IMES DISCUSSION PAPER SERIES

The Effects of Japanese Monetary Policy Shocks on Exchange Rates: A Structural Vector Error Correction Model Approach

Kyungho Jang and Masao Ogaki

Discussion Paper No. 2002-E-15

IMES

INSTITUTE FOR MONETARY AND ECONOMIC STUDIES

BANK OF JAPAN

C.P.O BOX 203 TOKYO
100-8630 JAPAN

IMES Discussion Paper Series 2002-E-15
September 2002

The Effects of Japanese Monetary Policy Shocks on Exchange Rates: A Structural Vector Error Correction Model Approach

Kyungho Jang* and Masao Ogaki†

Abstract

This paper investigates the effects of shocks to Japanese monetary policy on exchange rates and other macroeconomic variables, using structural vector error correction model methods with long-run restrictions. Long-run restrictions are attractive because they are more directly related to economic models than typical recursive short-run restrictions that some variables are not affected contemporaneously by shocks to other variables. In contrast with our earlier study for U.S. monetary policy with long-run restrictions in which the empirical results were more consistent with the standard exchange rate model than those with short-run restrictions, our results for Japanese monetary policy with long-run restrictions are less consistent with the model than those with short-run restrictions.

Keywords: Vector Error Correction Model, Impulse Response, Monetary Policy Shock, Cointegration, Identification, Long Run Restriction

JEL Classification: E32, C32

* The University of Alabama at Birmingham, Department of Finance, Economics and Quantitative Methods, Birmingham, AL 35294. Tel. (205) 934-8833, Fax: (205) 975-4427, E-mail: kjang@business.uab.edu.

† The Ohio State University, Department of Economics, Columbus OH 43210. Tel: (614) 292-5842, Fax: (614) 292-3906, E-mail: mogaki@econ.ohio-state.edu.

We thank Mr. Shigenori Shiratsuka, an anonymous referee, and seminar participants at the Bank of Japan for helpful comments and Mr. Toyoichiro Shirota for his research assistance regarding the data used in this study.

1 Introduction

This paper examines the effects of shocks to Japanese monetary policy on exchange rates and other macroeconomic variables, using structural vector error correction model (VECM) methods. The standard exchange rate model (see, e.g., Dornbusch, 1976) predicts that a contractionary shock to Japanese monetary policy leads to appreciation of the Japanese currency both in nominal and real exchange rate terms. However, empirical evidence for two important building blocks of the model is mixed at best. These two building blocks are uncovered interest parity (UIP) and long-run purchasing power parity (PPP). Therefore, it is not obvious whether or not this prediction of the model holds true in the data. Eichenbaum and Evans (1995) directly investigate this prediction by estimating impulse responses of U.S. monetary policy shocks and find evidence in favor of the prediction, even though their results do not support some aspects of the standard exchange rate model.

In order to investigate impulse responses of a monetary policy shock, it is necessary to identify the shock by imposing economic restrictions on an econometric model. When economic restrictions are imposed, the econometric model is called a structural model. Both the choice of the econometric model and the choice of the set of restrictions can affect point estimates and standard errors of impulse responses. For this reason, it is important to study how these choices affect the results.

Most variables used to study exchange rate models are persistent, and usually modeled as series with stochastic trends and cointegration. In such a case, both levels VAR and VECM can be used to estimate impulse responses. Levels VAR is more robust than VECM because it can be used even when the system does not have stochastic trends and cointegration. Perhaps for this reason, it is used in most studies of impulse responses and by Eichenbaum and Evans (1995). However, structural VECM has some important advantages in systems with stochastic trends and cointegration. First, other things being equal, estimators of impulse responses from SVECM are more precise. For example, levels VAR can lead to exploding impulse response estimates even when the true impulse response is not exploding. This possibility is practically eliminated with SVECM. Second, it is possible to impose long-run restrictions as well as short-run restrictions to identify shocks.

A method of imposing long-run restrictions on VECM is developed in King, Plosser, Stock, and Watson (1991, KPSW for short). This paper employs a recently developed Jang's (2001a) method rather than the KPSW method. Comparing with the KPSW method, Jang's method has an advantage in that it does not require identification nor estimation of individual cointegrating vectors. This greatly facilitates the impulse response analysis because identification assumptions for individual cointegrating vectors can be complicated and can be inconsistent with some long-run restrictions a researcher wishes to impose to identify shocks. Jang and Ogaki (2001) apply Jang's (2001a) method to Eichenbaum and Evans' (1995) data in order to study effects of U.S. monetary policy shocks. This paper applies Jang's (2001a) method in order to study effects of Japanese monetary policy shocks.

Long-run restrictions on VECM have not been used to study the Japanese monetary policy. Kasa and Popper (1997), Kim (1999), and Shioji (2000), among others, use levels VAR with short-run restrictions to study effects of Japanese monetary policy shocks [1] Iwabuchi (1990), and Miyao (2000a,b, 2002), among others, use

[1] Kim's (1999) study is for the G-7 countries including Japan.

differenced VAR with short-run restrictions. Mio (2002) uses differenced VAR with long-run restrictions.

2 Vector Error Correction Model

2.1 The Model

Vector autoregressive models originating with Sims (1980) have the following reduced form:

$$\mathbf{A}(L)\mathbf{x}_t = \boldsymbol{\mu} + \boldsymbol{\epsilon}_t, \tag{2.1}$$

where $\mathbf{A}(L) = \mathbf{I}_n - \sum_{i=1}^{p} \mathbf{A}_i L^i$, $\mathbf{A}(0) = \mathbf{I}_n$, and $\boldsymbol{\epsilon}_t$ is *white noise* with mean zero and variance $\boldsymbol{\Sigma}$. From the reduced form of the VAR model, $\mathbf{A}(L)$ can be re-parameterized as $\mathbf{A}(1)L + \mathbf{A}^*(L)(1-L)$, where $\mathbf{A}(1)$ has a reduced rank, $r < n$. Engle and Granger (1987) showed that there exists an error correction representation:

$$\mathbf{A}^*(L)\Delta\mathbf{x}_t = \boldsymbol{\mu} - \mathbf{A}(1)\mathbf{x}_{t-1} + \boldsymbol{\epsilon}_t, \tag{2.2}$$

where $\mathbf{A}^*(L) = \mathbf{I}_n - \sum_{i=1}^{p-1} \mathbf{A}_i^* L^i$, and $\mathbf{A}_i^* = -\sum_{j=i+1}^{p} \mathbf{A}_j$. Since $\mathbf{x}_t$ is assumed to be cointegrated $I(1)$, $\Delta\mathbf{x}_t$ is $I(0)$, and $-\mathbf{A}(1)$ can be decomposed as $\boldsymbol{\alpha}\boldsymbol{\beta}'$, where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are $n \times r$ matrices with full column rank, r.

2.2 Long-run Restrictions

As $\Delta\mathbf{x}_t$ is assumed to be stationary, it has a unique Wold representation:

$$\Delta\mathbf{x}_t = \boldsymbol{\delta} + \mathbf{C}(L)\boldsymbol{\epsilon}_t, \tag{2.3}$$

where $\boldsymbol{\delta} = \mathbf{C}(1)\boldsymbol{\mu}$ and $\mathbf{C}(L) = \mathbf{I}_n + \sum_{i=1}^{\infty} \mathbf{C}_i L^i$. The above, reduced form can be represented in structural form as:

$$
\begin{aligned}
\Delta \mathbf{x}_t &= \boldsymbol{\delta} + \boldsymbol{\Gamma}(L)\mathbf{v}_t \\
\boldsymbol{\Gamma}(L) &= \mathbf{C}(L)\boldsymbol{\Gamma}_0 \qquad (2.4) \\
\mathbf{v}_t &= \boldsymbol{\Gamma}_0^{-1}\boldsymbol{\epsilon}_t,
\end{aligned}
$$

where $\boldsymbol{\Gamma}(L) = \boldsymbol{\Gamma}_0 + \sum_{i=1}^{\infty} \boldsymbol{\Gamma}_i L^i$, and $\mathbf{v}_t$ is a vector of structural innovations with mean zero and variance $\boldsymbol{\Sigma}_v$.

Long-run restrictions are imposed on the structural form, as in Blanchard and Quah (1989). Stock and Watson (1988) developed a common trend representation that was shown equivalent to a VECM representation. When cointegrated variables have a reduced rank, r, there exist $k = n - r$ common trends. These common trends can be considered generated by permanent shocks, so that $\mathbf{v}_t$ can be decomposed into $(\mathbf{v}_t^{k\prime}, \mathbf{v}_t^{r\prime})'$, in which $\mathbf{v}_t^k$ is a k-dimensional vector of permanent shocks and $\mathbf{v}_t^r$ is an r-dimensional vector of transitory shocks. As developed in King, Plosser, Stock, and Watson (1989, 1991, KPSW for short), this decomposition ensures that

$$
\boldsymbol{\Gamma}(1) = \begin{bmatrix} \mathbf{A} & \mathbf{0} \end{bmatrix}, \qquad (2.5)
$$

where $\mathbf{A}$ is an $n \times k$ matrix and $\mathbf{0}$ is an $n \times r$ matrix with zeros, representing long-run effects of permanent shocks and transitory shocks, respectively.

If there is more than one common trend ($k \geq 2$), a set of long-run restrictions must be imposed to isolate the effects of each permanent shock. Consider a three-variable model with two permanent shocks ($n = 3$, $k = 2$), in which the second permanent shock,v_t^2, has no long-run effects on the level of the first variable, x_t^1. This long-run restriction implies a specific structure of the long-run multiplier, $\mathbf{A}$, after conformable re-ordering:

$$\mathbf{x}_t = \begin{bmatrix} x_t^1 \\ x_t^2 \\ x_t^3 \end{bmatrix}, \quad \mathbf{v}^k = \begin{bmatrix} v_t^1 \\ v_t^2 \end{bmatrix}, \quad \mathbf{A} = \begin{bmatrix} 1 & 0 \\ \times & 1 \\ \times & \times \end{bmatrix}.$$

In order to identify permanent shocks, in general, causal chains, 1in the sense of Sims (1980), are imposed on permanent shocks:

$$\mathbf{A} = \hat{\mathbf{A}}\mathbf{\Pi}, \tag{2.6}$$

where $\hat{\mathbf{A}}$ is an $n \times k$ matrix, and $\mathbf{\Pi}$ is a $k \times k$ lower triangular matrix with ones in the diagonal. Continuing the above example, $\mathbf{\Pi}$ has the following specific form:

$$\mathbf{\Pi} = \begin{bmatrix} 1 & 0 \\ \pi_{21} & 1 \end{bmatrix}.$$

Note that $\hat{\mathbf{A}}$ is assumed to be known, as in KPSW, or is estimated as shown in the next section. In particular, $\mathbf{\Pi} = 1$ and $\mathbf{A} = \hat{\mathbf{A}}$ if $k = 1$. Consider, for instance, the three-variable model in KPSW. Following our notation, the model can be summarized as: $\mathbf{x}_t = (y_t, c_t, i_t)'$, where y_t, c_t, and i_t are the natural logarithms of per capita output, consumption, and investment, respectively. There are two cointegrating vectors, so r = 2, and one stochastic common trend, so k = 1. The stochastic common trend is generated by a permanent shock, which is interpreted as a real balanced growth shock or a productivity shock. Long-run restrictions imply that:

$$\mathbf{\Gamma}(1) = \begin{bmatrix} \mathbf{A} & \mathbf{0} \end{bmatrix} = \begin{bmatrix} \hat{\mathbf{A}}\mathbf{\Pi} & \mathbf{0} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \times & 0 & 0 \\ \times & 0 & 0 \end{bmatrix}, \tag{2.7}$$

where $\mathbf{A} = \hat{\mathbf{A}} = \begin{bmatrix} 1 & \times & \times \end{bmatrix}'$, and $\mathbf{\Pi} = 1$.

2.3 Estimation of the Model

This section explains how we can construct $\hat{\mathbf{A}}$ from the estimates of cointegrating vectors. Engle and Granger (1987) showed:

$$\boldsymbol{\beta}'\mathbf{C}(1) = \mathbf{0}, \tag{2.8}$$

which by the property of cointegration implies that $\boldsymbol{\beta}'\mathbf{x}_t$ is stationary. It follows from $\boldsymbol{\Gamma}(1) = \mathbf{C}(1)\boldsymbol{\Gamma}_0$ and (2.5) that

$$\boldsymbol{\beta}'\mathbf{A} = \mathbf{0} \quad \text{or} \quad \boldsymbol{\beta}'\hat{\mathbf{A}} = \mathbf{0}. \tag{2.9}$$

This property enables one to choose $\hat{\mathbf{A}} = \boldsymbol{\beta}_\perp$ after re-ordering $\mathbf{x}_t$ conformably with $\boldsymbol{\beta}_\perp$, in which $\boldsymbol{\beta}_\perp$ is an $n \times k$ orthogonal matrix of cointegrating vectors, $\boldsymbol{\beta}$, satisfying $\boldsymbol{\beta}'\boldsymbol{\beta}_\perp = \mathbf{0}$. Johansen (1995) proposed a method to choose $\boldsymbol{\beta}_\perp$ by:

$$\boldsymbol{\beta}_\perp = (\mathbf{I}_n - \mathbf{S}(\boldsymbol{\beta}'\mathbf{S})^{-1}\boldsymbol{\beta}')\mathbf{S}_\perp, \tag{2.10}$$

where $\mathbf{S}$ is an $n \times r$ selection matrix, $(\mathbf{I}_r \;\; \mathbf{0})'$, and $\mathbf{S}_\perp$ is an $n \times k$ selection matrix, $(\mathbf{0} \;\; \mathbf{I}_k)'$. Note that $\boldsymbol{\beta}$ is identified up to the space spanned by $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$. This does not necessarily mean that each cointegrating vector is identified, because $\boldsymbol{\alpha}\boldsymbol{\beta}' = \boldsymbol{\alpha}\mathbf{F}\mathbf{F}^{-1}\boldsymbol{\beta}' = \tilde{\boldsymbol{\alpha}}\tilde{\boldsymbol{\beta}}'$, i.e., any linear combination of each cointegrating vector is a cointegrating vector. Yet this paper does not require the identification of each cointegrating vector, and may provide more robust estimation avoiding potential misspecification.

