Bank of Japan Working Paper Series

Evaluating Japanese Monetary Policy under the Non-negativity Constraint on Nominal Short-term Interest Rates

Koichiro Kamada*
kouichirou.kamada@boj.or.jp

Tomohiro Sugo*
tomohiro.sugou@boj.or.jp

No.06-E-17
October 2006

Bank of Japan
2-1-1 Nihonbashi Hongoku-cho, Chuo-ku, Tokyo 103-8660

* Monetary Affairs Department, Bank of Japan

EVALUATING JAPANESE MONETARY POLICY UNDER THE NON-NEGATIVITY CONSTRAINT ON NOMINAL SHORT-TERM INTEREST RATES[♦]

KOICHIRO KAMADA[*] AND TOMOHIRO SUGO[**]

[♦] We would like to thank Mr. Kiyohiko Nishimura and the staff of the Bank of Japan for their helpful comments. The opinions expressed here, as well as any remaining errors, belong to the authors and should not be ascribed to the Bank of Japan or the Monetary Affairs Department.

[*] Monetary Affairs Department, Bank of Japan (E-mail: kouichirou.kamada@boj.or.jp)
[**] Monetary Affairs Department, Bank of Japan (E-mail: tomohiro.sugou@boj.or.jp)

【ABSTRACT】

In this paper, we propose a new method for identifying monetary policy shocks under the non-negativity constraint on nominal short-term interest rates and use it to estimate the impact of monetary policy on the Japanese economy since the bursting of the asset bubble. Our method boasts three distinctive features. The first is the use of intermediate variables that describe aspects of the transmission mechanism of monetary policy. We use these to create a *monetary policy proxy*, which is able to approximate the policy stance of the monetary authority for a whole range of different policy measures. Second, we identify monetary policy shocks by imposing sign restrictions on the impulse response functions of the monetary policy proxy and nominal exchange rate to monetary policy shocks. Thirdly, we use the *Markov chain Monte Carlo* method to estimate the date of any structural change in the transmission mechanism of monetary policy. We show empirically that the effects of monetary policy on prices and output weakened in the 1990s. The decline in the impact of Japanese monetary policy is partly attributable to the non-negativity constraint on nominal short-term interest rates as well as to stagnant financial intermediation due to non-performing loans in the banking sector. Our analysis, however, identifies two further obstacles to monetary policy that were still more significant. First, households and entrepreneurs suffering from balance-sheet problems—the other side of the non-performing loan problem—were hesitant about aggressively expanding consumption and investment even amid ultra-loose monetary conditions. Second, the propagation mechanism in the private sector, through which economic activity prompts further economic activity, failed to function properly.

1. INTRODUCTION

After the asset bubble burst in the early 1990s, the Bank of Japan (BOJ) lowered the official discount rates successively to create easy monetary conditions. As a result, the overnight uncollateralized call rate—the BOJ's policy instrument—dropped to 0.25 percent in 1995. The BOJ implemented various policy measures thereafter: the *zero interest rate policy* in 1999; the *quantitative easing policy* in 2001; and, in 2003, the clarification of the commitment to continue the latter policy based on the consumer price index (see figure 1). There is a general consensus that the zero interest rate policy and the commitment to continue that policy played a role in lowering short- and medium-term interest rates, referred to as *policy duration effects* (see, for instance, Shiratsuka and Fujiki [2002] or Okina and Shiratsuka [2003]). Yet, we have little evidence to show that the easy monetary conditions thus created were effective in achieving the ultimate goals of monetary policy, i.e., the stabilization of output and prices. In this paper, we propose a new method for evaluating Japanese monetary policy since the mid-1990s, which takes into account the fact that monetary policy was constrained by the zero lower bound (ZLB) on nominal short-term interest rates. We are particularly interested in how much monetary policy contributed to the restoration of the Japanese economy after the asset bubble burst.

A standard way of investigating monetary policy is through a VAR model with three variables: output, prices, and nominal interest rates.[1] Such a model describes compactly the transmission mechanism of monetary policy from the policy instrument (i.e., the federal funds rate in the United States, or the call rate in Japan) through to output and prices. In the analysis, structural shocks to the policy instrument are mainly thought of as reflecting shifts in the central bank's policy stance. However, when short-term interest rates are at the ZLB, as in Japan since the mid-1990s, we cannot adopt this method anymore. In such a situation, we run the risk of

[1] Data on monetary aggregates are often used to evaluate monetary policy effects, instead of nominal short-term interest rates (Christiano et al. [1999] survey the recent literature on the identification of monetary policy effects). West (1993) tries to identify shifts in the BOJ's monetary policy stance from the money supply data. Recently, Miyao (2002, 2005) has analyzed models that include both call rates and monetary aggregates.

underestimating the contribution of monetary policy if we focus on the role of nominal short-term interest rates and the assumptions of the standard monetary economics.[2] Furthermore, we should be aware that since the asset bubble burst, the Japanese economy may have experienced structural changes. For instance, the introduction of the quantitative easing policy may have resulted in a structural change, as the BOJ changed its policy instrument from the call rate to the BOJ current account balances.

To circumvent the above problems, we take the following approach. First, we use intermediate variables, which are not directly affected by the ZLB, to identify shifts in the central bank's policy stance. Specifically, we use nominal exchange rates as well as lending rates and the lending attitude of financial institutions. The adoption of the latter can be justified by appealing to the substantial role of indirect financing in Japan.[3] Second, we adopt Uhlig's (2005) sign-restricted VAR, imposing relatively uncontroversial restrictions so as to minimize the possibility of overlooking shifts in the central bank's policy stance. Specifically, we propose the following sign restrictions on the direction of policy effects: an accommodative monetary policy weakens the yen, lowers lending rates, and softens the lending attitude of financial

---

[2] Consider, for example, the quantitative easing policy. The effects of the zero interest rate policy and a policy duration commitment are well-recognized in the standard economic theory. There is, however, no consensus among academics and practitioners about the effects on economic activity of the size of BOJ current account balances.

[3] We have considerable choice regarding intermediate variables: traditional ones, such as long-term interest rates and exchange rates (see Taylor [1994] for instance); and also non-traditional ones, such as commodity price indices and interest-rate spreads (see Woodford [1994], who discusses the use of intermediate variables in a context different from ours). Motonishi and Yoshikawa (1999) use the lending attitude of financial institutions as an indicator of the monetary policy stance. With regard to interest-rate spreads (defined as long-term interest rates net of short-term interest rates), they generally give us information on shifts in the central bank's policy stance: narrowing when monetary conditions are tight, and widening when they are accommodative. With short-term interest rates at the ZLB, however, interest-rate spreads contain no information on the central bank's policy stance. A strong commitment to the quantitative easing policy lowers long-term interest rates due to the policy duration effect, yet short-term interest rates are unable to fall because of the non-negativity constraint. As a result, interest-rate spreads narrow even under accommodative monetary conditions.

institutions.[4] Third, we use Chib's (1996, 1998) Markov chain Monte Carlo (MCMC) method to estimate the date of any structural change and to identify which part of the transmission mechanism of monetary policy may have broken down in Japan.

The paper is constructed as follows. In section 2, we give a detailed explanation about how to use intermediate variables. We also provide an overview of Uhlig's (2005) sign-restricted VAR. In section 3, we apply our method to the Japanese data and show that the effectiveness of monetary policy declined during the 1990s. In section 4, we use Chib's (1996, 1998) MCMC technique to estimate the date of any structural change and we also discuss some possible reasons why the effectiveness of monetary policy decreased in Japan. Section 5 concludes.

2. THE MODEL

This paper boasts three distinctive features: (i) the use of intermediate variables; (ii) the introduction of a sign-restricted VAR; and (iii) the inference of a structural-change point. We consider a number of potential intermediate variables. We then combine some of them to construct a monetary policy proxy, which can capture a wide variety of different monetary policy measures, and substitute it for the call rate. In this section, we also outline Uhlig's (2005) sign-restricted VAR. The problem of structural change is discussed exhaustively in section 4.

(1) The use of intermediate variables and the monetary policy proxy

To begin with, we use figure 2 to outline the standard view of the transmission mechanism of monetary policy in which the banking sector plays the main role. Suppose that the central bank adopts an accommodative monetary policy stance. In a normal situation, we would see the call rate decline. This makes it less costly to borrow from money markets, so that private banks are encouraged to lend more at lower rates. This in turn spurs entrepreneurs to make fixed investments and

---

[4] Uhlig (2005) calls this an "agnostic" approach (i.e., no *a priori* assumptions are made).

households to purchase durable goods. As aggregate demand exceeds potential output, prices are forced to rise. Once economic recovery is confirmed, the central bank returns to its neutral position. In this process, the call rate is the first variable that moves in response to a change in the central bank's policy stance and it is thus used in the literature as the key variable for identifying monetary policy shocks. When the call rate is at the ZLB, however, the central bank has no room to lower it. In this case, the call rate contains no information about the central bank's policy stance.

For the above reason, we focus on intermediate variables: those that would typically show some movement in between the initial shift in the policy instrument and the attainment of the policy goals. Specifically, we utilize lending rates and the lending attitude of financial institutions as well as nominal exchange rates. When we see a softening of lending attitudes, declines in lending rates, and depreciation of the yen, it is reasonable to attribute these at least partly to a shift in the central bank's policy stance, whatever particular policy measure is employed. This inference is still valid even when the call rate is at the ZLB. A further advantage of using intermediate variables is that they enable us to identify why economic deterioration occurs. Suppose for instance that a change in the central bank's policy stance leaves intermediate variables unmoved. We can then infer that non-performing loans are discouraging private banks from performing financial intermediation services. Alternatively, suppose that movements in intermediate variables are not affecting economic activity. Then, it can be inferred that balance-sheet problems—the other side of the non-performing loan problem—are impeding the economic activity of entrepreneurs and households.

A possible disadvantage of using intermediate variables is that they are subject to their own idiosyncratic shocks and not just driven by monetary policy shocks, thus complicating the precise identification of monetary policy shocks. Yet if these idiosyncratic shocks can be eliminated by combining the variables in some way, then this combination can be used in place of the call rate to identify shifts in the central bank's policy stance. In this paper, we call such a combination of intermediate variables the monetary policy proxy (MPP).

The use of the MPP has the following advantages. First, we need not replace policy variables, even if the central bank alternates its policy instruments. Before the Japanese money-market restructuring in 1988, the BOJ's policy stance could reasonably be represented by changes in the official discount rate. Thereafter, up until 1995, the BOJ gradually raised the priority of the call rate as a policy instrument. There was yet another shift of policy instrument, this time to current account balances at the BOJ, with the introduction of quantitative easing in 2001. Despite these changes in policy instruments, we can use the same MPP to identify monetary policy shocks, as long as it is constructed out of the same set of intermediate variables. The second advantage of the MPP is its ability to represent all of the BOJ's various policy measures in terms of an implied level of the call rate. Finally and most remarkably, the MPP can take even negative values and is thus free from the ZLB.

In this paper, we construct the MPP (i^c) out of two intermediate variables: lending rates (i^ℓ) and the lending attitude of financial institutions (d). Case 1 in table 1 shows the results of an OLS estimation of the relationships among the call rate, lending rates, and the lending attitude. We trim the sample at December 1995, since until then the ZLB had never constrained the call rate (see figure 3 (1) and the appendix for details of the data).

$$i_t^c = -3.602 + 1.558 \times i_t^\ell + 0.021 \times d_t . \tag{2-1}$$

In figure 3 (2), we compare the actual call rate with the MPP, i.e., the right-hand side of equation (2-1). Unsurprisingly, the MPP tends to lag behind the actual call rate, since it is based on intermediate variables. The high coefficient of determination (almost 90 percent) tells us, however, that the MPP traces the historical path of the actual call rate closely over the sample.[5]

---

[5] This paper's method involves a two-step procedure: first, we combine intermediate variables to create a monetary policy proxy; second, we include the proxy in a VAR model to identify shifts in the central bank's policy stance. An alternative method is to skip the first step and to include the intermediate variables directly in a VAR model. However, we consider the former method more useful than the latter for the following reasons: first, the monetary policy proxy approximates the actual call rate sufficiently; second, the former method allows for easier interpretation of the empirical results.

In interpreting equation (2-1), we should note that a negative correlation exists between lending rates and financial institutions' lending attitude. Suppose for instance that there is a credit crunch. Needless to say, lending rates rise, while the index describing the lending attitude declines (in other words, there is a hardening of attitudes to lending). Equation (2-1) tells us that if the central bank's policy stance is unchanged, lending rates must rise relative to the decline in the lending attitude index in the ratio of 0.021 to 1.558 on average. The implied call rate will then be left unchanged, which is consistent with the assumption of an unchanged monetary policy stance. Suppose, however, that the central bank in fact decides to relax monetary policy. Since funding costs are lowered, private banks do not raise lending rates as much as before. The call rate as defined by equation (2-1) will decline in this case, which is consistent with the assumption of monetary policy easing.

As shown in figure 3 (2), Japanese monetary conditions have been much more accommodative since 1996 than they were previously. First, we observe a decline in the MPP in late 1997, when uneasiness concerning the financial system broke out. Having remained at the same level for a few years, the MPP resumed its decline in 2001, when the BOJ introduced the quantitative easing policy. In April 2005, the MPP reached -1.3 percent in terms of the level of the implied call rate. This suggests that the BOJ created accommodative monetary conditions through a variety of measures other than call-rate control which were aimed at stabilizing financial markets and facilitating corporate financing, although we are unable to isolate the individual effects of each specific measure.

Lastly, let us consider alternative combinations of intermediate variables which could be used for constructing an MPP. In figure 4, we show alternative MPPs, where M_2+CD is included in the combination. First, the MPP constructed without lending rates cannot trace the historical path of the call rate before 1995, as shown by its poor goodness-of-fit of only 50 percent (see table 1). Second, the behavior of MPPs after 1995 depends heavily on whether or not the lending attitude index is included. Third, the behavior of MPPs constructed from lending rates and the lending attitude is influenced very little by the inclusion of M_2+CD. These results suggest that lending rates and the lending attitude are indispensable ingredients in constructing an MPP, but that there is little benefit in including the money supply.[6]

(2) Using the sign restricted VAR to identify monetary policy shocks

In this paper, we use Uhlig's (2005) sign-restricted VAR to identify monetary policy shocks. The Cholesky decomposition is the standard method most frequently used to identify structural shocks. Roughly speaking, it focuses on differences in the speeds at which various structural shocks influence economic variables.[7] This method, however, lacks theoretical foundations. Thus, it is quite likely to overlook true monetary policy shocks. With the sign-restricted VAR, however, we make assumptions concerning the directions of motion of several variables in response to a monetary policy shock and take the shocks satisfying those assumptions as monetary policy shocks. This seems to be a useful method, since we can reduce the likelihood of overlooking true monetary policy shocks by imposing minimum theoretical restrictions to identify monetary policy shocks.

The sign-restricted VAR belongs to the family of Monte Carlo simulation methods and consists of the following four steps. First, a set of parameters for a reduced-form VAR is generated randomly. Second, an *impulse vector* is generated randomly. The latter is the key concept in analysis using the sign-restricted VAR. For instance, a monetary policy impulse vector is defined as the innovations added to the VAR system in response to a unit of monetary policy shock. Third, based on the VAR parameters and impulse vector obtained in the preceding steps, impulse response functions are calculated. Fourth, we keep those impulse vectors whose impulse response functions satisfy the sign restrictions and discard the others.

---

[6] Relationships between the money supply and other indicators of economic activity have destabilized since the mid-1980s (see, for example, Okina [1993]). This is another reason why we exclude the money supply in the construction of the MPP.

[7] For instance, the Cholesky decomposition typically employs the following assumptions: both demand and supply shocks have immediate effects on output and prices, respectively, while it takes a long time for a monetary policy shock to influence those variables.

Step 1: Sampling VAR parameters

Consider the following reduced-form VAR.

$$Y_t = B_{(1)}Y_{t-1} + B_{(2)}Y_{t-2} + \cdots + B_{(\ell)}Y_{t-\ell} + u_t\,,\ \ E(u_t u_t{}') = \Sigma\,,\ \ t = 1,\ldots,T\,. \qquad (2\text{-}2)$$

Equivalently, we have

$$Y = XB + u\,, \qquad (2\text{-}3)$$

where $Y = [Y_1,\ldots,Y_T]'$, $X_t = [Y_{t-1}^{'},\ldots,Y_{t-\ell}^{'}]'$, $X = [X_1,\ldots,X_T]'$, $u = [u_1,\ldots,u_T]'$, and $B = [B_{(1)},\ldots,B_{(\ell)}]'$.

In this paper, we assume that a prior distribution of VAR parameters (B,Σ) is given by the Normal-Wishart distribution (see Zellner [1971]).[8] It is well-known that a posterior distribution of (B,Σ) is also given by the Normal-Wishart distribution in this case. If the hyper-parameters of the prior satisfy the assumption of a flat (or uninformative) distribution as in Uhlig (1994), we have

$$vec(B) \sim N(vec(\hat{B}), \Sigma \otimes (X'X)^{-1}) \ \text{ and } \ \Sigma^{-1} \sim W_m(\hat{\Sigma}^{-1}/T, T)\,, \qquad (2\text{-}4)$$

where

$$\hat{B} = (X'X)^{-1}X'Y\,,\ \ \hat{\Sigma} = \frac{1}{T}(Y - X\hat{B})'(Y - X\hat{B})\,. \qquad (2\text{-}5)$$

Equations (2-4) and (2-5) enable us to sample B and Σ.

Step 2: Sampling impulse vectors

Suppose that a variance-covariance matrix Σ is given. If we find an A such that $\Sigma = AA'$, we can obtain VAR innovations u from structural shocks v, using the relationship, $u = Av$. In general, there exist an infinite number of A's that satisfy the above condition; we need additional conditions to choose a specific A.[9] As pointed out by Bernanke and Mihov (1998), however, if interested in identifying only monetary

[8] Many statisticians who adopt a "classical" view think of the Normal-Wishart distribution as "informative" when used as a prior distribution in the family of AR models, especially in VAR models. On the other hand, it is the *de facto* standard method among Bayesians to use the Normal-Wishart distribution as a prior distribution. We follow the latter view in this paper.

