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Impact of Excess Reserves on Monetary Policy Transmission in Papua New Guinea

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Keywords

excess reserves, monetary policy transmission, structural VAR

JEL Classification

C5, E52, G21

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1 Introduction

The existence of excess reserves in the banking system poses significant threats to the financial system and macroeconomic stability. The potential impacts of excess reserves have attracted considerable research interests in developing economies (see, Agenor et al., 2004; Saxegaard, 2006; Bathaluddin et al., 2012; Nguyen and Boateng, 2013). The existing literature indicates that excess reserves affect an economy both at the micro and macro levels. At the micro level, Agenor et al. (2004) state that commercial banks with large involuntary excess reserves are willing to relax collateral requirements and ease credit standards to encourage borrowing. The expansion of loans can stimulate aggregate demand and economic growth (Saxegaard, 2006). However, the increased holding of unremunerated excess reserves may reduce bank profitability (Agenor et al., 2004). At the macro level, excess reserves weaken the effectiveness of monetary policy transmission, ignite inflationary pressure and raise cost of sterilization (Primus et al., 2014; Nguyen and Boateng, 2015). In Papua New Guinea (PNG), David and Nants (2006) and Vellodi et al. (2012) state that the interest rate channel is not responsive to monetary policy changes in the presence of large liquidity. This study, however, focuses on how excess reserves affect the effectiveness of monetary policy transmission in PNG.

The monetary policy transmission is a process through which the monetary policy decisions of the central bank affect economic activity and price level. However, the existence of excess reserves in the banking system may reduce the effectiveness of the interest rate channel, thus making monetary policy transmission weak (Primus et al., 2014). Consequently, a change in the central bank policy rate may not be fully reflected in the domestic interest rates and transmission to the real sector of the economy. If the central bank increases the policy rate or cash reserve requirement to control money supply and private sector lending, the expected outcomes may not be achieved since excess reserves naturally exert downward pressure on the interest rates. The transmission process is complex and there is always an uncertainty regarding the magnitude of influence on the real economy. In PNG, price stability and economic growth remain the primary objectives of monetary policy.

There are few studies conducted in developing countries to investigate the effectiveness of monetary policy transmission in the presence of excess liquidity (or excess reserves). Some of the studies such as Saxegaard (2006), Mehrotra (2008), Bathaluddin et al. (2012) and Jovanovic et al. (2015), employ excess liquidity and other macroeconomic variables under various vector autoregressive (VAR) frameworks. The studies of Moumni and Nahhal (2014) and Egesa (2014) use proxy variables for excess liquidity. In contrast, Khemraj (2007) employs excess reserves due to lack of a secondary money market in Guyana. The study, however, does not include a monetary policy variable in the generalized VAR framework. Hence, this study adopts and extends the empirical framework of Khemraj (2007) to include the lending rate since monetary policy plays an essential role in the management of PNG economy. Specifically, this study evaluates the causal effects of excess reserves and lending rate shocks on private sector loans, the exchange rate, the consumer price index (CPI) and real gross domestic product (GDP). In addition, this is the first empirical study to investigate the impacts of excess reserves on the effectiveness of monetary policy transmission in PNG.

This paper employs a structural VAR model to investigate the research question using quarterly data from March 2001 and December 2020. The model estimates the impulse response functions, forecast error variance decompositions and historical decompositions to measure the impacts that a one standard deviation shocks to excess reserves and the lending rate have on macroeconomic variables. First, the impulse responses reveal that the excess reserves shock immediately stimulates borrowing and output while having unanticipated impacts on the exchange rate and the CPI. Second, the lending rate shock generates price and exchange rate puzzles. However, the shock has anticipated flow-on effects on private sector loans and real GDP. Third, the variance decomposition results indicate that excess reserves contribute weakly to the variances of private sector loans, the exchange rate, the CPI and real GDP in the short horizon. However, in the long run, the lending rate contribute significantly to the variances of private sector loans, the CPI and GDP. Fourth, the historical decomposition results indicate that the CPI and GDP are less sensitive to the excess reserves shock than the lending rate shock. The findings suggest that accumulation of excess reserves in the banking system undermines the effectiveness of monetary policy transmission in PNG. The benchmark results are found to be robust to all alternative specifications in the sensitivity analysis.

This paper contributes to the emerging literature on the impacts of bank excess reserves in three ways. First, the paper provides some empirical evidence relating to the flow-on effects of interest rate shock in the presence of excess reserves for PNG. Specifically, the paper analyzes the magnitude, direction and speed of response at which the lending rate shock influences private sector loans, the exchange rate, price level and output. Second, unlike the past papers, this paper provides detailed analyses of the forecast error variance decomposition and historical decomposition results. For example, the paper evaluates the contributions that shocks to excess reserves and lending rate make on the variances of private sector loans, the exchange rate, the CPI and real GDP. Third, the impacts of excess reserves shock on monetary policy transmission were first analyzed in Khemraj (2007). This paper contributes to the empirical discussions under the structural VAR framework with the inclusion of lending rate and real output as additional variables.

The rest of the paper is structured as follows. Section two presents a literature review on the impacts of excess reserves and the effectiveness of monetary policy transmission in developing countries. This is followed by data description and empirical framework in Section three. Section four presents the empirical results and discusses them by drawing on similar findings and arguments from the literature. The main empirical results are supported by the robustness analysis in Section five. Finally, Section six summarizes the key findings.

2 Literature review

The accumulation of excess reserves has adverse impacts on bank profitability, private sector lending, inflationary pressure, cost of sterilization and effectiveness of monetary policy transmission (Primus et al., 2014; Nguyen and Boateng, 2015). The literature review of this study focuses on excess reserves and monetary policy transmission in developing countries. The empirical literature reveals that excess reserves mostly impede the transmission of monetary policy through the interest rate channel and cause undesirable effects on key macroeconomic variables such as the exchange rate, price level and output (Agenor et al., 2004; Saxegaard, 2006; Nguyen and Boateng, 2013; Egesa, 2014; Jovanovic et al., 2015). In PNG, Vellodi et al. (2012) investigated the relationship between inflation and excess liquidity using a simple econometric methodology. This study, however, examines the impacts of monetary policy shocks in the presence of bank excess reserves.

The earlier empirical studies on liquidity effects and monetary policy were conducted for developed countries, such as Sims (1992), Christiano and Eichenbaum (1992), Fung and Gupta (1994) and Bagliano and Favero (1998). In the United States, a prominent paper by Christiano and Eichenbaum (1992) argued that the use of non-borrowed reserves to assess liquidity effects is appropriate since reserves are directly influenced by the shocks in monetary policy variables. The study found that a positive shock to reserves generate persistent decrease in short-term interest rates and persistent increase in output. The results were in line with theoretical expectations indicating that effectiveness of monetary policy transmission exists through the interest rate channel. Using a VAR model, Fung and Gupta (1994) specifically examined the impacts of excess reserves on monetary policy transmission effectiveness in Canada. They used excess cash reserves of chartered banks and the surprise component of excess cash reserves as measures of monetary policy shocks. The findings stated that a positive shock to excess cash reserves is followed by a decline in the interest rate, an increase in output, and a depreciation of the dollar exchange rate. However, the weak negative response of the price level suggests that excess cash reserves impede the transmission of monetary policy.

The literature on monetary policy effectiveness under excess reserves in developing countries is sparse. One of the well-cited papers, Saxegaard (2006) conducted the first comprehensive empirical study on excess liquidity shocks and their implications on monetary policy transmission for African countries. With the use of a threshold VAR model, he measured the causal effects of excess reserves shock on the nominal exchange rate, inflation and real output. According to the results, a shock to money supply under the high excess reserves regime produced weak and inconsistent effects on inflation and the exchange rate. The author further argued that the involuntary component of excess reserves has more influence on monetary policy transmission than the precautionary component. In Indonesia, Bathaluddin et al. (2012) extended the empirical work of Saxegaard (2006) by including an additional variable, the bank interest rate, in the VAR model. They discovered that under the high excess liquidity regime, a one standard deviation shock to the bank interest rate generates price and exchange rate puzzles. Saxegaard (2006) and Bathaluddin et al. (2012) established in their papers that excess liquidity reduces the effectiveness of monetary policy for controlling inflation and promoting output growth. In addition, Jovanovic et al. (2015) conducted a similar empirical study to that of Bathaluddin et al. (2012). The findings suggested that the interest rate channel is weakly effective in influencing economic activity under surplus liquidity in Macedonia.

In a Southern American study, Khremaj (2007) examined the effects of persistent excess reserves in the banking system using a generalized VAR model for Guyana. He analyzed the dynamic interactions among four endogenous variables namely excess reserves, loans, the exchange rate and the CPI. The study revealed the impulse response function results are less consistent with economic theory. Particularly in the short run, a one standard deviation shock to excess reserves caused a weak response in the price level, a tiny response close to zero in private sector loans and a positive response in nominal exchange rate. The findings drew a similar conclusion as in Saxegaard (2006) that the presence of excess reserves in commercial banks undermines the efficiency of monetary policy transmission. In the Caribbean, Anderson-Reid (2011) theoretically analyzed the effects of bank excess reserves on the lending rate, private sector credit, the exchange rate, output and inflation. The author noted that the lending rate continues to remain high and private sector loans are not responsive to changes in the policy rate. Clearly, persistent excess reserves in Jamaican commercial banks become a concern for effective monetary policy transmission.

Moumni and Nahhal (2014) studied the impact of liquidity level on the effectiveness of monetary policy transmission under the excess and shortage liquidity situations for Morocco. They employed the standard VAR model with four variables ordered as follows; liquidity indicator, the interbank rate, real GDP and the price index. A one standard deviation shock to excess liquidity is measured with a short-term increase in the interbank rate, a decrease in economic activity, and a rise in the price level. The reaction of the interbank rate contradicts monetary theory, while the response of price is positively insignificant during the study period. However, in Uganda, Egesa (2014) took a different approach in his study, where he used broad money supply and the treasury bill rate as proxies for excess reserves and the policy rate, respectively. With the recursive ordering of variables, the study examined the causal effects of excess reserves on price stability and output growth. He found that a positive shock to the treasury bill rate under high excess reserves regime leads to a price puzzle. Moumni and Nahhal (2014) and Egesa (2014) suggested that when commercial banks accumulate excess reserves, monetary policy transmission becomes weak. Similarly, an empirical study by Nguyen and Boateng (2013) established that banks with larger involuntary excess reserves are less responsive to monetary policy rate shocks in China.

In the context of the Pacific, Jayaraman and Choong (2015) empirically estimated the effects of excess liquidity shock on macroeconomic variables for Fiji. Based on work of Khremaj (2007), they included an additional monetary policy variable in the model. Unlike Khremaj (2007), who employed excess reserves as a ratio in the model, the Fijian study used excess liquidity data in levels. The paper used the structural VAR model to analyze the internal relationships between excess liquidity, the lending rate, loans, the exchange rate, and the CPI.

The results suggested that excess liquidity is a major component of short-term forecast variations in loans and the lending rate. However, the CPI and the exchange rate did not respond correctly to the excess liquidity shock in the short horizon. For China, Mehrotra (2008) examined the effects of excess liquidity shock and established that the shock leads to higher output and inflation. Contrary to Jayaraman and Choong (2015), Mehrotra (2008) did not employ an alternative monetary policy variable. However, the findings of Mehrotra (2008) were generally consistent with theoretical expectations, indicating the effectiveness of monetary policy transmission in the presence of excess reserves.

3 Methodology and data

3.1 Data and variable definitions

To study the impacts of monetary policy shocks on selected macroeconomic variables, quarterly data from March 2001 to December 2020 is used, for a total of 80 observations for each variable. The selection of sample period is based on data availability, particularly the exposure of excess reserves in terms of their magnitude since 2001. Canova (1995) recommends that variable selection and use in the VAR system must be verified according to economic theory. In this study, the structural VAR model employs six variables, and their selection is based on the empirical work of Saxegaard (2006), Khemraj (2007), Mehrotra (2008), Bathaluddin et al. (2012) and Moumni and Nahhal (2014). The variables are excess reserves (XRS), the lending rate (RTL), private sector loans (PSL), the exchange rate (XRT), the CPI and real GDP. This study treats all variables as endogenous. Data for these variables is sourced from various Quarterly Economic Bulletin publications of the Bank of PNG (BPNG), the central bank. Full description of the variables and source of the data are provided in Table A.1 in the Appendix.

