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Measuring Japanese Monetary Policy: An Examination using the Bernanke-Mihov Econometric Methodology

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Abstract

This paper quantitatively conceptualizes the Bank of Japan (BOJ)'s policy decisions by employing Bernanke and Mihov's (1998) econometric methodology for developing monetary policy measures. The paper shows that, in the subperiod to March 2001, the call rate alone should be used as the policy indicator of the BOJ. However, in the subperiod from April 2001, an equally weighted average of the call rate and reserves should be used. Furthermore, the paper presents a useful measure of BOJ policy that identifies its past policy decisions over time.

JEL classification: C32; E52; E58

Keywords: monetary policy measure, structural vector autoregression, discount-window policy, reserve market, Japanese monetary policy

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1 Introduction

Accurate evaluation of monetary policy requires an adequate policy indicator. In the context of studies of U.S. monetary policy, Bernanke and Blinder (1992) argued that the federal funds rate has been the primary policy target of the Federal Reserve (Fed). Christiano and Eichenbaum (1992) used non-borrowed reserves as the policy indicator, and Strongin (1995) proposed using the component of non-borrowed reserves growth that is orthogonal to total reserve growth. While these studies suggest quantitative indicators based on monetary variables for the Fed's past policy decisions, Romer and Romer (1989) and Boschen and Mills (1991) suggested more qualitative indicators. Romer and Romer used publications of the Fed, such as minutes of the policy committee and other statements of the decision-making bodies, to extract information on the key policy actions taken. Building on Romer and Romer's work, Boschen and Mills rated monetary policy on a discrete scale.

Past studies of Japanese monetary policy (e.g., Honda and Kuroki (2006), Miyao (2000, 2002), Ogawa (1999) and Hatakeda (1997)) have assumed that the Bank of Japan (BOJ) has always implemented policy by changing the call rate, and that the behaviour of the call rate reflects the BOJ's policy decisions over time. However, does this assumption always apply when analysing Japanese monetary policy? Since July 1995, the call rate has hardly moved from around zero (see Figure 1). Since March 2001, the BOJ has adopted a new policy framework, which has involved expanding reserves as often as lowering the call rate. Furthermore, previous studies of the BOJ's policy indicators for the period up to June 1995, when the call rate remained positive and subject to change, do not necessarily support the view that only the call rate reflects the BOJ's

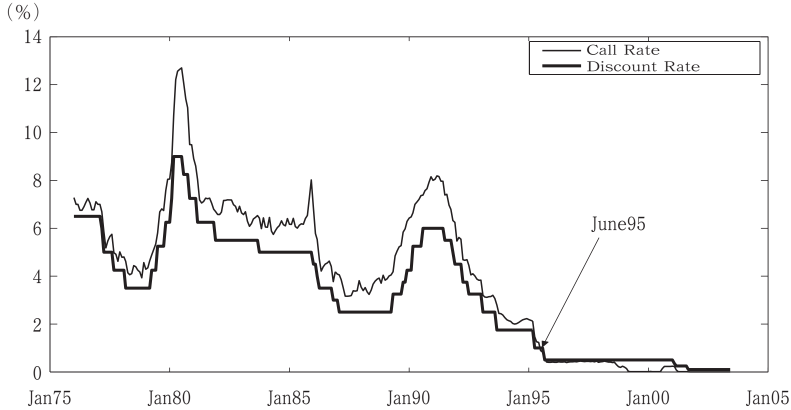

Figure 1: Call Rate and Discount Rate

policy decisions. For example, Shioji (2000) and Nakashima (2006) identified policy indicators of the BOJ to June 1995 by using a structural vector autoregression (VAR) methodology.[1] The former showed that the call rate and quantity indicators, such as M2+CD, and high-powered money, are useful as indicators of the BOJ's policy, and the latter showed that the call rate is the best indicator of the BOJ's policy.

This paper attempts to conceptualize quantitatively the BOJ's policy decisions by employing Bernanke and Mihov's (1998) structural vector autoregression methodology. Their methodology enables us to develop monetary policy meas-

(1) Shioji (2000) employed the identifying methodology of Sims (1986) that imposes a contemporaneous restriction on all economic variables in a VAR system, assuming that at least a subset of goods market variables are predetermined to model the Japanese high-powered money market. On the other hand, Nakashima (2006) employed Bernanke and Mihov's (1998) methodology that divides the macroeconomy into a policy sector and a non-policy sector, and after assuming a block recursive structure between the two sectors, imposes a contemporaneous restriction on monetary variables in the policy sector.

ures of central banks and to clarify their operating procedures by formulating equilibrium econometric models of the reserve market. In general, central banks aim to stabilize the macroeconomy by intervening in the reserve market and by setting reserves or short-term interest rates, such as the federal funds rate and the call rate, within a target range. The methodology assumes that monetary variables that are affected by the operating procedures of central banks in the reserve market embody the decisions of central banks.

When applying Bernanke and Mihov's (1998) econometric methodology to Japanese monetary policy, however, we take extreme care. Bernanke and Mihov developed an equilibrium model of the U.S. reserve market to discuss the Fed's operating procedures and to construct a quantitative policy measure of the Fed. In this paper, by thoroughly applying Bernanke and Mihov's econometric methodology to Japanese monetary policy, we consider the following: (1) the institutional differences between the U.S. and Japanese reserve markets, and (2) the shift in the BOJ's discount-window policy in July 1995. The former involves formulating a model of the Japanese reserve market that differs from that developed by Bernanke and Mihov for the U.S. reserve market. The latter involves modelling two equilibrium models of the Japanese reserve market: one each for before and after July 1995. In particular, to identify the BOJ's policy indicator over time, we present two original models of the Japanese reserve market. Each model captures the institutional features of the Japanese reserve market and reflects the difference in the BOJ's operating procedures before and after the BOJ changed its discount-window policy.

As previously discussed, in exploring the BOJ's policy indicator, Shioji (2000) and Nakashima (2006) did not cover the period from July 1995. Accordingly, they did not consider the shift in the BOJ's discount-window policy in July 1995.

In this paper, by carefully considering the BOJ's policy shift, we cover the period from July 1995 and thereby complement their analysis. In particular, by using the two equilibrium models of the Japanese reserve market for before and after July 1995, we show that, for the subperiod to March 2001, only the call rate should be used as the BOJ's policy indicator. However, for the subperiod from April 2001, an equally weighted average of the call rate and reserves should be used. Therefore, in this paper, we empirically demonstrate that individual monetary variables alone cannot explain the BOJ's past policy decisions over time. Furthermore, we present the BOJ's policy measure that is useful for the entire period from January 1980 to May 2003 by utilizing Bernanke and Mihov's methodology. The derived policy measure provides an explanation of the BOJ's historical decisions over time.

This paper is organized as follows. In Section 2, we discuss the differences in the BOJ's implementation of discount-window policy over time, and its differences from the Fed. Section 3 sets up two equilibrium models of the Japanese reserve market for before and after July 1995 by applying the econometric methodology of Bernanke and Mihov (1998). In Section 4, we discuss the data set and statistical methodology for estimating the two equilibrium models. Section 5 reports estimation results and develops a policy measure of the BOJ. In this section, we also examine the plausibility of the derived policy measure by conducting an impulse response analysis. Section 6 concludes the paper.

2 The BOJ's Discount-Window Policy

Applying Bernanke and Mihov's structural VAR methodology involves developing equilibrium econometric models of the reserve market. In particular, when modelling the Japanese reserve market, it should be noted that the introduction of a low interest-rate policy in July 1995 shifted the BOJ's discount-window policy.

