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Monetary Policy and the Real Economy: A Structural VAR Approach for Sri Lanka

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Abstract

This paper attempts to identify the monetary policy indicator that better explains the Sri Lankan monetary policy transmission mechanism. This study also estimates how shocks stemming from foreign monetary policy and/or oil price affect domestic macroeconomic variables. To that end, we use a seven variable structural VAR model by utilizing monthly time series data from Sri Lanka covering the period from January 1978 to December 2011. Impulse response functions and variance decompositions are used to describe the relationships among variables. Our empirical findings suggest that the interest rate shocks play a significant and better role in explaining the movement of economic variables than monetary aggregate shocks or exchange rate shocks. Second, the targeting of reserve money is a better strategy for the Sri Lankan economy than a focus on narrow or broad money. Third, our findings clearly show that foreign monetary policy shocks and oil price shocks do not seem to affect the domestic economy. Finally, the inclusion of oil price in the SVAR model helped us overcome the puzzles that often appear in the existing literature in monetary economics.

Keywords: Impulse responses, Monetary Policy, Small Open Economy, Structural VAR Models

JEL Classification: C32, E52, E58, F41

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1 Introduction

Monetary policy is broadly used by central banks as a stabilization policy toolkit in guiding their respective economies, to achieve sustained and high output growth rates and maintain low inflation rates. The effectiveness of monetary policy relies on the policy-makers' ability to make accurate assessments of the effects of monetary policy on price stability and economic activities, as well as those of the timing of policy implementation. The existing monetary literature addresses many questions regarding the relationship between macroeconomic variables and monetary policy. Since the seminal work of Sims (1980), the VAR model has been broadly used by researchers to answer these questions. However, there is no consensus among scholars with regard to the effect of monetary policy shock on macroeconomic variables.

The vast body of empirical literature, much of which investigates the monetary policy transmission mechanism by using VAR analyses of open and closed economies, has identified several empirical anomalies. Typically, such "puzzles" consist of price puzzles where the price level increases rather than decreases following interest rate (IR) innovations (e.g., Sims, 1992). Second, there are liquidity puzzles where the nominal IR increases rather than decreases following monetary aggregate shock (e.g., Leeper and Gordon, 1991). Third, there are exchange rate (ER) puzzles where domestic currency depreciates relative to the U.S. dollar, rather than appreciates, followed by a positive IR shock (see Sims, 1992; Grilli and Roubini, 1995). Finally, there are forward discount bias puzzles where "positive interest differentials on domestic assets are associated with persistent appreciations of the domestic currency" (Kim and Roubini, 2000 p. 562).

Sims (1992) demonstrates that IR innovations partly reflect inflationary pressures, which cause an increase in the price level. Therefore, some of the past empirical studies that take a VAR approach include inflationary expectation as a proxy variable (e.g., Gordon and Leeper, 1994; Christiano et al., 1996; Sims and Zha, 1998) to explain the price puzzles. Sims and Zha suggest a SVAR model with contemporaneous restrictions, which includes proxy variables for expected inflation. Grilli and Roubini (1995) include moments in long-term interest rates to solve the ER puzzle. Kim and Roubini (2000) suggest the world oil price (WOP) as a proxy for expected inflation, to surmount the problems of price puzzles and endogeneity; some

economists, however, include measures of commodity price in their information sets to sidestep the price puzzle (e.g., Christiano et al., 1996).

For this reason, many empirical studies have extended the closed economy benchmark VAR model (e.g., Bernanke and Blinder, 1992; Bagliano and Favero, 1998; Bernanke and Mihov, 1998; Amarasekara, 2009) so as to make it an open economy model (e.g., Eichenbaum and Evans, 1995; Cushman and Zha, 1997; Kim and Roubini, 2000; Kim, 2003; Fung, 2002; Raghavan et al., 2009; Mishra and Mishra, 2010). Such an extension with the VAR approach typically involves the addition of some foreign variables, such as WOP index, foreign IR, and movement of ER.

Economists do not agree on what is the best monetary policy indicator. Some researchers propose the IR as the best policy tool (e.g., McCallum, 1983; Bernanke and Blinder, 1992). However, Gordon and Leeper (1994) challenged this argument and find that the federal funds rate (FFR), as well as monetary aggregates, generate some dynamic responses. In contrast, among many others, Strongin (1995), Eichenbaum and Evans (1995), and Eichenbaum (1992) suggest that shocks to monetary policy with nonborrowed reserves may serve as a good proxy in describing changes in monetary policy. Moreover, Sims (1992) suggests the short-term IR, while Bagliano and Favero (1998) recommend the long-term interest rate as a good indicator in expressing change in monetary policy. Other groups of literature suggest that the exchange rate plays an important role in describing the monetary policy transmission mechanism (e.g., Cushman and Zha, 1997; Fung, 2002).

There has been an increasing number of studies that focus mainly on the transmission mechanism of monetary policy, within the contexts of the United States, the non-United States G7 countries, and the Eurozone area. With this in mind, recently, many researchers have applied a similar technique to analyses of their own countries. However, quantitative assessments of the effect of monetary policy shocks on macroeconomic variables in a Sri Lankan context are limited and otherwise inadequate. Existing studies of the Sri Lankan monetary policy transmission mechanism include only domestic monetary policy and macroeconomic nonpolicy variables (see, Amarasekara, 2009) in their VAR approach. However, Cushman and Zha (1997) note that a “small open economy is likely to be quite sensitive to a variety of foreign variables” (p. 435); with this in mind, we include in our model

set-up the FFR as well as the WOP index, to isolate any “exogenous” change in monetary policy. In this way, our study differs from past empirical studies that investigate the transmission mechanism of Sri Lankan monetary policy.

A review of past empirical works reveals that no study has examined the effect of foreign and domestic monetary policy shocks on macroeconomic variables, while using a SVAR framework and examining the Sri Lankan context. This study seeks to answer the following research questions: (i) Which policy instrument plays a significant role in explaining movement in the economic activities of Sri Lanka? (ii) Do foreign monetary policy shocks—defined as U.S. FFR shocks—affect the domestic variables? and (iii) Does the inclusion of oil price resolve the problem of price puzzles, and how much do variations in oil price account for output and price fluctuations?

Empirical studies that use various policy variables have obtained inconsistent results. Walsh (2003) illustrates that “the exact manner in which policy is measured makes a difference, and using incorrect measures of monetary policy can significantly affect the empirical estimate one obtains” (p. 40). This motivated us to investigate the transmission mechanism of Sri Lankan monetary policy. Another motivation of this study is that there are no clear relationships among the key economic indicators of Sri Lanka (see Figure 1). In some periods, economic indicators move as expected in response to the use of monetary policy tools, while in other periods they move in directions that run counter to those suggested by standard theory. This motivated us to investigate the impulse responses of key macroeconomic variables in response to monetary policy shock.

By examining monthly data from January 1978 to December 2011, this study found that output decreased significantly and domestic currency appreciated, following contractionary IR shocks. Second, it found that shocks to monetary aggregate tend to reduce the IR over some time horizon. Finally, the U.S. IR shock and oil price shock were found to have no significant impact on the domestic variables.

The remainder of this chapter is structured as follows. Section 2 discusses the current trends of the Sri Lankan monetary policy system. Selection of variables is discussed in section 3. Section 4 describes the construction of VAR models and the identification scheme. In

section 5, we present the estimation results of the econometric model and related findings. Finally, in section 6, we make concluding remarks and assess policy implications.

2 Monetary Policies in Sri Lanka

The Central Bank of Sri Lanka (CBSL) is the national authority responsible for implementing monetary policy in, and providing currency to, that country. As mentioned, the main goal of monetary policy is to promote a high and sustained level of output growth while keeping inflation at a desirable rate. Therefore, similar to many countries' central banks, the CBSL also sets price stability as its main monetary policy objective goal.

Monetary policy in Sri Lanka has undergone significant changes in the last four decades. Since 1977, the CBSL has progressively moved toward the use of market-oriented monetary policy tools. The CBSL has changed its priority of focus from ER stability to price stability, in the name of maintaining economic stability. In particular, the CBSL mainly focuses on stabilization objective rather than development objective. However, in 2002, the CBSL revised its monetary policy objectives, based on international trends and objectives that are now oriented toward (i) economic and price stability and (ii) financial system stability. In such a monetary management environment, Sri Lanka's monetary policy-setting has moved toward the broader adoption of inflation-targeting practices, in preference over either an ER or monetary aggregate. IRs and open market operations (OMO) are policy instruments by which the CBSL looks to achieve such a goal in a given monetary target.

3 Data and Variables

This section describes the domestic and international variables used to examine the Sri Lankan monetary policy framework. We chose variables similar to those used by Kim and Roubini (2000), that is, we use a seven-variable¹ SVAR model to explain the all-possible interrelations among nonpolicy and policy variables. These seven variables are adequate in explaining the monetary policy frameworks of small open economies (Kim and Roubini, 2000; Brischetto and Voss, 1999). Of the seven variables used in the model, two variables are foreign block, which contains the WOP, and the U.S. FFR. As discussed, the inclusion of foreign block is

¹See Table 1 for variable definitions and data source(s).

crucial in a VAR system to representing the model of an open economy. The foreign block is assumed to be exogenous in our model set-up. That is, we include these variables to isolate any exogenous change in monetary policy. Therefore, domestic variables do not enter the foreign variables equation, either with a lag or instantaneously. We made this assumption, given that the Sri Lankan economy is unusually small compared to the world economy. We include WOP as a proxy variable for expected inflation and FFR as a proxy for foreign IR.

