Structural Vector Autoregressions: The Case of Thailand*

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-Preliminary Draft Version-

Abstract

We employ a structural vector autoregression (SVAR) approach in analyzing Thailand macroeconomic data. In this SVAR model we study contemporaneous and long-run impacts of four key macroeconomic variables (price, interest rate, money supply, and real GDP) under theoretical relationship suggested by Keating (1992). We estimate impulse response functions to show economic impacts in short-and long run, and we use this model to generate out-of-sample forecasts and create scenarios by incorporating some exogenous variables in the model such as the exchange rate, the US real GDP, the world oil price, each of which has the potential to affect the Thai economy.
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1 Introduction

This paper presents a small model of the Thai macroeconomy. The model utilizes the structural form equations of IS-LM framework to show the main macroeconomic interrelationship in the Thai economy and adopts vector autoregression (VAR) time series technique to generate dynamic analysis from the specified structure. In this way the model can be used to analyze the economic development and the effects of shocks for the Thai economy.

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Although the structure of model is closely resemble to the study of Keating (1992), it has been modified to allow for international influences to the model so as to befit the macroeconomic nature of Thailand as a small open economy. In tandem, the data have been changed to be empirically consistent with the behavior of the main macroeconomic aggregates of the Thai economy.

The model consists of four equations. They are price, output, money demand, and money supply equations, simultaneously estimated, with three exogenous variables that can heavily influence the Thai economy, namely the exchange rate, the US real output, and the world oil price. Restrictions are imposed in two different ways based on short-and long-run theoretical relationship to identify the structural parameters of the model.

The paper is organized as follows: We begin by providing a broad overview of the model in Section 2. We then present our estimation results in Section 3. We start by using the contemporaneous modeling strategy and consequently the long-run modeling strategy to show the sensitivity of four key macroeconomic variables–price, interest rate, money supply, and real GDP– to different sources of shocks. We provide the conclusion of key findings and the application of empirical results in Section 4.

2 Model

This paper relies heavily on the approach of structural vector autoregressions. It is the set of dynamic equations that are used to investigate the interrelationship of economic variables in the economy with some initially specified assumptions on how the economy works. These initially specified assumptions are essential for adding economic contents in the results of vector autoregressions (VARs), at the same time providing more considerable way to identify structural parameters from OLS or reduced-form VAR estimates in relative to Choleski decomposition, which often generates the results sensitive to the ordering of variables in the model.

Estimating procedure is performed as follows: First, a reduced-form VAR with the appropriate number of lags is estimated by OLS. Next, we impose restrictions according to the proposed theoretical interrelationship of economic variable to derive structural parameters from reduced-form equations. Finally, we carry out impulse responses and variance decompositions to yield dynamic pattern consistent with the proposed structural model. By doing this it will allow us to gain structural interpretations from resulting impulse responses and variance decompositions.

To identify structural parameters, we employ the contemporaneous and long-run approaches with the common set of macroeconomic variables. It should be noted that the crucial difference between the contemporaneous and long-run approach is the latter allows the data to determine short-run dynamics almost independently, conditioned merely on the establishment of the long-term relationship between economic variables.

2.1 Contemporaneous Structural VAR Model

The following four-equation contemporaneous structural VAR model is used to derive structural parameters from a reduced-form VAR. Starting with residuals (e_t) from a VAR system of the price level (p), output (y), the interest rate (r), and money (m), we then impose the particular set of short-run identifying restrictions on the residuals. In addition, the number of restrictions needed for the model to be just-identified is $\frac{n(n-1)}{2}$, where n is the number of equations in the VAR. As $n = 4$, the number of restrictions required for any just-identified models is $\frac{4(4-1)}{2} = 6$.

$$e_t^p = \varepsilon_{tt}^{as} \tag{1}$$
$$e_t^y = A_1 e_t^p + A_2 e_t^r + A_3 e_t^m + \varepsilon_t^{is} \tag{2}$$
$$e_t^r = A_4 e_t^m + \varepsilon_t^{ms} \tag{3}$$
$$e_t^m = A_5(e_t^y + e_t^p) + A_6 e_t^r + \varepsilon_t^{md} \tag{4}$$

Three restrictions are collected in equations 1 by assuming the price level is predetermined, and only responded by aggregate supply shock. Equation 2 is a IS function that specifies output as a function of all variables in the model. Two more restrictions are obtained in equation 3, a money supply function, as a result of an underlying assumption that the central bank does not immediately observe the behavior of aggregate output and price level. In this model the central bank only alters the interest rate in response to the change in money supply. Equation 4 is a money demand function, which specifies the nominal money balance as a function of nominal output and interest rate. This specification of last equation, in turn, provides the final restriction for the model to be just-identified. Note that each equation entails a structural disturbance (ε).

