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Monetary Policy Transmission in Mauritius Using a VAR Analysis

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Monetary Policy Transmission in Mauritius Using a VAR Analysis [†]

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Abstract

Applying commonly used vector autoregression (VAR) techniques, this paper investigates the transmission mechanism of monetary policy on output and prices for Mauritius, using data for 1999–2009. The results show that (i) an unexpected monetary policy tightening—an increase in the Bank of Mauritius policy interest rate—leads to a decline in prices and output but the effect on output is weaker; (ii) an unexpected decrease in the money supply or an unexpected increase in the nominal effective exchange rate result in a decrease in prices; and (iii) variations of the policy variables account for small a percentage of the fluctuations in output and prices. Taken together, these results suggest a rather weak monetary policy transmission mechanism. Finally, we find some differences in the transmission mechanism depending on whether core or headline consumer price index is used in the estimations.

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I. INTRODUCTION

The economy's reaction to monetary policy usually occurs with a lag. Understanding this transmission lag and, more broadly, the transmission channels is essential for the design, management, and implementation of monetary policy. With an increasing number of countries basing monetary policy on explicit rules and preannounced targets, there has been a rising interest in the empirical study of the monetary policy transmission mechanism over the last decade or so.

The vector autoregression (VAR) framework pioneered by Sims (1980) has been the workhorse for this analysis.[1] VARs explicitly recognize the simultaneity between monetary policy (such as an increase in the short-term interest rate) and macroeconomic developments (such as changes in output, prices, exchange rates), as well as the dependence of economic variables on monetary policy. By placing minimal restrictions on how shocks affect the economy, the VAR framework allows for a more straightforward and less restrictive approximation of the true reduced form.

The VAR analysis is a particularly useful tool to investigate the monetary policy transmission also in the context of emerging economies, where short data series and structural changes complicate the use of structural models. Examples of studies using VARs to identify the monetary policy transmission mechanism in advanced economies include Christiano, Eichenbaum, and Evans (2000) for the United States, Kim and Roubini (2000) for industrial economies, and Angeloni, Kashyap and Mojon (2003) for the euro area. Applications to non-industrialized economies include Gottchalk and Moore (2001) on Poland, Arnoštová and Hurník (2005) on the Czech Republic, Dabla-Norris and Floerkemeier (2006) on Armenia, Cheng (2006) on Kenya, and Bakradze and Billmeier (2007) on Georgia.

This paper investigates the transmission mechanism of monetary policy in Mauritius using a VAR framework. Following the literature, we start by including the headline consumer price index (CPI) in the VAR analysis, and consider that our benchmark model. Given that some inflation models used for monetary policy—such as those used for inflation targeting frameworks—filter out volatile and exogenous components from the consumption basket, we also estimate an alternative VAR using a measure of core CPI, which essentially nets out administrative prices and energy prices and may give a more accurate picture of price trends. For both the baseline an alternative models, we examine how (i) changes to the existing monetary policy instrument—the official Bank of Mauritius (BOM) interest rate or repo rate—transmit to real output and the headline/core CPI; (ii) changes in two other policy instruments (the nominal effective exchange rate and money supply) transmit to output and CPI; and (iii) differences in two identification methods of the VAR influence the results.

Our findings suggest that overall the transmission channel is weak, particularly for output. While this conclusion holds for both the headline and core CPI models, there are significant

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[1] Although VARs were traditionally used for forecasting, Sims' work initiated their use for policy analysis.

differences in their respective monetary transmission mechanisms. The results are summarized as follows. *First*, for the case of headline CPI, changes in the repo rate result in small and short-lived (albeit statistically significant) responses of the headline CPI and to a lesser extent output. Similarly to the interest rate transmission channel, there is a statistically significant transmission of exchange rate shocks to the headline CPI and output, which tends to last longer than the repo rate shocks, and some evidence of a very short-lived transmission of money supply shocks to output (but not CPI). *Second*, in the case of core CPI, there is no transmission of repo rate shocks to output or core CPI. There is, however, a quick response of core CPI to the exchange rate shock as well as evidence of a statistically significant transmission of money supply shocks to both output and inflation (and to the exchange rate). *Finally*, results of the headline and core CPI analyses suggest that perhaps different monetary policy "rules" could be used depending on which CPI is targeted: for headline CPI where the interest rate channel is stronger, "Taylor-type" rules may be more applicable, while for core CPI, alternative "McCallum-type" rules that target money supply could be more appropriate.

The rest of the paper is organized as follows: Section II briefly describes the institutional monetary policy framework in Mauritius and presents some stylized facts to motivate the analysis. Section III presents the VAR empirical approach used in the paper. Section IV discusses the results and interpretations. Section V concludes.

II. Background And Stylized facts

A. Monetary Policy Framework in Mauritius

Containing inflation and maintaining price stability is the BoM's statutory responsibility. As stipulated in the BoM Act 2004, "the primary objective of the Bank shall be to maintain price stability and to promote orderly and balanced economic development." Similarly, the repealed BoM Act 1966 gives the BoM the responsibility to "safeguard the internal and external value of the currency" and focus its policies towards "increasing economic activity and the general prosperity of Mauritius".

The conduct of monetary policy by the Bank of Mauritius (BoM) has evolved with economic and financial conditions, particularly the process of economic and financial liberalization which started in the 1980s.[2] Up to the 1990s, the BoM's framework focused on direct monetary control, establishing a ceiling for the expansion of credit by banks and imposing reserve requirements, with interest rate guidelines issued to banks. With financial liberalization, the removal of exchange rate controls in the mid-1990s, and the more flexible exchange rate regime replacing the basket peg, the BoM moved to indirect monetary control by influencing the growth of money and market interest rates. Reserve money was initially the operating target of monetary policy, which was replaced by the use of a key interest rate— the Lombard rate—in 1999, while maintaining the money supply as the intermediate policy target.

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[2] For more details about the historical evolution of monetary policy in Mauritius see Heerah-Pampusa, Khodabocus, and Morarjee (2006).

More recent developments include the creation of the Monetary Policy Committee (MPC) (established by the Bank of Mauritius (BoM) 2004 Act), and the introduction of the repo rate in December 2006. The repo rate replaced the Lombard rate and became the BoM's key monetary policy instrument to signal its stance to market participants. The BoM typically regulates the supply of reserve money in order to bring the overnight interbank market rate close to the repo rate. In addition, the BoM frequently sterilizes excess liquidity stemming from large capital inflows by issuing bills through the open market operations. The MPC formulates the monetary policy of the BoM since April 2007.[3]

B. Stylized Facts and Recent Developments

The greater emphasis on controlling inflation using more market-based policy instruments since the mid-1990s was associated with a reduction of inflation and stronger growth. Inflation eased in recent years from an average of 8 percent in the 1990s to about 5 percent in the last five years and has also become less volatile, while real GDP growth has remained high, averaging more than 5 percent in 1996-2008. Figure 1 presents some of the stylized facts discussed below.

Monetary policy

Monetary policy has been responding to developments of the Mauritian economy. After a period with policy rates in excess of 12 percent in the late 1990's, monetary policy was eased to boost growth until end-2004, and tightened again as inflation started to pick until about end- 2006. Monetary policy has been loosening since early 2007. Recently, and against the background of the economic slowdown and sharp decline in the growth of private sector credit, the BoM reduced its policy rate by 250 basis points to 5.75. In addition, reserve requirements were cut to reduce the cost of financial intermediation, which helped keep the overnight interbank rate close to the policy rate.

Generally, as a small and highly open economy, the scope for monetary policy to be truly independent of external factors is necessarily limited. In practice, policy interest rate moves appear to place significant weight on the interest rate differential relative to major currencies (for example, the US federal funds rate) while reacting to domestic inflation when it is above a "tolerance" level.[4] In addition, looser monetary stance corresponds to accelerated growth rates of M1 and M2.

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[3] The MPC includes the BoM Governor and two Deputy Governors, two Board Directors and four members.

[4] Staff estimates of the reaction function $R_t = \beta_0 + ygap + D(\pi_{t-1} - \bar{\pi}) + USFed_t$ (where *R* is the real policy (repo) rate, *USFed* is the US federal funds rate, *D* is a dummy variable equal to unity when inflation exceeds the threshold level, and the threshold (tolerance) level of inflation is estimated using maximum likelihood methods to be 4.7 percent a year) find strong statistically significant responses. From the uncovered interest rate parity condition, a high coefficient on *USFed* approximately sets the *expected* change of the exchange rate to zero (as in a pegged exchange rate regime), but unexpected shocks can be absorbed by exchange rate movements (as in a floating regime). Moreover, the high coefficient on inflation (when it exceeds the tolerance level) implies that the policy reaction function obeys the Taylor principle. (For more details see Mauritius Report SM/09/310.)

Inflation

Despite the recent monetary loosening, inflationary pressures have eased since the reversal of last year's global food and commodity price shock and the slowdown of the domestic economy and portfolio inflows. Since 2006, the BoM calculates measures of core inflation which are used as complementary indicators of the trend component of inflation.[5] Core inflation volatility has also significantly declined, confirming that relative price adjustment (from administered prices) has an impact on inflation.

As shown in Figure 1, looser monetary stance tends to be followed by higher inflation. This is particularly true for the majority of the period of analysis except in 2003, 2006-07 and the recent period. Core inflation does not seem to be associated with changes to the monetary policy stance.[6] Also, exchange rate depreciations are associated with higher (core and headline) inflation.

Growth

Looser monetary stance is not always associated with stronger growth. Despite periods of lower policy rates and high growth (2002Q1-2004Q1 and 2006Q1-2008Q2), there does not appear to be a strong relationship between short-term interest rates and real output. Perhaps this is due to the fact that lower interest rates are associated with monetary expansions of 2000-06 and 2007-08 and have contributed to the private sector credit growth in 2003-2004 and 2007-08, while at the same time private sector credit growth was high under high interest rate environments of 2004-2006. In addition, growth developments in Mauritius depend heavily on the global economy (particularly the EU which is Mauritius' main market for exports and tourism).