The remaining five variables such as real GDP, CPI, IR, money and ER represent the Sri Lankan domestic economy that can be devoted to two blocks, such as the policy variables block and the nonpolicy variables block. Similar to other studies and as discussed earlier, the policy variables included in this model are the nominal ER, the interbank call money market rate, and reserve money (M0). These policy variables are categorized in three broader contexts: ER, IR, and monetary aggregate. The IR and money are commonly used by the central banks of many countries as a stabilization policy toolkit. The ER is taken as an information market variable.

Real GDP and CPI are chosen as the target variables, and known to be macroeconomic nonpolicy variables of the monetary policy model. We include these variables to measure the impact of the identified monetary policy shock on the real sector and the price level. Using real GDP with other macroeconomic nonpolicy and policy variables in nominal terms is a standard practice in the monetary literature (see, for example, Bagliano and Favero, 1998; Bernanke and Mihov, 1998; Brischetto and Voss, 1999; Cheng, 2006; Amarasekara, 2009). Therefore, in line with past empirical work, we too use GDP (real value) while the remaining variables were in nominal terms. In addition, for our practice, we use nominal GDP (in current U.S. dollars) instead of real GDP, to be consistent with the other variables; however, the results are robust to the choice of nominal and real GDP.² Including CPI inflation rather than a GDP deflator in an identified VAR is now common practice (e.g., Leeper and Gordon, 1991; Eichenbaum, 1992; Sims, 1992; Cushman and Zha, 1997; Bagliano and Favero, 1998; Kim and Roubini, 2000; Fung, 2002; Kim, 2003) in the monetary literature. Therefore, we also include in our model CPI inflation as a variable. On the other hand, data on GDP deflator is not accessible at the monthly level; they are available only on a quarterly basis.

² The results using from nominal GDP are not presented here but available upon request.

We use monthly data from Sri Lanka, from the January 1978–December 2011 period.³ Since we do not have monthly GDP data, we interpolate the series using Chow and Lin's (1971) annualized approach from the annual GDP series.⁴ All the variables used in this model are transformed into logarithm, except IRs. Moreover, all the data series are seasonally adjusted using the census X-12 approach.

3.1 Test for Stationarity, Lags Length Selection, and Cointegration

We perform an Augmented Dickey–Fuller (ADF) unit root test to ensure that data series possessed the time series property of stationarity. For the ADF test, we assume there to be no autocorrelation among the error terms when deciding the number of lags included in a series to test for the unit root. However, several papers have proposed methods to test the null hypothesis of a unit root against a time series stationary that exhibits breaks (Perron, 1989; 1997; 2005; Zivot and Andrews, 1992; Lumisdaine and Papell, 1998) or nonlinearities (Hwan Seo, 2008; Balke and Fomby, 1997). These studies show how bias in the commonly used unit root test can be reduced by endogenously determining the time of structural breaks or nonlinearities. However, the unit root test that we used here is not robust to the above mentioned issues. We leave this issue for future research.

The model estimating the causal relationship between variables is highly sensitive to the lag length involved. This implies how many lagged values should enter the system of equation. The appropriate number of lags for the estimated VAR model has been decided based on Schwarz's Bayesian information criterion (SBIC), the Akaike information criterion (AIC), and the Hannan–Quin information criterion (HQIC).

Johansen's cointegration test is applied to confirm that the series are not cointegrated or cointegrated with an "N" relationship; this is done to ensure that the VAR is stable. In addition, we also use a residual correlation test to determine whether the residuals are correlated.

³ Sri Lankan economy is liberalized in late 1977, and CBSL has progressively moved towards market oriented monetary policy tools since 1977. Therefore, we have chosen 1978 as a starting period in order to analyze the small open economy situation.

⁴ Although quarterly real GDP series is available from 1996, we used annual GDP series for the whole period for the interpolation.

4 Methodology

4.1 Modeling of Structural VAR

In our basic model setup, we use a seven variable SVAR model, similar to that used by Kim and Roubini (2000), to represent a small, open, and developing economy while including foreign block variables. The VAR model assumes that the Sri Lankan economy is represented by a structural-form equation as follows:

$$A(L)Y_t + B(L)X_t = v_t \quad (1)$$

where $A(L)$ and $B(L)$ are the $n \times n$ and $n \times k$ matrix polynomial of the lag operator, respectively; and Y_t is a $n \times 1$ vector of endogenous domestic variables of interest that can be divided into two blocks, such as vector of nonpolicy variables and vector of policy variables. We assume that the policy variables are controlled by the central bank. X_t is a $k \times 1$ vector of exogenous foreign variables of interest, and v_t is an $n \times 1$ vector of structural disturbances with a 0 mean and $var(v_t) = \Psi$ (where Ψ denotes a diagonal matrix). The elements of the diagonal matrix represent variances of structural disturbances; therefore, we assume that the structural disturbances are mutually uncorrelated.

The estimation of the reduced-form equation of the structural model (1) can be described as follows:

$$Y_t = C(L)Y_t + D(L)X_t + u_t, \quad (2)$$

where $C(L)$ and $D(L)$ are the matrix polynomial of the lag operator and u is a vector of the VAR residuals with a 0 mean and $var(u_t) = \Sigma$.

Given the reduced-form estimation, we could estimate the parameters in the structural-form equation in many ways. However, the estimation of structural parameters requires the imposition of some restrictions on the elements of matrix A . Past studies of VAR models have employed various restriction methods based on existing theory and model preferences. One group of studies identifies the model through the commonly used Cholesky decomposition of orthogonalized reduced-form disturbances (e.g., Sims, 1980). However, this identification approach assumes only a recursive method; in this case, the ordering of variables changes the

estimation results obtained. On the other hand, other groups of studies use a generalized method with nonrecursive structures (defined as SVAR), which impose restrictions only on contemporaneous structural parameters (e.g., Sims, 1986; Bernanke, 1986; Blanchard and Watson, 1986; Kim and Roubini, 2000).

The VAR residual u_t can be obtained by estimating the “N” equations from (2), using OLS. Let H be the contemporaneous coefficient matrix (nonsingular) in the structural-form equation, and $M(L)$ be the coefficient matrix without a contemporaneous coefficient in the structural equation. That is, the relationship can be represented as:

$$A(L) = H + M(L). \quad (3)$$

Then, the structural-form equation parameters and those in the reduced-form equation are correlated by:

$$C(L) = -H^{-1}M(L) \text{ and } D(L) = H^{-1}B(L). \quad (4)$$

Moreover, the structural disturbances and the VAR residuals of the reduced-form equation are related by:

$$v_t = Hu_t, \quad (5)$$

which indicates that

$$\begin{aligned} E(u_t u_t') &= H^{-1}(v_t v_t')H^{-1} \\ \Sigma &= H^{-1}\Psi H^{-1}. \end{aligned} \quad (6)$$

Consistent estimates of H and Ψ are obtained using sample estimates of Σ , which can be calculated through the maximum likelihood estimation technique. In equation (6), H contains $n \times (n + 1)$ free parameters to be estimated. The summation comprises only $n \times (n + 1)/2$ parameters, which requires at least $n \times (n + 1)/2$ restrictions on the system of equation. However, since we normalize the diagonal elements of H to be unity, we need at least $n \times (n - 1)/2$ additional restrictions on H to attain identification. We impose the restrictions based on past empirical findings and on economic theory.

4.2 Identification Scheme: Nonrecursive Approach

In this model, the exogenous vector $\{X_t: \text{FFR}, \text{WOP}\}$ of variables is assumed to be a foreign block. The foreign variables are included to control for exogenous change in the global economic stance. The endogenous vector $\{Y_t: \text{GDP}, \text{CPI}, \text{M0}, \text{IR}, \text{ER}\}$ is assumed to be a domestic block, which comprises two blocks in the system: one is the nonpolicy block with two variables $\{\text{GDP}, \text{CPI}\}$, and the other is the policy block with three variables $\{\text{M0}, \text{IR}, \text{ER}\}$.

For the restrictions on the contemporaneous matrix of structural parameters H , we follow the general idea of Kim and Roubini (2000); however, doing so substantially modifies the monetary policy reaction function based on existing theory and empirical findings. Equation (7) summarizes the nonrecursive identification approach based on equation (6), as below:

$$\begin{bmatrix} v_{GDP} \\ v_{CPI} \\ v_{MS} \\ v_{MD} \\ v_{ER} \\ v_{OP} \\ v_{FFR} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} & 0 \\ a_{21} & 1 & 0 & 0 & 0 & a_{26} & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & a_{36} & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{GDP} \\ u_{CPI} \\ u_{IR} \\ u_{M0} \\ u_{ER} \\ u_{WOP} \\ u_{FFR} \end{bmatrix}, \quad (7)$$

where v_{GDP} , v_{CPI} , v_{MS} , v_{MD} , v_{ER} , v_{WOP} , and v_{FFR} are the structural disturbances—output shocks, domestic inflationary shocks, money supply shocks, money demand shocks, ER shocks, oil price shocks, and foreign monetary policy shocks, respectively—and u_{GDP} , u_{CPI} , u_{IR} , u_{M0} , u_{ER} , u_{WOP} , and u_{FFR} are reduced-form residuals that describe the unanticipated movements of each regressor, respectively.