According to economic theory expected signs of coefficients in contemporaneous model are illustrated as follow: In this model favorable aggregate supply shock should contribute positively to output. Following the line of model construction, A_1 is, thus, likely to be positive. Generally a rise in the interest rate will slow down the economic growth while higher money supply will foster the economic expansion. This translates into likely negative and positive signs of A_2 and A_3, respectively. A_4 determines the central bank's behavior in governing the monetary policy. Money demand should respond to nominal output and the price level positively, and negatively to the interest rate. Thus, A_5 and A_6 are expected to be positive and negative, respectively.

2.2 Long-Run Structural VAR Model

Long-run structural VAR model used for estimation in this paper is the long-run approach developed by Blanchard and Quah (1989). Equations 5 through 8 present the long run identifying restrictions used in the empirical section. The time subscripts are dropped because the restrictions are imposed on the steady-state economic variables.

$$y = \varepsilon^{\text{as}} \tag{5}$$

$$r = S_1 y + \varepsilon^{\text{is}} \tag{6}$$

$$m - p = S_2 y + S_3 r + \varepsilon^{\text{md}} \tag{7}$$

$$m = S_4 y + S_5 r + S_6 (m - p) + \varepsilon^{\text{ms}} \tag{8}$$

Under this setting aggregate supply shock appears to be a sole source of permanent change in output. Thus, three restrictions are obtained in equation 5. Equation 6 is a IS or spending balance equation, providing two more restrictions by assuming that the interest rate is a function of output and IS shock. The final restriction come from equation 7, which specifies real money $(m - p)$ as a function of output, the interest rate, and money demand shock. Equation 8 sets money supply to be a function of all variables in the model, including money supply shock.

Expected signs of coefficients in long-run model are presented as follows: In this long-run model the IS equation should exhibit negative relationship between output and the interest rate. S_1 is, thus, expected to be negative. S_2 and S_3 are likely to be positive and negative, respectively as output and the interest rate should contribute positively and negatively to real money. Money supply equation is the policy reaction function of the central bank to change money supply in response to the movement of all other variables in the model which depends on the central bank's behavior, and the source of the instabilities emerged in the economy. It is, nevertheless, generally agreed that the central bank will accommodate the rise in money demand by increasing money supply proportionately and vice versa. S_6 is, thus, expected to be positive.

3 The Results of Estimation

To better reflect aggregate behavior of Thai economic variables, data used for contemporaneous and long-run models have been modified slightly.

Within the context of the Thai economy, we choose real GDP to measure output, CPI for the price level, M2 for money supply, and 3-month deposit rate as a proxy for the interest rate[1]. (All variables used for estimating the VARs here except for the interest rate are presented in log forms.) Comparison of data used for the US model and this model is described in Table 1.

Variable	US Model	Thai Model
Output	Real GNP	Real GDP
the Price Level	GNP deflator	CPI
Money Supply	M1	M2
Interest Rate	3-month Treasury Bill Rate	3-month Deposit Rate

Table 1: Data Comparison between the US and Thai Model

3.1 Parameter Estimates for Contemporaneous Structural Model

We begin our estimation with contemporaneous structural model which includes aforementioned variables to identify their structural relationships. In addition to constant term we incorporate the exogenous variables baht/US exchange rate, the world oil price, and US real GDP to the model to allow for international influences on the Thai economy as well as control for the effects of Asian crisis. We use quarterly unseasonalized data from the first quarter of 1993 to the last quarter of 2002 to estimate structural parameters in the model[2]. All variables are first differenced. We choose only one lag for this model over two lags, though suggested by most lag length criteria, because we prefer to keep the model parsimonious, and avoid encountering the degree of freedom problems, typically arisen when too many lags are included in VARs.

Table 2 reports parameter estimates for contemporaneous structural model. In the IS equation estimated coefficient on price is positive as the aggregate supply shock modeled via price would boost up output. Coefficient on interest rate is negative as hypothetized; however, negative coefficient on money would be unexpected in the IS equation. Positive coefficient on interest rate in money supply equation suggests central bank's behavior towards tightening monetary policy by raising the interest rate to stabilize money growth. Coefficient on nominal spending

[1]3-month deposit rate seems to be an appropriate choice of the interest rate because Thai citizens' behavior of holding money is sensitive to deposit rate, as the banking system remains to be the biggest source of collecting saving from the public in Thailand.

[2]The results are similar when we add seasonal dummies into the model to take care of seasonality problems.

and interest rate in the money demand equation is positive and negative, respectively, consistent to what we expected earlier. Unfortunately estimated coefficients in this model are insignificant.

