy shock ($\varepsilon_t^{MS} < 0$) does not generate any movement in the interest rate, but leads to an increase in the monetary base. In other words, when the interest rate is positive, both the interest rate and the monetary base contain information about monetary policy actions in either direction. But under the ZIRP regime, exogenous monetary expansions can only be reflected in the corresponding movements of the monetary base, while the interest rate remains on its lower bound.[10] When the central bank switches the operating target from the short-term rate to the monetary base, two equations in (2) switch their roles as

$$R_t^* = b_1' \varepsilon_t^Y + b_2 \varepsilon_t^{MS} + b_3 \varepsilon_t^{MD}, \tag{3a}$$

$$MB_t = a_1' \varepsilon_t^Y + a_2 \varepsilon_t^{MS}. \tag{3b}$$

Under the QEP regime, (3b) represents the monetary policy reaction function where the money demand shock ε_t^{MD} is fully accommodated. On the other hand, the short rate reflects the money demand shock as well as the policy shock.

In summary, there are three regimes in monetary policy conducted by the BOJ during our sample period. They are (1) the positive interest rate (PIR) regime, (2) the ZIRP regime, and (3) the QEP regime. The short rate is positive under the PIR regime, while it is essentially zero under the ZIRP regime and the QEP regime. The operating target of monetary policy is the overnight call rate under the PIR and ZIRP regimes, while it is the monetary base (more rigorously, bank reserves or the BOJ's current account balance) under the QEP regime. The difference between the ZIRP regime and the QEP regime lies only in their operating targets that were used, and both regimes share the common policy goal. Our ZIRP regime is defined as the period when the call rate is below 50 basis points. Hence, it covers the period of the BOJ's ZIRP but also includes some period before that policy (1995 to 1999) as well as the period after the QEP was lifted (several months in 2007).

D. Implications of Zero Bound on Term Structure

Under the EH, the yield on the j-period zero coupon bond is expressed as

$$R_t^j = \frac{1}{j}[R_t + E(R_{t+1} \mid I_t) + \cdots + E(R_{t+j-1} \mid I_t)] + \phi_j, \tag{4}$$

where ϕ_j is the term premium, which is assumed to be time invariant. We call the first term on the right-hand side of equation (4) the EH component of the j-period bond yield, and denote it by $\hat{R}_t^j$. Ruge-Marcia (2006) derives explicit expressions of the EH component of long-term rates when shocks are distributed according to a multivariate normal distribution.

The implications of the zero bound on the long-term rate (4) are as follows: first, the long-term nominal rate cannot be expressed as a linear function of the conditional means of future short rates. It becomes nonlinear. Second, the response of the long-term rate to a change in the short-term rate becomes smaller as the short-term rate is close to zero. Third, the response becomes asymmetric in terms of the sign of the shock.

10. The maintained assumption is that there is no structural change in the policy rule during the whole sample period. This allows us to address the central issue of how the monetary policy effects are altered when the interest rate reaches its lower bound but the central bank continues to follow the same policy rule. Although the BOJ switched its operating target from a short-term rate to the monetary base under the QEP regime, we do not regard it as a structural change in the policy rule.

In the following empirical analysis, we do not impose the EH explicitly except when we draw the entire yield curve in the last part of our analysis. Our VAR system lets the long-term rates react freely to monetary policy shocks. As in Evans and Marshall (1998, 2007), the no-arbitrage condition is not imposed either, so the responses are not estimated in a fully efficient manner. But they provide consistent estimates. If the EH holds, our estimates should coincide with the results of Ruge-Marcia (2006). If the no-arbitrage condition is imposed but the zero bound is ignored as in Ang and Piazzesi (2003), the VAR results would not provide consistent estimates in this case.