The first two equations relate to real GDP and prices, which represent the goods market equilibrium of the domestic economy. Similar to several past empirical works (e.g., Cheng, 2006; Kim, 2003; Bagliano and Favero, 1998; among many others), we assume that money, IR, ER, and the U.S. IR do not affect the output and price contemporaneously; they are assumed to have affects only with a lag. However, since oil is an essential input for most economic sectors, we assume that the oil price affects the real sector and the domestic price level contemporaneously. The motivation of this identification assumption is that “firms do not change their price and output unexpectedly in response to unexpected changes in financial

signals or monetary policy within a month due to the inertia, adjustment cost and planning delays, but they do in response to those in oil prices following their mark-up rule” (Kim and Roubini, 2000 pp. 568–569). Overall, we assume that real GDP responds to the WOP, and that the domestic price level responds to output and oil price contemporaneously.

The next two equations relate to money supply and money demand, which represent the money market equilibrium. The IR equation—that is, the money supply equation—is assumed to be the monetary authority reaction function. We use a standard form of the money supply and money demand function: in other words, the monetary policy reaction function is assumed to be contemporaneously affected by prices, output, and the IR. The contemporaneous inclusion of prices and output in the IR equation gives a form of reaction function similar to that of Taylor rule identification. Further, we allow the WOP to enter contemporaneously into the monetary authority reaction function, to control for the negative supply shocks and inflationary pressure. Next we assume that, similar to cases seen in the work of Kim and Roubini (2000) and Cushman and Zha (1997), the demand for money responds contemporaneously to income, prices, and the nominal IR,⁵ and that all other variables—such as the ER, WOP, and FFR—will affect money only with lags.

The fifth equation is the ER equation, which represents the financial market equilibrium. We assume that the ER is contemporaneously affected by all the variables in the system of equation, since the ER is a forward-looking asset price (see, Kim and Roubini, 2000; Cushman and Zha, 1997). Further, through this equation, we allow foreign variables to influence domestic variables implicitly.

The last two equations relate to WOP and U.S. IR, which are assumed to be exogenous shocks that arise from the world economy. This indicates that domestic variables do not affect the oil price and the FFR contemporaneously, since these equations are exogenous to the domestic economy. However, we assume that the U.S. Federal Reserve may tighten monetary policy when it faces oil price related inflationary shocks.

⁵Alternatively, Tang (2006) assumed that the interest rate affect the money only in the lag structure.

5 Estimation Results

5.1 Estimation Results of the Unit Root Test, Optimal Lag, and Cointegration

The ADF test affirms that only one variable—namely, the interest rate—had no unit root in level, whereas all the other variables were integrated in order one (see Table 2). That is all the variables except the IR become stationary at the 1% significance level, only after either the first difference or the first-difference of the logarithm, while the domestic IR is stationary in levels (see, Table 2). Thus, we use the IR in levels, and all other series in the first difference of logarithm. Note that we use the standard form of the money supply and money demand function, which is normally specified as a function of the inflation in level. For example, Taylor (1993) describes the U.S. monetary policy reaction function through the IR feedback rule, which depends on changes in inflation, output, or other economic conditions. Therefore, by using the first difference of the logarithm of CPI, we are effectively using inflation as one of our variables.

The SBIC, AIC, and HQIC lag-length selection criteria each choose one lag as an optimal lag, while the likelihood ratio statistics recommend longer lags and select 20 lags⁶. We, therefore, use one lag to estimate the parameters of the SVAR, and 20 lags for the impulse responses function and variance decomposition, as one lag is inadequate in capturing the dynamic system of the model.

It is also possible to analyze a model bearing a long-term identification restriction, since the Johansen cointegration test detects four cointegrating relationships within our model (see Table 3). However, in line with the existing monetary literature (e.g., Bagliano and Favero, 1998; Fung, 2002; Cheng, 2006; among many others), in our analysis, we focus on the SVAR model, which implicitly allows the cointegrating relationship in the data. In addition, we undertook a residual correlation test to ensure that the residuals are serially uncorrelated, so that the VAR model can be used. We found the residuals not to be correlated when including three lags in the model (results are available upon request). Therefore, we estimate the system with all variables in the first difference of logarithm, except interest rate and no imposition of the cointegrating correlation. In so doing, the long-term identification problem is avoided.

⁶ The results are not presented here, but available upon request.

5.2 Estimation Results of Contemporaneous Coefficients

Coefficients of the SVAR identification restrictions are estimated using the OLS method; the estimated results are presented in Table 4 (see Appendix). According to Table 4, some of the estimated structural contemporaneous parameters support their respective equations significantly. In particular, the parameters of the monetary policy reaction function are statistically more significant than are the other equations, indicating that innovations in IR work more efficiently than other monetary policy shocks. The significant and negative coefficient of GDP in the money supply equation indicates that the rise in IR lowers the output. The negative value of the estimated coefficient of the consumer price reveals that the domestic price level declines when the IR increases. The positive value of the estimated coefficient of the oil price index reveals that the monetary authority increases the IR when it detects an unexpected rise in the oil price, indicating that the CBSL tightens monetary policy when it faces inflationary pressure. The coefficient of the oil price enters the output equation positively and the inflation equation negatively—circumstances that run counter to standard economic theory. However, the coefficient of oil price is not statistically significant.

5.3 Estimation Results of Impulse Response Function

This section explains the estimated impulse response function used to understand the dynamic responses of domestic variables to various domestic and foreign monetary policy shocks within the SVAR system. The estimated impulse responses of the variables, over a 20-month period and to structural one-standard-deviation monetary policy shocks, are described. In each figure (Figures 2 to 11), each of the two dashed lines represents the 95% confidence band.

5.3.1 Responses to a Positive Interest Rate Shocks

Following a monetary contraction, it is expected that prices, output, and money demand will all decline, whereas the IR will increase and the ER will appreciate. Figure 2 (see Appendix) presents the estimated impulse responses of key economic variables to the shock to call money market rate.

The model with an IR as a monetary policy tool presents theoretically consistent results for both the output and the ER. That is, positive IR shocks reduce the output significantly over

a few months, and then gradually moves to its initial baseline. The domestic currency appreciates after a horizon relative to the U.S. dollar, and such an impact effect appreciation is statistically significant over a longer horizon. Although the price level initially increases⁷ and is followed by an IR shock, it is not statistically significant at any level of significance. In addition, this demand-driven inflationary pressure vanishes after a few months and returns to its pre-shock level, leaving no evidence of a price puzzle. Hence, the inclusion of oil price in the system of equation to account for inflationary expectation helps us to surmount the issue related to empirical puzzles. The shock to IR does not change money demand; this is a surprising result in view of money demand theory, which states that money demand decreases as the IR increases.

We also re-examine the money supply equation with alternative identifying restrictions, and compare those results to the previous one. That is, we restrict the parameters a_{34} and a_{35} , which are different from 0, together with traditional Taylor rule in the model. The estimated results are no different from those obtained in the system of exclusion of these restrictions. Hence, our discussion in section 4.2 and the estimated results suggest that restrictions on the structural parameters, such as $a_{34} = 0$ and $a_{35} = 0$, are reasonable.⁸

5.3.2 Responses to Positive Exchange Rate Shocks

Figure 3 (see Appendix) shows the responses of economic variables to a structural one-standard-deviation nominal effective ER shock. Positive ER shocks, representing the domestic currency depreciation, did not produce significant results on major economic variables. The output declines over the first horizon; this is a somewhat surprising finding for Sri Lanka, which became an export-oriented economy in 1977. However, the response of output is short-lived and not statistically significant. Although the price level increases as expected, the increase in price is not statistically significant at any level of significance. The consumer price package in Sri Lanka includes only a few imported goods, causing a positive ER shock that does not affect the price level significantly.

⁷Kim and Roubini (2000) stated that “if the monetary contraction is really exogenous in the sense that it is not a systematic response to any shock then almost no theory implies that output or price level increase” (p.572). However, Beaudry and Devereux (1995) derive the theoretical model and suggest that monetary contraction leads to rise in price level.

⁸The estimated results are not presented, but available upon request.

The positive ER shock has no significant impact on the IR or money. The Sri Lankan public has no incentive to hold more U.S. dollars for their daily transactions, since the rupee is not dollarized; this might be why the IR is not affected by ER shocks. Note that Sri Lanka's money supply is controlled by the CBSL; therefore, it is obvious that any change in ER may not affect monetary aggregates. Overall, positive ER shocks give rise to no significant findings in major economic activities, since Sri Lanka's level of openness is quite small compared to those of other developing Asian economies, such as China, India, Hong Kong, Malaysia, and Thailand.

5.3.3 Responses to Positive Reserve Money Shocks

Figure 4 (see Appendix) shows the estimated impulse responses of each economic variable to positive money growth shocks. The positive money shock on output did not produce the expected results, as the output declined rather than increased. However, the response of output is short-lived, declining for only a few months and then returning to pre-shock values. Neither the price level nor the ER responded significantly to innovations in monetary aggregates. A positive shock to money causes the nominal IR to decrease in a manner consistent with the liquidity effect, thus suggesting no evidence of liquidity puzzle. The decline in IR is statistically significant at the 10% level. Overall, only one variable—namely, the IR—responds significantly as expected following a positive money growth shock.

5.3.4 Responses of Domestic Variables to Positive U.S. Interest Rate Shocks

We next estimate the impact of foreign monetary policy shocks on the Sri Lankan economy. Shocks to the U.S. FFR may reflect not only its own shocks but also other structural shocks. Figure 5 (see Appendix) shows the responses of domestic variables to a positive U.S. IR shock.