Exchange rate

Mauritius' exchange rate regime has been reclassified from a managed float to a free float in the Fund's AREAR classification. Foreign exchange intervention by the BoM is in principle limited to smoothing operations. This allows the Mauritian monetary and exchange rate regime to combine the flexibility of a floating exchange rate with some of the discipline of a less flexible regime. Recently, within the floating regime, the BoM accumulated reserves through mid-2008 then allowed them to decline as capital inflows eased late last summer. This trend continued when, in step with international developments, monetary policy was eased in November and again in early December. The BoM has since refrained from

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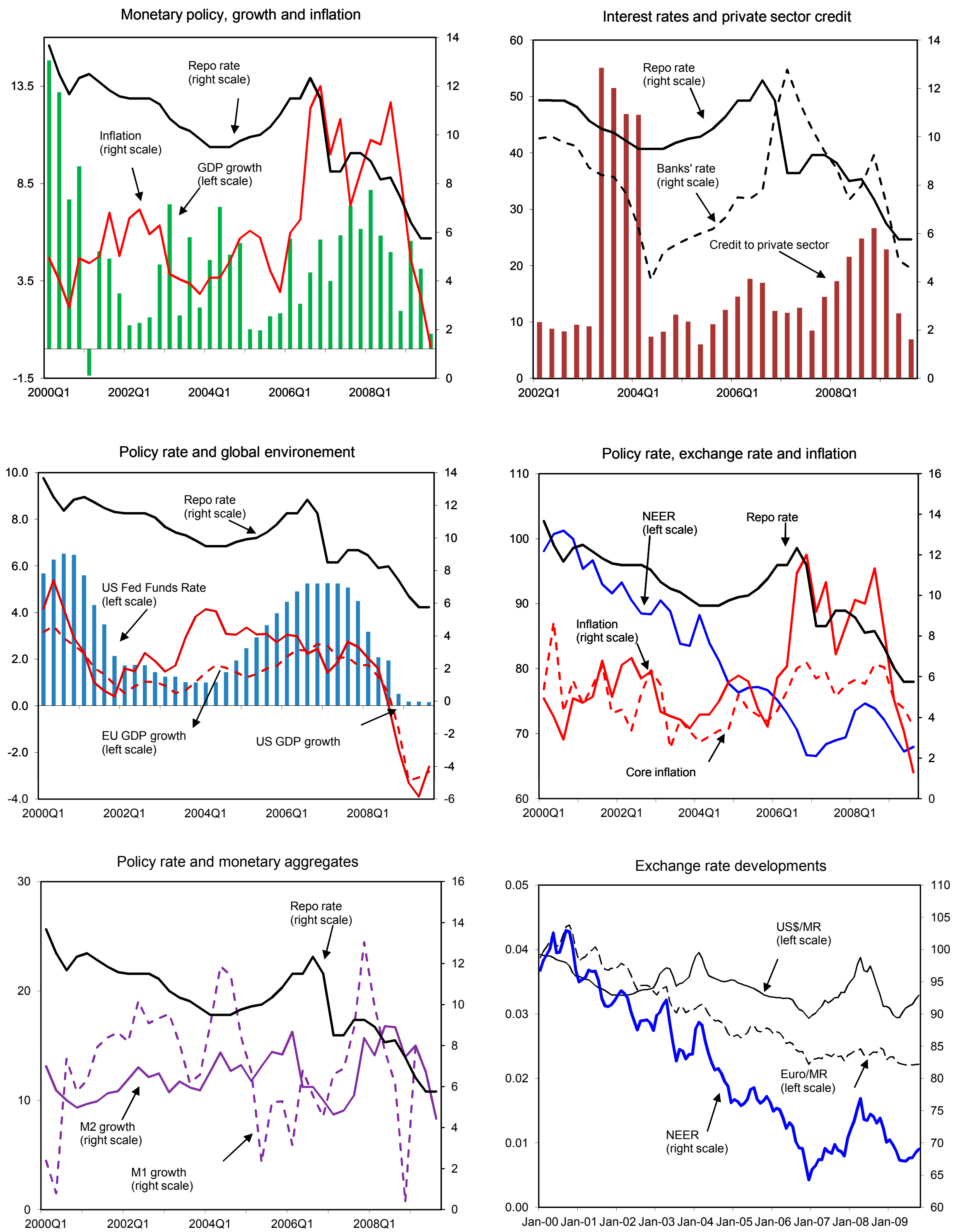
[5] For more details on the calculation of various measures of core inflation see Bissessur and Morarjee (2006).

[6] Both the headline and core CPI's (i.e. the levels) are highly negatively correlated with the repo rate. Looser monetary policy translates to increases in the (core and headline) price level.

Figure 1. Recent Developments, 2000-09



Source: CSO, Bank of Mauritius and IMF Staff estimates.

interventions, and the floating exchange has depreciated in nominal effective terms by about 4 percent since January 2009, while remaining relatively stable against the U.S. dollar.

Overall, monetary policy easing tends to be followed by a depreciation of the rupee. With the exception of a short period in the mid 2000s, movements of the nominal effective exchange rate (NEER) have followed the short-term interest rate (perhaps with a lag).

III. Empirical Approach

A. The VAR Model Setup

We examine the relationships between output, CPI, money aggregates, the repo rate and nominal effective exchange rate discussed above in a VAR setting. The VAR model assumes that the economy can be described by the following structural form equation:

$$G(L)Y_t = C(L)X_t + u_t \tag{1}$$

where $G(L)$ and $C(L)$ are $n \times n$ and $n \times k$ matrix polynomials in the lag operator L; Y_t is an $n \times 1$ vector of endogenous variables; X_t is an $k \times 1$ vector of exogenous variables; u_t is an $n \times 1$ vector of structural disturbances with $E[u_t u_t'] = \Lambda$ where Λ is a diagonal matrix (suggesting that the structural disturbances are mutually uncorrelated).[7]

The endogenous variables include real GDP (*lgdp*), consumer price index (*lcpi*), money stock (*lm2*), the repo rate (*repo*), and the nominal effective exchange rate (*lneer*). The vector of endogenous variables Y_t is

$$Y_t = \begin{bmatrix} \text{Real GDP} \\ \text{Consumer price index} \\ \text{Money stock} \\ \text{Repo rate} \\ \text{Nominal effective exchange rate} \end{bmatrix}.$$

As discussed in the introduction, while the main policy variable of interest is the repo rate, we also examine the effects of the two other policy variables (money stock and nominal effective exchange rate) on output and CPI. In the benchmark model we include the headline CPI in the VAR, which is replaced with the core CPI in the alternative specification.

[7] Technically, (1) represents a VARX model (that is, a VAR with exogenous variables), an extension of Sims's (1980) original approach which treats every variable in the system as endogenous. The exogeneity of the variables used in a VARX model can be justified on a priori grounds but also established statistically by testing for weak exogeneity. In our case, exogeneity tests performed establish that the variables used are indeed weakly exogenous, in the sense that Y_t does not Granger cause X_t.

The exogenous vector contains the U.S. Federal Fund's rate (*ffr*), and the U.S. real GDP (*lgdp_us*) which are included to control for changes in overall global economic stance affecting economic developments in Mauritius and it is motivated by the discussion in the stylized facts section. The vector of exogenous variables is

$$X_t = \begin{bmatrix} \text{U.S. Federal Funds rate} \\ \text{U.S. real GDP} \end{bmatrix}.$$

From the structural equation (1), a reduced-form VAR can be written in the form

$$Y_t = A(L)Y_t + B(L)X_t + e_t, \tag{2}$$

where $A(L)$ and $B(L)$ are matrix polynomials (without the constant term); e_t is a vector of observed (reduced-form disturbances) with $E[e_t e_t'] = \Sigma$.

There are several ways to uncover the parameters in the structural form equation from the reduced form. One method is to place restrictions on contemporaneous structural parameters, for example, by orthogonalizing reduced form disturbances using the Cholesky decomposition (see Sims (1980)), essentially a recursive structure. Another approach is to assume a non-recursive structure giving restrictions only on contemporaneous structural parameters (see Blanchard and Watson (1986), and Sims (1986)).

Define G_{00} the contemporaneous coefficient matrix in the structural form and $G_0(L)$ the coefficient matrix $G(L)$ without the contemporaneous coefficient G_{00} so that

$$G(L) = G_{00} + G_0(L). \tag{3}$$

Then, the structural and reduced form equations are related as follows:

$$A(L) = -G_{00}^{-1}G_0(L), \tag{4}$$
$$B(L) = G_{00}^{-1}C(L). \tag{5}$$

In addition, the error terms are related by $e_t = G_{00}^{-1}u_t$ or

$$u_t = G_{00}e_t, \tag{6}$$

which implies that

$$\Sigma = G_{00}^{-1}\Lambda G_{00}^{-1'}. \tag{7}$$

Estimates of Λ and G_{00} are obtained with maximum likelihood estimates of Σ. There are

$n \times (n+1)$ parameters to estimate in (7), and since Σ contains $\frac{n \times (n+1)}{2}$ parameters, we need at least $\frac{n \times (n+1)}{2}$ restrictions. Normalization of the diagonal elements of G_{00} to 1's leaves $\frac{n \times (n-1)}{2}$ restrictions on G_{00} for identification.

B. Identification

In order to identify the required restrictions, we examine two identification schemes, the recursive and structural. This is in line with studies on monetary policy transmission mechanism. The recursive modeling with the Cholesky decomposition assumes that G_{00} is triangular, while the structural identification G_{00} assumes any structure (as long as there are enough restrictions).

I - Recursive VAR

We begin with estimating the VAR in reduced form and computing the Cholesky factorization of the reduced form covariance matrix. Essentially, the covariance matrix of the structural disturbances is assumed to be diagonal (implying that the structural shocks are orthogonal) and the matrix G_{00} is assumed to be lower triangular. This assumption imposes a recursive form on the contemporaneous correlations in the system as follows: the first variable responds only to its own shock, the second variable responds to the first variable plus to a shock to the second variable, and the last variable in the system reacts without delay to all shocks, but disturbances to this variable have no contemporaneous effect on the other variables.

The relation between the reduced-form errors and the structural disturbance is given by:

$$\begin{bmatrix} u_t^{\text{lgdp}} \\ u_t^{\text{lcpi}} \\ u_t^{\text{lm2}} \\ u_t^{\text{repo}} \\ u_t^{\text{lneer}} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ g_{21} & 1 & 0 & 0 & 0 \\ g_{31} & g_{32} & 1 & 0 & 0 \\ g_{41} & g_{42} & g_{43} & 1 & 0 \\ g_{51} & g_{52} & g_{53} & g_{54} & 1 \end{bmatrix} \begin{bmatrix} e_t^{\text{lgdp}} \\ e_t^{\text{lcpi}} \\ e_t^{\text{lm2}} \\ e_t^{\text{repo}} \\ e_t^{\text{lneer}} \end{bmatrix}.$$

This recursive scheme entails that the ordering of the variables has important implications for the identification of the shocks.[8] In terms of our setup, the first identification scheme assumes that prices have immediate effects on output; the money stock has no immediate effect on

[8] Before performing the Cholesky decomposition is imposed we test the correlations between the reduced form residuals which were found to be low (see Appendix). This suggests that the reduced form shocks are fairly orthogonal to each other and ensures that the results presented are robust with respect to the ordering of the variables. Nevertheless, we carry through both identifications to compare the robustness of the results.

prices; the monetary policy shock has no immediate effect on the money stock, and the nominal effective exchange rate has no immediate effect on the monetary policy.