At first, to develop an equilibrium model of the reserve market, we must understand the central bank's policy behaviour in the reserve market; i.e., how it supplies high-powered money (reserves plus currency). In general, central banks have two ways of controlling the supply of high-powered money. One is to engage in open-market operations and the other is to engage in discount-window lending. In particular, management of the discount window takes two forms depending on the relationship between the discount rate and short-term policy rates such as the call rate and the federal funds rate. One form relates to the way in which a central bank sets the discount rate below the short-term policy rate. The other relates to the way in which it sets the short-term rate below the discount rate.

Historically, the BOJ has adopted both forms of discount-window policy. Figure 1 shows paths of the call rate and the discount rate, which indicate that the discount rate remained below the call rate until June 1995 and has remained above it since July 1995, when the BOJ implemented a low interest-rate policy. This suggests that management of the BOJ's discount-window policy before June 1995 was similar to that of the Fed, because the U.S. discount rate is persistently below the federal funds rate. However, there is an important difference. The BOJ eased (tightened) policy by increasing (reducing) discount-window borrowing quotas for private banks. Therefore, the BOJ took the initiative to control the level of discount-window lending and regulated the quantity of borrowing. Because moral suasion is not used in Japan in the manner used by the Fed to reduce discount-window borrowing, private banks usually borrow their quota amounts. In the literature on Japan's monetary policy, this type of management of the BOJ's discount window is generally termed 'credit rationing'.[2] On the other hand, in the literature on U.S. monetary policy, it is supposed that borrowing from the Fed depends on private banks' decisions, and that the Fed endogenously accommodates the demand for discount-window borrowing by private banks. To model the Japanese reserve market, we must consider differences between discount-window management in Japan and the U.S.[3]

In July 1995, the BOJ, by setting the discount rate above the call rate, converted the discount rate into a penalty rate. The penalty rate eliminates the need for rationing at the discount window, and private banks usually have no incentive to borrow from the BOJ. Therefore, the BOJ's discount window accommodates demand shocks for discount-window borrowing provided that systemic risk in the short-term money market makes it difficult for private banks to obtain finance in this market.

Given the history of the BOJ's discount-window policy, we must develop two equilibrium models of the Japanese reserve market: for before and after June 1995. In the following section, we present two equilibrium models of the Japanese reserve market. One is the Credit Rationing (CR) model, applicable up to June 1995, and the other is the Low Interest-rate Policy (LIP) model, applicable from July 1995.

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(2) Hamada and Iwata (1980) and Honda (1984) each developed theoretical models of the credit-rationing view, and the former used empirical analysis to support their view. Furthermore, Ueda (1993) stated 'The discount rate has always been lower than the call rate. Therefore, discount-window lending has been rationed in Japan. And the level of lending has been changed by the BOJ, not by private banks' (p. 12, lines 17-19).

(3) The type of discount-window policy pursued by the U.S. is generally referred to as the 'implicit cost regime' in the literature on Japan's monetary policy.

3 Two Models of the Japanese Reserve Market

In this section, we introduce Bernanke-Mihov's structural VAR model and set up two equilibrium models of the Japanese Reserve Market by considering the shift in the discount-window policy and the institutional differences between operating procedures in Japan and the U.S.

3.1 Bernanke and Mihov's Methodology

To determine the actual policy measure of the BOJ, we follow Bernanke and Mihov in supposing that the economy is described by the linear structural model given by equations (1) and (2):

$$\boldsymbol{Y}_t = \sum_{i=0}^{k} \boldsymbol{B}_i \boldsymbol{Y}_{t-i} + \sum_{i=1}^{k} \boldsymbol{C}_i \boldsymbol{P}_{t-i} + \boldsymbol{A}^y \boldsymbol{v}_t^y \qquad (1)$$

$$\boldsymbol{P}_t = \sum_{i=0}^{k} \boldsymbol{D}_i \boldsymbol{Y}_{t-i} + \sum_{i=0}^{k} \boldsymbol{G}_i \boldsymbol{P}_{t-i} + \boldsymbol{A}^p \boldsymbol{v}_t^p, \qquad (2)$$

where variables in bold type denote vectors or matrices.

Following Bernanke and Mihov, we refer to $\boldsymbol{Y}$ and $\boldsymbol{P}$ as 'non-policy' and 'policy' variables, respectively. The set of policy variables includes variables that are potentially useful as direct indicators of the stance of monetary policy, such as short-term interest rates and reserve measures. Non-policy variables include other economic variables, such as output and inflation. In equations (1) and (2), the $\boldsymbol{v}$'s are mutually uncorrelated 'structural' or 'primitive' disturbances. In particular, one element of $\boldsymbol{v}_t^p$ is a money-supply shock or monetary-policy shock. The other elements of $\boldsymbol{v}_t^p$ may include shocks to money demand or any disturbance that affects the policy variables.

Bernanke and Mihov assumed that the non-policy variables, $\boldsymbol{Y}$, depend only on lagged values of the policy variables ($\boldsymbol{C}_0=0$). Given the timing assumption, the system given by (1) and (2) can be rewritten in VAR form (with only lagged variables on the right-hand side) and estimated by standard methods. As in Bernanke and Mihov, let $\boldsymbol{u}_t^p$ be the parts of the VAR residuals in the policy block that are orthogonal to the VAR residuals in the non-policy block. Then Bernanke and Mihov showed that $\boldsymbol{u}_t^p$ satisfies:

$$(\boldsymbol{I}-\boldsymbol{G}_0)\boldsymbol{u}_t^p=\boldsymbol{A}^p\boldsymbol{v}_t^p. \qquad (3)$$

Equation (3) is a standard structural VAR system, which relates observable VAR-based innovations, $\boldsymbol{u}$, to unobservable structural shocks, $\boldsymbol{v}$. The Bernanke-Mihov methodology involves identifying exogenous components of monetary policy and examining policy indicators by developing equilibrium models of the reserve market in the form of (3).

3.2 Before June 1995−CR (Credit Rationing) Model

The following system, (4)-(9), describes the CR model:

$$u^{re}=u^{br}+u^{mo}-u^{gd}-u^{cu} \qquad (4)$$

$$u^{gd}=u^{gd} \qquad (5)$$

$$u^{cu}=-\alpha u^{r}+v^{cu} \qquad (6)$$

$$u^{re}=-\beta u^{r}+v^{re} \qquad (7)$$

$$u^{br}=\phi^{gd}v^{gd}+\phi^{cu}v^{cu}+\phi^{re}v^{re}+\phi^{mo}v^{mo}+v^{br} \qquad (8)$$

$$u^{mo}=\theta^{gd}v^{gd}+\theta^{cu}v^{cu}+\theta^{re}v^{re}+\theta^{br}v^{br}+v^{mo}, \qquad (9)$$

where gd, cu, re, br and mo denote government deposits, currency, reserves, borrowed reserves and assets held through open-market operations by the BOJ, respectively, and r denotes the call rate.

Equation (4) is the market-equilibrium condition for bank reserves, which is based on an identity between assets and liabilities on the BOJ's balance sheet (see Table 1)[4]. Equation (5) implies that the BOJ accommodates fluctuations in the demand for government funds, v^{gd}. Equation (6) relates innovations in the demand for currency, u^{cu}, to innovations in the call rate, u^{r}, and an autonomous shock to currency demand, v^{cu}. Similarly, equation (7) represents the bank's demand for reserves, expressed in the form of innovations: it states that innovations in the demand for reserves, u^{re}, depend negatively on innovations in the call rate, u^{r}, and on a reserve demand shock, v^{re}.