	Parameter	Standard Error
A_1	11.64859	8.472296
A_2	-0.119504	0.096563
A_3	-2.510877	3.148375
A_4	142.7622	96.17033
A_5	0.952497	0.661238
A_6	-0.029511	0.022923

Table 2: Estimates for the Contemporaneous Structural Model

Impulse response functions from the contemporaneous model are presented in Figure 1-4. The aggregate supply shock raises price and output up by construction. The increase in output contributes to higher money demand. Then, the interest rate would rise to restore the equilibrium in money market. The rise in the interest rate makes the output fall in subsequent periods. Money increases only slightly. This evidence suggests weak relationship between money and aggregate supply shock. IS shock increases price, output, and the interest rate. Output expansion and price increase leads to the tighter money market, which results in positive uphold in interest rate for the first 3-4 quarters. The hike in interest rate subsequently slows down the economic activities, as reflected by the decline in the economic growth. As one can expect, the unexpected tightening of monetary policy (negative money supply shock) would increase the interest rate, depresses output, and brings down inflation. Surprisingly money demand shock increases price. Nevertheless, this shock raises the interest rate and dampens growth as economic theory suggests.

We now turns to variance decompositions for this contemporaneous model. Table 3 presents how different shocks contribute to fluctuation in a given variable at forecast horizons of 1-4 years. It discloses price change is directly related to aggregate supply shock. Money demand and IS shocks account for around 60 and 27 percent of output growth fluctuation, respectively, at longer horizons while aggregate supply shock gradually gains explanatory power on this variable's variability. It is important to note that money supply shock virtually has no influence on the movement of price and output. IS and aggregate supply shocks, after one year, account for around 47.5 and 32.2 percent of the fluctuation in interest rate change, respectively, with money demand and supply shocks accounting equally for the rest. Own shock accounts for

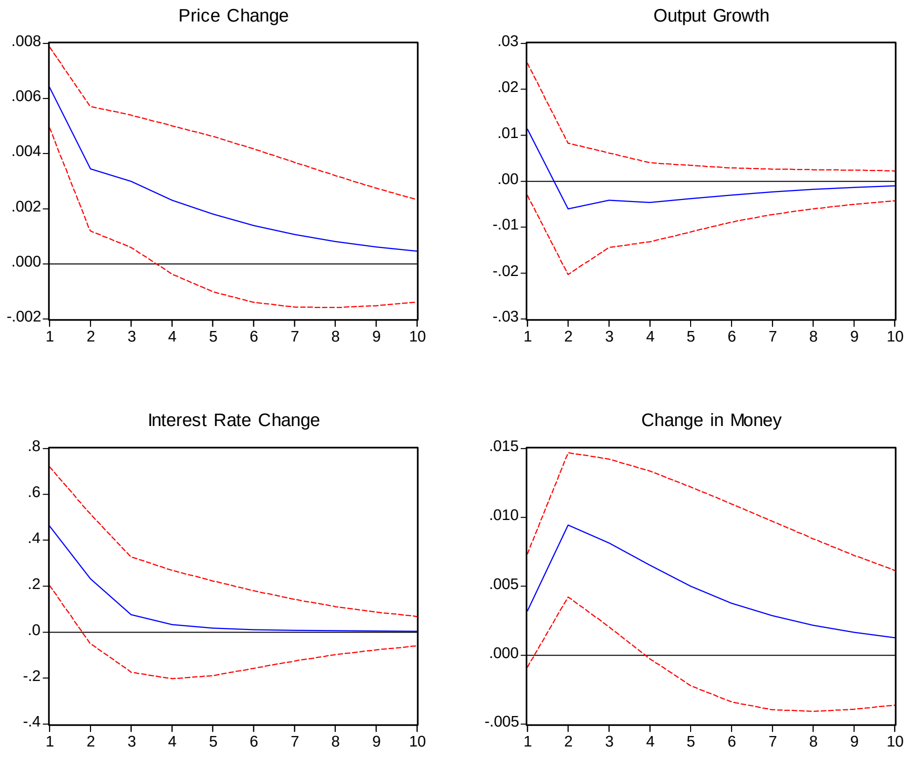

Figure 1: Responses to an Aggregate Supply Shock in the Contemporaneous Structural Model