Excess reserves are surplus funds that commercial banks hold in their own vaults and their exchange settlement accounts at BPNG. This study uses total excess reserves without distinguishing between precautionary and involuntary reserves. The weighted average lending rate of commercial banks is employed as a proxy for the policy rate due to its direct association with the domestic monetary policy. The desired minimum lending rate of commercial banks is one of the determinants of excess reserves in the banking system. The private sector loans variable is the amount of credit that commercial banks provide to the private sector. It has a strong correlation of about 77 percent with the lending rate. The nominal exchange rate is the PNG kina exchange rate against the Australian dollar under the managed floating and fixed peg regimes. The Australian dollar is selected ahead of the US dollar because Australia is the top trading partner of PNG both in terms of export and import values. The domestic interest rate movements influence the exchange rate in the foreign exchange market.

The CPI is a measure of the average change over time in the prices of a fixed basket of goods and services consumed by urban households across selected towns in PNG. It is the indicator of headline inflation in the country. GDP measures the total value of domestic production and is adjusted for inflation. The mineral, oil and gas sectors contribute a significant share of GDP in PNG (BPNG, 2020). As the data for GDP is available on an annual basis for the sample period, the quarterly data series is generated using the interpolation method proposed by Chow and Lin (1971). The annual GDP data is disaggregated to quarterly series using the quarterly data for total domestic export as an indicator variable. The proposed method was employed by Dungey and Fry (2009) and Vellodi and Aba (2012) to generate missing data points in their respective studies for New Zealand and PNG. In this study, quarterly data is favoured ahead of monthly data since the central bank compiles data for key macroeconomic variables on a quarterly basis. Appendix B outlines the construction of quarterly GDP data series.

The lending rate and excess reserves enter the structural VAR model as instruments of monetary policy, the exchange rate and private sector loans are intermediate targets of monetary policy, and the CPI and real GDP are monetary policy outcomes. Excess reserves ignite the initial shock while the lending rate performs as an alternative instrument. In order to use a single unit of measurement in the model, all variables are transformed into the natural logarithm form except for the lending rate, which is a percentage. Thereafter, all non-stationary variables are detrended using a linear trend. The use of detrended data in VAR models to measure the effects of monetary policy shocks is common (see, Christiano and Eichenbaum, 1992; Saxegaard, 2006). The variables are plotted in Figure 1 and their correlations are presented in Table 1.

The selection of an optimal lag length in the VAR model is essential as it affects the results significantly. There are several methods of choosing the optimal lag order and in this study, standard information criteria guide the selection process. With the use of transformed data, Akaike information criterion (AIC), Schwarz-Bayesian information criterion (SIC) and

Hannan-Quinn criterion (HQ) indicate 2 lags while likelihood ratio (LR) and final prediction error (FPE) select 3 lags. Both lag lengths confirm no autocorrelation in residuals and satisfy stability condition of the VAR system. However, the optimal lag length is set to 2 based on lowest information criteria. The lag length determination results are reported in Table C.1 in the Appendix.

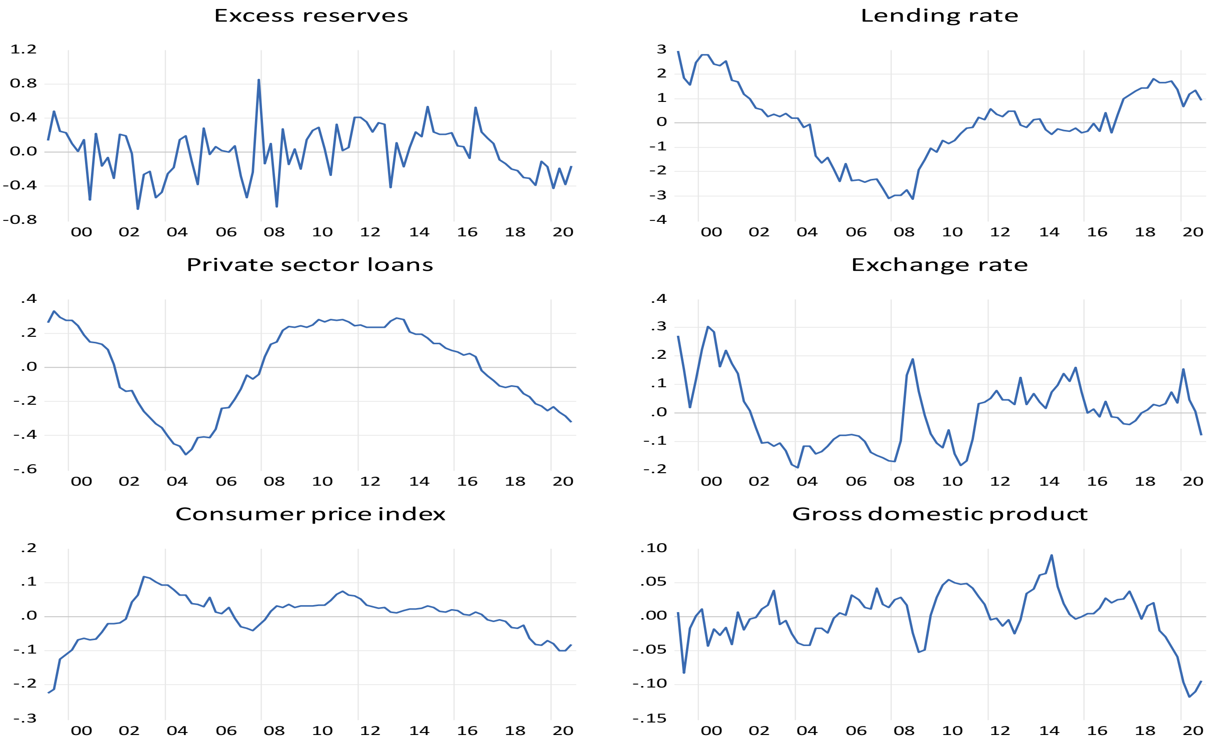

Figure 1: Plot of the variables, Mar 2001 to Dec 2020

Note: All variables are expressed in natural logarithms and linearly detrended except for the lending rate, which is in percent.

Table 1: Correlation between variables, Mar 2001 to Dec 2020

Variable		XRS	RTL	PSL	XRT	CPI	GDP
Excess reserves	XRS	1.000					
Lending rate	RTL	-0.156	1.000				
Private sector loans	PSL	0.394	0.141	1.000			
Exchange rate	XRT	0.165	0.555	0.486	1.000		
Consumer price index	CPI	-0.128	-0.495	-0.164	-0.530	1.000	
Gross domestic product	GDP	0.228	-0.302	0.348	-0.235	0.398	1.000

Note: All variables are expressed in natural logarithms and linearly detrended except for the lending rate, which is in percent.

3.2 VAR model

The VAR model is one of the most useful multivariate models first proposed by Sims (1980) to explore causal relationships among macroeconomic variables using the time-series data. The VAR model is a dynamic system in which every endogenous variable is treated as a function of its own lagged values and the lagged values of other endogenous variables. The VAR models are widely used to measure the flow-on effects of monetary policy shocks on macroeconomic variables such as output and inflation (Sims, 1992; Bagliano and Favero, 1998). The key advantage of using the VAR model is that it imposes minimal restrictions and allows for tracing of the relationships between endogenous variables over time through the impulse response functions, forecast error variance decompositions and historical decompositions.

In developing countries, researchers such as Khemraj (2007), Bathaluddin et al. (2012), Egesa (2014) and Jayaraman and Choong (2015) employed various VAR models to estimate the impacts of excess liquidity shocks. Considering the scope and data availability for PNG, this study uses a structural VAR model to measure the flow-on effects of excess reserves and lending rate shocks on private sector loans, the exchange rate, the CPI and real GDP. The structural VAR model assumes that the system is contemporaneously recursive.

As in Khemraj (2007), this study is interested in the dynamic interactions among the six endogenous variables and not parameter estimation. Sims (1980) and Canova (1995) suggested that the VAR must be specified in levels to uncover the interrelationships among macroeconomic variables appropriately. Hence, VAR in differences would miss essential information regarding variable movements. Consequently, all variables used in this study enter the VAR system in levels.

The standard form of a multivariate structural VAR model is mathematically expressed as

$$A_0 Y_t = a + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \quad (1)$$

where $Y_t = (y_{1t}, y_{2t}, \dots, y_{it})$ is a vector containing endogenous variables in levels, $y_{it} \equiv [XRS_t, RTL_t, PSL_t, XRT_t, CPI_t, GDP_t]$, a contains a vector of intercept terms, A_0 is a matrix of parameters on the contemporaneous endogenous variables, $A_p (p = 1, 2, \dots, p)$ is a matrix of coefficient on the lagged endogenous variables, ε_t is a vector of structural shocks in the economy, p is the number of lags of the endogenous variables, and t is a time script for the quarter. Equation (1) is estimated with the OLS method.

Equation (1) can be transformed to the reduced form VAR as follows:

$$Y_t = B_p Y_{t-p} + \mu_t \quad (2)$$

where μ_t is a vector of error terms and B_p is a matrix of coefficient on the lagged endogenous variables.

From the VAR systems represented in equations (1) and (2), the orthogonal contemporaneous shocks identification proceeds according to the following representation in equation (3).

$$\mu_t = A_0 \varepsilon_t \quad (3)$$

The structural VAR model uses a recursive system where the identification of the structural shocks takes place through the lower triangular restrictions in matrix A_0. This study employs the Cholesky decomposition technique to identify the structural shocks based on the assumption that shocks in the vector ε_t are serially uncorrelated. The diagonal elements are normalized to have unitary values because each endogenous variable is also affected by its own shock. Using the rationale of Sims (1992), Khemraj (2007), Moumni and Nahhal (2014) and Jayaraman and Choong (2015), the contemporaneous identification assumes the recursive ordering is as follows: XRS_t, RTL_t, PSL_t, XRT_t, CPI_t and GDP_t. The variables are ordered from the least to the most endogenous in the VAR system.

The identification of the shocks is highly responsive to the ordering of variables and selection of optimal lag length (Jayaraman and Choong, 2015). The recursive structure in equation (4) assumes that the lending rate has no immediate effect on excess reserves, private sector loans have no immediate effect on the lending rate, the exchange rate has no immediate effect on private sector loans, price level has no immediate effect on the exchange rate and output has no immediate effect on price level. The relationship between the reduced form innovations and the structural shocks is specified in matrix form as follows:

$$\begin{bmatrix} \mu_{XRS_t} \\ \mu_{RTL_t} \\ \mu_{PSL_t} \\ \mu_{XRT_t} \\ \mu_{CPI_t} \\ \mu_{GDP_t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ t_{21} & 1 & 0 & 0 & 0 & 0 \\ t_{31} & t_{32} & 1 & 0 & 0 & 0 \\ t_{41} & t_{42} & t_{43} & 1 & 0 & 0 \\ t_{51} & t_{52} & t_{53} & t_{54} & 1 & 0 \\ t_{61} & t_{62} & t_{63} & t_{64} & t_{65} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{XRS_t} \\ \varepsilon_{RTL_t} \\ \varepsilon_{PSL_t} \\ \varepsilon_{XRT_t} \\ \varepsilon_{CPI_t} \\ \varepsilon_{GDP_t} \end{bmatrix} \quad (4)$$

The monetary policy shocks are widely analyzed with the support of VAR tools such as the impulse response functions, forecast error variance decompositions and historical decompositions (Moumni and Nahhal, 2014). The method to compute the impulse response functions is the recursive calculation of the reduced form VAR system. The impulse response function is expressed as follows:

$$Y_{t+p} = A_p\varepsilon_t = \sum_{p=0}^{\infty} A_p\varepsilon_t \quad (5)$$

where each A_p is a matrix of parameters from the structural model that measures the response of Y_{t+p} to ε_t. The order of A_p from $p = 0, 1, \ldots, \infty$ shows the dynamic response of the endogenous variables to the shock ε_t. That is, a unit change in ε_t causes Y_t to change by A_0 and continues in a recursive manner.

The variance decomposition measures how the variances of the endogenous variables are explained by each uncorrelated shock. The forecast of the variances for periods ahead is computed as

$$var(Y_{i,h}) = v^2{}_{i,h} = E[Y_{i,h} - E(Y_{i,h})]^2 = E(s_{i,jk}\,\varepsilon_{i,h})^2 = s^2{}_{i,jk} \quad (6)$$

where i refers to variables used in the system, h is the forecast for longer horizons (h-step forecast), s is the coefficients of structural shocks and jk refers to rows and columns respectively in the system. The decomposition of the variance is given by ($s^2{}_{i,jk}$).