Equation (8) represents the distinguishing feature of the CR model. It shows that the BOJ controls the level of discount-window lending and rations lending to private banks. Hence, we interpret this equation as a behaviour function for the BOJ. In particular, v^{br} represents the supply shock for discount-window lending and is defined as a policy shock[5]. Equation (9) is the second behaviour function in the CR model, and it shows how the BOJ supplies high-powered money by

(4) It is important to note that, unlike the Fed, the BOJ has not used the concept of non-borrowed reserves. This is a major difference between the operating procedures of the BOJ and those of the Fed. Bernanke and Mihov's econometric model of the U.S. reserve market incorporates an equilibrium condition for total reserves, (member-bank deposits plus vault cash) = borrowed reserves + non-borrowed reserves. Kasa and Popper (1997) have already applied the Bernanke-Mihov methodology to Japanese monetary policy. However, their analysis is deficient because it uses the concept of non-borrowed reserves: it does not take account of the institutional differences between Japan and the U.S.

(5) Equation (8) indicates another major difference between the operating procedures of the BOJ and those of the Fed. In the literature on U.S. monetary policy, it is supposed that private banks are reluctant to borrow from the discount window because of various sanctions and restrictions imposed by the Fed on banks' use of the window. Hence, the Fed only accommodates demand for discount-window borrowing by private banks. Specifically, Bernanke and Mihov used a conventional borrowing function, in which borrowing depends positively on the spread between the funds rate and the discount rate. Using data to June 1995, Nakashima (2006) found strong evidence against a model of the Japanese reserve market that incorporates a U.S.-type borrowing function rather than one of the form of equation (8).

using open-market operations. In particular, v^{mo} represents the high-powered money supply shock from using open-market operations and can be considered as the second monetary-policy shock, with v^{br} in equation (8) being the first.

The CR model implies that the BOJ affects the short-term money market and the macroeconomy through both open-market operations and discount-window lending, because the model has two BOJ behaviour functions. Furthermore, the two BOJ behaviour functions are essentially equivalent in that they are high-powered money supply functions of the BOJ. Therefore, in the CR model, it is the quantity, rather than the composition, of high-powered money that matters. Hence, adding equations (8) and (9) yields the following system, which is essentially equivalent to the CR model.

$$u^{re}=u^{md}-u^{gd}-u^{cu}$$
$$u^{gd}=u^{gd}$$
$$u^{cu}=-\alpha u^{r}+v^{cu}$$
$$u^{re}=-\beta u^{r}+v^{re}$$
$$u^{md}=\phi^{gd}v^{gd}+\phi^{cu}v^{cr}+\phi^{re}v^{re}+v^{md} \tag{10}$$

In this context, the VAR innovation, u^{md}, is defined as follows.

$$u^{md}=u^{br}+u^{mo}$$

The above system can be represented in the form of equation (3) as follows.

$$\boldsymbol{I}-\boldsymbol{G}_0=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & \alpha & 0\\ -1 & -1 & \beta & 1\\ 0 & 0 & 0 & 1\end{bmatrix},\quad \boldsymbol{A}^p=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ \phi^{gd} & \phi^{cu} & \phi^{re} & 1\end{bmatrix}$$

$$\boldsymbol{u}'=[u^{gd}\quad u^{cu}\quad u^{r}\quad u^{md}],\quad \boldsymbol{v}'=[v^{gd}\quad v^{cu}\quad v^{re}\quad v^{md}]$$

Inverting the above relationship reveals how the monetary policy shock, v^{md}, depends on the VAR innovations.

$$v^{md} = -(\alpha\phi^{cu} + \beta\phi^{re})u^{r} + (1-\phi^{re})u^{re} + (1-\phi^{cu})u^{cu} + (1-\phi^{gd})u^{gd} \quad (11)$$

The CR model described by the above system has nine unknown parameters (including the variances of four structural shocks) to be estimated from 10 covariances. Hence, there is one overidentifying restriction.

3.3 After July 1995—LIP (Low Interest-rate Policy) Model

The following system of equations describes the LIP model.

$$u^{re} = u^{br} + u^{mo} - u^{gd} - u^{cu}$$

$$u^{gd} = v^{gd}$$

$$u^{cu} = -\alpha u^{r} + v^{cu}$$

$$u^{re} = -\beta u^{r} + v^{re}$$

$$u^{br} = v^{br} \quad (12)$$

$$u^{mo} = \theta^{gd}v^{gd} + \theta^{cu}v^{cu} + \theta^{re}v^{re} + \theta^{br}v^{br} + v^{mo} \quad (13)$$

The structure of the LIP model differs from that of the CR model in equation (12). This equation indicates that the BOJ passively accommodates the demand shock for discount-window borrowing by private banks, vbr. Equation (13) represents the open-market operations behaviour of the BOJ. The LIP model assumes that the BOJ can use only open-market operations to supply high-powered money proactively. Therefore, the high-powered money supply shock, v^{s}, is defined as the monetary-policy shock of the BOJ in this model. Consequently, the LIP model can be written in the form of equation (3) as follows.

$$\boldsymbol{I} - \boldsymbol{G}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & \alpha & 0 \\ 0 & 0 & 1 & \beta & 0 \\ 1 & 1 & 1 & -\gamma & -1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \boldsymbol{A}^{p} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ \theta^{gd} & \theta^{cu} & \theta^{re} & \theta^{br} & 1 \end{bmatrix}$$

$$\boldsymbol{u}' = [u^{gd} \quad u^{cu} \quad u^{re} \quad u^{r} \quad u^{mo}], \quad \boldsymbol{v}' = [v^{gd} \quad v^{cu} \quad v^{re} \quad v^{br} \quad v^{mo}]$$

One can also invert the above relationship to determine how the monetary policy shock, v^s, depends on the VAR innovations.

$$v^s = -(\alpha\theta^{cu} + \beta\theta^{re})u^r + (\theta^{br} + 1)u^{mo} - (\theta^{br} + \theta^{re})u^{re} - (\theta^{br} + \theta^{cu})u^{cu} - (\theta^{br} + \theta^{gd})u^{gd} \quad (14)$$

The LIP model described by the above structural VAR system has 11 unknown parameters (including the variances of five structural shocks) to be estimated from 15 covariances. Hence, there are four overidentifying restrictions.

3.4 Theoretical Models for Alternative Operating Procedures

Parameters in the BOJ behaviour functions, given by equation (10) in the CR model and by equation (13) in the LIP model, define how the BOJ controls the market for bank reserves in each model. For example, the proposition that the BOJ targets only the call rate can be represented by three additional restrictions in the CR model, $\phi^{gd}=1$, $\phi^{cu}=1$ and $\phi^{re}=1$, and by four additional restrictions in the LIP model, $\theta^{gd}=1$, $\theta^{cu}=1$, $\theta^{re}=1$ and $\theta^{br}=-1$. In this case, the monetary policy shocks can be recovered by using the VAR innovations to the call rate. According to this proposition, the call rate provides the best policy indicator of the BOJ. We call this model CL (Call Rates Targeting) model. On the other hand, the proposition that the BOJ targets only the high-powered money can be represented by three additional restrictions in the CR model, $\phi^{gd}=1$, $\phi^{cu}=0$ and $\phi^{re}=0$, and by four additional restrictions in the LIP model, $\theta^{gd}=1$, $\theta^{cu}=0$, $\theta^{re}=0$ and $\theta^{br}=-1$. We call this model HP (High-Powered Money Targeting) model.

