Monetary Policy in Japan Reconsidered: A Regime-switching VAR Analysis

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Abstract

Using a regime-switching VAR, this paper investigates the effect of monetary policy in Japan. Unlike previous studies, this paper considers more than two regimes and introduces into the VAR analysis standard variables such as the money supply and price level. Based on the standard procedure, the independent regime for a quantitative easing policy is identified when the policy effect is insignificant.

Keywords: quantitative easing, regime switching, monetary policy, zero-interest-rate policy

JEL Classification Numbers: C32, E31, E52

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I. Introduction

The purpose of this paper is to reconsider the effect of monetary policy in the 1980s and 1990s in Japan using a standard regime-switching VAR. In this period, the real economy, as well as monetary policy, was subject to severe fluctuations. That is, significant events occurred such as an asset price bubble (1987–1991), a low-interest-rate policy (1995–), a zero-interest-rate policy (February 1999–August 2000), and a quantitative easing policy (March 2001–March 2006). These epoch-making events are likely to have resulted in switched "regimes." [1]

*** Insert Figure 1 about here ***

In fact, Figure 1(a) plots M2+CD and real GDP, which changed drastically between the 1980s and 1990s. Figure1(a) shows (1) high real GDP growth rates in 1980s and low growth rates in the 1990s (a change in trend), (2) the magnitude of swings in real GDP, which were smaller in the 1980s than the 1990s (cycles), and (3) a sudden increase in real GDP as well as M2+CD in the bubble period.

These observations help us identify at least *three* regimes: pre-bubble, bubble, and post-bubble. Furthermore, the drastic changes in monetary policy settings—that is, the low-interest-rate policy, the zero-interest-rate policy and the quantitative easing policy—reinforce the existence of these three regimes. The existing studies of Japanese monetary policy that use a regime-switching approach (Miyao [2000], Fujiwara [2006], Inoue and Okimoto [2008]), however, have not considered these three regimes. This paper addresses this shortcoming and consequently has the following five advantages over existing studies.

(1) Sufficient number of regimes

Existing studies considered only two regimes, with a single structural change around 1995–1996. Miyao (2000) showed that the break point is around 1995–1996 by observing the differences in the shape of the impulse response functions in the subsamples, and tested the

1 The Bank of Japan (BOJ) adopted the zero-interest-rate policy (ZIRP) from February 1999 to August 2000 to cope with increased deflationary concern following sharp increases in long-term interest rates. It was early March 1999 when the uncollateralized overnight call rate declined to almost zero. On 19 March 2001, the BOJ introduced an unprecedented quantitative easing policy to address deflation, changing the operational target for money market operations from the uncollateralized overnight call rate to the outstanding balance of the current accounts at the BOJ, which constitute the monetary base together with notes and coins on issue, and lifted it on 9 March 2006. The BOJ removed its ZIRP on 14 July 2006 to raise the uncollateralized overnight call rate to 0.25% and implemented another 0.25% rise on 21 February 2007. Thus, Japanese monetary policy is beginning to be operated normally again. The BOJ cut its policy interest rate to 0.30% from 0.50% amid rising concern about Japan's growth outlook on October 31 2008.

stability of the model. Furthermore, Fujiwara (2006) restricted his analysis to two regimes *a priori*. These studies, therefore, cannot answer the following questions: How does an asset price bubble affect the real economy and monetary policy? What is the difference between a zero-interest-rate policy and a quantitative easing policy? In contrast, this paper considers more than three regimes during the response to the drastic change in economic conditions.

(2a) Choice of variables with regard to monetary policy

Both Miyao (2000) and Inoue and Okimoto (2008) used a nonstandard treatment of monetary variables; they considered the effect of monetary policy by using the call rate (the nominal short-term policy interest rate) and the monetary base without including the money supply. This paper, however, considers the regime changes, using the standard VAR framework including a money supply variable.

To explore the possibility of regime changes in the Japanese economy with attention to her monetary policy, the following monetary variables are considered: (i) a quantitative measure of money for describing quantitative easing policy (monetary base), (ii) policy interest rate for the low-interest-rate policy and the zero-interest-rate policy, and (iii) money supply including private credit creation. Previous studies, however, employed restricted variables, and therefore cannot answer the following questions: Are the regimes different between the quantitative easing period and the zero-interest-rate period? How are the pre-bubble, bubble, and post-bubble periods different? What is the cause of the decreasing monetary multiplier in the 1990s?

(2b) Choice of variables with regard to goods markets

Previous studies employed an index of industrial production (IIP), which represents activity in stable sectors such as manufacturing in the period considered here. Using IIP has various problems, including whether excessive investment occurred in the nonmanufacturing sector in the bubble period, and recent tendency of discrepancy between IIP and GDP, which leads us to question whether IIP is an appropriate variable to represent activity in the goods markets. This paper employs the index of all-industry activity (IAA), which is available monthly.

(2c) Choice of variables with regard to price data and bubble

Miyao (2000) and Inoue and Okimoto (2008) disregarded the price level, which is an unusual variable selection choice in performing VAR analysis. Furthermore, monetary easing policy in the bubble period is also an interesting issue for evaluating policy effectiveness.

(3) Sample period

Previous studies employed data before the end of the so-called “lost decade“ (Miyao [2000] used data until 1998, Fujiwara [2006] used data from January 1985 to December 2003, and Inoue and Okimoto [2008] used data until 2002). Therefore, the data used in these studies missed the important period of recovery from the lost decade starting in 2003. The year 2003 is also the period in which the difference between long-term and short-term interest rates changed significantly, which shows the quantitative easing policy. Furthermore, our analysis includes the period after the quantitative easing and zero-interest-rate policies.

In summary, our analysis includes a more appropriate number of variables and regimes compared with existing studies. Fujiwara (2006) used a sufficient number of appropriate variables but restricted his analysis to two regimes *a priori*, while Inoue and Okimoto (2008) omitted important variables such as the money supply and price level. Although existing studies showed coincidentally that a unique structural change occurred around 1995–1996, the following question remains unanswered: Are two regimes sufficient for describing the bubble, zero-interest-rate policy and quantitative easing policy periods? At the end of the quantitative easing policy, it is a good time to reconsider the effects of monetary policy, and therefore this paper investigates the possibilities of regime switching and the effect of monetary policy under the standard VAR framework.

The rest of this paper is organized as follows. Section 2 provides the baseline models used for the empirical analysis. In Section 3, the empirical results are presented and discussed. In Section 4, the baseline model is extended. Section 5 concludes the paper.

II. Basic Models

Over a quarter century from 1980 to the present day after two oil crises, the Japanese economy has experienced drastic fluctuations: high growth and asset price bubbles in the late 1980s, and low growth and deflation in the 1990s (the so-called “lost decade“). As a result, careful management of monetary policy by the Bank of Japan (hereafter BOJ) was required. In particular, after the financial crisis in Southeast Asia in 1997, a liquidity trap, which had originally proposed as a theoretical possibility by John Maynard Keynes (1936) but long considered to be doubtful practical relevance, hit the Japanese economy, and extraordinary monetary policies such as the zero-interest-rate policy and the quantitative easing policy were implemented as can be seen from Figure 1 (b). A quantitative easing policy can be defined as where the BOJ supplies the monetary base including the current account balances beyond those needed to keep short-term policy interest rate (the call rate) at zero.

The zero-interest-rate policy was carried out from February 1999 to August 2000. During this period, the call rate was fixed at zero percent, and the BOJ did not control monetary policy using interest rates as the policy instrument. Since the tough deflation, however, did not halt in spite of zero-interest-rate policy as can be seen from Figure 1 (c), a quantitative easing policy was implemented between March 2001 and March 2006 as the last resort of monetary policy, and the policy instrument was moved from interest rates to the current account balances at the BOJ. Although the target of the current account balances at the BOJ was 5,000 billion yen at the beginning of 2001, the upper limit of 32,000 billion yen was reached in October 2003. The zero-interest-rate policy, adopted following the end of the quantitative easing policy, also ended in July 2006, because the start of an economic recovery was observed.[2]

Firstly, this paper considers a three-variable VAR model excluding monetary policy instrument variables, taking recent extraordinary monetary policy in Japan into account. We investigate the regime changes in macroeconomic structure excluding the operation of monetary policy for the last two decades. This three-variable VAR model is a standard macroeconomic VAR model using (i) real output, (ii) the price level, and (iii) money supply. The stabilization of the former two variables, real output and the price level, are the final target of monetary policy, whereas the quantity of money supply is interpreted as the intermediate target as well as the equilibrium of demand and supply in the money market. So the impulse response of real output and the price level to the shock of money supply derived from the VAR model can be regarded as the indirect effect of monetary policy. Both Miyao (2000) and Inoue and Okimoto (2008) used nonstandard monetary variables; they considered the effect of monetary policy by using the call rate and the monetary base without introducing the money supply. This paper, however, examines the regime changes, using a standard VAR framework with a money supply variable.

Next, we consider a five-variable VAR model including two additional monetary policy instruments: (iv) the nominal short-term policy interest rate and (v) the monetary base, for the above-mentioned three-variable VAR model. Since the 1980s, the BOJ has greatly downgraded the role of the money supply in the implementation of monetary policy, as well as the Western central banks. Instead, it has placed importance on the nominal short-term interest rate. However, there is controversy over what monetary policy instruments the BOJ uses. Nakashima (2006) concluded that the BOJ targeted only the call rate using data between January 1975 and

2 Recently, a large number of studies have considered the zero-interest-rate policy and liquidity trap since the late 1990s in Japan. For example, see the collected papers edited by Ito and Rosen (2006). Iwata and Wu (2006), Kimura et al. (2003) and Jinnai (2007) focused on the zero-interest-rate policy, whereas Ugai (2007) and Yamasawa (2006) considered the qualitative easing policy in Japan.

June 1995, applying the identification method of VAR models proposed by Bernanke and Mihov (1998). Meanwhile, Shioji (2000) identified shocks that relate to the monetary base as the monetary policy shock from a sample period between February 1977 and May 1995.[3] Despite these previous studies, it is plausible for us to choose both variables as indicators of monetary policy. Both variables played an important role in monetary policy in the period after 1999, which Nakashima (2006) and Shioji (2000) did not consider.

Comparing two VAR models with and without monetary policy instruments, we could verify the discrepancy of the regime changes between monetary policy and macroeconomic structure. Only estimating a five-variable VAR model with two policy instruments might mislead to the following two possibilities. Firstly, the number of regime changes tends to be specified to too many numbers. It is natural to think that the number of regime changes would increase by adding monetary policy instruments to the standard three variable VAR model, because the regime changes of a five-variable VAR model likely capture idiosyncratic breakings of five individual variables. Alternatively, it is also plausible that regimes estimated in a five-variable model reflect only the policy instruments but not the target of policy such as real output, the price level and money supply, since the two monetary policy instruments switched to extraordinary values despite no remarkable changes for other three variables around 2000 as described above. Inoue and Okimoto (2008) estimated only a regime-switching VAR with monetary policy instruments: the call rate and monetary base, and concluded that there was just one structural change around 1995. But there is possibility that their estimation result was derived only from drastic change of two policy instruments implemented between 1995 and 2001 but not from regime changes of other endogenous variables of economic structure.