Since $\boldsymbol{\beta}_\perp$ is normalized so that the last $k \times k$ submatrix is an identity matrix, one should *re-arrange* the variables $\mathbf{x}_t$ conformably in order to maintain Blanchard and Quah (1989)-type long-run restrictions. Alternatively, one may *re-normalize* $\boldsymbol{\beta}_\perp$ as shown below. Consider the six-variable model in KPSW, for instance. Let $\mathbf{x}_t$ be

$(y_t, c_t, i_t, m_t - p_t, R_t, \Delta p_t)'$, in which $m_t - p_t$ is the logarithm of the real balance, R_t is the nominal interest rate, and p_t is the logarithm of the price level, respectively. KPSW noted that there are three permanent shocks: a real balanced growth shock, a neutral inflation shock, and a real interest shock. We impose long-run restrictions that a neutral inflation shock has no long-run effect on output, and that a real interest rate shock has no long-run effect on either output or the inflation rate. These restrictions imply a specific form of $\hat{\boldsymbol{\beta}}_\perp$ as in:

$$\mathbf{A} = \hat{\boldsymbol{\beta}}_\perp \boldsymbol{\Pi} = \begin{bmatrix} 1 & 0 & 0 \\ \times & \times & \times \\ \times & \times & \times \\ \times & \times & \times \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ \pi_{21} & 1 & 0 \\ \pi_{31} & \pi_{32} & 1 \end{bmatrix}, \tag{2.11}$$

where $\times$ denotes that those parameters are not restricted other than $\boldsymbol{\beta}'\hat{\boldsymbol{\beta}}_\perp = 0$. From $\mathbf{A} = \hat{\mathbf{A}}\boldsymbol{\Pi}$, we can choose $\hat{\mathbf{A}}$ using:[2]

$$\hat{\mathbf{A}} = \hat{\boldsymbol{\beta}}_\perp. \tag{2.12}$$

2.4 Identification of Permanent Shocks

Is it possible to derive structural parameters from reduced-form estimates? This is a general identification problem that arises in most economic models. The identification problem in this paper is how structural parameters ($\boldsymbol{\Gamma}(L)$) and the structural shock ($\mathbf{v}_t$) can be derived from parameters ($\mathbf{C}(L)$) and residuals ($\boldsymbol{\epsilon}_t$) estimated from the reduced form. From the equations in (2.4), all structural parameters and structural shocks can be derived from the estimates of the reduced form in (2.2) once $\boldsymbol{\Gamma}_0$ is identified.

[2] KPSW, instead, assume that $\hat{\mathbf{A}}$ is known *a priori*, which is estimated by dynamic OLS in each cointegrating equation.

In the framework of traditional VAR models, Sims (1980)-type causal chain restrictions are imposed, and $\mathbf{\Gamma}_0$ is assumed to be a lower triangular matrix. It is debatable, however, whether the causal chain that is assumed to identify innovations in traditional VAR models is appropriate. As a result, VAR models have evolved to structural VAR models with various restrictions. Contemporaneous short-run restrictions are used in Blanchard and Watson (1986), Bernanke (1986), and Blanchard (1989), while long-run restrictions are used in Blanchard and Quah (1989).

It is worth noting that Sims (1980)-type causal chain restrictions cannot be directly applied to VECMs, as $\mathbf{\Gamma}_0$ cannot simply be assumed to be a lower triangular matrix due to the presence of cointegration.[3] This paper imposes long-run restrictions on structural shocks. These additional assumptions not only provide sufficient conditions to identify structural shocks, but also enable investigation of impulse response analysis in a Johansen (1988)-type VECM.

The main interest lies in the identification of structural permanent shocks, but not in structural transitory shocks.[4] Following KPSW, we decompose $\mathbf{\Gamma}_0$ and $\mathbf{\Gamma}_0^{-1}$ as:

$$\mathbf{\Gamma}_0 = \begin{bmatrix} \mathbf{H} & \mathbf{J} \end{bmatrix}, \quad \mathbf{\Gamma}_0^{-1} = \begin{bmatrix} \mathbf{G} \\ \mathbf{E} \end{bmatrix} \tag{2.13}$$

where $\mathbf{H}, \mathbf{J}, \mathbf{G}$ and $\mathbf{E}$ are $n \times k$, $n \times r$, $k \times n$, and $r \times n$ matrices, respectively. Note that the permanent shocks are identified once $\mathbf{H}$ (or $\mathbf{G}$) is identified, and that these

[3]This is the reason that the impulse response analysis is hardly investigated in Johansen (1988)-type VECM without further restrictions. Instead, the main interest lies on the estimation of cointegrating vectors and the test for economic hypotheses.

[4]Fisher, Fackler, and Orden (1995) consider the identification of transitory shocks imposing causal chains on transitory shocks.

two matrices have a one-to-one relation, $\mathbf{G} = \mathbf{\Sigma}_v^k \mathbf{H}' \mathbf{\Sigma}^{-1}$, where $\mathbf{\Sigma}_v^k$ is the variance-covariance matrix of permanent shocks, $\mathbf{v}_t^k$.[5] Therefore, the above decomposition of $\mathbf{\Gamma}_0$ does not generate additional free parameters.

The identifying scheme of the present paper basically follows that of KPSW, but enables one to generalize their model as described below. Our identification uses the results of Engle and Granger (1987):

$$\mathbf{C}(1)\boldsymbol{\alpha} = \mathbf{0}. \tag{2.14}$$

Following KPSW, let $\mathbf{C}(1) = \hat{\boldsymbol{\beta}}_\perp \mathbf{D}$ and $\mathbf{A} = \hat{\boldsymbol{\beta}}_\perp \mathbf{\Pi}$, where $\hat{\boldsymbol{\beta}}_\perp$ is an $n \times k$ matrix, $\mathbf{\Pi}$ is a $k \times k$ matrix and $\mathbf{D} = (\hat{\boldsymbol{\beta}}_\perp' \hat{\boldsymbol{\beta}}_\perp)^{-1} \hat{\boldsymbol{\beta}}_\perp' \mathbf{C}(1)$. Assuming that the permanent shocks are mutually uncorrelated and orthogonal to transitory shocks:

$$\mathbf{\Sigma}_v = \begin{bmatrix} \mathbf{\Sigma}_v^k & \mathbf{0} \\ \mathbf{0} & \mathbf{\Sigma}_v^r \end{bmatrix}, \tag{2.15}$$

where $\mathbf{\Sigma}_v^k$ is a diagonal matrix denoted by $\mathbf{\Lambda}$.

The order condition can be verified by the following three sets of restrictions. First, it follows from $\mathbf{C}(1)\boldsymbol{\epsilon}_t = \mathbf{\Gamma}(1)\mathbf{v}_t$ that $\hat{\boldsymbol{\beta}}_\perp \mathbf{D}\boldsymbol{\epsilon}_t = \hat{\boldsymbol{\beta}}_\perp \mathbf{\Pi}\mathbf{v}_t^k$. This implies the first set of restrictions:

$$\mathbf{\Pi}\mathbf{\Lambda}\mathbf{\Pi}' = \mathbf{D}\mathbf{\Sigma}\mathbf{D}', \tag{2.16}$$

where $\mathbf{\Pi}$ is assumed to be a lower triangular matrix with ones on the diagonal.[6] This condition gives $\frac{k(k+1)}{2}$ restrictions for $\frac{k(k+1)}{2}$ unknowns on $\mathbf{\Pi}$ and $\mathbf{\Lambda}$, provided that $\mathbf{\Lambda}$ is diagonal, and yields unique solutions for $\mathbf{\Pi}$ and $\mathbf{\Lambda}$. Let $\mathbf{P}$ be a lower

[5] One can easily derive this relation from the relation of $\mathbf{\Gamma}_0^{-1}\mathbf{\Sigma} = \mathbf{\Sigma}_v \mathbf{\Gamma}_0'$.

[6] One can relax this assumption as long as the order condition is satisfied. See Jang (2001b) for the algorithm for solving this nonlinear equation.

triangular matrix chosen from the Cholesky decomposition of $\mathbf{D\Sigma D}'$. Then $\mathbf{\Pi}$ and $\mathbf{\Lambda}$ are uniquely determined by

$$\mathbf{\Pi} = \mathbf{P\Lambda}^{-\frac{1}{2}}, \tag{2.17}$$

where $\mathbf{\Lambda} = [diag(\mathbf{P})]^2$.

Second, $\mathbf{C}(1)\mathbf{\Gamma}_0 = \mathbf{\Gamma}(1)$ implies $\mathbf{C}(1)\mathbf{H} = \hat{\boldsymbol{\beta}}_{\perp}\mathbf{\Pi}$, so that we have the second set of restrictions of the form:

$$\mathbf{DH} = \mathbf{\Pi}, \tag{2.18}$$

which gives k^2 restrictions on $\mathbf{H}$, provided that $\mathbf{\Pi}$ has already been derived.

Finally, (2.14) can be expressed as $\mathbf{\Gamma}(1)\mathbf{\Gamma}_0^{-1}\boldsymbol{\alpha} = \mathbf{0}$, so that $\mathbf{G}\boldsymbol{\alpha} = \mathbf{0}$. Since $\mathbf{G} = \mathbf{\Lambda H}'\mathbf{\Sigma}^{-1}$, we have the third set of restrictions of the form:

$$\boldsymbol{\alpha}'\mathbf{\Sigma}^{-1}\mathbf{H} = \mathbf{0}, \tag{2.19}$$

which gives kr restrictions on $\mathbf{H}$.

The above three sets of restrictions give nk restrictions on $\mathbf{H}$, and the model is just identified in the sense of identifying the matrix $\mathbf{H}$ uniquely. Having estimated the model (2.2), one can compute all the structural parameters sequentially. The last two restrictions (2.18) and (2.19) yield

$$\mathbf{H} = \begin{bmatrix} \mathbf{D} \\ \boldsymbol{\alpha}'\mathbf{\Sigma}^{-1} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{\Pi} \\ \mathbf{0} \end{bmatrix} \tag{2.20}$$

and

$$\mathbf{G} = \mathbf{\Lambda H}'\mathbf{\Sigma}^{-1}. \tag{2.21}$$

Accordingly, the permanent shocks and the short run dynamics are identified by

$$\mathbf{v}_t^k = \mathbf{G}\epsilon_t \tag{2.22}$$

and

$$\mathbf{\Gamma}(L)^k = \mathbf{C}(L)\mathbf{H}, \tag{2.23}$$

where $\mathbf{\Gamma}(L)^k$ denotes the first k columns of $\mathbf{\Gamma}(L)$.

The specific solutions for $\mathbf{H}$ and $\mathbf{G}$ in the form of matrices enable one to generalize the model. Jang (2001b) considered a structural VECM in which structural shocks are partially identified using long-run restrictions and are fully identified by means of additional short-run restrictions (See Jang (2001b) for the method of identification in structural VECMs with short-run and long-run restrictions). Jang and Ogaki (2001) considered a special case, where impulse response analysis is used to examine the effects of only one permanent shock, and the recursive assumption on the permanent shocks in (2.6) can be relaxed. A block recursive assumption for permanent shocks, instead, suffices to investigate the impulse responses of economic variables to one permanent shock. Continuing the previous example, in order to identify the k_{th} permanent shock, $v^k_{t,k}$, the following restrictions are sufficient:

$$\mathbf{A} = \hat{\boldsymbol{\beta}}_\perp \mathbf{\Pi} = \begin{bmatrix} 1 & 0 & 0 \\ \times & \times & \times \\ \times & \times & \times \\ \times & \times & \times \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & \pi_{12} & 0 \\ \pi_{21} & 1 & 0 \\ \pi_{31} & \pi_{32} & 1 \end{bmatrix} \tag{2.24}$$

where $\times$ denotes that these parameters are not restricted, other than $\boldsymbol{\beta}'\hat{\boldsymbol{\beta}}_\perp = \mathbf{0}$. Thus, only two long-run restrictions are sufficient to identify the k_{th} permanent shock. In general, $k-1$ long-run restrictions are sufficient to identify the last permanent shock, $v^k_{t,k}$. The long-run restriction for this example ($k = 3$, $r = 3$) is that a real interest rate shock has no long-run effect on either output or the inflation rate. Note that we can compute the impulse responses to the third shock, the k_{th} shock, as long as the

k_{th} column of $\mathbf{H}$, $\mathbf{H}_k$, is identified. Note also that the third column of $\mathbf{\Pi}$ does not contain any unknown parameters. Analogous to (2.20), $\mathbf{H}_k$ is identified by

$$\mathbf{H}_k = \begin{bmatrix} \mathbf{D} \\ \boldsymbol{\alpha}'\mathbf{\Sigma}^{-1} \end{bmatrix}^{-1} \mathbf{S}_k \tag{2.25}$$

where $\mathbf{S}_k$ is an n-dimensional selection vector with one at the k_{th} row and zeros at other rows, $(0,0,1,0,0,0)'$ for this example. Similarly, $\mathbf{G}_k$ is identified by:

$$\mathbf{G}_k = \mathbf{\Lambda}_{k,k}\mathbf{H}_k'\mathbf{\Sigma}^{-1} \tag{2.26}$$

and it follows from the identity relation of $\mathbf{GH} = \mathbf{I}_k$ that

$$\mathbf{\Lambda}_{k,k} = (\mathbf{H}_k'\mathbf{\Sigma}^{-1}\mathbf{H}_k)^{-1}, \tag{2.27}$$

where $\mathbf{\Lambda}_{k,k}$ is the variance of the k_{th} permanent shock. Thus, the k_{th} permanent shock is identified by

$$v_{t,k}^k = \mathbf{G}_k\boldsymbol{\epsilon}_t. \tag{2.28}$$

3 Impulse Response Analysis with Long Run Restrictions

This section investigates the effects of contractionary shock to the monetary policy on economic variables including output, price and the yen/dollar exchange rate. Monthly observations from January 1975 to December 1993 are used in our empirical analysis. We end the sample period in December 1993 because Bank of Japan's low interest rate policy starting around this period is likely to cause a structural break (see, e.g, Miyao, 2000b). The seven-variable model includes the call rate(r_{jp}), a measure of monetary aggregate, output in Japan (y_{jp}), price in Japan(P_{jp}), output in the United States(y_{us}), federal funds rate in the United States (r_{us}), and real exchange rate(e_r, yen/dollar). The call rate is taken from International Financial Statistics