II - Structural VAR

The recursive identification assumes no contemporaneous between monetary policy, money, and the exchange rate. Following Sims and Zha (1998) and Kim and Roubini (2000) an alternative identification scheme relaxes these assumptions. Specifically, the following restrictions are used

$$\begin{bmatrix} u_t^{\text{lgdp}} \\ u_t^{\text{lcpi}} \\ u_t^{\text{lm2}} \\ u_t^{\text{repo}} \\ u_t^{\text{lneer}} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ g_{21} & 1 & 0 & 0 & 0 \\ g_{31} & g_{32} & 1 & g_{34} & 0 \\ 0 & 0 & g_{43} & 1 & g_{45} \\ g_{51} & g_{52} & g_{53} & g_{54} & 1 \end{bmatrix} \begin{bmatrix} e_t^{\text{lgdp}} \\ e_t^{\text{lcpi}} \\ e_t^{\text{lm2}} \\ e_t^{\text{repo}} \\ e_t^{\text{lneer}} \end{bmatrix}.$$

As before, the first two equations represent a slow response of real GDP and prices to shocks to money, interest rates, and the nominal effective exchange rate. The third equation can be interpreted as a short-run money demand equation, with money demand allowed to respond contemporaneously to shocks to output, prices, and the repo rate. The fourth equation removes the effect of the shocks on prices and output and adds the effect of the exchange rate: now the monetary policy reaction function responds contemporaneously to money demand and the exchange rate, but does not respond immediately to contemporaneous output and price shocks because data on output and prices is usually only available with a lag. The last equation implies that the nominal exchange rate responds to all other variables.

While structural VARs are useful to better understand the empirical regularities of the monetary transmission mechanism, imposing a structure in the transmission mechanism requires a good understanding of the monetary policy inter-linkages in the economy. The specification discussed and estimated here is just one attempt to do so.

IV. Estimation Results

A. Modeling the Data

We estimate the two VARs in levels using monthly data between 1999 Q1 and 2009 Q3. All variables are expressed in logarithms and seasonally adjusted except the repo rate. Figure 2 shows the data used for the analysis.

The results of various unit root tests (Table A1 in Appendix A) suggest that all series are integrated of order one in levels, that is, they are $I(1)$, and $I(0)$ in differences.[9] Using standard cointegration tests there is evidence of at least two cointegrating relationships. These results suggest that the system could be estimated either in levels (essentially with the rank if the system unrestricted) or in a vector error correction form (imposing a rank restriction of two vectors). The latter approach requires identification and the imposition of restrictions (because of the cointegration rank of at least two), and is better suited for exploring the long-run dynamics of a proposed theoretical model. Due to the short sample of analysis—which cannot be considered for an explicit analysis of the long-run behavior of the economy—and in order to avoid theoretical identification restrictions, we do not impose a cointegration rank. Therefore, we investigate the monetary policy transmission mechanism using VARs in levels.

We estimate VARs with constant and no trend, with endogenous and exogenous variables defined in the previous section.[10] We estimate two models (i) the benchmark model with headline price index in the VAR and (ii) the alternative model where core price index is modeled. Lag length criteria indicate the use of 2 lags for both models (Table A2, Appendix A). Residual diagnostic tests in Table A3 suggest well-behaved residuals.[11] Finally, using recursive estimation techniques, we conduct Chow tests in order to test for model constancy and stability.[12] Figures A1 and A2 in Appendix A suggest that the VARs are stable at the 1 percent significance level. In summary, the analysis for modeling the data suggests that the VARs are empirically well behaved and with good residual diagnostics.

To assess the monetary transmission mechanism, we use impulse responses of a one-standard deviation monetary policy shock (an exogenous, unexpected, temporary rise in the repo rate) on output, prices, the repo rate, money supply, and the nominal effective exchange rate. Also, the relative importance of the monetary policy shock for fluctuations in each variable can be examined through the forecast error variance decompositions. These indicate the forecast error variance of output, prices, money supply and the nominal effective exchange rate at different forecast horizons that can be attributed to the monetary policy shock. We estimate both the benchmark and alternative models using the two identification strategies (recursive and structural) discussed in the previous section. Both the impulse responses and the variance decompositions are dependent on the identification.

Finally, we test the models' performance for inflation using dynamic in-sample forecasting as well as their predictive performance using out of sample forecasts and compare with actual values.

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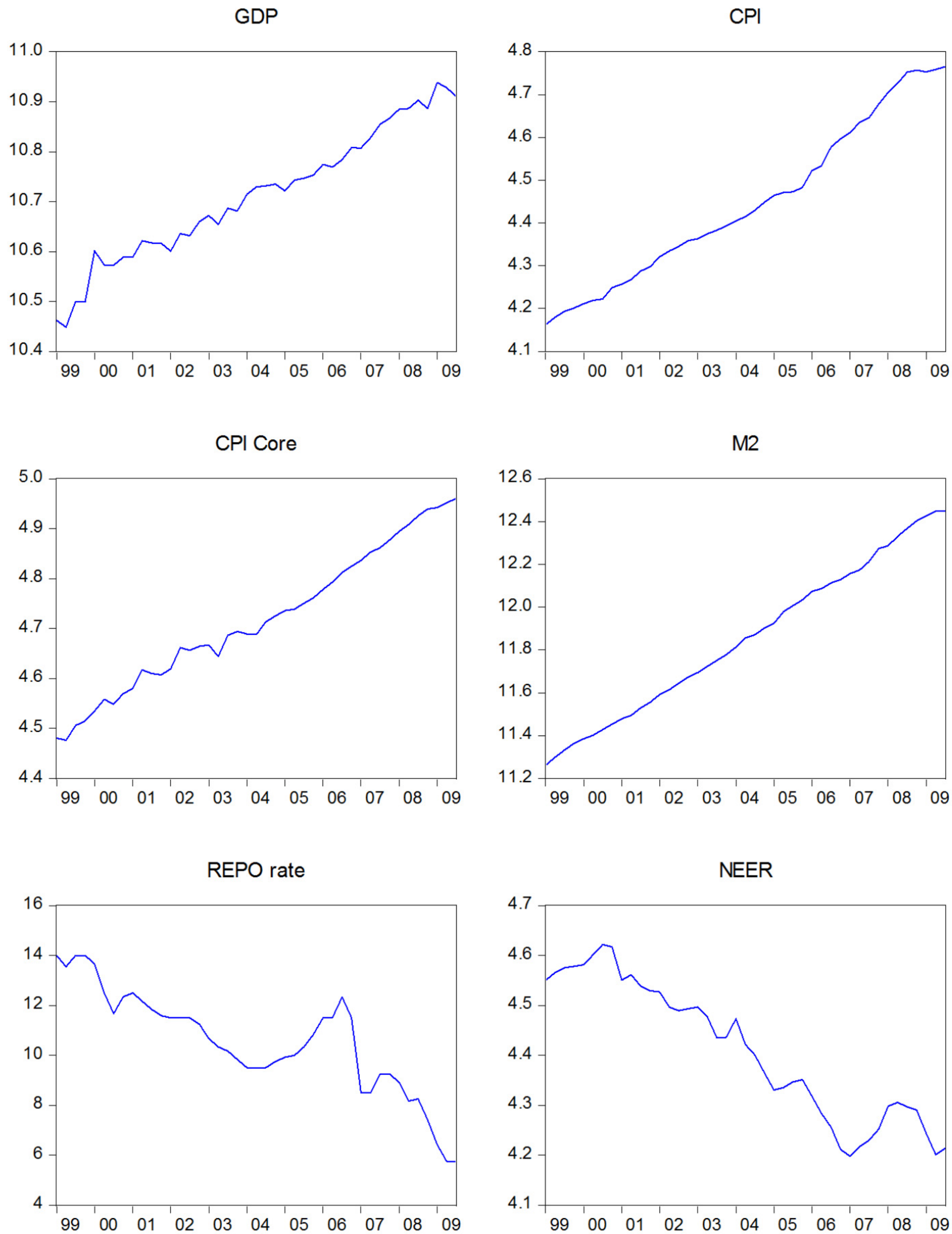
[9] The unit root tests are based on specifications with a constant term included. Alternative specifications including both a constant and a deterministic time trend were also used with similar results.

[10] Dummy variables were used as needed to capture effects of "structural" changes in the economic environment (such as changes in monetary statistics in 2003, the 2006 abolition of the Lombard rate, and the 2008 financial crisis) as well as the presence of outliers.

[11] The diagnostic tests mentioned in the text are tests performed on each equation of the VAR separately and on the entire system and yield the same results.

[12] The basic idea behind recursive estimation is to fit the VAR to an initial sample of M-1 observations, and then fit the VAR to samples of M, $M+1$, … up to T observations, where T is the total sample size.

Figure 2. Data Used for the VAR Estimation (1999 Q1-2009Q3)
Seasonally Adjusted and Expressed in Logarithms (Except the Interest Rate)



Source: Author's estimates.

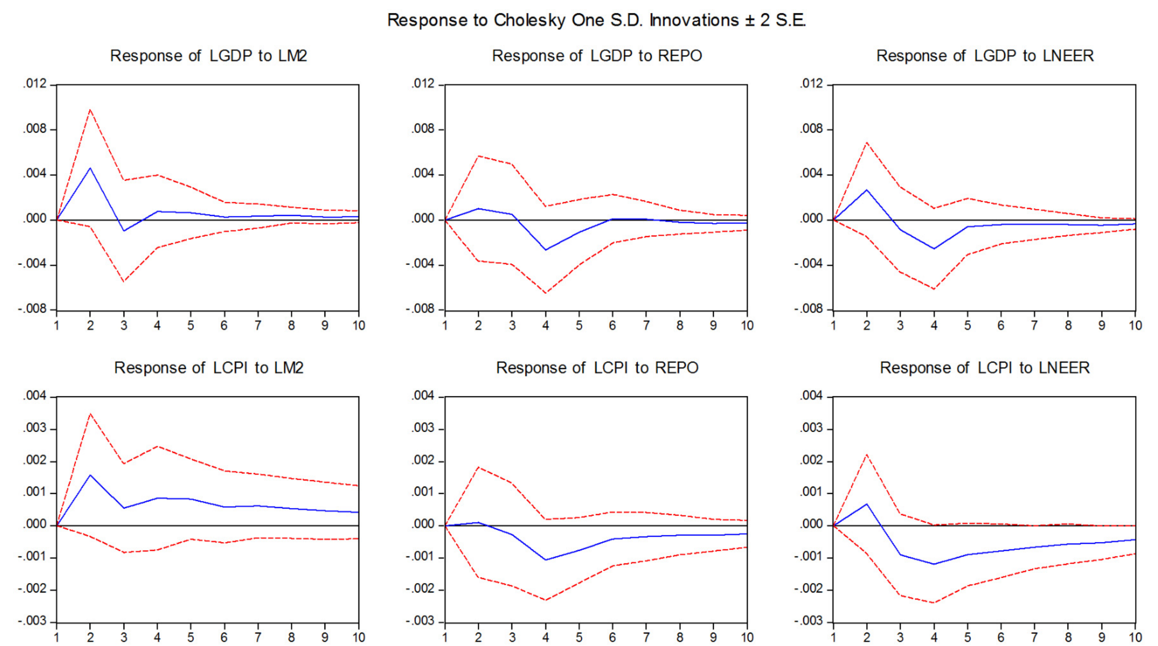
B. Benchmark Model

Impulse responses and variance decomposition

Figures 3a and 3b present impulse response functions of the impact of policy variables on output and CPI (with the associated confidence intervals) from the recursive and structural identification methods, respectively. The results are summarized as follows.

- A monetary policy shock has small (in magnitude) albeit statistically significant effects for both output and inflation which appear 4 periods after the shock: an increase in the repo rate causes both output and inflation to decline by about 0.5 and 0.2 percent, respectively. The effect is more persistent (and more statistically significant) for inflation, as output returns to the pre-shock levels by the end of the 6^{th} period, while inflation continues to be lower than the pre-shock value for more than 10 periods (with some effects marginally insignificant).