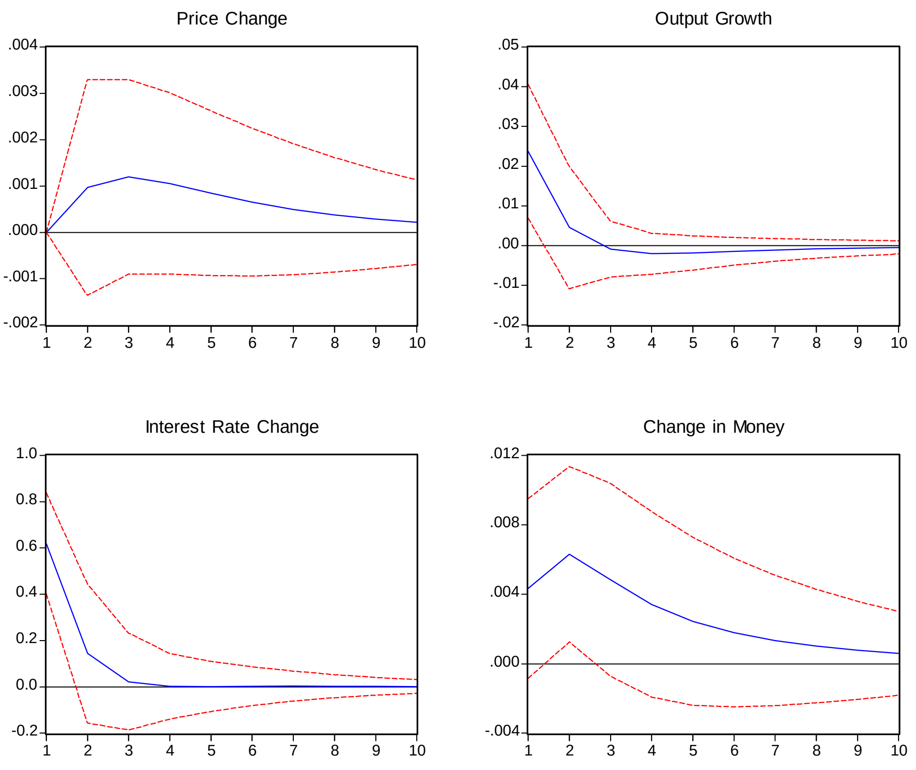

Figure 2: Responses to an IS Shock in the Contemporaneous Structural Model

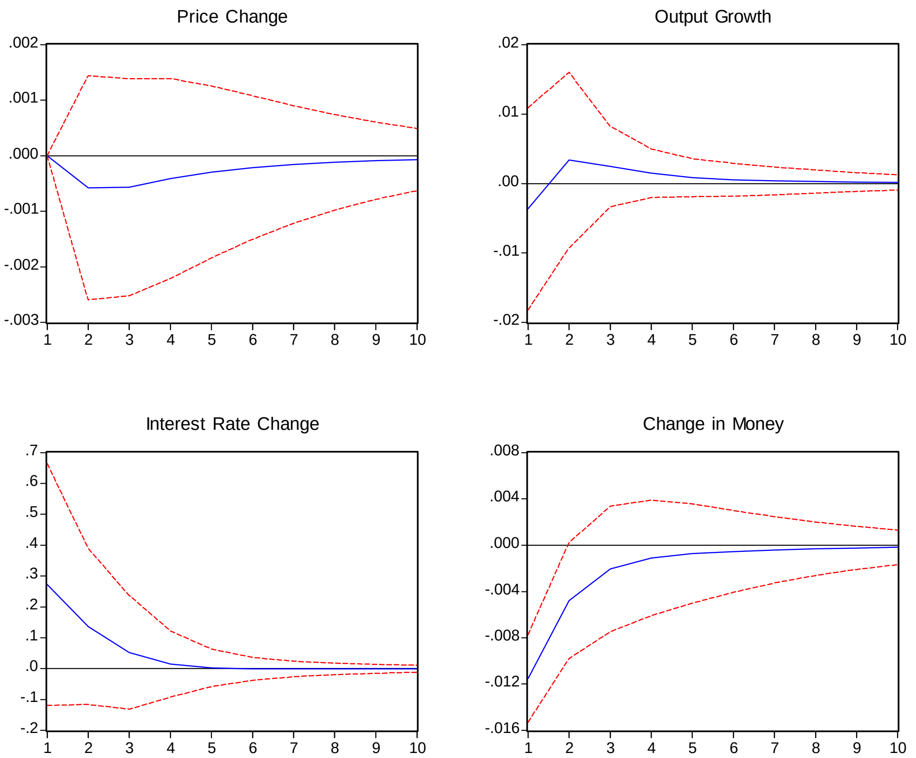

Figure 3: Change in a Money Supply Shock in the Contemporaneous Structural Model

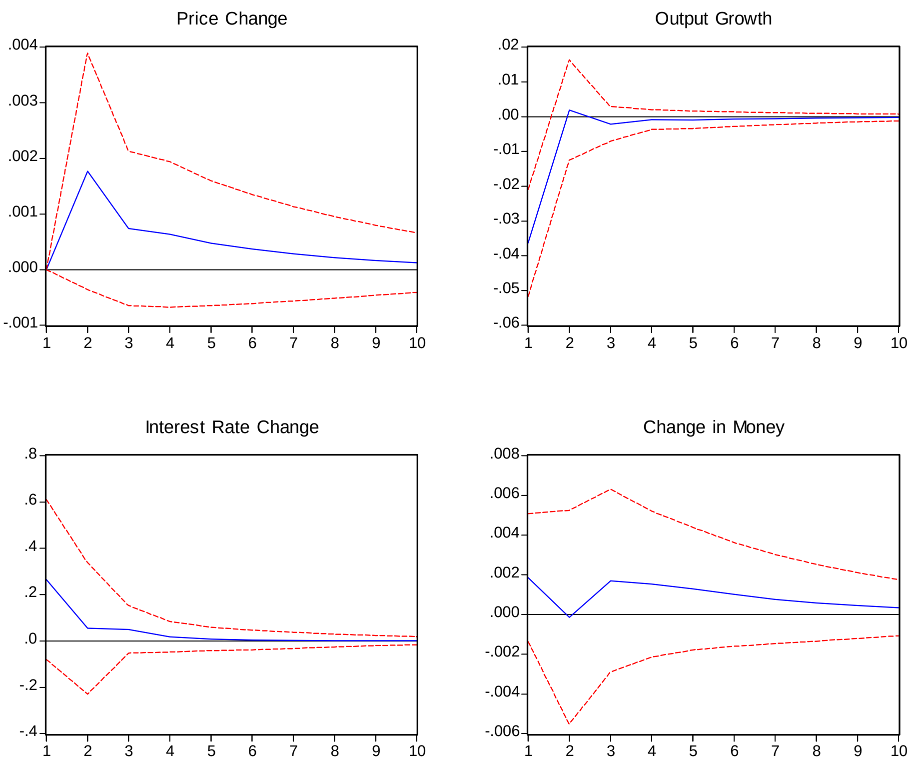

Figure 4: Responses to a Money Demand Shock in the Contemporaneous Structural Model

most of the fluctuation in the change in money in the first quarter, but afterwards the role of aggregate supply shock in explaining this fluctuation becomes more pronounced at the expense of diminishing influence of money supply shock.

Variance Decompositions of Price Change				
Period	Aggregate Supply	IS	Money Supply	Money Demand
1	100.0	0.0	0.0	0.0
4	88.9	4.6	1.1	5.4
8	87.5	5.9	1.2	5.4
12	87.4	6.0	1.2	5.4
16	87.4	6.0	1.2	5.4
Variance Decompositions of Output Growth				
Period	Aggregate Supply	IS	Money Supply	Money Demand
1	6.3	27.8	0.6	65.3
4	9.4	27.3	1.5	61.8
8	10.7	27.1	1.5	60.6
12	10.8	27.1	1.5	60.5
16	10.8	27.1	1.5	60.5
Variance Decompositions of Interest Rate Change				
Period	Aggregate Supply	IS	Money Supply	Money Demand
1	28.7	51.7	10.0	9.5
4	32.2	47.5	11.3	9.0
8	32.2	47.5	11.3	9.0
12	32.2	47.5	11.3	9.0
16	32.2	47.5	11.3	9.0
Variance Decompositions of the Change in Money				
Period	Aggregate Supply	IS	Money Supply	Money Demand
1	6.3	11.4	80.2	2.1
4	44.2	19.8	34.1	1.8
8	48.2	19.5	30.0	2.3
12	48.6	19.5	29.6	2.3
16	48.7	19.5	29.5	2.3

Table 3: Variance Decompositions for the Contemporaneous Structural Model

3.2 Parameter Estimates for Long-Run Structural Model

In the long-run model we use the same set of macroeconomic variables as in the contemporaneous model, but allow only constant term as exogenous variables[3]. Given our sample size is not that long and avoiding the loss of information about the long-run relationships (when the data are first differenced), we prefer to estimate the long-run model in level. Particularly a VAR using the first differenced data provides not much information on the long-run