



# Estimating monetary policy effects when interest rates are close to zero<sup>☆</sup>

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## Abstract

Using a nonlinear structural VAR approach, we estimate the effects of exogenous monetary policy shocks in the presence of a zero lower bound constraint on nominal interest rates and examine the impact of such a constraint on the effectiveness of counter-cyclical monetary policies based on the data from Japan. We find that when interest rates are at zero, the output effect of exogenous shocks to monetary policy is cut in half if the central bank continues to target the interest rate. The conditional impulse response functions allow us to isolate the effect of monetary policy shocks operating through the interest rate channel when other possible channels of monetary transmission are present.

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## 1. Introduction

Since nominal interest rates cannot be lower than zero, one implication of the monetary transmission through the interest rate channel is that a liquidity trap would eliminate the

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effect of monetary shocks on the real economy. This possibility is not just a purely theoretical concern in the face of the recent experience of Japan, Europe and the United States. In the case of Japan, the overnight call rate, which is the policy instrument for the Bank of Japan, has been below 50 basis points since mid-1995, accompanied by economic stagnancy and deflationary pressure.

In this paper we propose a structural vector autoregression (VAR) model with a censored variable and use the data on Japanese economy to obtain empirical estimates of the monetary policy effects when nominal interest rates hit the zero bound, and to investigate the extent to which such a constraint might affect the ability of a central bank to conduct its policy.<sup>1</sup> There are three distinct contributions of our study to the analysis of the modern Japanese experience, which is a major historical period of substantial interest to monetary and financial economists. First, we show that macroeconomic responses to a standard measure of policy shocks are different at low levels of interest rates. Second, our analysis suggests that the zero bound constraint was important for the evolution of the Japanese economy. Third, we show that a quantitative monetary policy may have effects that are quite strong at these low levels of rates and indeed, which look very similar to monetary policy variations brought about by interest rate movements at higher levels of rates. These results are useful in evaluating different policy options for the Japanese economy and allow us to draw lessons for other countries regarding the impact of the zero bound on monetary policy. The study can also help us evaluate empirically the relative importance of different monetary transmission mechanisms.<sup>2</sup>

## 2. Empirical methodology

### 2.1. Data

Since the collapse of the speculative asset price bubble in early 1990, Japan has suffered prolonged deflation and economic stagnancy. Fig. 1 exhibits (a) log industrial production and log wholesale price, (b) money growth rate together with (c) the inter-bank call rates in Japan during the 1990s.<sup>3</sup> It can be seen clearly that output has failed to grow during the past decade while price level has been continuously declining (Fig. 1(a)). Such economic distress has prompted the Bank of Japan (BoJ) to adopt an expansionary monetary policy by lowering nominal interest rates. By September 1995, the inter-bank call rate, which has been the policy instrument for the BoJ, was pushed down to below 50 basis points and remained at that low level until the end of 2001 (Fig. 1(c)). The experience of the Japanese

<sup>1</sup>Using structural models of the U.S. economy, several authors perform numerical simulations to examine the extent to which the zero bound prevents real rates from falling and hence affects the central bank's ability to optimally respond to adverse macroeconomic shocks, Fuhrer and Madigan (1997), Orphanides and Wieland (1998), Reifschneider and Williams (2000), Rotemberg and Woodford (1997), Wolman (1998). In contrast, our study is based on direct empirical evidence on macroeconomic performance in a "zero interest rates" environment.

<sup>2</sup>Many monetarist economists, such as Meltzer (1995), have emphasized the importance of the monetary transmission mechanism operating through other asset prices. Some economists also view frictions in the credit markets due to asymmetric information as playing an important role in the process of monetary transmission, e.g. Bernanke and Gertler (1995). See also Mishkin (1995) and Taylor (1995).

<sup>3</sup>Data on the price level and the interest rate are obtained from the BoJ. Data on industrial production and M1 are obtained from International Financial Statistics of the IMF.