Alternative propositions that define the BOJ's policy in terms of both the call rate and quantity indicators, such as currency and reserves, can also be

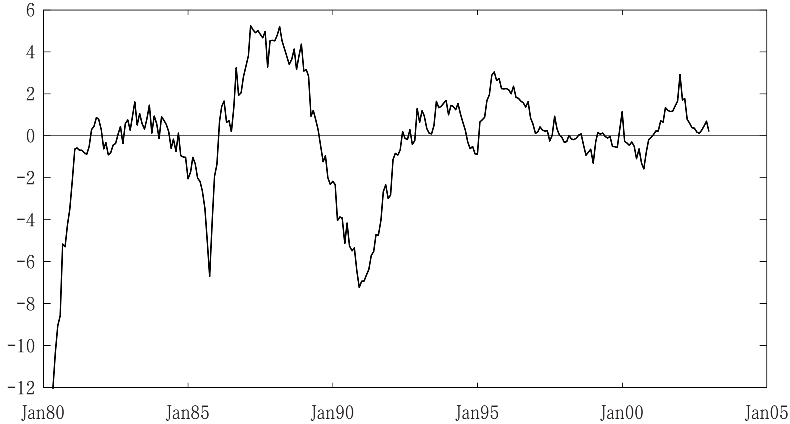

Figure 2: The Bank of Japan's Policy Measure

represented by parametric restrictions in the BOJ behaviour functions. For example, the proposition that the BOJ targets both the call rate and reserves can be written in terms of two additional restrictions in the CR model, $\phi^{gd}=1$ and $\phi^{cu}=1$, and three additional restrictions in the LIP model, $\phi^{gd}=1$, $\phi^{cu}=1$ and $\phi^{br}=-1$. In this case, the policy shocks can be recovered by using linear combinations of the VAR innovations to the call rate and reserves. According to this proposition, a hybrid variable comprising the call rate and reserves provides a good policy indicator of the BOJ. Hence, imposing various parametric restrictions on equations (10) and (13), respectively, yields six alternative models that are nested within the CR and LIP models. In particular, we describe two of the six models as single-targeting models, which assume that the BOJ targets a single monetary variable, while four are described as mixed-targeting models, which assume that the BOJ targets a combination of the following policy-sector variables: the call rate, currency, reserves and high-powered money (currency plus reserves).

Table 2 presents the models, which imply different forms of BOJ operating procedures. In what follows, we examine the BOJ's policy indicator by estimating the six alternative models and the CR and LIP models.

4 Data and Estimation Method

The Bernanke-Mihov methodology accommodates the inclusion of both policy variables and non-policy variables in the VAR system (1) and (2). Included in the non-policy sector are the output gap (y) for the industrial production index (1995=100, seasonally adjusted) and the rate of inflation (π) in the consumer price index (1995=100, excluding food products). As explained in Subsection 3. 1, the estimation of the structural VAR system (3) needs policy-sector innovations $\boldsymbol{u}_t^p$ that are 'orthogonal' to non-policy sector innovations. Hence, compared with policy variables, non-policy variables play only a minor role in the Bernanke-Mihov methodology. We limit the inclusion of non-policy variables to a bare minimum.(6) The output gap was measured by using percentage deviations from the trend, which was constructed by using the Hodrick. Prescott filter.(7) The consumer price index is seasonally adjusted by the X11 method, and the inflation rate is annual.

Consider the policy variables in the VAR system. As discussed in Subsections 3. 2 and 3. 3, the development of equilibrium models of the market for bank re-

(6) Indeed, we also include the exchange-rate gap or the money-supply gap of M2+CD, each constructed in a manner similar to producing the output gap, as one of the non-policy variables, but the inclusion of the new variables does not affect at all our estimation results for the structural VAR system (3).

(7) To apply the Hodrick-Prescott filter, we used a value of the smoothing parameter for monthly data of 129,600, as proposed by Ravin and Uhlig (2002). We also used a quadratic trend to obtain a measure of the output gap. The choice of the trends does not materially affect the results.

Table 1: The BOJ's Balance Sheet

Assets	Liabilities
Discount-window Lending (u^{br})	Government Deposits (u^{gd})
Assets Held via Open-Market Operations (u^{mo})	Currency Held by the Public (u^{cu})
(Security, Float, Other Net Assets)	Bank Deposits (u^{re})

serves involves the use of identities between assets and liabilities in the BOJ's balance sheet (Table 1). Government deposits (GD), currency (CU) and reserves (RE) are used for liabilities. Furthermore, 'the assets held via open-market operations (MO)', which comprise bills, bonds and overseas assets acquired by the BOJ through these operations, are used for assets.(8) In addition to these four variables, the call rate (R) is included in the policy sector.(9) Therefore, we estimate the seven-variable VAR system for y, π, GD, CU, RE, R and MO. All data were obtained from the Nikkei NEEDS, and the sample period is from January 1976 to May 2003.(10) To determine the number of lags in the VAR sys-

(8) Each equilibrium condition in the CR and LIP models requires one of the quantity variables in the policy sector to be redundant. Therefore, we exclude borrowed reserves (BR) from the policy sector.

(9) For details of MO, see Appendix A. Normalizing the policy-sector variables, except for R, causes log-linear estimation to violate the identity relationship between assets and liabilities. To deal with this problem, Bernanke and Mihov suggested that the policy-sector variables should be normalized by using a 36-month moving average of past values of total reserves. We adopt this approach by normalizing the policy-sector variables by using a 36-month moving average of past values of 'the BOJ's assets held via open-market operations and discount-window lending (MD)', generated by summing MO and discount-window lending. For details of MD, see Appendix A.

(10) A primary reason for omitting the period after May 2003 is that in May 2003, the BOJ significantly revised statistics from the Bank of Japan accounts, which comprises statistics on reserves, currency, borrowed reserves, government deposits and foreign assets. Because of this revision, statistics before and after May 2003 are incompatible. Because this break significantly affects our analysis of the BOJ's operating procedures, we omit the period from June 2003.

tems, we applied the Akaike Information Criterion (AIC). This criterion suggested 15 lags.[(11)]

To estimate the CR and LIP models, we use a two-step procedure. In the first step, by assuming the stability of the reduced-form VAR over time, we estimate the VAR using equation-by-equation OLS estimation for the full-sample period from 1976 to 2003.[(12)] OLS estimation generates two non-policy sector VAR innovations and five policy-sector VAR innovations. Furthermore, we regress each of the five policy-sector VAR innovations on the two non-policy sector VAR innovations using OLS estimation in order to obtain five policy-sector innovations of u^{gd}, u^{cu}, u^{re}, u^{r} and u^{mo} that are 'orthogonal' to the non-policy sector innovations. For post-1995 estimation of the LIP model, we can use the five orthogonal innovations. However, pre1995 estimation of the CR model requires the construction of u^{md}, which is the innovation of 'the assets held via open-market operations and discount-window lending (MD)'. To obtain u^{md}, after generating u^{br} from u^{gd}, u^{cu}, u^{re} and u^{mo} by using the market-equilibrium condition in equation (4), we add u^{br} and u^{mo}. Therefore, for pre-June 1995 estimation of the CR model, we use the four policy-sector innovations of u^{gd}, u^{cu}, u^{r} and u^{md}.[(13)] In addition, for

(11) We also applied the Schwartz-Bayesian Information Criteria (SBIC) and the Hannan and Quinn information criterion (HQIC). The former criterion suggested six lags, and the latter criterion suggested nine lags. We estimate the VAR systems with six lags, and nine through 17 lags. The ordering of the VARs does not qualitatively affect our estimation results reported in Section 5.

(12) In Section 5, we examine the stability of the reduced-form VAR for the full period in detail.