The historical decomposition explains the observed values of a variable in the VAR system in terms of the structural shock and the path of the baseline projection over time. The historical decomposition of a variable (Y_t) is calculated using the following equation.

$$Y_t = \sum_{i=0}^{t-1} D_i\, \varepsilon_{t-i} + \sum_{i=t}^{\infty} D_i\, \varepsilon_{t-i} \quad (7)$$

The historical decomposition represented by equation (7) has two components on the right-hand side. The first component is the difference between the actual time series and the baseline projection due to the structural shocks. The baseline projection is the second component which indicates how a time series may change over time in the absence of a shock.

4 Results and discussion

This section evaluates the dynamic responses of positive orthogonal shocks to excess reserves and lending rate on the other variables employed in the system. Specifically, the empirical analysis focuses on the impacts that excess reserves have on the effectiveness of monetary policy transmission. The empirical results are presented and discussed in terms of impulse response functions, forecast error variance decompositions and historical decompositions.

4.1 Impulse response function analysis

The impulse response functions indicate how endogenous variables react to the shocks to other variables in the VAR system. In this impulse response analysis, the ordering of the variables is essential to appropriately measure the effects of monetary policy shocks. The responses of private sector loans, the exchange rate, the CPI and real GDP to the one standard deviation shocks in excess reserves and lending rate are examined for up to a 24-quarter horizon. The dashed lines are the one standard deviation error bands around the impulse responses (solid lines) at 95 percent analytical confidence intervals. If at any point the error bands include zero, the impulse responses are not significant. The responses of monetary policy shocks are analyzed separately to understand better their impacts over the short (1 to 4 quarters) and long (5 to 24 quarters) horizons.

4.1.1 Shock to excess reserves

The impulse responses of the macroeconomic variables to a one standard deviation positive shock to excess reserves are presented in Figure 2. The expansionary monetary shock is followed immediately by a fall in the lending rate, an increase in private sector loans, an appreciation of the exchange rate, a decline in the CPI and an increase in real GDP. According to the impulse response functions, private sector loans react positively to the shock and peak at 4.5 percent above the baseline in the 8th quarter. The response is consistent with theoretical expectations that a positive shock to excess reserves puts downward pressure on the lending rate in the first 2 quarters and subsequently stimulates private sector borrowing. It then changes to a significant downward movement from the 12th quarter on as it approaches its long-run equilibrium. The shock has a positive impact on the exchange rate in the first 3 quarters before depreciating from the fourth quarter. However, in the long horizon, the response of exchange rate remains stable but insignificant above the baseline as the effect of shock subsides. One reason can be that PNG has adopted the managed floating and fixed peg regimes since 2000 in which the daily exchange rate fixings are not purely market-determined. The results are consistent with those of Khemraj (2007), who discovered that excess reserves shocks have unanticipated effects on private sector loans and the exchange rate in Guyana.

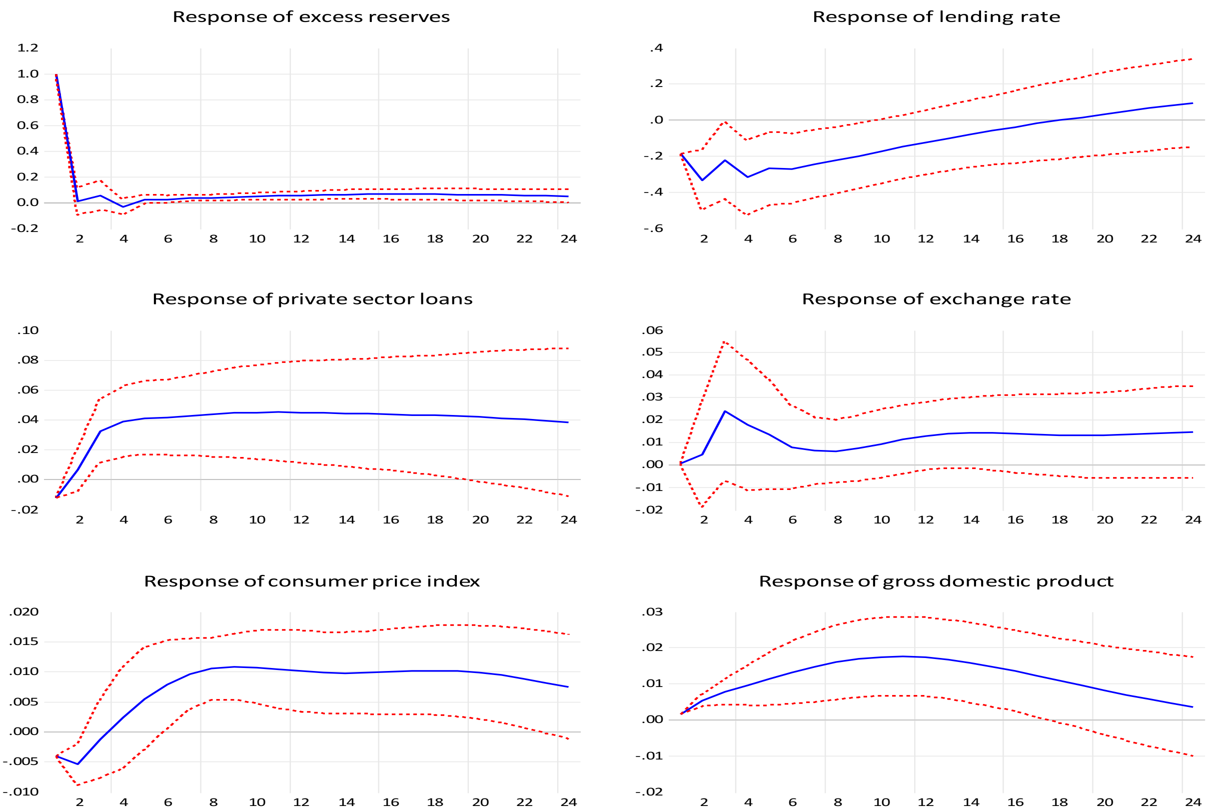

Figure 2: Impulse response functions to a shock to excess reserves, Mar 2001 to Dec 2020

The CPI initially falls in response to the excess reserves shock, but after the second quarter, it significantly recovers to remain above the baseline for the rest of the quarters. The initial response indicates that the high level of reserves in the banking system does not translate to excessive credit growth since commercial banks use their oligopolistic market power to demand excess reserves. The unexpected effect on the CPI is supported by previous findings of Saxegaard (2006) and Moumni and Nahhal (2014) that excess reserves reduce the transmission of monetary policy shocks for controlling inflation in Sub-Saharan Africa and Morocco, respectively. Nevertheless, the price level significantly increases as expected from the third quarter on and peaks at 1.1 percent in quarter 10. The positive response of the CPI can be explained using economic intuition. The real GDP increases significantly and peaks at 1.8 percent above the baseline in the 12^{th} quarter. The initial response of GDP conforms to the theoretical views, that is, a fall in lending rate stimulates investment and aggregate demand in the domestic economy. The finding is in line with Mehrotra (2008), who found in his study that excess liquidity shock leads to a short-term positive impact on real output in China.

4.1.2 Shock to lending rate

As is a common practice, the lending rate is used as a proxy for the policy rate in this study to assess the effects of its shock on the transmission of monetary policy. Figure 3 shows that a one standard deviation positive shock to the lending rate produces mirror-image responses to those of the excess reserves shock. Under the contractionary monetary policy shock, the immediate dynamic responses of private sector loans, the exchange rate and real GDP are found to be statistically significant, except the CPI. More specifically, an increase in the lending rate has a contemporaneous effect on private sector loans and real GDP in accordance with the theoretical expectations. That is, both variables fall significantly, but their responses vary in magnitude and horizon. For instance, in the fourth quarter, private sector loans and real output decrease to about 4.2 percent and 1.0 percent, respectively. The short-term findings concur with that of Abeygunawardana et al. (2017), who stated in their paper that significant influences of monetary policy shocks on real variables occur in the short run. However, both private sector loans and real GDP gradually recover to reach the baseline in the long horizon.

The initial responses of the exchange rate and the CPI are weak and not compatible with established monetary views. In particular, the CPI shows the emergence of a price puzzle in the first 2 quarters, which suggests that inflation is not effectively restrained by raising the lending rate. As shown in Figure 3, the price level peaks at 0.14 percent in quarter 2. Then it persistently declines in line with monetary theory and remains below the baseline for 20 quarters. In the case of the exchange rate, a puzzle is observed in the first 2 quarters, in which the domestic currency depreciates by 3.5 percent. Thereafter, the exchange rate appreciates as expected until it moves downward from quarter 10 and remains below the baseline. The puzzles reveal that excess reserves impede the transmission of monetary policy. The findings of this study are supported by several researchers such as Chuku (2009), who stated in his study that the impacts of monetary policy shocks on real economic variables are weak and full of puzzles in developing countries. In particular, Bathaluddin et al. (2012) and Egesa (2014) found evidence of price puzzle and perverse exchange rate response from the restrictive monetary policy shocks in their respective country-specific studies. Overall, the impulse responses of the underlying variables are more sensitive to the lending rate shock than the excess reserves shock.

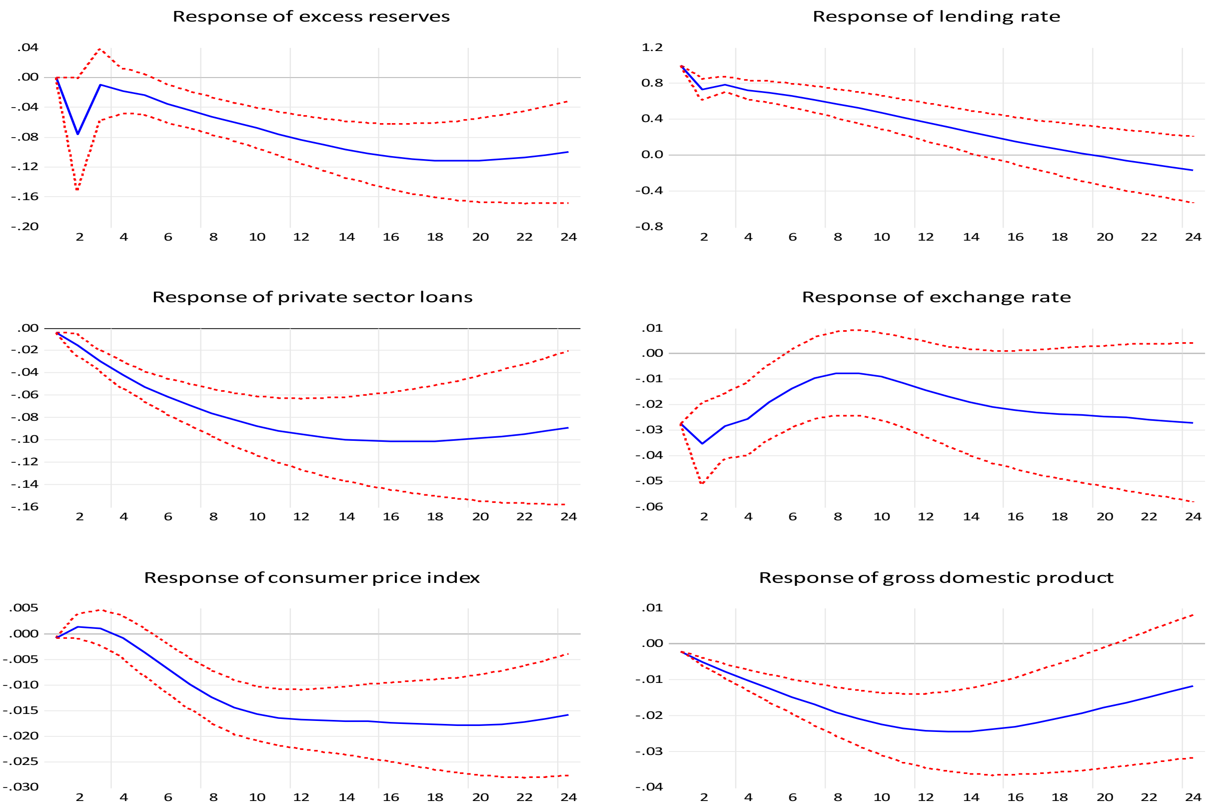

Figure 3: Impulse response functions to a shock to lending rate, Mar 2001 to Dec 2020

4.2 Variance decomposition analysis

The variance decomposition analysis determines the proportion of the forecast error variance in each variable that is contributed by its own shock and shocks from other variables over a 24-quarter horizon. Thus, the focus of this study is to evaluate the degrees of influence that the shocks to excess reserves and lending rate have on the variances of private sector loans, the exchange rate, the CPI and real GDP. Based on the initial Cholesky ordering, Table 2 presents the forecast error variance decomposition results of each variable over the short (1 and 4 quarters) and long (12 and 24 quarters) horizons.