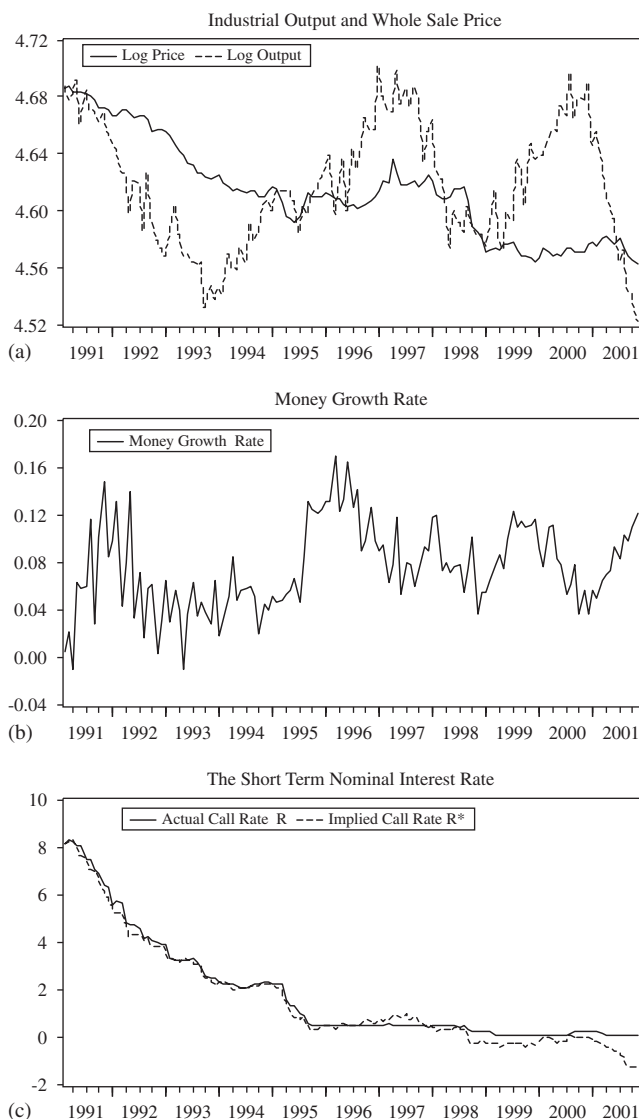


Fig. 1. (a) Industrial output and whole sale price; (b) money growth rate; (c) the short-term nominal interest rate.

monetary policy during this period therefore provides a good opportunity to study the impact on monetary policy of the zero bound constraint on nominal interest rates.

We focus on the time period between 1991 and 2001 in this paper because there appears to be several structural changes in the Japanese monetary policy during the past 30 years. For example, in the second half of the 1980s, stabilizing the exchange rate seemed to be the main policy goal for the BoJ due to the Plaza Accord. Moreover, the dramatic rise in asset prices starting in the late 1980s caused the BoJ to refocus its policy activities on asset prices. See Hetzel (1999) for a discussion of Japanese monetary policy since the 1970s.

After the burst of the asset price bubble in 1990, however, the main concern of the BoJ is to deal with deflation and to revive its domestic economic activity, and there does not seem to be any major structural change in its policy. During the 1990s, the BoJ explicitly uses a short-term nominal interest rate (the overnight inter-bank call rate) as its policy instrument. And in the late 1990s, the BoJ adopted the so-called “zero interest rate policy”. The goal of this policy is to avoid further intensifying deflationary pressures and to stop the economic downturn. The BoJ’s firm commitment to the zero interest rate policy is reflected in the well-cited statement of the BoJ’s official: “We (the BoJ) will continue the zero interest rate policy until we reach a situation where deflationary concerns are dispelled” (Governor Hayami’s statement at a press conference on April 13, 1999). In short, the policy undertaken by the BoJ in the late 1990s is to move nominal interest rates down to a level as low as possible by satiating the money market with excess supply of funds. One important aspect of the zero interest rate policy is that an exogenous monetary easing will not result in any further movement in the interest rate when the rate is already on the zero 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.

## 2.2. VAR with a censored variable

The nature of the Japanese experience described in the previous section motivates our empirical procedure. To examine the effect of monetary policy given the zero bound constraint, we propose a nonlinear VAR model that incorporates a censored variable.<sup>4</sup> Let  $R_t$  be the nominal short-term interest rate and  $R_t^*$  be a latent variable measuring the stance of monetary policy.  $R_t^*$  is in general not observable. However, under the monetary policy regime that uses the short-term interest rate as the operating target,  $R_t^*$  is directly linked to  $R_t$  through the relation

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

where  $c$  is a lower bound on the nominal interest rate at which  $R_t$  is regarded as essentially zero.<sup>5</sup> Eq. (1) treats  $R_t$  as a censored variable. 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. Our focus is to identify exogenous monetary policy shocks to  $R_t^*$  and to estimate their dynamic effects on key macroeconomic aggregates.<sup>6</sup>

<sup>4</sup>Ruge-Murcia (2006) also uses a censored-variable approach to investigate the implications of the zero bound for the term structure of interest rates in Japan.

<sup>5</sup>In general, the call rate cannot become exactly zero because of the existence of various transaction costs. See Okina and Oda (2000) for more details. Therefore, following Krugman (1998) who argues that at a nominal rate of 0.43% “the economy is clearly in a very good approximation to liquidity trap conditions”, we choose  $c$  to be 50 basis points, and use the terms such as “zero interest rate” or “zero bound” throughout the paper even when the actual lower bound is not exactly equal to zero.

<sup>6</sup> $R_t^*$  can also be thought of as the interest rate level the monetary authority would set according to its policy rule if there were no lower bound on the interest rate, or the intended interest rate.