relationships between the variables in the VAR, and it is this aspect the economic theory is usually most informative. Furthermore, although the estimation in level may cause some losses of efficiency, it comes at no costs in terms of the consistency of the estimators. In fact, most empirical literature tend to estimate the VARs that are unrestricted in level. We will do the same for this long-run model.

We report the parameter estimates for the long-run structural model in Table 4. Estimated coefficients on output in the IS equation is negative as expected. In the money demand function estimated coefficients on output and the interest rate are positive and negative, respectively, consistent to economic theory. Central bank's policy reaction function is represented by money supply equation, which shows the positive response of money supply to the rise of money demand.

	Parameter	Standard Error
S_1	-1.162160*	0.460193
S_2	0.228114*	0.037765
S_3	-0.013844	0.027507
S_4	0.354876*	0.063652
S_5	-0.025041	0.049285
S_6	0.306639*	0.034864

Table 4: Estimates for the Long-Run Structural Model
Remark: An asterisk (*) represents the 5 percent level of significance.

Impulse response functions from the long-run model are presented in Figure 5-8. The aggregate supply shock raises output, as one can expect. Its effect lasts around 11 periods before it starts to dissipate. As the aggregate supply shock boosts production of goods and services, the interest rate falls initially before rising due to higher demand in the economy. Money and real money increase slightly in response to aggregate supply shock. The IS shock causes output and the interest rate to rise, as anticipated. However, output increases only slightly and temporarily because the restriction allows the aggregate supply shock to be sole source of driving output in long run. Money and real money, in

[3] Lag length is set to one, as in the contemporaeneous model. Moreover, we obtain similar results when we add seasonal dummies in the model.