III. Econometric Framework

A. Model

Our system consists of three groups of variables. The first group includes standard macroeconomic variables such as industrial output (Y), and CPI (P). Monetary policy is assumed to respond to these variables contemporaneously. The second group is money market variables including a short-term nominal interest rate (the interbank overnight call rate, R) and the monetary base at the BOJ (MB). These variables contain information about the stance of monetary policy. The last group includes interest rates on bonds with various maturities (R^m). These are the variables that are of central interest in this paper and play an important role, particularly when the nominal interest rate is on the zero bound. Let $\boldsymbol{X}_{gt} = [Y_t, P_t]'$, $\boldsymbol{X}_{mt} = [R_t, MB_t]'$, and $\boldsymbol{R}_t^m = \{R_t^j\}$, which describes the good market, the money market, and the capital market, respectively. Let $\boldsymbol{X}_{mt}^* = [R_t^*, MB_t]'$ and denote $\boldsymbol{X}_t = [\boldsymbol{X}_{gt}', \boldsymbol{X}_{mt}']'$ and $\boldsymbol{X}_t^* = [\boldsymbol{X}_{gt}', \boldsymbol{X}_{mt}^{*\prime}]'$. Our empirical analysis is based on the AR process given by

$$\mathbf{A}\boldsymbol{X}_t^* = \mathbf{A}(L)\boldsymbol{X}_{t-1} + \boldsymbol{\mu}_X + \boldsymbol{\varepsilon}_{Xt}, \tag{4a}$$

$$R_t^j = \boldsymbol{a}_j(L)'\boldsymbol{X}_t + f_j(L)R_{t-1}^j + \mu_R^j + \varepsilon_{Rt}^j, \tag{4b}$$

where $\mathbf{A}$ is a matrix of constants; $\mathbf{A}(L)$, $\boldsymbol{a}_j(L)$, and $f_j(L)$ are matrix polynomials of lag operators; and $\boldsymbol{\mu}_X$ and μ_R^j are vectors of constants. The term $\boldsymbol{\varepsilon}_{Xt} = [\boldsymbol{\varepsilon}_{gt}', \boldsymbol{\varepsilon}_{mt}']'$ is a vector of the fundamental structural shocks, where $\boldsymbol{\varepsilon}_{gt} = [\varepsilon_t^{AS}, \varepsilon_t^{AD}]'$ and $\boldsymbol{\varepsilon}_{mt} = [\varepsilon_t^{MS}, \varepsilon_t^{MD}]'$. The terms ε_t^{AS} and ε_t^{AD} indicate the aggregate supply and demand shocks, while ε_t^{MS} and ε_t^{MD} indicate the exogenous money supply and demand shocks, respectively. We assume that the variables in $\boldsymbol{X}_t$ span the state space for the system, which implies the zero restrictions in (4a). The interest rate R_t^j is determined by the state variables together with the idiosyncratic shocks ε_{Rt}^j, which correspond to the latent factor used in the financial economic models. We assume $\boldsymbol{\varepsilon}_t = [\boldsymbol{\varepsilon}_{Xt}', \varepsilon_{Rt}^j]'$ has a zero mean vector and a variance-covariance matrix equal to an identity matrix. It is important to note that in equation (4) $\boldsymbol{X}_t^*$ on the left-hand side of the equation includes the latent variable R_t^*, while $\boldsymbol{X}_t$ on the right-hand side of the equation includes the actual interest rate R_t, which is related to R_t^* in a nonlinear way. This specific feature yields a model that exhibits interesting dynamics.

The reduced form of (4a) is written as

$$X_t^* = \mathbf{B}(L)\boldsymbol{X}_{t-1} + \boldsymbol{b}_X + \boldsymbol{u}_{Xt}, \tag{5}$$

where $\mathbf{B}(L) = \mathbf{A}^{-1}\mathbf{A}(L)$ and $\boldsymbol{b}_X = \mathbf{A}^{-1}\boldsymbol{\mu}_X$. The term $\boldsymbol{u}_{Xt} = \mathbf{A}^{-1}\boldsymbol{\varepsilon}_{Xt}$ stands for a vector of one-step-ahead forecast errors and is assumed to be distributed as $N(0, \boldsymbol{\Sigma})$ where $\boldsymbol{\Sigma}$ is a symmetric positive definite matrix. The equations (5) and (4b) consist of a block recursive system. We estimate the reduced-form (5) common under the three regimes.