[9] For example, the Cholesky decomposition assumes that A is a lower triangular matrix.

policy shocks, it is enough to find a column vector a that is associated with monetary policy shocks and not necessary to specify all the elements of matrix A. Uhlig (2005) calls it an impulse vector and shows that it is given by

$$a = \tilde{A}\alpha, \tag{2-6}$$

where $\tilde{A}$ indicates the Cholesky decomposition matrix; α denotes a unit-length vector sampled randomly.

Step 3: Calculating impulse response functions

Given an arbitrary impulse vector a, we can calculate VAR innovations, $u^{(a)} \equiv av^{(a)} = a$ from a unit monetary policy shock $v^{(a)}$. Combining these innovations with the VAR model parameterized by B, we can calculate impulse response functions to the monetary policy shock.

Step 4: Imposing sign restrictions

A monetary policy impulse vector is a column vector a such that the associated impulse response functions satisfy the prescribed sign restrictions that identify monetary policy shocks. We keep an a if its impulse response functions satisfy all the sign restrictions that we impose; otherwise, we discard it. Once an a is obtained, we can identify historical structural shocks $v^{(a)}$ from historical VAR innovations u.

The impulse vector and associated impulse response functions thus obtained are associated with a particular set of B, Σ, and α sampled randomly. We iterate the above process to generate multiple B, Σ, and α; each time, we calculate an impulse vector a and impulse response functions. We save those a's whose impulse response functions satisfy the sign restrictions. Assuming that the identifying restrictions are loose enough, we will be able to collect a number of a's. We repeat this Monte Carlo simulation 40,000 times and use the resulting histogram as a sample analogue of the true probability distribution for the purposes of statistical inference.[10]

[10] Following Uhlig (2005), we divide the sampling procedure into two steps. In the first step, we generate 200 pairs of B and Σ randomly; in the second, we generate 200 a for each of the pairs. This gives us a total sample of 40,000 randomly-generated values. About 15% of these values satisfy our sign restrictions.

3. RESULTS

In this section, we apply Uhlig's (2005) sign-restricted VAR to the Japanese data, including the MPP, in order to identify shifts in the BOJ's policy stance and to evaluate the effectiveness of past Japanese monetary policy. Our benchmark VAR consists of the following five variables: output, prices, exchange rates, long-term interest rates, and short-term interest rates. Output is measured by the *index of industrial production*; prices by the *consumer price index* (excluding fresh food); exchange rates by the *yen* spot rate against the US dollar; long-term interest rates by the yield of *10-year interest-bearing government bonds*; short-term interest rates by the MPP. As is explained in section 2, we construct the MPP out of the *average contracted interest rates on loans and discounts* and *the lending attitude of financial institutions DI*. The sample is monthly, spanning from February 1978 to April 2005.[11] We create a monthly series of *the lending attitude of financial institutions DI* by interpolating the quarterly data linearly (see the data appendix for details). We take the logarithms of output, prices, and exchange rates. We take lags of three months for the benchmark VAR. Following Uhlig (2005), we estimate the VAR model without a constant or a time trend.[12]

To identify monetary policy shocks, we impose the following sign restrictions on impulse response functions. In the benchmark model, the horizons of sign restrictions are all six months.

1. An accommodative monetary policy shock lowers the MPP for at least six months.
2. An accommodative monetary policy shock weakens the yen for at least six months.

The purpose of the second restriction is to distinguish so-called *strong-yen recessions* from accommodative monetary policy shocks. A steep appreciation of the yen may

---

[11] We transform the series of data according to Uhlig's (2005) method, which is also adopted by Braun and Shioji (2002) among others.

[12] Uhlig (1994) discusses how to modify a prior distribution when a time trend is added on to a simple AR model. In this paper, however, we follow Uhlig (2005) and assume no time trend in our VAR model.

trigger an economic recession and thus cause interest rates to decline. Without the second restriction, we would be liable to wrongly interpret yen-appreciation shocks as accommodative monetary policy shocks. By adding the second restriction, however, we can exclude yen-appreciation shocks correctly and thus identify monetary policy shocks more precisely.

In identifying U.S. monetary policy shocks, Uhlig (2005) imposes an additional sign restriction, namely that prices do not decline in response to accommodative monetary policy shocks. The purpose of this restriction is to eliminate the *price puzzle*, i.e., price falls in response to accommodative monetary policy shocks.[13] Our objective, however, is to discuss the effectiveness of monetary policy in protecting the Japanese economy from a deflationary spiral as well as from economic recessions. Therefore, an *a priori* restriction on prices aimed at eliminating the possibility of deflation would be inappropriate for our purposes. We impose no restrictions on the long-term interest rate, either. The reason is that the behavior of long-term interest rates appears to be a conundrum all over the world, so that investigating the effects of monetary policy on long-term interest rates, without imposing *a priori* restrictions, is of significant interest.

(1) Monetary policy in the absence of the ZLB: the benchmark case

As a benchmark, we use a sub-sample, consisting of observations up until 1995 to analyze the effects of monetary policy in the absence of the ZLB, i.e., a situation where the BOJ can control the call rate freely. Figure 5 shows the impulse response functions to an accommodative monetary policy shock. The thick lines indicate medians (i.e., 50 percentile points), while the two dashed lines indicate one-standard error bands (i.e., 16 and 84 percentile points). The median price response involves a small decline

[13] An initial drop in prices in response to an accommodative monetary policy is first pointed out by Sims (1992), who refers to the phenomenon as the *price puzzle*. It is well-known that the puzzle is ameliorated by including a commodity price index in the VAR model. In this paper, however, we do not include commodity prices, both because we wish to keep the number of variables in the VAR model as small as possible, and also because the puzzle is frequently observed in VAR models that include price data.

immediately following the shock, although it then turns up within six months, and continues rising thereafter. The median output response is an initial drop that lasts for a few months, although it soon turns up, and remains above the initial level for about five years. Hence, at least until 1995 the BOJ is seen to have been able to lead output and prices in its preferred directions; in other words monetary policy is seen to have been effective.

Let us characterize the ways in which monetary policy shocks affect other variables. The median response of the MPP (the short-term interest rate) shows that an accommodative monetary shock creates easy monetary conditions for a year, but that tight monetary policy soon follows. Uhlig (2005) reports similar results in his analysis of the U.S. economy and suggests the following two explanatory hypotheses. First, monetary policy shocks may stem from an incorrect economic assessment by the central bank, which, when it realizes its misperception, is obliged to reverse its policy course. Second, real interest rates may decline even when nominal interest rates rise (i.e., the Fisherian effect).[14]

Here, we examine the plausibility of the second hypothesis by focusing on real interest rates. Figure 6 shows the impulse response functions of one-year-ahead expected inflation rates, short-term real interest rates (the MPP net of the expected inflation rate), and long-term real interest rates. The responses of short-term and long-term real interest rates indicate that tight monetary conditions do indeed emerge after two years of easy monetary conditions. Thus, the behavior of the MPP cannot be explained by the second hypothesis alone, and we are unable to reject the first hypothesis completely.

Long-term interest rates fall in response to an accommodative monetary policy shock, but turn up after a few months. It seems that the accommodative effects of monetary policy on long-term interest rates are short-lived, compared with those on the MPP which last for more than a year. It is worth noting, however, that a rise in long-term interest rates is a consequence of successfully implemented monetary policy.

---

[14] Uhlig (2005) favors the first view rather than the second, justifying his opinion by looking at the impulse response functions of reserves.

An accommodative monetary policy shock stimulates production and raises inflation expectations, both of which push up long-term nominal interest rates. This spur to production is likely to stimulate credit demand and thus raise real long-term interest rates. Actually, as shown in figure 6, the impulse response of long-term real interest rates starts to turn up two and a half years after an accommodative monetary policy shock. The response of long-term interest rates to a monetary policy shock depends on the expectations of market participants about how monetary policy affects output and prices in the future.

The yen depreciates sharply in response to accommodative monetary policy shocks. The one-standard error band also indicates that this happens with rather high probability. Note that this high probability does not imply that the sign restriction on the exchange rate is unbinding. Figure 7 shows how the response of the exchange rate depends on the sign restriction: in particular, the median response of the yen is close to zero if no restriction is imposed on the yen. The implication is that in Japan "declines in interest rates due to strong-yen recessions" occur with as much probability as "depreciation of the yen due to monetary policy easing."[15]

(2) Monetary policy in the presence of the ZLB

Next, we extend the sample up to April 2005 to evaluate the performance of monetary policy in the presence of the ZLB. The sample is extended in several steps: (i) in the benchmark case, we restrict attention to the period before the call rate reached virtually zero percent (i.e., up until December 1995); (ii) this is then extended to include the period before the adoption of the *zero interest rate policy* (i.e., up until January 1999); (iii) the next sample period runs up to the adoption of the *quantitative easing policy* (i.e., up until February 2001); (iv) finally, we look at the full sample (i.e., up until April 2005).

Figure 8 shows how extending the sample period affects the impulse response

[15] Braun and Shioji (2002) point out that there is considerable empirical evidence against uncovered interest-rate parity and so impose no sign restrictions on the exchange-rate response. As discussed above, however, the reason that uncovered interest-rate parity does not hold in practice is that the exchange rate is as likely to be disturbed by various other forms of noise as it is driven by shifts in the central bank's policy stance.

functions. Let us begin with the response of prices. Extending the sample has no influence on the initial decline in prices observed immediately after a monetary policy shock. What it does do, however, is to reduce the speed of the price increase in the following expansion phase. The maximum rate of expected inflation based on the full sample is only half that of the benchmark case (figure 6).

The sample extension influences the response of output substantially. First, it magnifies the initial drops in output observed immediately after a monetary policy shock. Second, in the following expansion phase, output grows more slowly the further the sample is extended. The literature to date has paid little attention to the first observation, which is called the *output puzzle*.[16] Obviously, whether or not the output puzzle is considered to be a direct effect of monetary policy will have a significant impact on how we evaluate monetary policy. We therefore need to explore why the output puzzle emerges so as to evaluate monetary policy effects correctly.

Sims's (1992) explanation of the *price puzzle* may help us understand the mechanism of the output puzzle.[17] Suppose that a central bank foresees deflation in the future. The central bank lowers interest rates today to suppress the forthcoming deflation. The decline in interest rates, however, is not enough to cancel out the deflationary pressure completely. As a result, price declines and an accommodative monetary policy coexist. A similar explanation is applicable to the output puzzle. Suppose that a central bank foresees recession in the future. The central bank lowers interest rates today to counteract the forthcoming recession. The decline in interest rates, however, is not enough to cancel out the recessionary pressure completely. As a consequence, output reductions and accommodative monetary policy coexist.[18]

---

[16] An exception is Wong (2000), which investigates the output puzzle and discusses how to resolve it.

[17] According to his extensive VAR study, Sims (1992) points out that the price puzzle, the decline in prices following immediately after an accommodative monetary policy shock, is a phenomenon observed in all times and all places.

[18] Cochrane (1998) presents an alternative theoretical explanation for the output puzzle which runs as follows. Suppose that households expect accommodative monetary policy in the future. This expectation drives up price levels immediately and reduces wealth in

The above explanation of the output puzzle, however, raises another question: why is the central bank reluctant to lower interest rates enough to counteract the forthcoming recession completely? In the case of the price puzzle, a central bank has the option of boosting production to counteract the deflationary pressure created by a cost shock. Output fluctuation, however, is considered to be a cost in itself. Therefore, it is an optimal policy for the central bank to choose to offset only a portion of the deflationary pressure, balancing the costs of boosting output against the benefits of suppressing deflation (Clarida et al. [1999]). In the case of the output puzzle, however, "optimality" for the central bank would seem to involve offsetting the future recession completely. This is because, by doing so, the central bank would be able not only to offset the future recession, but also to eliminate the source of the future deflation.

Several reasons can be put forward to explain why the central bank in Japan may have deviated from the "optimal" policy mentioned above: (1) Brainard's conservatism under policy-effect uncertainty (Brainard [1967]); (2) possible delays by the BOJ in revising its economic assessment downward after the bursting of the asset bubble (Jinushi et al. [2000]); and (3) the non-negativity constraint on nominal interest rates. Regarding (3), if the non-negativity constraint on nominal interest rates prevented the central bank from canceling out negative output shocks, then this may be thought to have weakened the effectiveness of monetary policy. Similarly, if the structural changes in the 1990s exacerbated the problems generated by (1) and (2), this would also have acted to weaken monetary policy. Therefore, although there is no need to consider the whole output puzzle as having its origin in monetary policy, the fact that the output puzzle grows more severe (in other words, the initial declines in output exceed those observed in the benchmark case) should be, at least in part, laid at the door of reduced monetary policy effectiveness.

---

real terms. Real balance effects then gradually reduce both demand and output. When the accommodative policy actually starts, output appears to decrease because of the policy.

(3) Robustness checks

Below, we check the robustness of our conclusion that the effectiveness of monetary policy has decreased in Japan since the mid-1990s. We focus on the following points: (i) changes in the VAR lag length, (ii) changes in the sign-restriction horizon, and (iii) the addition of new variables in the VAR model. We show that these changes leave the conclusion intact at least qualitatively.

A. Changes in the lag length of the VAR model

First, we examine the robustness of our conclusion to alternative assumptions on the lag length of the VAR model. Figure 9 shows how the impulse response functions change as the lag length increases from 3 (the benchmark case) to 6, 9, and 12 months. No substantial changes are observed except in the output response. With regard to this change in the output response, however, no regularity is found between the lag length and the extent of the change. We also check the robustness of our conclusions concerning the effects of extending the sample period, examining how our results are affected if we change the lag length from three months to nine months. Our conclusion remains the same: namely, the effectiveness of Japanese monetary policy decreased during the 1990s.

B. Changes in the horizon of sign restrictions

Next, we investigate the robustness of our conclusion to a change in the horizon of the sign restrictions. Figure 10 shows how the impulse response functions change as the sign restriction horizon is varied from 3 to 6 (the benchmark case), 12, and 24 months. We find a clear negative correlation between the restriction horizon and the levels of the impulse response functions: that is, the longer the restriction horizon, the lower the levels of the impulse response functions. We also look at the impact of varying the restriction horizon from six months to twelve months on our conclusion regarding the effects of extending the sample period. We reach the same conclusion that the effectiveness of monetary policy weakened in Japan during the 1990s.

It is worth noting that the longer the restriction horizon, the more severe the output puzzle. As discussed above, an output puzzle will emerge if a central bank cannot lower interest rates enough due to the non-negativity constraint even though an upcoming recession is foreseeable. Hence, when we see a large output puzzle, it is likely that the central bank is about to come up against or has already come up against the non-negativity constraint on nominal interest rates. Since the uncollateralized overnight call rate reached virtually zero percent, the BOJ has continued to keep and strengthen accommodative monetary conditions, with the exception of its lifting of the zero interest rate policy in 2000. The results obtained here simply reflect the low interest rate policy that the BOJ has conducted for a long time.

C. Addition of new variables (the effect of stock prices)

The rise in stock prices in the 1980s followed by their decline at the beginning of the 1990s left banks and firms suffering from the so-called balance-sheet problem, which hindered the economic recovery of Japan during the 1990s. Here, we add stock prices (TOPIX) to the VAR model to see whether such balance sheet problems have any effect on the conclusions stated above.[19]

Figure 11 shows the impulse response functions generated by the VAR model with stock prices as an additional variable. We find that the inclusion of stock prices makes the recovery of output faster than in the benchmark case. No substantial differences, however, are observed in the behavior of other variables. We therefore stick to our conclusion that the effectiveness of monetary policy decreased in Japan during the 1990s. Another reason for sticking to our conclusion is the lack of an intuitive interpretation for the impact of monetary policy on stock prices. Extending the sample is no help in this regard. Indeed the intuition becomes even harder to find: we end up with the paradoxical result that accommodative monetary policy does not boost stock prices. Thus, there are few gains to be had from taking stock prices into consideration.

---

[19] Miyao (2002) includes stock prices in his VAR analysis of the Japanese economy for the following three reasons: (i) households increase consumption due to the wealth effect; (ii) a higher Tobin's q encourages entrepreneurs to increase fixed investment; (iii) increased corporate value makes external finance easier.

4. STRUCTURAL CHANGE

The previous section demonstrated that the effectiveness of monetary policy decreased gradually during the 1990s. What we have not yet done, however, is to identify precisely when the effectiveness of monetary policy became compromised and for what reason. The main purpose of this section is to answer these questions by extending the benchmark model to estimate the date of any structural change in the Japanese economy.

(1) The extended model

Here, we use the Markov chain Monte Carlo (MCMC) method to estimate the date of any structural change in the Japanese economy. We present an overview of the estimation procedure below. The details of the estimation are found in the original paper by Chib (1996, 1998).

Step 1: Sampling VAR parameters, impulse vectors, and impulse response functions

For simplicity, we assume one structural-change point, denoted by τ. We call the state until τ-1 "state 1" and the state from τ onward "state 2." Suppose that we know when the structural change occurs.[20] Applying Uhlig's (2005) method to states 1 and 2, we obtain various characteristics of the two states: VAR parameters (B, Σ), monetary policy impulse vectors a, and impulse response functions.

Step 2: Sampling structural-change points

Next, taking as given the two sets of VAR parameters (B, Σ), we specify a date of structural change. For each VAR model, we calculate its likelihood function and evaluate how closely the model fits the data. Suppose that one model's likelihood is higher than the other's in a certain month. Then we can infer that the former is the working model in that month. Let p denote the *non-transition probability* with which the economy remains in state 1 in this month, starting from state 1 in the previous month. Suppose that we know this probability.[21] Following Chib (1996, 1998), we

[20] In this paper, we choose the center of the sample as the initial point of structural change.

[21] In this paper, we choose 0.5 as the initial value of the non-transition probability.

combine this information on p and the likelihood functions obtained above to obtain the distribution from which we sample a date of structural change τ.

Step 3: Sampling non-transition probabilities

Finally, taking as given the date of structural change τ, we specify a non-transition probability p. Following Chib (1996, 1998), we assume that the prior distribution of p is given by the *Beta* distribution. Since we know the date of structural change τ, we can say how many months the economy remains in state 1 and calculate the associated likelihood function. Combining this information with the prior, we obtain the following posterior:

$$p \sim Beta(a_T, b_T), \tag{4-1}$$

where $a_T = a_0 + n$ and $b_T = b_0 + 1$. a_0 and b_0 are the hyper-parameters that characterize the shape of the prior distribution. To assume a flat prior, we start with $a_0 = b_0 = 1$. Each value for p is generated from the above posterior distribution.