(13) We can also estimate the CR model by directly using 'the assets held via open-market operations and discount-window lending (MD)', which comprises MO and discount-window lending. This requires estimation of the six-variable VAR system (in y, π, GD, CU, R and MD) for the CR model. The author confirms that there is no significant difference between the estimation results for the CR model based on the six-variable VAR and those based on the seven-variable VAR. However, the use of the six-

post-1995 estimation of the LIP model, we must take it into account that, in March 2001, the BOJ officially adopted a new operating procedure by targeting the level of reserves as much as by continuing with the so-called zero interest-rate policy. We should carefully examine whether the LIP model can capture this change in the BOJ's operating procedures in March 2001. Hence, for pre-and post-2001 estimation of the LIP model, we split the five policy-sector VAR innovations, which are generated for post-1995 estimation of the LIP model, at March 2001. Thus, we conduct not only post-1995 estimation of the LIP model but also pre-and post-2001 estimation of it, and thereby carefully examine the change in the BOJ's operating procedures in 2001.

In the second step, full-information maximum likelihood estimation is applied to the structural VAR system of equation (3). The log likelihood function to be maximized is as follows:

$$L(\boldsymbol{I}-\boldsymbol{G},\ \boldsymbol{A},\ \boldsymbol{\Sigma}_v) = -(T/2)\{log|\boldsymbol{I}-\boldsymbol{G}|^2 - log|\boldsymbol{A}|^2 - log|\boldsymbol{\Sigma}_v|^2\}$$
$$-(T/2)\,trace\{(\boldsymbol{I}-\boldsymbol{G})'(\boldsymbol{A}^{-1})'\boldsymbol{\Sigma}_v^{-1}\boldsymbol{A}^{-1}(\boldsymbol{I}-\boldsymbol{G})\boldsymbol{\Sigma}_u\},$$

where $\boldsymbol{\Sigma}_u$ is the estimate of the covariance matrix of the policy-sector innovations and $\boldsymbol{\Sigma}_v$ is the diagonal matrix that diagonally locates the variances of the structural shocks.[(14)] Following Bernanke and Mihov, we performed two types of

variable VAR requires estimation of separate VAR systems for the pre-and post-1995 periods. Therefore, the CR and LIP models on different VAR systems differ not only in their contemporaneous structures of the reserve market but also in their dynamic structures of the macroeconomy. Given that we are attempting to identify a useful policy measure over time by focusing on the difference in the contemporaneous structure of the reserve market before and after 1995, it is important to minimize differences between the two models through the use of a single VAR system. This approach is adopted in this paper.

(14) To conduct the full-information maximum likelihood estimation, we employ the BFGS algorithm in the Constrained Maximum Likelihood Estimation (CML) GAUSS package.

test on the models: (1) tests of the validity of the full set of overidentifying restrictions, and (2) joint hypothesis tests on parametric restrictions with the single and mixed-targeting models, conditional on the validity of both the CR and LIP models.

For ease of interpretation, we define 'weighting parameters', ω, in the CR, LIP and mixed-targeting models. The weighting parameters are the absolute values of the parameters corresponding to the VAR innovations in the BOJ behaviour functions, (10) and (13). The absolute values in the behaviour functions are normalized to sum to unity. For example, the weighting parameters in the CR model are:

$$v^{md} = \omega^r u^r + \omega^{re} u^{re} + \omega^{cu} u^{cu} + \omega^{gd} u^{gd},$$

where $\omega^r + \omega^{re} + \omega^{cu} + \omega^{gd} = 1$. Each ω satisfies $\omega^r = |(\alpha\phi^{cu} + \beta\phi^{re})/k|$, $\omega^{re} = |(1-\phi^{re})/k|$, $\omega^{cu} = |(1-\phi^{cu})/k|$ and $\omega^{gd} = |(1-\phi^{gd})/k|$, where $k = |\alpha\phi^{cu} + \beta\phi^{re}| + |1-\phi^{re}| + |1-\phi^{cu}| + |1-\phi^{gd}|$.(15)

5 Empirical Results

In this section, we report estimation results for the equilibrium models of Japanese reserve markets, and we develop the BOJ's policy measure. In addition, we examine the plausibility of the derived policy measure by conducting an impulse response analysis.

(15) Similarly, the weighting parameters in the LIP model are:

$$v^s = \omega^r u^r + \omega^{mo} u^{mo} + \omega^{re} u^{re} + \omega^{cu} u^{cu} + \omega^{gd} u^{gd},$$

where $\omega^r + \omega^{mo} + \omega^{re} + \omega^{cu} + \omega^{gd} = 1$. Each ω satisfies $\omega^r = |(\alpha\theta^{cu} + \beta\theta^{re})/k|$, $\omega^{re} = |(\theta^{br} + \theta^{re})/k|$, $\omega^{cu} = |(\theta^{br} + \theta^{cu})/k|$ and $\omega^{gd} = |(\theta^{br} + \theta^{gd})/k|$, where $k = |\alpha\theta^{cu} + \beta\theta^{re}| + |\theta^{br} + \theta^{re}| + |\theta^{br} + \theta^{cu}| + |\theta^{br} + \theta^{gd}|$. The weighting parameters in each of the four mixed-targeting models, including the CL-CU-RE, CL-CU, CL-RE and CL-HP models, shown in Table 2, are defined similarly.

Table 2: Alternative Models for the BOJ's Operating Procedures

CR Model (Before June 1995)

Models	BOJ Equations ϕ^{gd}	ϕ^{cu}	ϕ^{re}	Monetary Policy Shocks
CL (Call Rate)	1.00	1.00	1.00	$v^{md}=-(\alpha+\beta)u^{r}$
HP (High-powered Money)	1.00	0.00	0.00	$v^{md}=u^{hp}(=u^{re}+u^{cu})$
CL-CU-RE	1.00	—	—	$v^{md}=-(\alpha\phi^{cu}+\beta\phi^{re})u^{r}+(1-\phi^{re})u^{re}+(1-\phi^{cu})u^{cu}$
CL-CU	1.00	—	1.00	$v^{md}=-(\alpha\phi^{cu}+\beta)u^{r}+(1-\phi^{cu})u^{cu}$
CL-RE	1.00	1.00	—	$v^{md}=-(\alpha+\beta\phi^{re})u^{r}+(1-\phi^{re})u^{re}$
CL-HP	1.00	$\phi^{re}=\phi^{cu}$		$v^{md}=-\{(\alpha+\beta)\phi^{cu}\}u^{r}+(1-\phi^{cu})u^{hp}$

LIP Model (After July 1995)

Models	BOJ Equations θ^{gd}	θ^{cu}	θ^{re}	θ^{br}	Monetary Policy Shocks
CL (Call Rate)	1.00	1.00	1.00	-1.00	$v^{s}=-(\alpha+\beta)u^{r}$
HP (High-powered Money)	1.00	0.00	0.00	-1.00	$v^{s}=u^{hp}(=u^{re}+u^{cu})$
CL-CU-RE	1.00	—	—	-1.00	$v^{s}=-(\alpha\theta^{cu}+\beta\theta^{re})u^{r}+(1-\theta^{re})u^{re}+(1-\theta^{cu})u^{cu}$
CL-CU	1.00	—	1.00	-1.00	$v^{s}=-(\alpha\theta^{cu}+\beta)u^{r}+(1-\theta^{cu})u^{cu}$
CL-RE	1.00	1.00	—	-1.00	$v^{s}=-(\alpha+\beta\theta^{re})u^{r}+(1-\theta^{re})u^{re}$
CL-HP	1.00	$\theta^{re}=\theta^{cu}$		-1.00	$v^{s}=-\{(\alpha+\beta)\theta^{cu}+\gamma\}u^{r}+(1-\theta^{cu})u^{hp}$

1. CL, HP, CU and RE imply the call rate, high-powered money, currency and reserves, respectively.
2. We descrive the CL and HP models as single-targeting models, which assume that the BOJ targets a single-monetary variable.
3. We descrive the CL-CU-RE, CL-CU, CL-RE and CL-HP models as mixed-targeting models, which assume that the BOJ targets a combination of the following policy-sector variables: CL, HP, CU and RE.