(IFS) database, line 60b. Output in Japan is measured by industrial production, line66c. The consumer price index is used as the price. Federal Funds rate is from the Federal Reserve database. The yen/dollar exchange rate is obtained from the Federal Reserve database. The real exchange rate is calculated from the nominal exchange rate and consumer price indexes. Seven alternative measures of monetary aggregate are used as described below. None of the data series is seasonally adjusted. Therefore, we include seasonal dummies in the VECM and VAR. We select 11 lags as the lag length of structural VECM, which is equivalent to 12 lags in levels VAR.

Jang and Ogaki (2001) apply Jang's (2001a) method to U.S. data to study effects of U.S. monetary policy shocks to economic variables. They follow Eichenbaum and Evans (1995) and use the non-borrowed reserve ratio (the ratio of non-borrowed reserves to total reserves) as the measure of monetary aggregate. They show that long-run restrictions lead to estimates of impulse responses that are roughly consistent with standard exchange rate models. For the U.S. monetary policy, open market operations play a very important role, and non-borrowed reserves are considered to be an appropriate measure of the monetary aggregate for the purpose of studying monetary policy. This is in contrast with Japanese monetary policy for which open market operations has not been important. For this reason, we report results for alternative measures of monetary aggregates.

For measures of monetary aggregates, M1, M2, M2+CDs, monetary base, non-borrowed reserve ratio, total reserves, and borrowed reserves are used. Monthly average data for total reserves, monetary base, M1, M2, and M2+CDs were obtained from the Bank of Japan homepage. Borrowed reserves are measured as "Lendings from Monetary Authorities" taken from the end of period data in the Bank of Japan

Monetary Survey. Non-borrowed reserve ratio is calculated from end of period data for total and borrowed reserves in the Bank of Japan Monetary Survey by first taking the difference between total reserves and borrowed reserves and then dividing the difference by total reserves.

As mentioned above, non-borrowed reserve ratio is not a natural measure of monetary aggregate in order to study monetary policy in Japan. This variable is included in our study for the purpose of comparing the results in this paper with those for U.S. monetary policy in the papers cited above. Borrowed reserves are included in our study because of possible importance in Bank of Japan loans to banks (see, eg., Shioji, 2000). However, it should be noted that the end of period data are used for these two variables.

Table 4.1 summarizes Johansen's (1988) cointegration rank tests over the sample period 1975:1–1993:12. The maximum eigenvalue tests and trace tests suggest $r = 2$ for M1 and monetary base, $r = 3$ for M2, M2+CDs, non-borrowed reserve ratio, and total reserves, and $r = 4$ for borrowed reserves as the number of cointegrating vectors with a 5% significance level.[7] Given these mixed results, we choose r by conjecturing the number of permanent shocks in the model. The permanent shocks include a Japanese supply shock and a U.S. supply shock. The permanent shocks also include a shock that affects the long-run level of real exchange rates (a real-exchange-rate shock) and a Japanese monetary policy shock that affects the long-run level of Japanese price. A U.S. monetary policy shock can be considered as a transitory shock since the model does not include the U.S. price, while it can be considered as a permanent shock if it affects the long-run level of U.S. interest rates. Therefore, we

[7] We select the model that satisfies the deterministic cointegration restriction developed in Ogaki and Park (1997).

report the results with four permanent shocks ($k = 4$, $r = 3$) in a benchmark model, and we check the robustness of the results using $k = 5$ and $r = 2$. In a benchmark model, the Japanese monetary shock is identified by three long-run restrictions: the shock does not affect Japanese output, U.S. output, and real exchange rates in the long run. Our main results do not change when we adopt $k = 5$ with an additional assumption that the Japanese monetary shock does not affect the U.S. interest rates in the long run.[8]

Results for M1, M2, M2+CDs, monetary base, non-borrowed reserve ratio, total reserves, and borrowed reserves are reported in Figures 3.1 – 3.7. In these figures, a contractionary monetary shock is defined to be a shock that initially increases the Call rate. Significance intervals are drawn by Monte Carlo integration with one standard deviation. Impulse responses for aggregate output in Japan show that the shock defined in this manner shows statistically significant increases in aggregate output in initial periods when M2, M2+CDs, or monetary base is used. We call this phenomenon of the association of a rise in the short-term interest with aggregate output an "output puzzle." In the VAR studies with short-run restrictions, we typically do not find the output puzzle. As we will report later, we do not find the output puzzle with our seven-variable VAR system when short-run restrictions are used. On the other hand, statistically significant decreases are observed for some of the initial periods when M1, non-borrowed reserve ratio, or borrowed reserve is used. The point estimates of the impulse responses for aggregate output in Japan are negative when total reserve is used, but they are not statistically significant.

[8]The results are available upon request.

In many impulse response studies with levels VAR with short-run restrictions, researchers have often found the "price puzzle" that the price level rises in response to a contractionary monetary policy shock. Jang and Ogaki (2001) report that short-run restrictions lead to the price puzzle, but they do not find the price puzzle with long-run restrictions in their seven-variable system for U.S. monetary policy. For Japanese monetary policy, we do not find the price puzzle when M2 or M2+CDs is used, but we find the price puzzle when the other monetary aggregate measures are used with long-run restrictions.

We found the "liquidity puzzle" that a rise in the interest rate accompanies an increase in money supply for M1, non-borrowed reserves, borrowed reserves, or total reserves. For other monetary aggregate measures, we did not find the liquidity puzzle.

The standard exchange rate model predicts that the real exchange rate immediately moves in the direction of appreciation of yen and then gradually moves in the direction of depreciation of yen. However, we observe initial depreciation for all monetary aggregate measures. These responses are not statistically significant for M2+CDs, monetary base, non-borrowed reserves, and total reserves.

As long-run restrictions alone do not seem to contain enough information to Japanese monetary policy shocks, we combine short-run and long-run restrictions for identification.[9] We impose a short-run restriction that a Japanese monetary policy shock does not affect Japanese output contemporaneously, while discarding a long-run restriction that the shock does not affect the real exchange rate in the long run.

[9] Jang (2001b) recently developed such a method for VECM along the line of Gali (1992), who combine short-run and long-run restrictions for differenced VAR.

Figure 3.8– 3.12 show that even the combination of both horizon restrictions does not help resolving puzzles with long-run restrictions.[10]

For comparison, we have analyzed the same data with a seven-variable VECM model and VAR model with short run restrictions. In these models, we measure a monetary policy shock by an unexpected increase in nominal interest rate that is normalized to raise the nominal interest rate by one percent in the first period. With this measure, we consider a VECM model and an alternative levels VAR model with short run restrictions: Japanese monetary policy shock does not affect Japanese output, Japanese price, U.S. output, U.S. interest rate contemporaneously. These variables are ordered conformably before Japanese monetary policy variable that is ordered fifth. Other variables such as Japanese monetary aggregate and real exchange rate are ordered after the monetary policy variable. With the choice of six as the lag length, Figure 3.13 shows impulse responses of economic variables to the Japanese contractionary monetary policy shock when M2+CDs is used for monetary aggregate. Results with other monetary aggregate are available upon requests. Regardless of the choice of monetary aggregate, impulse responses of Japanese interest rate, Japanese price and real exchange rate are similar. The effects on Japanese interest rate are positive for ten months after the shock, and it becomes negative thereafter. The responses of Japanese price show the price puzzle: Japanese price rises for at least 18 months after the contractionary policy shock. The effect on real exchange rate exhibits delayed overshooting behavior as in Eichenbaum and Evans (1995), but it is

[10]We have tried other combinations of short-run and long-run restrictions with different monetary aggregate measures: i) a Japanese monetary shock does not affect U.S. output contemporaneously, and Japanese output or U.S. output in the long run ii) a Japanese monetary shock does not affect Japanese output or U.S. output contemporaneously, and Japanese output. We failed to find results that are consistent with standard exchange rate models.

not significantly different from zero in most cases. On the other hand, the responses of monetary aggregates depend on the choice. When money supply is measured by M2, M2+CDs, non-borrowed reserve ratio, we found liquidity effects that a contractionary monetary policy accompanies a rise of the interest rate and a decrease of money supply. However, we found the liquidity puzzle when other monetary aggregates including M1, monetary base, total reserve, and borrowed reserve are used. We also get similar results in a VECM model with short-run restrictions when M2+CDs is used for a monetary aggregate measure as shown in Figure 3.14.[11]

Thus, the impulse response results from long-run restrictions were much less consistent with the standard exchange rate model than those from short-run restrictions. Because we found the liquidity puzzle, price puzzle, and output puzzle which are not related to exchange rates with long-run restrictions for some monetary aggregate measures, we have tried smaller systems which do not include exchange rates in order to see if these puzzles are solved in smaller systems.

Figure 3.15 shows typical results from the smaller systems. In the figure, we report impulse responses in a four-variable VECM with long run restrictions using Japanese output, price, interest rate, and money supply. Based on the Johansen's cointegration rank test results, the cointegration rank of two was chosen. The long-run restriction that a permanent monetary policy shock does not affect output in the long-run is used to identify the monetary policy shock. The results show that a contractionary monetary policy shock that initially raise the interest rate accompanies a decrease of money supply, but it leads to an increase of price level and output in

[11]Main results do not change when other monetary aggregate measures are used.

the short run. Therefore, long-run restrictions tend to lead to puzzles even in smaller systems for Japanese data.

These results for Japanese monetary policy are in contrast with those for U.S. monetary policy in Jang and Ogaki (2001). We reproduce two figures from the paper, so that the results can be easily compared. The reader is referred to the paper for details about these figures. These two figures describe the impulse responses in a seven-variable model that consists of the federal funds rate, the non-borrowed reserve ratio ($NBRX$), U.S. output, U.S. price, Japanese output, the Japanese interest rate, and the real exchange rate (dollar/yen). Figure 3.16 shows the effects of a contractionary monetary policy shock for these seven-variable when short-run restrictions are used in a levels VAR as in Eichenbaum and Evans (1995). Figure 3.17 reports impulse responses for a U.S. contractionary monetary policy shock that is measured by a shock that affects the federal funds rate to rise in the initial period when long-run restrictions are used in a VECM. Comparing the results in these two figures, the impulse responses based on long-run restrictions are more consistent with predictions from standard exchange rate models than those based on short-run restrictions in two respects. First, the standard exchange rate models with overshooting implies that the U.S. dollar starts to appreciate immediately and then gradually depreciates in response to a contractionary monetary policy shock. The impulse responses for the real exchange rate based on long-run restrictions imply more immediate appreciation of the U.S. dollar than those based on short-run restrictions. Second, the short-run restrictions lead to the price puzzle, while the long-run restrictions resolve the puzzle.

4 Conclusion

This paper is an initial step of our project to use long-run restrictions in VECM to investigate the effects of Japanese monetary policy shocks on macroeconomic variables and exchange rates. Because all standard exchange rate models imply that monetary policy shocks do not affect the real exchange rate in the long run, it is attractive to impose this restriction to estimate impulse responses of monetary policy shocks. Jang and Ogaki (2001) applied the same method used in this paper to estimate impulse responses for U.S. monetary policy shocks on the dollar/yen exchange rate. They compared the estimates from long-run restrictions and those from short-run restrictions, and concluded that long-run restrictions yielded impulse responses that were more consistent with standard exchange rate models than short-run restrictions. In particular, they found the price puzzle (a rise in the price level in response to contractionary monetary policy shocks) with short-run restrictions, but not with long-run restrictions. The impulse response function of the real exchange rate was also more consistent with standard exchange rate models when long-run restrictions were used.

In contrast, the present paper finds that the same method yields impulse response estimates that are not consistent with standard macroeconomic and exchange rate models when it is applied to investigate effects of Japanese monetary policy shocks with several measures of monetary aggregate. A natural interpretation is that our method failed to identify the true Japanese monetary policy shocks.

Our results indicate a major direction for future research. It seems necessary to pay more attention to the objectives and operating procedures of the Bank of Japan because the impulse response results based on non-borrowed reserves are very different for Japanese and U.S. monetary policy shocks. Indeed, Kasa and Popper (1997) find evidence for the hypothesis that the Bank of Japan weights both variation in the call rate and variation in non-borrowed reserves with time-varying weights. This line of research also requires a new method for VECM with long-run restrictions. It should be possible to modify Bernanke and Mihov's (1998) method for this purpose.