Although domestic output and the price level increase—in moves quite the opposite of what theory suggests—following U.S. monetary policy shocks, the responses of these variables are not statistically significant. This may occur for two reasons. First, despite the United States having been the main destination for Sri Lanka's exports and having absorbed a large proportion of exports since 1977,⁹ exports to the United States have been remarkably

⁹ The U.S. absorbed 25% of the total export in 1990 which has been reduced as 20.3% in 2011.

small in terms of GDP.¹⁰ Second, Sri Lanka's imports from the United States are negligible, representing 2.6% of the total GDP in 1990 and having been reduced to 0.04% in 2011. The domestic IR increases initially, following a positive U.S. IR shock. This could be why the monetary authorities of other countries may respond immediately by raising their own IR, to invalidate the inflationary effect of domestic currency devaluation in response to an increase in foreign IRs. In any case, the response of domestic IR is not statistically significant. Moreover, domestic currency and monetary aggregates are not affected by FFR shocks. Overall, positive shocks to the U.S. FFR do not generate the expected significant effect on domestic economic variables.

5.3.5 Responses of Domestic Variable to World Oil Price Shock

Figure 6 (see Appendix) presents the responses of key economic variables to WOP shocks. As expected, although the output decreases and the price level increases initially in response to WOP shocks, the impact on these variables are negligible and not statistically significant. This could be so, for two reasons. First, Sri Lanka's industrial sector hinges largely on "soft" industrial products (e.g., rubber-based products, garments, and textile products), which mainly use labor-intensive technology. Second, the oil consumption expenditure of Sri Lanka is truly negligible, in an amount representing 0.03% of total GDP in 1980 and 0.014% in 2010. Further, shocks to the WOP do not affect the IR, money, or ER significantly. In summary, positive oil price shocks do not generate a significant effect with regard to domestic economic variables.

5.4 Estimation Results for Variance Decomposition

The variance decomposition is another useful method by which to investigate interactions among economic variables over the impulse response horizon. Table 5 (see Appendix) presents proportion of variations in major economic variables that can be explained by shocks to other economic variables in the equation system. The decomposition values for the 1st, 3rd, 12th, and 20th horizon into the future are displayed in that table.

¹⁰ Sri Lanka's export to US was 6.1% of total GDP in 1990, which has been reduced as 3.6% in 2011.

The results suggest that apart from their own shocks, much of the output variation is explained by the IR innovation and, to a lesser extent, by oil price shocks and U.S. IR shocks. Compared to other shocks, IR shocks seem to explain much of the consumer price variation, while less of the variation is explained by ER and monetary aggregate shocks (i.e., which explain only 0.03% and 0.04% of the volatility in inflation, respectively). In addition, oil price shocks explain about 0.03% of output fluctuations and 0.45% of price fluctuations, at all forecasting horizons except the first month; this finding implies that the oil price does not have a significant effect on output and price.

We can infer that around 25% of IR fluctuations are due to output shocks, at all forecasting horizons. The domestic IR is less likely affected by oil price or U.S. IR shocks, which explain only 0.11% and 0.16% of the IR volatility, respectively, at the forecasting horizons of three months and later. A substantial proportion of money and ER fluctuations are mainly explained by shocks to output, rather than other shocks (except their own shocks).

Overall, variations in output and prices are mainly explained by movements in the IR shock, whereas ER shocks are not. Moreover, shocks to money play a marginal role in explaining the movements of domestic variables. Oil price and U.S. IR shocks are less likely to explain the movement of domestic variables than shocks to domestic variables.

5.5 Robustness of the Results

We use various identification restrictions to ensure that these restrictions do indeed produce different impulse responses among the economic variables. First, we change the monetary policy reaction function by imposing the restriction used by Kim and Roubini (2000). Therefore, equation (7) can be rewritten as:

$$\begin{bmatrix} v_{GDP} \\ v_{CPI} \\ v_{MS} \\ v_{MD} \\ v_{ER} \\ v_{WOP} \\ v_{FFR} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} & 0 \\ a_{21} & 1 & 0 & 0 & 0 & a_{26} & 0 \\ 0 & 0 & 1 & a_{34} & a_{35} & a_{36} & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{76} & 1 \end{bmatrix} \begin{bmatrix} u_{GDP} \\ u_{CPI} \\ u_{IR} \\ u_{M0} \\ u_{ER} \\ u_{WOP} \\ u_{FFR} \end{bmatrix} \quad (8)$$

The authors assume that data with regard to aggregate output and price level are not available within a month, but that pertaining to IR, money, ER, and oil price are available within a period. Therefore, following the informational assumption, IR, money, ER, and oil price are assumed to affect the money supply function contemporaneously, while both output and consumer price affect only with a lag. The reason for the contemporaneous exclusion of the FFR from this equation is that, although data are available within a period, the monetary authority cares about unexpected changes in the ER relative to the U.S. dollar rather than unexpected changes in the U.S. IR (Kim and Roubini, 2000). They include oil price in the money supply equation to control for the inflationary pressure and current systematic response of supply shocks.

Based on this restriction, positive IR shocks produce results similar to the major findings of this study with regard to price level, ER, and money (see Figures 2 and 7). However, the response of output is inconsistent with theory and the major findings of this study—that is, the output increases significantly over a few horizons, then falls significantly as expected, followed by an IR shock. This implies that the identification restriction of this study is more credible than the restrictions of Kim and Roubini in explaining the Sri Lankan monetary policy transmission mechanism.

Second, we use narrow money (M1) as an alternative to reserve money (M0) in equation (4.7), for robustness. When using M1, IR shocks reduce the money demand significantly,¹¹ while all other domestic variables respond as observed in Figure 2. However, positive M1 shocks do not generate a significant effect on any of the domestic variables (see Figure 8), whereas shocks to reserve money decrease the IR significantly, as expected (see Figure 4). We also examine the impulse response of the economic variables using broad money (M2) as monetary policy instruments. Shocks to M2 also have no significant impact on these variables,¹² which indicates that for the Sri Lankan economy, targeting reserve money is more effective than targeting narrow or broad money.

Next, we clarify the estimates of structural identification by taking the commonly used Cholesky decomposition approach, a special case of exactly identified model that is used in

¹¹The results of interest rate shock do not reported, but available upon request.

¹²The results are not presented, but available upon request.

several identification schemes. The Cholesky approach raises the recursive ordering or Wold causal chain and prevents simultaneous interaction between certain variables. The recursive approach with numerous ordering does indeed produce empirical puzzles (see, for example, Cushman and Zha, 1997). In this case, we restrict the contemporaneous matrix H to be lower-triangular with ordering of the foreign block, the nonpolicy block, and the policy block, as explained by Cushman and Zha (1997) and Jääskelä and Jennings (2010).¹³

Figures 9, 10, and 11 (see Appendix) show the impacts of one standard deviation of positive IR shocks, ER shocks, and money shocks, respectively, on major economic variables, using a recursive VARs approach with the ordering of WOP, FFR, GDP, CPI, IR, M0, and ER.

As expected, the output declined significantly following positive IR shocks, whereas positive ER shocks and money shocks did not produce the expected results on output, with output declining rather than increasing. However, the decline in output was not statistically significant following ER and monetary aggregate shocks. Although innovations in IR, positive ER shocks, and positive money shocks led to an increase in price level, which is not statistically significant at any level. The domestic currency appreciates after a month, as expected, following IR shocks; this provides no evidence of an ER puzzle. Shock to IRs provided no significant results on money growth, while shocks to money growth tended to reduce the IR as expected, at the 10% level of significance. Overall, recursive VARs with the aforementioned ordering produce results similar to the main findings of this study.

6 Conclusions

In this study, we used an open-economy SVAR framework to examine the movements of Sri Lankan economic activities. Particularly, we investigated the impact of the domestic and foreign monetary policy shocks and the oil price shocks on domestic major economic variables. The orthogonal policy shocks attained from the SVAR model were employed to assess the success of monetary policy in affecting the output, prices, and other major economic activities in Sri Lanka. Moreover, we applied various policy variables to identify the policy instrument that most effectively explains the Sri Lankan monetary policy transmission

¹³ Alternatively, Kim (2003) normalized lower triangular order of nonpolicy block, foreign block and policy block.

mechanism. For this purpose, we used monthly data from Sri Lanka during the January 1978–December 2011 period. We chose this sample period to cover the post-liberalization period of the Sri Lankan economy.

The model with an IR as a policy tool provides significant results, compared to the model with the ER. There is also substantial evidence that shocks to money explain the volatility of some of the economic variables (e.g., IR) significantly. The output decline and domestic currency appreciates significantly followed positive IR shocks; this was prevalent in several past empirical studies. The ER shocks had no significant impact on output, even though it led to a decline, in contrast to the pertinent theory. Meanwhile, a positive money shock provides significant but inconsistent results on output, that is, output decline rather than increase.

Positive IR shocks had no significant effect on the price level, although the price level increased rather than decreased, suggesting no evidence of a price puzzle. In contrast, Amarasekara (2009) found that inflation decreases initially following IR shocks. As expected, although the price level rose after positive ER and money shocks, the increase in prices were not statistically significant. The interest rate decreased significantly at the 10% level, when the monetary aggregate was used as a policy instrument—indicating no evidence of liquidity puzzles.

Overall, first, our empirical findings suggest that the IR plays a significant role in explaining the monetary policy transmission mechanism of Sri Lanka; this finding contrasts with those of some past empirical studies that proposed the transmission mechanism of monetary policy is driven by the ER, not the IR (see, for example, Cushman and Zha, 1997; Fung, 2002). Second, foreign monetary policy shocks and oil price shocks seem not to be vulnerable to domestic economic activities. Finally, the inclusion of the oil price in the SVAR model helped us overcome the puzzles that are normally inherent in the monetary literature. The results of the variance decomposition and the various identification restrictions used here also support these findings.