5.1 Stability of VAR System

Our two-step procedure for estimating the structural VAR system (3) assumes the stability of the seven-variable VAR system over time. In this subsection, we examine the stability of the reduced-form VAR by employing the three types of Lagrange multiplier (LM) test, the Sup LM, the Exp LM, and the Ave

Table 3: Test Results for Structural Change of the VAR System

Variables	Sup LM		Exp LM		Ave LM	
	Test statistics	Asymptotic p-values	Test statistics	Asymptotic p-values	Test statistics	Asymptotic p-values
Non-policy Sector						
y	60.8	**0.10**	26.5	**0.11**	48.8	0.02
π	83.2	0.00	36.3	0.00	34.5	**0.58**
Policy Sector						
GD	63.5	**0.06**	28.3	**0.05**	44.2	**0.08**
CU	61.5	**0.09**	26.5	**0.11**	37.5	**0.37**
RE	63.0	**0.07**	28.0	**0.06**	44.5	**0.07**
R	87.0	0.00	39.1	0.00	45.8	**0.05**
MO	57.3	**0.19**	25.7	**0.14**	46.5	**0.09**

1. Each equation in the seven variable VAR system is estimated with 6 lags.
2. LM denotes the Lagrange multiplier statistic of the null hypothesis of no structural change.
3. Sup LM denotes the sup test for structural change proposed by Andrews (1993). Exp LM and Ave LM, respectively, denote the exponential test and the average test proposed by Andrews and Ploberger (1994).
4. Asymptotic p-values for the structural-change tests are computed using the methodology proposed by Hansen (1997).

LM test, proposed by Andrews (1993) and Andrews and Ploberger (1994). In the tests of structural change, the null hypothesis of parameter stability of each of seven equations in the reduced-form VAR is tested against the alternative hypothesis of parameter instability. Furthermore, we use the methodology presented by Hansen (1997) to calculate asymptotic p-values for the structural change tests.(16) Each equation in the seven-variable VAR system is estimated with six lags.

Table 3 reports the test results of parameter stability for each equation. For the non-policy sector equations, there is no strong evidence against parameter

(16) We compute the LM test statistics and the corresponding p-values using the GAUSS code programmed by Professor Bruce Hansen. The LM statistics are computed using the middle 70 per cent of the sample.

stability. Parameter stability of the output-gap (y) equation is not rejected at the five per cent level of significance by the Sup LM and the Exp LM tests, and at the one per cent level of significance by the Ave LM test. Furthermore, parameter stability of the inflation equation (π) is not rejected at the five per cent level of significance by the Ave LM test.

For the policy sector equations, the LM test statistics also support parameter stability over time. The Sup LM, Exp LM, and Ave LM tests do not reject parameter stability for each of government deposits (GD), currency (CU), reserves (RE), and market operations (MO) equations at the five per cent level of significance. Parameter stability for the call rate (R) equation is not rejected at the five per cent level of significance by the Ave LM test. Overall, our estimated VAR system seems to pass the structural change tests. Stability of the reduced form VAR system is also accepted for shorter lag lengths (e.g., three or four lags).

5.2 Estimation Results for the CR and LIP models

Next, we discuss estimation results for the CR and LIP models. Tables 4 and 5 report estimation results for the two models. Table 6 shows subperiodestimation results for the LIP model. We take into account the following points.(17)

1. For the pre-June 1995 period (Table 4), the parameter estimates of the BOJ behaviour function in the CR and mixed-targeting models are close to unity. This is consistent with the CL model being the most easily accepted, and with the estimates of ω^r being relatively high. Furthermore, all other models except the HP model are easily accepted. These results indicate that the

(17) In all 14 models, the parameter estimates of the demand functions are of the expected sign, although some estimates are not statistically significant.

Table 4: Estimation Results from the Credit Rationing (CR) Model
(1976: 1-1995: 6)

Models	Demand Equations		BOJ Equations			OIR	JOINT	Weights			
	α	β	ϕ^{gd}	ϕ^{cu}	ϕ^{re}			ω^{r}	ω^{cu}	ω^{re}	ω^{gd}
CR	0.04 (0.05)	0.05 (0.06)	0.99 (0.01)	0.99 (0.12)	0.99 (0.01)	1.52 (**0.21**)	—	0.75	0.08	0.08	0.08
CL	0.02 (0.02)	0.02 (0.02)	1.00	1.00	1.00	1.91 (**0.75**)	0.38 (**0.94**)	—	—	—	—
HP	0.03 (0.01)	0.03 (0.00)	1.00	0.00	0.00	179 (0.00)	179 (0.00)	—	—	—	—
CL-CU-RE	0.07 (0.04)	0.07 (0.05)	1.00	0.99 (0.13)	0.99 (0.15)	1.56 (**0.46**)	0.03 (**0.86**)	0.87	0.06	0.06	—
CL-CU	0.06 (0.01)	0.02 (0.02)	1.00	0.99 (0.01)	1.00	2.71 (**0.44**)	0.74 (**0.69**)	0.89	0.10	—	—
CL-RE	0.01 (0.01)	0.02 (0.02)	1.00	1.00	0.99 (0.01)	1.91 (**0.59**)	0.39 (**0.82**)	0.75	—	0.24	—
CL-HP	0.07 (0.05)	0.07 (0.04)	1.00	0.99 (0.03)	0.99 (0.03)	1.56 (**0.67**)	0.03 (**0.98**)	0.93	0.06	0.06	—

1. For the Demand Equations and BOJ Equations, standard errors are in parentheses.
2. OIR and Joint indicate overidentifying restrictions test statistics and joint test statistics, respectively. p-values are in parentheses.
3. A likelihood ratio test was used to test the overidentifying restrictions. The degrees of freedom are one for the CR model, four for the CL and HP models, two for the CL-CU-RE model and three for the CL-CU, CL-RE and CL-HP models.
4. A likelihood ratio test was used to test the joint hypotheses. The degrees of freedom are three for the CL and HP models, one for the CL-CU-RE model and two for the CL-CU, CL-RE and CL-HP models.

call rate would be the best policy indicator of the BOJ for the period before June 1995.

2. For the post-July 1995 period (Table 5), the HP model is rejected at the five per cent level of significance, whereas the CL model is not rejected. The LIP model and the two mixed-targeting models, the CL-CU-RE and CL-RE models, are accepted with better p-values than the CL model. In particular, the estimates of ω in the three models indicate that the BOJ has been concerned about the call rate and reserves. These results imply that the

Table 5: Estimation Results from the Low Interest Rates (LIP) Model
(1995: 7-2003: 5)