Figure 3a. Impulse Responses for Model with LCPI
Cholesky - recursive identification



Source: Author's estimates.

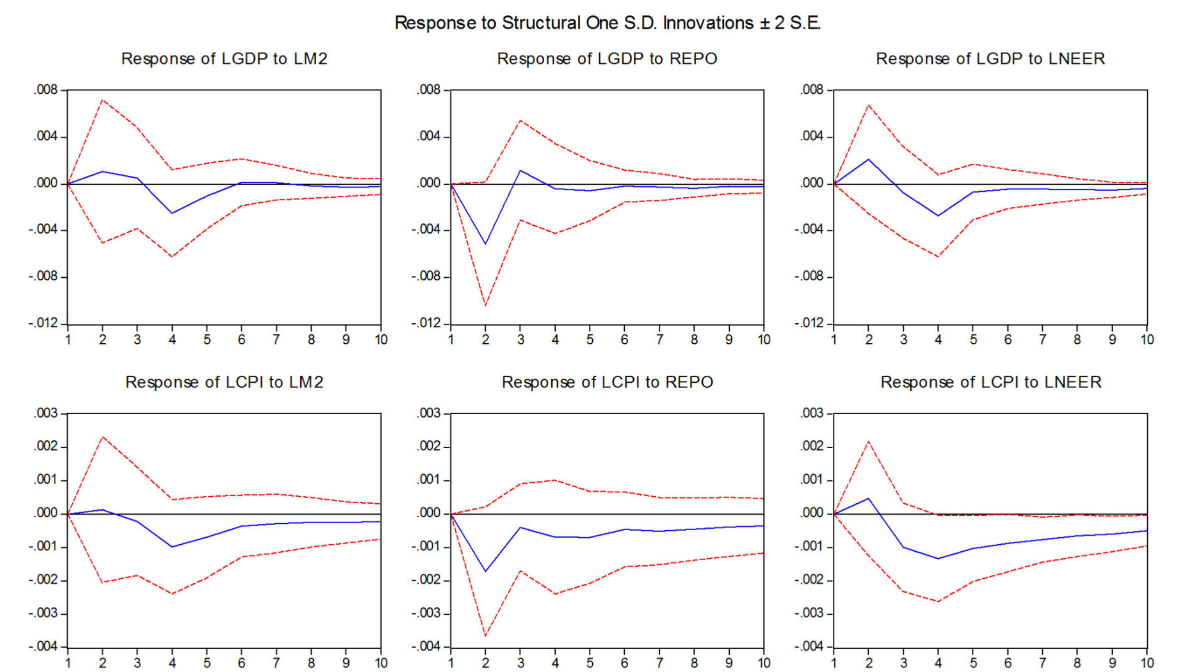
- Similarly, a positive shock resulting from an unexpected nominal appreciation lowers both output and inflation, with statistically significant effects persisting for more than 10 quarters in the case of inflation. Both effects appear about 4 periods after the shock, and appear stronger for inflation. Similarly to the repo shock, output returns to the pre-shock levels almost immediately. These effects suggest a slow and persistent pass through of exchange rate changes to prices.

- A positive shock to the money supply translates to a persistent increase in the inflation lasting for more than 10 periods (although the effects are not always statistically significant) and a short-lived increase to output which disappears by period 3.

- In addition, there is no statistically significant response of the nominal effective exchange rate to the repo shock. There is a no statistically significant change in the nominal effective exchange rate following the shock to M2. (See Appendix B for the full set of impulse responses.)

- Results with the structural identification (Figure 3b) suggest that the transmission of a repo shock to both output and inflation is faster, almost immediately after the shock with statistically significant effects disappearing after the period 3. The transmission of a shock to the exchange rate is the same as in the recursive case, while the reaction to a shock to money supply is insignificant for both output and prices.

Figure 3b. Impulse Responses for Model with LCPI
Structural identification



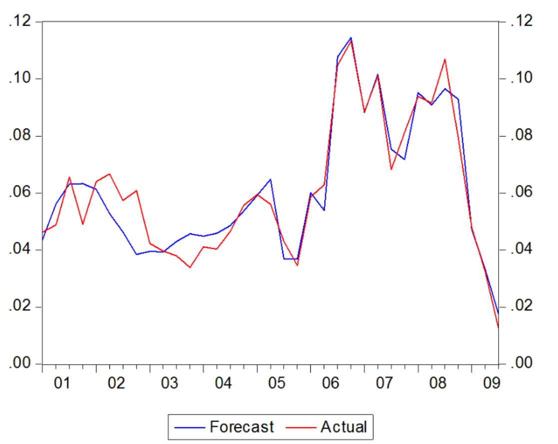
Source: Author's estimates.

- Variance decomposition analysis (Appendix Figures B2a and B2b) shows that a shock to the repo rate accounts for a very small percentage (about 2-8 percent, on average) of the fluctuations in both prices and output. Similarly, shocks to exchange rates account for a small proportion of the fluctuations in output and prices.

Overall, shocks to the repo rate have small and statistically significant transmission to both prices and output. The same is true for exchange rate shocks and money supply shocks, particularly for inflation. Combined with evidence from variance decompositions these results suggest that the transmission mechanism for all three policy variables is not very strong, particularly for output. The transmission is stronger for nominal variables (inflation) rather than real variables (output), which is typical in transition economies.

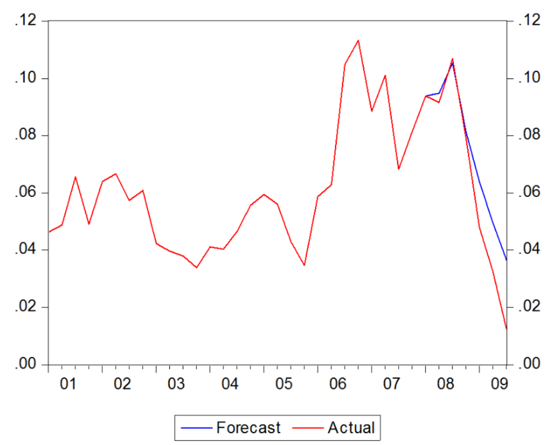
The lack of transmission to real variables could imply money neutrality, although money neutrality would be expected to hold in the long-run (while in the short run money would still be expected to affect output). More plausibly, the lack of a transmission to real variables may reflect bottlenecks and structural problems in financial markets. Traditional analyses of monetary policy assume complete markets which are free of frictions. However, various models in the credit channel and bank lending literature suggest that financial market frictions and rigidities may be manifested in a variety of ways, and are likely to introduce uncertainty into the magnitude and timing of the economy's response to changes in the monetary policy.

Figure 4. Variance Decompositions for Model with LCPI
Forecast 2001-2009



Source: Author's estimates.

Figure 5. Out-of-Sample Forecast for Model with LCPI
Forecast 2008:Q2-2009:Q3



Source: Author's estimates.

Model diagnostics and forecasting

We use the estimated VAR of the benchmark model to examine dynamic within and out-of-sample forecasts for year-on-year inflation. Figures 4 and 5 show the dynamic within and out-of-sample forecasts which perform quite well.[13] This finding is consistent with the finding of model stability and parameter constancy from the Chow tests and the overall good fit of the models. For the out-of-sample forecast, the model performs extremely well up to 2008Q4, but overestimates inflation for the three quarters of 2009 by about 1.5-2 percent. This estimate not unreasonable considering that 2009 was the year of the global recession, which is not directly modeled in our VAR.

[13] The dynamic out of sample forecast is estimated using a VAR model from 1999 Q1 to 2008Q1. Using static forecasting (i.e. where series' forecasts are based on one-step forecasts) the forecasted inflation series is even closer to the actual.

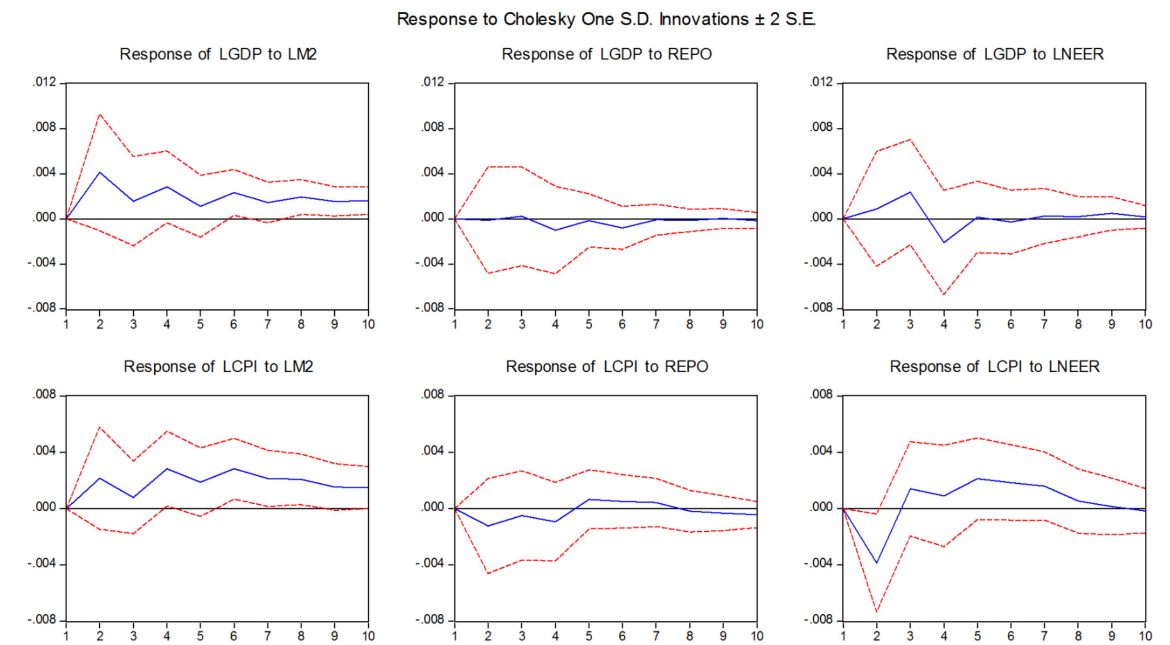
We also use the VAR model to forecast inflation for 2009 Q4 to 2010 Q3. The results show that after a small further drop in inflation in 2009 Q4, inflation resumes to the range of 3 to 4 percent in 2010.

C. Alternative Model

Impulse responses and variance decomposition

Impulse responses from the new VAR using core CPI instead of headline CPI are shown in Figures 6a and 6b, and are summarized as follows.

Figure 6a. Impulse Responses for Model with LCPI core
Cholesky



Source: Author's estimates.