According to the results of the variance decomposition, 80.29 percent of the forecast variance in excess reserves is explained by its own shock in the fourth quarter, while shocks from other variables have negligible influence in predicting the variance of excess reserves. Even though variables such as the lending rate (20.45 percent) and the exchange rate (8.97 percent) display an upsurge in their degrees of influence in the 24th quarter, excess reserves (55.84 percent) strongly maintain its own contribution to the forecast variance in the long run. Furthermore, excess reserves contribute weakly to the forecast variances of the lending rate, private sector loans, the exchange rate, the CPI and real GDP in the short horizon. On the contrary, Jayaraman and Choong (2015) found that excess liquidity is a major component of the forecast variance in loans, lending rate and exchange rate. Regarding the lending rate, a large share of influence comes from its own shock (98.50 percent) in the first quarter. A similar level of influence is observed in quarter 4, except some negligible contributions originate from excess reserves (4.17 percent) and the exchange rate (5.44 percent). Over the long forecast horizon (quarter 24), private sector loans (12.09 percent), the exchange rate (8.98 percent) and real GDP (9.48 percent) become important sources of shocks to the lending rate. Notably, the CPI and excess reserves have weak influences on the lending rate over the period of 24 quarters.

The forecast variance of private sector loans is mostly explained by itself (98.95 percent) in the short run, while other variables exhibit weak influences. In quarter 24, a combination of shocks from the lending rate (52.81 percent), real GDP (8.18 percent) and the exchange rate (6.52 percent) contribute to most of the variance of private sector loans. The strong contribution from the lending rate is anticipated because it is directly related to private sector loans. It is of great interest to examine the shocks that affect the exchange rate. In quarter 4, about 80.72 percent of the variation in exchange rate is explained by its own shock. Similar findings were reported by Jayaraman and Choong (2015) and Kara and Afsal (2018), who found that own shocks of loans and exchange rate significantly explain their respective variances in the short horizon. In the long run, the influence from own shock reduces to 63.12 percent while shocks from the lending rate (13.10 percent), the CPI (11.69 percent) and private sector loans (8.76 percent) increase significantly to explain the variance in the exchange rate.

Table 2: Forecast error variance decomposition (in percent), Mar 2001 to Dec 2020

Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
Variance decomposition of excess reserves							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.243	100.000	0.000	0.000	0.000	0.000	0.000
4	0.272	80.285	1.175	7.992	6.582	0.619	3.347
12	0.288	72.505	5.608	9.487	6.859	1.626	3.916
24	0.335	55.836	20.450	7.943	8.972	2.152	4.646
Variance decomposition of lending rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.374	1.499	98.501	0.000	0.000	0.000	0.000
4	0.650	4.170	87.487	0.334	5.439	2.381	0.190
12	0.958	4.265	76.805	3.870	9.810	1.924	3.325
24	1.087	3.540	63.207	12.087	8.984	2.698	9.483
Variance decomposition of private sector loans							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.032	0.860	0.190	98.950	0.000	0.000	0.000
4	0.071	3.239	7.909	86.485	0.893	0.084	1.389
12	0.148	4.878	32.652	46.941	4.538	0.433	10.557
24	0.209	5.376	52.809	26.641	6.521	0.471	8.182
Variance decomposition of exchange rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.052	0.001	3.773	3.453	92.773	0.000	0.000
4	0.087	0.712	6.313	8.988	80.724	2.583	0.682
12	0.100	0.993	6.421	7.821	70.370	13.122	1.273
24	0.109	1.983	13.098	8.763	63.121	11.694	1.340
Variance decomposition of consumer price index							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.008	1.498	0.135	1.457	0.892	96.018	0.000
4	0.024	0.555	0.110	2.268	1.301	95.433	0.333
12	0.033	4.209	16.392	6.240	10.882	58.767	3.510
24	0.044	5.719	34.691	4.485	12.923	36.589	5.592
Variance decomposition of gross domestic product							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.004	0.958	4.756	0.333	0.035	2.768	91.149
4	0.018	3.364	8.284	0.263	0.136	11.860	76.094
12	0.048	5.588	19.948	0.414	4.582	14.088	55.380
24	0.060	6.006	30.924	1.347	11.949	9.688	40.086

Note: SE stands for standard error and period is in quarters.

The CPI is highly sensitive to its own shock, about 96.02 percent of the forecast variance is explained by itself in the short horizon. In quarter 12, over half of the variance of the CPI comes from a combination of its own shock (58.77 percent) and those of the lending rate (16.39 percent) and the exchange rate (10.88 percent). While in China, Huang et al. (2010) argued that excess liquidity and output gap are the most important factors explaining the variation in inflation. Furthermore, excess reserves (4.21 percent), private sector loans (6.24 percent) and real GDP (3.51 percent) have weak influences on the variance of the CPI in the 12^{th} quarter. Like other variables, real GDP strongly influence its own variance (76.09 percent) in quarter 4. Over the long horizon, apart from its own shock (40.09 percent), the lending rate (30.92 percent), the exchange rate (11.95 percent), the CPI (9.69 percent) and excess reserves (6.01 percent) explain a large portion of the variance in real GDP. This result is expected because of the direct association between the lending rate and GDP. The exchange rate has a weak influence on the variance of GDP in the short run, which is against theoretical priors. Overall, the variance decomposition analysis suggests that the lending rate shock is more effective than excess reserves shock in terms of transmitting their impacts to the real economy.

4.3 Historical decomposition analysis

The historical decomposition measures the relative contribution of each structural shock on the actual development of an observed time series over the sample period. Figure 4 presents the historical decomposition of CPI and GDP, highlighting the contributions of excess reserves, the lending rate, private sector loans and the exchange rate shocks. The bars represent the actual values of CPI and GDP while the lines indicate the contributions of shocks made by the variables in the system at each point in time. The baseline projection is also represented by a line. The zero line is the steady-state or trend value of the variables.

Given that inflation is the primary objective of the central bank, assessing the historical decomposition of CPI with respect to the contributions of monetary policy shocks is necessary. The historical decomposition results in Figure 4(a) show that the shocks of most variables contributed negatively to the CPI movements between 2001 and 2012. Apart from own shocks, the lending rate and the exchange rate shocks explain most of the variations in the CPI series. For instance, the contribution of lending rate to the CPI from 2009 to 2018 was largely positive. Clearly, BPNG responds to domestic price conditions through the adjustments of the policy rate. However, the lending rate shocks do not have consistent influence on the evolution of CPI for some quarters. The unexpected impact can be partially explained by the existence of excess reserves in the banking system. Shocks to excess reserves and private sector loans generally have the expected but weak influences on the fluctuations of price level.

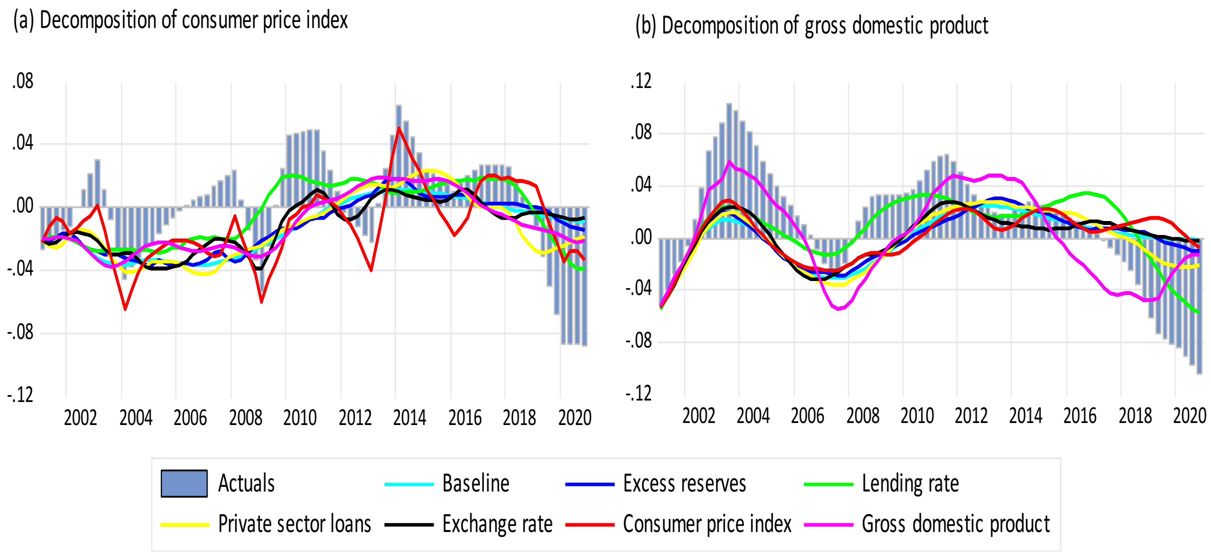

Figure 4: Historical decomposition of CPI and GDP, Mar 2001 to Dec 2020

Since economic growth is also the target of monetary policy in PNG, the decomposition of GDP is of some interest. As shown in Figure 4(b), the sign of the shock of each variable changes several times throughout the sample period. The presence of excess reserves may obstruct the shocks from having consistent influences on GDP over time. Apart from own shocks, the lending rate shocks contribute strongly to the development of GDP series. For example, between 2008 and 2013, when the contribution of the lending rate shocks was positive, domestic output moved above the steady-state instead of being in the negative zone. The third most important contribution is attributed to the exchange rate shocks. Shocks to excess reserves and private sector loans have the expected influences on GDP but small in magnitude. Overall, among the monetary policy shocks, the lending rate influences the movements of the CPI and GDP comparatively stronger than excess reserves.

5 Robustness checks

In this section, four robustness checks are performed using alternative specifications to examine the sensitivity of the benchmark model. The alternative specifications include (i) variable reordering, (ii) alternative monetary policy variable, (iii) different lag order and (iv) short sample period. The alternative model identification, variable ordering, sample period and variable transformation remain the same as the benchmark model except robustness exercise one changes the order of variables and exercise four uses truncated sample data. The data for the treasury bill rate is linearly detrended to use in exercise two. The optimal lag lengths of the alternative model specifications are set to 2 using the information criteria except for robustness exercise three, which uses 3 lags. The alternative models satisfy the stability condition and are free from autocorrelation problems. The impulse responses and forecast error variance decompositions of the alternative specifications are analyzed for a 24-quarter period to determine the robustness of the benchmark results reported in Section 4.

5.1 Variable reordering

In the first robustness exercise, following the rationale of Saxegaard (2006), Bathaluddin et al. (2012) and Egesa (2014), the order of the variables in the VAR system is changed. Using the recursive ordering, real GDP comes first, followed by the CPI, the exchange rate, private sector loans, the lending rate and excess reserves. Figure 5 presents the impulse responses of a one standard deviation shock to the lending rate. As in the benchmark model, an increase in the lending rate significantly causes price and exchange rate puzzles, which reflect the weakness of monetary policy transmission in the presence of excess reserves. Buigut (2009) reported similar results in his study that a positive shock to the interest rate has insignificant impacts on the exchange rate, output and price level in East Africa. Moreover, the lending rate shock has varying quantitative effects on each variable relative to the magnitude of the benchmark results. For example, real GDP decreases to 0.40 percent in quarter 4 compared to a 1.30 percent fall in the same quarter of the benchmark model. In the case of a one standard deviation shock to excess reserves, the variables are responding in a similar manner to those of the main model (see Figure C.1 in the Appendix). In particular, the responses of the exchange rate and the CPI do not meet theoretical expectations in the short horizon. The findings conform to those of Khemraj (2007), who found that dynamic responses of private sector loans, the exchange rate and the CPI are not consistent with established views.

The variance decomposition results of the quarterly forecast horizons are reported in Table C.4 in the Appendix. All variables significantly explain their own variances in the short horizon as in the benchmark model. However, the magnitude of the variance for each variable is slightly lower than the benchmark results. The share of variance contributed by the CPI and GDP shocks increase in all variables except for private sector loans, which is below 3.00 percent. Furthermore, a combination of shocks from the lending rate (21.78 percent), the exchange rate (21.84 percent) and real GDP (16.20 percent) explains a significant component of long-term variation in the CPI. Similar to the benchmark results, the excess reserves shock explains only a small percentage of variation in each variable over the entire horizon.