Given a date of structural change τ and a non-transition probability p, we can generate another set of τ and p by repeating steps 1 through 3 above. Iterating this procedure, we can obtain the joint distribution of τ and p. Since the sample values obtained in the early stages of iteration are likely to depend on the initial values of τ and p, it is common to throw away some of these early values (this is called "burn-in"). In this paper, we dispose of the first 1,000 sample values and iterate the procedure until 10,000 sample values are obtained.[22]

(2) Estimation results

Figure 12 (1) shows a histogram for the structural-change point in between February 1978 and April 2005 (Figure 12 (2) shows a histogram for the non-transition probability). It is most likely that the structural change occurred in October 1990. The probability that the structural change occurred in between August 1990 and

---

[22] Unlike section 2, we generate one triple of α, τ, and p for each pair of B and Σ. We keep 10,000 such triples eventually, excluding those that fail to satisfy the sign restrictions.

February 1991 is 98%. Hence, if there was only one structural change, its date must have been around the peak of the asset bubble. Thus, for the sake of simplicity, we call the period before the structural break the *pre-bubble period* and the period thereafter the *post-bubble period*.

To be sure that no further structural change occurred after the one in October 1990 as estimated above, we apply the same estimation procedure to the post-bubble sample. We have several candidates for a structural-change point: the year 1995, when nominal interest rate reached virtually zero percent; the period from 1997 to 1998, when the Japanese financial system experienced a loss of stability; the year 1999, when the zero interest rate policy was adopted; and the year 2001, when the BOJ introduced the quantitative easing policy. No structural change points, however, are inferred after October 1990, at least according to the econometric method employed in this paper.[23]

The histograms in figure 13 show how the monetary policy impulse vector changed around the peak of the asset bubble. The distribution of the MPP impulse shifted to the right. What this means is that, even when the central bank relaxed its policy stance, monetary conditions did not ease as much as would have been expected before. A possible reason is that the large pile of non-performing loans prevented the Japanese system of financial intermediation from functioning properly after the bursting of the asset bubble.

The other elements in a monetary policy impulse vector represent the direct effects of monetary policy on the economy that bypass the banking system. Looking at the price impulse, we find that the distribution tends to shrink toward zero percent in the post-bubble period. There are two possible explanations for this phenomenon.

---

[23] Although we estimate when structural change occurred under the assumption that it occurred only once, Chib's (1996, 1998) original method is applicable to the general case of an arbitrary number of structural changes. If we assumed a number of structural changes, different conclusions might obtain. Note, however, that the more structural changes we assume, the shorter the average size of the resultant sub-samples and the fewer the degrees of freedom in the estimation of VAR parameters. This makes incorrect identification of points of structural change much more likely.

First, it may be that monetary policy saved the Japanese economy from entering a deflationary spiral by affecting expectation formation in the private sector. Second, the result may simply suggest that expectation formation in the private sector became inflexible. This second interpretation becomes all the more plausible when we observe that inflationary expectations are suppressed as much as deflationary ones.

The distribution of the long-term interest rates impulse also displays a tendency to shrink toward zero in the post-bubble period. This result is explained by two factors: the policy duration effects since the late 1990s, and the stabilization of inflation expectations in the private sector.

Figure 14 shows how impulse response functions changed around the peak of the asset bubble. The responses in the pre-bubble period are represented by solid curves; those in the post-bubble period by dashed curves (the medians by thick curves; one-standard-error bands by thin curves). Overall, the effects of monetary policy in the post-bubble period were much smaller than in the pre-bubble period. Looking at the response of the MPP, we see that the BOJ usually lowered and raised interest rates swiftly and boldly in the pre-bubble period. In contrast, the BOJ continued accommodative monetary policy in a weak but long-lasting fashion in the post-bubble period.

The price response indicates that, in the pre-bubble period, prices responded to a monetary policy shock by rising continuously for a few years after an initial half-year decline. In the post-bubble period, however, monetary policy has only ambiguous effects on prices. With regard to output, the response is plagued in the post-bubble period by a large and long-lasting output puzzle, which contrasts with the small and short-lived output puzzle in the pre-bubble period. As a result, monetary policy does not seem to have a positive impact on output in the post-bubble period.

The response of long-term interest rates in the pre-bubble period shows long-term interest rates jumping up after an initial short period of decline. In the post-bubble period, however, it took long time for long-term interest rates, which declined in response to a monetary policy shock, to come back to the initial level. This primarily reflected private sector expectations that the accommodative monetary policy would last for a long time. Remember, however, that long-term interest rates move in accordance with business conditions. Therefore, low long-term interest rates also serve as an indication that monetary policy is failing to stimulate economic activity sufficiently.

The response of exchange rates in the pre-bubble period shows that accommodative monetary policy caused a long-lasting depreciation of the yen. In the post-bubble period, however, the yen weakens for at most two years. It is worth noting that this will have limited the impact of monetary policy on output and prices operating through this channel.

(3) Counterfactual experiments

As discussed above, after the bursting of the asset bubble, the effectiveness of Japanese monetary policy was weakened by both changes in the impulse vector and changes in the impulse response functions. Our question here is which of these factors made the larger contribution to this weakening. To answer this question, we will conduct counterfactual experiments, replacing the impulse vectors and the VAR parameters between the two states.[24]

Figure 15 shows the counterfactual impulse responses obtained by combining the pre-bubble impulse vector with the pre- and post-bubble VAR parameters. The three solid curves indicate the combination of the pre-bubble impulse vector and the pre-bubble VAR parameters (the median and the one-standard-error band), while the three dashed curves indicate the combination of the pre-bubble impulse vector and the post-bubble VAR parameters. It is worth noting that the pre-bubble impulse vector together with the post-bubble VAR parameters is capable of producing almost the same impulse responses as observed in the post-bubble period. This suggests that the reduction in the effectiveness of Japanese monetary policy came mainly from the changes in the VAR parameters.

Figure 16 shows the counterfactual impulse responses obtained by combining the

[24] Kim *et al*. (2005) use a similar methodology in investigating why output volatility has declined in the United States.

post-bubble impulse vector with the pre- and post-bubble VAR parameters. The three dashed curves indicate the combination of the post-bubble impulse vector and the pre-bubble VAR parameters (the median and the one-standard-error band), while the three solid curves indicate the combination of the post-bubble impulse vector and the post-bubble VAR parameters. The result shows that the post-bubble impulse vector, if combined with the pre-bubble VAR system, would at least exert inflationary pressures on prices. This experiment also supports the argument that the changes in the VAR parameters weakened the effectiveness of Japanese monetary policy in the post-bubble period.

Finally, we investigate how the VAR parameters changed so as to curtail the effectiveness of monetary policy so substantially. Figure 17 shows how the distributions of VAR parameters (summed over lags, i.e., $\Sigma_i B_{(i)}$) changed around the peak of the asset bubble. The changes in the parameters on prices indicate that the link from output to prices weakened (in row 4 and column 5), while the stickiness of prices strengthened (in row 4 and column 4). The changes in the parameters on output tell us that the persistence of output declined (in row 5 and column 5), while the disappearance of the link from the MPP to output implies that monetary policy was impeded at the very entrance of its transmission path (in row 5 and column 1).

5. CONCLUSION

The purposes of this paper are to introduce a new method of identifying shifts in the central bank's monetary policy stance that can be used whether or not nominal interest rates are at the zero lower bound, and to estimate quantitatively how effective Japanese monetary policy was at stimulating economic recovery after the bursting of the asset bubble. To begin with, we pick up bank lending rates and lending attitude as intermediate variables, which are not subject to the non-negativity constraint on nominal interest rates, and construct a monetary policy proxy, which can represent a whole range of different monetary policy measures. The behavior of the monetary policy proxy indicates that the BOJ succeeded in easing monetary conditions even after encountering the zero lower bound on nominal interest rates.

Next, we use the monetary policy proxy to construct a VAR model. In particular, we utilize Uhlig' (2005) sign-restricted VAR to identify monetary policy shocks. We adopt relatively uncontroversial restrictions: "Accommodative monetary policy shocks lower the monetary policy proxy for at least half a year" and "accommodative monetary policy shocks weaken the yen for at least half a year." The empirical analysis based on the Japanese data shows that the effects of monetary policy on output and prices weakened gradually during the 1990s.

Furthermore, we use the MCMC method, as introduced by Chib (1996, 1998), in order to specify when the effectiveness of monetary policy weakened. According to our statistical method, it is likely that a structural change occurred around the end of 1990, whereas no structural change is identified after that. This means that Japanese monetary policy most probably began to lose its effectiveness with the bursting of the asset bubble.

It is undeniable that the impact of monetary policy on prices and output weakened during the 1990s in Japan, although it was still effective enough to save the Japanese economy from entering a deflation spiral. We show that this decline in the effectiveness of policy is partly attributable to the non-negativity constraint on nominal short-term interest rates and stagnant financial intermediation due to non-performing loans in the banking sector. Our analysis shows, however, that the more important reasons for the decline in policy effectiveness are as follows. First, households and entrepreneurs suffering from balance-sheet problems—the other side of the non-performing loan problem—were hesitant about aggressively expanding consumption and investment even amid ultra-loose monetary conditions. Second, the amplifying mechanism in the private sector, through which economic activity prompts further economic activity, failed to function properly.

APPENDIX. DATA SOURCES

The following list includes the definitions and sources of the data used in this paper. The sample is monthly and spans the period from February 1978 through April 2005. When data are quarterly, we interpolate the appropriate monthly data.

Data	Definitions and Sources
Output	Indices of Industrial Production. Year 2000=100. Seasonally adjusted. Source: *Indices of Industrial Production*, Ministry of Economy, Trade and Industry.
Prices	Consumer Price Index. General, excluding "fresh food." Year 2000 =100. Seasonally and consumption-tax adjusted. Source: *Consumer Price Index*, Ministry of Internal Affairs and Communications
Exchange rate	¥ / $ spot rates. Source: *Financial and Economic Statistics Monthly*, Bank of Japan.
Long-term interest rates	Interest-bearing 10-year government bonds. Source: *Reference Price for Over-the-counter Bond Transactions (Average)*, Japan Securities Dealers Association.
Short-term interest rates	Uncollateralized overnight (or collateralized overnight). Source: *Financial and Economic Statistics Monthly*, Bank of Japan. Note: Uncollateralized rate since July 1985; prior to this, collateralized rates are used, adding the mean spread between uncollateralized and collateralized rates, as in Miyao (2005).
Lending attitude	Lending attitude of Financial Institutions DI. Percentage share of enterprises responding that attitudes are *accommodative* minus those responding that they are *severe*. Source: *TANKAN: Short-term Economic Survey of Enterprises in Japan*, Bank of Japan. Note: Monthly data are created by interpolating the quarterly data.
Lending rates	Average Contracted Interest Rates on Loans and Discounts. Stock. Short-term. Source: *Financial and Economic Statistics Monthly*, Bank of Japan
Stock Prices	TOPIX. Jan.4.1968=100. Source: *Monthly Statistics Report*, Tokyo Stock Exchange

REFERENCE

Bernanke, B. S., and I. Mihov, "Measuring Monetary Policy," *Quarterly Journal of Economics*, Vol. 113, No. 3, 1998, pp. 869-902.

Brainard, W. C., "Uncertainty and the Effectiveness of Policy," *American Economic Review*, Vol. 57, No.2, 1967, pp. 411-425.

Braun, R. A., and E. Shioji, "Monetary Policy and Economic Activity in Japan and the United States," mimeo, 2002.

Chib, S., "Calculating Posterior Distributions and Modal Estimates in Markov Mixture Models," *Journal of Econometrics*, Vol. 75, No. 1, 1996, pp. 79-97.

Chib, S., "Estimation and Comparison of Multiple Change-Point Models," *Journal of Econometrics*, Vol. 86, No. 2, 1998, pp. 221-241.

Christiano, L. J., M. Eichenbaum, and C. L. Evans, "Monetary Policy Shocks: What Have We Learned and To What End?" in *Handbook of Macroeconomics*, Vol. 1, edited by J. B. Taylor and M. Woodford, Elsevier Science B. V.: Amsterdam, 1999, pp. 65-148.

Clarida, R., J. Gali, and M. Gertler, "The Science of Monetary Policy: A New Keyesian Perspective," *Journal of Economic Literature*, Vol. 37, No. 4, 1999, pp. 1661-1707.

Cochrane, J. H., "What Do the VARs mean? Measuring the Output Effects of Monetary Policy," *Journal of Monetary Economics*, Vol. 41, No. 2, 1998, pp. 277-300.

Fujiki, H., and S. Shiratsuka, "Policy Duration Effect under the Zero Interest Rate Policy in 1999-2000: Evidence from Japan's Money Market Data," Monetary and Economic Studies, January, 2002, pp. 1-32.

Jinushi, T., Y., Kuroki, and R., Miyao, "Monetary Policy in Japan Since the Late 1980s: Delayed Policy Actions and Some Explanations," In Japan's Financial Crisis and Its Parallels to U.S. Experience, edited by R., Mikitani, and A. S., Posen, Institute for International Economics, 2000.

Kim, C., J. M. Morley, and J. Piger, "A Bayesian Approach to Counterfactual Analysis of

Structural Change," Federal Reserve Bank of St. Louis Working Paper Series, No. 2004-014c, 2005.

Kim, C., C. R. Nelson, and J. Piger, "The Less-Volatile U. S. Economy: A Bayesian Investigation of Timing, Breadth, and Potential Explanations," *Journal of Business and Economic Statistics*, Vol. 22, No. 1, 2004, pp. 80-93.

Miyao, R., "The Effects of Monetary Policy in Japan," *Journal of Money, Credit, and Banking*, Vol. 34, No. 2, 2002, pp. 376-392.

Miyao, R., "Use of the Money stock in the Conduct of Japan's Monetary Policy: Re-Examining the Time-Series Evidence," *Japanese Economic Review*, Vol. 56, No. 2, 2005, pp. 165-187.

Motonishi, T., and H. Yoshikawa, "Causes of the Long Stagnation of Japan during the 1990s: Financial or Real?" *Journal of the Japanese and International Economics*, Vol. 13, No. 3, 1999, pp. 181-200.

Okina, K., "Kinyu Seisaku – chuoginko no shiten to sentaku (in Japanese)", Toyokeizai Shimposha, 1993

Okina, K., and S., Shiratsuka, "Komittomento ga Kitaikeisei ni ataeru eikyo: Jikanjiku Koka no Jisshotekikento (in Japanese)", Kinyu kenkyu, Vol. 22, No.4, 2003, pp.255-292.

Romer, C., and D. Romer, "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz," in *NBER Macroeconomics Annual*, edited by O. Blanchard and S. Fischer, MIT Press, Cambridge MA, 1989, pp. 121-170.

Sims, C. A., "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy," *European Economic Review*, Vol. 36, No. 5, 1992, pp. 975-1011.

Taylor, J. B., "The Monetary Transmission Mechanism: An Empirical Framework," *Journal of Economic Perspectives*, Vol. 9, No. 4, 1994, pp. 11-26.

Uhlig, H., "What Macroeconomists Should Know about Unit Roots—A Bayesian Perspective," *Econometric Theory*, Vol. 10, No. 3/4, 1994, pp. 645-671.

Uhlig, H., "What are the effects of monetary policy on output? Results from an agnostic identification procedure," *Journal of Monetary Economics*, Vol. 52, No. 2, 2005, pp. 381-419.

West, K.D., "An Aggregate Demand-Aggregate Supply Analysis of Japanese Monetary Policy, 1973-1990," in *Japanese Monetary Policy*, edited by K.J. Singleton, Chicago: University of Chicago Press, 1993, pp. 161-188.

Wong, K-F, "Variability in the Effects of Monetary Policy on Economic Activity," *Journal of Money, Credit, and Banking*, Vol. 32, No. 2, 2000, pp. 179-198.

Woodford, M., "Nonstandard Indicators for Monetary Policy: Can Their Usefulness Be Judged from Forecasting Regressions?" in *Monetary Policy*, edited by Mankiw, N.G., NBER Studies in Business Cycles, Vol. 29, Chicago: University of Chicago Press, 1994, pp. 95-115.

Zellner, A., *An Introduction to Bayesian Inference in Econometrics*, New York: John Wiley & Sons, 1971.