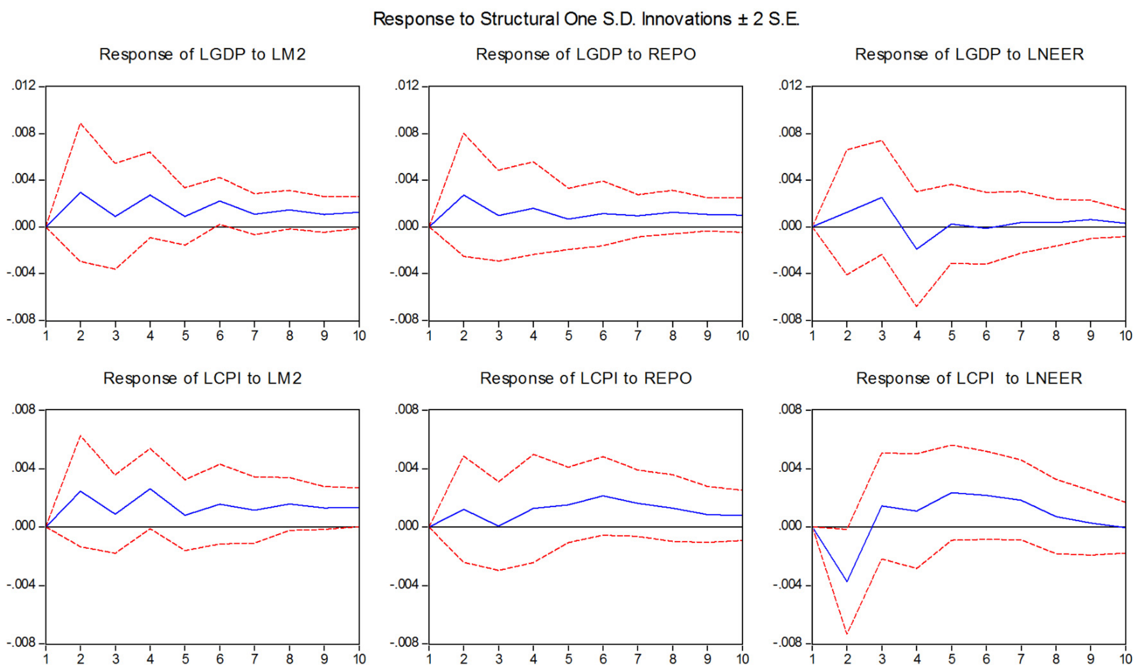
- Unlike the case of headline CPI, a monetary policy shock has no statistically significant effect on output or inflation. Both output and inflation fluctuate about their pre-shock values throughout the period.

- A positive shock to the nominal effective exchange rate has a small, statistically significant negative effect on core CPI that lasts two periods after the shock. Compared to the results with headline CPI, the transmission is much shorter and not persistent. This suggests a lower exchange rate pass-through, given that the volatile energy prices and other administrative prices are eliminated from the price index. There is no statistically significant effect of an exchange rate shock on output.

- A positive shock to the money supply increases both output and prices and this effect persists (although not always statistically significant). In addition, there is a statistically significant response of the nominal effective exchange rate to the monetary shock. (See the full set of impulse responses in Appendix B.)

- Impulse responses using the structural model give similar conclusions are for both the monetary and exchange rate shocks. There is no effect of the monetary policy shock on either output or inflation, while there is a small statistically significant effect of the exchange rate shock on inflation (Figure 6b).

Figure 6b. Impulse Responses for Model with LCPI core
Structural



Source: Author's estimates.

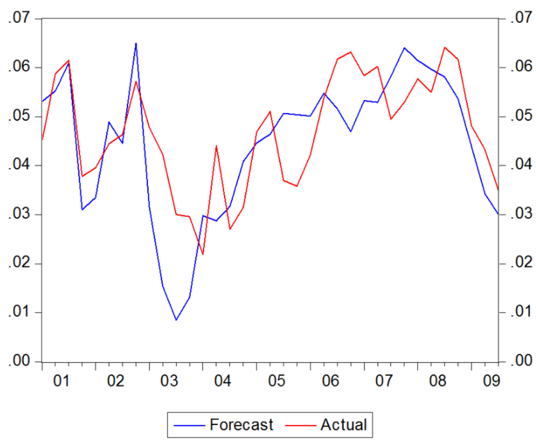
- The results from the variance decomposition (Figures A6a and A6b in Appendix A) are consistent with the impulse response analysis, and echo the results of the headline CPI analysis. The repo shock accounts for a negligible percentage (less than 2 percent, on average) of the fluctuations in prices and output. The exchange rate shock accounts on average, for about 12 percent of the fluctuation in prices. However, a shock to money supply accounts for about 10-11 percent of the fluctuations in output and prices, and about 7 percent of the fluctuations in the nominal exchange rate.

Overall, when core CPI is modeled, shocks to the repo rate have no effect on output and prices, while nominal effective exchange rate shocks have a small effect on prices. Compared to the case of headline CPI, shocks to money supply appear to transmit to both output and prices, and somewhat to the nominal effective exchange rate.

Model diagnostics and forecasting

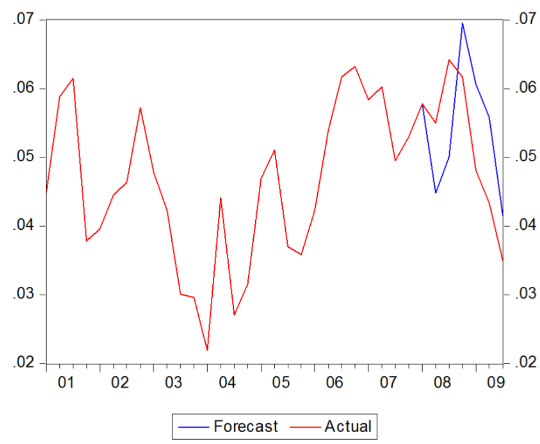
As in the case of headline index, we use the estimated VAR for the alternative model to examine dynamic within and out-of-sample forecasts for year-on-year core inflation. The dynamic within and out-of-sample forecasts (Figures 7 and 8) perform reasonably well, but perhaps not as well as the headline inflation case. We also use the VAR model to forecast core inflation for 2009 Q4 to 2010 Q3. The results show that after a small further drop in inflation in 2009 Q4, inflation resumes to an average of 2.5 percent in 2010.

Figure 7. Variance Decompositions for Model with LCPI Core
Forecast 2001-2009



Source: Author's estimates.

Figure 8. Out-of-Sample Forecast for Model with LCPI Core
Forecast 2008:Q2-2009:Q3



Source: Author's estimates.

V. Conclusion And Policy Considerations

We investigate the transmission mechanism of monetary policy in Mauritius using VAR models with core and headline CPI and two types of VAR identification schemes (recursive and structural). Our findings show that the overall monetary policy transmission transmission channel of an unexpected temporary increase in the repo rate is weak, for both headline and core CPI models, particularly for output. In addition, there is evidence that a shock to repo rate—the BoM's primary policy instrument—as well as a shocks to the other two policy variables (exchange rate and money supply) result in statistically significant changes of the headline CPI. For output, the transmission effects are not always statistically significant. Also, results from modeling core CPI suggest that there is a transmission of exchange rate and money supply shocks—but not shocks to the repo rate—on prices. Furthermore, the transmission of money supply shocks is stronger (for both output and prices) compared to the case of headline CPI. Finally, given the transmission mechanism differences, these results suggest the possibility that different monetary policy rules could be considered depending on whether headline or core CPI is targeted: for headline CPI where the interest rate channel is stronger, "Taylor-type" rules may be more applicable, while for core CPI, alternative "McCallum-type" rules that target money supply could be more appropriate.

The results suggest that more needs to be done to understand the transmission mechanism before formulating more concrete policy advice. The apparent lack of a transmisssion to output suggests the need to improve structural rigidities in the financial system and regulatory framework which may hamper the proper transmission of monetary policy to the real sector of the economy. In terms of estimation, it is important to continue to improve the models so that they better reflect the characteristics of the Mauritian economy. While an attempt was made in this paper to consider a structural identification which imposes a commonly used set of relations for the variables in the system, other structural identifications may be better suited. Last but not least, it is important to keep in mind possible data limitations given the short period of analysis.

Appendix A. VAR Modeling and Diagnostics

Table A1. Unit Root Tests
Variables in Levels and Differences

Variable	ADF			KPSS		Result
	Lags	t-ADF stat	p-value	Bandwidth	KPSS stat	
LGDP	1	-1.64	0.45	5	0.83 ***	I(1)
ΔLGDP	0	-10.33	0.00 ***	11	0.23	I(0)
LCPI	0	0.99	1.00	5	0.80 ***	I(1)
ΔLCPI	0	-5.36	0.00 ***	3	0.20	I(0)
LCPI Core	2	0.15	0.97	5	0.81 ***	I(1)
ΔLCPI Core	1	-6.29	0.00 ***	39	0.39 *	I(1)
LM2	0	0.66	0.99	5	0.81 ***	I(1)
ΔLM2	0	-7.32	0.00 ***	1	0.12	I(0)
Repo rate	0	-0.26	0.92	5	0.70 **	I(1)
ΔRepo rate	1	-5.49	0.00 ***	6	0.15	I(0)
LNEER	1	-0.41	0.90	5	0.76 ***	I(1)
ΔLNEER	0	-4.56	0.00 ***	1	0.12	I(0)

Notes:
1. Δ denotes the difference operator.
2. ADF is the Augmented Dickey–Fuller test with the null hypothesis of nonstationarity. The lags have been chosen automatically on the basis of the Schwartz criterion (with maximum lag 9). KPSS is the test proposed by Kwiatkowski et al. (1992) with stationarity as the null hypothesis.
3. The symbols *, ** and *** denote rejection of the null hypothesis at the 10, 5, and 1 percent critical values, respectively.

Table A2. VAR Lag Length Selection
Criterion Selection and Model Reduction

Model with LCPI

Lag/Criterion	LogL	LR	FPE	AIC	SC	HQ
0	369.4867	NA	1.91E-14	-17.40957	-16.12991	-16.95044
1	475.7784	152.624	3.17E-16	-21.57838	-19.23233	-20.73664
2	532.0267	66.34411+	7.62e-17+	-23.18085	-19.76842+	-21.9565
3	552.2388	18.65737	1.42E-16	-22.93532	-18.4565	-21.32836
4	597.6617	30.28194	1.05E-16	-23.98265+	-18.43745	-21.99308+

Model reduction	Statistic	Value	p-value	Result
From lag 4 to lag 3	F(25,34)	1.22	0.292	valid
From lag 4 to lag 2	F(50,44)	0.97	0.544	valid
From lag 4 to lag 1	F(75,47)	1.70	0.027	*not valid*
From lag 4 to lag 0	F(100,48)	4.86	0.000	*not valid*
From lag 3 to lag 2	F(25,53)	0.69	0.844	valid
From lag 3 to lag 1	F(50,67)	1.83	0.011	*not valid*
From lag 3 to lag 0	F(75,71)	5.77	0.000	*not valid*
From lag 2 to lag 1	F(25,72)	3.38	0.000	*not valid*
From lag 2 to lag 0	F(50,90)	9.40	0.000	*not valid*
From lag 1 to lag 0	F(25,90)	12.10	0.000	*not valid*

Model with LCPI core

Lag/Criterion	LogL	LR	FPE	AIC	SC	HQ
0	356.0397	NA	2.94E-14	-16.9764	-15.91001	-16.59379
1	446.0803	133.9065	1.10E-15	-20.31181	-18.17904+	-19.54659
2	480.0381	41.79412+	8.08e-16+	-20.77118	-17.57203	-19.62335+
3	504.234	23.57554	1.17E-15	-20.72995	-16.46441	-19.19951
4	543.1264	27.92274	1.10E-15	-21.44238+	-16.11045	-19.52933

Model reduction	Statistic	Value	p-value	Result
From lag 4 to lag 3	F(25,38)	1.10	0.389	valid
From lag 4 to lag 2	F(50,48)	1.01	0.485	valid
From lag 4 to lag 1	F(75,52)	1.27	0.182	valid
From lag 4 to lag 0	F(100,53)	3.29	0.000	*not valid*
From lag 3 to lag 2	F(25,57)	0.91	0.594	valid
From lag 3 to lag 1	F(50,71)	1.33	0.137	valid
From lag 3 to lag 0	F(75,76)	3.94	0.000	*not valid*
From lag 2 to lag 1	F(25,75)	1.81	0.000	*not valid*
From lag 2 to lag 0	F(50,94)	5.74	0.000	*not valid*
From lag 1 to lag 0	F(25,94)	9.31	0.000	*not valid*

Notes:
1. The symbol "+" indicates lag order selected by the criterion.
2. The F statistic tests the hypothesis that the reduction to the model to the right is valid.