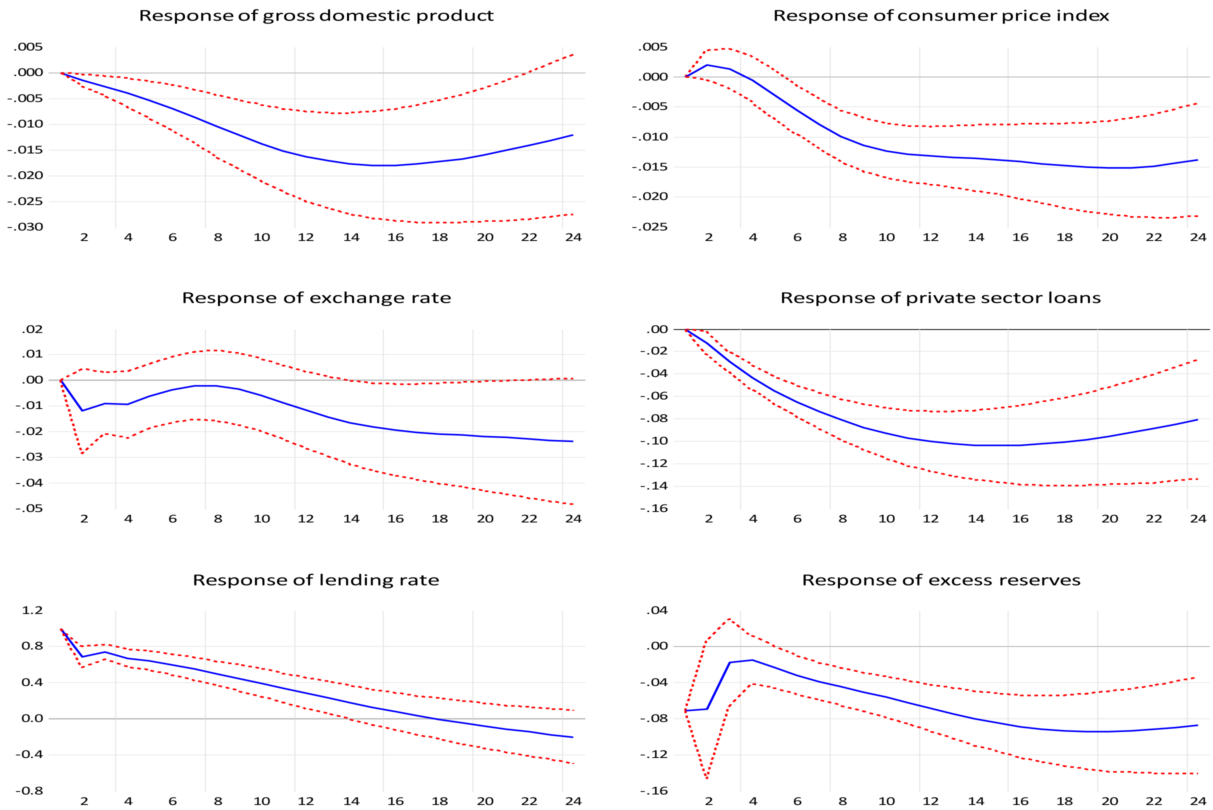

Figure 5: Robustness of impulse response functions of a shock to lending rate (reordering of variables), Mar 2001 to Dec 2020

5.2 Alternative measure of lending rate

In the second robustness exercise, the weighted average treasury bill rate (TBR) substitutes the lending rate in the VAR system (see, Egesa, 2014). The treasury bill rate performs as a proxy for the monetary policy rate. The impulse responses of a one standard deviation shock to the treasury bill rate are presented in Figure 6. The results show similar patterns of response to those of the benchmark model, which signifies the robustness of the initial findings. The treasury bill rate shock has real effects on private sector loans, the exchange rate, the CPI and real GDP in the short run. The magnitudes of the impulse responses are slightly higher than those of the benchmark model. For instance, in quarter 4, real GDP decreases to 2.10 percent in response to the treasury bill rate shock compared to a 1.00 percent fall from the lending rate shock. Like in the benchmark model (see Figure 3), the restrictive monetary policy shock generates a price puzzle and a perverse exchange rate response, which contradicts the central bank's objective of price stability. However, real GDP responds correctly to the shock in the short run. The findings conform to that of authors such as Chuku (2009) and Bathaluddin et al. (2012), who found that the policy rate shock has a negligible effect on price level and a favourable impact on output. Interestingly, in this study, the exchange rate does not recover from the puzzle and continues to remain below the baseline for the entire horizon.

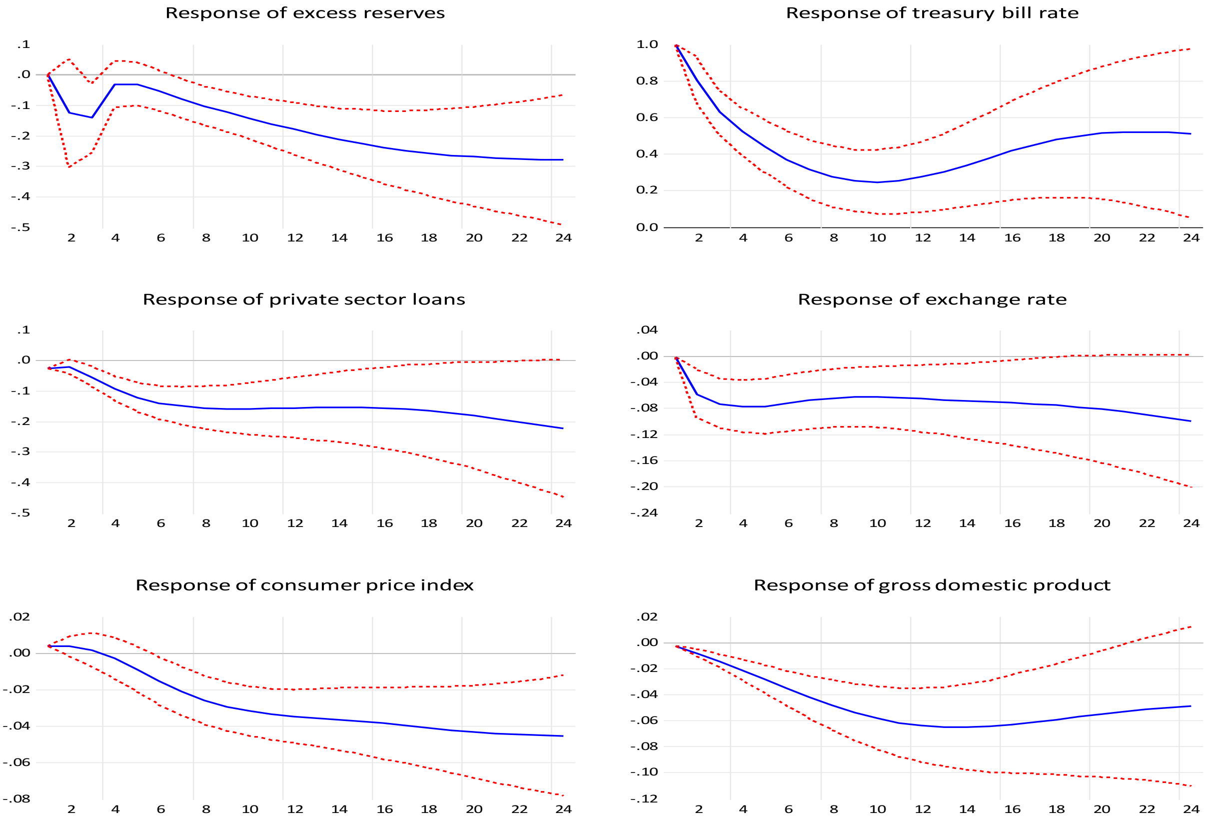

Figure 6: Robustness of impulse response functions of a shock to treasury bill rate (using an alternative monetary policy variable), Mar 2001 to Dec 2020

The variance decomposition results of the alternative specification estimated with the treasury bill rate are reported in Table C.5 in the Appendix. The treasury bill rate shock significantly explains the forecast variances of private sector loans (27.62 percent), the exchange rate (23.61 percent), the CPI (32.96 percent) and real GDP (38.07 percent) in the 24th quarter. Similar to the results of the benchmark model (see Table 2), excess reserves contribute weakly to the forecast variances of all other variables in the short horizon. The short-run results support the findings of Moumni and Nahhal (2014), who found that excess liquidity shock makes negligible contributions to the variances of output and price level.

5.3 Different lag order

In the third robustness exercise, the optimal lag length of 3 selected by information criteria is used to assess the robustness of the impulse response functions and the forecast error variance decompositions. Following the one standard deviation shock to the lending rate, the CPI rises while private sector loans, the exchange rate and real GDP fall. As shown in Figure 7, the impulse response functions produce similar effects compared to the results of the benchmark model. However, the magnitude of response improves slightly for all variables. To illustrate, private sector loans decrease to 6.60 percent in quarter 4 compared to a benchmark fall of 4.20 percent during the same period. The perverse effects that the lending rate shock has on the CPI and the exchange rate are akin to those of the benchmark model. The findings confirm with that of authors such as Primus (2016), who concluded that a positive shock to the policy rate has a weak transmission to the real variables. In Macedonia, Jovanovic et al. (2015) established that the interest rate channel is weak to influence inflation and output under an excess liquidity situation.

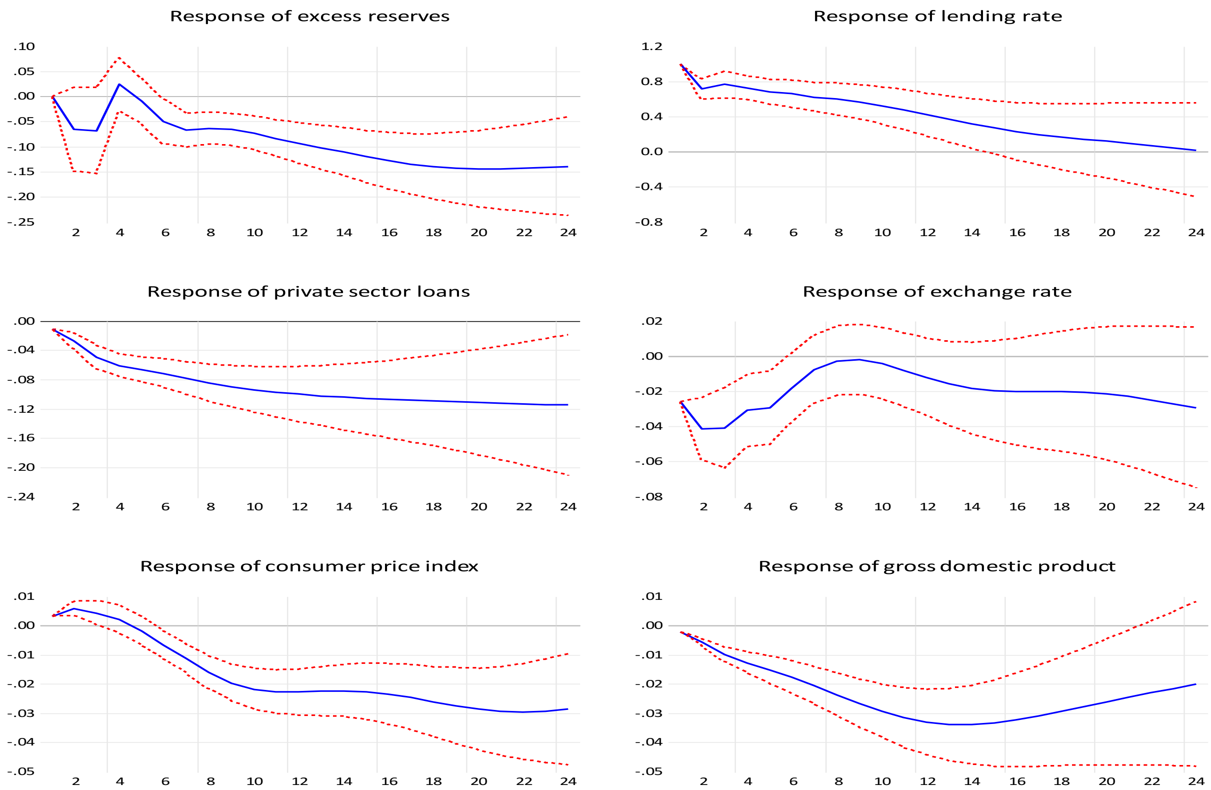

Figure 7: Robustness of impulse response functions of a shock to lending rate (using 3 lags), Mar 2001 to Dec 2020

The forecast variance decomposition results reveal that in the model estimated with 3 lags, the shock to the lending rate explains at least 38.00 percent of the variance in private sector loans, the CPI and GDP in the 24th quarter. The excess reserves shock, on the other hand, contributes a small component of the variation in the exchange rate (4.73 percent), the CPI (3.22 percent) and GDP (1.86 percent) in period 24. The negligible results suggest that monetary transmission becomes slow in the presence of excess reserves. Similar to those of the benchmark results, each variable significantly explains a large percentage of their own variance in the 24th quarter except the CPI (below 14.00 percent). Jayaraman and Choong (2015) and Primus (2016) reported similar long-term results in their papers. The forecast variance decomposition results are presented in Table C.6 in the Appendix.