B. Identification

We impose the following restrictions to identify the model. First, we assume that the exogenous money market shocks ε_t^M do not affect output and price level ($\boldsymbol{X}_{gt}$) in the same period, which is a quite standard identification restriction in the literature (e.g., Christiano, Eichenbaum, and Evans [1999]), especially when monthly data are used. Second, it is assumed that the money demand shock to the short-term rate is accommodated when setting the policy rate at a target level under the PIR and ZIRP regimes, while the money demand shock to the monetary base is absorbed under the QEP regime. These assumptions lead to $\mathbf{C} = \mathbf{A}^{-1}$ matrix taking the form as

$$\mathbf{C} = \begin{bmatrix} \underset{(2\times 2)}{\mathbf{C}_{11}} & \underset{(2\times 2)}{\mathbf{0}} \\ \underset{(2\times 2)}{\mathbf{C}_{21}} & \begin{matrix} \times & 0 \\ \times & \times \end{matrix} \end{bmatrix}$$

under the PIR and ZIRP regimes and

$$\mathbf{C} = \begin{bmatrix} \underset{(2\times 2)}{\mathbf{C}_{11}} & \underset{(2\times 2)}{\mathbf{0}} \\ \underset{(2\times 2)}{\mathbf{C}_{21}} & \begin{matrix} \times & \times \\ \times & 0 \end{matrix} \end{bmatrix}$$

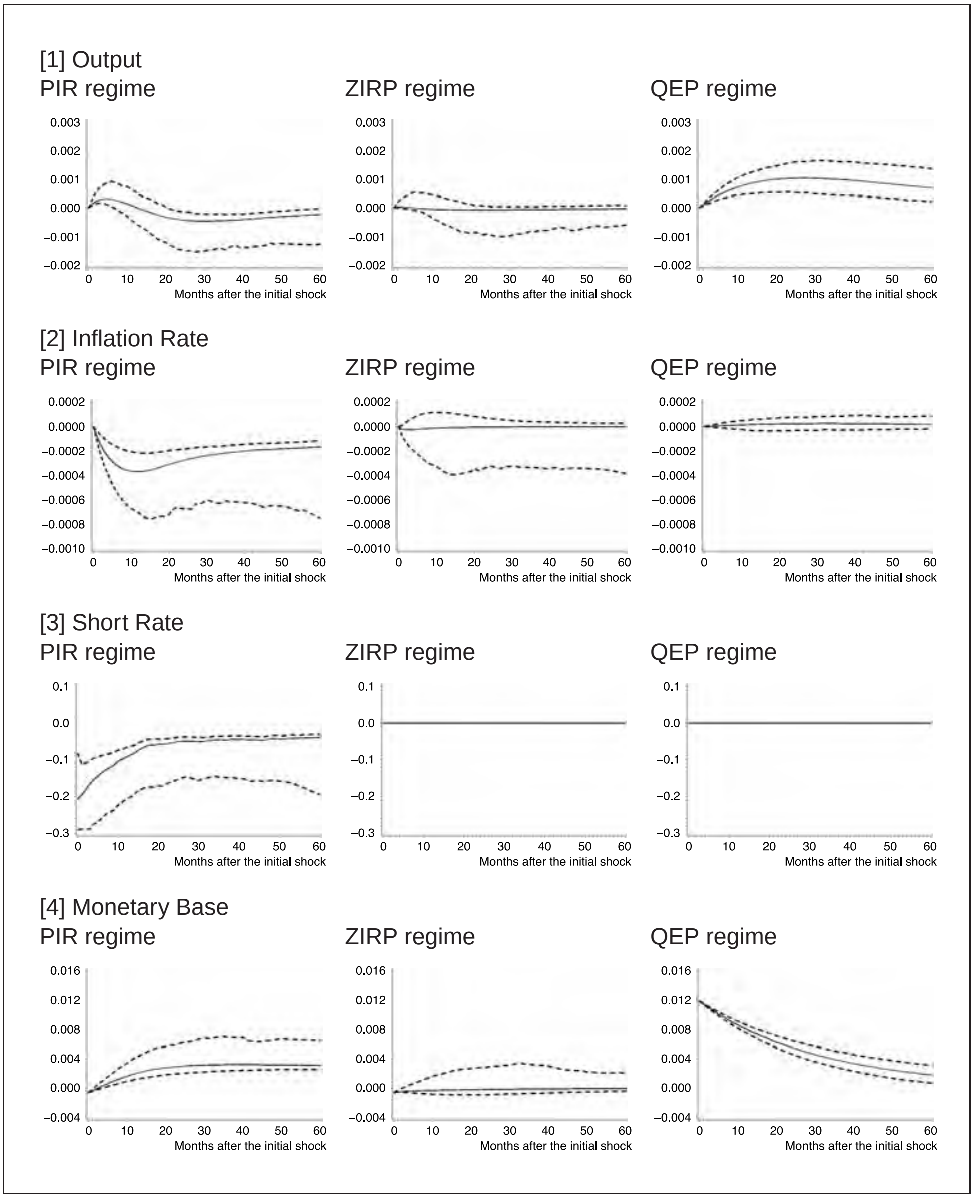
under the QEP regime, where "0" indicates zero restriction and "$\times$" indicates a free parameter. This form imposes sufficient identifying restrictions to investigate the dynamic response of R_t^m to a monetary policy shock ε_t^{MS}.