To connect the above scheme to the macroeconomic shocks, consider a standard money market model given by (abstracting from all the lagged variables that may also enter the equations)

$$R_t^* = \beta_1' \varepsilon_t^Y + \beta_2 \varepsilon_t^s + \beta_3 \varepsilon_t^d, \quad (2)$$

$$\Delta m_t = \alpha_1' \varepsilon_t^Y - \alpha_2 \varepsilon_t^s + \alpha_3 \varepsilon_t^d, \quad (3)$$

where  $\Delta m_t$  is the growth rate of money,  $\varepsilon_t^Y$  is a vector of innovations to the macroeconomic variables,  $\varepsilon_t^s$  is an exogenous monetary policy shock, and  $\varepsilon_t^d$  stands for an exogenous money demand shock. Note that the short-term interest rate  $R_t$  is determined jointly by the censoring rule (1) and the monetary policy reaction function (or policy rule) (2). When the interest rate is the policy instrument, we have  $\beta_3 = 0$ . In other words, the monetary authority fully accommodates money demand shocks so that  $\varepsilon_t^d$  only affects money growth without having any immediate effect on the interest rate, while the exogenous monetary policy shock  $\varepsilon_t^s$  affects both the interest rate and money growth. We call this policy scheme “Standard Identification”. When the interest rate is positive, both the interest rate and money growth contain information about monetary policy actions in either direction. But under the zero interest rate regime, exogenous monetary expansions can only be reflected in the corresponding movements of money growth, while the interest rate remains on its zero bound.

The BoJ has been criticized for not being aggressive enough to combat persistent deflation and prolonged economic stagnancy. Many critics argue that effective monetary policy requires quantitative easing when the interest rate is stuck at zero. The sharp decline of our estimated latent policy variable  $R_t^*$  near the end of our sample period (the dotted line in Fig. 1(c)) suggests that the BoJ might have indeed started to take alternative policy actions under increasing pressures. If the BoJ decided to target money growth after the interest rate was pushed down to zero, we would have  $\alpha_3 = 0$  but  $\beta_3 \neq 0$ . In other words,  $\Delta m_t$  is only affected contemporaneously by the exogenous monetary policy shock  $\varepsilon_t^s$  (in addition to  $\varepsilon_t^Y$ ). We call this alternative policy scheme “Monetary Targeting Identification”.

### 3. Model

#### 3.1. VAR system

The small VAR system we estimate consists of two groups of variables. The first group includes standard macroeconomic variables such as output and price. 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 overnight inter-bank call rate is used in this paper) and the growth rate of aggregate money. These variables contain information about the stance of monetary policy.<sup>7</sup>

<sup>7</sup>In an alternative specification, we include some broad financial market variables such as stock market indices. These are the variables that can potentially play important roles in the monetary transmission process as suggested by Meltzer (1995), particularly when the nominal interest rate is on the zero bound.

Denote two groups of variables mentioned above by  $\mathbf{Y}_t, \mathbf{W}_t^*$ , respectively, where  $\mathbf{Y}_t$  is a  $k \times 1$  vector and  $\mathbf{W}_t^*$  is an  $l \times 1$  vector. The VAR system is then given by

$$\begin{bmatrix} \mathbf{Y}_t \\ \mathbf{W}_t^* \end{bmatrix} = \mathbf{B}(L) \begin{bmatrix} \mathbf{Y}_t \\ \mathbf{W}_t \end{bmatrix} + \mu + \mathbf{u}_t, \tag{4}$$

where  $\mathbf{W}_t^* = (R_t^*, \Delta m_t)'$ ,  $\mathbf{W}_t = (R_t, \Delta m_t)'$ ,  $\mathbf{B}(L) = \mathbf{B}_1 L - \dots - \mathbf{B}_p L^p$  with  $L$  being the lag operator, and  $\mu$  is a vector of constants. The  $\mathbf{u}_t$  stands for a vector of one-step-ahead forecast errors and we assume that  $\mathbf{u}_t \sim \mathcal{N}(\mathbf{0}, \Sigma)$  where  $\Sigma$  is a symmetric positive definite matrix. It is important to note that in Eq. (4),  $\mathbf{W}_t^*$  on the left-hand side of the equation includes the latent variable  $R_t^*$ , while  $\mathbf{W}_t$  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.

### 3.2. Identification

The structural form of the system (4) can be written as

$$\mathbf{A}_0 \mathbf{Z}_t^* = \mathbf{A}(L) \mathbf{Z}_t + \mathbf{A}_0 \mu + \varepsilon_t, \tag{5}$$

where  $\mathbf{Z}_t^* = [\mathbf{Y}_t', \mathbf{W}_t^{*'}]'$ ,  $\mathbf{Z}_t = [\mathbf{Y}_t', \mathbf{W}_t']'$ , and  $\varepsilon_t = [\varepsilon_t^Y, \varepsilon_t^M]'$  stands for the fundamental macroeconomic shocks. Note that  $\varepsilon_t^M = (\varepsilon_t^s, \varepsilon_t^d)'$  where  $\varepsilon_t^s$  is the exogenous monetary policy shock and  $\varepsilon_t^d$  is the exogenous money demand shock. We assume that  $\varepsilon_t \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$ .