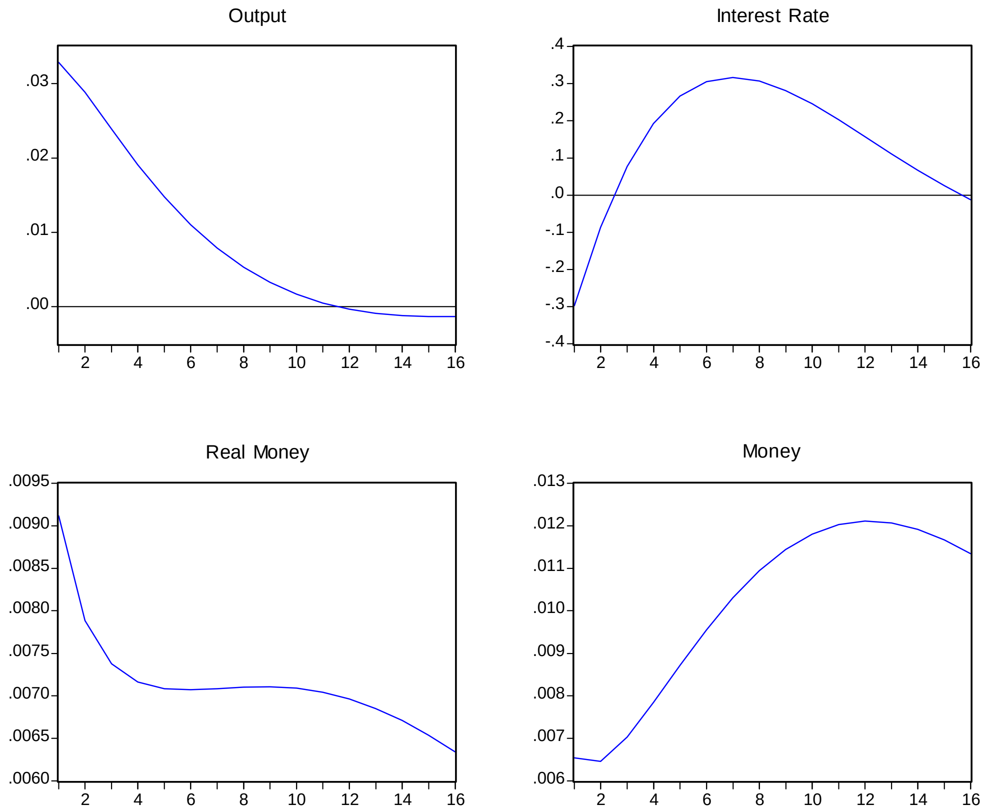

Figure 5: Responses to an Aggregate Supply Shock in the Long-Run Structural Model

response, decrease by small amount. The money demand shock raises output initially, but output declines quickly after the second period. The interest rate increases significantly by this shock. The money demand shock is responded by the rise in money supply both in real and nominal terms. Money supply shock causes output to fall initially, nevertheless output changes the course and stays in positive territory for most of the time. The interest rate decreases in response to an increase in money supply, which is reflected by the rise in money and real money.

Table 5 presents variance decompositions of each endogenous variables in this long-run model. Aggregate supply shock dominantly explains the fluctuation in output, accounting around 80 percent of overall variability in the long run. Fluctuation in the interest rate is mostly explained by the money demand shock; however, its influence on the interest rate appears to be lessened at longer horizon as the effect of the