(Table 1)

Relationships among Call Rates and Intermediate Variables

＜estimated equation＞

$$i^c_t = const + \alpha i^l_t + \beta d_t + \gamma m_t + \varepsilon_t$$

i^c_t : Call rates (%)

i^l_t : Average contracted interest rates on loans and discounts (%)

d_t : Lending attitude of financial institutions D.I. (% points)

m_t : M2+CD (seasonally adjusted, logarithm)

<sample period> 1978:2-1995:12

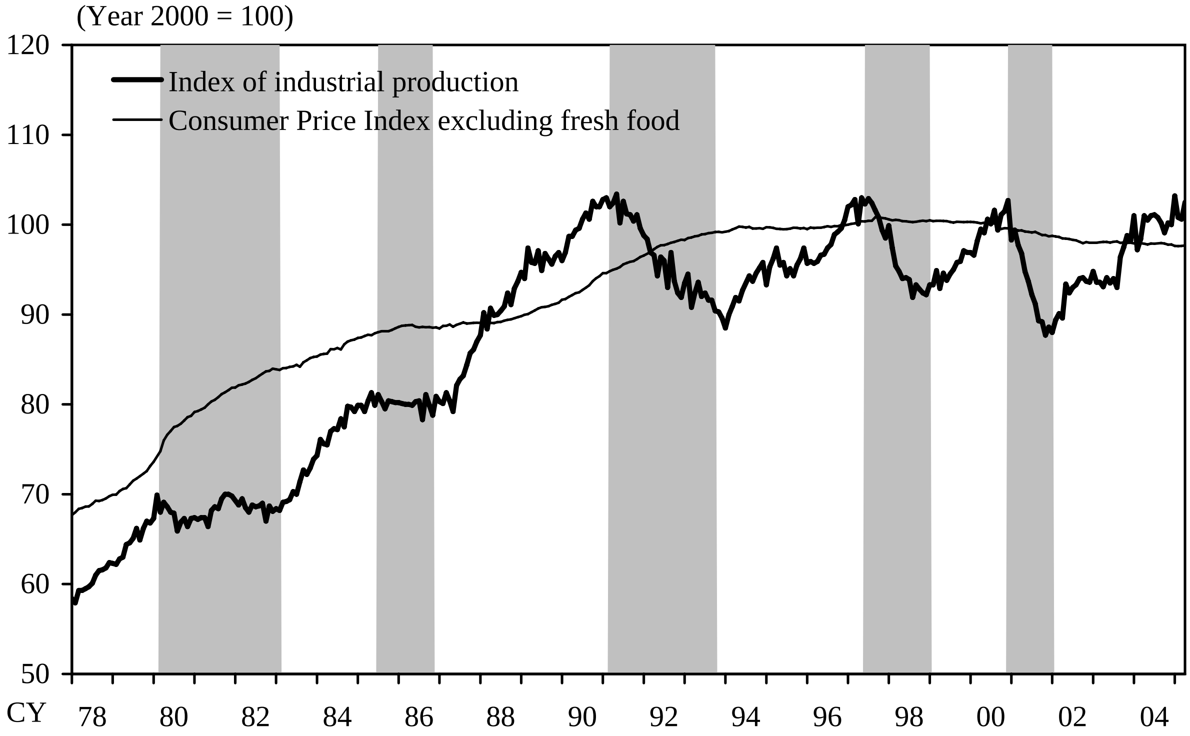
case	explanatory variable	const	α	β	γ	R^2
1	i^l_t, d_t	-3.602	1.558	0.021	—	0.89
		(-12.659)	(37.358)	(5.056)		
2	d_t, m_t	57.649	—	-0.075	-3.386	0.48
		(12.751)		(-9.927)	(-11.301)	
3	i^l_t, m_t	9.767	1.360	—	-0.792	0.89
		(4.200)	(35.714)		(-5.335)	
4	i^l_t, d_t, m_t	5.473	1.459	0.013	-0.559	0.90
		(2.018)	(29.001)	(2.939)	(-3.364)	

Note: 1. The regressions are estimated by OLS.
2. t-statistics are in parenthesis.

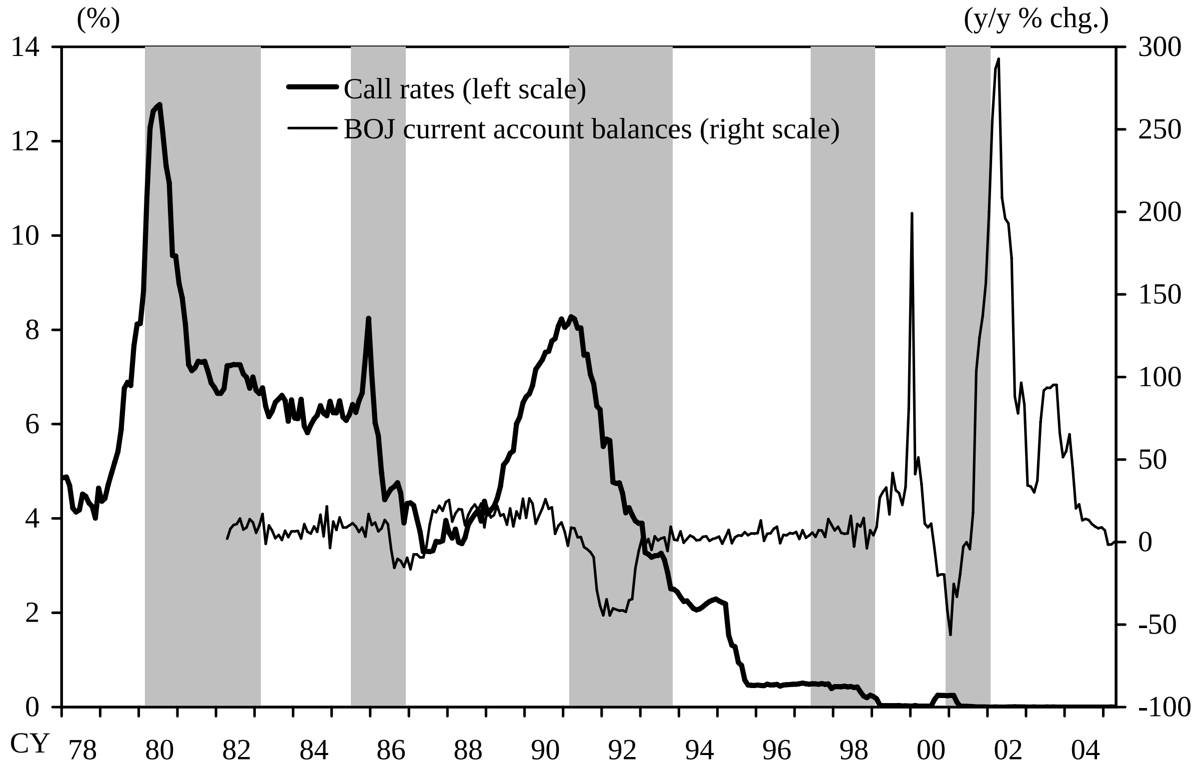
(Figure 1)

Economic Activity and Policy Instruments

(1) Output and Prices



(2) Policy Instruments

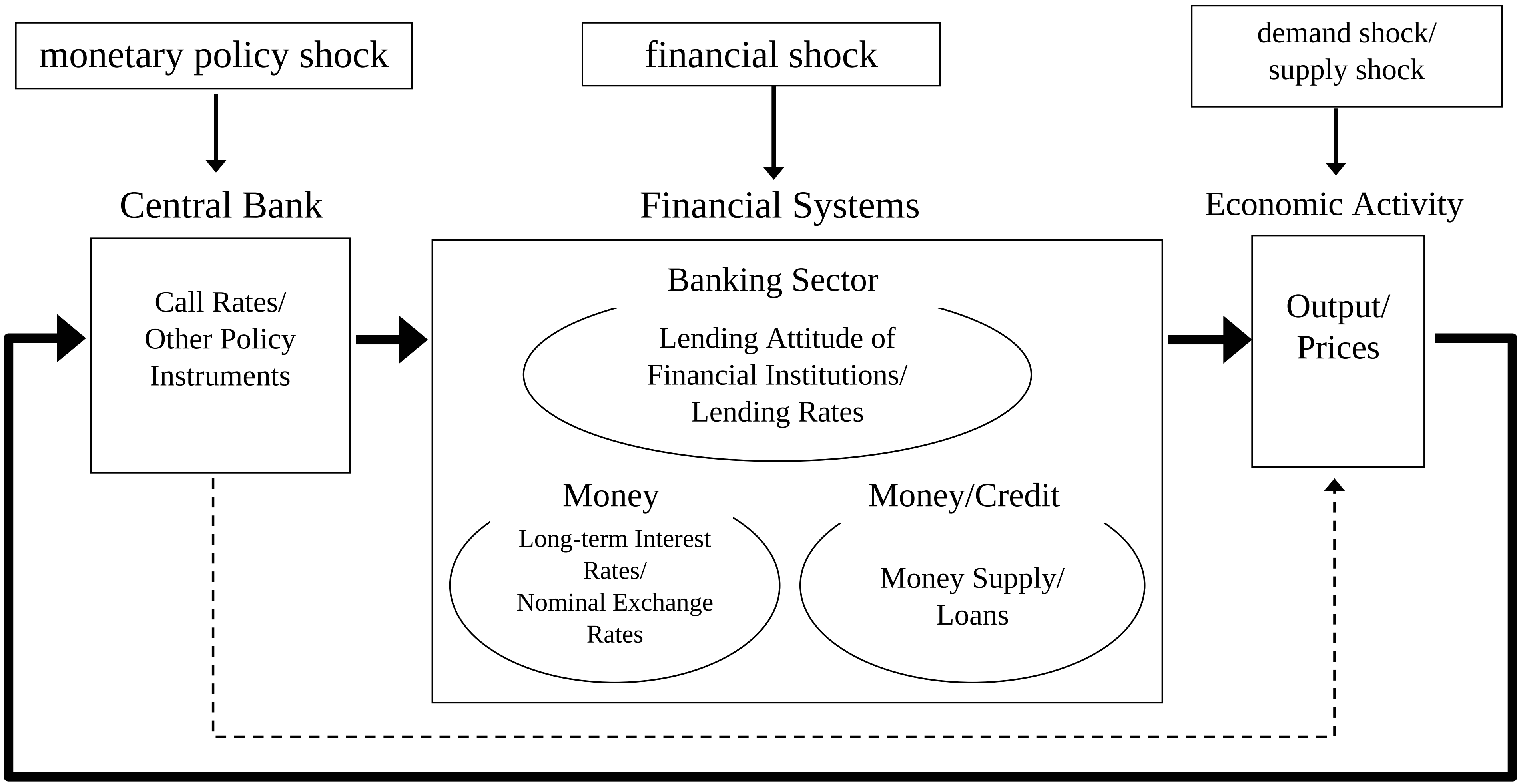


Note: Shaded areas indicate recessions.

Sources: Ministry of Economy, Trade and Industry, "Indices of Industrial Production".
Ministry of Internal Affairs and Communications, "Consumer Price Index".
Bank of Japan, "Financial and Economic Statistics Monthly".

(Figure 2)

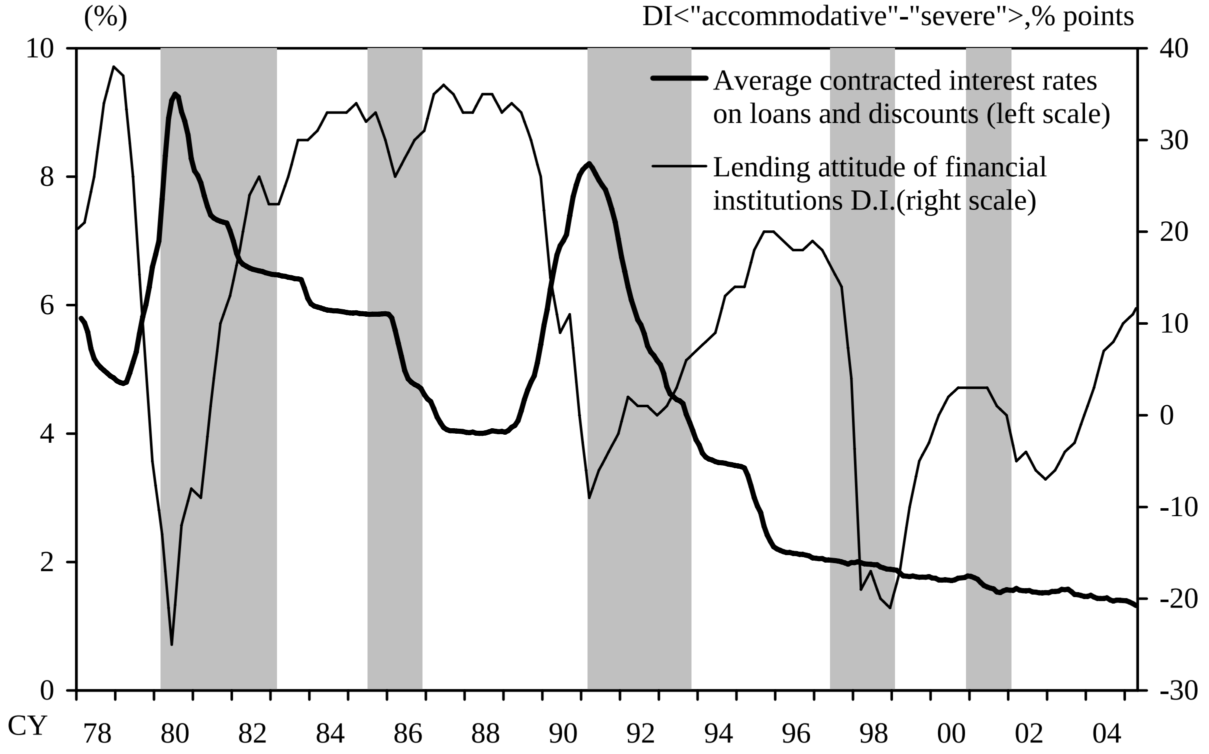
Transmission Mechanism of Monetary Policy



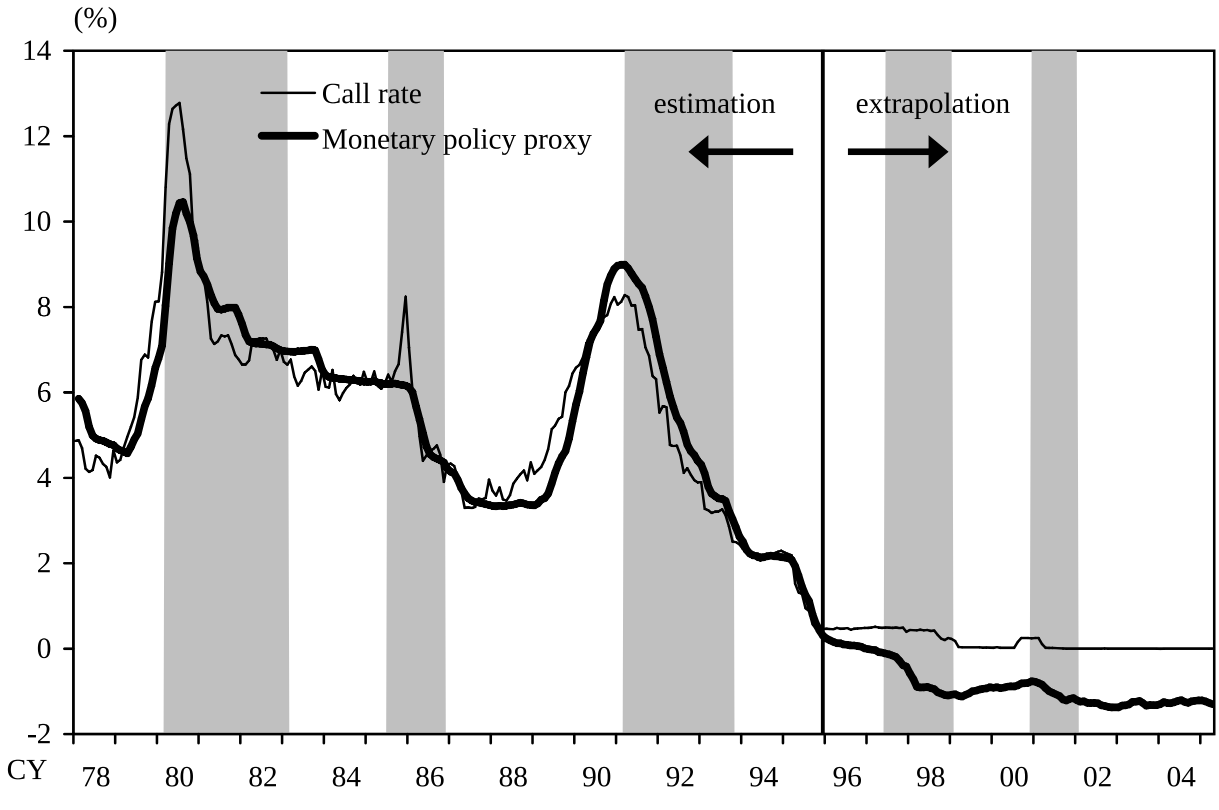
(Figure 3)

Monetary Policy Proxy

(1) Lending Rates and Lending Attitude of Financial Institutions



(2) Call Rate and Monetary Policy Proxy

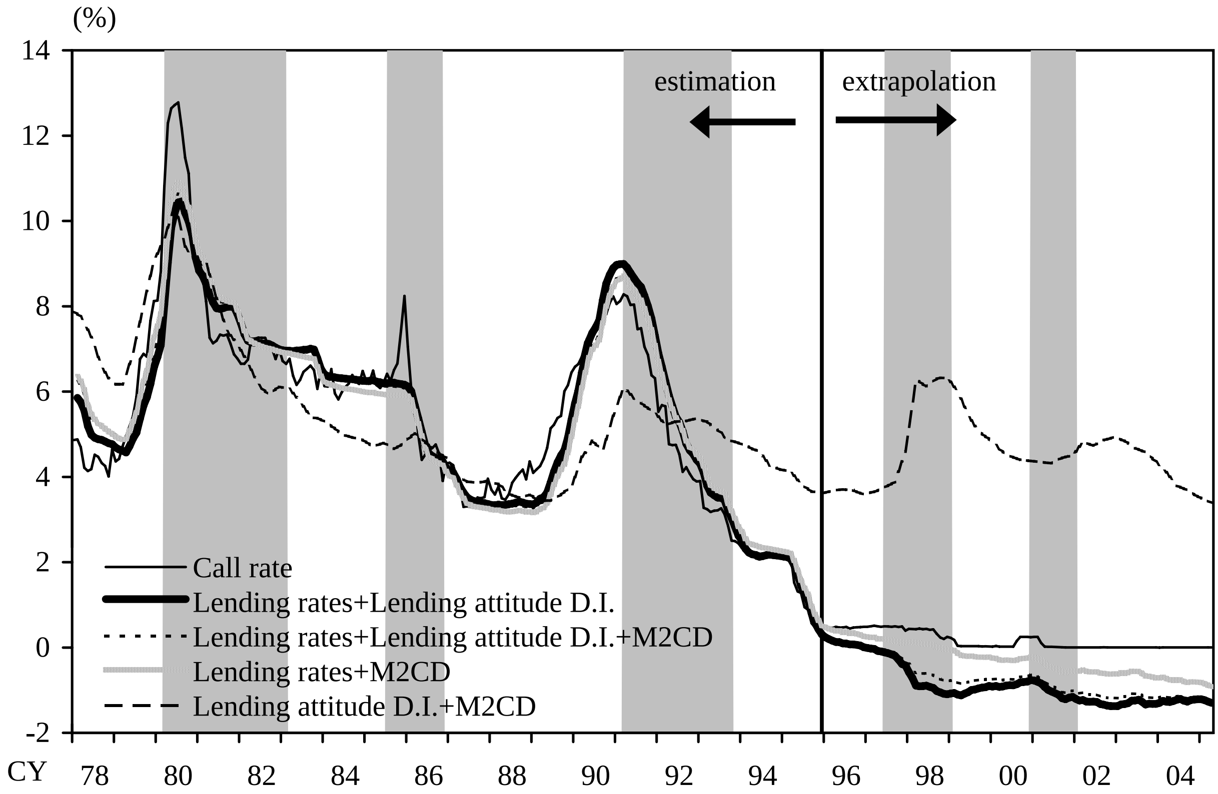


Note: Shaded areas indicate recessions.