REFERENCES

Bernanke, B. S. (1986): "Alternative Explanations of the Money-Income Correlation," *Carnegie-Rochester Conference Series on Public Policy*, 25, 49–100.

Bernanke, B. S., and I. Mihov (1998): "Measuring Monetary Policy," *Quarterly Journal of Economics*, 113(3), 869–902.

Blanchard, O. J. (1989): "A Traditional Interpretation of Macroeconomic Fluctuations," *American Economic Review*, 79(5), 1146–1164.

Blanchard, O. J., and D. Quah (1989): "The Dynamic Effects of Aggregate Supply and Demand Disturbances," *American Economic Review*, 77, 655–673.

Blanchard, O. J., and M. W. Watson (1986): "Are Business Cycles All Alike?," in *The American Business Cycle: Continuity and Change*, ed. by R. J. Gordon, vol. 25 of *National Bureau of Economic Research Studies in Business Cycles*, pp. 123–182. University of Chicago Press, Chicago.

Dornbusch, R. (1976): "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 84(6), 1161–1176.

Eichenbaum, M., and C. L. Evans (1995): "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rate," *Quarterly Journal of Economics*, 110, 975–1009.

Engle, R. F., and C. Granger (1987): "Co-Integration and Error Correction: Representation, Estimation, and Testing," *Econometrica*, 55, 251–276.

Fisher, L. A., P. L. Fackler, and D. Orden (1995): "Long-run Identifying Restrictions for an Error-Correction Model of New Zealand Money, Prices and Output," *Journal of International Money and Finance*, 14(1), 127–147.

Gali, J. (1992): "How Well Does the IS-LM Model Fit Postwar U.S. Data?," *Quarterly Journal of Economics*, 107(2), 709–738.

Iwabuchi, J. (1990): "Kinyu-Hensu ga Jittai Keizai ni Ataeru Eikyo ni tuite," *Kinyu Kenkyu*, 9, 79–118.

Jang, K. (2001a): "Impulse Response Analysis with Long Run Restrictions on Error Correction Models," Working Paper No. 01-04, Department of Economics, Ohio State University.

——— (2001b): "A Structural Vector Error Correction Model with Short-Run and Long-Run Restrictions," Manuscript.

Jang, K., and M. Ogaki (2001): "The Effects of Monetary Policy Shocks on Exchange Rates: A Structural Vector Error Correction Model Approach," Working Paper No. 01-02, Department of Economics, Ohio State University.

Johansen, S. (1988): "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12, 231–254.

——— (1995): *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press, Oxford.

Kasa, K., and H. Popper (1997): "Monetary Policy in Japan: A Structural VAR Analysis," *Journal of the Japanese and International Economies*, 11, 275–295.

Kim, S. (1999): "Do Monetary Policy Shocks Matter in the G-7 Countries? Using Common Identifying Assumptions about Monetary Policy Across Countries," *Journal of International Economics*, 47(2), 871–893.

King, R. G., C. I. Plosser, J. H. Stock, and M. W. Watson (1989): "Stochastic Trends and Economic Fluctuations," Manuscript.

——— (1991): "Stochastic Trends and Economic Fluctuations," *American Economic Review*, 81(4), 810–840.

Mio, H. (2002): "Identifying Aggregate Demand and Aggregate Supply Components of Inflation Rate: A Structural Vector Autoregression Analysis for Japan," *Monetary and Economic Studies*, 20(1), 33–56.

Miyao, R. (2000a): "The Price Controllability of Monetary Policy in Japan," Manuscript, Kobe University.

——— (2000b): "The Role of Monetary Policy in Japan: A Break in the 1990s?," *Journal of the Japanese and International Economies*, 14, 1–19.

——— (2002): "The Effects of Monetary Policy in Japan," *Journal of Money, Credit, and Banking*, 34(2), 376–392.

Ogaki, M., and J. Y. Park (1997): "A Cointegration Approach to Estimating Preference Parameters," *Journal of Econometrics*, 82, 107–134.

Osterwald-Lenum, M. (1992): "A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics," *Oxford Bulletin of Economics and Statistics*, 54(3), 461–471.

Shioji, E. (2000): "Identifying Monetary Policy Shocks in Japan," *Journal of the Japanese and International Economies*, 14, 22–42.

Sims, C. A. (1980): "Macroeconomics and Reality," *Econometrica*, 48, 1–48.

Stock, J. H., and M. W. Watson (1988): "Testing for Common Trends," *Journal of the American Statistical Association*, 83(404), 1097–1107.

Table 4.1: Cointegration Rank Tests

Eigen Value	λ_{max}	Trace	Number of Cointegration (r)	Critical Value 95% λ_{max}	Trace
			Panel A: M1		
0.3608	102.05*	211.51 *	0	45.28	124.24
0.1849	46.60*	109.47 *	1	39.37	94.15
0.1142	27.64	62.87	2	33.46	68.52
0.0623	14.67	35.22	3	27.07	47.21
0.0489	11.42	20.56	4	20.97	29.68
0.0278	6.43	9.14	5	14.07	15.41
0.0118	2.71	2.71	6	3.76	3.76
			Panel B: M2		
0.3999	116.42 *	230.00 *	0	45.28	124.24
0.1675	41.81 *	113.58 *	1	39.37	94.15
0.1444	35.56 *	71.77 *	2	33.46	68.52
0.0729	17.26	36.21	3	27.07	47.21
0.0600	14.11	18.95	4	20.97	29.68
0.0158	3.63	4.85	5	14.07	15.41
0.0053	1.22	1.22	6	3.76	3.76
			Panel C: M2+CDs		
0.3779	108.23 *	229.59 *	0	45.28	124.24
0.1802	45.30 *	121.37 *	1	39.37	94.15
0.1565	38.80 *	76.07 *	2	33.46	68.52
0.0762	18.06	37.27	3	27.07	47.21
0.0609	14.32	19.21	4	20.97	29.68
0.0172	3.96	4.89	5	14.07	15.41
0.0041	0.93	0.93	6	3.76	3.76
			Panel D: monetary base		
0.3833	110.21 *	215.31 *	0	45.28	124.24
0.1696	42.36 *	105.10 *	1	39.37	94.15
0.1118	27.04	62.74	2	33.46	68.52
0.0783	18.60	35.71	3	27.07	47.21
0.0545	12.78	17.11	4	20.97	29.68
0.0157	3.60	4.32	5	14.07	15.41
0.0032	0.72	0.72	6	3.76	3.76

Table 4.1 (Continued)

Eigen Value	λ_{max}	Trace	Number of Cointegration (r)	Critical Value 95% λ_{max}	Critical Value 95% Trace
			Panel E: non-borrowed reserve ratio		
0.3838	110.39 *	232.77 *	0	45.28	124.24
0.1796	45.13 *	122.38 *	1	39.37	94.15
0.1515	37.45 *	77.26 *	2	33.46	68.52
0.0851	20.26	39.81	3	27.07	47.21
0.0512	11.98	19.53	4	20.97	29.68
0.0219	5.04	7.55	5	14.07	15.41
0.0109	2.51	2.51	6	3.76	3.76
			Panel F: total reserves		
0.3612	102.19 *	231.47 *	0	45.28	124.24
0.1830	46.07 *	129.28 *	1	39.37	94.15
0.1526	37.75 *	83.21 *	2	33.46	68.52
0.0917	21.94	45.46	3	27.07	47.21
0.0500	11.69	23.52	4	20.97	29.68
0.0325	7.53	11.83	5	14.07	15.41
0.0187	4.30	4.30	6	3.76	3.76
			Panel G: borrowed reserves		
0.3871	111.62 *	249.21 *	0	45.28	124.24
0.1738	43.52 *	137.59 *	1	39.37	94.15
0.1502	37.10 *	94.07 *	2	33.46	68.52
0.1360	33.32 *	56.97 *	3	27.07	47.21
0.0508	11.89	23.65	4	20.97	29.68
0.0384	8.92	11.76	5	14.07	15.41
0.0124	2.84	2.84	6	3.76	3.76

Note: The last two columns are critical values with a 5% significance level in Osterwald-Lenum's (1992) Table 1. * denotes that the null hypothesis is rejected with the significance level.

Figure 3.1: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using M1)

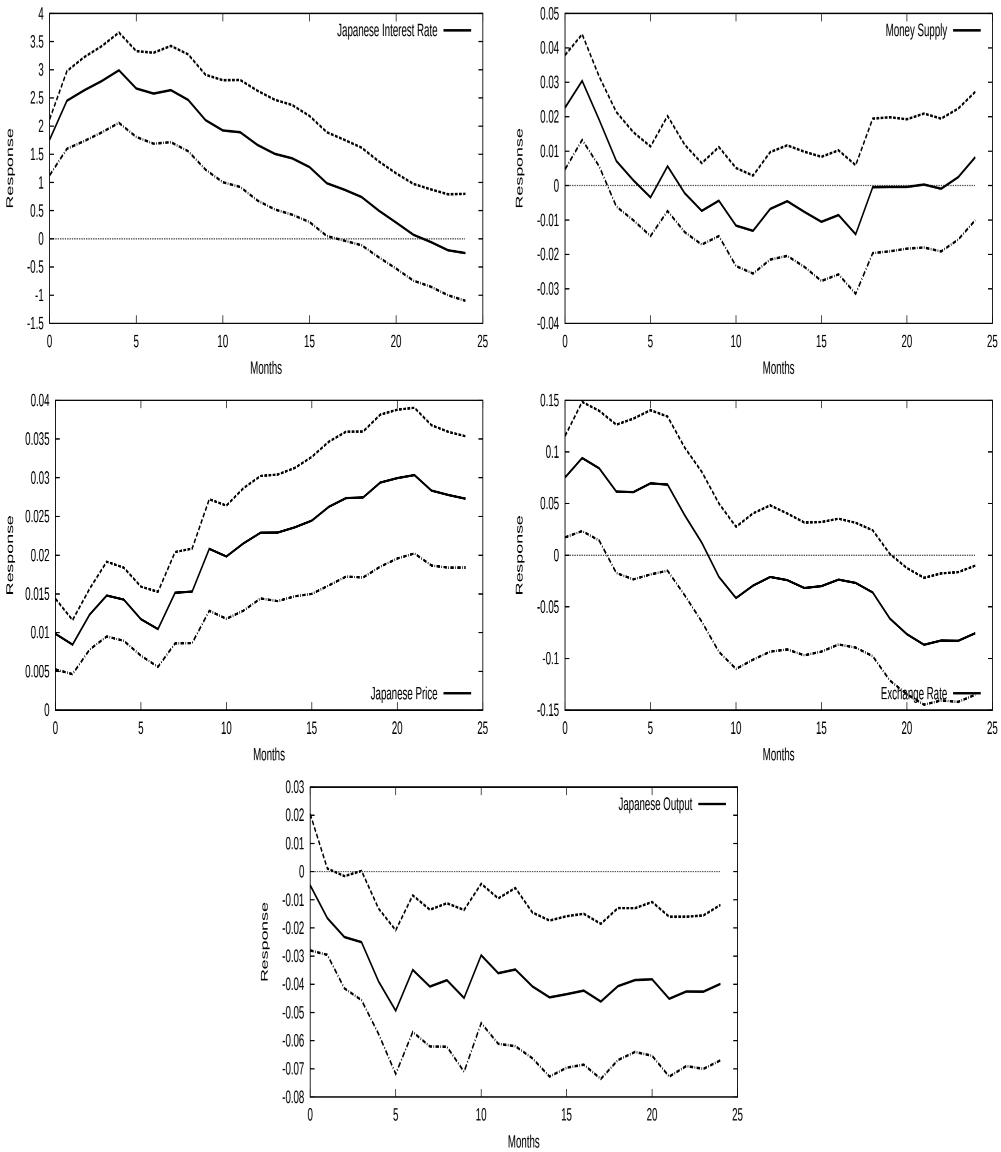

Figure 3.2: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2)