We impose block recursive restrictions to identify the model by assuming that the exogenous money market shock  $\varepsilon_t^M$  does not affect output and price level ( $\mathbf{Y}_t$ ) in the same period, which is a quite standard identification restriction in the literature (e.g. Christiano et al., 1999) especially when monthly data are used. This assumption implies that the matrix  $\mathbf{A}_0$  is block triangular. Rewrite (5) as

$$\mathbf{Z}_t^* = \mathbf{B}(L) \mathbf{Z}_t + \mu + \mathbf{C}_0 \varepsilon_t, \tag{6}$$

where  $\mathbf{C}_0$  is the matrix of the impact multipliers. Since  $\mathbf{C}_0 = \mathbf{A}_0^{-1}$ , the matrix  $\mathbf{C}_0$  is also a block lower triangular matrix

$$\mathbf{C}_0 = \begin{bmatrix} \mathbf{C}_{11} & \mathbf{0} \\ \mathbf{C}_{21} & \mathbf{C}_{22} \end{bmatrix}, \tag{7}$$

which relates the fundamental shocks  $\varepsilon_t$  to the VAR residual  $\mathbf{u}_t$ .

Note that under the policy scheme of interest rate targeting (Standard Identification),  $\mathbf{C}_{22}$  is an  $l \times l$  lower triangular matrix, while it is upper triangular under policy regime of money growth targeting (monetary targeting identification). These assumptions therefore impose sufficient identifying restrictions to investigate the dynamic response of  $\mathbf{Z}_t$  to a monetary policy shock  $\varepsilon_t^s$ . System (6) subject to (1) and (7) can be estimated by the maximum likelihood method with additional necessary zero restrictions on  $\mathbf{C}_{11}$ .<sup>8</sup> The Akaike's information criterion (AIC) is used to choose the number of lags in (6).

<sup>8</sup>When the economy is in liquidity trap, 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, money growth  $\Delta m_t$  responds differently to  $\varepsilon_t^Y$  as well as  $\varepsilon_t^M$ . Accordingly, the elements in the second row of matrices  $\mathbf{C}_{21}$  and  $\mathbf{C}_{22}$  may have different values when the interest rate is at zero. We also allow for different

#### 4. Results

We estimate the nonlinear structural VAR model with the monthly data on Japanese wholesale price index, industrial output, the inter-bank call rate, and the annual growth rate of money, denoted by  $\mathbf{Z} = (\mathbf{p}, \mathbf{y}, \mathbf{R}, \Delta \mathbf{m})$ , from 1991 to 2001.<sup>9</sup> Since our primary interest is in the dynamic responses of the variables, we do not report the point estimates of the VAR parameters here but only mention some features of the estimated model. First, the signs of the estimates of the elements in  $\mathbf{C}_{21}$  and  $\mathbf{C}_{22}$  (not shown here) are consistent with the counter-cyclical monetary policy pursued by the BoJ during that period. Namely, the BoJ takes expansionary policy actions by cutting the interest rate when facing a deflationary shock or a negative shock to output. Second, nonlinearity is an important feature of the data because of the censorship and the different behavior of money demand depending on whether the interest rate is at zero. Fig. 1(c) displays the fitted value of  $R_t^*$  based on our VAR estimates together with the actually observed call rate  $R_t$ . We can see that there are still large fluctuations in  $R_t^*$  under the zero interest rate regime, indicating active policy movements during that period even when the actual interest rate rarely moves. The figure also shows that the estimates of the policy stance  $R_t^*$  track the lower bound on the interest rate closely after 1995, consistent with the zero interest rate policy stated by the monetary authority. It is interesting to notice a sharp decline in  $R_t^*$  near the end of the sample period, implying that there were large monetary expansions in the second half of 2001. This significant easing of its policy suggests that the BoJ might have finally abandoned the zero interest rate policy and adopted a more expansionary monetary stance.

Based on the estimated VAR model, we now examine the dynamic responses of output, price, and other variables to an expansionary monetary policy shock when the interest rate is at zero and when it is positive under two identification schemes. Our interest centers around the following two questions: (i) How much of the effect of an expansionary monetary policy shock on output is actually eliminated by the zero bound constraint on nominal interest rates? (ii) How important is the interest-rate channel compared with other channels of monetary transmission?

The impulse response function (IRF) is often obtained by the difference of the  $h$ -step-ahead forecast of the series with a current shock of a unit size from the same forecast without a shock. In a linear model, this difference reduces to the  $h$ th order parameters in its moving-average (MA) representation. In a VAR with a censored left-hand variable, however, the MA representation is no longer linear in the shocks. As a result, the IRF for the nonlinear model is dependent upon the entire history of the series as well as the size and direction of the shock. This state-dependent feature of the IRF allows us to analyze the policy effects conditional on the current state of the system.