Contrast to previous studies, we can avoid these misled results and see the presence or absence of effect of regime switches to the fluctuation of two policy instruments by comparing the two VAR models. If we successfully see common regimes in the two VAR models with and without monetary policy instruments, it is evidence that regimes estimated in a five-variable VAR model can be robust estimation extracted both from factors of policy instruments and from factors of macroeconomic structure. This point is the reason why we estimate the two VAR models with and without monetary policy instruments.

3 In July 1995, the BOJ shifted from a discount lending policy to open market operations. Until June 1995, the discount rate remained below the call rate (interest rate of the interbank call market), whereas it remained above the call rate after July 1995, when the BOJ implemented a low-interest-rate policy.

For estimating regime changes in macroeconomic structure and monetary policy, following Fujiwara (2006) and Inoue and Okimoto (2008), this paper adopts a Markov-switching VAR model (hereafter MS VAR model). Their works, however, restricted the number of regimes to two states or at most three states, whereas we do not restrict the number of regimes, and we estimate how many regimes have existed over the last 25 years in the Japanese economy. As Sims and Zha (2006) pointed out, the advantage of the MS VAR model is that we can examine changes in the rational behavioral structure of the macroeconomy and monetary policy, which are predicted to regime-switch probabilistically, not to switch monotonically. On the other hand, the traditional structure-change model regards these changes as one-time-only nonstochastic regime switches. [4]

Furthermore, most empirical studies, including Fujiwara (2006) and Inoue and Okimoto (2008), used IIP, which only includes the activity of the manufacturing sector as real output. Using IIP presents various problems including excessive investment in the nonmanufacturing sector in the bubble period, and a recent tendency of discrepancy between IIP and GDP, which raises the question of whether IIP is the appropriate variable to measure activity in the goods markets. This paper employs IAA, which includes activity in the nonmanufacturing sector as well as the manufacturing sector.

The remainder of this section describes the econometric method used in this paper: (1) definition and estimation methodology of an MS VAR model, and the specification of the number of regime changes, (2) data description, (3) identification of a MS VAR model, and (4) derivation of impulse response functions in an MS VAR model.

(1) MS VAR model

In this paper, a reduced VAR model is derived from a Markov-switching VAR model with a p lag order and with m regimes (hereafter MS(m)-VAR(p) model), which was developed by Hamilton (1989). In these VAR models, all parameters such as the constant terms v_i , coefficients B_{pi} and variance covariance matrices $\sum_i$ switch among the m regimes following a hidden Markov chain. This MS(m)-VAR(p) model is expressed as equations (1), (2), (3) and (4).

4 As an alternate method to the MS VAR model, time-varying parameter VAR models were estimated by Primiceri (2005) and Kimura et al. (2003). Although their impulse response functions were derived from these results, these studies showed the effect of policy at one point in time. It does not consider the effects of policy change. On the other hand, the impulse responses of the MS VAR model are adequate to evaluate the effect of policy change. Another model is the smooth transition VAR used by Kasuya (2003) to study the effect of monetary policy.

$$Y_t = \begin{cases} v_1 + B_{11} \quad Y_{t-1} + \cdots + B_{p1} Y_{t-p} + B_{x1} \quad X_t + A_1 u_t, & \text{if} \quad S_t = 1, \\ \vdots & \\ v_m + B_{1m} Y_{t-1} + \cdots + B_{pm} Y_{t-p} + B_{xm} \quad X_t + A_m u_t, & \text{if} \quad S_t = m, \end{cases} \tag{1}$$

$$u_t \sim N(0, I_K),$$

where Y_t and X_t denote endogenous variables and exogenous variables, respectively. In this MS VAR model, we set the trend and dummy variables as exogenous variables. Furthermore, subscript *K* denotes the number of variables, *m* is the number of regimes and S_t denotes the regime identifier in period *t* and is assigned a number from *1* to *m*. $A_i u_t$ represents the disturbance terms of regime *i* in period *t*. Although the elements u_t follow an independent standard normal distribution, a matrix A_i has different values in each regime *i*. From the disturbance terms $A_i u_t$, the variance covariance matrix $\sum_i$ can be represented as equation (2).

$$\textstyle\sum_i = E(A_i u_t u_t' A_i') = A_i E(u_t u_t') A_i' = A_i I_K A_i' = A_i A_i' \tag{2}$$

Next, we consider the mechanism of regime switching in VAR models such as equation (1). It is assumed that the state variables S_t follow a hidden *m*-state Markov chain, and that the probabilities of transition to a regime *j* in the next period conditional on a regime *i* in the present time are exogenous and constant. Then, the conditional transition probabilities of regime S_t and the transition probabilities matrix can be represented as equations (3) and (4), respectively.

$$\Pr(S_{t+1} = j \mid S_t = i) = p_{ij} \tag{3}$$

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \cdots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mm} \end{bmatrix} \tag{4}$$

In this way, according to the hidden *m*-state Markov chain, the regime in period *t*, S_t, can continue or switch based not on the influence of other factors such as the endogenous variables but only on the transition probabilities matrix (4) in a MS VAR model.

Because state variables, S_t, are unobservable variables, we must also estimate them as well as the parameters. To do so, we use the Hamilton filter (Hamilton, 1989) and Kim smoother (Kim, 1993), which are quite general methods for estimating unobservable variables S_t. Furthermore, Hamilton (1990) proposed an EM-algorithm, a kind of maximum likelihood estimator, for estimating an MS model, because it is quite effective and easy for estimating parameters and filtering the state variables S_t simultaneously. We follow Hamilton (1990).[5]

The hardest task in estimating an MS model is specifying the numbers of regimes, because it is known that the distribution of the likelihood ratio (LR) test in MS models might not converge to the asymptotic standard chi-square distribution. Hansen (1992) and Garcia (1998) struggled with this issue. Unfortunately, this issue requires the implementation of a Monte Carlo simulation for obtaining the critical values of the LR test. Accordingly, it is impractical to derive empirical distributions of the LR test for all MS-VAR models that we want to examine. Inoue and Okimoto (2008) specified the number of regimes using the Akaike information criterion (AIC) from the Bayesian view, although they estimated the MS-VAR model using Bayesian inference via MCMC (Markov Chain Monte Carlo). On the other hand, Fujiwara (2006) adopted the Schwarz Bayesian information criterion (SBC) to specify the lag order, although he restricted his analysis to two regimes *a priori*. Accordingly, we follow them by adopting these two criterions, AIC and SBC, for specifying the lag order and number of regimes.[6]

(2) Data description and sample period

We use monthly data following previous studies such as Fujiwara (2006) and Inoue and Okimoto (2008). As pointed out above, one feature of our study is the use of the seasonally adjusted IAA excluding agriculture, forestry and fisheries as a measure of monthly real output. The coefficient of correlation between IAA and quarterly real GDP is 0.992, while that of IIP and real GDP is 0.913 (Figure 1 (d)). The fluctuations in IAA could be much closer to the movement of real GDP than his counterpart. The derivation of IAA is described in more detail in the data appendix section at the end of this paper.

Furthermore, we use a consumer price index excluding perishables (CPI, 2005 average = 100) to measure the price level, and M2+CD [7](average amounts outstanding) as the money supply. The two policy indicators are the call rate (Call, an overnight interest rate of the interbank call market, monthly average), and monetary base (MB, average amounts outstanding). All variables, excluding the call rate, are seasonally adjusted by Census X12. The sample period is from January 1980 to April 2007.

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5 For estimating the MS VAR models, we use the OX software and the MS-VAR package developed by J. Doornick and H-M. Krolzig.

6 Krolzig (1997) showed how to specify the lag orders and the number of regimes. According to him, first specify the lag orders from a linear AR model using the SBC or AIC, then specify the number of regimes. However, as can be seen from Tables 1 and 2, even using this procedure, adequate lag orders and number of regimes for the MS models cannot be found.

7 The discontinuity because of the change of definition of financial institutions is adjusted.

We estimate both MS VAR models in levels for all variables.[8] For IAA, CPI and Call, raw data are used because the former two variables are indexes, and the latter is expressed as a percentage. M2+CD and MB are transformed into natural logarithms and are multiplied by 100.[9] In addition, the dates of the adoption and hike of the consumption tax, April 1989 and April 1997 respectively, are included as dummy variables in both MS VAR models. Furthermore, we estimate the MS VAR models with various kinds of data processing, but we cannot find any economically meaningful changes compared with our original models.[10]

(3) Identification of MS-VAR models

To structuralize VAR model for estimating the effect of monetary policies, Christiano, Eichenbaum, and Evans (1999) adopted and recommended the Choleski decomposition. Our models also use a Choleski decomposition following them.[11]

As mentioned above, the value of the variance covariance matrix $\sum_i$ of the MS-VAR model depends on regime *i* and switches between regimes, and this matrix is the product of the matrix of disturbance term A_i as can be seen from equation (2). By estimation, the matrix $\sum_i$ is derived first, and then the matrix A_i is derived using the matrix $\sum_i$ as in equation (2). The

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8 Sims and Zha (2006) and Fujiwara (2006) estimated in levels, and Sims (1992) recommended using level data. On the other hand, Inoue and Okimoto (2008) employed the first difference following Miyao (2000). However, according to Hamilton (1994, p. 167–172), data processing by first difference omits low-frequency factors including the trend component. As a result, it is difficult to isolate regime changes of macroeconomic structure from the trend. Therefore, we follow the former author's approaches.

9 We also estimate models using the logarithm of all variables except the call rate. However, there is no distinct difference from the original models.

10 We also estimate models using various kinds of detrending methods for the IAA, MB, and M2+CD, including the HP and Band Pass filters. According to Canova (2007, chapter 3), for nonstationary variables in the model, the HP and Baxter King filters mistake part of the trend component for the cyclical component of the series. Furthermore, because the Baxter King filter involves two-sides filtering, the disadvantage is that more recent data cannot be used. Therefore, Canova (2007) recommended the Band Pass filter proposed by Christiano and Fitzgerald (2003), which overcomes the problems of nonstationarity and two-sidedness. We use the Christiano and Fitzgerald filter.
However, Miyao (2006) pointed out that the HP and Band Pass filters cannot separate the output gap (cyclical component) from real GDP in Japan, because the trend is kinked according to their empirical result by estimating a production function for Japan. In fact, the output gap derived from a Cobb-Douglas production function at the BOJ or the Cabinet Office is quite different from the cyclical component of the HP filter. Unfortunately, because these data are quarterly not monthly, we cannot use them. Accordingly, based on his theory, we use a linear trend as an exogenous variable in the MS VAR model. In the case of the MS VAR model, the slope of the trend also switches as well as the coefficients of the endogenous variables.