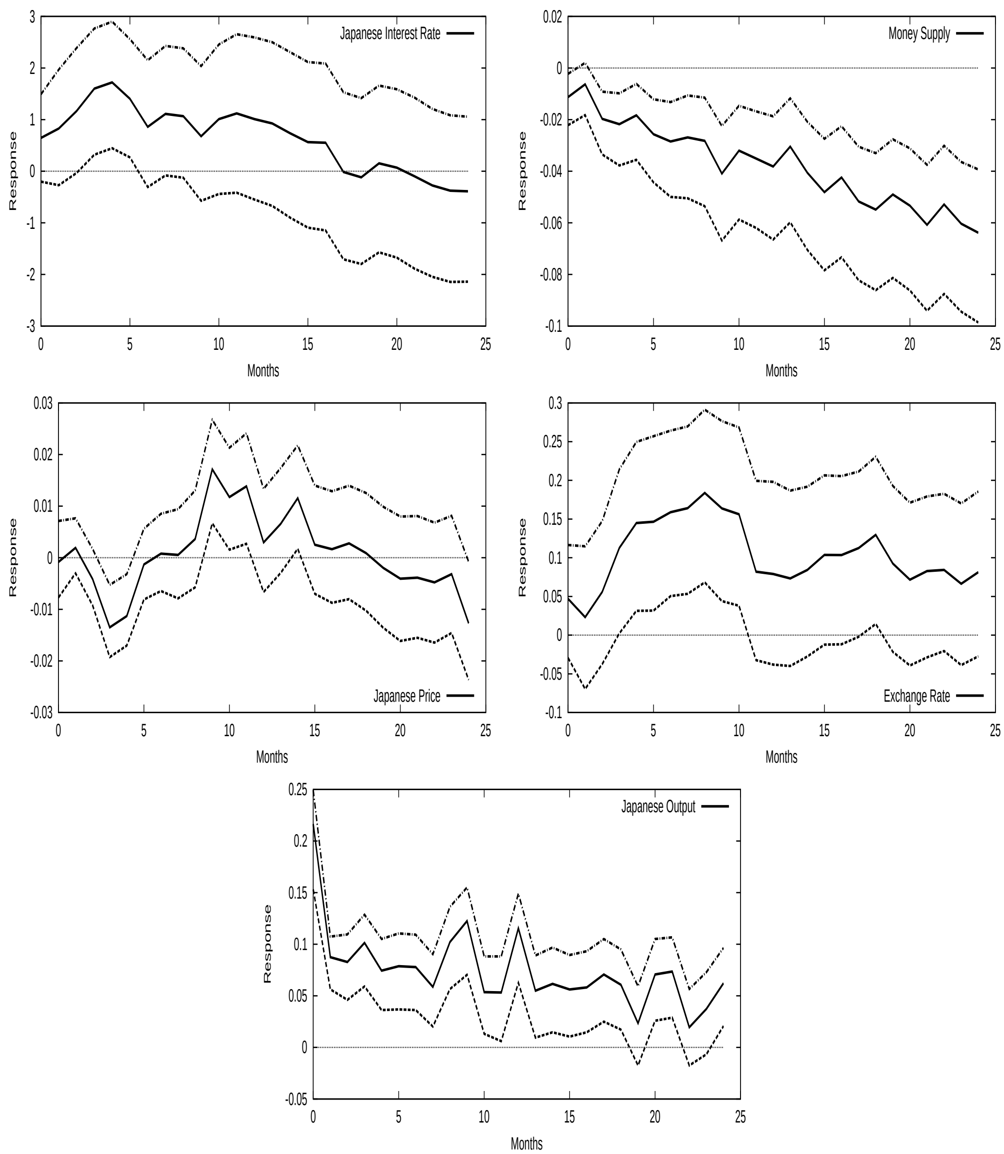

Figure 3.3: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using M2+CDs)

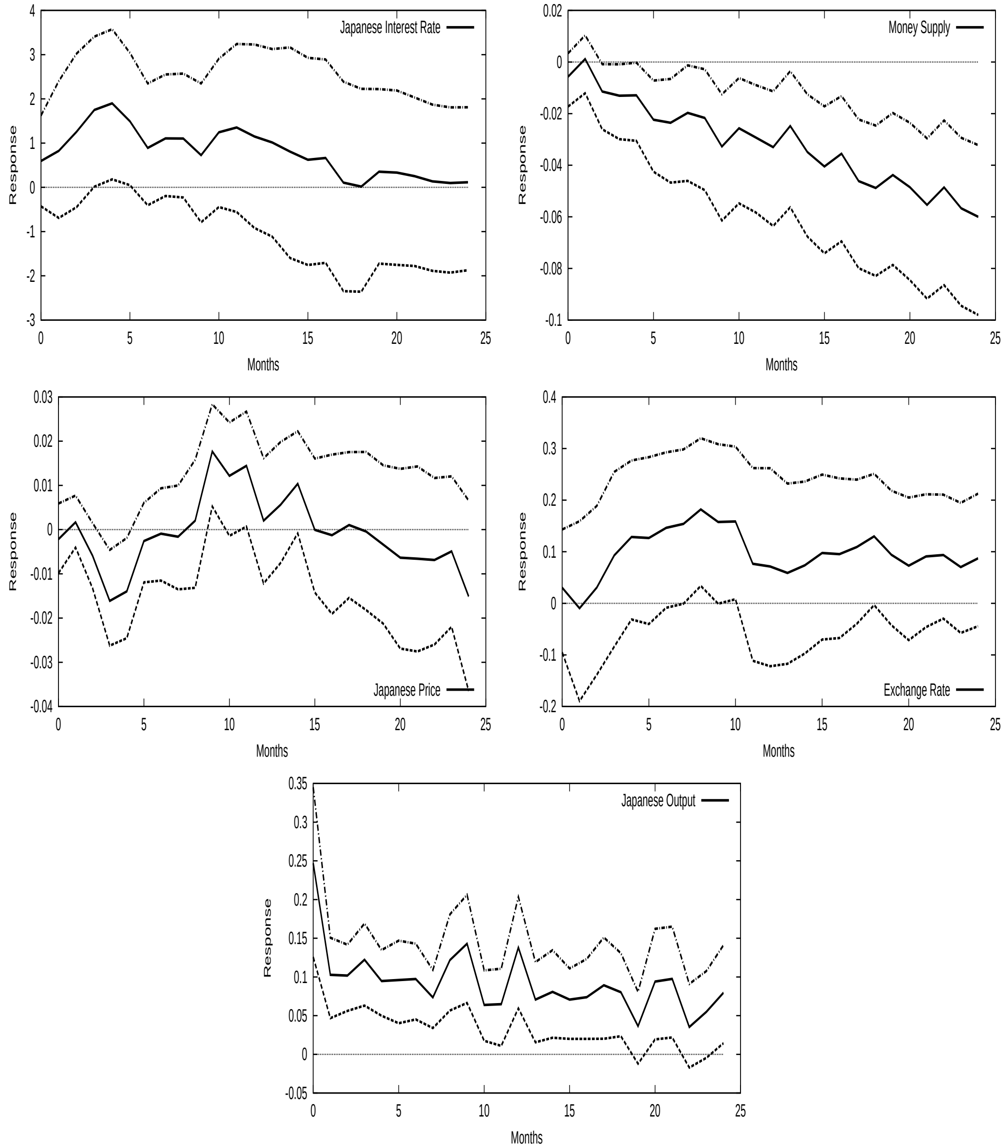

Figure 3.4: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using monetary base)

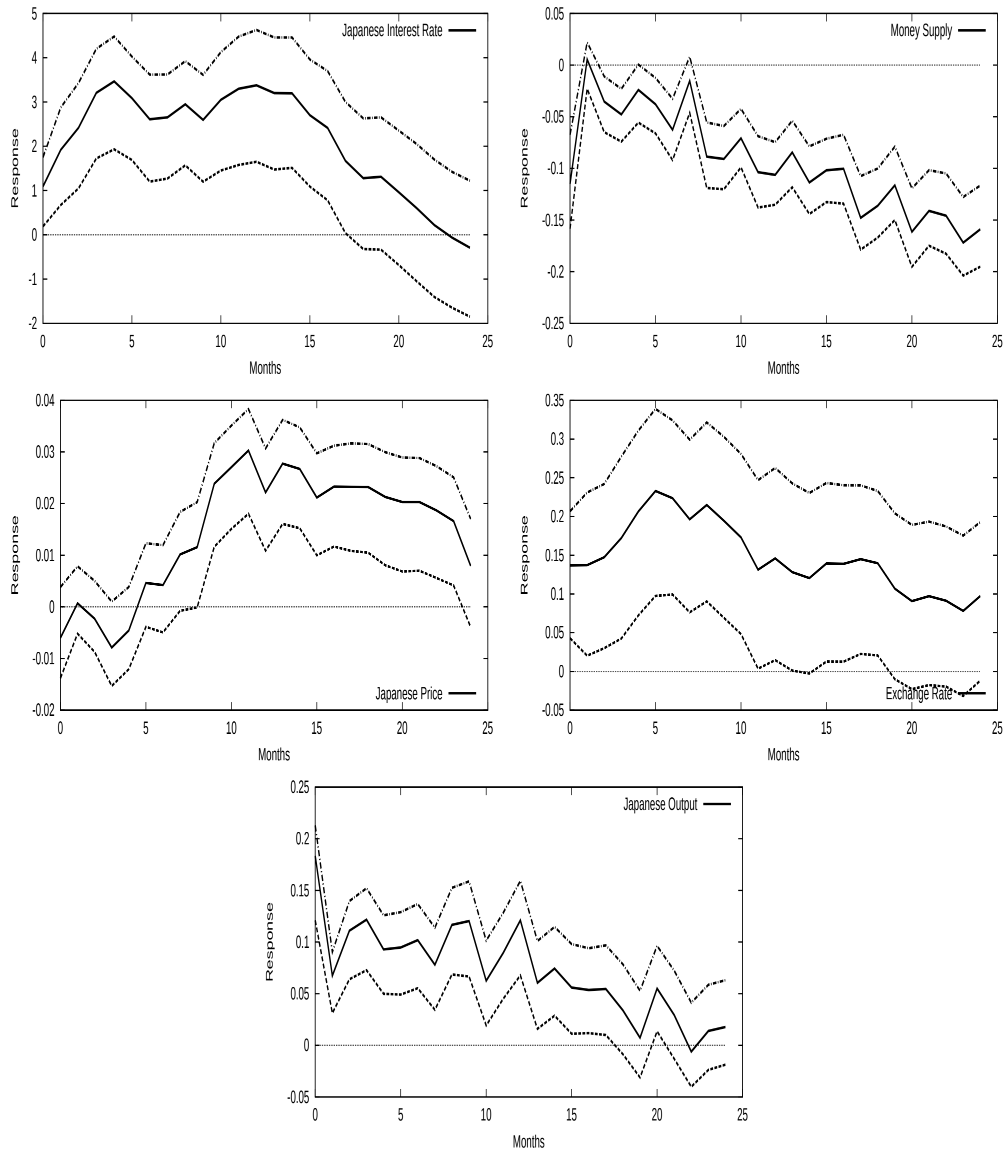

Figure 3.5: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using non-borrowed reserve ratio)

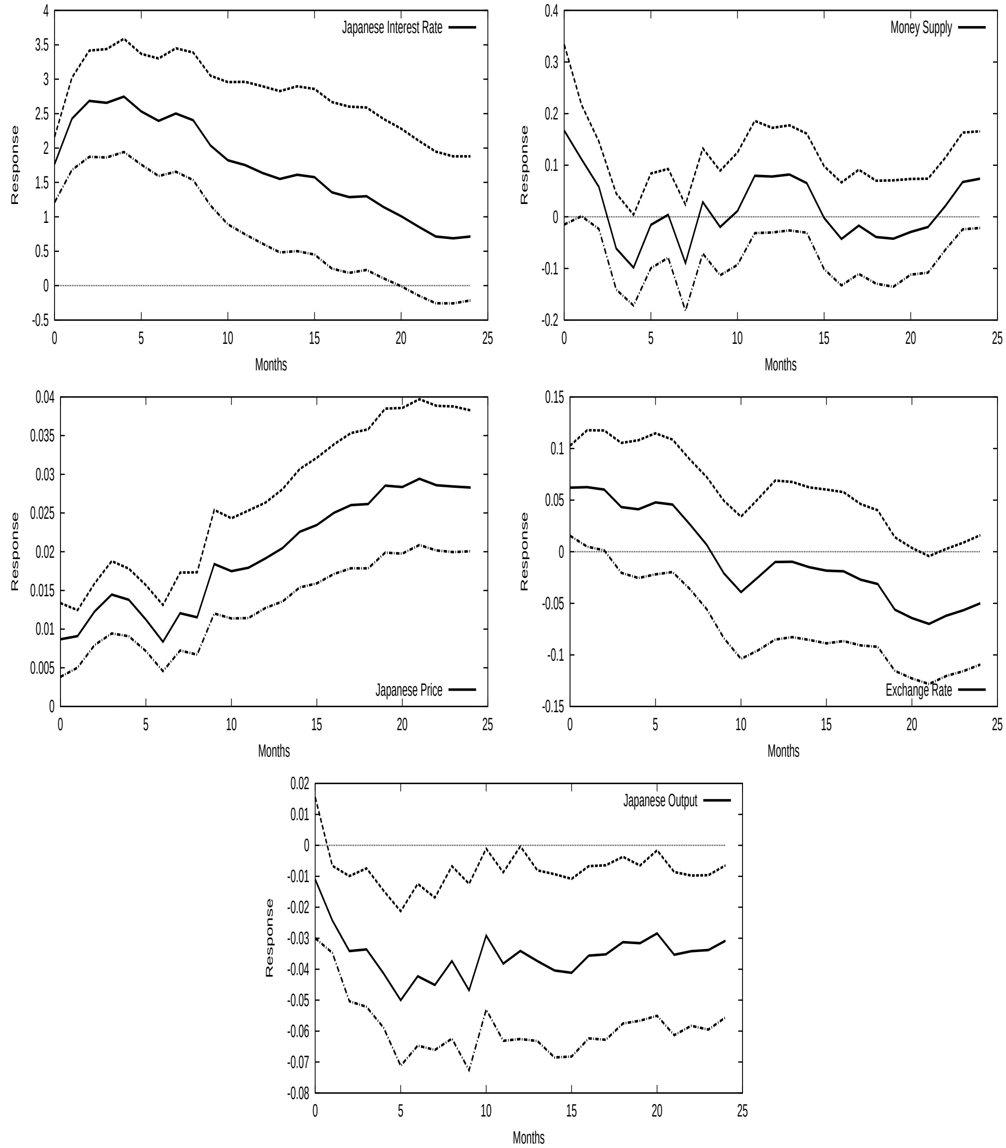

Figure 3.6: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using total reserves)