Models	Demand Equations α	Demand Equations β	BOJ Equations θ^{gd}	BOJ Equations θ^{cu}	BOJ Equations θ^{d}	BOJ Equations θ^{b}	OIR	JOINT	Weights ω^{r}	Weights ω^{cu}	Weights ω^{re}	Weights ω^{gd}	Weights ω^{mo}
LIP	0.06	0.43	0.99	0.92	0.61	-0.96	2.31	—	0.37	0.04	0.49	0.04	0.06
	(0.03)	(0.02)	(0.03)	(0.11)	(0.03)	(0.03)	(**0.68**)						
CL	0.04	0.25	1.00	1.00	1.00	-1.00	11.1	6.13	—	—	—	—	—
	(0.03)	(0.05)					(**0.19**)	(**0.19**)					
HP	0.05	0.31	1.00	0.00	0.00	-1.00	66.0	61.0	—	—	—	—	—
	(0.01)	(0.02)					(0.00)	(0.00)					
CL-CU-RE	0.07	0.43	1.00	0.88	0.61	-1.00	8.05	4.29	0.40	0.14	0.45	—	—
	(0.03)	(0.03)		(0.11)	(0.03)		(**0.33**)	(**0.12**)					
CL-CU	0.15	0.14	1.00	0.99	1.00	-1.00	20.2	16.2	0.99	0.01	—	—	—
	(0.05)	(0.05)		(0.01)			(0.00)	(0.02)					
CL-RE	0.05	0.41	1.00	1.00	0.58	-1.00	7.32	5.42	0.40	—	0.60	—	—
	(0.02)	(0.02)			(0.04)		(**0.39**)	(**0.14**)					
CL-HP	0.04	0.15	1.00	0.99	0.99	-1.00	16.2	10.5	1.00	0.00	0.00	—	—
	(0.02)	(0.01)		(0.06)	(0.06)		(0.02)	(0.00)					

1. For the Demand Equations and BOJ Equations, standard errors are in parentheses.
2. OIR and Joint indicate overidentifying restrictions test statistics and joint test statistics, respectively. p-values are in parentheses.
3. A likelihood ratio test was used to test the overidentifying restrictions. The degrees of freedom are four for the LIP model, eight for the CL and HP models, six for the CL-CU-RE model and seven for the CL-CU, CL-RE and CL-HP models.
4. A likelihood ratio test was used to test the joint hypotheses. The degrees of freedom are four for the CL and HP models, two for the CL-CU-RE model and three for the CL-CU, CL-RE and CL-HP models.

accurate grasp of the BOJ's policy decisions for the post-July 1995 period requires using not only the call rate but also reserves.

3. For the post-July 1995 period, estimation results for before and after March 2001 differ (Table 6). For the first subperiod, before March 2001, the parameter estimates of the BOJ behaviour function in the LIP and mixed-targeting models are close to unity. In addition, the CL model is easily accepted, whereas the HP model is strongly rejected. These results suggest that the call rate would be the policy indicator of the BOJ for the pre-March

2001 period.

4. For the second subperiod, from April 2001, the single-targeting models, the CL and HP models, are rejected at the five per cent level of significance. However, the LIP model and the two mixed-targeting models, the CL-CU-RE and CL-RE models, are easily accepted. In particular, the estimates of ω in the three models indicate that, since April 2001, the BOJ has been equally concerned about the call rate and reserves. These results suggest that an equally weighted average of the call rate and reserves can be used as the policy indicator of the BOJ in the post-April 2001 period.

Each of the estimation results for the post-July 1995 and post-April 2001 periods reasonably reflects the change in the BOJ's operating procedures in 2001. In addition, the estimation result for the post-July 1995 period is consistent with that for each of the pre-and post-2001 periods. Hence, taking the pre-June 1995 and pre-March 2001 results into account, we conclude that the call rate alone represents the BOJ's actual policy decisions for the pre-March 2001 period, including the pre-June 1995 period. On the other hand, for the post-April 2001 period, an equally weighted average of the call rate and reserves can capture the BOJ's policy decisions.

5.3 The Policy Measure of the BOJ

The estimation results suggest that the composition of the BOJ's policy measure might differ between periods. Hence, to calculate a useful policy measure over time, we apply the method proposed by Bernanke and Mihov. First, we calculate the sum of the policy shock and the corresponding element of $\boldsymbol{A}^{-1}(\boldsymbol{I}-\boldsymbol{G})\boldsymbol{P}_t$. Specifically, in terms of equation (3), this is the fourth element in the context of the CR model and its six associated models, and is the fifth element in the context of the LIP and its six associated models. We plug the estimate of $\boldsymbol{A}$ and $\boldsymbol{I}-\boldsymbol{G}$ from each estimation for the pre-June 1995, July 1995 to March 2001 and post-April 2001 periods into the corresponding rows of $\boldsymbol{A}^{-1}(\boldsymbol{I}-\boldsymbol{G})$ in each of the 14 models. For the CR model and its six associated models, $\boldsymbol{P}_t$ includes the four policy variables, R, RE, CU and GD, while for the LIP model and its six associated models, $\boldsymbol{P}_t$ includes the five policy variables, R, MO, RE, CU, GD. This procedure generates seven series in the three periods.

Next, we normalize the p-values of the tests of the overidentifying restrictions performed in each subperiod so that they sum to unity. Using the normalized values, we derive a weighted average policy measure in each period. Then, we normalize the calculated policy measure at each date by subtracting it from a 36-month moving average of its own past values over the entire period. This implies that zero is the benchmark for 'normal' monetary policy ('normal' at least in terms of recent experience), and that positive values indicate an easing of monetary policy, while negative values indicate a tightening.(18)

(18) The issue of how we should define normal (or neutral) policy is an important macroeconomic issue. Following Bernanke and Mihov, we use the 36-month moving average method to derive a neutral policy indicator in each month. As an alternative to our neutral policy indicator, arguably, the natural rate of interest, which is the real short-term interest rate consistent with output being at its natural rate and inflation being constant, is the most appropriate indicator of neutral policy (see, e.g., Blinder (1998)). However, the use of the natural real interest rate is problematic for two reasons. First, the standard approach to calculating the path of the natural rate has not yet been established. As Laubach and Williams (2003) have pointed out, econometric estimates of the natural rate of interest are imprecise. Second, quantitative conceptualization of the BOJ's policy stance based on the natural rate of interest is quite inconsistent with the framework of this paper. This is because the BOJ's policy indicator obtained by using estimates from the CR, LIP and their associated models implies different monetary indicators, including the call rate, reserves and currency, which are not measured in comparable units. The moving average method proposed by Bernanke and Mihov has the advantage of alleviating this problem of inconsistent units of measurement. Hence, in

Figure 2 shows the obtained policy measure from January 1980 to May 2003. The policy measure is scaled so that it has the same variance as the call rate. Several features are noteworthy.

1. After a temporary tightening immediately following the Plaza Agreement of September 1985, the policy stance in the late 1980s was substantially expansionary.
2. In the early 1990s, when the bubble economy of the late 1980s burst, the policy stance was contractionary.
3. In the mid 1990s, the policy stance was expansionary at the beginning of the period of the low interest-rate policy in June 1995. After that, the policy stance in the late 1990s was neutral.
4. Except for a temporary tightening involving raising the call rate in August 2000, the policy stance has been expansionary since the beginning of the quantitative easing of policy in March 2001.

5.4 Discussion

The previous section has presented a policy measure of the BOJ that represents its past policy decisions over time. This section discusses the plausibility of the obtained policy measure by using impulse response functions.