When the economy is in a liquidity trap with zero interest rates, money demand is likely to behave quite differently than in the normal environment with positive interest rates. We therefore allow for the possibility that when the nominal interest rate is zero, the monetary base *MB* responds differently to ε_t^Y and ε_t^M as well as ε_t^x. We also allow for different intercept term for *MB* in model (5) when the zero bound is approached.

IV. Empirical Results

In Figure 3, we plot the estimated latent rate R_t^* over the entire sample period (January 1990 through October 2007) to see the BOJ's policy stance in terms of the short rate. We can observe that the BOJ acted quite aggressively in monetary expansion, especially during the period 2004–06.

Figure 4 Dynamic Responses to Expansionary Monetary Shocks



Note: The solid line in each diagram is the response curve, and the two dotted lines are the one-standard-error confidence bands.

Figure 4 displays the dynamic responses of output, price, the short-term interest rate, and the monetary base to an expansionary monetary policy shock under the three policy regimes.[11] To calculate the size of the responses, we estimate

11. A monetary shock is defined here as a one-standard-error shock to ε_t^{MS}, which affects the interest rate equation under the PIR and ZIRP regimes and affects the monetary base equation under the QEP regime.

$E(\boldsymbol{X}_{t+h} \mid \varepsilon_t^{MS} = \bar{\varepsilon}, \mathbf{X}^t) - E(\boldsymbol{X}_{t+h} \mid \varepsilon_t^{MS} = 0, \mathbf{X}^t)$ where $\mathbf{X}^t = [\boldsymbol{X}_t, \boldsymbol{X}_{t-1}, \ldots]$, $h = 1, 2, \ldots,$ by averaging the generated data under each regime based on the estimated VAR model as in Iwata and Wu (2006); see also Koop, Pesaran, and Potter (1996) and Potter (2000). The results show that the policy shock pushes down the short-term rate under the PIR regime, but the rate does not move at all under the ZIRP as well as the QEP regime (see Figure 4 [3]) due to the zero bound constraint. When the interest rate is positive, the level of output rises significantly after the negative interest rate shock, exhibiting the typical humped-shape responses (Figure 4 [1], the first column) and inflation declines slightly (Figure 4 [2], the first column). When the interest rate already hits the zero bound, however, a further monetary expansion does not help increase output much under the ZIRP regime (Figure 4 [1], the second column), but appears to do so slightly under the QEP regime (Figure 4 [1], the third column).[12]

To calculate the dynamic responses of medium- to long-term rates $R^1, \ldots, R^{20}$ to an expansionary monetary policy shock, we proceed in a similar fashion. More specifically, we define

$$
\begin{aligned}
IR_{ht}^m = {} & E(R_{t+h}^m \mid \varepsilon_t^{MS} = \bar{\varepsilon}, \mathbf{X}^t, \mathbf{R}^{mt}, \boldsymbol{\varepsilon}_{t+1}, \ldots, \boldsymbol{\varepsilon}_{t+h}) \\
& - E(R_{t+h}^m \mid \varepsilon_t^{MS} = 0, \mathbf{X}^t, \mathbf{R}^{mt}, \boldsymbol{\varepsilon}_{t+1}, \ldots, \boldsymbol{\varepsilon}_{t+h}),
\end{aligned}
$$

where m indicates the bond maturity and $\mathbf{R}^{mt} = [R_t^m, R_{t-1}^m, \ldots]$. Shocks $\boldsymbol{\varepsilon}_{t+j}$ are drawn from the distribution $N(\mathbf{0}, \mathbf{I})$ for $j = 1, \ldots, h$ each 500 times, and we take an average to obtain IR_{ht}^m. Then we compute $IR_h^m(r) = (1/N_r) \sum_{t \in r} IR_{ht}^m$ for each regime $r =$ PIR, ZIRP, and QEP, separately.