We follow the literature on nonlinear impulse response (Koop et al., 1996; Gallant et al., 1993; Potter, 2000) and treat a nonlinear IRF as the difference between a pair of conditional expectations of the variables given a non-zero shock and a zero shock at the

(footnote continued)

intercept term for  $\Delta m_t$  in model (6) when the zero bound is approached. The derivation of the likelihood function is provided in the working paper version of the paper available on the internet.

<sup>9</sup>The five-variable VAR including the stock market price  $\mathbf{x}$ , that is,  $\mathbf{Z} = (\mathbf{p}, \mathbf{y}, \mathbf{R}, \Delta \mathbf{M}, \mathbf{x})$ , is also estimated. The results are very similar to those from the four-variable VAR.

current period, i.e.

$$E(\mathbf{Z}_{t+h}|\Omega_{t-1}, \varepsilon_t) - E(\mathbf{Z}_{t+h}|\Omega_{t-1}, \varepsilon_t = 0),$$

where  $\Omega_{t-1}$  stands for the information set at  $t - 1$ , and  $h = 1, 2, \dots$  is the time horizon. In other words, to calculate the nonlinear IRF, we have to specify the nature of the shock (its size and sign) and the initial condition,  $\Omega_{t-1}$ . To calculate the conditional expectations, we simulate the model in the following manner. First, we randomly draw  $\varepsilon_{t+j}$  from  $\mathcal{N}(\mathbf{0}, \mathbf{I}_m)$  for  $j = 1, 2, \dots, h$  and then simulate the model conditional on an initial condition  $\Omega_{t-1}$  and a particular shock  $\varepsilon_t$ . This process is repeated 500 times and the estimated conditional expectation is obtained as the average of the outcomes.

### 4.1. Results from the standard identification

#### 4.1.1. The effects of monetary policy shocks

Figs. 2(a)–(d) report the estimated IRFs of the variables included in our model. The solid and broken lines stand for, respectively, the IRFs of the variables to an expansionary monetary policy shock of size equal to one standard deviation when the interest rate is at zero and when it is positive. The horizontal axis measures the number of months after the shock. The IRF under each regime is calculated as an average of all the IRFs

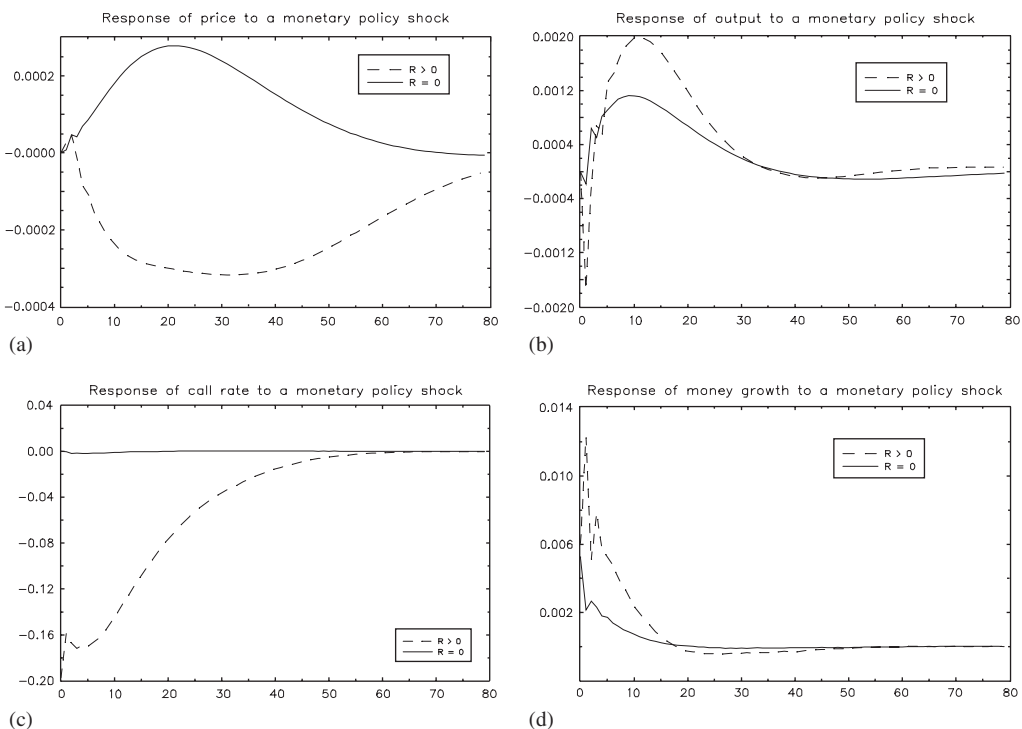


Fig. 2. (a) Response of price to a monetary policy shock; (b) response of output to a monetary policy shock; (c) response of call rate to a monetary policy shock; (d) response of money growth to a monetary policy shock.

corresponding to the historical dates belonging to each of the two regimes: the regime where the call rate is at zero and the regime where it is positive. We find a striking difference in the IRFs under the two regimes, which are consistent with the standard textbook explanation of the interest rate channel of monetary transmission.