11 Christiano, Eichenbaum, and Vigsson (2007) pointed out that an advantage of the Choleski decomposition is that the identification of short-run restrictions such as the Choleski decomposition is superior in terms of robustness to long-run restrictions such as the Blanchard and Quah (1989) decomposition.

matrix A_i possesses K^2 elements, whereas the symmetric matrix $\sum_i$ contains only *K(K+1)/2* elements. To derive the matrix A_i, *K(K–1)/2* restrictions are required for the matrix A_i. By conducting a Choleski decomposition, these restrictions are satisfied, and the lower triangular matrix A_i is derived. In the MS-VAR model, the matrix A_i in each regime is implemented using a Choleski decomposition.

As the order of variables in VAR models influences the size and sign of the parameters of the structural VAR and the shapes of the impulse response functions in the case of the Choleski decomposition, the correct ordering of variables is important. Generally speaking, the order is decided by the order of causality among the variables, from the most influential variable to the least. And the order of a three-variable model is (1) real output, (2) the price level, and (3) money supply. Following Christiano, Eichenbaum, and Evans (1999), the order of a five-variable VAR model is: (1) real output (IAA), (2) the price level (CPI), (3) interest rate (Call), (4) monetary base (MB), and (5) money supply (M2+CD).[12]

(4) Derivation of impulse responses in the MS-VAR model

Following Ehrmann, Ellison, and Valla (2003), we calculate the "regime-dependent" impulse responses of the MS-VAR model. The "regime-dependent" impulse responses of the MS-VAR model represent the relationship between the endogenous variables and exogenous shocks within the period of one regime. In other words, we assume that one regime exists, and we do not switch to another regime, and we separate the impulse responses functions for each regime under this assumption. This is because our aim is comparing the feature of the macroeconomic structure and monetary policy in each regime and because the transition effect from one regime to another is not considered.

The impulse response after h periods for the shock of the k-th variable in regime *i* of the MS-VAR model can be written as follows:

$$\frac{\partial E_t(\ Y_{t+h})}{\partial u_{k,t}}\Big|_{st=\cdots=st+h=i} = \theta_{ki.h}\ , \qquad \text{for} \quad h \geq 0, \tag{5}$$

where the impulse responses $\theta_{ki,h}$ are K-dimensional vectors in which K is the number of variables. The impulse responses $\theta_{ki,h}$ are derived by equations (6) and (7) as follows:

12 The order between interest rates and the monetary base depends on whether we set interest rates as the policy instrument or the monetary base. If we regard interest rates as the instrument, it is followed by the monetary base and *vice versa.* The impulse response functions are not significantly different between these orderings.

$$\hat{\theta}_{ki,0} = \hat{A}_i \quad u_0 \, , \tag{6}$$

$$\hat{\theta}_{ki,h} = \sum_{j=1}^{\min(h,p)} B_{ji}^{h-j+1} \hat{A}_i u_0 \, , \qquad \text{for} \quad h \geq 0 \, , \tag{7}$$

where the value of the coefficient B_{pi} and the matrix of A_i are different in each regime. Accordingly, the number of impulse response functions $\theta_{ki,h}$ is mK^2.[13]

III. Empirical Results

(1) Deciding the number of regimes

To begin with, we consider the appropriate number of regimes. Previous studies considered only two regimes as stated in Section 1. Figure 2 plots the smoothed probabilities from two to five regimes. In fact, if we set the number of regimes equal to two, we find that there exists a structural break in regimes around the middle of the 1990s as Miyao (2000) and others pointed out. It was around the middle of the 1990s when the BOJ introduced the low-interest-rate policy. This means that the sample period can be divided into the low-interest-rate period and the prior period according to this view. However, we cannot necessarily conclude that there exist only two regimes.

*** Insert Figure 2 about here ***

Table 2 shows that four regimes has the lowest AIC, and in the case of the three variable model shown in Table 1, there is little difference in the values of the AIC from three regimes to five regimes. Therefore, we conduct our analyses assuming four regimes. Figure 3 displays the smoothed probabilities of the three-variable model and Figure 7 those of the five-variable model.

*** Insert Table 1 about here ***

*** Insert Table 2 about here ***

Based on the above consideration, we find that the sample period can be divided into the following four regimes.

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13 The error bands of the impulse response are calculated from 500 samples generated by Monte Carlo simulation, and the 68% band (or one standard deviation error band) are depicted following Christiano et al. (1996), Miyao (2000, 2002) and Inoue and Okimoto (2008).

[1] The stable growth regime until around the middle of the 1980s and before the bubble era. (We call this Regime I in the following discussion.)

[2] The boom regime in the 1990s (the bubble era and the semi-boom period until around the middle of the 1990s). (We call this Regime II.)

[3] The depression regime in the 1990s (the period following the burst of the asset price bubble and the period of so-called financial crisis). (We call this Regime III.)

[4] The quantitative easing policy regime in the 2000s after the zero-interest-rate policy (1999). (We call this Regime IV.)

It is noteworthy that we cannot find any structural breaks around the middle of the 1990s, contrary to the previous studies that set the number of regimes equal to two.

Besides, as shown particularly in the case of the five-variable model (Figure 7), Regime I (item [1] above) and Regime IV (item [4] above) can be clearly separated in chronological order in the sample as a whole, although the duration of Regime II (item [2] above) is somewhat different according to the models, and the smoothed probability of Regime II and that of Regime III (item [3] above) interchange with each other in the 1990s. This tendency is almost true of the other models and for other than four regimes. Thus, we may say that our model is closer to the state of continuous structural changes than one of regime switching.

*** Insert Figure3 about here ***

*** Insert Figure7 about here ***

That is to say, it is revealed that Regime I (the stable growth regime) and Regime IV (the quantitative easing policy regime) are almost stable regimes. With respect to the judgment as to the boom and depression in the 1990s, however, we need to pay attention because there also exist the following cases in other specifications of models that are not shown here.

[2′] The bubble regime until around 1991.

[3′] The burst of the bubble regime until around the so-called "global IT bubble" in 2000.

In addition, the above Regime II can be divided into the bubble era and the semi-boom period until around the middle of the 1990s if we adopt five regimes.

(2) Impulse responses of IAA

We consider the salient features of each regime, taking into account impulse response functions. Impulse responses of IAA to monetary policy variable shocks are as follows.

(2-i) M2+CD shock not controlling other operating instruments

The results of the three-variable models show that impulse responses of IAA to a M2+CD shock is the highest in Regime II, and it declines with the order being Regime I, Regime III, and Regime IV (Figure 6).

(2-ii) Call shock

Turning to the impulse response of IAA to a Call shock in the five-variable model, Regime II and Regime III have the almost the same shape of response, which shows a more significant effect in the latter regime. In Regime IV, the impulse response of IAA to a Call shock is positive, suggesting that an increase in Call leads to an expansion in IAA (Figure 10). In Regime IV, where the operating instrument is mainly MB, zero interest rates persist during most of the period. In spite of this fact, we obtain the above results. This is because Regime IV includes the period of the lifting of the zero-interest-rate policy.

*** Insert Figure 6 about here ***

*** Insert Figure 10 about here ***

(2-iii) MB shock (the quantitative easing policy)

Although the impulse response of IAA to an MB shock has a positive sign in Regime I, Regime II, and Regime III, an MB shock has only a small stimulatory effect on IAA in Regime IV (Figure 11).

(2-iv) M2+CD shock controlling other operating instruments

According to the results of the five-variable model, which controls other operating instruments such as MB and Call, the M2+CD shock has a positive effect on IAA even in Regime III (Figure 12). This implies that autonomous credit creation in the private sector has a positive impact on IAA.

In summary, the most important finding is that monetary policy has not had a stimulatory impact on IAA in Regime IV since 2000. Previous studies, which assume two regimes, argued that the effect of monetary policy gradually weakened in the latter regime. Our findings suggest that there has existed an independent regime since 2000, where monetary policy variables have had only a small positive effect on IAA.

*** Insert Figure 11 about here ***

*** Insert Figure12 about here ***

(3) Impulse response of prices

The results of the three-variable model show that the impulse response of CPI to an M2+CD shock has a negative sign in Regime III and Regime IV, suggesting the existence of the so-called "price puzzle". Call and MB shocks in Regime III also lead to the price puzzle (Figures 10 and 11). Summarizing, we can say that the price puzzle mainly occurs in Regime III. However, the impulse responses of CPI to Call and MB shocks in Regime IV are almost zero (Figure 10).

(4) Money multiplier and liquidity puzzle

With respect to the money multiplier, MB does not have a positive effect on M2+CD in Regime IV (Figure11). The phenomenon that an increase in the money supply leads to an increase in interest rates is called the "liquidity puzzle". The impulse response of Call to an MB shock shows a slightly negative sign in Regime IV, reflecting the fact that it includes the period of the lifting of the zero-interest-rate policy (Figure 11), while the liquidity puzzle is observed in other regimes.

In Regime II, which includes the bubble era, the impulse response of CPI to an M2+CD shock is significantly positive in both the three-and five-variable models, while that to Call is insignificant (Figures 6 and 10). This result suggests that credit creation in the private sector had a positive effect on CPI in the bubble era.

(5) Selection of the sample period

In the five-variable model, the sample period including the period after the lifting of the quantitative easing policy (March 2006) and that not including it show similar results. If we adopt the sample period ending March 2006, MB has a positive effect on IAA. This seems to be because the estimation not including the period after the lifting of the quantitative easing policy does not take into account the effect of a sharp decrease in MB, while the basic model including the period after the lifting of the quantitative easing policy does account for such an effect. The period after the end of the quantitative easing policy (2006~) is the third regime (depression regime, Figure7).

IV. Augmented Models

To examine the robustness of the basic model and other channels of monetary policy transmission, the basic five-variable model is augmented as follows.

(1) Six-variable model including the unemployment rate

Following Christiano, Eichenbaum and Evans (1999)[14], we estimate a six-variable model that incorporates the unemployment rate into the basic five-variable model, using the Choleski decomposition as an identification method of structural shocks and the same ordering of the endogenous variables as Christiano et al. (1999). The results are very similar to those of the basic model.

(2) Six-variable model incorporating the Nikkei Commodity Index

Fujiwara (2006) considered a model that incorporates a commodity price index in order to avoid the price puzzle, following previous US studies. Following Fujiwara (2006), we estimate a six-variable model incorporating the Nikkei Commodity Index into the basic five-variable model. The results of this model show that the difference in the shapes of regimes is negligible and that there are few changes in the effects of MB, Call and M2+CD shocks on IAA as compared with the basic model. On the other hand, the price puzzle of Call and that of MB are generated in Regime III and Regime IV respectively.