This SVAR model provided some useful perceptions about the theoretical framework of Sri Lanka's monetary policy evolution. The inter-bank call money market rate provides theoretically consistent result for output and the ER, and the reserve money shocks produce

theoretically consistent results with regard to the IR. Second, targeting reserve money is more effective than narrow money or broad money. Third, ER shocks were found to play no significant role in explaining the volatility of major economic activities. Finally, U.S. monetary policy shocks and oil price shocks did not seem to be vulnerable to the Sri Lankan economy.

The next interesting field for future study will involve the inclusion of fiscal policy instruments to measure the impact of such shocks on principal economic activities. It would be interesting to consider in future research the time-varying parameter structural vector autoregressive (TVP-SVAR) model in a Bayesian framework within the context of the Sri Lankan economy, as well as the Bayesian SVAR.

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List of Tables

Table 1: Variables Included in the Sri Lankan Monetary Policy Model

Variable	Definition	Source	Abbreviation
Foreign			
Oil Price	World oil price index (log) Base year 2005(=100)	IFS	WOP
US interest rate	Federal Funds rate (%)	IFS	FFR
Domestic (Non-Policy)			
Output	Gross domestic product at 2000 Constant prices in US \$ (log)	WDI	GDP
Price Index	Colombo consumer price index (logs) Base year 2005(=100)	IFS	CPI
Domestic (Policy)			
Exchange rate	Exchange rate-per US \$ (log)	IFS	ER
Interest Rate	Inter-bank call money market rate (%)	IFS	IR
Money	Reserve money (log)	IFS	M0

Note: IFS and WDI represent international financial statistics and world development indicator respectively.

Table 2: Unit Root Test

Variable	Level		Log		1 st Difference		Log 1 st difference	
	test-stat	p-value	test-stat	p-value	test-stat	p-value	test-stat	p-value
CPI	8.950	1.000	-2.756	0.064	-12.26	0.000	-17.05	0.000
GDP	0.708	0.990	-1.102	0.714	-20.73	0.000	-18.27	0.000
M0	8.598	1.000	-1.448	0.558	-21.47	0.000	-25.92	0.000
ER	0.734	0.990	-2.282	0.178	-18.37	0.000	-19.07	0.000
WOP	0.489	0.984	-0.671	0.854	-13.59	0.000	-15.26	0.000
FFR	-1.159	0.691	2.168	0.998	-13.94	0.000	-12.05	0.000
IR	-6.815	0.000	-5.014	0.000	-24.00	0.000	-24.05	0.000

Note: Augmented Dicky-Fuller unit root test for the variables in the model. Test critical value at 1% significance level is -3.447

Table 3: Johansen's Cointegration Rank Test

Series: CPI_SA GDP_SA IR_SA ER_SA M0_SA FFR_SA WOP_SA

Hypothesized No of CE(s)	Eigenvalue	Trace Statistics	0.05 Critical Value	Prob. **
None*	0.320087	364.6029	125.6154	0.0000
At most 1*	0.196826	207.9721	95.75366	0.0000
At most 2*	0.136385	118.9837	69.81889	0.0000
At most 3*	0.079225	59.45283	47.85613	0.0028
At most 4	0.043800	25.94168	29.79707	0.1304
At most 5	0.016817	7.757838	15.49471	0.4917
At most 6	0.002146	0.872186	3.841466	0.3504

Note: * denotes rejection of the hypothesis at the 0.05 level, ** denotes the Mackinnon-Haug-Michelis (1999) p-values. Trace test indicates 4 co-integrating equation(s) at the 0.05 level.

Table 4: Estimated Contemporaneous Coefficients of SVARs

Restriction	Estimate	Restriction	Estimate	Restriction	Estimate	Restriction	Estimate
a_{16}	0.0786 (1.58)	a_{32}	-14.608*** (-294.3)	a_{43}	-0.0002 (-0.00)	a_{54}	0.3534*** (7.12)
a_{21}	-0.0121 (-0.24)	a_{36}	0.3544*** (7.120)	a_{51}	-0.0588 (-0.02)	a_{56}	0.0055 (0.10)
a_{26}	-0.0022 (-0.04)	a_{41}	-0.0240 (-0.01)	a_{52}	-0.1367 (-0.19)	a_{57}	-0.0054 (-0.11)
a_{31}	-53.024*** (-10.68)	a_{42}	0.1044 (0.150)	a_{53}	0.0001 (0.001)	a_{76}	-0.222*** (-4.48)

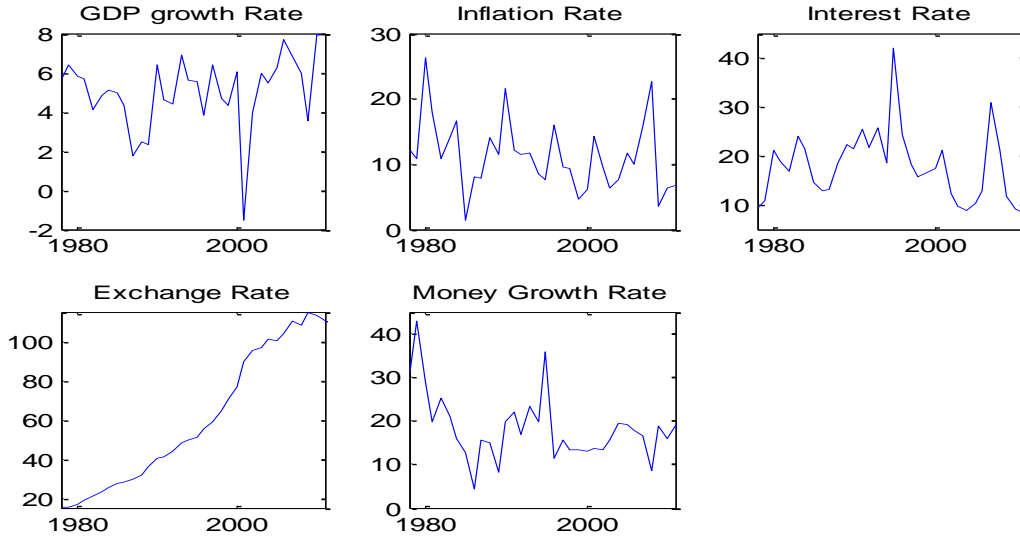
Notes: Numbers in parenthesis are z-values. *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

Table 5: Forecast Error Variance Decomposition of Major Economic Variables

T	% of Variation due to the shocks to						
	GDP	CPI	IR	M0	ER	WOP	FFR
FEV of GDP							
1	100 (3.7e-17)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)
3	95.9(.0174)	0.17(.0038)	1.34(.0082)	1.99(.0132)	0.50(.0068)	0.03(.0016)	0.04(.0020)
12	94.7(.0207)	0.21(.0038)	2.47(.0142)	1.97(.0131)	0.49(.0067)	0.03(.0016)	0.05(.0021)
20	94.7(.0208)	0.21(.0038)	2.50(.0143)	1.97(.0131)	0.49(.0067)	0.03(.0016)	0.05(.0021)
FEV of CPI							
1	0.37(.0060)	99.6(.0060)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)
3	0.40(.0059)	98.2(.0123)	0.31(.0041)	0.04(.0017)	0.03(.0018)	0.43(.0066)	0.50(.0050)
12	0.56(.0063)	97.5(.0171)	0.79(.0096)	0.04(.0017)	0.03(.0018)	0.46(.0069)	0.56(.0076)
20	0.56(.0063)	97.5(.0172)	0.80(.0098)	0.04(.0017)	0.03(.0018)	0.46(.0069)	0.56(.0076)
FEV of IR							
1	26.3(.0375)	0.23(.0041)	73.4(.0375)	0.00(0.000)	0.00(0.000)	0.00(0.000)	0.00(0.000)
3	23.2(.0431)	1.46(.0138)	74.6(.0444)	0.42(.0049)	0.01(.0011)	0.11(.0032)	0.08(.0030)
12	22.4(.0478)	1.96(.0184)	74.9(.0505)	0.41(.0053)	0.01(.0009)	0.11(.0041)	0.16(.0053)
20	22.3(.0480)	1.97(.0185)	74.9(.0507)	0.41(.0053)	0.01(.0009)	0.11(.0041)	0.16(.0054)
FEV of M0							
1	0.74(.0084)	0.26(.0051)	0.20(.0044)	98.7(.0108)	.005(.0006)	0.00(0.000)	0.00(0.000)
3	0.69(.0078)	0.41(.0067)	0.24(.0048)	98.0(.0130)	.005(.0006)	0.37(.0055)	0.19(.0036)
12	0.69(.0078)	0.41(.0067)	0.25(.0049)	98.0(.0132)	.005(.0006)	0.38(.0056)	0.20(.0037)
20	0.69(.0078)	0.41(.0067)	0.25(.0049)	98.0(.0132)	.005(.0006)	0.38(.0056)	0.20(.0037)
FEV of ER							
1	3.48(.0178)	0.67(.0079)	0.06(.0024)	.001(.0003)	95.7(.0195)	0.00(0.000)	0.00(0.000)
3	3.85(.0186)	0.69(.0080)	0.93(.0068)	0.39(.0058)	93.5(.0230)	0.28(.0050)	0.27(.0048)
12	3.94(.0185)	0.71(.0079)	1.50(.0114)	0.39(.0058)	92.8(.0250)	0.31(.0052)	0.28(.0049)
20	3.95(.0185)	0.71(.0079)	1.51(.0115)	0.39(.0058)	92.8(.0251)	0.31(.0052)	0.28(.0049)
FEV of WOP							
1	1.46(.0118)	0.02(.0016)	.003(.0006)	0.06(.0025)	0.02(.0044)	98.2(.0129)	0.00(0.000)
3	1.59(.0129)	0.08(.0024)	.003(.0005)	0.54(.0074)	0.27(.0056)	96.7(.0181)	0.73(.0084)
12	1.59(.0128)	0.08(.0024)	0.01(.0008)	0.54(.0075)	0.27(.0055)	96.6(.0187)	0.81(.0094)
20	1.59(.0128)	0.08(.0024)	0.01(.0008)	0.54(.0075)	0.27(.0055)	96.6(.0187)	0.81(.0094)
FEV of FFR							
1	6.91(.0242)	.008(.0008)	3.07(.0162)	0.11(.0031)	0.01(.0009)	5.11(.0202)	84.7(.0328)
3	6.67(.0259)	0.29(.0060)	3.48(.0184)	0.94(.0101)	0.06(.0029)	9.78(.0329)	78.7(.0414)
12	6.58(.0256)	0.29(.0061)	3.79(.0219)	0.97(.0104)	0.06(.0029)	10.2(.0346)	78.1(.0434)
20	6.58(.0256)	0.29(.0061)	3.80(.0220)	0.97(.0104)	0.06(.0029)	10.1(.0346)	78.1(.0435)

Note: Figures in parenthesis are standard errors.