Sources: Bank of Japan, "*TANKAN*, Short-term Economic Survey of Enterprises in Japan".

(Figure 4)

Alternative Monetary Policy Proxies

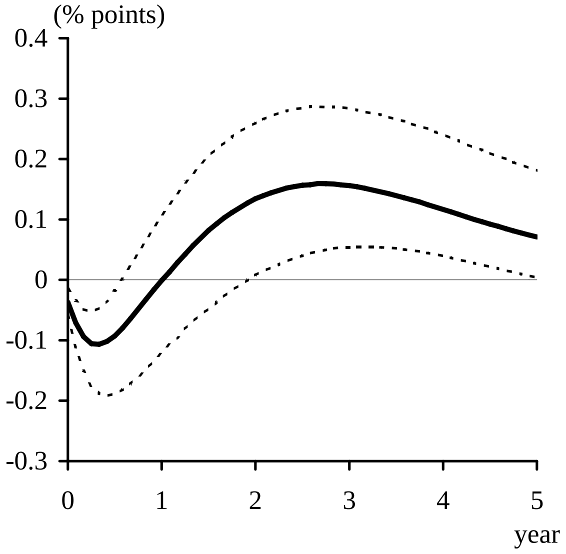


Note: 1. "Lending rates" stands for the Average Contracted Interest Rates on Loans and Discounts, and "Lending attitude D.I." stands for the *TANKAN* Lending Attitude of Financial Institutions D.I.

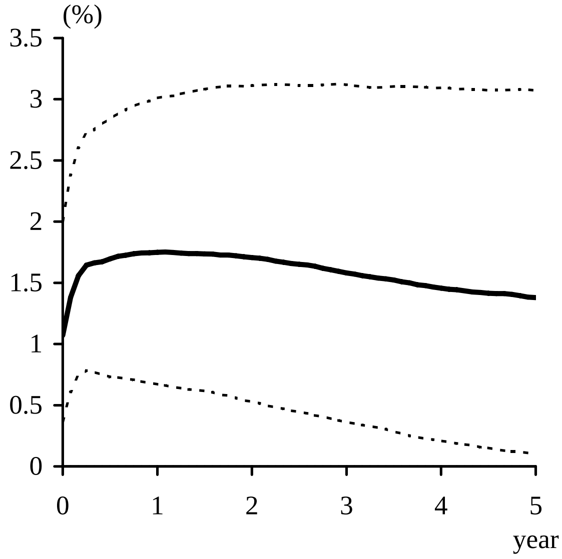
2. Shaded areas indicate recessions.

Impulse Responses to an Accommodative Monetary Policy Shock

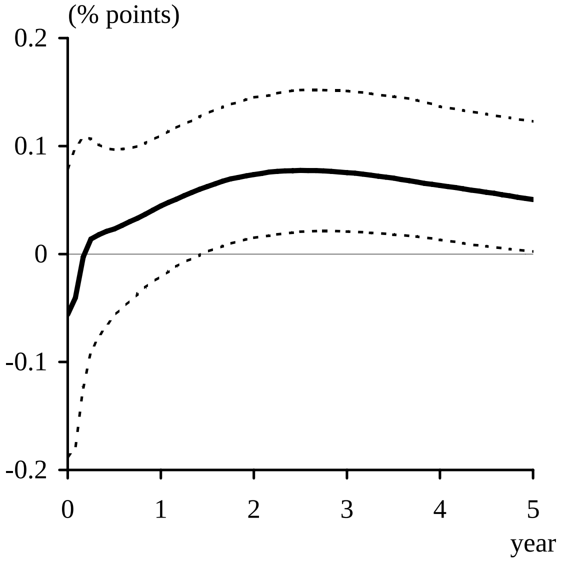
(1) Monetary Policy Proxy



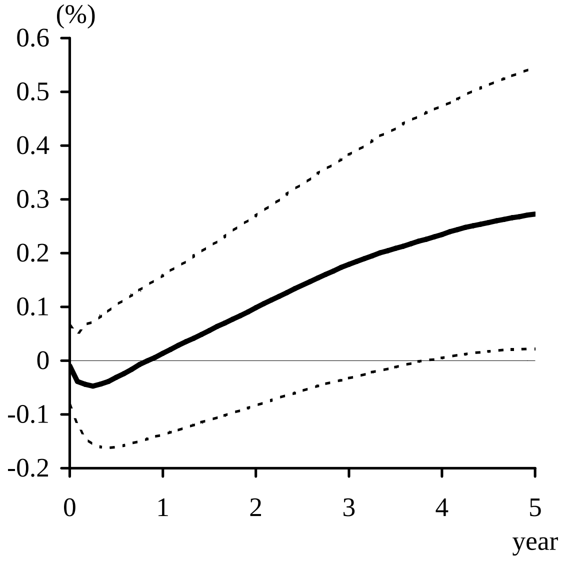
(2) Nominal Exchange Rates



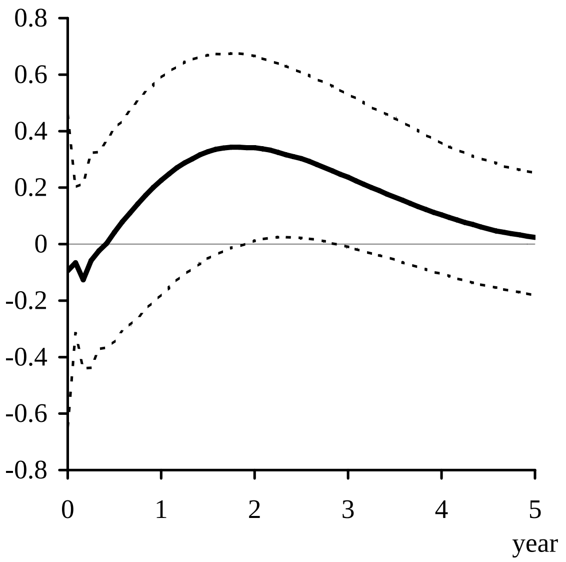
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

1. Sign restictions are imposed on the impulse response functions of monetary policy proxy and nominal exchange rates for at least six months.

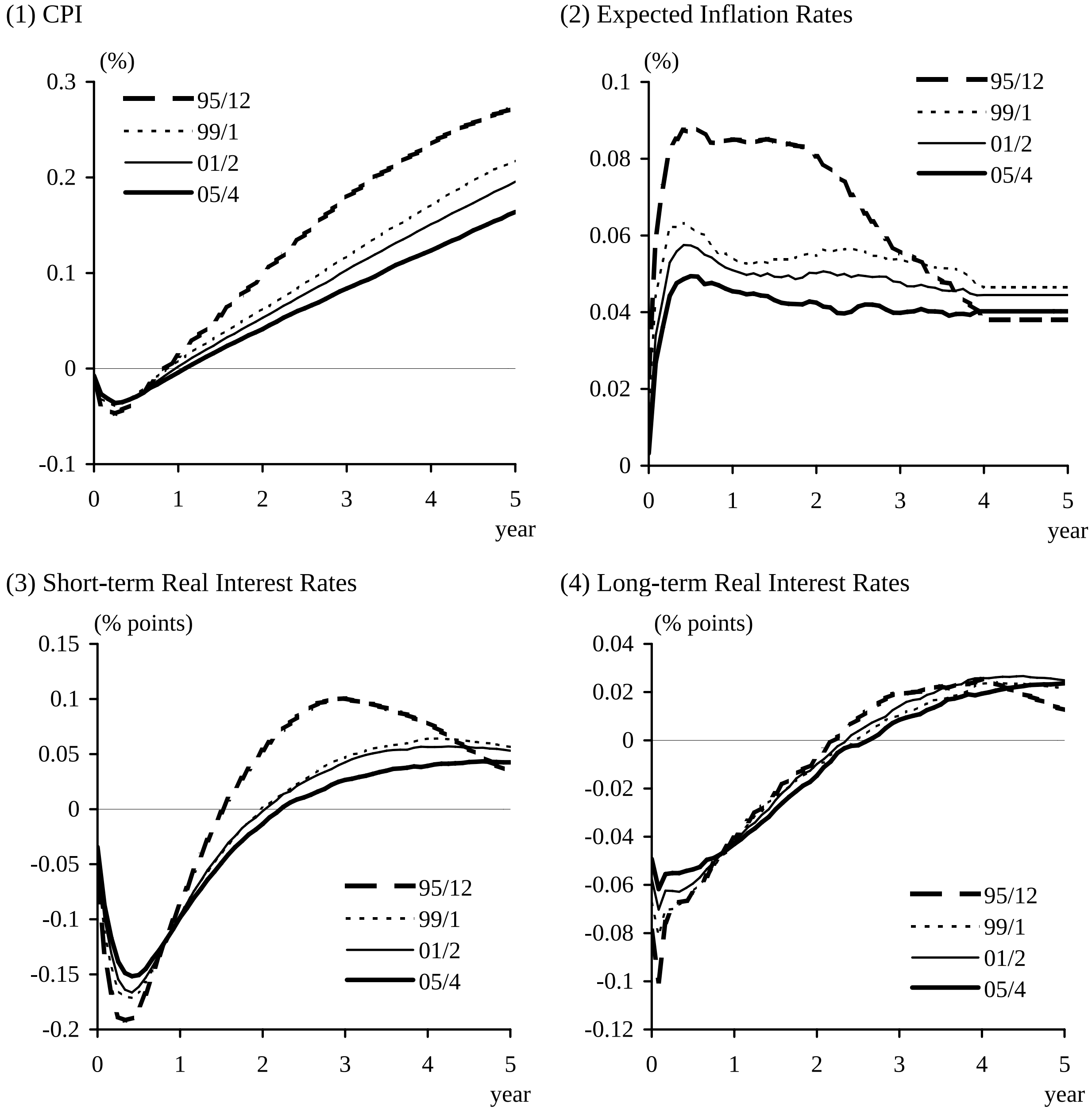
2. The sample is monthly data, spanning from 1978:2 to 1995:12.
   The VAR lag length is three months.

3. The number of Monte Carlo iterations is 40,000.

4. The thick lines indicate medians (i.e., 50 percentile points), while the two dashed lines indicate one-standard error bands.

(Figure 6)

Impulse Responses of Expected Inflation Rates and Real Interest Rates



Note:
1. The beginning of the sample is 1978:2.
2. The impulse responses of real interest rates (both short-term and long-term) to an accommodative monetary policy shock are calculated as follows:

(1) responses of expected inflation rates in period *t*
= <responses of CPI in period *t* +12> - <responses of CPI in period *t*>

(2) responses of the short-term real interest rates in period *t*
= <responses of MPP in period *t*> - <responses of the expected inflation rates in period *t*>

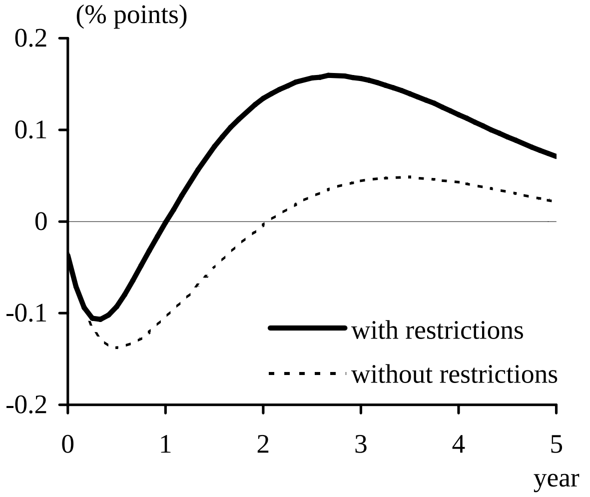
responses of the long-term real interest rates in period *t*
= <responses of long-term nominal interest rates in period *t*>
- <responses of the expected inflation rates in period *t*>

3. It is assumed that the expected inflation rates after four years remain the same as those at the end of three years.

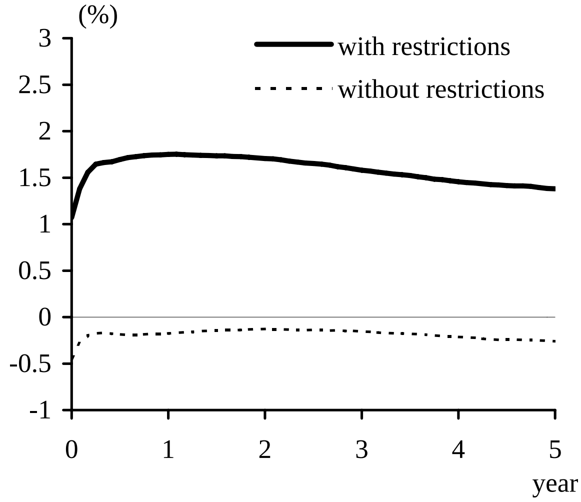
(Figure 7)

The Effects of Exchange Rate Sign Restrictions on Impulse Responses

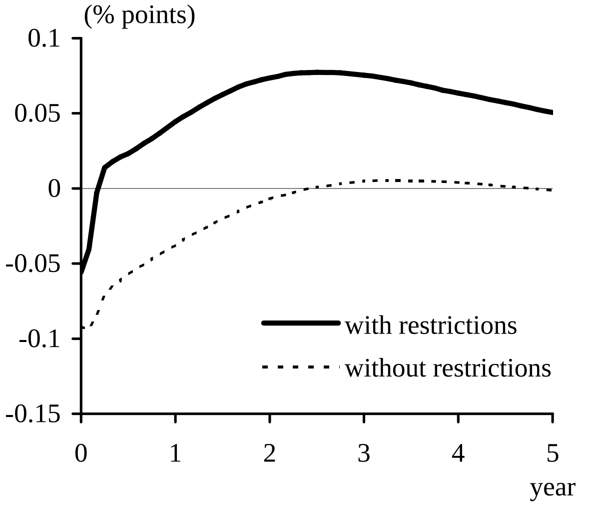
(1) Monetary Policy Proxy



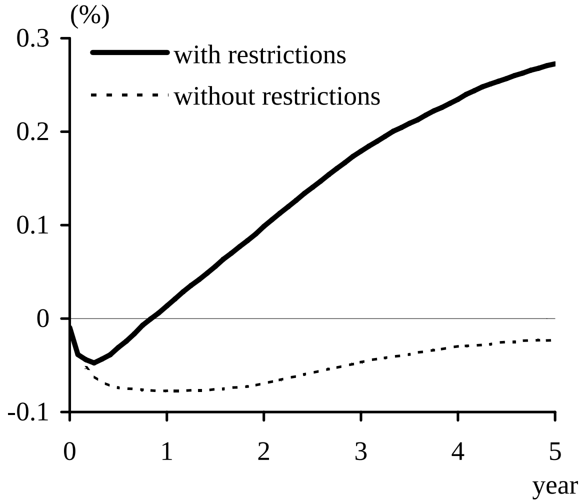
(2) Nominal Exchange Rates



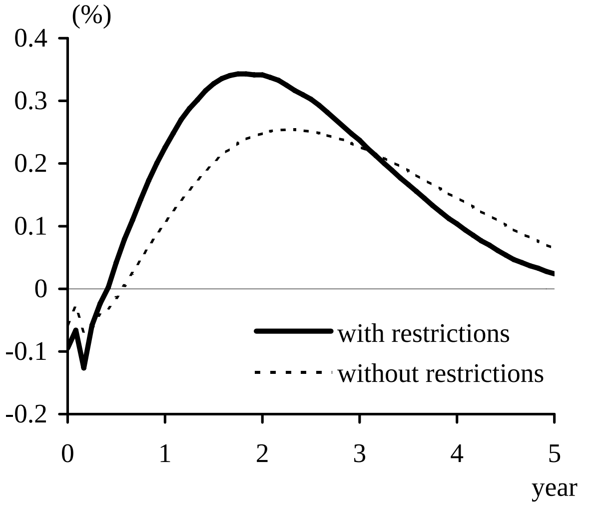
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production

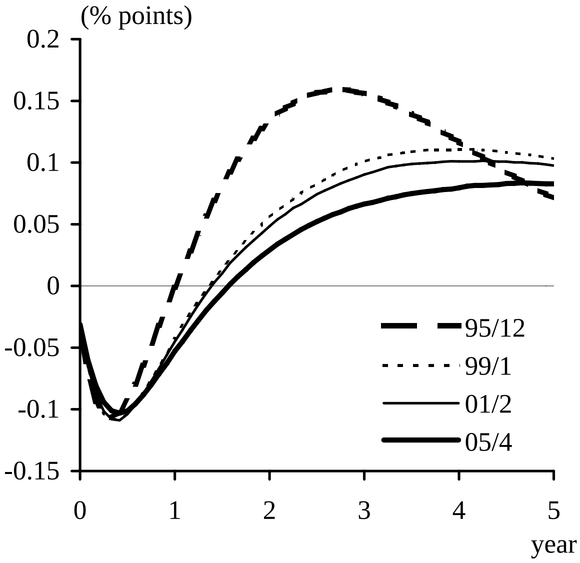


Note: The sample spans from 1978:2 to 1995:4.