(3) Discrepancy in the yields of long- and short-term interest rates and the quantitative easing policy

In order to check the relationship between discrepancy in the yields of long- and short-term interest rates and the quantitative easing policy, we estimate a five-variable model replacing Call with the above discrepancy (differential between the yield of 10-year JGBs and Call). The results are also very similar to those of the basic model. It is noteworthy that the correlation between the MB shock and this discrepancy is positive in Regime IV, suggesting that the so-called policy duration effect through the quantitative easing policy does not necessarily work well.

(4) An alternative model replacing IAA with IIP

Finally, we estimate an alternative model replacing IAA with IIP to examine the usefulness of IAA as a comprehensive indicator of business activity. The results report that setting four regimes, we cannot find any economically meaningful changes in the regimes, especially in the period since the early 1990s, in both the three- and five-variable models. The results also show that MB has a positive impact on IIP in the period since the early 2000s. The BOJ progressively raised the target of current account balances at the BOJ during the period from early 2001 to early 2004, resulting in rapid MB growth. The latter half of this period includes in the period in

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14 Christiano, Eichenbaum and Evans (1999) use nonborrowed reserves instead of using MB, in a seven-variable model.

which the Japanese economy attained an export-led recovery. Given the close relationship between exports and IIP, the above relationship between them can be interpreted as a spurious correlation. If we add real exports to the basic five-variable model and replace CPI with the nominal effective exchange rate, we find that the response of IAA to MB has a small negative coefficient. This estimate seems to support the above-mentioned interpretation.

V. Conclusion

Using a Markov regime-switching VAR, this paper investigated the effect of monetary policy in Japan. The following five points are presented.

[1] This paper considered more than three regimes, unlike the unique regime change in the middle of the 1990s used by previous studies. We identified a pre-bubble regime (~1987), and the zero-interest-rate policy and quantitative easing regime (1999~). Although the regime changes of the 1990s vary according to our empirical specification, the unique regime change reported by the previous studies is not observed.

[2] The order of causality among our main three variables is not changed in comparing the three-variable model (IAA, CPI, M2+CD) and the five-variable model (IAA, CPI, M2+CD, MB and Call) except for the confusing quantitative easing regime. Although the previous studies showed a decreasing effect of monetary policy, this paper shows the existence of a regime in which there is no effect of monetary policy since 1999.

[3] The price puzzle is observed in the last two regimes. In these periods, it is well known that deflation was severe.

[4] No significant difference in regime changes exists when using IAA and IIP, although IIP is more sensitive to policy variables in the quantitative easing regime.

[5] The period after the end of the quantitative easing policy (2006~) is the third regime (depression regime).

The most important discovery is that the independent regime for the quantitative easing policy is identified when no policy effect exists, rather than for the regime characterized by the gradually decreasing policy effect that many previous studies considered. This result is based on standard procedures and variable selection, and no restriction on the number of regimes.

Data Appendix for the Linking IAA Series

With respect to Index of All-industry Activity except for agriculture, forestry and fisheries (2000 average = 100, IAA) published by METI, the monthly time-series data are only available since January 1987 on its Home Page. On the other hand, the former MITI published IAA on a quarterly basis prior to December 1987, when it published Index of Tertiary-industry Activity

(ITA). The compiling method used by the former MITI was to take a weighted average of ITA, which accounts for the major part of IAA and IIP because the Index of Construction Activity on a quarterly basis were not available, and to seasonally adjust it by using the MITI method III. In addition, monthly data (1980 average = 100) from January 1979 to September 1988 are also available.

In this paper, we link the monthly data series of IAA, following the former MITI's compiling method, as follows.

(1) We take a weighted average of the monthly series of IIP (1980 average = 100) and the monthly series of ITI (1980 average = 100) using the weights of IAA (1980 average = 100).
(2) We calculate the averaged link coefficient for Q1 and Q2 in 1988 for the published IAA (2000 average = 100, seasonally adjusted) on a quarterly basis and the IAA published by the former MITI on a quarterly basis (1980 average = 100, seasonally adjusted), which is the point at which the two series overlap.
(3) We calculate the original series of IAA (2000 average = 100) prior to December 1987 using the above-mentioned averaged link coefficient. We find that the difference between the current series and the connected series in January–September 1988, when both series overlap, is negligible.
(4) Using the above original series prior to December 1987 and the current original series since January 1988, we seasonally adjust the original series for the period from January 1980 to February 2008 using X-12ARIMA.

Thus we can obtain the connected series of Index of All-industry Activity except for agriculture, forestry and fisheries (2000 average = 100, IAA, seasonally adjusted). Figure 13 plots both the connected seasonally adjusted series and the published seasonally adjusted series. We find a very minor discrepancy between the series for the period since January 1988 because of the difference in the methods of seasonally adjusting. Although the series prior to December 1987 do not include the Index of Construction Activity, we find no difficulty in identifying the basic trend of IAA because of the former's low weight. As for construction activity, the METI has changed the estimation methods frequently since 1988.

*** Insert Figure 13 about here ***

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Table 1. Loglikelihood, SBC and AIC in the Three Variables Models.

		Lag Order 1	Lag Order 2	Lag Order 3	Lag Order 4	Lag Order 5
Linear VAR Model	Log Likelihood	−434.572	−373.027	−340.019	−313.477	−308.505
	SBC	3.083	2.874	2.840 *	2.845	2.984
	AIC	2.805	2.491	2.351	2.250 *	2.282
Two Regimes Model	Log Likelihood	−352.015	−309.543	−284.96	−262.284	−253.492
	SBC	3.038	3.106	3.284	3.475	3.752
	AIC	2.459	2.316	2.283	2.261	2.325
Three Regimes Model	Log Likelihood	−337.901	−287.586	−259.526	−218.224	−202.36
	SBC	3.448	3.628	3.946	4.184	4.58
	AIC	2.544	2.409	2.409	2.329	2.405
Four Regimes Model	Log Likelihood	−323.672	−275.716	−246.177	−155.934	−149.169
	SBC	3.892	4.248	4.718	4.816	5.431
	AIC	2.64	2.575	2.623	2.296	2.484
Five Regimes Model	Log Likelihood	−289.365	−239.024	−205.339	−137.357*	−152.949
	SBC	4.249	4.75	5.357	5.754	6.671
	AIC	2.626	2.601	2.679	2.545	2.929
Six Regimes Model	Log Likelihood	−309.225	−232.574	−208.257	−165.725	N.A.
	SBC	4.972	5.474	6.3	7.018	
	AIC	2.956	2.826	3.017	3.097	

Note: Two dummy variables of the dates of adoption and hike of consumer tax add as regressors including endogenous variables in each VAR model. SBC and AIC denote Schwarz Bayesian information criterion, and Akaike information criterion, respectively.

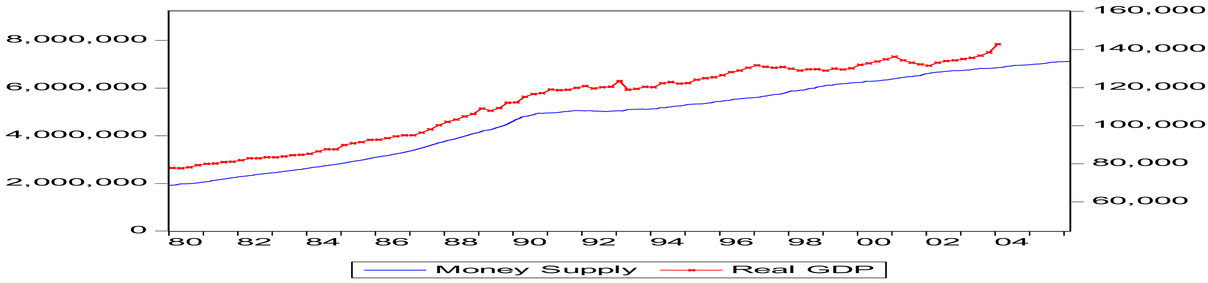
Asterisk represents the fittest Model selected by each criterion. And N.A. represents the model we can not estimate because of encountering non-singular matrix.

Table 2. Loglikelihood, SBC and AIC in the Five Variables Models.

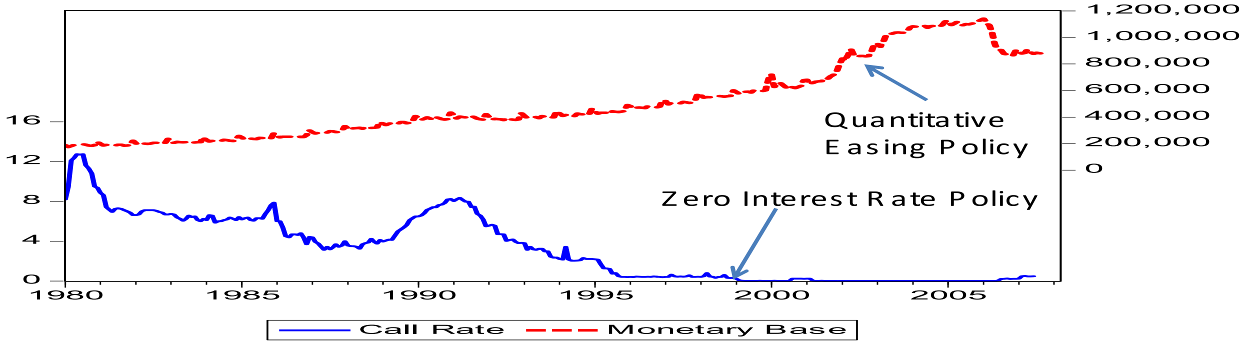
		Lag Order 1	Lag Order 2	Lag Order 3	Lag Order 4	Lag Order 5
Linear VAR Model	Log Likelihood	−1033.864	−961.742	−881.788	−844.082	−827.52
	SBC	7.297	7.32	7.295	7.53	7.897
	AIC	6.66	6.391	6.073	6.013	6.084
Two Regimes Model	Log Likelihood	−874.217	−789.492	−722.042	−660.557	−614.662
	SBC	7.33	7.719	8.216	8.752	9.387
	AIC	6.032	5.837	5.748	5.695	5.738
Three Regimes Model	Log Likelihood	−625.384	−537.417	−446.585	−416.688	−360.153
	SBC	6.853	7.664	8.461	9.638	10.655
	AIC	4.871	4.806	4.724	5.017	5.147
Four Regimes Model	Log Likelihood	−421.852	−470.373	−296.976 *	−1103.261	−1127.55
	SBC	6.688 *	8.779	9.516	16.302	18.287
	AIC	3.999 *	4.923	4.486	10.094	10.895
Five Regimes Model	Log Likelihood	−404.194	−353.182	−293.855	−780.387	−718.389
	SBC	7.696	9.622	11.507	16.771	18.669
	AIC	4.276	4.743	5.162	8.953	9.371
Six Regimes Model	Log Likelihood	N.A.	−1094.208	−1062.787	N.A.	N.A.
	SBC		15.766	18.286		
	AIC		9.842	10.602		

Note: Two dummy variables of the dates of adoption and hike of consumer tax add as regressors including endogenous variables in each VAR model. SBC and AIC denote Schwarz Bayesian information criterion, and Akaike information criterion, respectively.