Table A3. Residual Correlation Matrix
VARs for CPI and CPI Core

Model with LCPI

	LGDP	LCPI	LM2	Repo rate	LNEER
LGDP	1	-0.38	-0.13	-0.29	-0.04
LCPI	-0.38	1	-0.11	0.30	-0.16
LM2	-0.13	-0.11	1	-0.05	-0.14
Repo rate	-0.29	0.30	-0.05	1	0.12
LNEER	-0.04	-0.16	-0.14	0.12	1

Model with LCPI core

	LGDP	LCPI Core	LM2	Repo rate	LNEER
LGDP	1	0.04	0.24	-0.24	-0.08
LCPI Core	0.04	1	-0.03	0.00	0.09
LM2	0.24	-0.03	1	-0.03	0.08
Repo rate	-0.24	0.00	-0.03	1	0.28
LNEER	-0.08	0.09	0.08	0.28	1

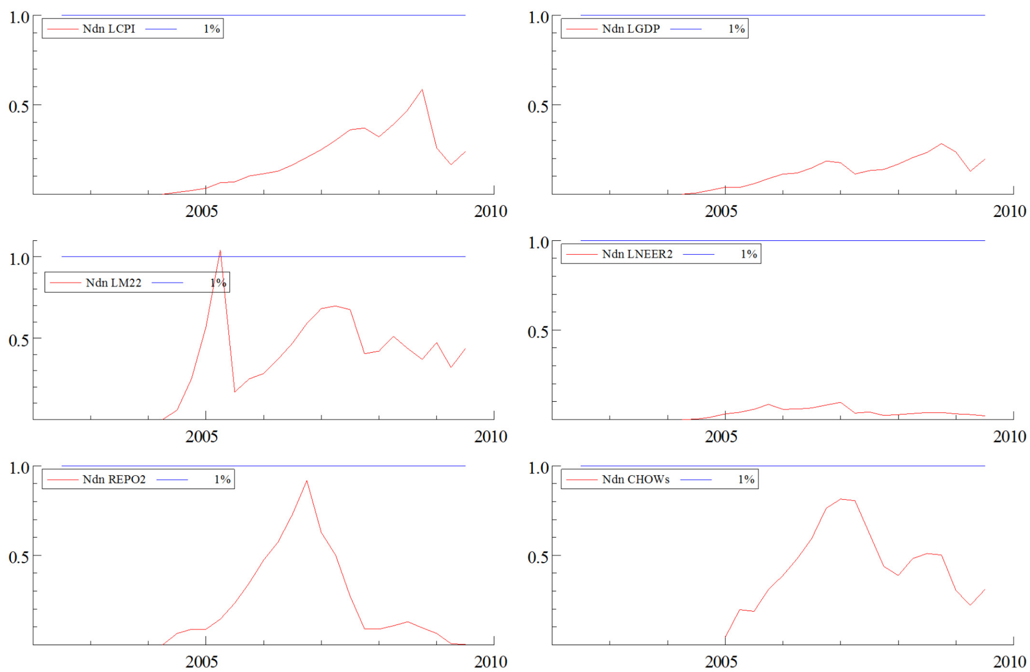
Table A4. Residual Diagnostics
Various Tests

Model with LCPI				Model with LCPI core			
Test	Statistic	Value	p-value	Test	Statistic	Value	p-value
AR 1-3 test				AR 1-3 test			
LGDP	F(3,20)	0.50	0.69	LGDP	F(3,20)	0.39	0.76
LM	F(3,20)	1.28	0.31	LM	F(3,20)	1.39	0.28
LNEER	F(3,20)	0.89	0.46	LNEER	F(3,20)	1.96	0.15
REPO	F(3,20)	3.23	0.04 *	REPO	F(3,20)	3.76	0.03
LCPI	F(3,20)	0.84	0.49	LCPI core	F(3,20)	0.13	0.94 **
Normality test				Normality test			
LGDP	$Chi^2(2)$	0.28	0.87	LGDP	$Chi^2(2)$	0.85	0.65
LM	$Chi^2(2)$	5.39	0.07	LM	$Chi^2(2)$	2.42	0.30
LNEER	$Chi^2(2)$	2.12	0.35	LNEER	$Chi^2(2)$	0.24	0.89
REPO	$Chi^2(2)$	1.52	0.47	REPO	$Chi^2(2)$	2.75	0.25
LCPI	$Chi^2(2)$	0.81	0.67	LCPI core	$Chi^2(2)$	3.98	0.14
Hetero test				Hetero test			
LGDP	F(20,2)	0.07	1.00	LGDP	F(20,2)	0.10	1.00
LM	F(20,2)	0.08	1.00	LM	F(20,2)	0.11	1.00
LNEER	F(20,2)	0.04	1.00	LNEER	F(20,2)	0.06	1.00
REPO	F(20,2)	0.12	1.00	REPO	F(20,2)	0.14	1.00
LCPI	F(20,2)	0.07	1.00	LCPI core	F(20,2)	0.06	1.00
Vector AR 1-3	F(75,23)	2.25	0.02 **	Vector AR 1-3	F(75,23)	1.79	0.06
Vector Normality	$Chi^2(10)$	16.70	0.08	Vector Normality	$Chi^2(10)$	12.60	0.25
Vector Hetero	$Chi^2(300)$	305.49	0.40	Vector Hetero	$Chi^2(300)$	286.95	0.70

Notes:
1. For the AR, Normality, and Heteroskedasticity tests, the null hypotheses are of no autocorrelation, normality, and no heteroskedasticity, respectively.
2. The symbols *, ** and *** denote rejection of the null hypothesis at the 10, 5, and 1 percent values, respectively.

Figure A1. Model Stability Tests for Model With LCPI

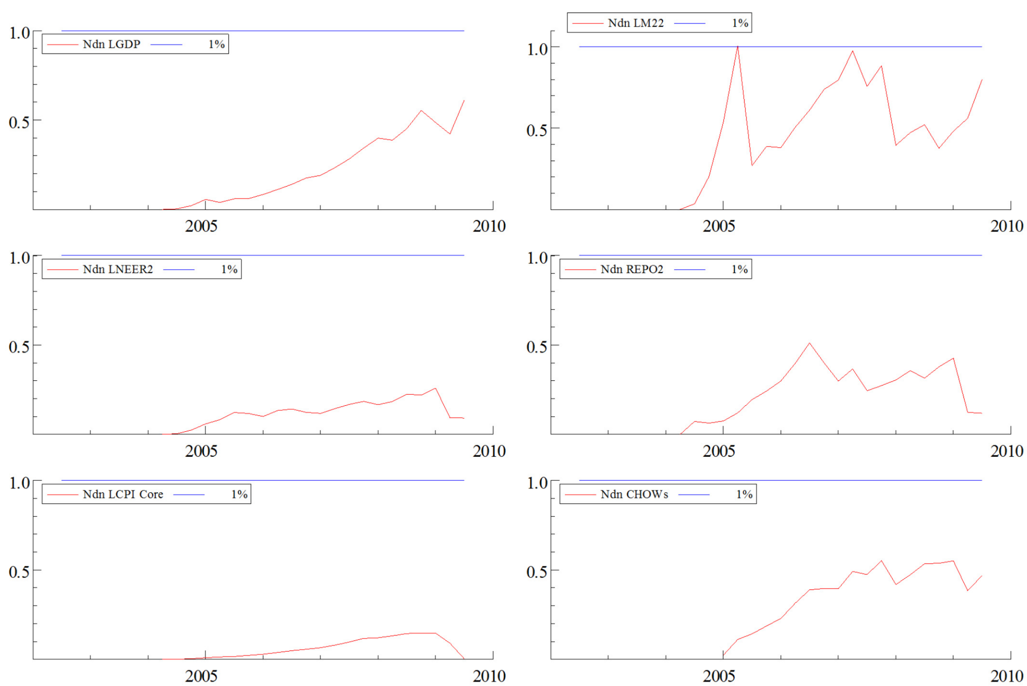
Recursive Chow Tests



Source: Author's estimates.