When the interest rate is positive, we obtain the IRFs commonly observed in the standard monetary VAR literature. An expansionary policy shock decreases the nominal interest rate (Fig. 2(c)) and increases money growth (Fig. 2(d)). The decrease in the interest rate then leads to increases in real output (Fig. 2(b)). The full impact on output reaches its peak in about 10 months after the initial monetary expansion. Moreover, the IRF of the aggregate price level (Fig. 2(a)) exhibits the usual “price puzzle”, where the price level initially declines under an expansionary monetary shock.

The same monetary policy shock, however, generates quite different dynamic responses of the macroeconomic variables when the interest rate is on the zero bound. While money growth continues to rise in response to the expansionary policy shock (Fig. 2(d)), the IRF of the price level (Fig. 2(a)) does not show the usual “price puzzle” under the zero interest-rate regime. More importantly, the interest rate is now constrained by the zero bound and can no longer fall (Fig. 2(c)). As a result, although the rising price level still generate a lower real interest rate, the decrease in the real rate is only moderate, leading to much smaller increases in output. In fact, our estimates suggest that the peak impact of the monetary policy shock on output when the nominal interest rate is at zero is only about half the size of what the monetary policy can achieve when the rate is positive (Fig. 2(b)).

The difference in the dynamic responses of output under two regimes provides an empirical estimate of the extent to which the zero bound constraint on interest rates impedes the transmission of monetary innovations. It suggests that the monetary authority cannot achieve the full effect of its policy actions by continuing to target the nominal interest rate when the rate is stuck at zero. It also suggests that if the central bank generates high enough inflation, probably through some quantitative measures, so that the real interest rate decreases as much as in the normal circumstance, then it may be possible to overcome this zero interest-rate constraint.

Some economists such as Meltzer (1995) have argued that a monetary innovation not only changes a short-term interest rate, but also alters the relative prices of a variety of assets. For example, stock prices can rise in response to an expansionary monetary policy shock. Such an increase in asset prices can have positive influence on real output either through the wealth effect on consumption or through a mechanism involving Tobin’s  $q$  theory of investment. It can also magnify the interest-rate channel impact through a credit channel effect (Bernanke and Gertler, 1995). When the interest rate is always positive, it is difficult to separate empirically the effect of monetary policy shocks operating through the standard interest-rate channel from those through any other channels. When the interest rate hits the zero bound, however, we can construct a pair of IRFs under two regimes and take the difference as a measure of the relative importance of the interest-rate channel. More specifically, the difference of the responses of output provides a lower bound of the contribution of the interest-rate channel because the real interest rate is still decreasing due to the rising price level even when the nominal rate is at zero. The large difference of the IRFs in Fig. 2(b) appears to confirm that the interest-rate channel is by far the most important monetary transmission.

#### 4.1.2. The impact on counter-cyclical monetary policy

Some recent studies investigate the effect of the zero bound constraint on the ability of monetary authority to conduct effective policy (e.g. Fuhrer and Madigan, 1997; Orphanides and Wieland, 1998 among others). They use numerical simulation to find the extent to which a zero bound prevents the monetary authority from pursuing a counter-cyclical interest-rate policy in response to negative macroeconomic shocks. We perform an analogous exercise by subjecting our VAR model to some adverse macroeconomic shocks to see how differently the system would respond depending on whether or not the interest rate is on the zero bound.

To conduct this exercise, we choose a macroeconomic shock (any mixture of inflation, output, and monetary shocks) that would generate an output decline for two consecutive quarters—the standard definition of a recession—in the normal situation. We then subject our VAR model to the same shock conditional on the interest rate being zero. Figs. 3(a) and (b) display the IRFs of the interest rate and output, respectively. In the normal situation where the interest rate is not constrained (the dashed lines), such a negative shock drives down output as well as the interest rate as the monetary authority pursues a counter-cyclical policy. The resulting lower interest rate would eventually push the economy out of the recession. In contrast, if the interest rate is at zero when the adverse macroeconomic shock hits the economy (the solid lines), the monetary policy would lose much of its