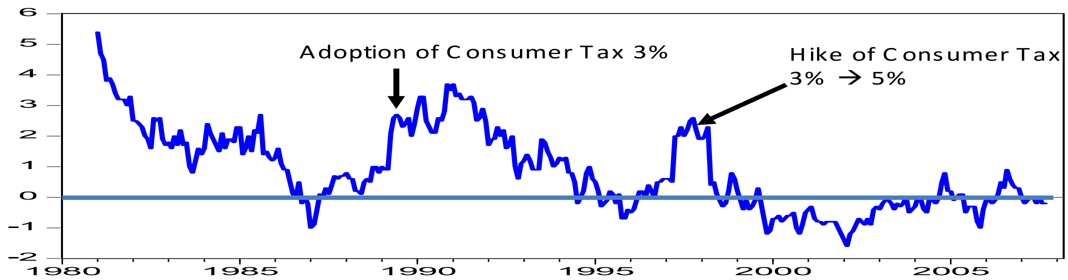
Asterisk represents the fittest Model selected by each criterion. And N.A. represents the model we can not estimate because of encountering non-singular matrix.



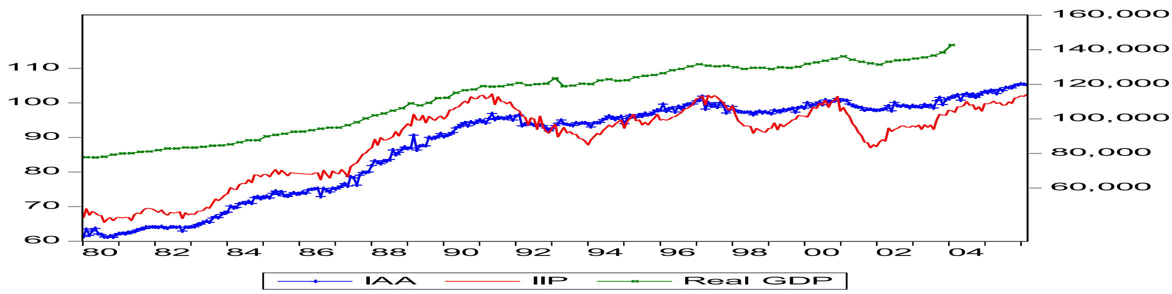
(a) Real GDP and Money Supply



(b) Call Rate and Monetary Base



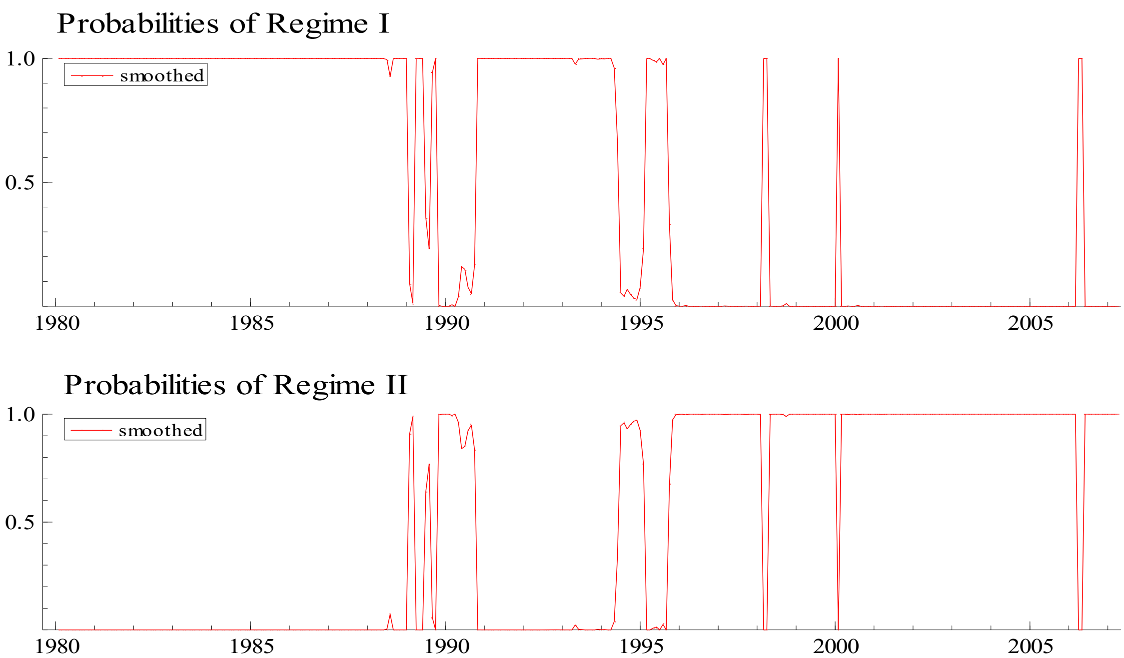
(c) CPI Inflation



(d) Real GDP, IAA and IIP

Figure 1

(a) Two Regime Model (MS(2)-VAR(1) Model)



(b) Three Regime Model (MS(3)-VAR(1) Model)

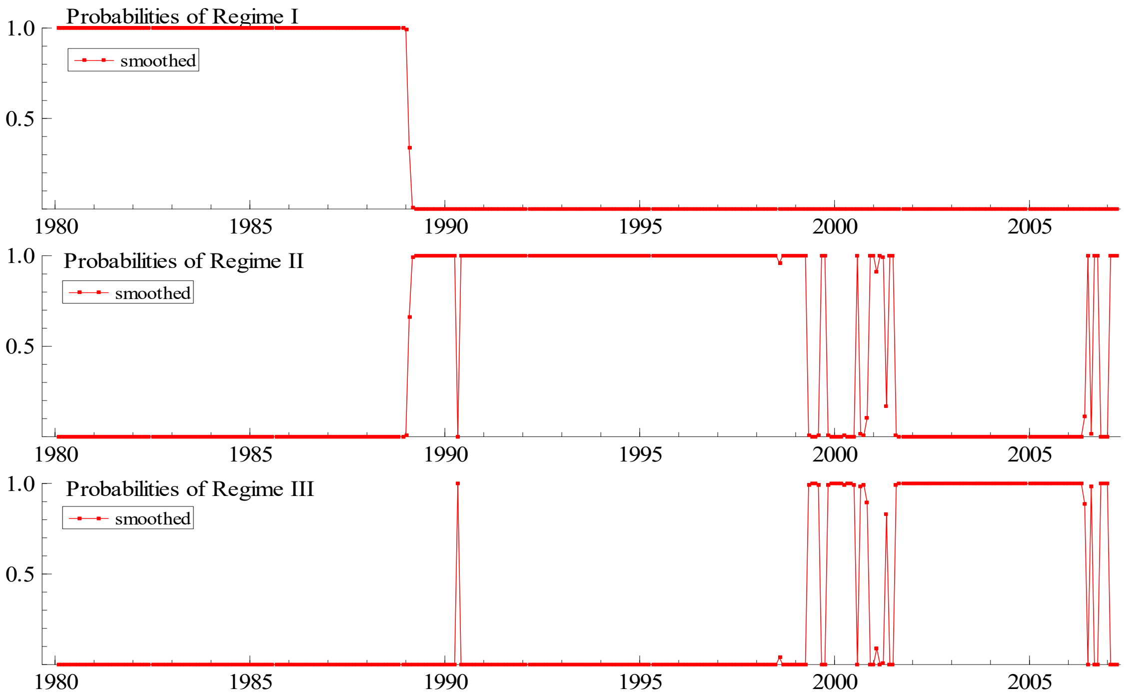
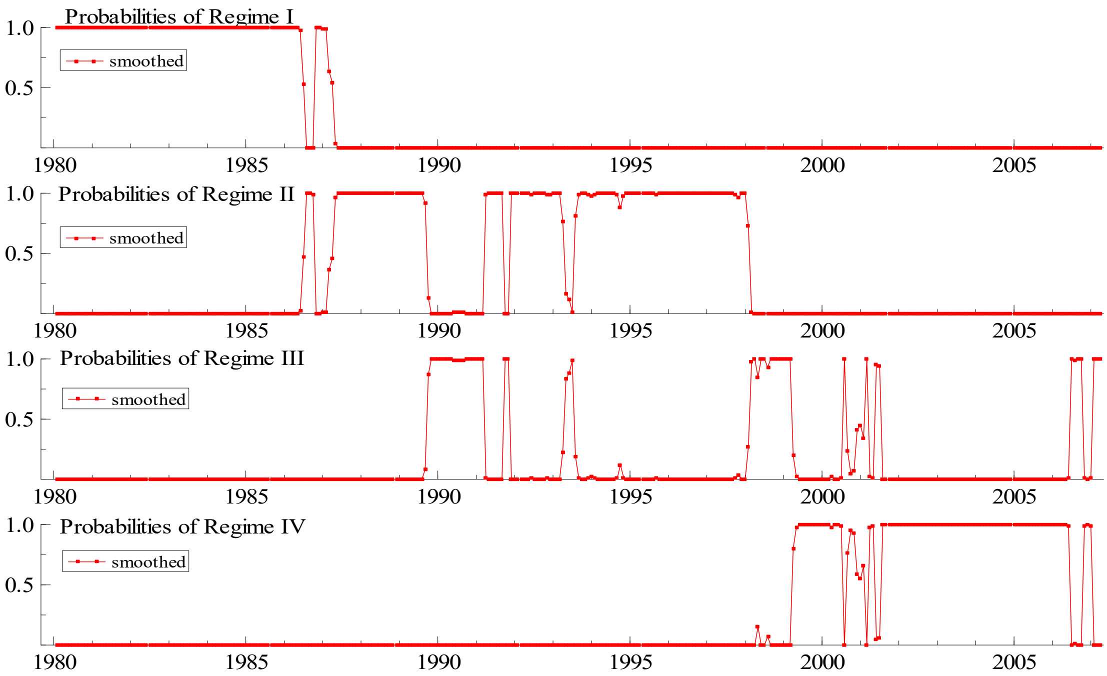


Figure 2. Regime Probabilities in the Five Variable Model

(c) Four Regime Model (MS(3)-VAR(1) Model)