5.4 Short sample period

In the final robustness check, the sub-sample from March 2008 to December 2020 is employed in the VAR model to capture the impact of the liquefied natural gas project, a major economic development in PNG. The impulse response functions of a one standard deviation shock to the lending rate are reported in Figure 8. The impulse responses appear to follow similar patterns compared to those of the benchmark results presented in Figure 3. Specifically, the shock generates significant responses from private sector loans, the exchange rate, the CPI and real GDP in the short run. However, in the long run, the contractionary monetary policy shock has insignificant and unanticipated effects on the macroeconomic variables. The long-run findings are well in line with that of Lahura (2010) and Bathaluddin et al. (2012), who discovered that shock to the interbank rate has unanticipated effects on output, price level and the exchange rate. In the case of a one standard deviation shock to excess reserves, the variables are responding significantly to the shock in the short horizon (see Figure C.4 in the Appendix). However, the responses of the exchange rate and the CPI do not accord with theoretical priors. The short-run findings are not different to those reported in Saxegaard (2006), Egesa (2014) and Moumni and Nahhal (2014).

The variance decomposition results of the short sample period are presented in Table C.7 in the Appendix. Similar to those of the benchmark results (see Table 2), the shock to excess reserves exhibits weak influence on the forecast variances of private sector loans (2.29 percent), the exchange rate (2.05 percent), the CPI (6.70 percent) and real GDP (7.06 percent) in the short horizon. In the long run, apart from own shocks, the lending rate explains a greater share of the variance in all other variables. Furthermore, private sector loans contribute significantly to the variances of the CPI (22.06 percent) and real GDP (28.65 percent) in period

24. These results are expected because of direct relationship between loans and CPI and GDP. Overall, the results of the alternative specifications highly support the benchmark results.

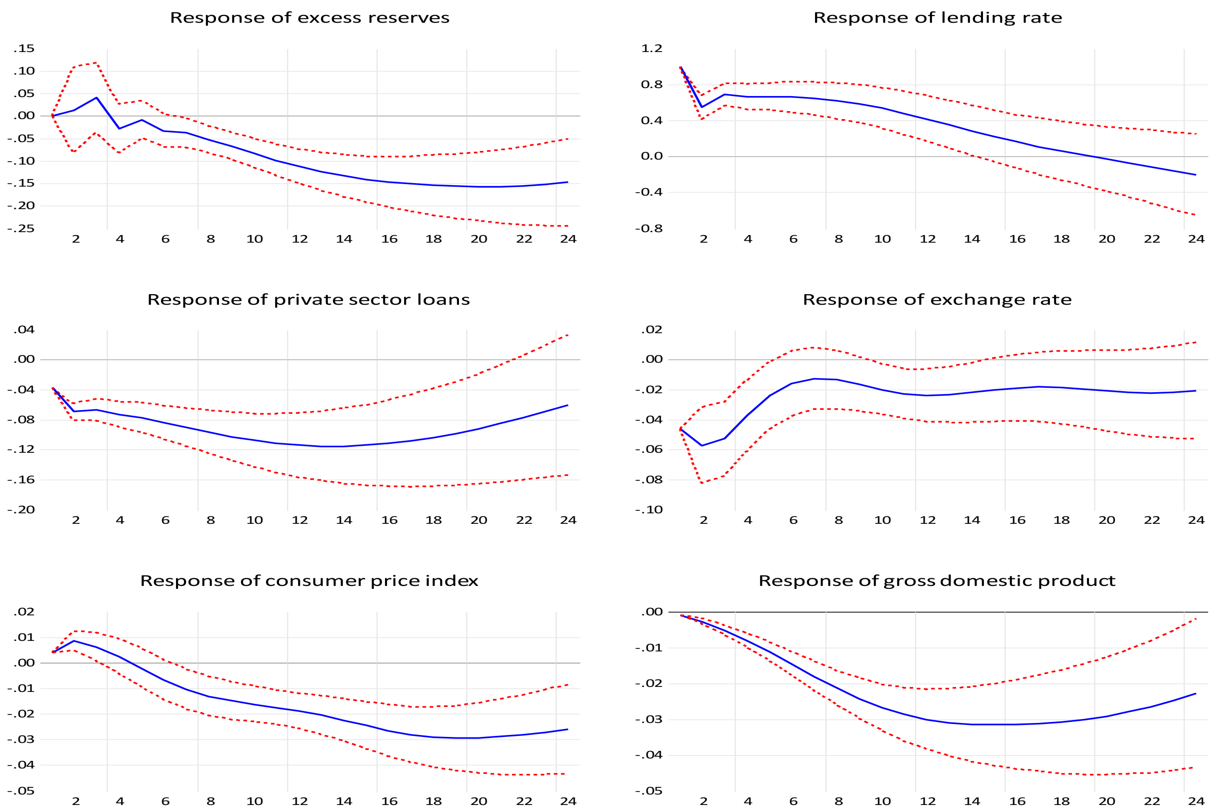

Figure 8: Robustness of impulse response functions of a shock to lending rate (using short sample period), Mar 2008 to Dec 2020

6 Conclusion

It is essential to understand the ability of monetary policy of BPNG to influence the real economy in the presence of excess reserves. Excess reserves affect the monetary policy transmission process mainly through the interest rate channel. Hence, this paper has investigated the effects of the excess reserves and lending rate shocks on private sector loans, the exchange rate, the CPI and real GDP using the structural VAR methodology. The impulse response functions, forecast error variance decompositions and historical decompositions were estimated to measure the flow-on effects on the real economy under different monetary policy settings. Two of the variables under study exhibit insignificant and unanticipated responses to the shocks in the short horizon. Specifically, the lending rate shock generates price and exchange rate puzzles in the short run while the excess reserves shock has unexpected impacts on the exchange rate and the CPI. Similarly, in the long run, the responses of private sector loans and GDP are against the theoretical views. Furthermore, excess reserves make negligible contributions to the forecast variances of all variables. The historical decomposition results determine that the movements of the CPI and GDP series are slightly sensitive to the excess reserves shock. Overall, there is little evidence to suggest that the transmission of monetary policy works effectively for PNG. The findings of this study support the results of previous studies such as Saxegaard (2006), Khremaj (2007), Nguyen and Boateng (2013), Moumni and Nahhal (2014) and Jovanovic et al. (2015), who establish that excess reserves reduce the effectiveness of monetary policy transmission. The results of the benchmark model are generally consistent with those of the alternative specifications in the robustness checks. In particular, the reordering of the variables generates similar responses in terms of magnitude and significance to those of the benchmark model.

The obvious policy implication relating to the findings is the effective transmission of monetary policy in the presence of excess reserves. Excess reserves naturally exert downward pressure on the domestic interest rates. Hence, any attempt made by the central bank to implement a tight monetary policy may not deliver the expected economic outcomes. The findings of this paper confirm that the interest rate shock generates price and exchange rate puzzles in the domestic economy. To improve transmission of monetary policy, consistent with that of Nguyen and Boateng (2013) and Egesa (2014), this study strongly supports the need for regular decumulation of excess reserves through market-based and regulatory interventions. This can be achieved by restructuring the domestic monetary policy framework, especially the conduct of open market operations and implementation of cash reserve requirement. Specifically, the central bank should improve the market terms and conditions of medium and long-term government securities such as inscribed stocks and treasury bonds. This will encourage commercial banks to invest their excess reserves in these securities for long-term liquidity management. Besides the conventional monetary policy tools, the domestic financial system needs further improvement in order to facilitate active flow of cash reserves between economic agents.

The findings of the paper have implications for further research relating to the impacts. This paper investigates the impact of excess reserves on transmission of monetary policy. However, other impacts can be equally considered for future research given their implications on the economy. More specifically, since the main objective of the central bank is to maintain price stability, it is essential to thoroughly investigate how excess reserves affect inflation.

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Appendix A: Data

Table A.1: Variable descriptions and data sources

Variable	Symbol	Description	Source
(a) Main variables			
Excess reserves	XRS	Excess funds at the central bank accounts and commercial bank vaults (in millions of kina). The series is seasonally adjusted using the Census X-13 method.	BPNG and author
Lending rate	RTL	Weighted average lending rate (in percent).	BPNG
Private sector loans	PSL	Loans provided to private sector by commercial banks (in millions of kina). The series is seasonally adjusted using the Census X-13 method.	BPNG
Exchange rate	XRT	Nominal exchange rate under managed floating and fixed peg regimes (PGK/AUD).	BPNG
Consumer price index	CPI	It is a measure of price change and an indicator of headline inflation (in percentage point).	BPNG and NSO
Gross domestic product	GDP	Total value of economic activity and is discounted for inflation (in millions of kina). It is the indicator of economic growth. The series is interpolated and seasonally adjusted using the Census X-13 method.	BPNG, NSO and author
(b) Alternative variable for robustness check			
Treasury bill rate	TBR	The treasury bill rate is a proxy for the policy rate (in percent). TBR replaces RTL in the alternative model specification.	BPNG
(c) Variable used as an indicator for interpolation			
Total exports	TEV	Total value of domestic exports (in millions of kina). GDP is interpolated on the basis of TEV using the Chow-Lin method.	BPNG

Note: PNG kina (PGK) and Australian dollar (AUD). NSO is PNG's National Statistical Office.

Appendix B: Construction of GDP series

The ultimate purpose of this section is to construct the quarterly GDP data series for PNG. Since GDP data is available only on an annual basis for the sample period, the quarterly data series is generated using the interpolation method proposed by Chow and Lin (1971). The Chow-Lin method is a temporal disaggregation technique that has significant benefits over the standard interpolation methods. In particular, the method has the ability to combine the information contained in both the low frequency series and the higher frequency indicator series. That is, the newly generated high frequency series is consistent with the low frequency series while keeping the overall profile of the higher frequency indicator series. The study by Islaqm (2013) established that the Chow-Lin method generates better results than other interpolation techniques in the case of export data for Bangladesh.

For interpolation to be precise under the proposed method, consider a variable that is closely associated with GDP. In this study, the quarterly data series for total exports is employed as an indicator series for GDP. More specifically, exports data is used to interpolate the quarterly GDP series since domestic exports account for at least 30 percent of GDP on average annually. Moreover, the correlation coefficient between the two series is about 80 percent. Even through other variables influence the correlation, the selected variables exhibit a strong association. The newly interpolated data and indicator variable data are plotted in Figure B.1.