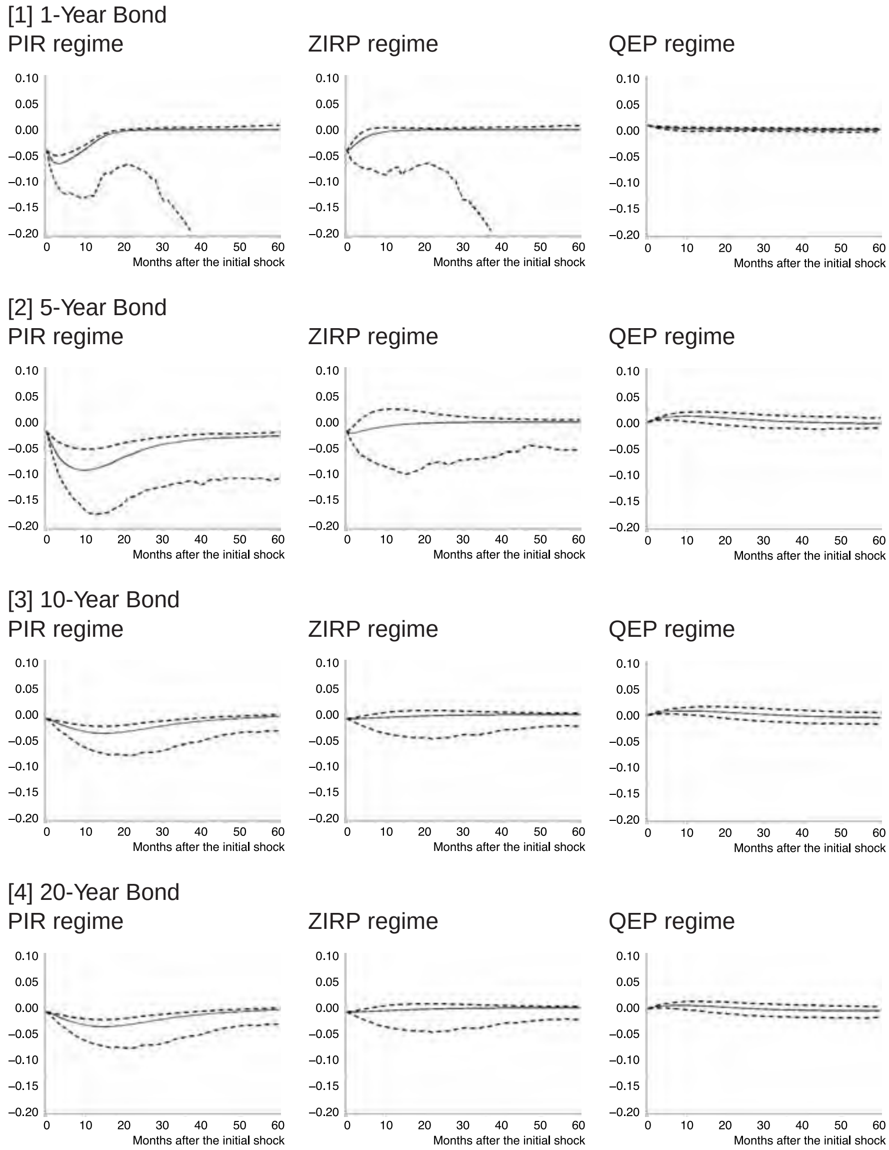
Figure 5 displays the results for 1-, 5-, 10-, and 20-year JGBs under each of the three policy regimes. First, when the interest rate is positive, we observe that a cut in the policy interest rate leads to a strong, significant fall in the 1-year bond yield after the shock from six months to a full year (Figure 5 [1], the first column). Around one and a half years after the shock, the impact disappears. The response of the 5-year bond is slightly weaker and disappears after two years (Figure 5 [2], the first column). This pattern repeats with bonds of longer maturities. There are only little effects on 10-year and 20-year bonds (Figures 5 [3] and 5 [4], the first column).