Figure 1: Trend of Key Economic Indicators



Source: Author's calculation using data from world development indicator for GDP growth rate, inflation rate and monetary aggregate (M2) growth rate and international financial statistics for exchange rate and inter-bank call money market rate during the period from 1978 to 2011.

Figure 2: Impulse Responses to a Positive Interest Rate Shocks: SVAR

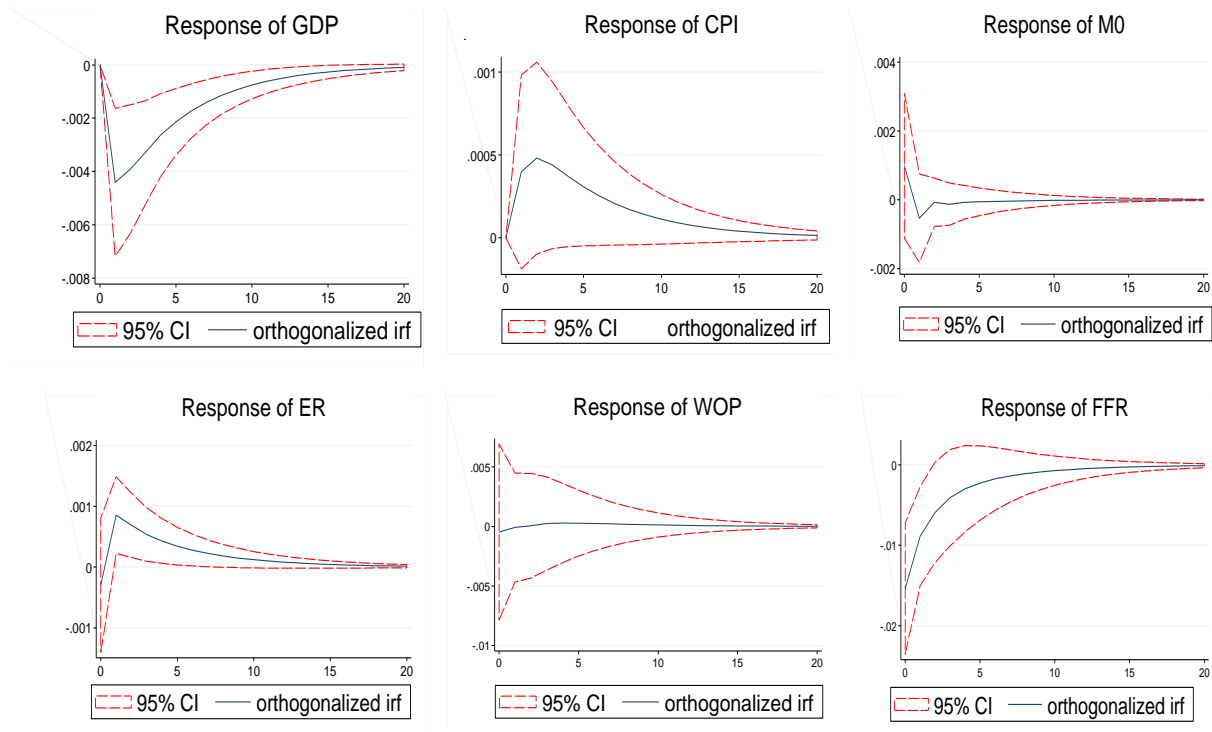


Figure 3: Impulse Responses to a Positive Exchange Rate Shocks: SVAR

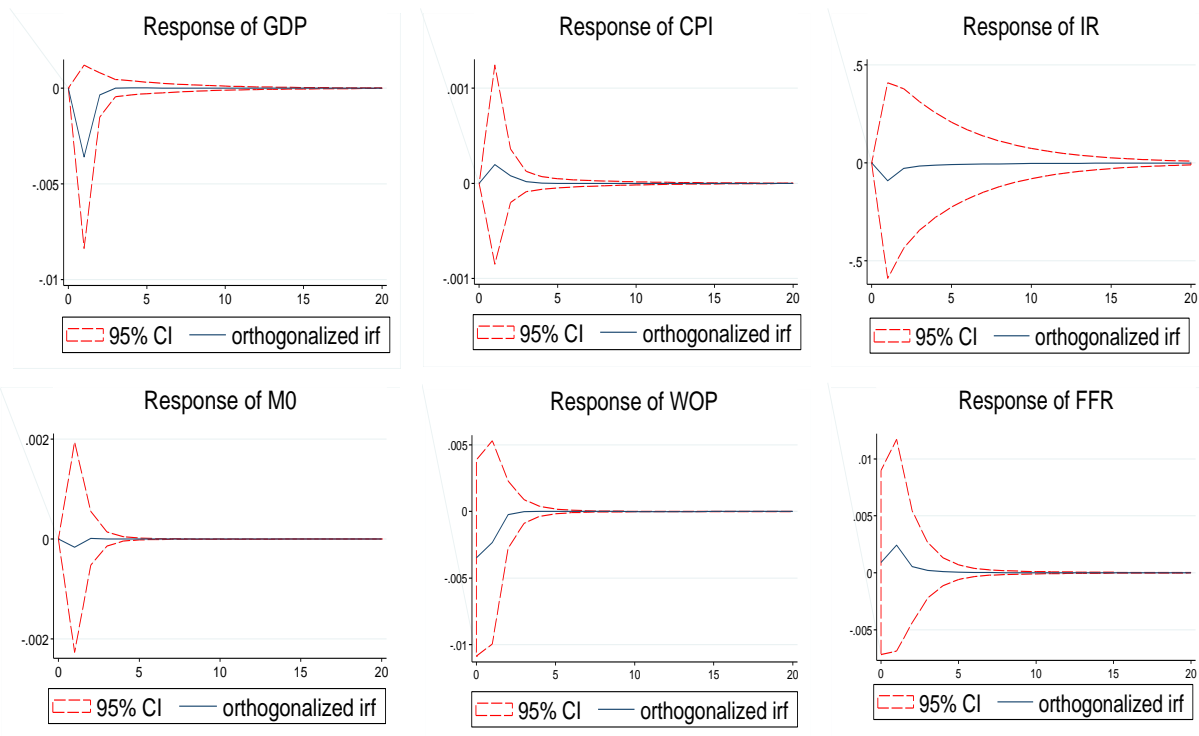


Figure 4: Impulse Responses to a Positive Money Growth Shocks: SVAR

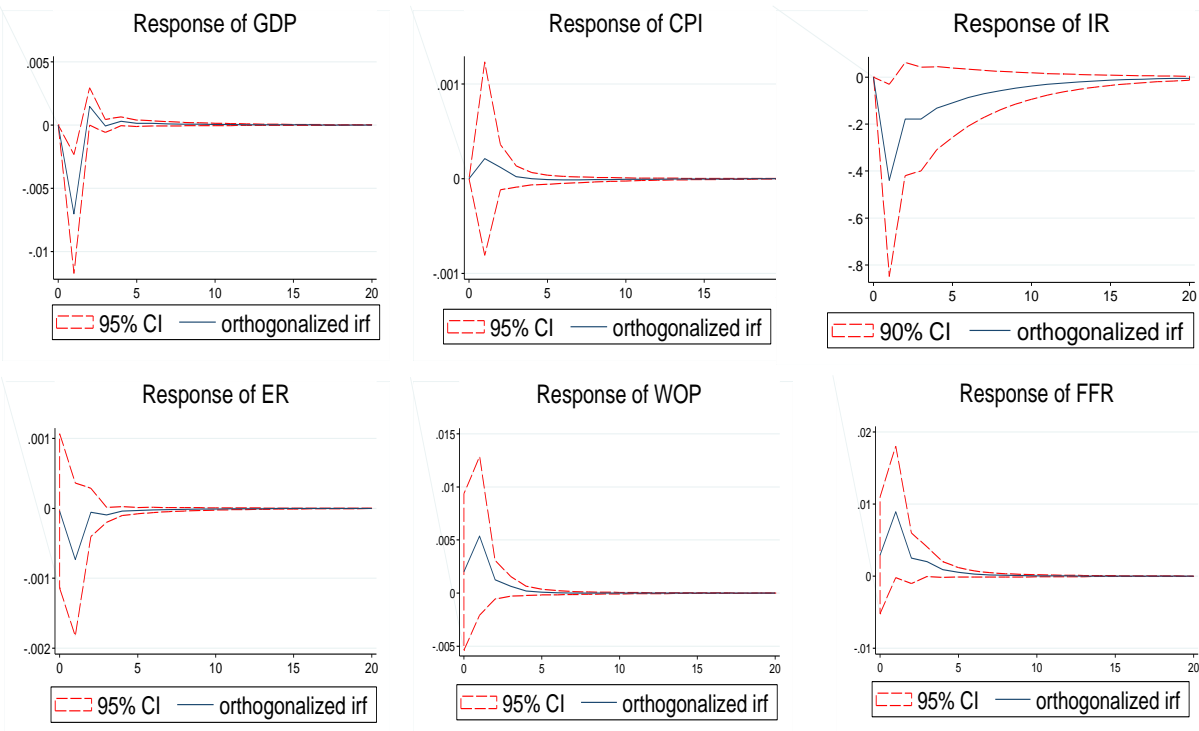


Figure 5: Impulse Responses of Domestic Variables to U.S. Interest Rate Shock

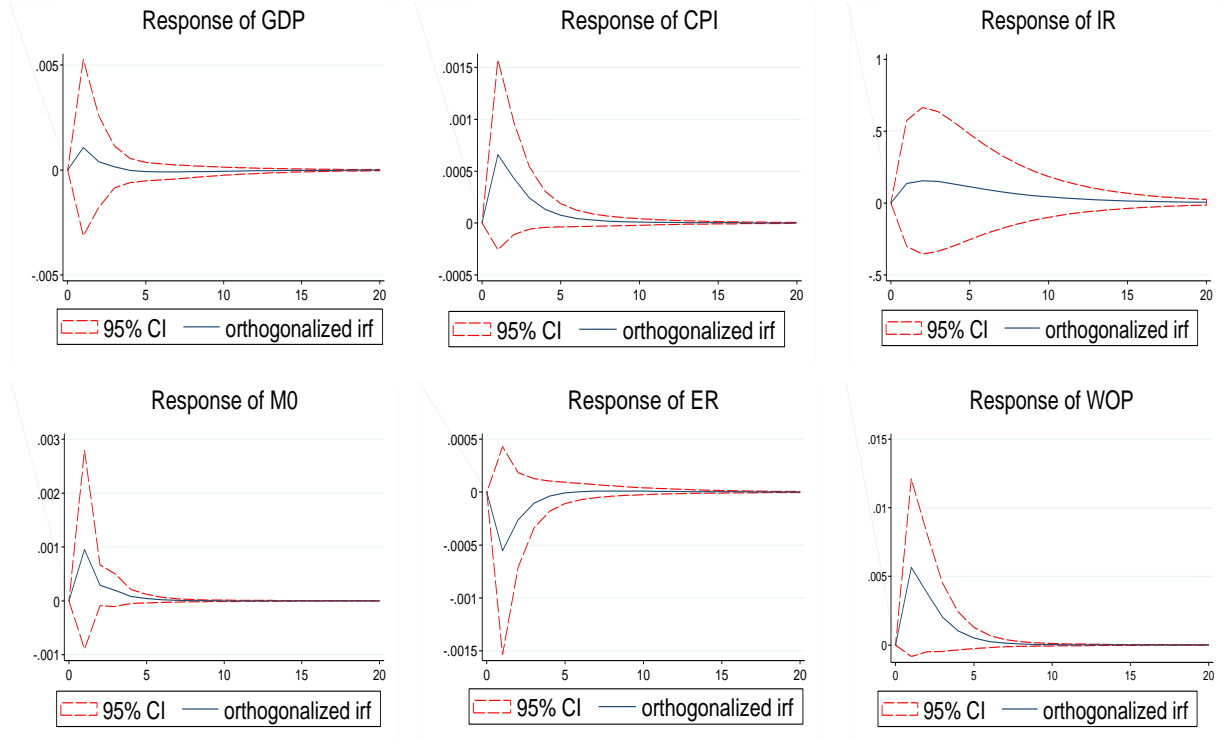
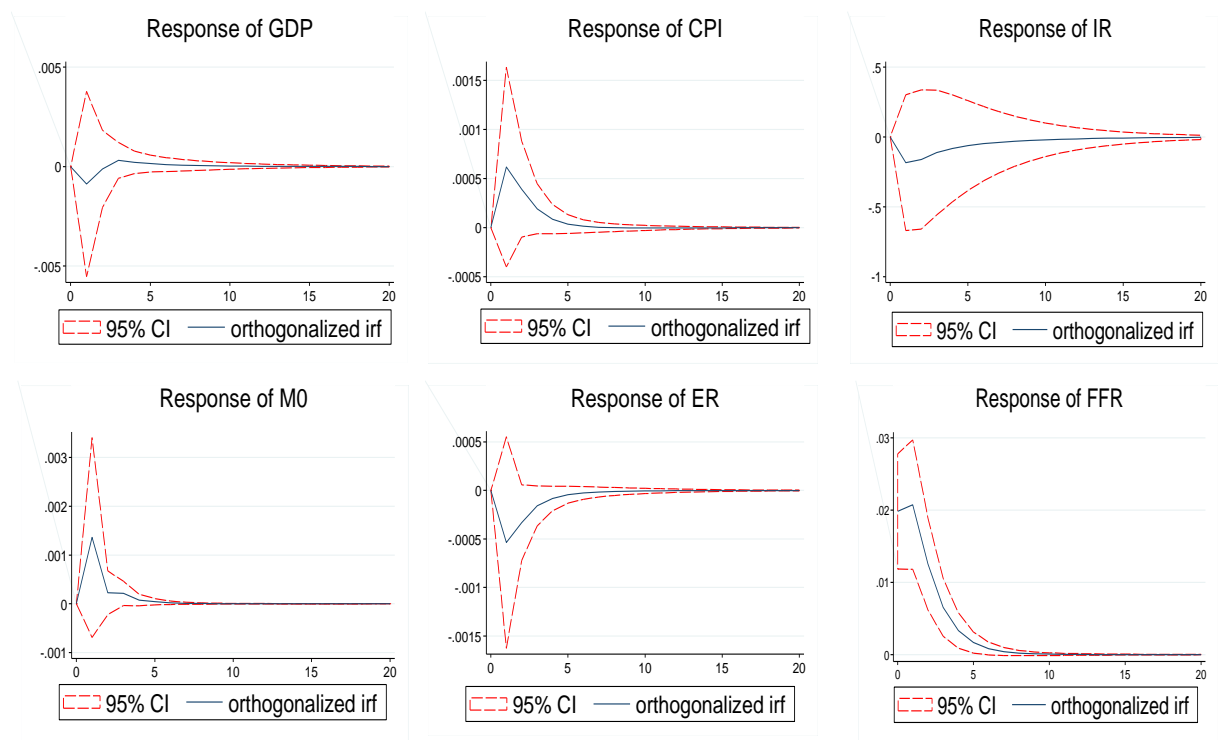