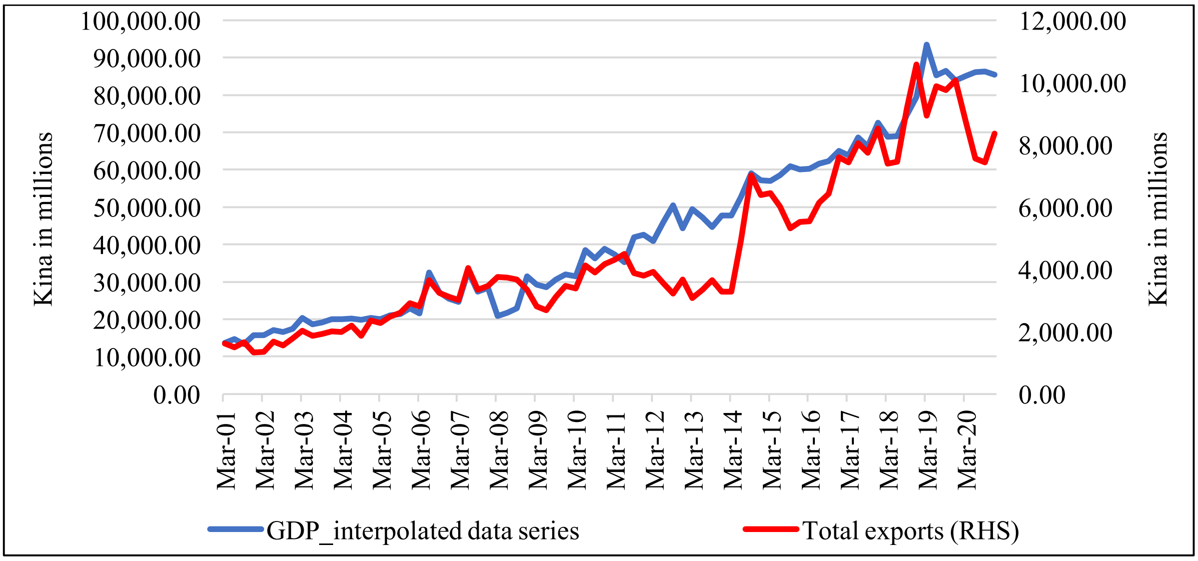

Figure B.1: The interpolated GDP data and the total export data, Mar 2001 to Dec 2020
Note: RHS refers to the right-hand side.
Sources: BPNG and author's calculation

The interpolated data series and annual version of GDP are plotted in Figure B.2. The annual GDP data is expanded for each quarter of the year to have the same value, so that there is equal number of observations in the quarterly and annual series. The interpolated data series that combines the information in the low frequency series and the higher frequency indicator series is used in the structural VAR model.

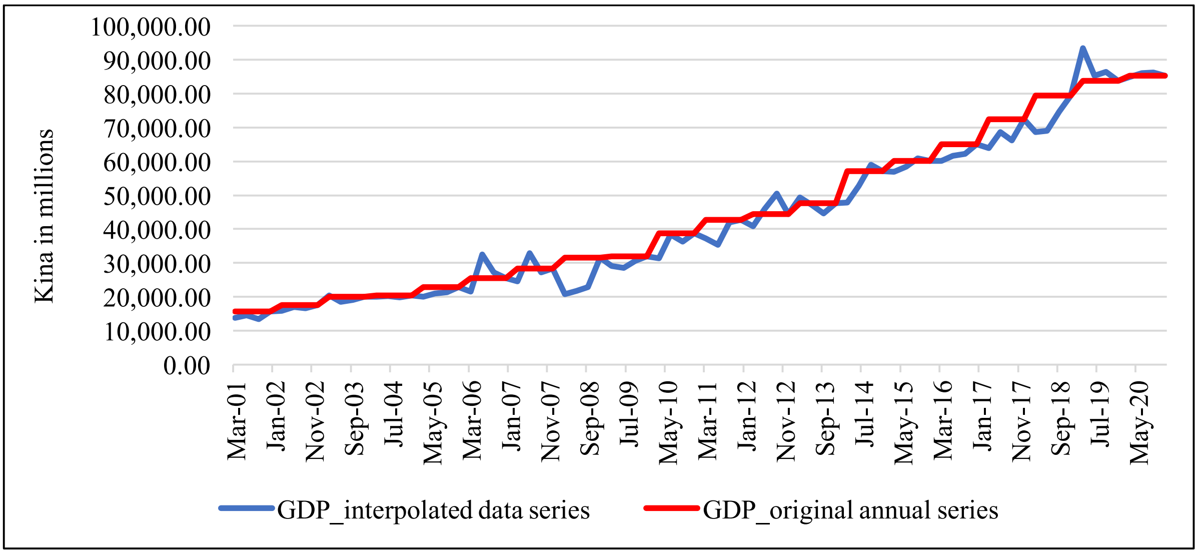

Figure B.2: The interpolated and original GDP series, Mar 2001 to Dec 2020
Sources: BPNG and author's calculation

Appendix C: Estimated results of the benchmark model and robustness checks

Table C.1: Determination of lag specification

Lag Length	LR	FPE	AIC	SIC	HQ
0	NA	0.000	-6.222	-6.044	-6.151
1	960.556	0.000	-18.481	-17.230	-17.979
2	214.752	0.000	-20.896**	-18.463**	-19.855**
3	60.828**	0.000**	-20.883	-17.489	-19.522
4	46.059	0.000	-20.820	-16.354	-19.030
5	47.742	0.000	-20.895	-15.357	-18.674
6	50.240	0.000	-20.763	-14.553	-18.513

Note: ** indicates optimal lag order selected by each criterion at 5 percent level of significance.

Table C.2: Roots of characteristic polynomial

Root	Modulus
0.969 - 0.080i	0.972
0.969 + 0.080i	0.972
0.932 - 0.161i	0.946
0.932 + 0.161i	0.946
0.885	0.885
0.771 - 0.396i	0.867
0.771 + 0.396i	0.867
-0.376 - 0.048i	0.379
-0.376 + 0.048i	0.379
0.218 - 0.301i	0.372
0.218 + 0.301i	0.372
0.071	0.071

No root lies outside the unit circle.
VAR satisfies the stability condition.
Note: With 2 lags.

Table C.3: Residual correlation matrix

	XRS	RTL	PSL	XRT	CPI	GDP
XRS	1.000					
RTL	-0.122	1.000				
PSL	-0.093	-0.032	1.000			
XRT	0.003	-0.193	0.193	1.000		
CPI	-0.127	-0.021	-0.107	-0.107	1.000	
GDP	0.098	-0.228	0.058	0.072	0.150	1.000

Note: The coefficients of the residual correlation matrix below the diagonal are less than one.

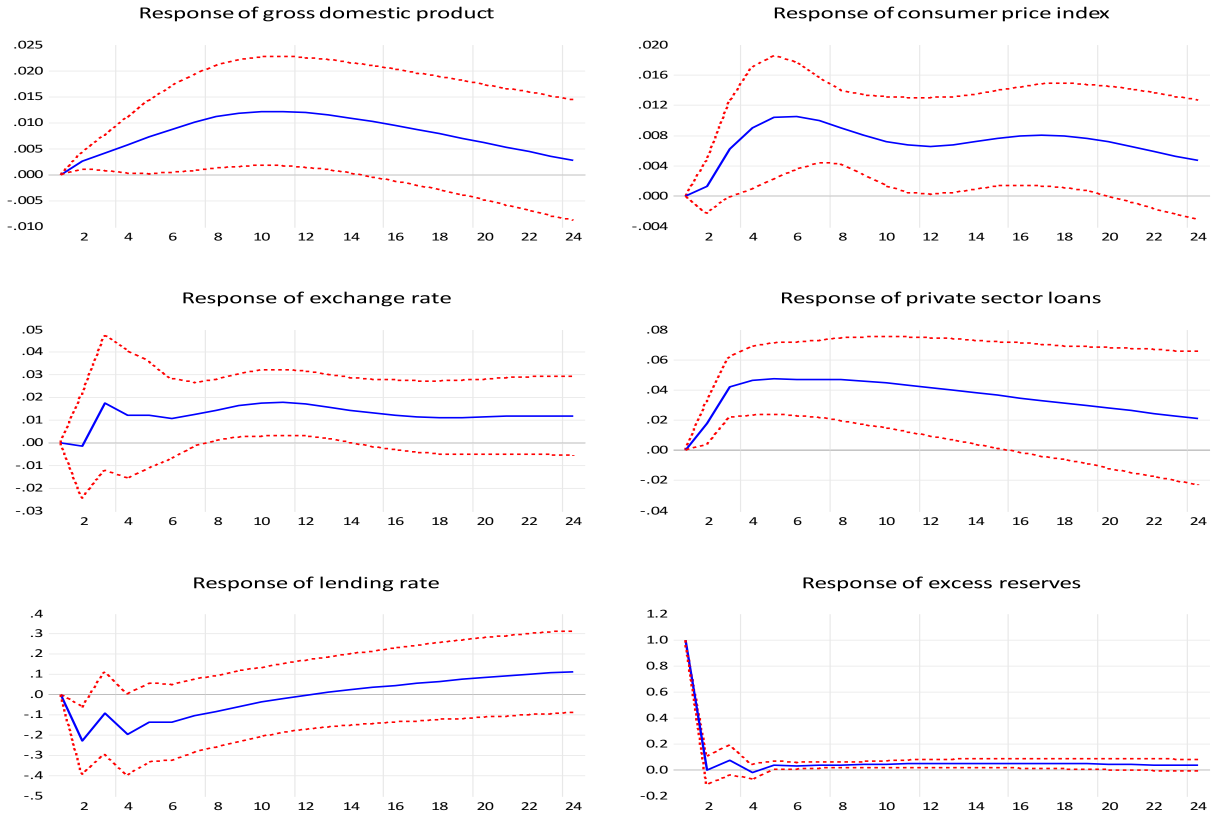

Figure C.1: Robustness of impulse response functions of a shock to excess reserves (reordering of variables), Mar 2001 to Dec 2020

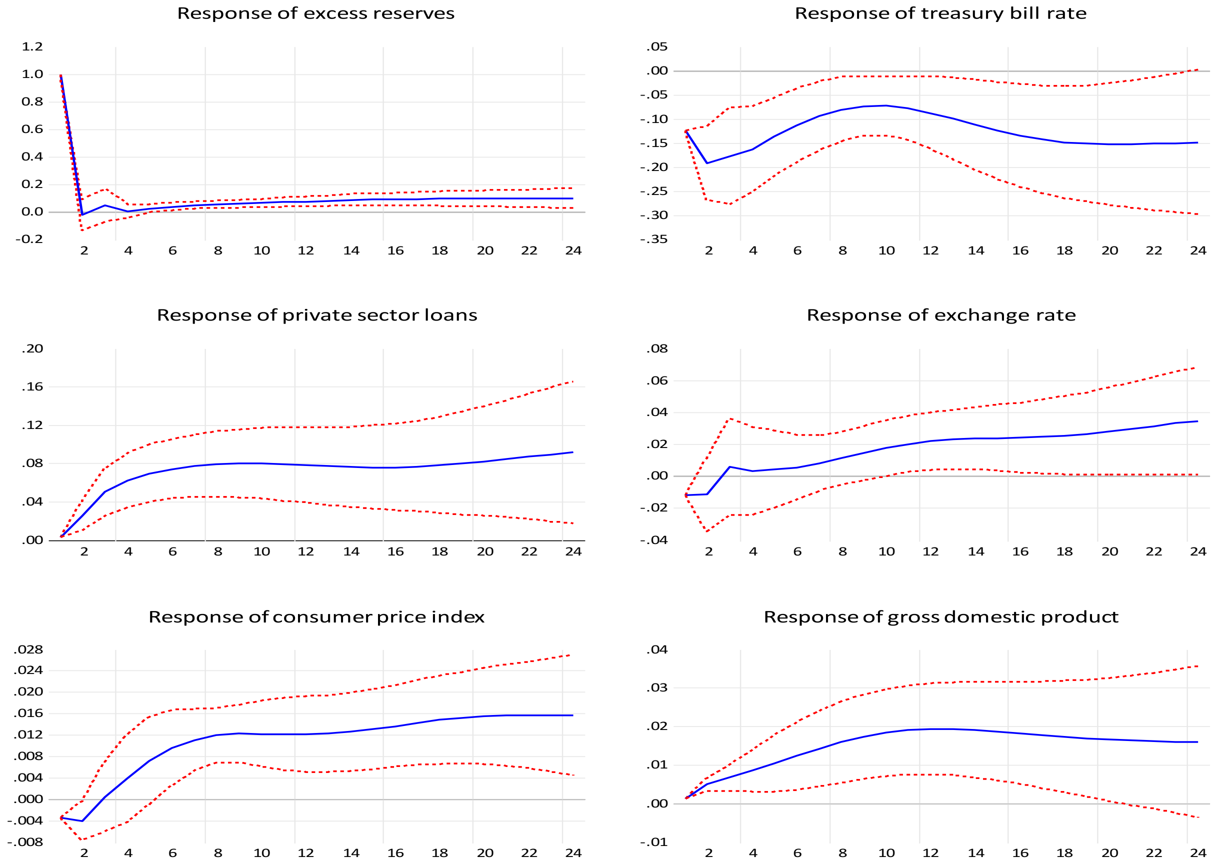

Figure C.2: Robustness of impulse response functions of a shock to excess reserves (using treasury bill rate as an alternative variable), Mar 2001 to Dec 2020