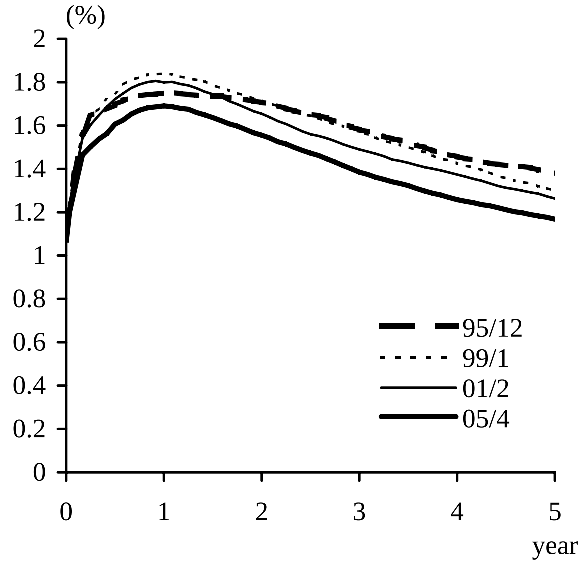
(Figure 8)

The Effects of Varying the End of Sample on Impulse Responses

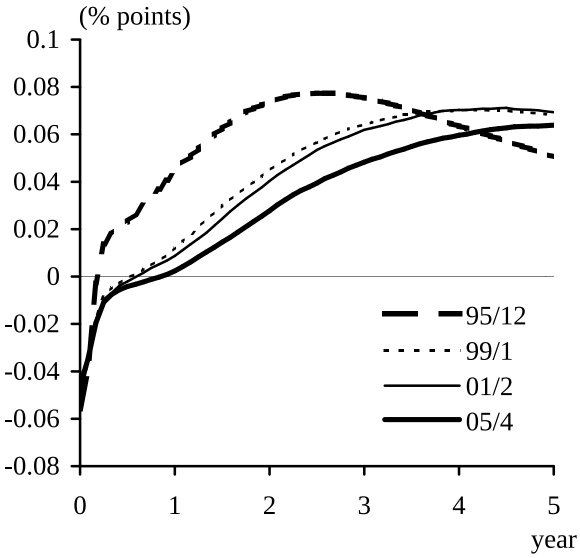
(1) Monetary Policy Proxy



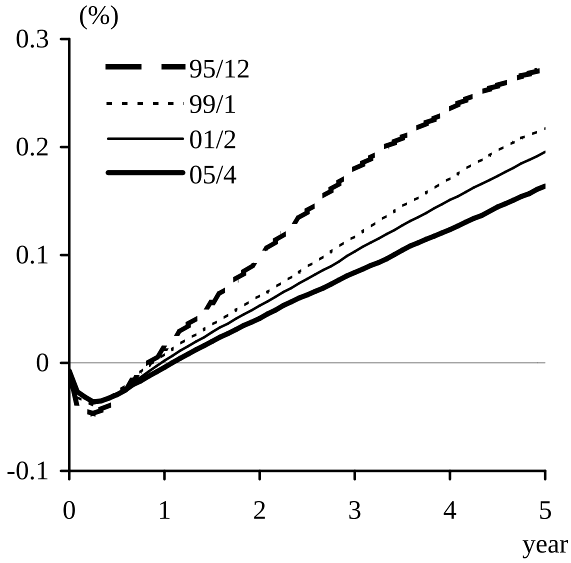
(2) Nominal Exchange Rates



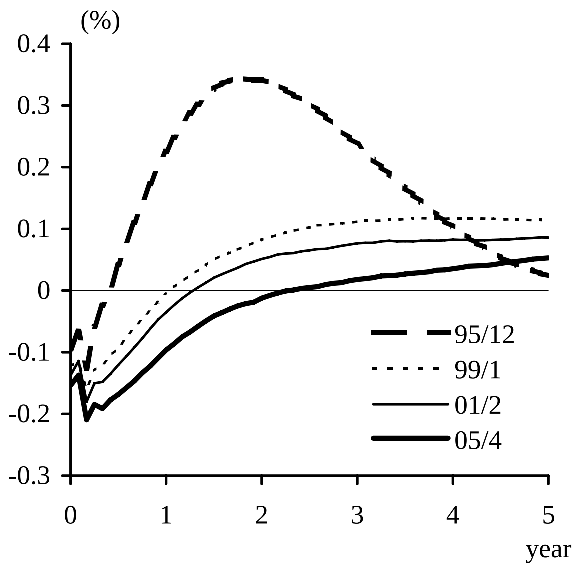
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

1. Each graph indicates the medians of impulse response functions to an accommodative monetary shock with the end of sample varied.

2. The sample starts in February 1978. The end of sample is changed as follows:

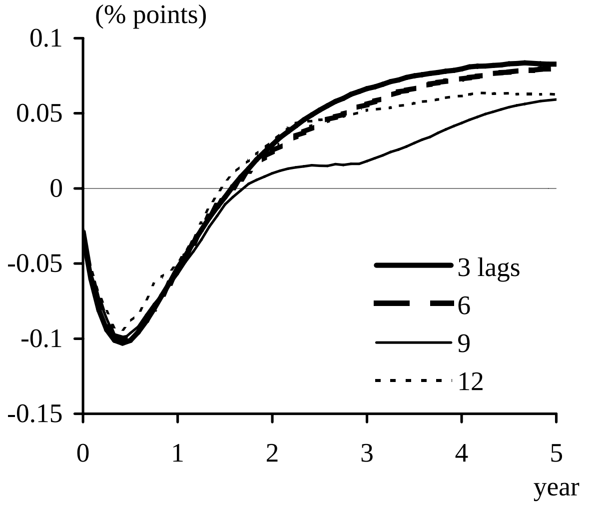
(i) 1978:2-1995:12
(ii) 1978:2-1999:1
(iii) 1978:2-2001:2
(iv) 1978:2-2005:4

3. The VAR lag length is three months. The number of Monte Carlo iterations is 40,000.

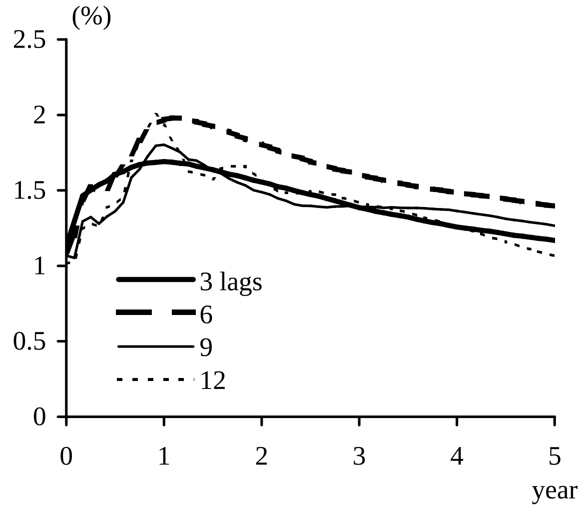
(Figure 9)

The Effects of Changing the VAR Lag Length on Impulse Responses

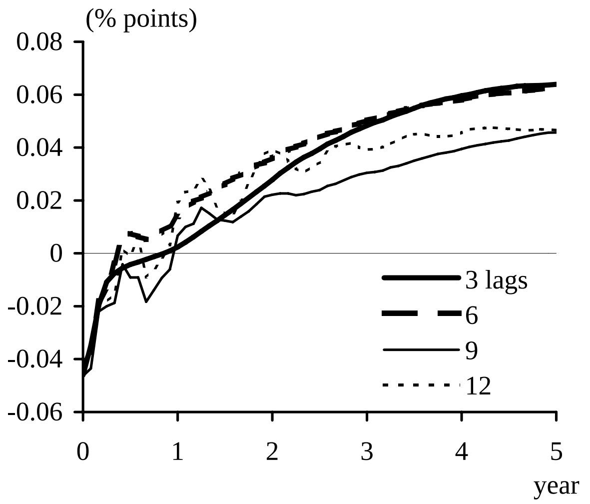
(1) Monetary Policy Proxy



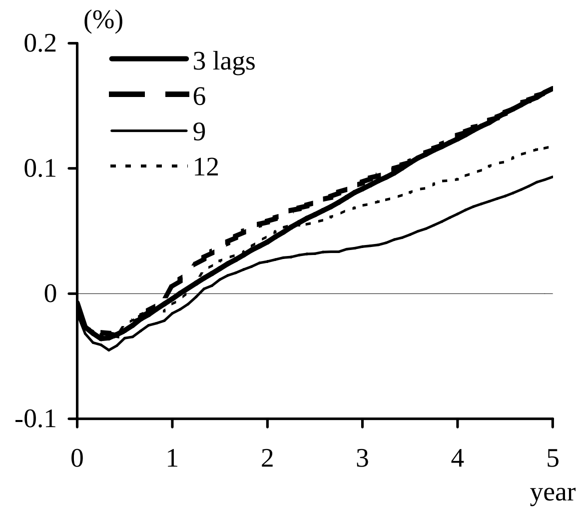
(2) Nominal Exchange Rates



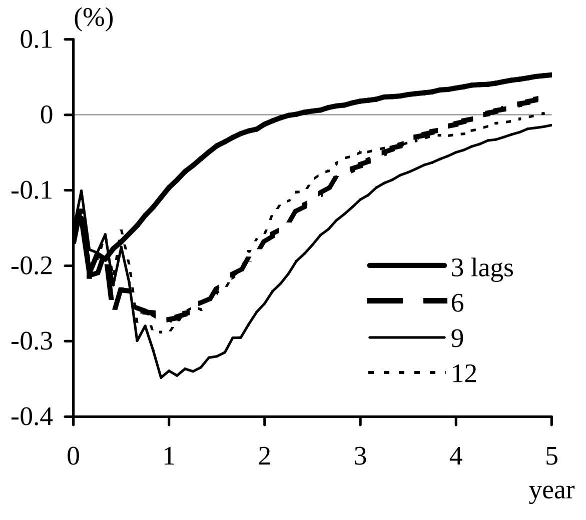
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

1. Each graph indicates the medians of impulse response functions to an accommodative monetary policy shock with the VAR lag length varied from 3 (the benchmark case) to 6, 9, and 12 months.

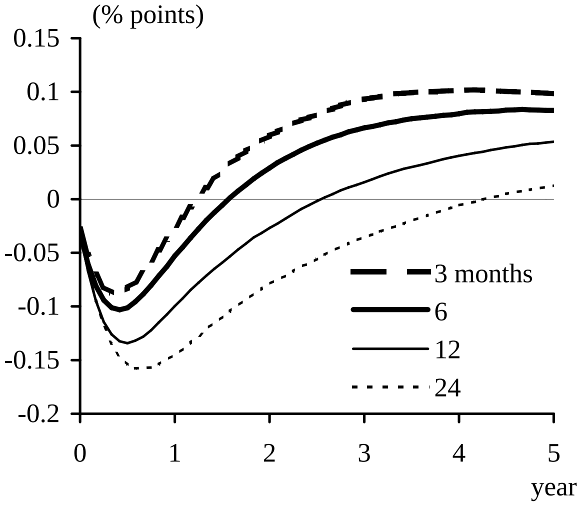
2. The number of Monte Carlo iterations is 40,000.

3. The sample spans from 1978:2 to 2005:4.

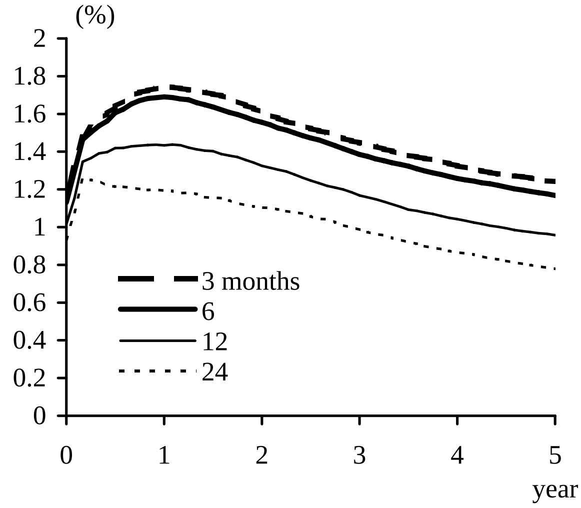
(Figure 10)

The Effects of Changing the Sign-Restriction Horizon on Impulse Responses

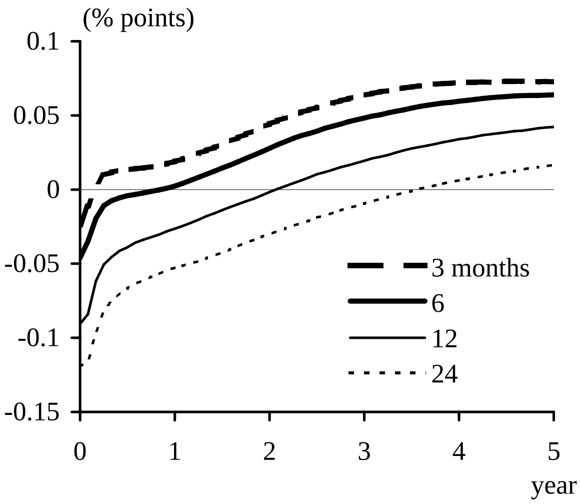
(1) Monetary Policy Proxy



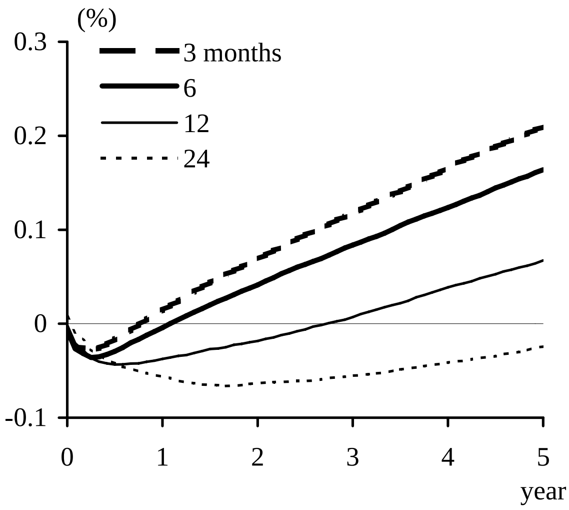
(2) Nominal Exchange Rates



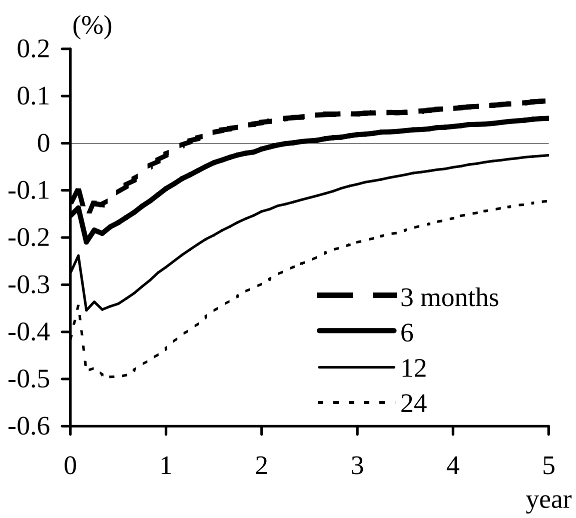
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

1. Each graph indicates the medians of impulse response functions to an accommodative monetary policy shock with the sign restriction horizon varied from 3 to 6 (the benchmark case), 12, and 24 months.

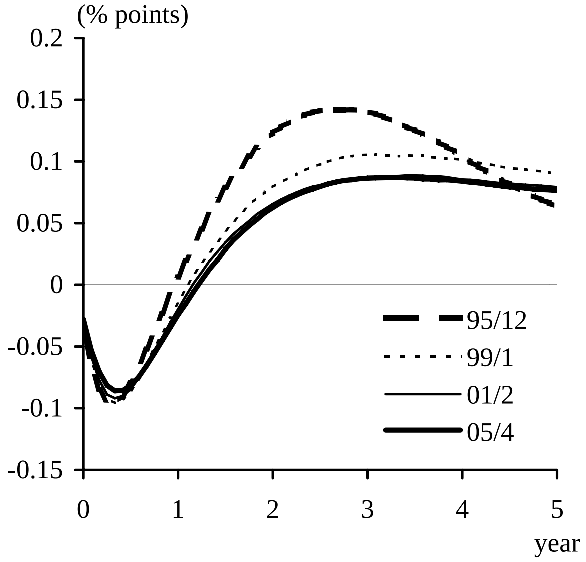
2. The VAR lag length is three months. The number of Monte Carlo iterations is 40,000.