Figure 6: Impulse Responses of Domestic Variables to World Oil Price Shock



Using Kim and Roubini (2000) identification Restriction

Figure 7: Impulse Responses to a Positive Interest Rate Shocks: SVAR

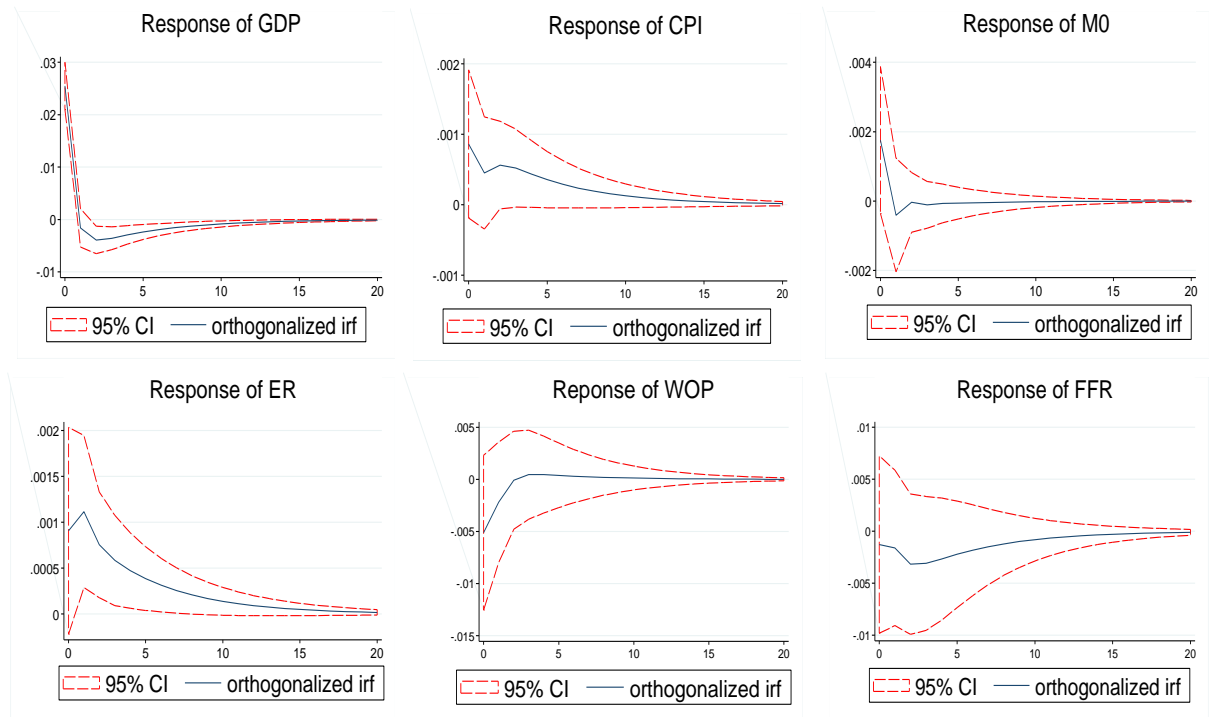


Figure 8: Impulse Responses to a Positive Money Growth Shocks (M1): SVAR

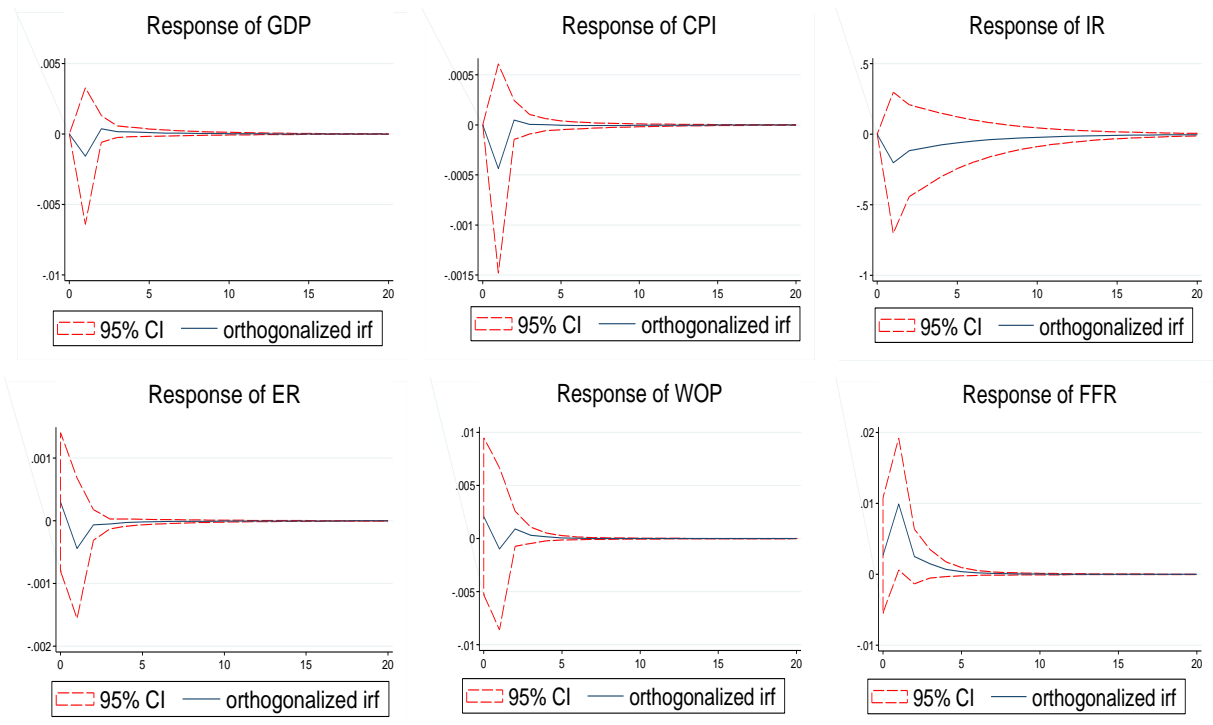


Figure 9: Impulse Responses to a Positive Interest Rate Shocks: Recursive VAR

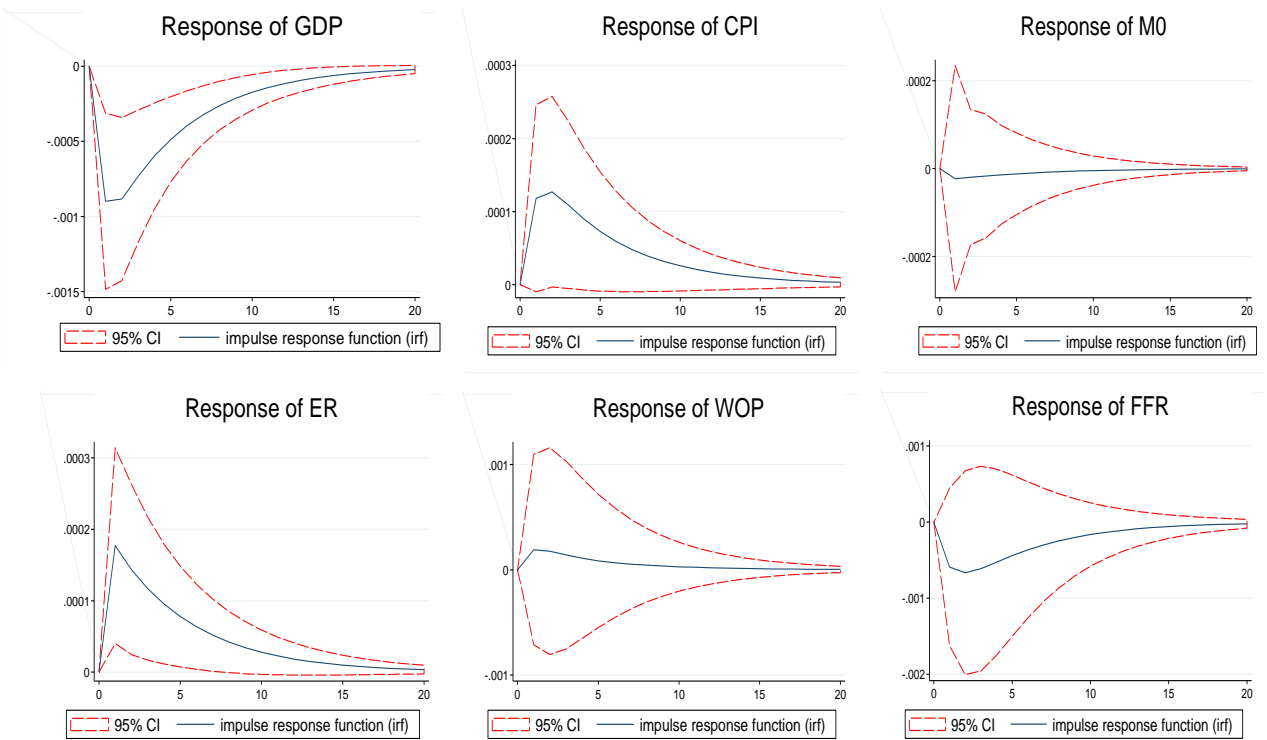


Figure 10: Impulse Responses to a Positive Exchange Rate Shocks: Recursive VAR

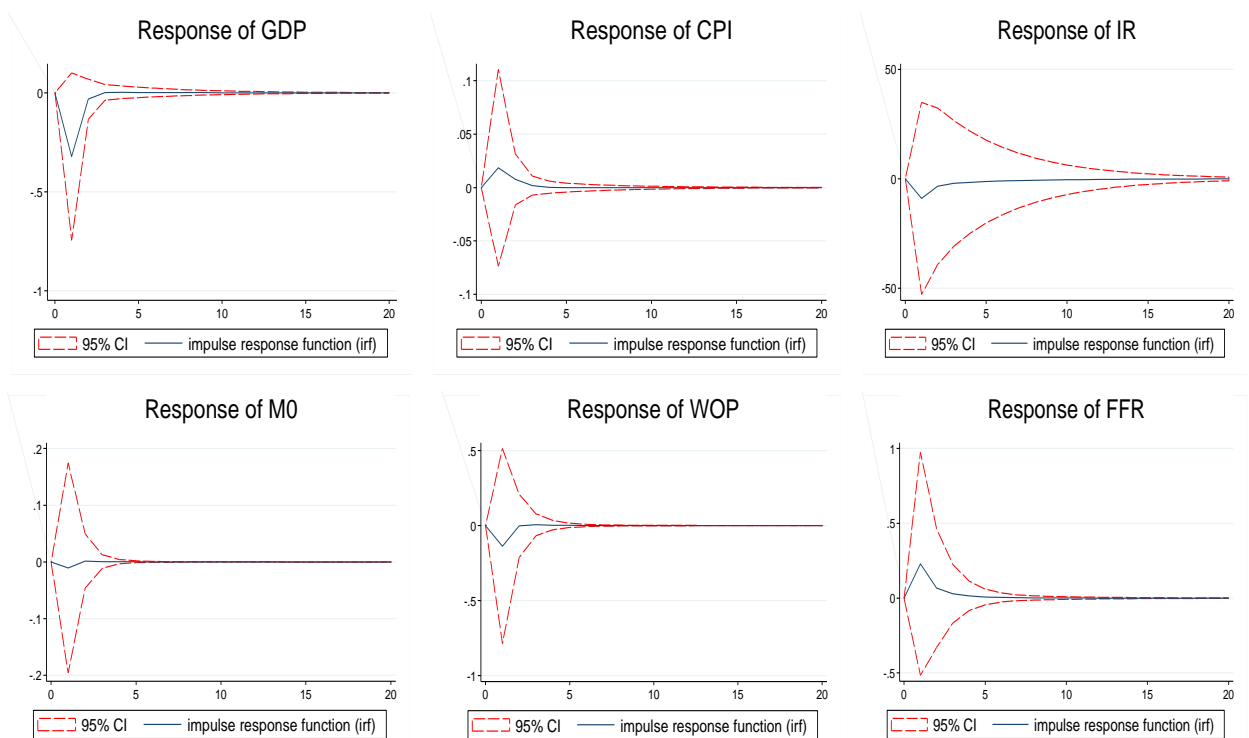


Figure 11: Impulse Responses to a Positive Money Shocks: Recursive VAR