(d) Five Regime Model (MS(3)-VAR(1) Model)

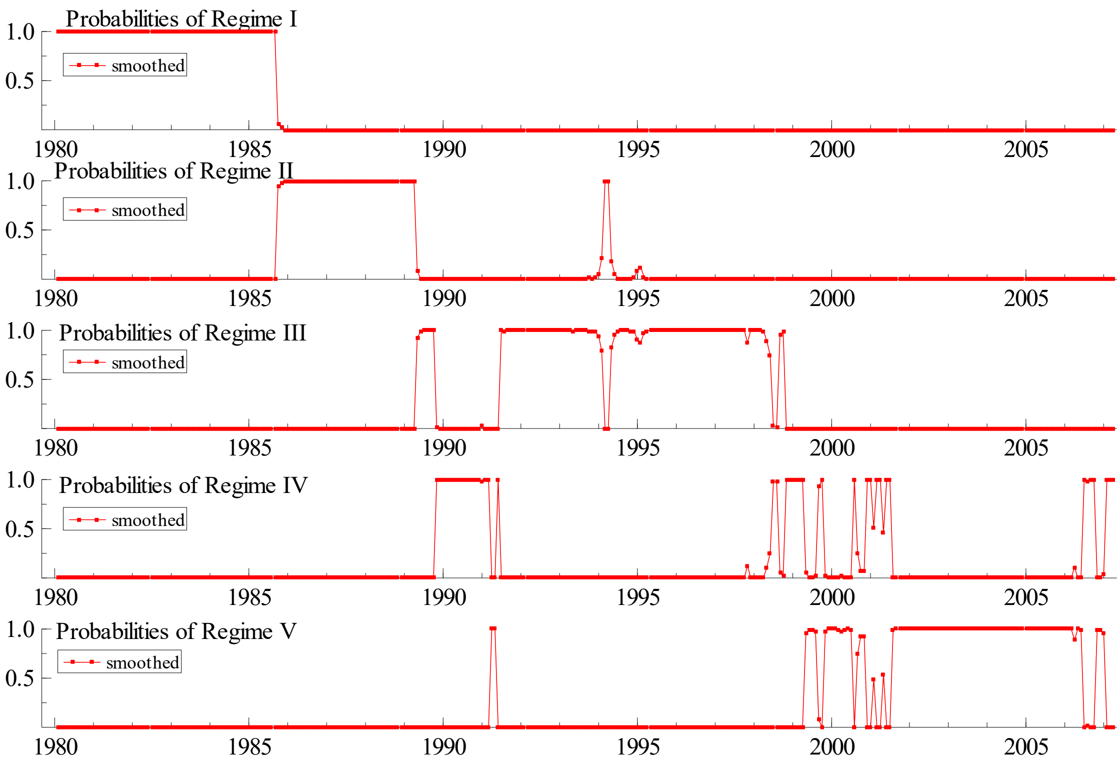


Figure 2. (continued)

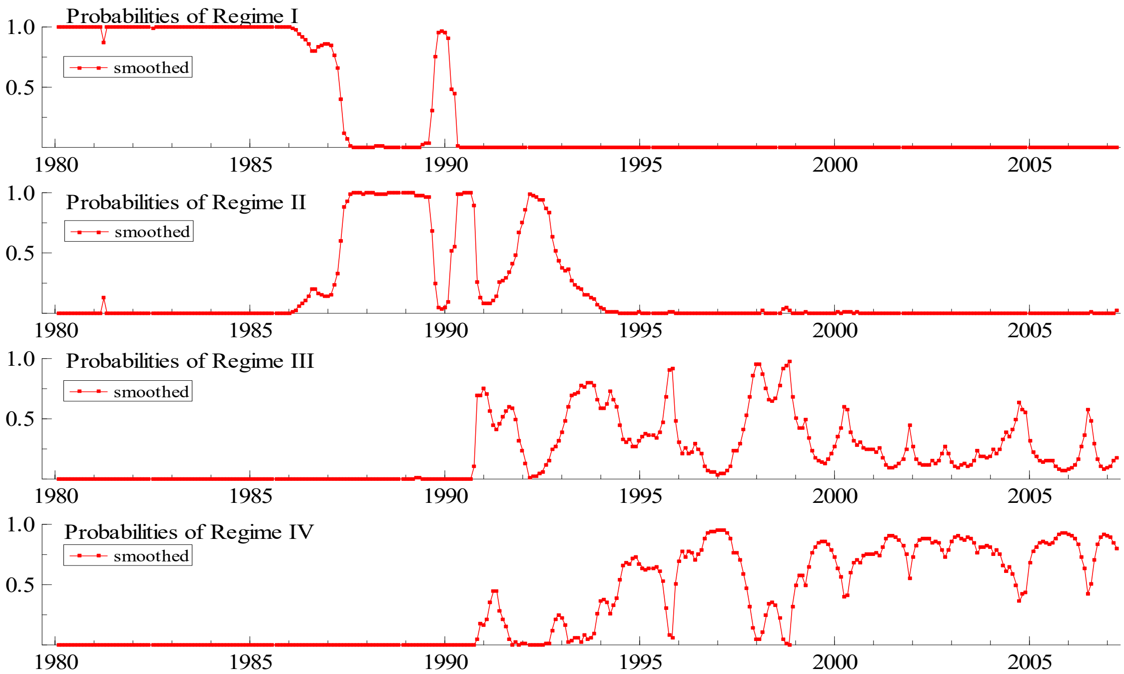


Figure 3. Smoothing Probabilities of Regimes in Three variable Model

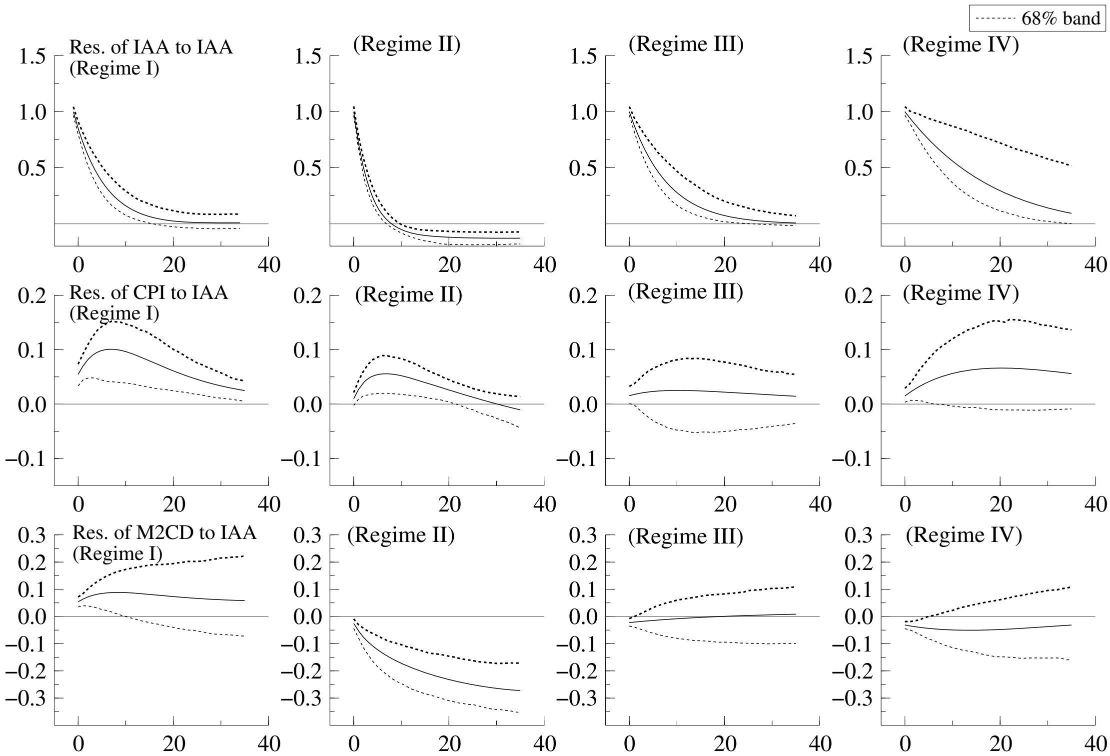


Figure 4. Impulse Response of Three Variables to Output Shock

in Three Variable Model

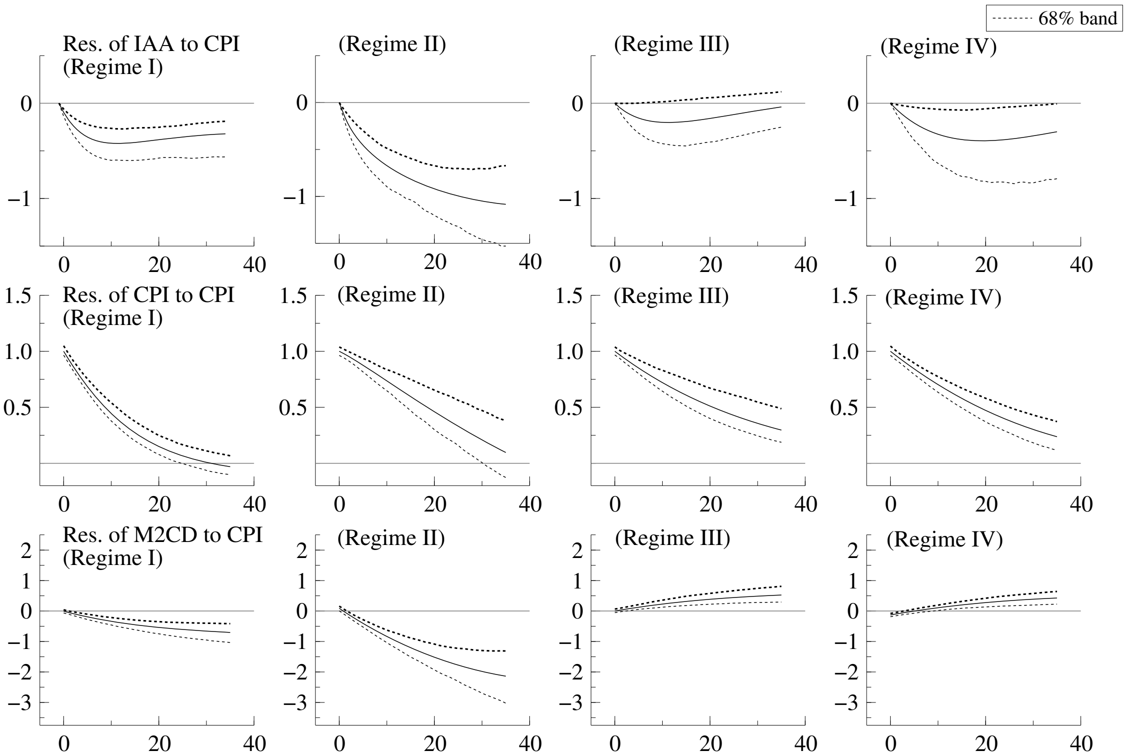


Figure 5. Impulse Response of Three Variables to Price Level Shock in Three Variable Model