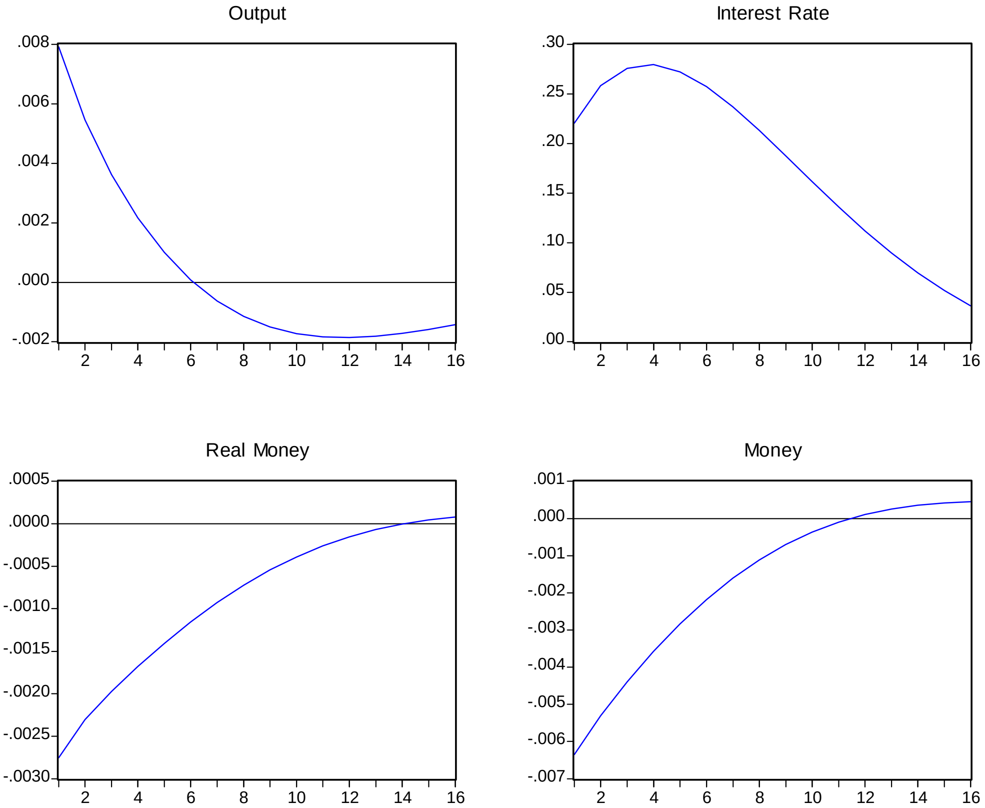

Figure 6: Responses to an IS Shock in the Long-Run Structural Model

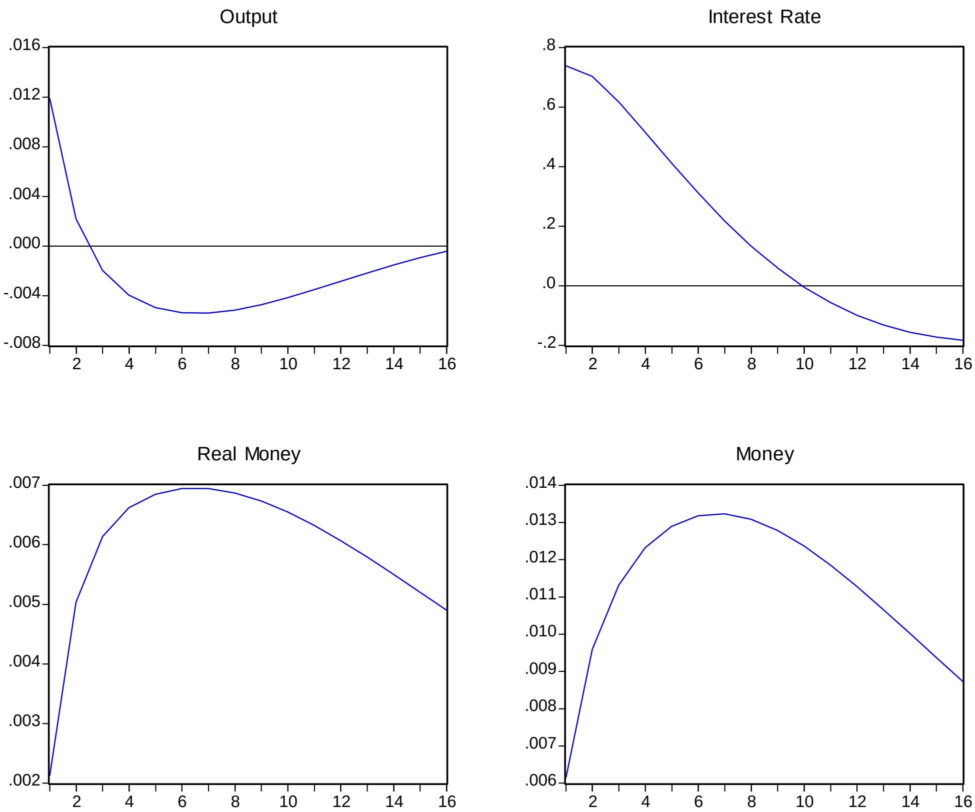

Figure 7: Response to a Money Demand Shock in the Long-Run Structural Model

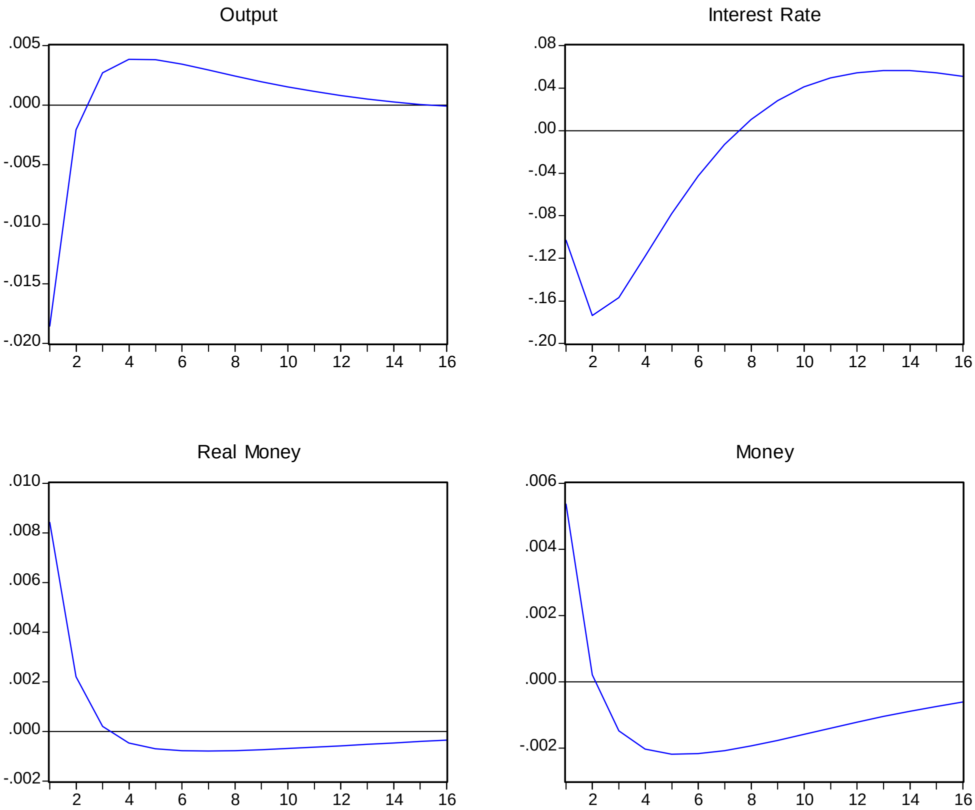

Figure 8: Responses to a Money Supply Shock in the Long-Run Structural Model

aggregate supply shock becomes more pronounced in explaining the fluctuation of this variable. The aggregate supply shock steadily explains the fluctuation in real money, accounting about a half of this variable's entire fluctuation. It should be noted the money demand shock gains more important role of explaining the volatility of this variable overtime. The fluctuation in money are attributable to all four shocks in the first period. However, overtime explaining role of the IS and money supply shocks on the money variability diminishes. Thus, the aggregate supply and money demand shocks become dominant factors to explain the money fluctuation in the long run.

Variance Decompositions of Output				
Period	Aggregate Supply	IS	Money Demand	Money Supply
1	66.3	3.9	8.7	21.2
4	81.5	3.2	4.7	10.6
8	80.4	2.8	6.7	10.1
12	78.9	3.0	8.0	10.1
16	78.6	3.2	8.2	10.0
Variance Decompositions of Interest Rate				
Period	Aggregate Supply	IS	Money Demand	Money Supply
1	12.8	7.0	78.7	1.5
4	6.4	12.4	77.6	3.6
8	15.9	16.4	64.8	2.8
12	20.4	17.6	59.2	2.8
16	20.1	17.3	59.7	3.0
Variance Decompositions of Real Money				
Period	Aggregate Supply	IS	Money Demand	Money Supply
1	50.1	4.6	2.7	42.6
4	54.8	4.3	24.3	16.6
8	52.8	2.9	35.3	9.1
12	53.2	2.0	38.2	6.5
16	54.6	1.6	38.5	5.3
Variance Decompositions of Money				
Period	Aggregate Supply	IS	Money Demand	Money Supply
1	28.6	26.9	25.3	19.3
4	26.4	13.6	55.3	4.8
8	31.7	6.3	59.1	2.8
12	38.2	3.9	55.8	2.1
16	43.2	3.0	52.2	1.6

Table 5: Variance Decompositions for the Long-Run Structural Model

