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Determinants of Excess Reserves in the Banking System of Papua New Guinea

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The accumulation of excess reserves in the banking system of PNG may have undesirable implications on the financial system, macroeconomic stability and monetary policy implementation. Hence, this paper examines the factors that induce commercial banks to hold unremunerated excess reserves. The paper employs an ARDL model to estimate the determinants of excess reserves using monthly time-series data for the period January 2002 to December 2017. The model includes three precautionary variables of volatility of demand deposits, discount rate and cash reserve requirement and four involuntary variables of foreign reserve inflows, private sector lending, private sector deposits and treasury bill rate. The selection of these variables is determined by data availability and relevance to the economy of PNG. The findings suggest that the discount rate, volatility of demand deposits and private sector deposits significantly contribute to the accumulation of excess reserves. In contrast, foreign exchange reserves, private sector credit and the treasury bill rate effectively reduce excess reserves pressure in the banking system. However, the cash reserve requirement is not effective in influencing the demand for excess reserves. The empirical analysis concludes that involuntary variables are the leading determinants of excess reserves in PNG. Hence, the central bank should review the involuntary variables to take appropriate policy actions in order to reduce the level of excess reserves in the banking system.

Keywords

excess reserves, precautionary variables, involuntary variables, banking system, ARDL method

JEL Classification

C29, E52, G21

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The accumulation of excess reserves in the banking system of PNG may have undesirable implications on the financial system, macroeconomic stability and monetary policy implementation. Hence, this paper examines the factors that induce commercial banks to hold unremunerated excess reserves. The paper employs an ARDL model to estimate the determinants of excess reserves using monthly time-series data for the period January 2002 to December 2017. The model includes three precautionary variables of volatility of demand deposits, discount rate and cash reserve requirement and four involuntary variables of foreign reserve inflows, private sector lending, private sector deposits and treasury bill rate. The selection of these variables is determined by data availability and relevance to the economy of PNG. The findings suggest that the discount rate, volatility of demand deposits and private sector deposits significantly contribute to the accumulation of excess reserves. In contrast, foreign exchange reserves, private sector credit and the treasury bill rate effectively reduce excess reserves pressure in the banking system. However, the cash reserve requirement is not effective in influencing the demand for excess reserves. The empirical analysis concludes that involuntary variables are the leading determinants of excess reserves in PNG. Hence, the central bank should review the involuntary variables to take appropriate policy actions in order to reduce the level of excess reserves in the banking system.

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1 Introduction

The existence of excess reserves in the banking system is a common feature in developing countries (Agenor et al., 2004; Khemraj, 2009; Nguyen et al., 2015). Commercial banks hold unremunerated excess reserves for several reasons. Agenor et al. (2004) and Saxegaard (2006) identify them as precautionary and involuntary factors. The precautionary motives are related to uncertainty and volatility factors, while involuntary motives are associated with structural and cyclical factors. From the macroeconomic perspective, these factors may have positive and negative influences on demand for excess reserves. For example, Primus et al. (2014) suggest that increased government expenditure can lead to persistent accumulation of involuntary excess reserves in commercial banks. In Papua New Guinea (PNG) where the financial system is largely underdeveloped, commercial banks hold substantial amount of cash reserves in own vaults and their central bank accounts. Hence, this study explores why profit-maximizing banks hold unremunerated excess reserves in PNG.

The intermediate activity of commercial banks is to accept short-term deposits and provide medium and long-term loans. These transactions involve risks that banks need to manage, such as meeting the demands for private sector loans and unexpected customer withdrawals. Thus, holding sufficient reserves is essential to protect banks against liquidity risk. In doing so, banks incur opportunity costs through the loan and asset markets. The opportunity cost of holding reserves also affects the demand for excess reserves. Moreover, high capital inflows associated with foreign direct investments, privatization of state enterprises, personal remittances and mineral exports inject involuntary excess reserves in the banking system (Saxegaard, 2006). In order to discharge some of the excess reserves from the banking system, Vellodi et al. (2012) identify various channels such as lending to the private sector, investing in domestic government securities and purchasing foreign assets.

There are several papers that have empirically studied the demand for excess reserves (or excess liquidity) in developing economies. Some studies such as Fielding and Shorthand (2005), Nguyen et al. (2015) and Kigabo and Gichondo (2018) investigate precautionary reasons for holding excess reserves by commercial banks. Other studies such as Khemraj (2009), Hamma and Ejbari (2013) and Ukeje et al. (2015) explore precautionary and involuntary factors that influence excess reserves. Saxegaard (2006) and Bathaluddin et al. (2012), on the other hand, examine the determinants of precautionary and involuntary excess liquidity using two separate models. In PNG, several reports have acknowledged the presence of excess reserves in the banking system (see, BPNG, 2016; IMF, 2017). However, there is no empirical study has been conducted to identify the drivers of excess reserves. Hence, this study fills the research gap by adopting and extending the empirical framework of Agenor et al. (2004) to investigate the potential determinants of excess reserves. Specifically, this paper includes involuntary variables representing the opportunity costs, banking activities and foreign capital inflows in the structural framework. Moreover, the paper uses an autoregressive distributed lag (ARDL) model to estimate a demand function for excess reserves using monthly data from January 2002 to December 2017.