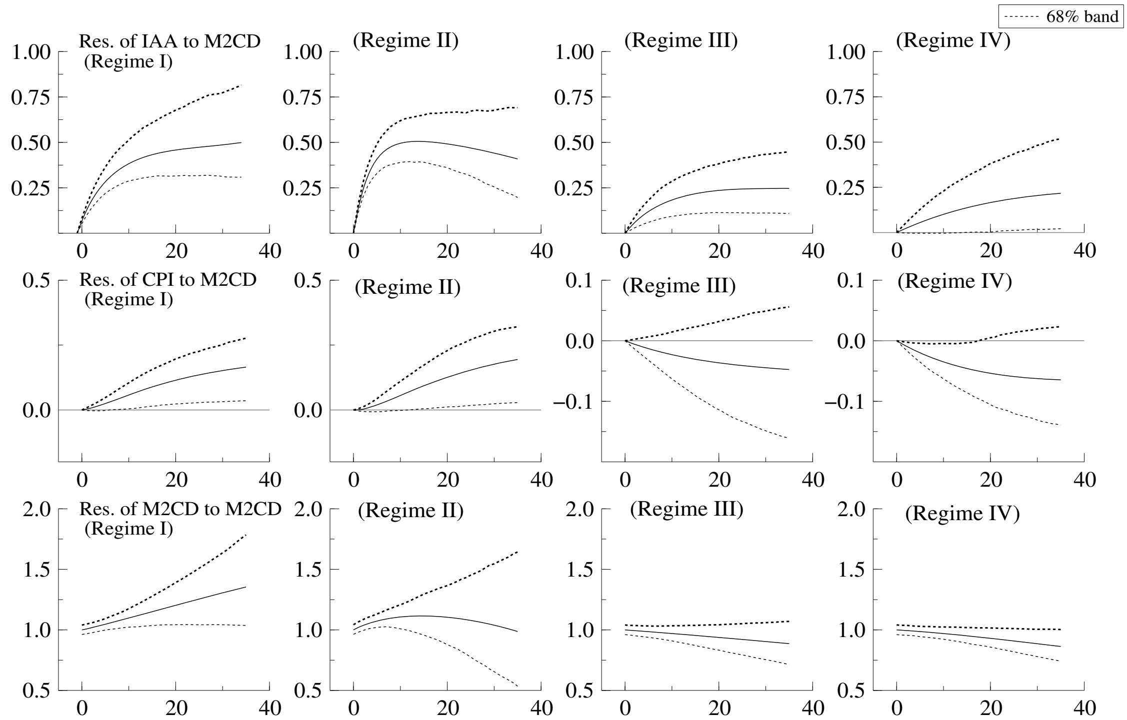


Figure 6. Impulse Response of Three Variables to Money Supply Shock

in Three Variable Model

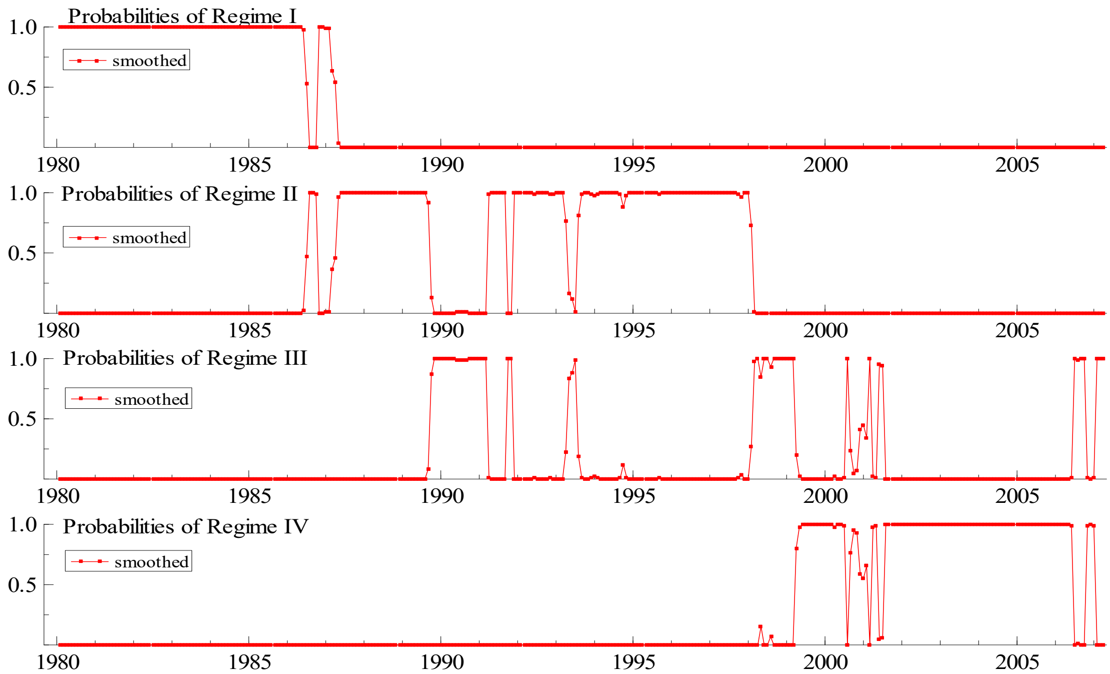


Figure 7. Smoothing Probabilities of Regimes in Five variable Model

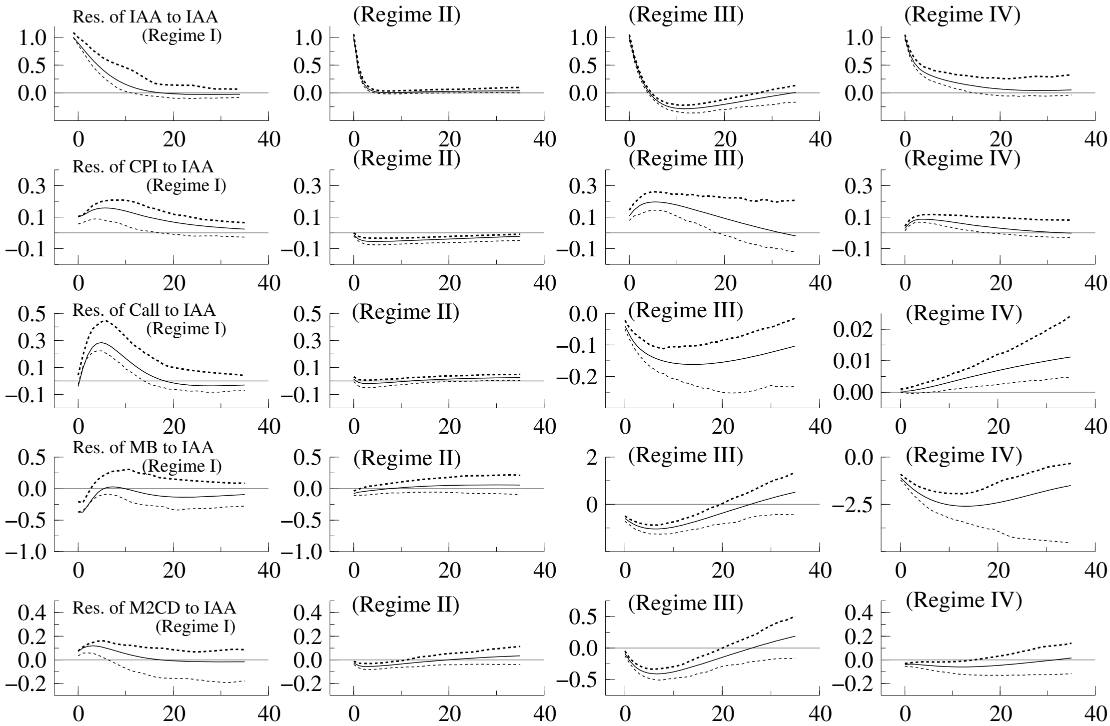


Figure 8. Impulse Response of Five Variables to Output Shock

in Five Variable Model

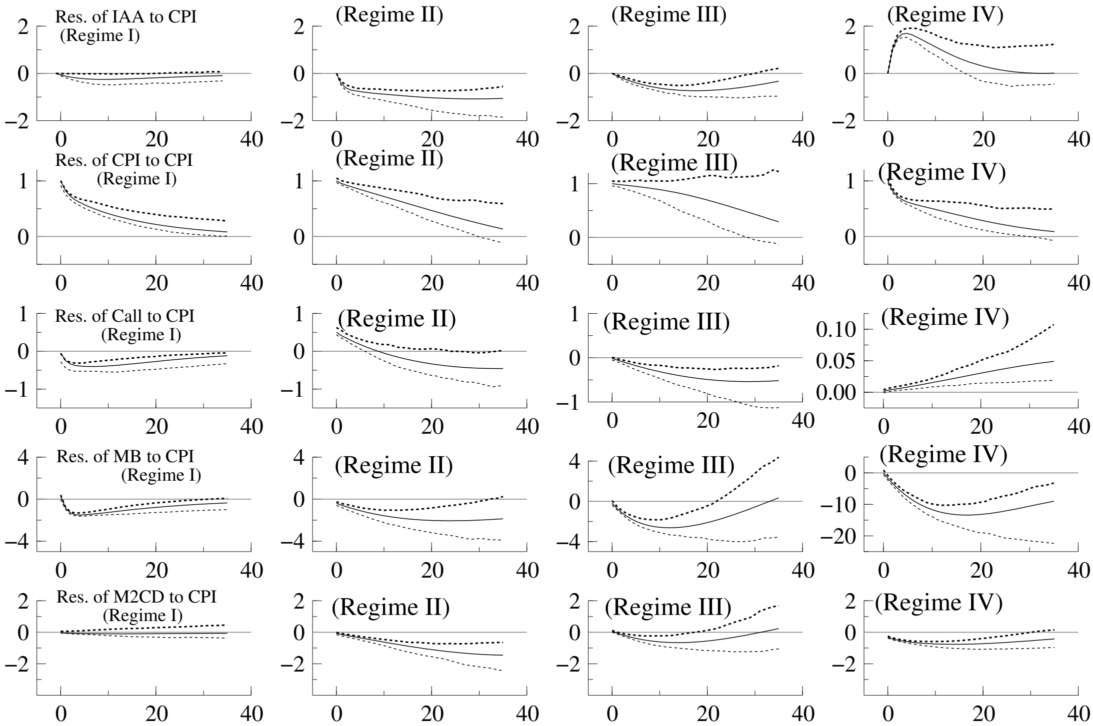


Figure 9. Impulse Response of Five Variables to Price Level Shock

in Five Variable Model