Figure A2. Model Stability Tests for Model With LCPI core

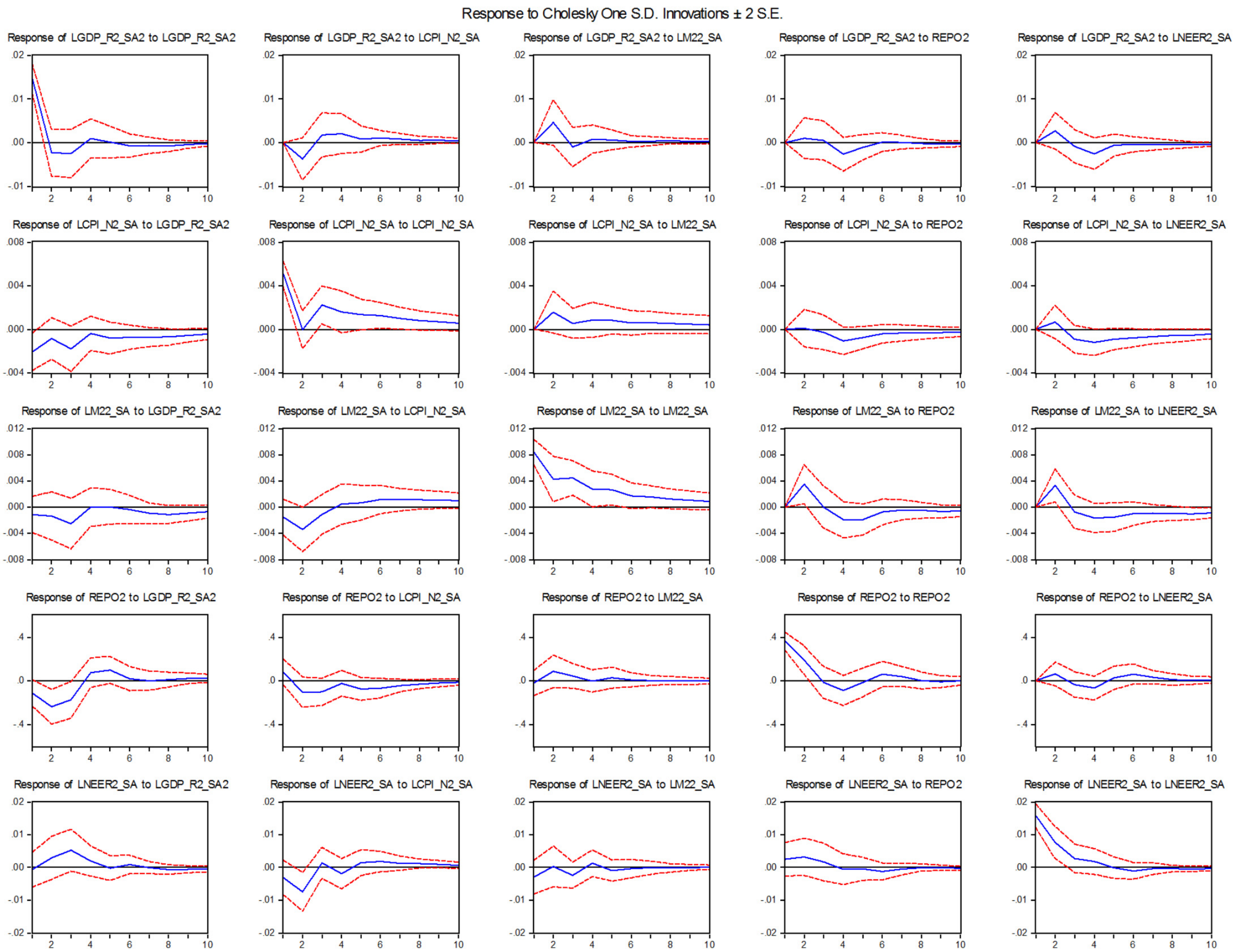
Recursive Chow Tests



Source: Author's estimates.

Appendix B. Additional Impulse Responses and Variance Decompositions

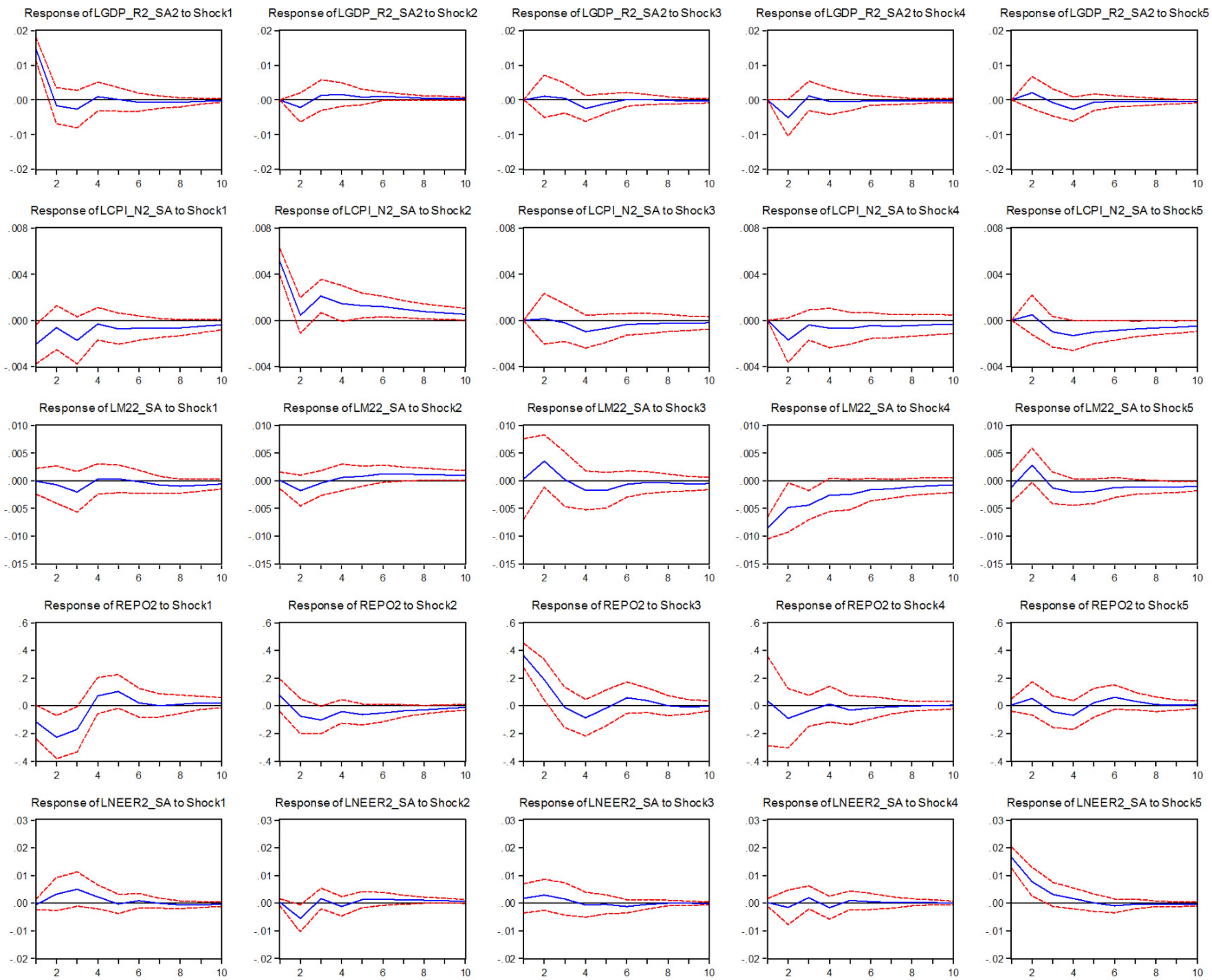
Figure B1a. Impulse Responses for Model With LCPI
Recursive Model



Source: Author's estimates.

Figure B1b. Impulse Responses for Model With LCPI
Structural Model

Response to Structural One S.D. Innovations ± 2 S.E.



Source: Author's estimates.

Figure B2a. Variance Decomposition for Model with LCPI
Cholesky

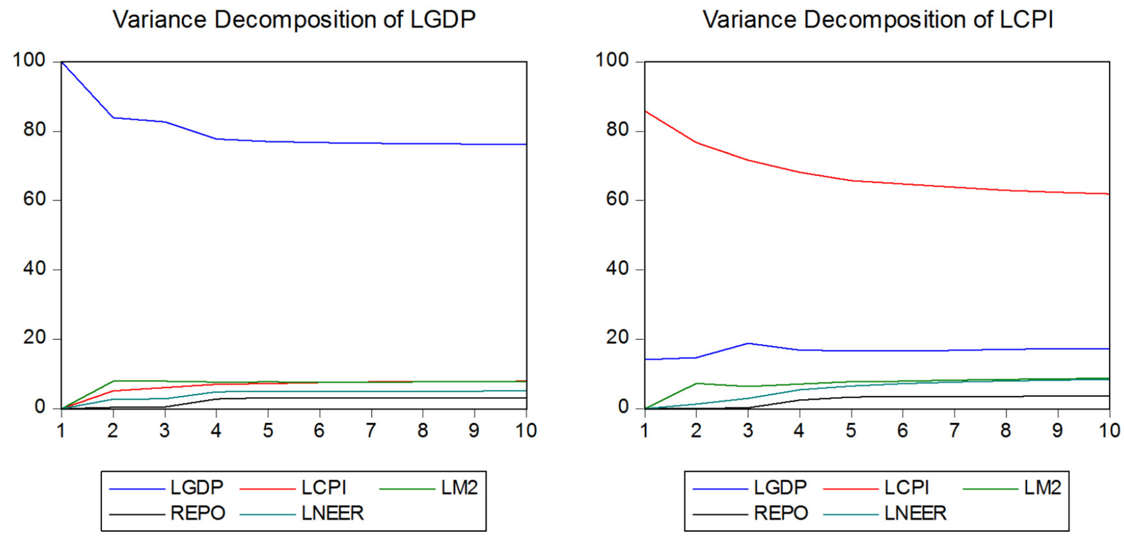
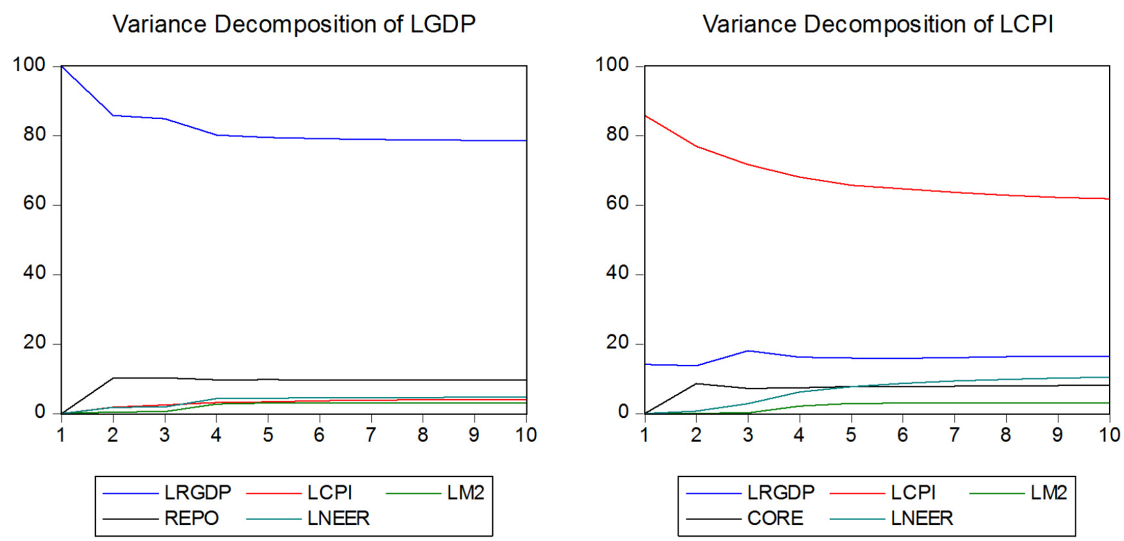
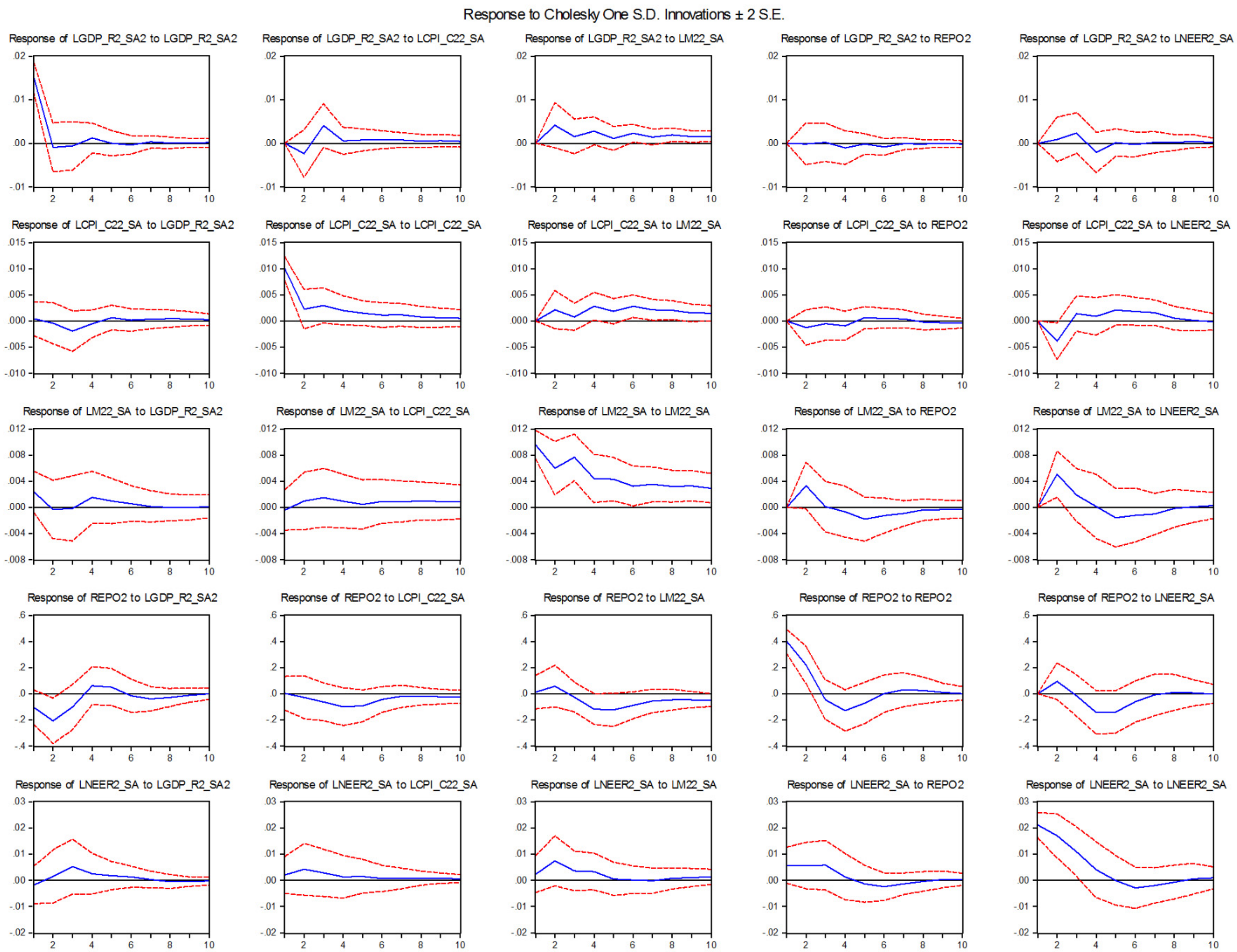