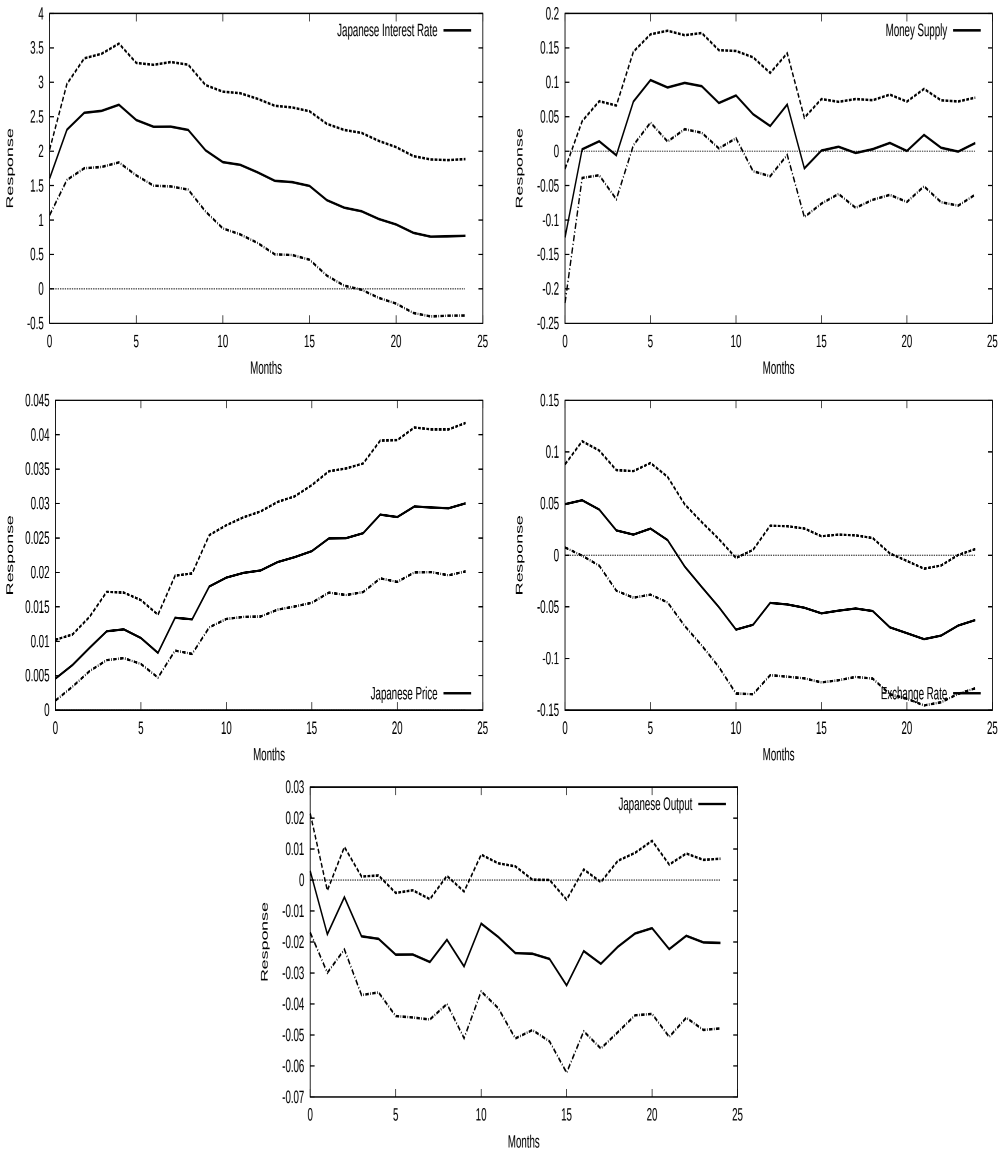

Figure 3.7: Impulse Responses to the Contractionary Monetary Policy Shock
(A Seven-Variable VECM, using borrowed reserves)

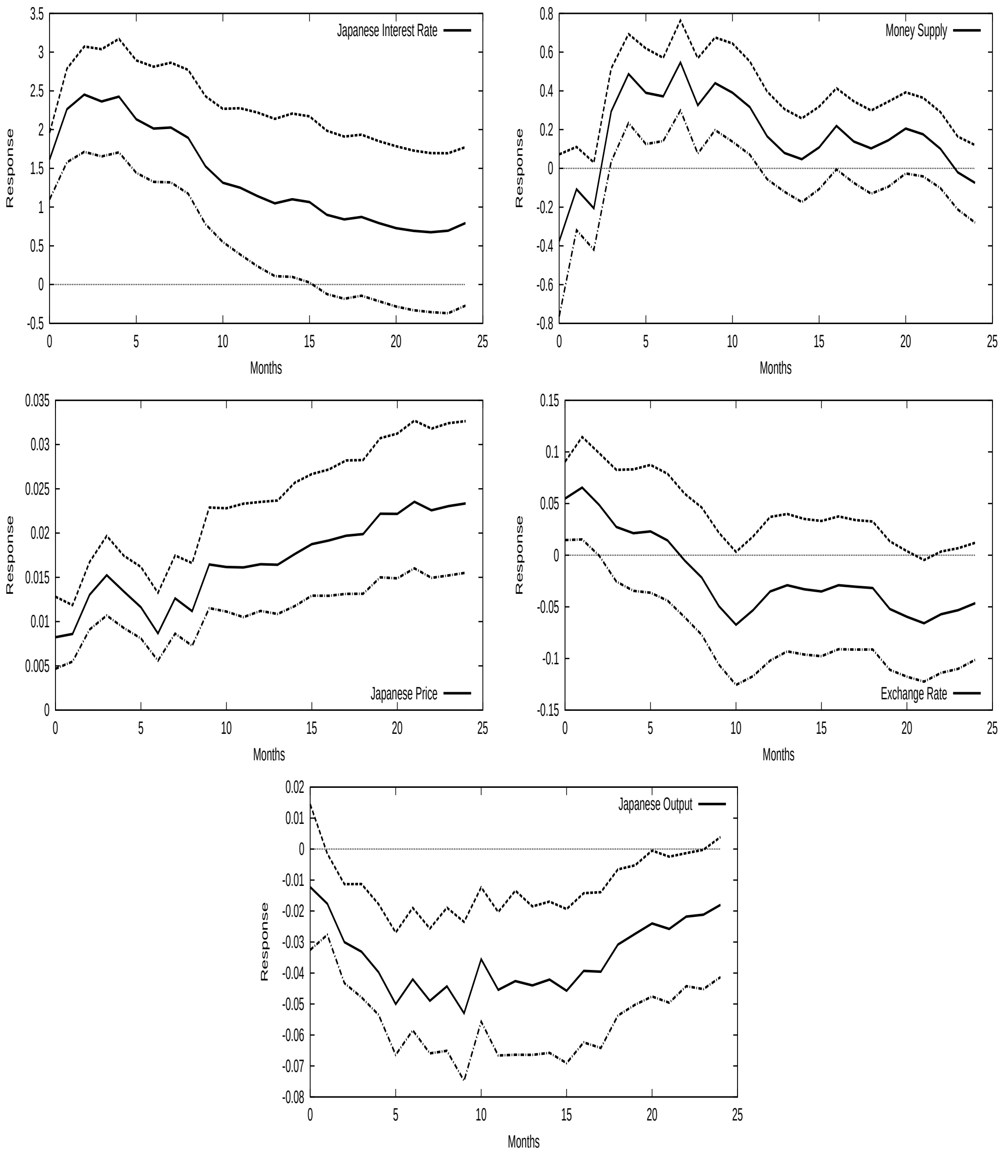

Figure 3.8: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run and Long-Run Restrictions - I)

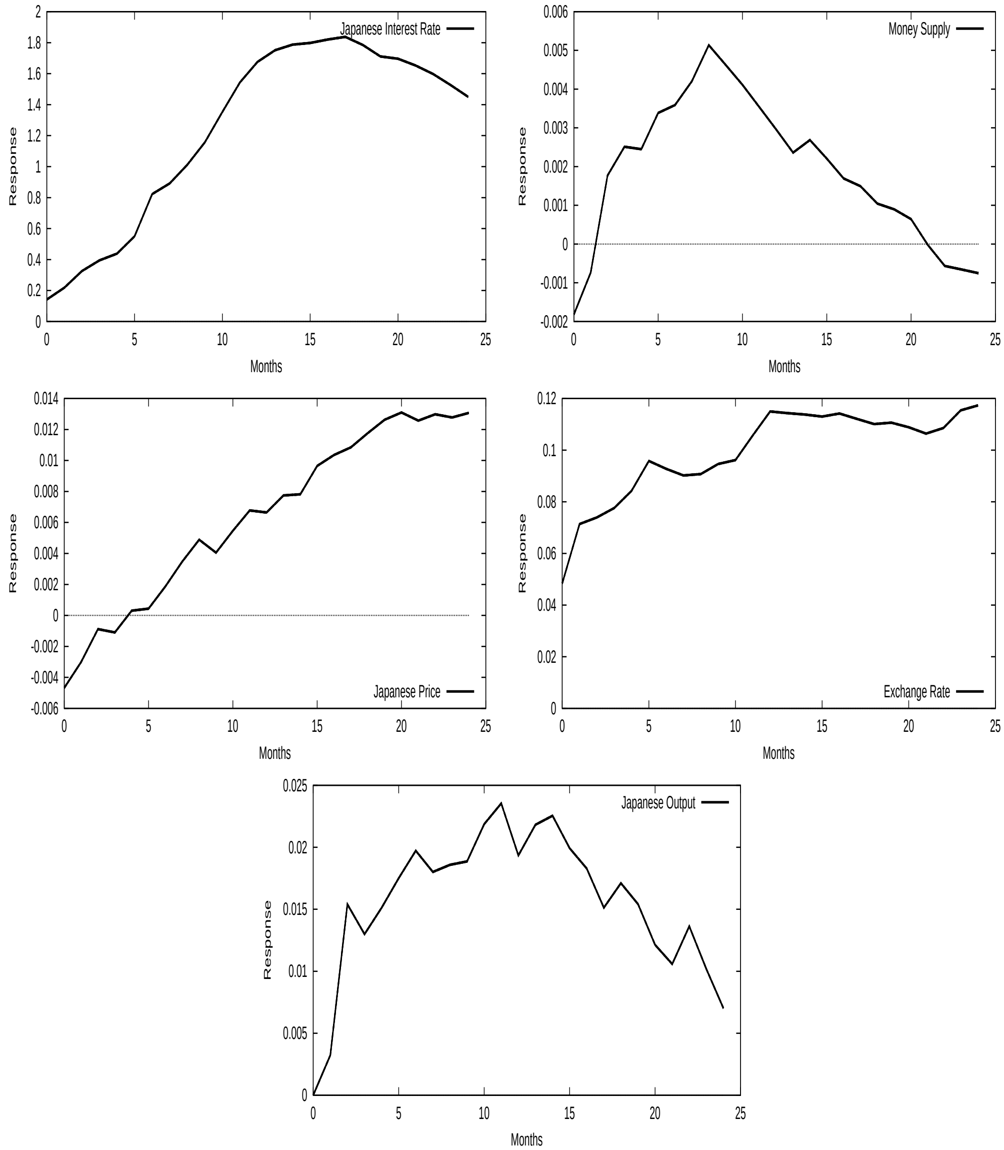

Figure 3.9: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run and Long-Run Restrictions - II)

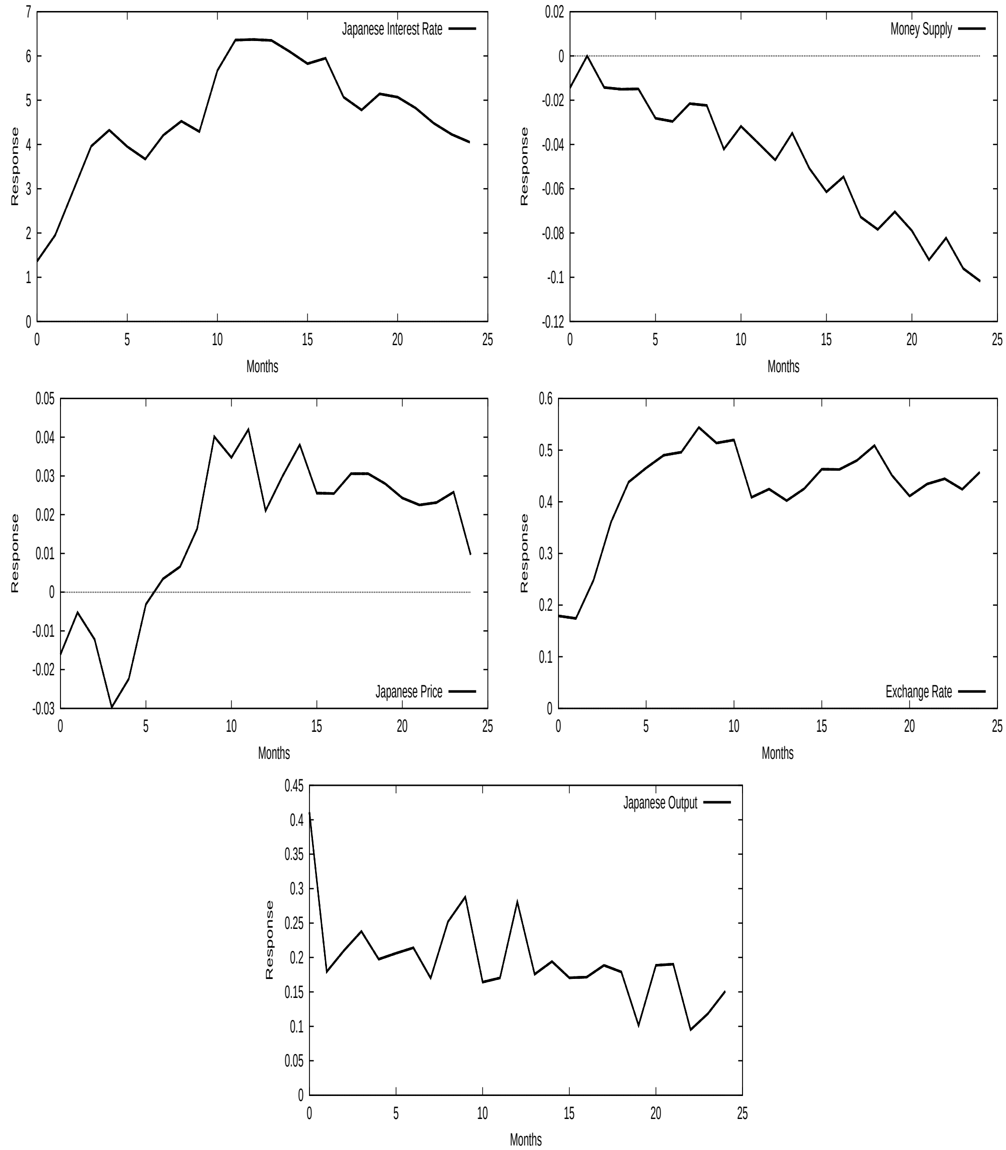

Figure 3.10: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run and Long-Run Restrictions - III)