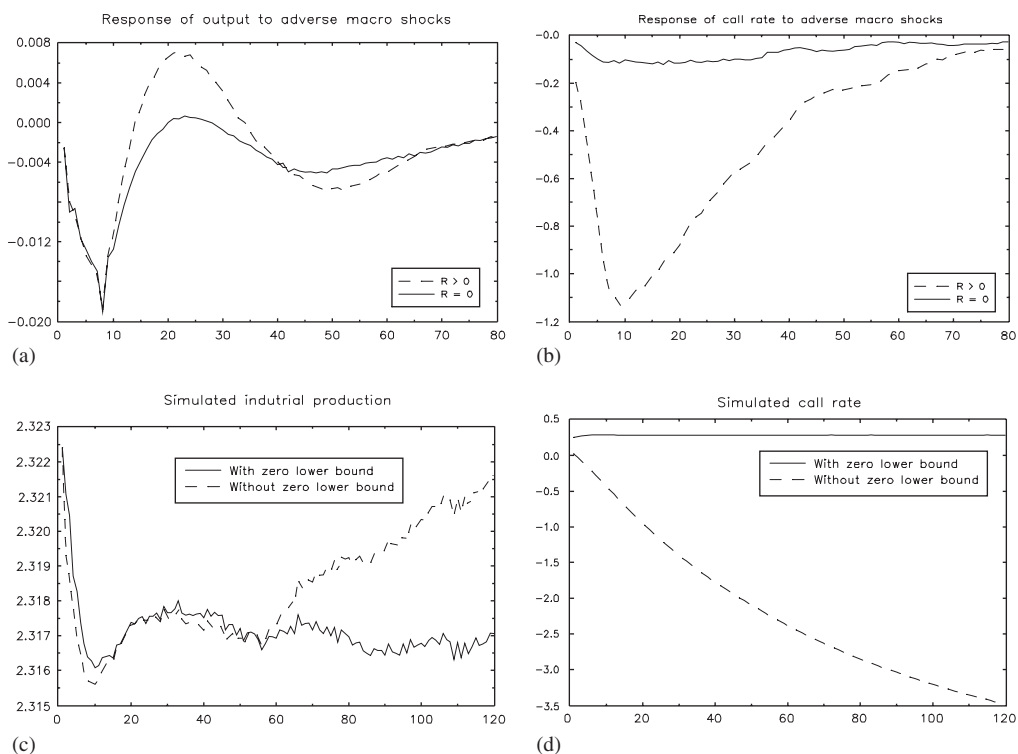


Fig. 3. (a) Response of output to adverse macroshocks; (b) response of call rate to adverse macroshocks; (c) simulated industrial production; (d) simulated call rate.

leverage against such a negative shock. Figs. 3(a) and (b) show that the interest rate cannot fall any further, while the recovery is not only slower, but also weaker. If the interest rate is above zero when the negative shock hits the economy, the output will fully recover in about 14 months and then continues to rise about its original level. But if the interest rate is at zero when the shock hits the economy, it would take more than 20 months for output to barely come back to its original level.

An alternative way to look at the impact of the zero bound constraint is to postulate a hypothetical situation in which the zero bound constraint is entirely removed. How differently would the economy evolve after 2001 under stochastic macroeconomic shocks with and without the zero bound constraint? We simulate the estimated VAR starting from the last sample period, and compare the dynamics of output and the interest rate. Figs. 3(c) and (d) display the results from such an exercise. We can see that without zero bound constraint (the dashed lines), the interest rate would have become significantly negative, which in turn stimulates the economy and output would eventually rise and reach a level much higher than it would be with the constraint. One major caveat of such a comparison is obviously that the model parameters are estimated while imposing the zero bound constraint. Nevertheless, the large discrepancy between the two output series in Fig. 3(c) suggests that the zero bound has a significant impact on the macroeconomic performance of the Japanese economy.

#### 4.2. Results from the monetary targeting identification

In this section we estimate the effect of quantitative measures when the interest rate is on the zero bound. Unfortunately, the VAR model with monetary targeting identification is observationally equivalent to the VAR model with standard identification. Therefore, it is simply not possible to test whether such quantitative measures are part of the actual monetary policy. However, it is still possible to use the above specification to investigate the effects of exogenous monetary policy shocks assuming the BoJ had switched its policy instrument to quantitative measures when the interest rate is on the zero bound. In particular, we estimate a VAR model, assuming that the monetary authority targets the interest rate when  $R_t > 0$  but switches its target to money growth when  $R_t = 0$ .

Fig. 4 displays the reactions of the aggregate price level, real output, the interest rate and money growth to an exogenous expansionary policy shock under both positive and zero interest-rate regimes. It shows that if monetary authority switches its operating target to money growth when the interest rate is at zero, the effect of a monetary shock on output would be almost as strong as when the interest rate is positive. In contrast, the zero bound can eliminate almost 50% of the output effect of policy shocks if the monetary authority continues to target the interest rate as found in Fig. 2.