3. The sample spans from 1978:2 to 2005:4.

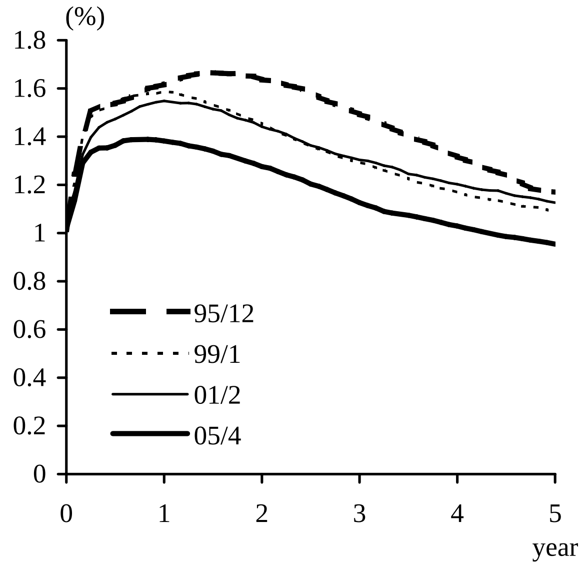
(Figure 11)

The Effect of Including Stock Prices on Impulse Responses

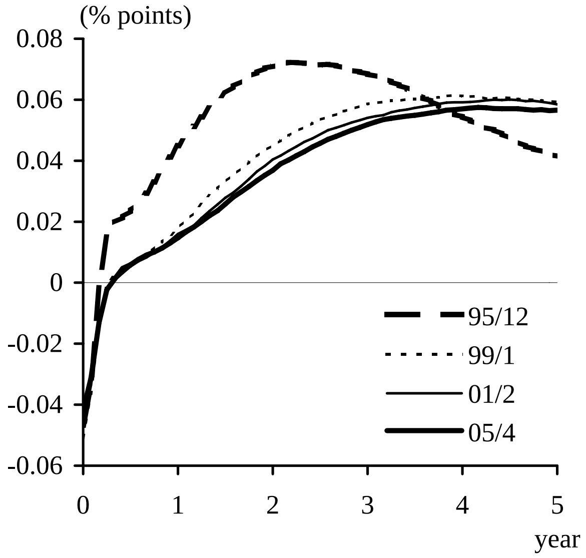
(1) Monetary Policy Proxy



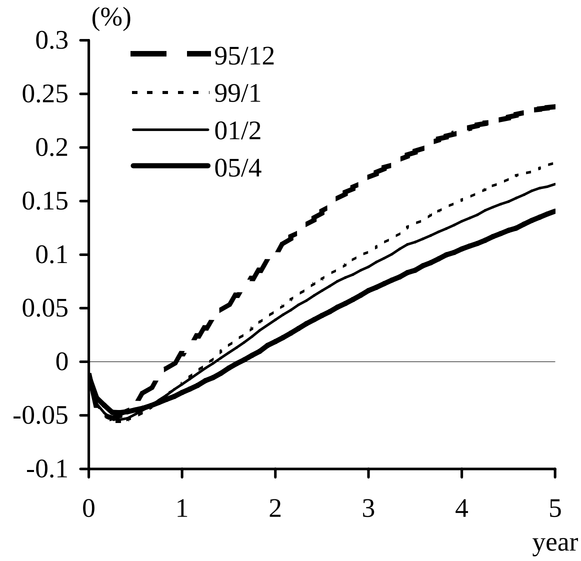
(2) Nominal Exchange Rates



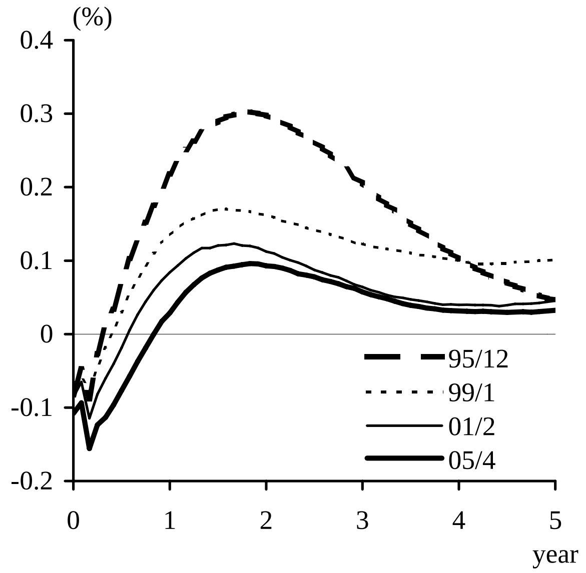
(3) Interest-bearing 10-year Government Bonds



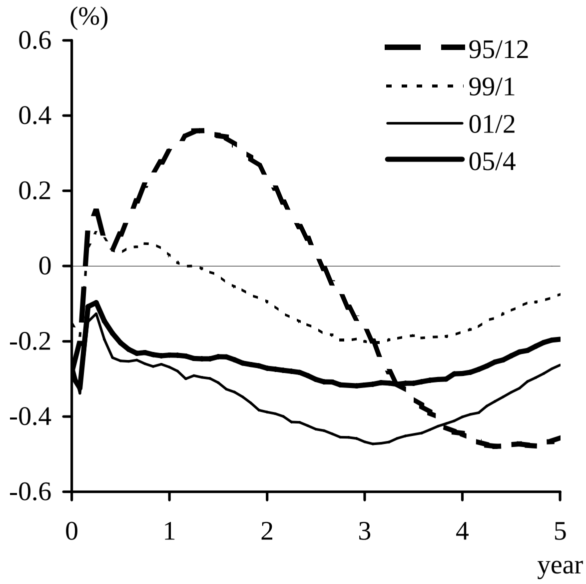
(4) CPI



(5) Index of Industrial Production



(6) TOPIX

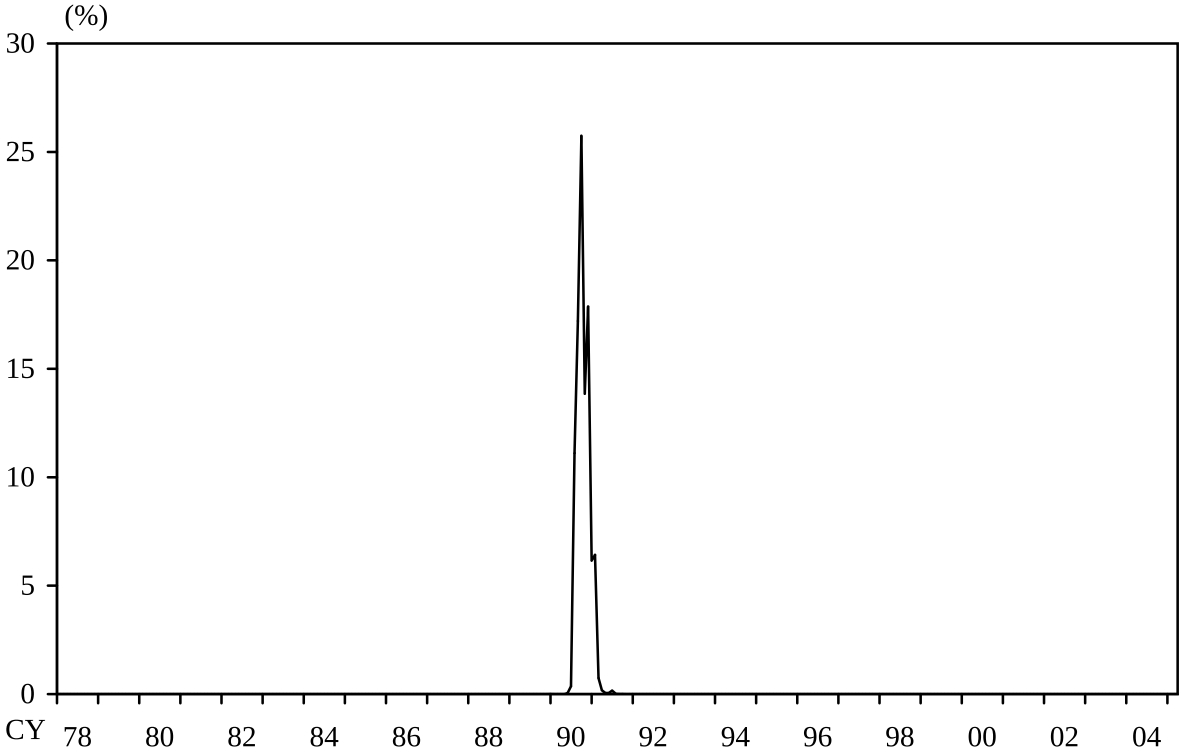


Note: The beginning of the sample is 1978:2.

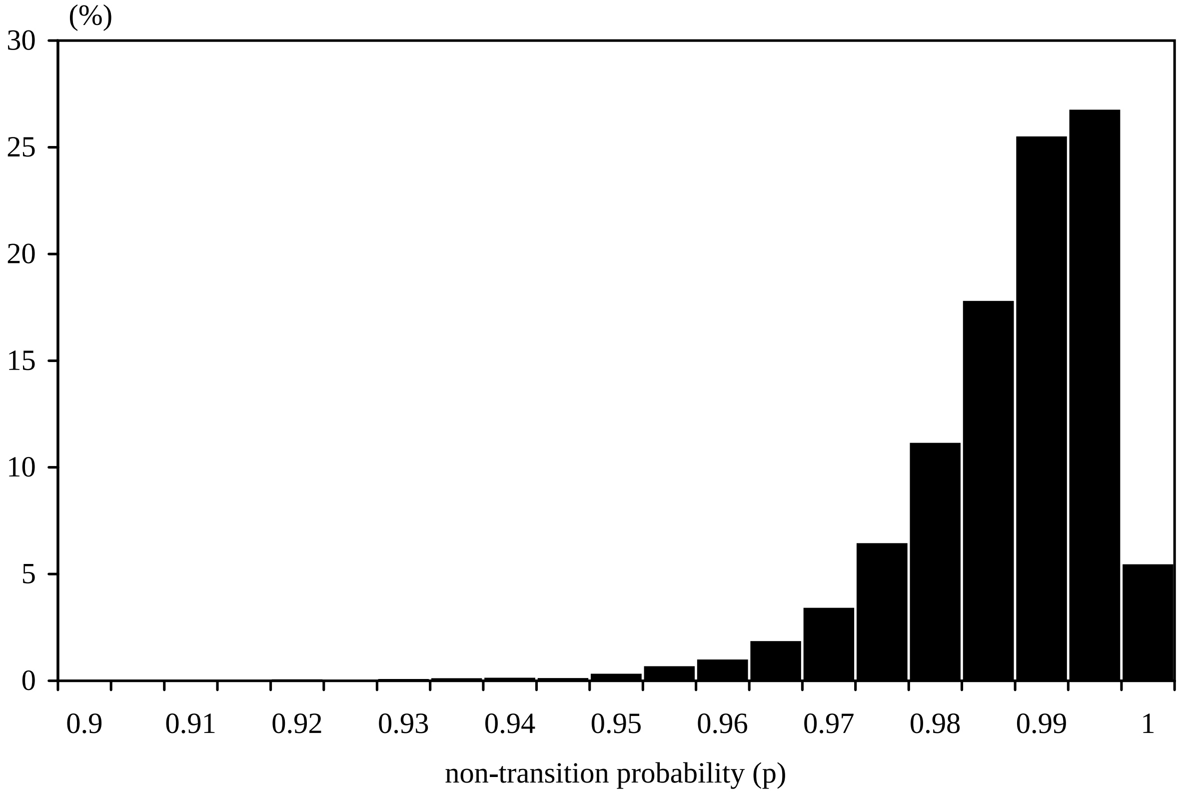
(Figure 12)

Inference of a Structural-change Point

(1) Probability Distribution of the Structural-change Point



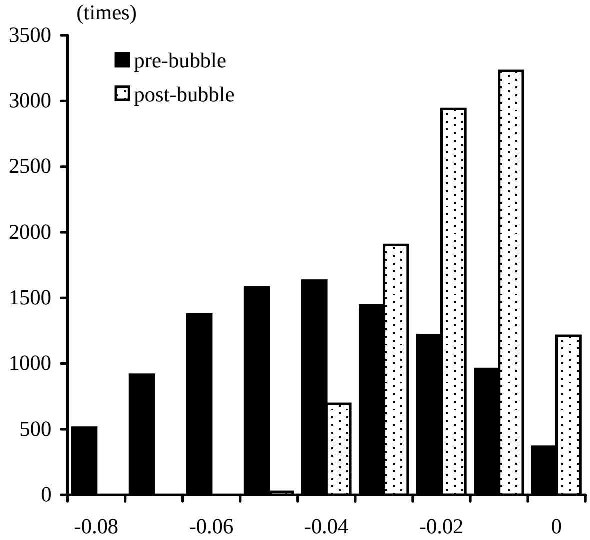
(2) Probability Distribution of the Non-transition Probability



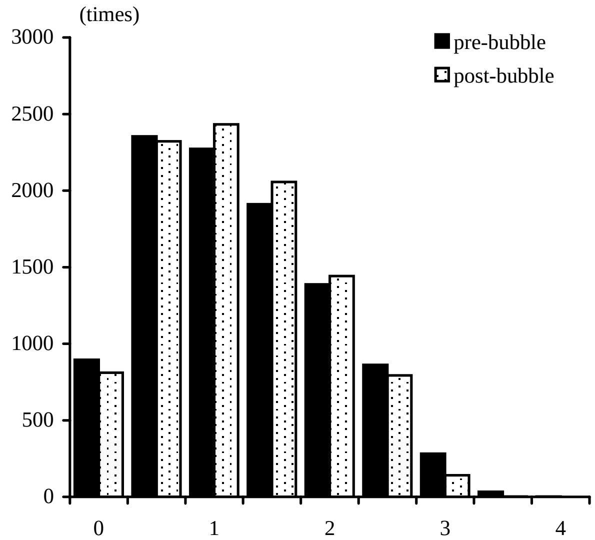
(Figure 13)

Histograms of the Elements of the Impulse Vector

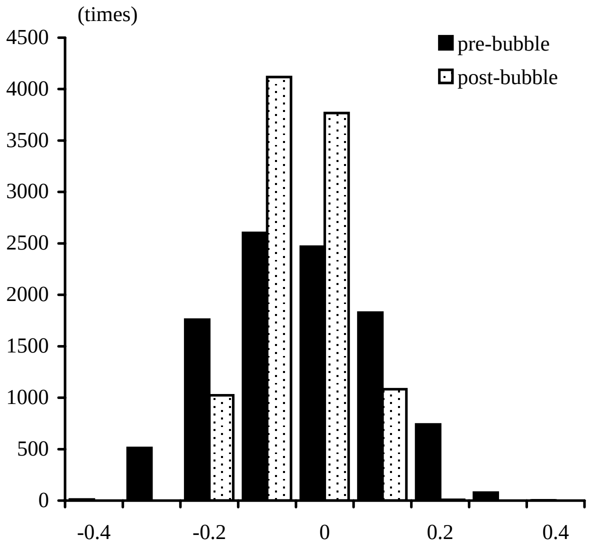
(1) Monetary Policy Proxy



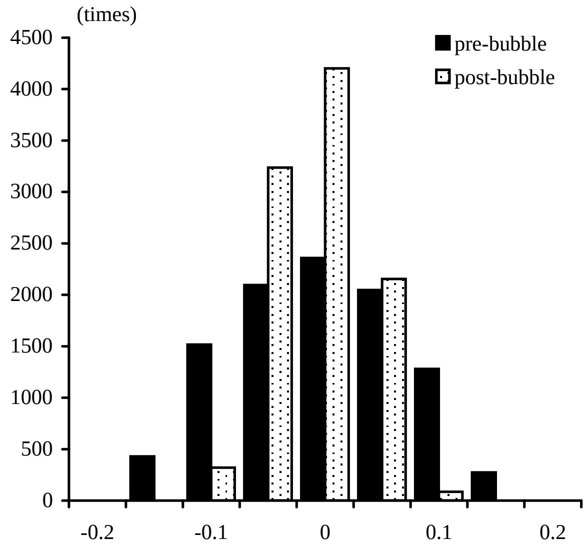
(2) Nominal Exchange Rates



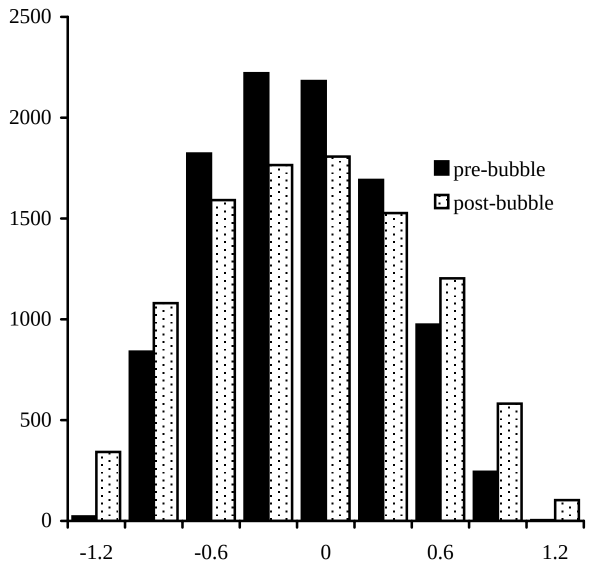
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

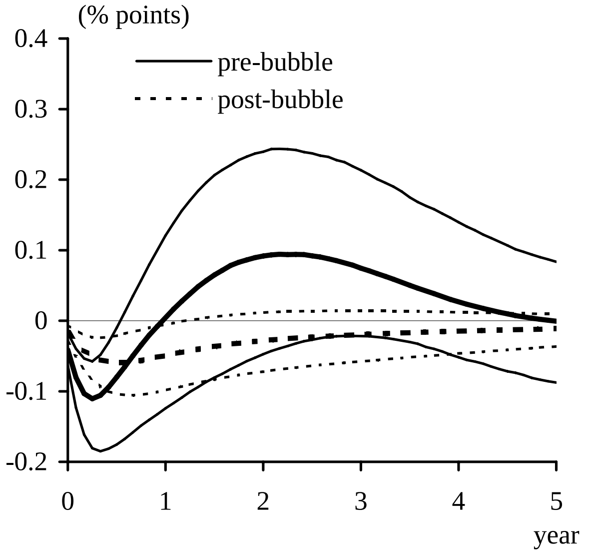
1. The number of Monte Carlo iterations is 10,000.

2. The unit of changes in the MPP impulse and interest-bearing 10-year governments bonds impulse is % points, while that of changes in other variable impulses is %.