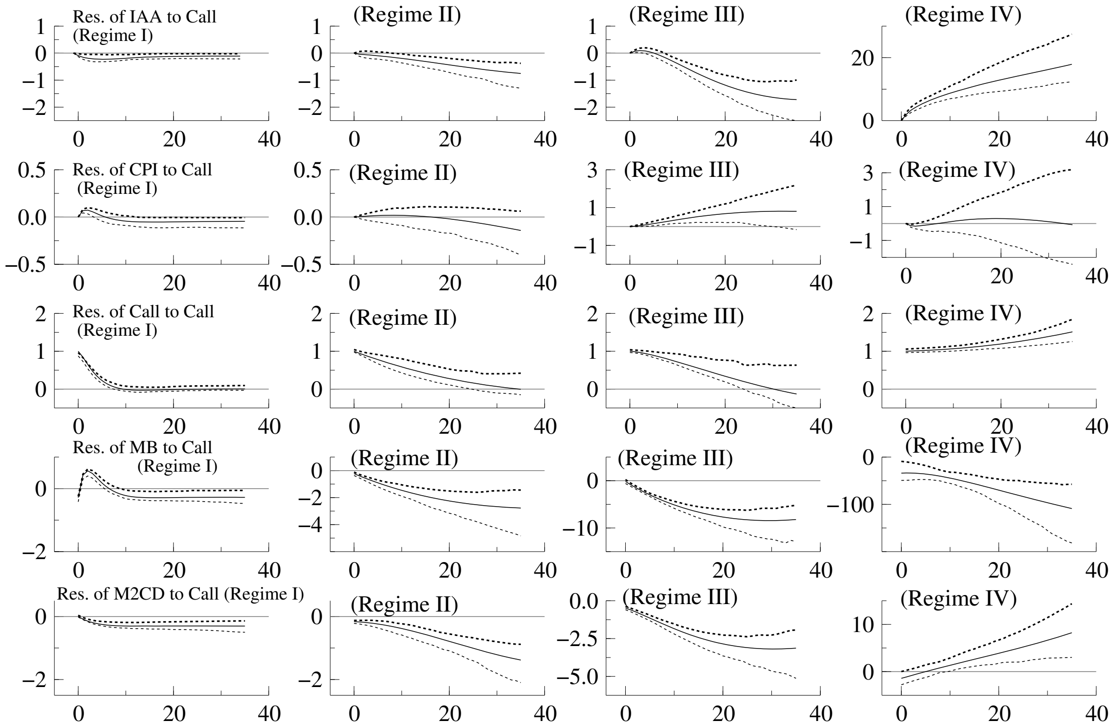


Figure 10. Impulse Response of Five Variables to Interest Rate Shock

in Five Variable Model

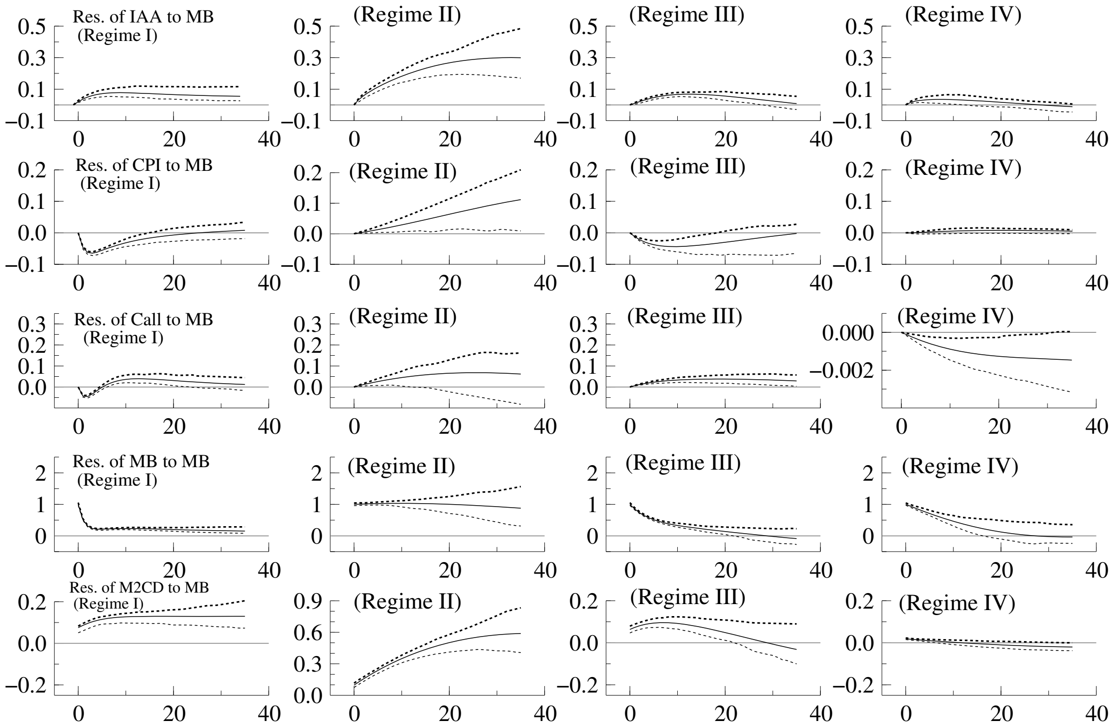


Figure 11. Impulse Response of Five Variables to Monetary Base Shock in Five Variable Model

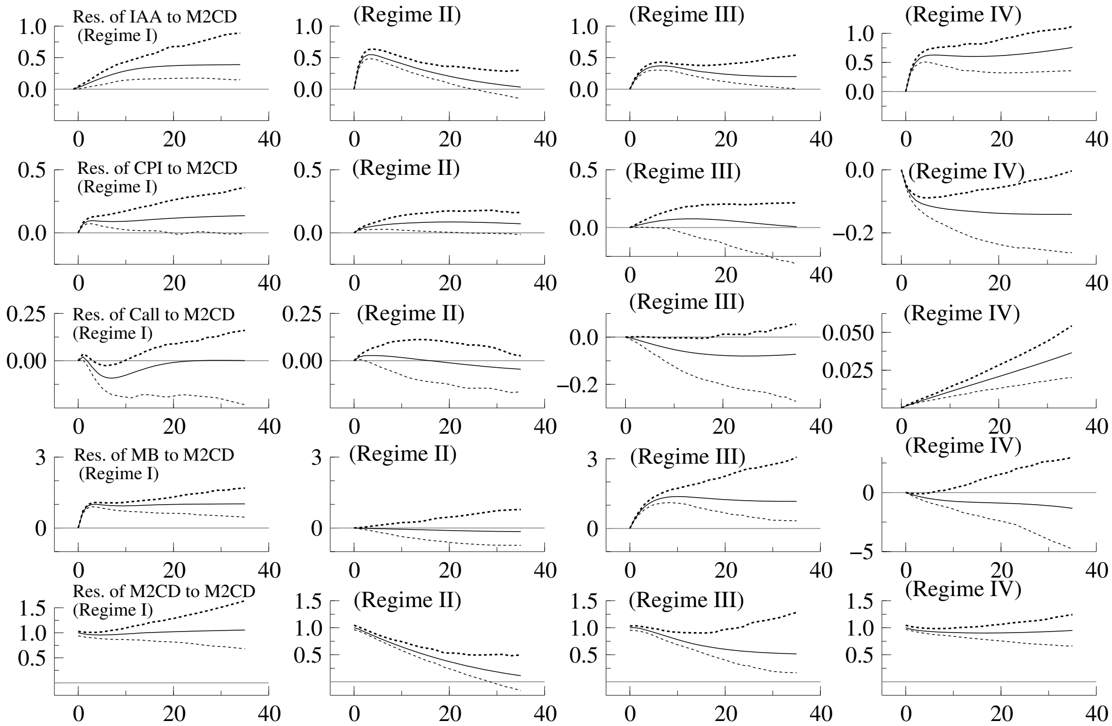


Figure 12. Impulse Response of Five Variables to Monetary Supply Shock

in Five Variable Model

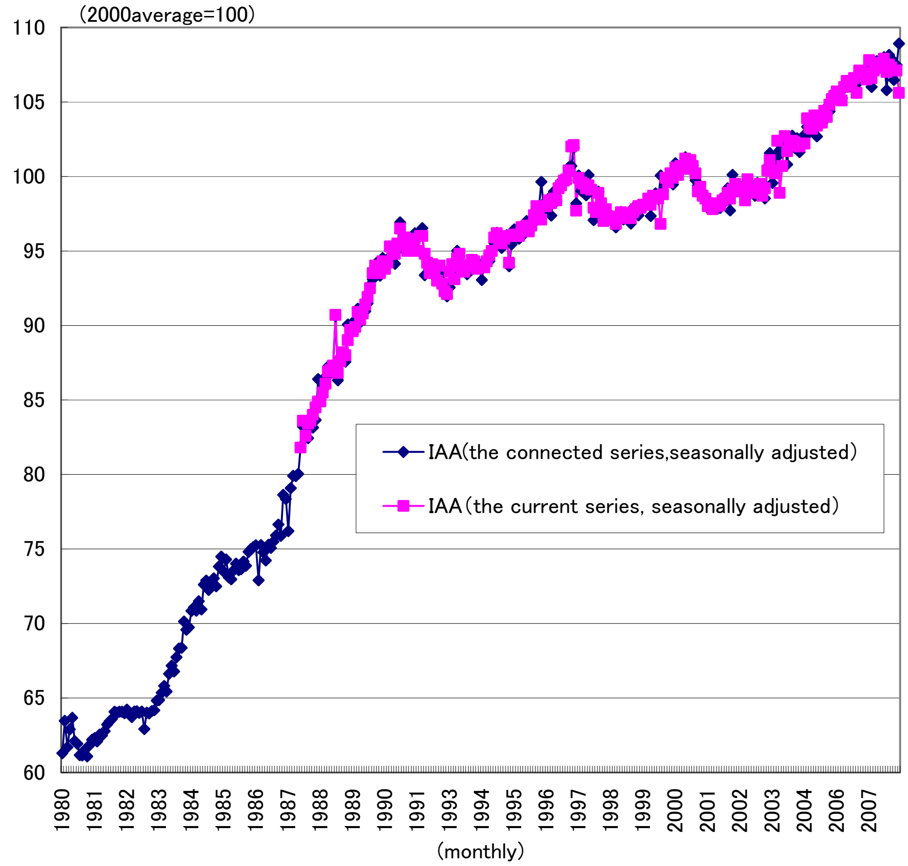


Figure13. The comparison of the current and the connected series of IAA