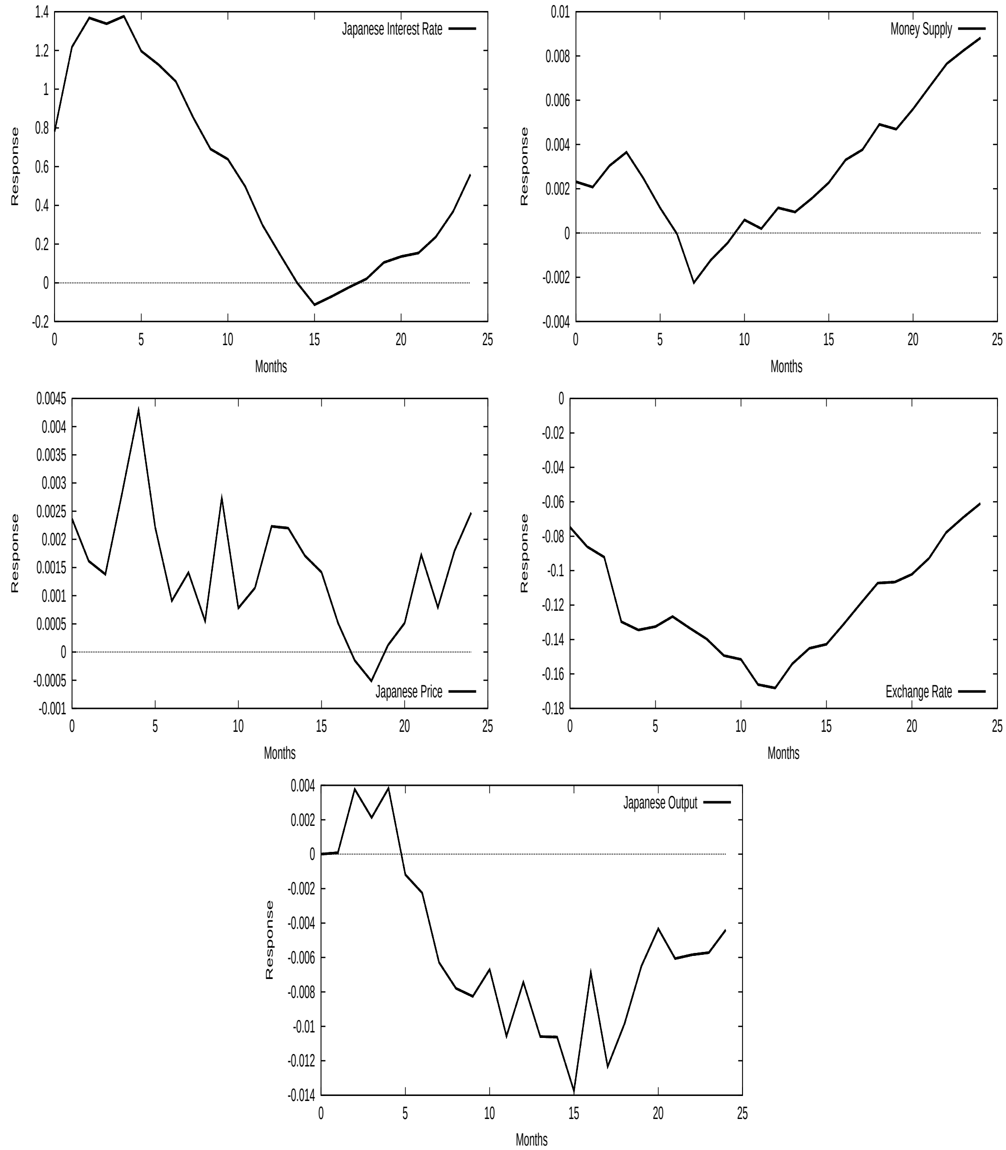

Figure 3.11: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run and Long-Run Restrictions - IV)

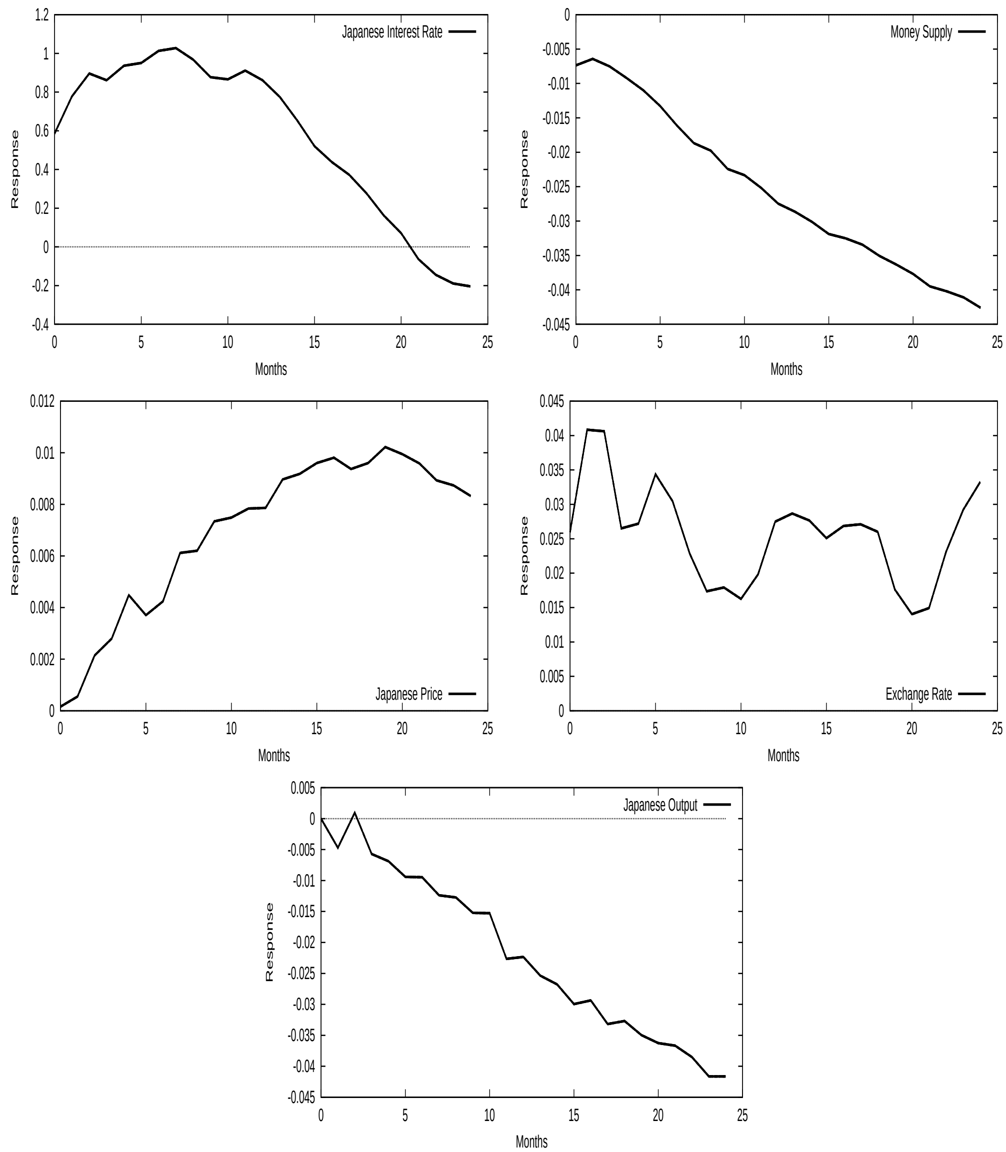

Figure 3.12: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run and Long-Run Restrictions - V)

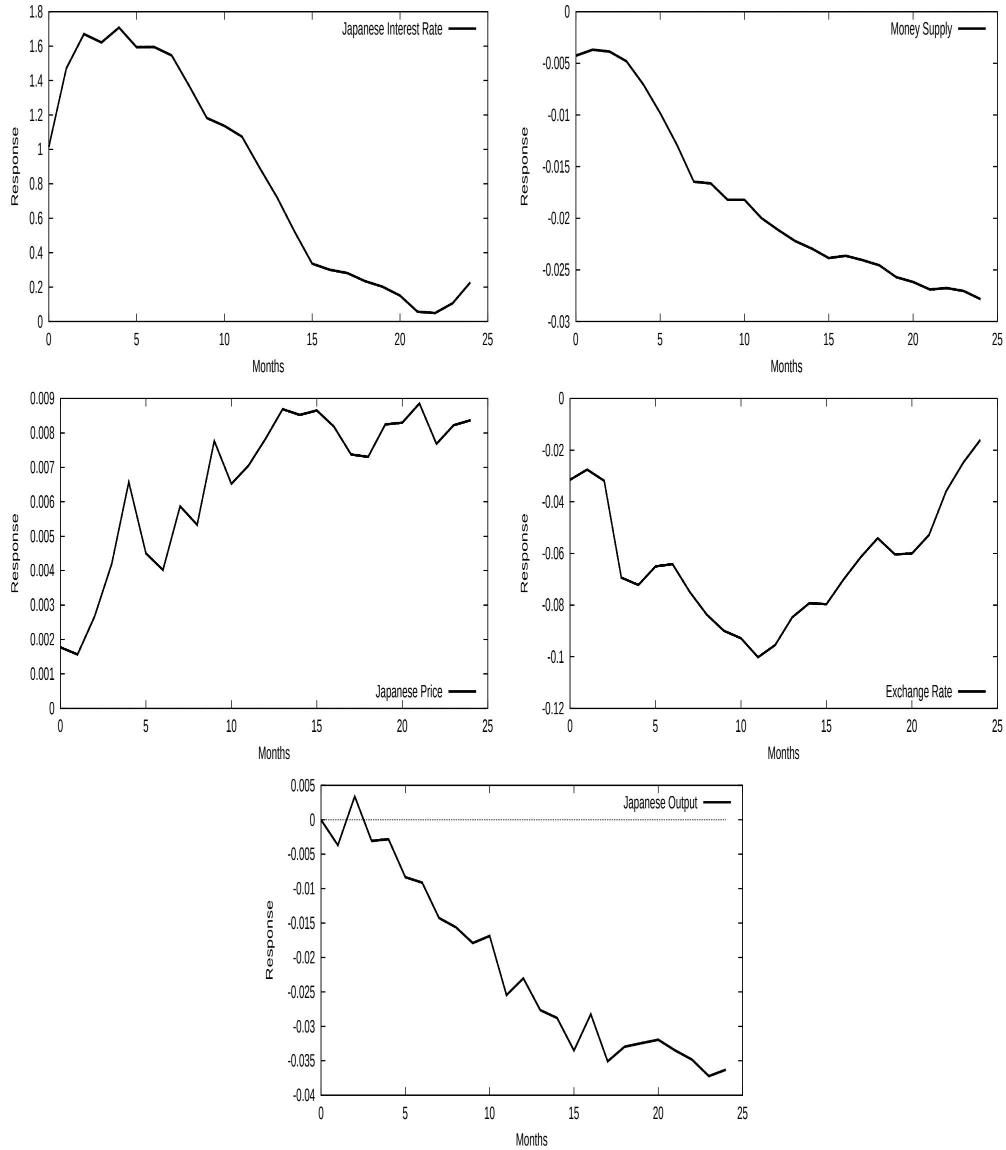

Figure 3.13: Impulse Responses to the Japanese Interest Rate Shock
(A Seven-Variable VAR, using M2+CDs)