Although these two structural models are different in terms of specification and restriction, they are constructed to answer the same questions i.e. how the key macroeconomic variables respond to the same structural shocks in different models. It will, therefore, be beneficial to compare the results of these two models. By looking at variance decompositions in Table 3 and 5, we find the aggregate supply shock is a salient factor to explain the output variation in the long-run model while, in the contemporaneous model, the fluctuation in output attributes to the money demand shock. Both models, however, indicate the aggregate supply shock is an important factor to explain the money fluctuation, and also point out the money supply shock virtually has no effect on explaining the fluctuation in the interest rate.

4 Conclusion

In this paper we have employed two structural VAR models to study contemporaneous and long-run impacts of Thailand four key macroeconomic variables. It appears the long-run model yields more consistent results to economic theory than the contemporaneous model due mainly to the property of the long-run model that allows the data to determine short-run dynamics almost independently and the fact that economic theory has been more settled on how the long-run relationships of macroeconomic variables should be. It, however, does not discourage us to use the contemporaneous model in explaining dynamic behavior of the economy. To improve the performance of the contemporaneous model, we need to modify the specified structure of the model to fit the context of the Thai economy, and take into account the extraordinary movement of nominal economic variables especially in the post-crisis period (which are often included in the contemporaneous model)[4].

So far the two models can be used to explain business fluctuation in the Thai economy. Next, we will use these two models to generate out-of-sample forecasts and create scenarios, caused by the significant change in exogenous variables which have the potential to affect the Thai economy (e.g. exchange rate, the world oil price).

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