Examining Figs. 2 and 4 helps find the possible source of this large difference. If the monetary authority switches its target to money growth when the interest rate is at zero, an exogenous monetary expansion would generate a price increase so large (Fig. 4(a)) that even though the nominal rate is stuck at zero (Fig. 4(c)), there would be enough decline in the real interest rate to push up the level of output (Fig. 4(b)). However, if the monetary authority continues to target the interest rate, the impact of the monetary expansion on the price level is not large enough (Fig. 2(a)) to offset the negative impact of

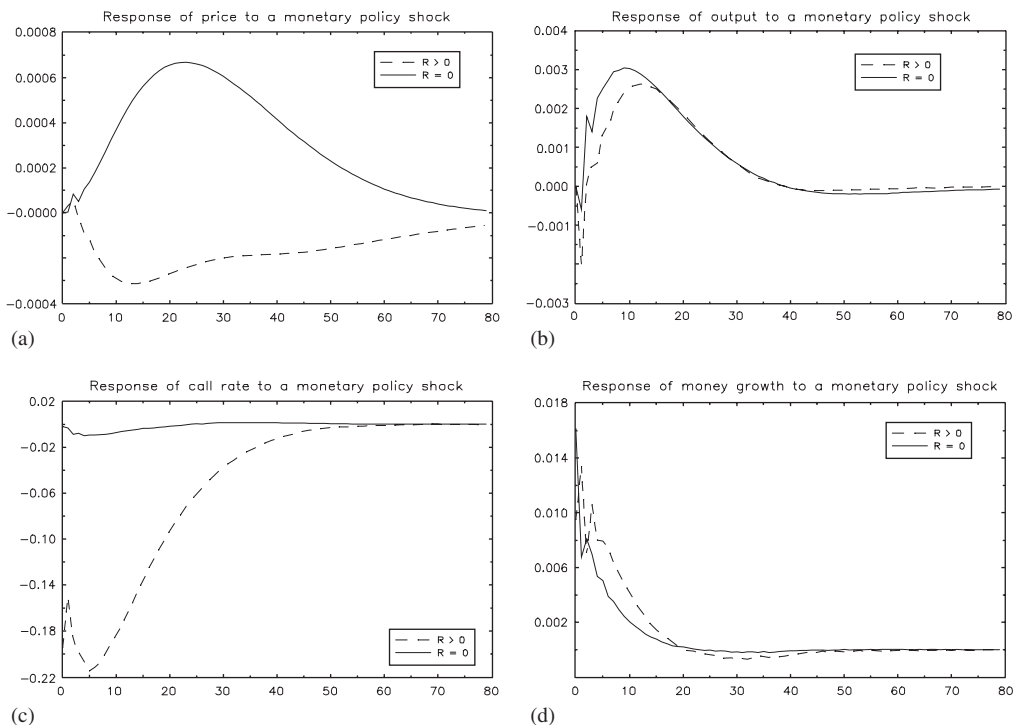


Fig. 4. (a) Response of price to a monetary policy shock; (b) response of output to a monetary policy shock; (c) response of call rate to a monetary policy shock; (d) response of money growth to a monetary policy shock.

the zero interest rate (Fig. 2(c)). As a result, monetary policy becomes much less effective (Fig. 2(b)).

Since we cannot test which scheme is a better description of the true monetary behavior under the zero interest-rate regime, the above estimates are subject to the caveat of “identification errors”. The BoJ has repeatedly made it public that it is pursuing an interest-rate targeting policy throughout the sample period. To the extent this is true, the results reported in Fig. 2 give us the empirical estimates of the effect of the zero bound on the interest-rate channel of monetary transmission. If the true policy is a mixture of both interest rate and money targeting, our results reported in Fig. 4 would provide direct empirical evidence favoring quantitative measures as a way to conduct effective monetary policy when the interest rate is on the zero bound.

## 5. Concluding remarks

In this paper we estimate the effect of an exogenous monetary shock when nominal interest rates are at zero and examine the impacts of the zero bound constraint on the effectiveness of counter-cyclical monetary policy. While there are many recent studies trying to evaluate the extent to which the zero bound interferes with the conduct of monetary policy by simulating structural models of the U.S. economy, those quantitative results are inevitably model specific and often lack direct empirical support. The low

interest rates and the apparent presence of the liquidity trap in Japan during the past decade make it possible to address such issues empirically using a nonlinear structural VAR.

We find that when the interest rate is on the zero bound, up to 50% of the impact of an exogenous monetary innovation on output can be eliminated if the monetary authority continues to target the interest rate. The conditional IRFs allow us to isolate the impact of monetary shocks operating through the interest-rate channel when other possible channels of monetary transmission are present. We find that (i) an exogenous monetary shock may still have a significant effect on the real economy when nominal interest rates are at zero, (ii) it is the interest-rate channel that appears to be the most important mechanism of monetary transmission. Moreover, we also find that the presence of the zero bound on nominal interest rates could severely limit the ability of central banks to pursue a counter-cyclical interest-rate policy when facing adverse macroeconomic shocks.

It is often debated whether or not the BoJ should conduct a further monetary easing given the stagnant domestic economy and the zero bound constraint on its policy instrument. This paper provides some empirical evidence supporting the view that the monetary authority can rely on quantitative measures to conduct an effective monetary policy when the interest rate is on the zero bound.

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