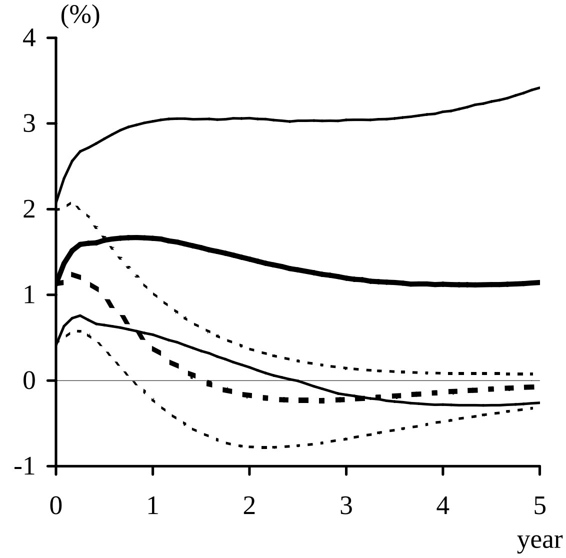
(Figure 14)

Impulse Responses to Monetary Policy Shocks around the Asset Bubble Peak

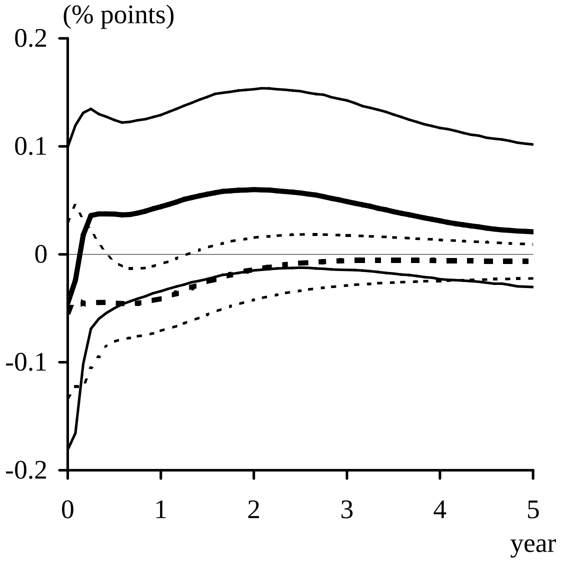
(1) Monetary Policy Proxy



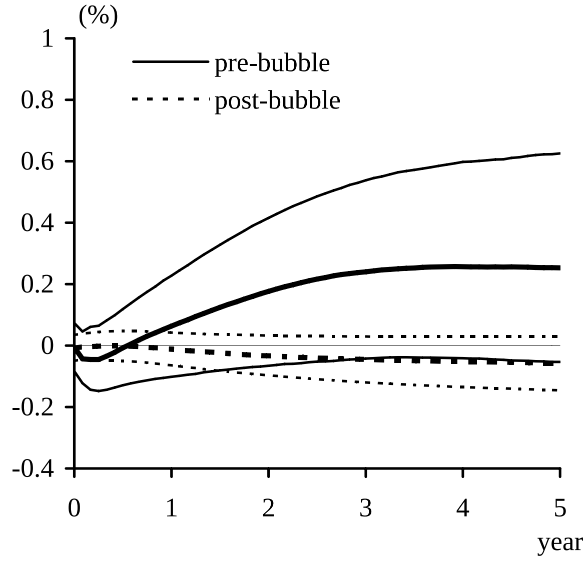
(2) Nominal Exchange Rates



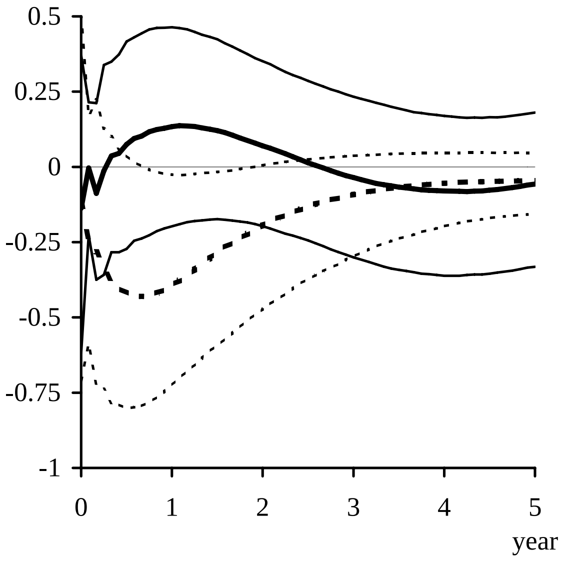
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

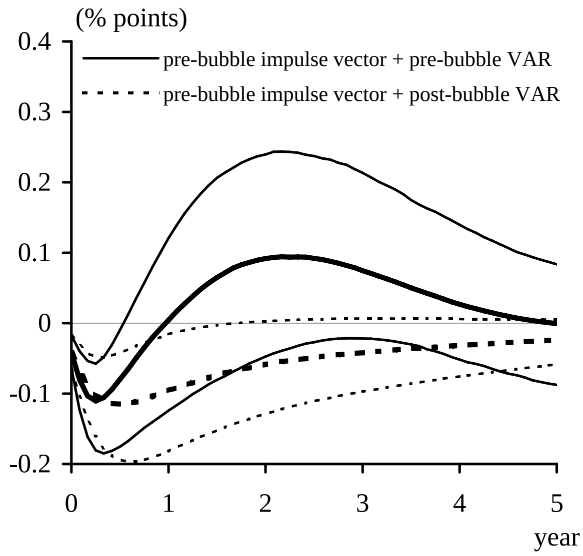
1. The solid curves indicate the responses in the pre-bubble period, while the dashed curves indicate those in the post-bubble period.

2. The thick curves indicate the medians, while the thin curves indicate one-standard-error bands.

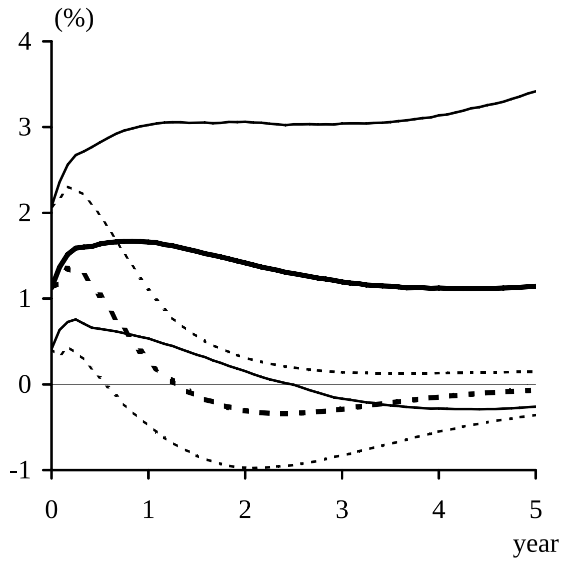
(Figure 15)

Counterfactual Experiments (1)

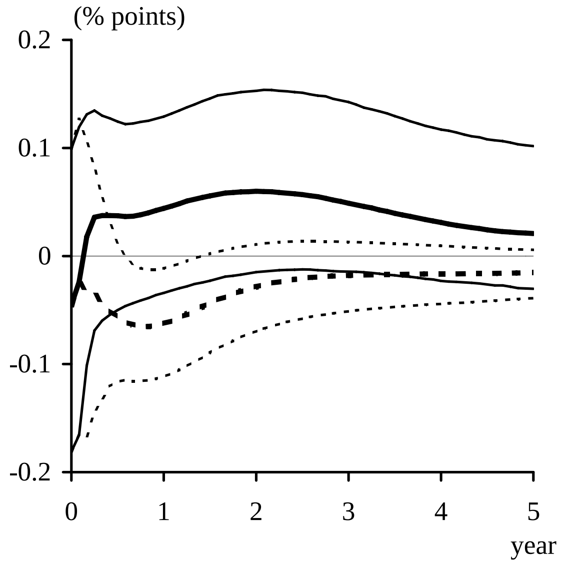
(1) Monetary Policy Proxy



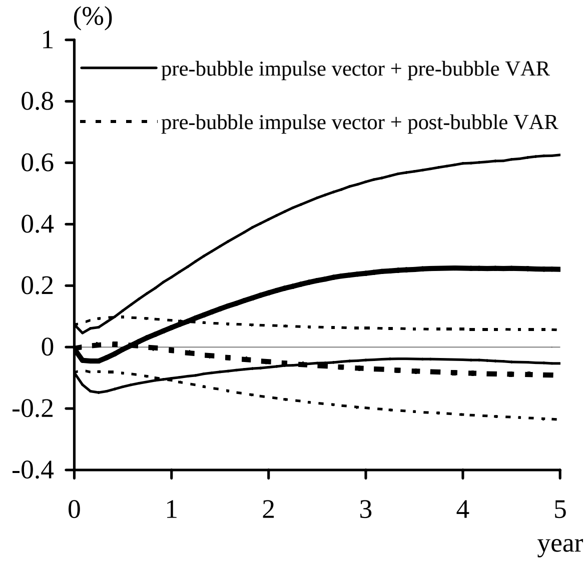
(2) Nominal Exchange Rates



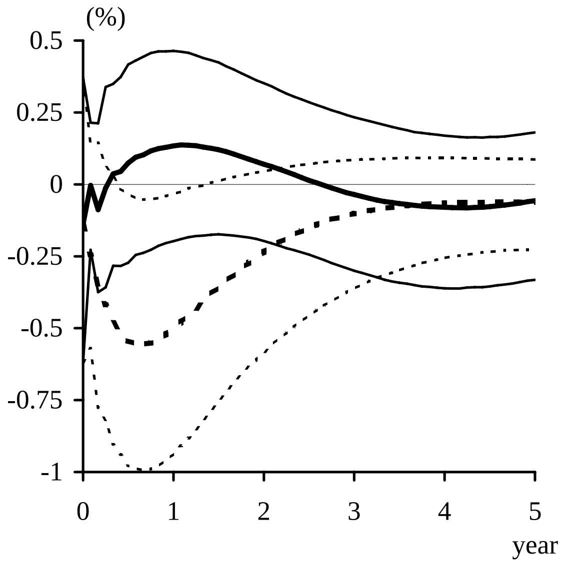
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production



Note:

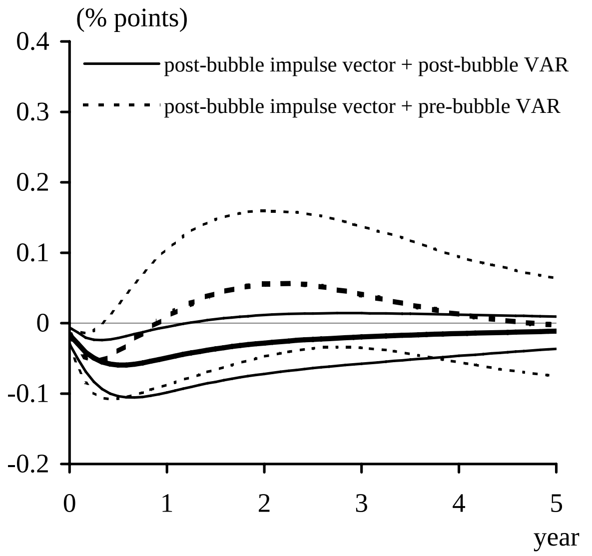
1. The three solid curves indicate the comibination of the pre-bubble impulse vector and the pre-bubble VAR parameters, while the three dashed curves indicate the combination of the pre-bubble impulse vector and the post-bubble VAR parameters.

2. The thick curves indicate the medians, while the thin curves indicate the one-standard-error bands.

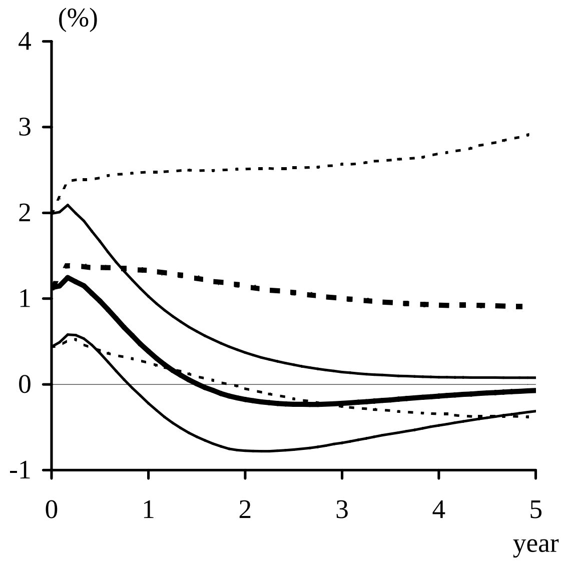
(Figure 16)

Counterfactual Experiments (2)

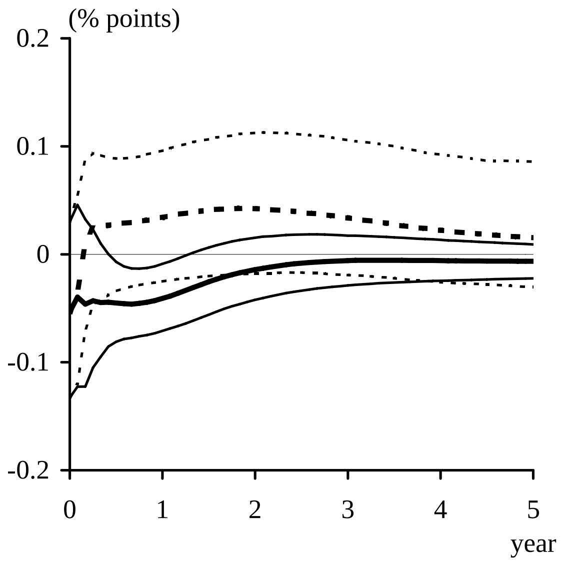
(1) Monetary Policy Proxy



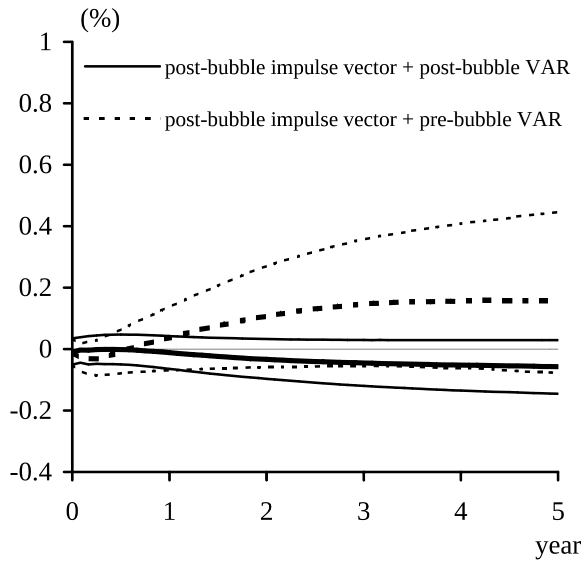
(2) Nominal Exchange Rates



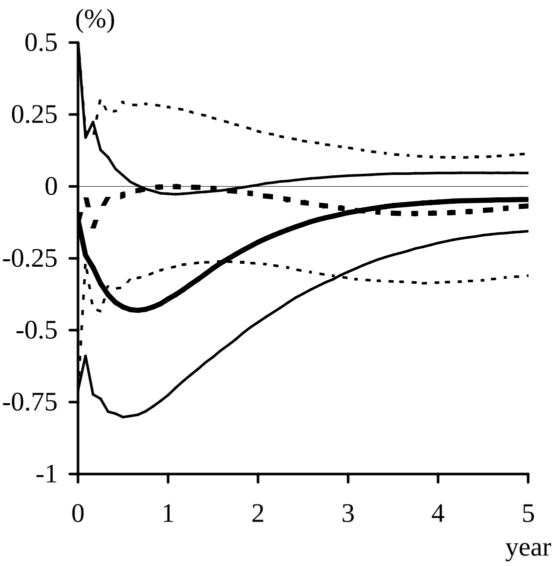
(3) Interest-bearing 10-year Government Bonds



(4) CPI



(5) Index of Industrial Production

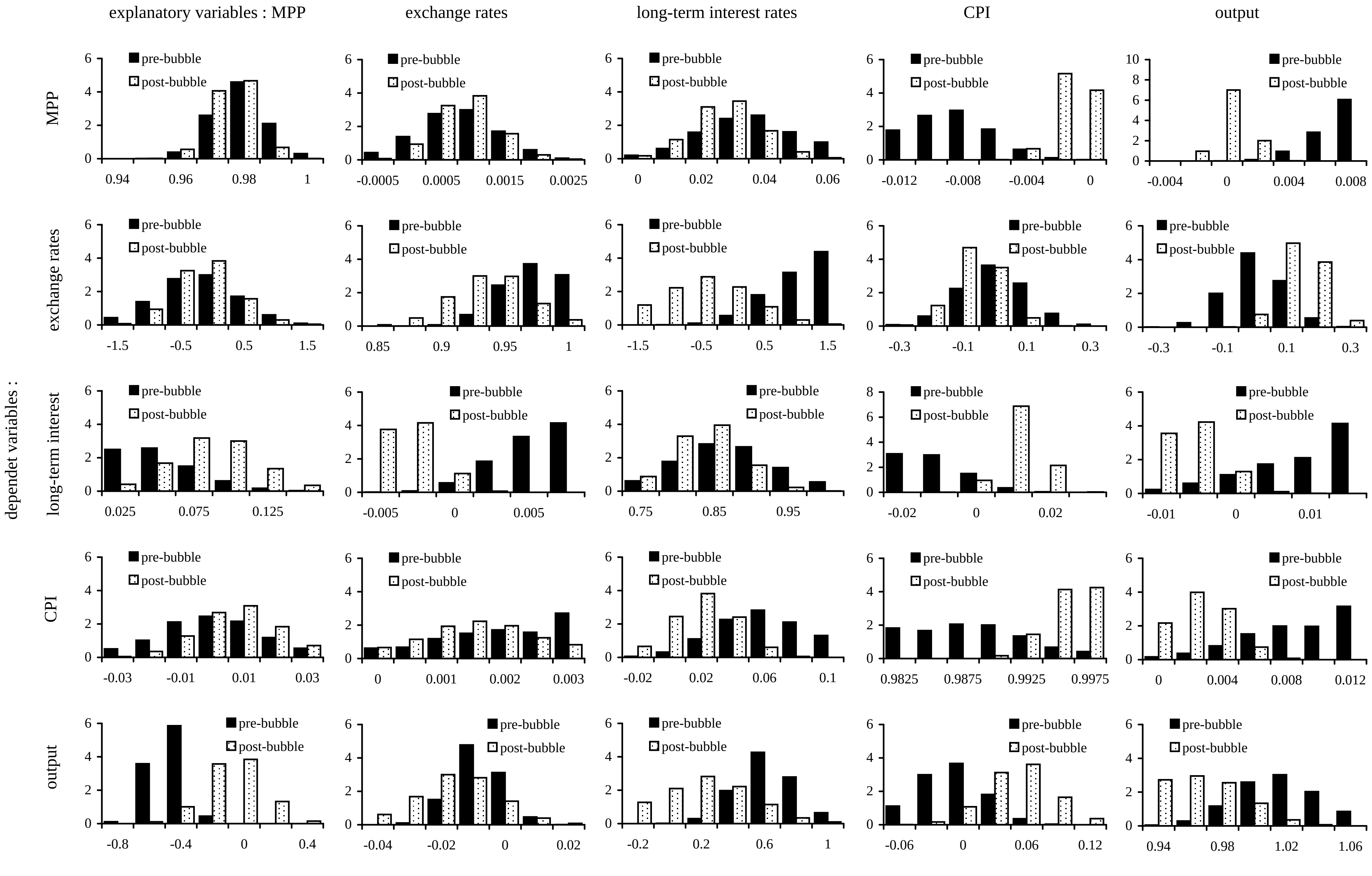


Note:

1. The three dashed curves indicate the combination of the post-bubble impulse vector and the pre-bubble VAR parameters, while the three solid curves indicate the comibination of the post-bubble impulse vector and the post-bubble VAR parameters.

2. The thick curves indicate the medians, while the thin curves indicate the one-standard-error bands.

Distributions of VAR Parameters (summed over lags) (Figure 17)



Note: The unit in vertical axis is the number of times (thousand).