Under the ZIRP regime, the policy impact on the bond yields get slightly weaker than that under the PIR regime, but still exhibits a similar pattern of diminishing influences (Figures 5 [1]–[4], the second column). Under the QEP regime, however, there appears to be almost no impact observed (Figure 5 [1], the third column).

In summary, consistent with the pattern reported in Iwata and Wu (2006), the reaction of output and inflation to an expansionary monetary shock is similar under the PIR regime and under the ZIRP regime, although the impact of reaction is much weakened when the zero bound is reached. The above patterns of output and inflation reactions in the first and second columns of Figure 4 are consistent with the reactions

12. This statement refers to the fact that the error bands do not contain the zero value so that the output reaction under the QEP regime is definitely positive. However, because the sizes of the shocks under the first two regimes and the QEP regime are not directly comparable, we cannot say whether the magnitude of output reaction to the monetary shock under the QEP regime is larger or smaller than that under the ZIRP regime.

Figure 5 Dynamic Responses of Medium- to Long-Term Rates



Note: The solid line in each diagram is the response curve, and the two dotted lines are the one-standard-error confidence bands.

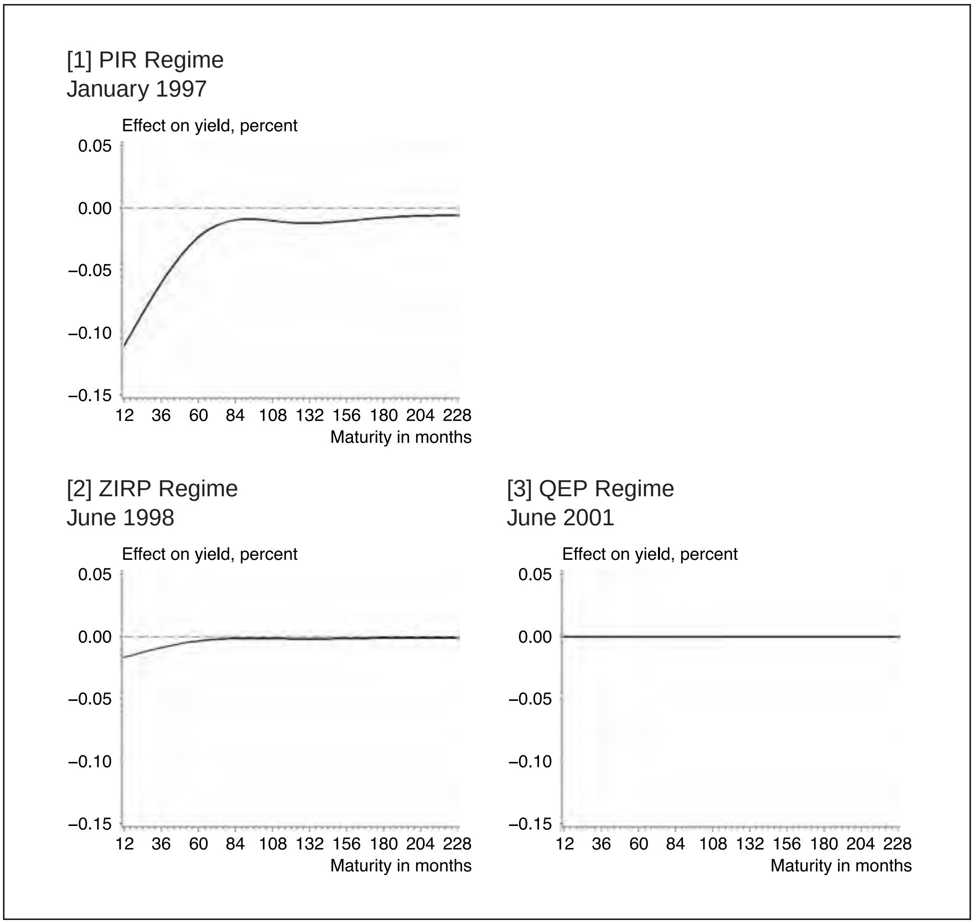
of medium- to long-term rates exhibited in the same columns of Figure 5. A monetary policy is linked to the output level through the interest rate channel. When the policy interest rate hits the zero bound, it cannot be lowered from the floor of zero, which constrains the effectiveness of monetary policy. Even when the policy rate hits the zero bound, the long-term rates are still positive and a further action to increase the monetary base could push down those rates. We do not know what level is exactly the lower bound for the long-term rate, but as long as the long-term rate is still above its floor, an expansionary monetary policy through the interest rate channel should work even after the short-term policy rate hits its own bound and can no longer function as a policy indicator.