Figure B2b. Variance Decomposition for Model with LCPI
Structural



Source: Author's estimates.

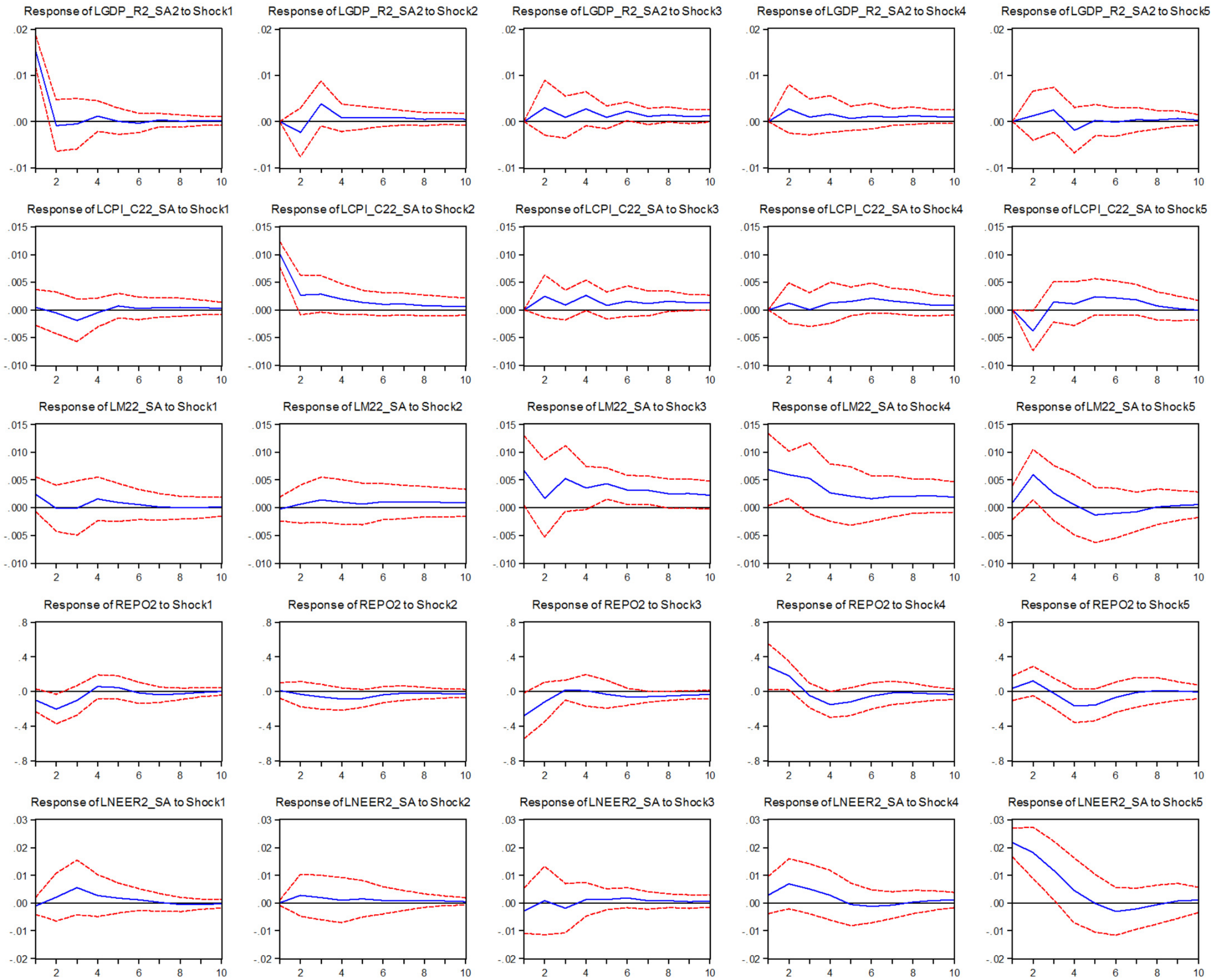
Figure B3a. Impulse Responses for Model With Core CPI
Recursive Model



Source: Author's estimates.

Figure B3b. Impulse Responses for Model With Core CPI
Structural Model

Response to Structural One S.D. Innovations ± 2 S.E.



Source: Author's estimates.

Figure B4a. Variance Decompositions for Model with LCPI core
Cholesky

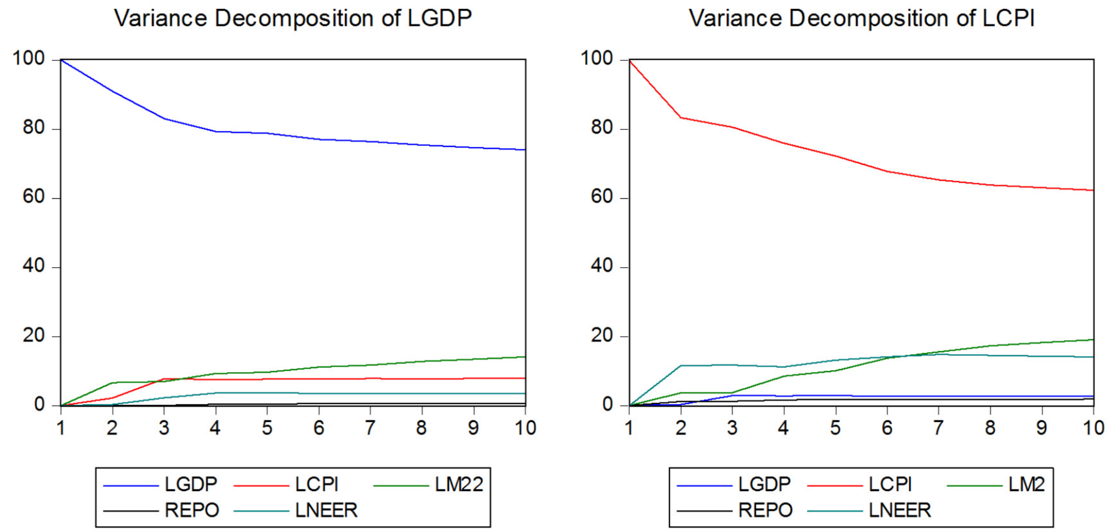
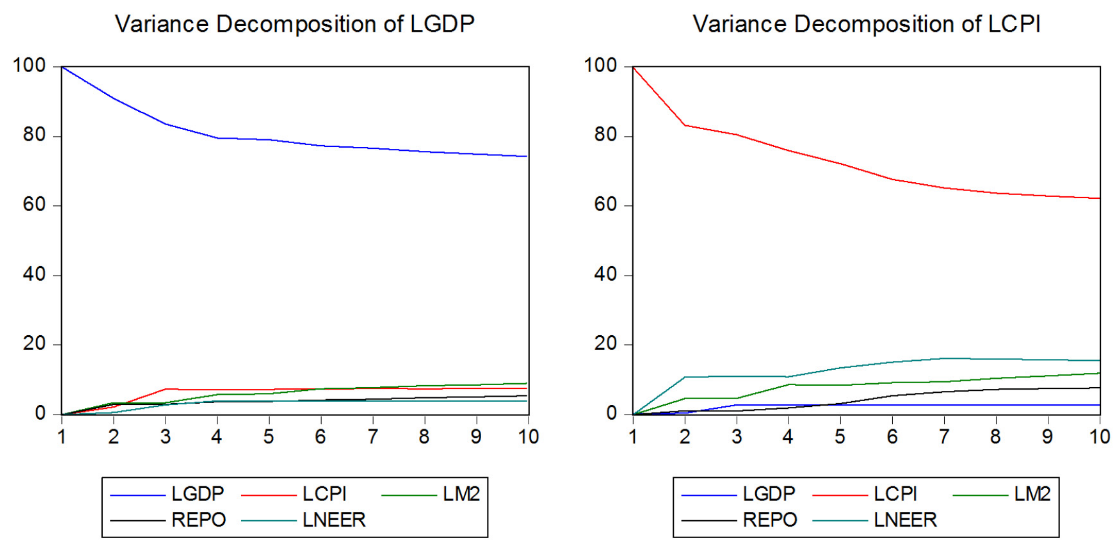


Figure B4b. Variance Decompositions for Model with LCPI core
Structural



Source: Author's estimates.

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