Analogously to Bernanke and Mihov's VAR system, given by equations (1) and (2), we assume that the economy is described by the following linear structural model:

$$\boldsymbol{Y}_t=\sum_{i=0}^{k}\boldsymbol{B}_i\boldsymbol{Y}_{t-i}+\sum_{i=1}^{k}\boldsymbol{C}_i p_{t-i}+A^y v_t^y$$

---

what follows, we measure the BOJ's policy stance based on the neutral policy indicator obtained by using the moving average method.

$$p_t = \sum_{i=0}^{k} \boldsymbol{D}_i \boldsymbol{Y}_{t-i} + \sum_{i=1}^{k} \boldsymbol{G}_i p_{t-i} + v_t^p,$$

where p_t is the obtained policy measure. The vector of non-policy variables in the VAR is given by $\boldsymbol{Y}_t' = (y_t,\ \pi_t)$, which includes the output gap for industrial production (y) and the rate of inflation (π). The $\boldsymbol{v}_t^y$ and v_t^p terms indicate the uncorrelated structural disturbances, an output shock, an inflation shock, and a policy shock to the system. The AIC suggests the use of 12 lags in the VAR system.(19) The identification of the structural shocks is achieved through a Choleski decomposition, with the ordering of the variables as $y_t,\ \pi_t,\ p_t$.(20)

Figure 3 shows the estimated impulse response to an expansionary policy shock of a one-standard-deviation increase in v_t^p. Solid lines indicate point estimates of impulse responses up to the 48th month. Dashed lines represent their 95 per cent confidence intervals, computed by using a Monte Carlo integration with 1000 replications. The effect of the expansionary policy shock on output builds gradually and reaches its peak after about one year, before declining back to zero. The timing of the estimated peak and decline of output corresponds to the estimated timing of the 'policy tightening', which indicates that the policy measure becomes negative about one year after the expansionary shock. The effect on the inflation rate exhibits a modest 'price puzzle' and reaches its peak in about two years.

The left column of Figure 4 shows the estimated responses to a positive output shock, while the right column shows the estimated responses to an inflation

(19) We examine the stability of the three-variable VAR system by employing the tests of structural change proposed by Andrews (1993) and Andrews and Ploberger (1994). We confirm that our estimated VAR system passes the structural change tests.

(20) To conduct impulse response analysis, we use the RATS (Regression Analysis of Time Series) software package.

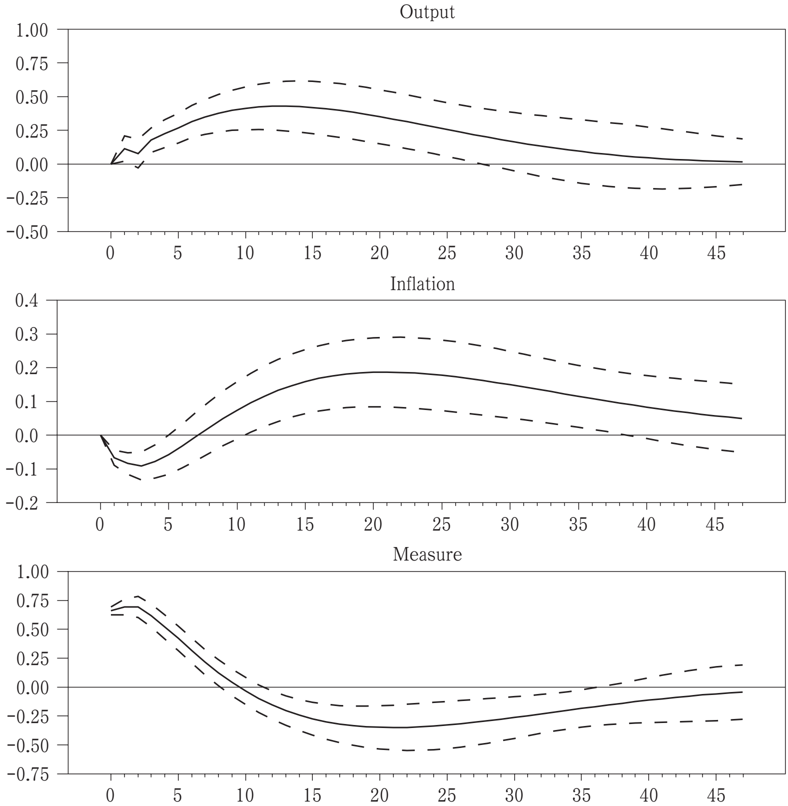

Figure 3: Impulse Response to Policy Shock

1. The figure shows the estimated impulse response to a one standard deviation policy shock.
2. The solid line and the dashed line represent point estimates and their 95 percent confidence intervals, computed by using a Monte Carlo integration with 1000 replications, respectively.

shock. The impulse response conveys a plausible story: positive innovations to output and inflation lead to policy tightenings, as captured by falls in the policy measure. The pattern seems to confirm the 'leaning against the wind' story. These impulse response results suggest that the obtained policy measure is plausible.

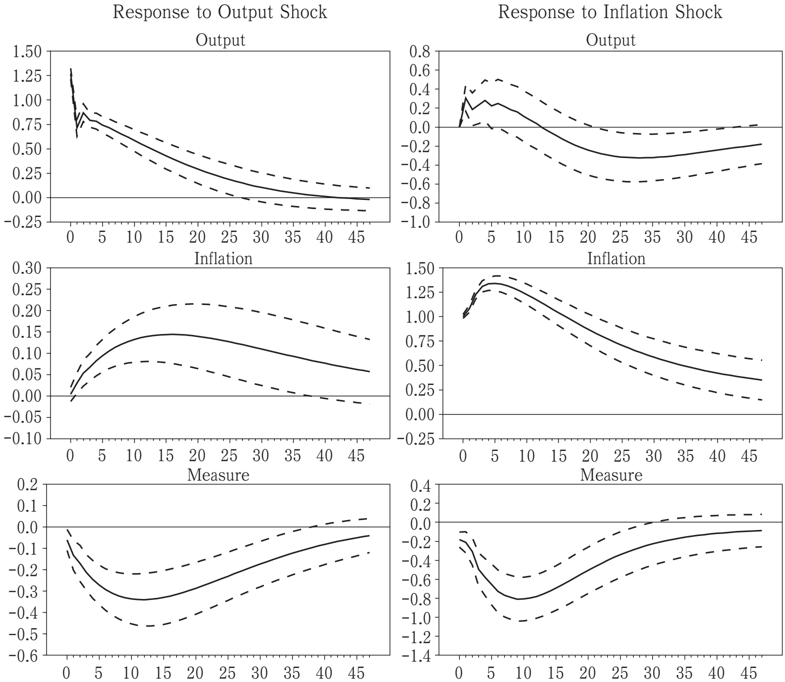

Figure 4: Impulse Response to Output Shock and to Inflation Shock

1. The left column shows the estimated responses to a positive output shock, while the right column shows the estimated responses to an inflation shock.
2. The solid line and the dashed line represent point estimates and their 95 percent confidence intervals, computed by using a Monte Carlo integration with 1000 replications, respectively.

6 Conclusion

The main conclusion of this paper is that no simple monetary measure represents the BOJ's past policy decisions over time. In particular, we suggest that the call rate should be used as the policy indicator of the BOJ to March 2001, and that an equally weighted average of the call rate and reserves should be used as the BOJ's policy indicator from April 2001.

This paper, by applying Bernanke and Mihov's methodology, has presented a useful measure of BOJ policy that identifies its past policy decisions over time. One could use this indicator to conduct various exercises, including comparative analyses of the BOJ's actual and optimal decisions. We leave this and other analysis using this measure to future research.(21)

Appendix A: Constructing MO and MD

- Construction of MO:

  First, we apply X11 to foreign assets (net), claims on government, claims on deposit-money banks, lending to deposit-money banks, and unclassified assets (net). Second, we subtract lending to deposit-money banks (SA) from the claims on deposit-money banks (SA)(22). The transformed data measure claims that the BOJ acquires via open-market operations on deposit-money banks. Then, we define the sum of the transformed data, foreign assets (SA), claims on government (SA), and the unclassified assets (SA) as MO: the BOJ's assets held via open-market operations. All the data are obtained from Nikkei NEEDS (Monetary Survey, Accounts of Monetary Authority).

- Construction of MD:

  After applying X11 to lending to deposit-money banks, we define the sum of lending (SA) and MO as MD: the BOJ's assets held via open-market operations and discount-window lending.

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(21) The resulting policy measure is obtainable from the author.
(22) SA denotes seasonally adjusted data.

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