Our results under the PIR and ZIRP regimes are consistent with the above view. After the call rate was lowered to 0.5 percent in 1995, the 10-year bond rate fell to 2.8 percent (Figure 2). The call rate stayed at around the same level for the following three years, while the 10-year rate continued to fall to a level as low as 1.5 percent in 1998. This is what some economists call the policy duration effect of the ZIRP (Fujiki and Shiratsuka [2002], Ueda [2005], and Oda and Ueda [2005]). In fact, there was a continuous monetary expansion during this period as is observed in the latent rate movements in Figure 3 or directly in the behavior of the monetary base in Figure 1.

In contrast, the policy shock by increasing the base money during the QEP period does not have any visible impact on medium- to long-term bond rates, as can be seen in the third column of Figure 5. Actually, the plots in Figure 2 suggest that the 10-year bond rate looks a little lower during the QEP period of 2001–06 than the period before 2001 and after 2006. However, this difference appears too small compared to the sheer size of the monetary expansion undertaken during this period by the BOJ, as observed in Figure 3. If the exogenous expansionary shock to the base money does not generate a decline in long-term rates during the QEP period, however, what led the output increase observed in the third column of Figure 4 [1]? This can be interpreted as monetary policy working through a non-interest-rate channel, as is often argued by some monetarists (e.g., Meltzer [1995]). But a better way might be to view it in a more time-specific context. During the 2001–06 period, a massive injection of liquidity by the BOJ finally started to improve the credit market environment, which lifted the economy slightly.

Figure 6 shows the estimated impact of an expansionary monetary policy shock on the entire yield curve in each of three cases. It is constructed by taking a difference between the two predicted short rates, one with a policy shock and the other without a shock, given the historical level of all variables in a specific time point as the initial value, and then calculating long rates based on the EH given in (4). When the interest rate is positive (as in January 1997), the negative interest rate shock makes the yield curve steeper in a significant magnitude as we normally expect (Figure 6 [1]). When the short rate hits the zero bound, only the short end of the yield curve is affected by an expansionary monetary policy shock (Figure 6 [2]). The yield curve becomes steeper, but only weakly. When the central bank abandons the short rate as a policy instrument and attempts to directly increase the monetary base as in June 2001, there is no longer any visible impact on the yield curve, which remains unchanged (Figure 6 [3]). Since the long-term rate is positive even during the QEP period, according to expectations theory the future short rate is expected to be positive, and so is the future inflation rate. Our exercise above shows, however, that there is no additional increase in the inflation expectation due to a further expansion of the monetary base during the QEP period.

Figure 6 Effects of an Expansionary Monetary Policy Shock on Yield Curves



Note: The effect in each case is calculated by taking a difference of the two predicted EH components given in equation (4), one with a policy shock and the other without a shock, given the historical data in a specific time point as the initial condition.

V. Conclusion

This paper investigated how the zero interest rate environments alter the mechanism of a movement of the policy rate driving market rates of longer maturities, and in particular, empirically examined the effect of monetary policy on the term structure of interest rates when nominal short-term rates were close to zero, using Japanese data in the 1990s and early 2000s.

We found that when the policy short rate is already close to zero but longer rates are still positive in the zero interest rate period, an expansionary monetary policy still works through the conventional interest rate channel by pushing down longer rates, although the effect is much weakened relative to the normal time. When the longer rates are already lowered to some level, however (for example, the 10-year bond rate went down to the level as low as 1.5 percent during the QEP period of 2001–06), a further expansion of the monetary base by increasing excess reserves of banks appears to have little effect in lowering longer-term rates.

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