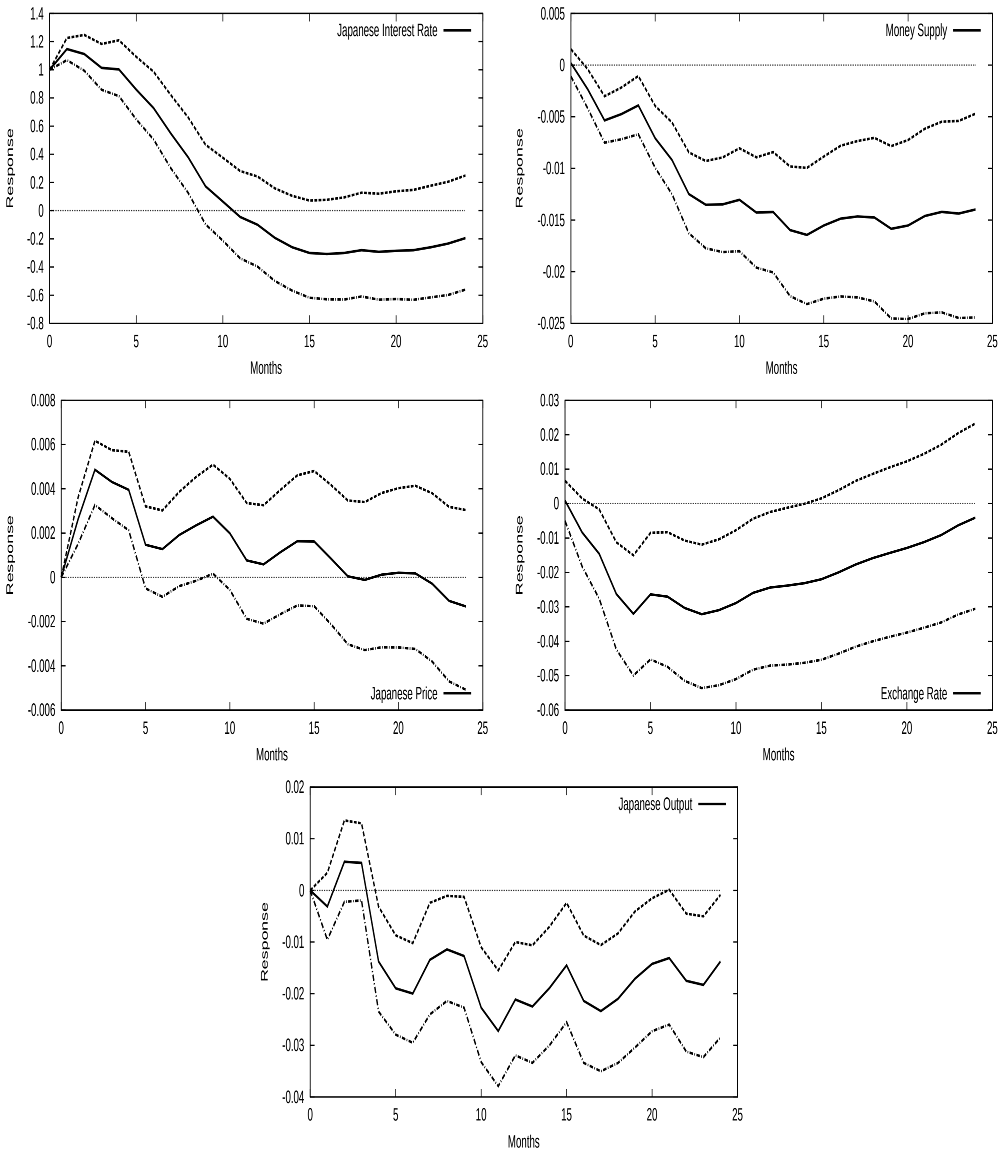

Figure 3.14: Impulse Responses to the Contractionary Monetary Policy Shock (A Seven-Variable VECM, using M2+CDs with Short-Run Restrictions)

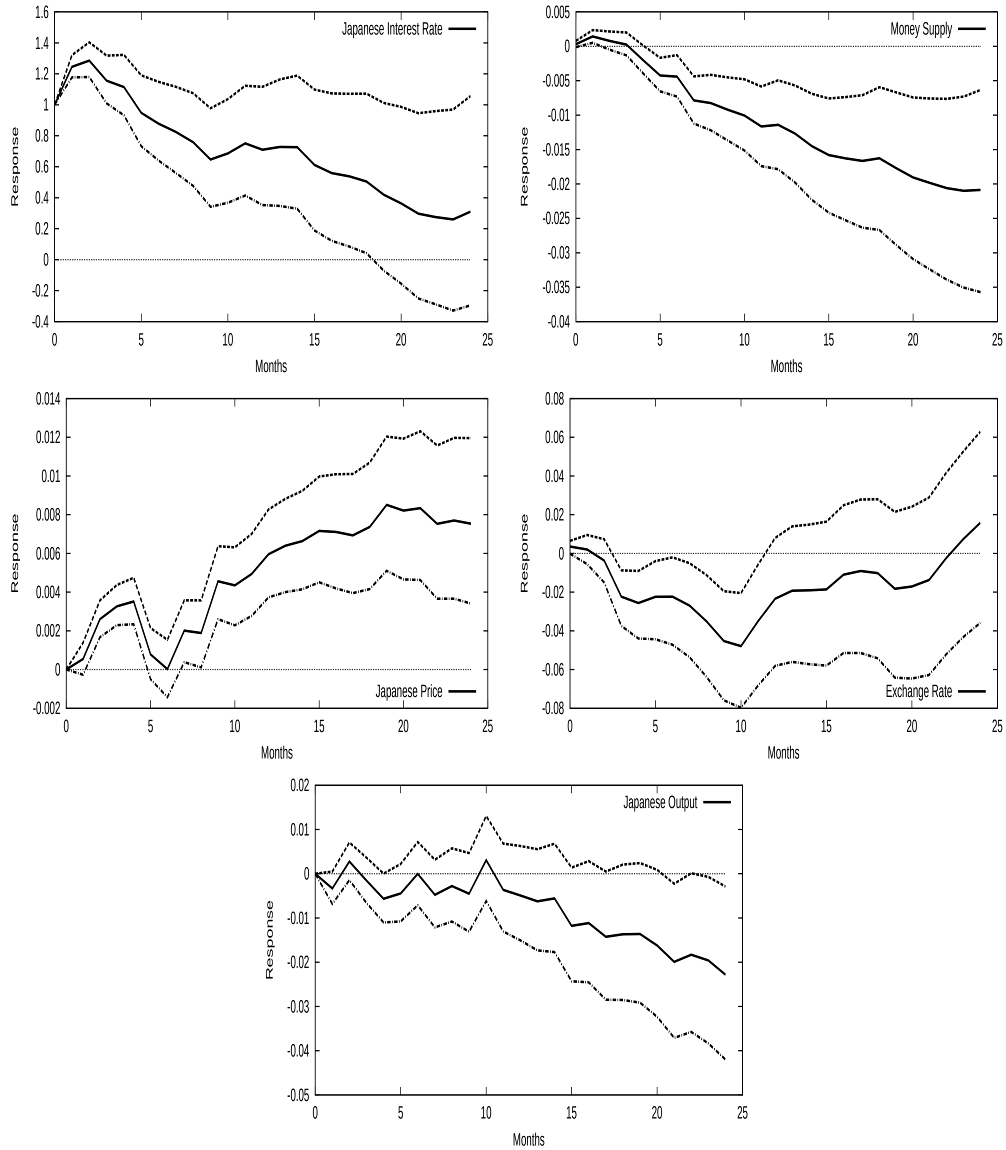

Figure 3.15: Impulse Responses to the Contractionary Monetary Policy Shock
(A Four-Variable VECM, using M2+CDs)

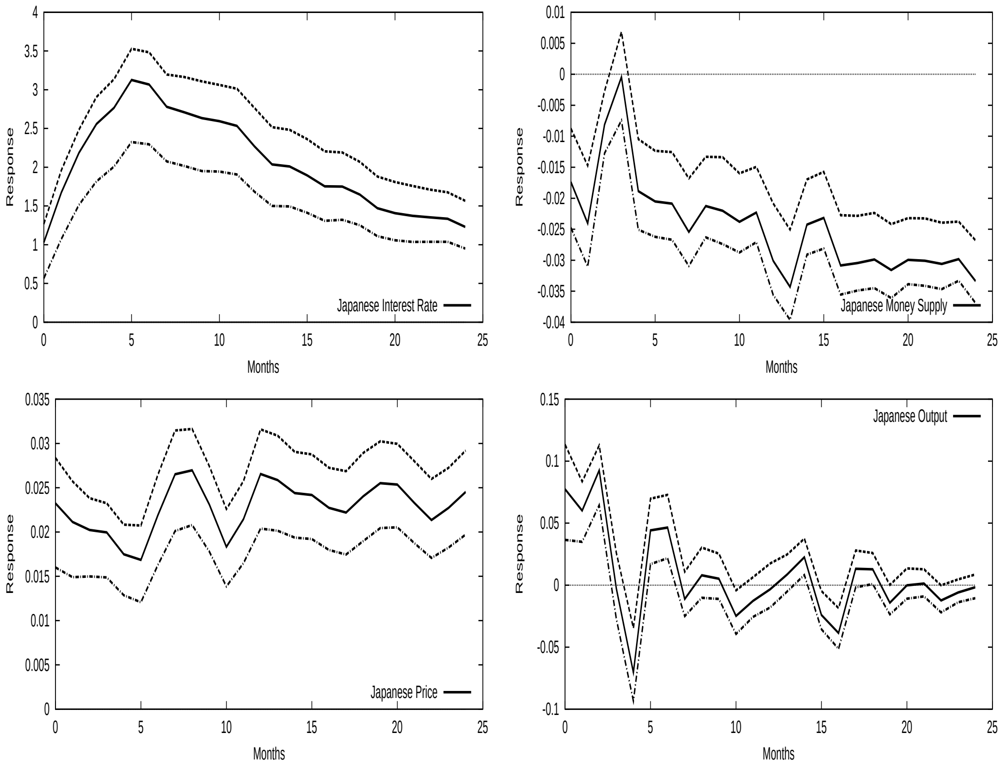

Figure 3.16: Impulse Responses to the U.S. Contractionary Monetary Policy Shock
(A VAR model with Short-Run Restrictions)

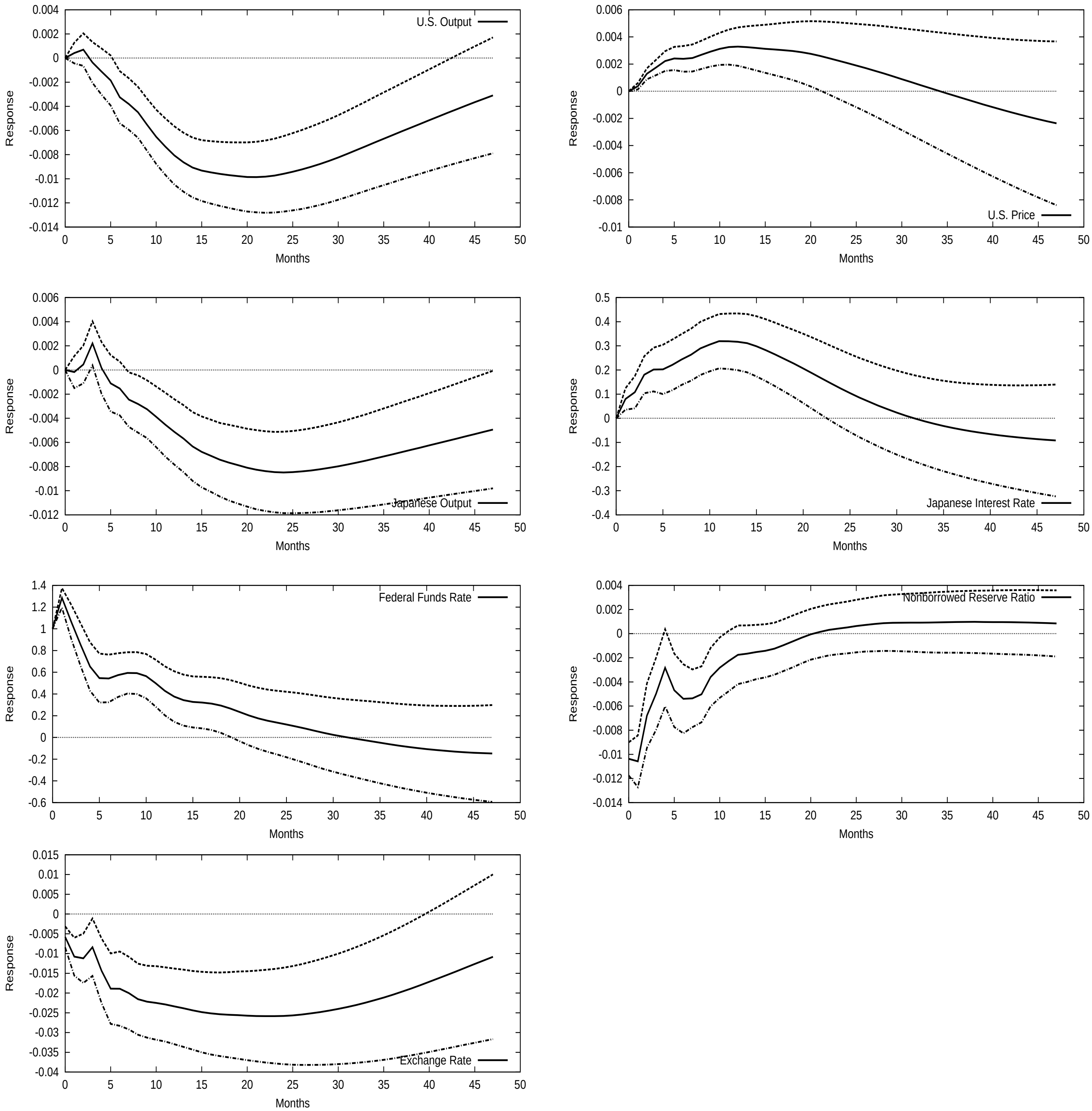

Figure 3.17: Impulse Responses to the U.S. Contractionary Monetary Policy Shocks
(A VECM with long-run restrictions)