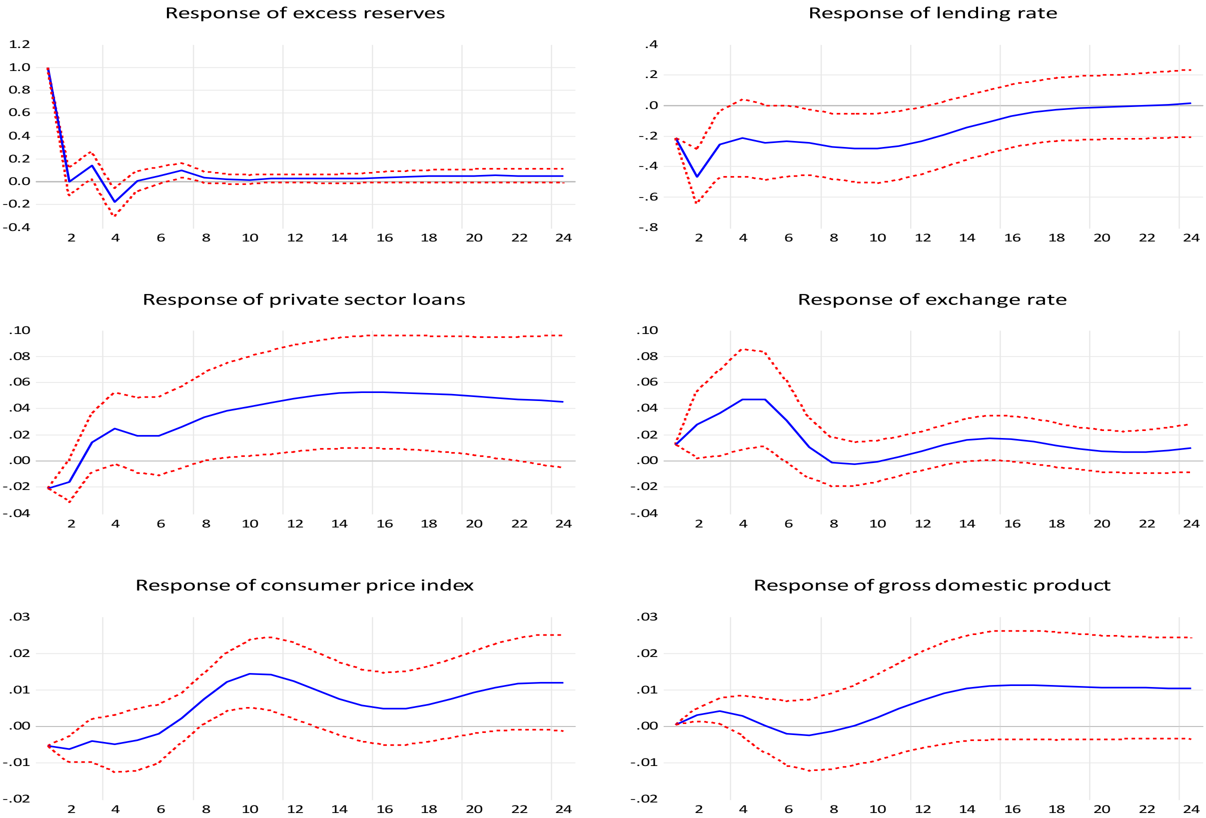

Figure C.3: Robustness of impulse response functions of a shock to excess reserves (using 3 lags), Mar 2001 to Dec 2020

Figure C.4: Robustness of impulse response functions of a shock to excess reserves (using short sample period), Mar 2008 to Dec 2020

Table C.4: Robustness of forecast error variance decomposition results (reordering of variables), Mar 2001 to Dec 2020 (in percent)

Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
Variance decomposition of gross domestic product							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.004	100.000	0.000	0.000	0.000	0.000	0.000
4	0.018	93.363	3.877	0.129	0.638	1.012	0.981
12	0.048	79.256	4.649	6.959	0.435	6.284	2.416
24	0.060	59.966	3.010	18.647	0.352	15.326	2.699
Variance decomposition of consumer price index							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.008	2.259	97.741	0.000	0.000	0.000	0.000
4	0.024	1.021	97.160	0.323	0.139	0.130	1.226
12	0.033	8.409	60.018	16.679	1.742	9.485	3.667
24	0.044	16.199	35.279	21.842	1.118	21.776	3.787
Variance decomposition of exchange rate							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.052	0.512	1.411	98.077	0.000	0.000	0.000
4	0.087	2.016	8.274	87.499	1.334	0.537	0.340
12	0.100	3.017	14.818	78.776	1.298	0.812	1.280
24	0.109	3.603	12.880	73.250	2.093	6.222	1.953
Variance decomposition of private sector loans							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.032	0.334	1.372	3.120	95.174	0.000	0.000
4	0.071	0.183	2.473	8.127	77.270	7.301	4.647
12	0.148	2.098	2.193	17.998	38.655	33.739	5.317
24	0.209	2.852	1.390	20.412	21.322	49.864	4.160
Variance decomposition of lending rate							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.374	5.218	0.017	3.134	0.021	91.610	0.000
4	0.650	7.871	1.059	13.945	1.021	74.790	1.314
12	0.958	13.544	0.716	17.347	6.960	60.455	0.977
24	1.087	18.115	1.469	14.395	15.530	49.413	1.077
Variance decomposition of excess reserves							
Period	S.E.	GDP	CPI	XRT	PSL	RTL	XRS
1	0.243	0.958	1.924	0.041	1.296	1.096	94.685
4	0.272	2.842	2.653	6.476	10.073	1.808	76.148
12	0.288	5.145	2.732	8.301	10.558	4.596	68.668
24	0.335	10.154	2.127	13.601	8.012	14.205	51.902

Note: SE stands for standard error and period is in quarters.

Table C.5: Robustness of forecast error variance decomposition results (using treasury bill rate as an alternative variable), Mar 2001 to Dec 2020 (in percent)

Variance decomposition of excess reserves							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.250	100.000	0.000	0.000	0.000	0.000	0.000
4	0.270	85.950	1.463	4.414	5.222	0.706	2.244
12	0.289	76.338	5.205	8.346	4.829	0.960	4.321
24	0.360	54.396	20.620	10.174	3.761	0.747	10.301
Variance decomposition of treasury bill rate							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.174	3.177	96.823	0.000	0.000	0.000	0.000
4	0.289	8.254	80.921	1.552	3.074	3.184	3.014
12	0.389	7.487	59.459	1.532	4.394	11.095	16.033
24	0.593	7.392	46.655	1.378	5.055	7.746	31.774
Variance decomposition of private sector loans							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.034	0.042	1.610	98.349	0.000	0.000	0.000
4	0.087	5.887	4.870	88.353	0.283	0.583	0.024
12	0.174	11.308	18.441	62.362	0.389	4.710	2.791
24	0.246	13.881	27.624	47.006	0.752	4.099	6.637
Variance decomposition of exchange rate							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.051	0.332	0.004	1.133	98.532	0.000	0.000
4	0.087	0.262	5.697	1.551	86.661	4.588	1.241
12	0.104	1.129	13.631	1.723	70.460	11.534	1.523
24	0.125	4.426	23.611	3.831	50.802	8.732	8.597
Variance decomposition of consumer price index							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.008	1.106	0.580	0.354	2.472	95.488	0.000
4	0.023	0.489	0.198	0.169	4.523	94.543	0.078
12	0.033	5.870	14.994	7.659	6.148	59.653	5.677
24	0.048	9.657	32.958	9.081	4.243	29.252	14.808
Variance decomposition of gross domestic product							
Period	S.E.	XRS	TBR	PSL	XRT	CPI	GDP
1	0.004	0.866	1.766	0.193	0.029	2.369	94.777
4	0.018	2.706	6.477	0.225	0.513	8.952	81.127
12	0.050	5.471	24.105	0.477	2.284	8.325	59.339
24	0.069	7.799	38.069	3.035	5.929	4.540	40.627

Note: SE stands for standard error and period is in quarters.

Table C.6: Robustness of forecast error variance decomposition results (using 3 lags), Mar 2001 to Dec 2020 (in percent)

Variance decomposition of excess reserves							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.246	100.000	0.000	0.000	0.000	0.000	0.000
4	0.282	80.223	1.483	8.313	5.965	1.464	2.552
12	0.303	70.650	6.192	11.772	6.364	1.747	3.276
24	0.374	47.326	22.860	12.395	10.321	1.374	5.724
Variance decomposition of lending rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.357	2.182	97.818	0.000	0.000	0.000	0.000
4	0.623	5.852	84.220	1.703	5.453	0.763	2.008
12	0.966	5.884	70.536	1.535	16.728	0.513	4.804
24	1.146	4.543	54.808	3.013	17.784	0.859	18.993
Variance decomposition of private sector loans							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.032	2.551	1.574	95.875	0.000	0.000	0.000
4	0.069	1.883	17.934	78.400	1.133	0.208	0.442
12	0.151	3.077	36.132	51.338	4.538	0.085	4.829
24	0.227	4.855	50.441	31.498	8.792	0.259	4.155
Variance decomposition of exchange rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.053	0.330	3.012	7.115	89.543	0.000	0.000
4	0.092	3.218	7.385	17.088	69.491	2.205	0.612
12	0.102	4.577	7.783	16.931	63.586	5.811	1.311
24	0.111	4.727	12.447	18.655	57.218	5.354	1.600
Variance decomposition of consumer price index							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.007	3.296	2.588	1.433	0.353	92.330	0.000
4	0.020	1.722	2.223	1.211	3.204	91.199	0.441
12	0.037	4.083	22.326	14.595	21.349	33.133	4.514
24	0.059	3.223	38.673	12.552	20.260	14.030	11.263
Variance decomposition of gross domestic product							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.003	0.062	4.462	0.043	0.702	0.478	94.253
4	0.016	0.788	13.965	0.866	0.095	2.802	81.485
12	0.046	0.359	32.215	4.413	8.173	3.000	51.839
24	0.069	1.860	39.794	9.154	18.644	1.365	29.183

Note: SE stands for standard error and period is in quarters.

Table C.7: Robustness of forecast error variance decomposition results (using short sample period), Mar 2008 to Dec 2020 (in percent)

Variance decomposition of excess reserves							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.219	100.000	0.000	0.000	0.000	0.000	0.000
4	0.237	89.408	0.448	2.324	6.481	1.230	0.108
12	0.255	78.334	6.104	6.045	6.211	3.089	0.216
24	0.349	48.712	23.791	17.352	3.756	6.193	0.196
Variance decomposition of lending rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.310	0.676	99.324	0.000	0.000	0.000	0.000
4	0.522	11.555	77.652	3.569	6.240	0.385	0.599
12	0.888	12.579	59.560	14.928	3.573	8.252	1.109
24	0.991	12.544	51.572	15.375	3.070	16.501	0.938
Variance decomposition of private sector loans							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.026	1.928	19.318	78.754	0.000	0.000	0.000
4	0.063	2.287	38.453	56.279	2.152	0.570	0.258
12	0.144	11.574	42.803	37.683	2.749	4.845	0.346
24	0.227	14.118	38.318	31.256	1.720	14.418	0.170
Variance decomposition of exchange rate							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.058	3.603	6.091	0.413	89.893	0.000	0.000
4	0.087	2.050	12.170	6.174	70.786	8.330	0.490
12	0.095	2.044	13.159	8.942	60.685	13.239	1.931
24	0.104	3.945	15.544	11.182	51.902	15.200	2.226
Variance decomposition of consumer price index							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.008	6.067	2.097	1.689	2.892	87.255	0.000
4	0.024	6.699	2.182	1.471	4.676	81.971	3.002
12	0.032	8.709	14.888	8.466	5.695	57.935	4.307
24	0.054	12.287	33.420	22.059	2.916	27.667	1.651
Variance decomposition of gross domestic product							
Period	S.E.	XRS	RTL	PSL	XRT	CPI	GDP
1	0.002	0.110	3.373	16.588	5.843	0.875	73.213
4	0.008	7.058	16.401	20.592	22.887	7.161	25.900
12	0.029	11.203	48.030	29.138	4.431	5.093	2.105
24	0.058	14.431	41.511	28.650	1.780	13.025	0.605

Note: SE stands for standard error and period is in quarters.