This paper provides a number of important findings. First, the long-run analysis indicates that the discount rate, foreign exchange reserves, private sector deposits, private sector credit and the treasury bill rate significantly influence excess reserves in commercial banks. However, the cash reserve requirement, volatility of demand deposits and dummy variable have no real effect on demand for excess reserves. Furthermore, the estimation results indicate that private sector credit has greater impact on excess reserves than other variables in the long run. Second, the short-run analysis reveals that the estimated coefficients of most variables are consistent with the long-run results. One exception is that the volatility of demand deposits becomes a significant determinant of excess reserves in the short run. This result is consistent with normal banking practice that commercial banks hold extra reserves to meet unexpected customer withdrawals over the counter. The analysis of the long-run and short-run estimation results establishes that involuntary variables are main determinants of excess reserves in the banking system. Third, the robustness analysis confirms that foreign capital inflows associated with high commodity prices and resources boom contribute significantly to excess reserves in PNG.

This paper makes a twofold contribution to the emerging literature on the demand for excess reserves. Firstly, this is the first empirical study to evaluate the determinants of excess reserves in the banking system of PNG. More specifically, the study analyzes the long-run and short-run dynamic effects of precautionary and involuntary motives for holding excess reserves by commercial banks. The empirical findings may contribute to a sound monetary policy and promote an effective banking system in PNG. Secondly, this paper establishes a negative relationship between excess reserves and opportunity cost in relation to the monetary benefits that commercial banks may forego in the domestic loan and asset markets. Several papers discuss the connection between opportunity cost and excess reserve holdings in the context of developing countries. However, only few studies such as Maynard and Moore (2005) and Khasawneh (2013) empirically estimate their relationship. The analysis of this study contributes to the literature using an ARDL framework.

The rest of the paper is organized as follows. Section two reviews and discusses the empirical literature on demand for excess reserves in developing countries. The paper then outlines the empirical framework and variable definitions in Section three. Section four presents the empirical results and discusses them by drawing on similar findings and arguments from past papers. The main empirical results are supported by robustness checks in Section five. Section six discusses other fundamental factors that influence excess reserves. Finally, Section seven summarizes the key findings and policy recommendations.

2 Literature review

The existing literature on the determinants of bank excess reserves in developing countries is limited. Despite the importance of excess reserves to monetary policy transmission process, only a few studies have empirically investigated the relationship between excess reserves and their determinants. This study relates to some of the widely known papers including those of Agenor et al. (2004) for East Asia, Fielding and Shorthand (2005) for Egypt, Maynard and Moore (2005) for Barbados, Saxegaard (2006) for Sub-Saharan Africa, Aikaeli (2006) for Tanzania, Khemraj (2009) for Guyana, Anderson-Reid (2011) for Jamaica, Bathaluddin et al. (2012) for Indonesia, Pontes and Murta (2012) for Cape Verde, Khasawneh (2013) for Jordan, Hamma and Ejbari (2013) for Morocco, Primus et al. (2014) for Trinidad and Tobago, Nguyen et al. (2015) for China, Ukeje et al. (2015) for Nigeria, and Kigabo and Gichondo (2018) for Rwanda. The authors employed various empirical methods to estimate the demand functions for excess reserves in their respective countries.

In the banking sector, Frost (1971) was one of the first authors to use the classic reserve management model to examine the determinants of excess reserves for advanced economies. The model considers a bank’s objective to minimize the expected cost of holding reserves incurred through the opportunity cost and penalty for illiquidity. The reserve model was modified by Agenor et al. (2004) to accommodate precautionary motives for holding unremunerated bank excess liquid assets in East Asia. Saxegaard (2006) further extended the empirical model of Agenor et al. (2004) to include variables that account for involuntary accumulation of excess reserves in Sub-Saharan Africa. He separated excess reserves into precautionary and involuntary components and estimated a demand function for each component using their respective determinants. This study, on other hand, measures the effects of precautionary and involuntary factors using a single demand function for excess reserves.

The literature has mentioned several factors that influence demand for excess reserves in developing countries. Agenor et al. (2004) and Saxegaard (2006) broadly classified the determinants of excess reserves into precautionary and involuntary factors. Agenor et al. (2004) suggested that precautionary variables are associated with liquidity risk and uncertainty. Several past papers used the volatility measures of demand deposits, deposits, loans, output gap and gross income to test for precautionary excess reserve holdings. For example, Agenor et al. (2004) and Primus et al. (2014) empirically examined the relationship between excess reserves and precautionary variables and established that the volatility of demand deposits has a positive relationship with excess reserves. Furthermore, in an unsafe banking environment, the volatility of deposits and increased riskiness of private sector lending may force commercial banks to hold precautionary reserves. Saxegaard (2006) and Pontes and Murta (2012) discovered that the volatility of private sector deposits adds substantial excess reserves in the banking system. Khemraj (2009), on the other hand, argued that the volatility of private sector credit is not significant in explaining the accumulation of excess reserves in commercial banks. The other precautionary measure is the currency in circulation, high volume of currency circulation in an economy is an indication of high liquidity in the banking system.

The ratio of required reserves to total deposits captures the impact of cash reserve requirement set by the central bank for regulatory purposes. A high cash reserve requirement is expected to affect all banks equally depending on their account balances with the central bank. Some past papers suggested that positive adjustments to cash reserve requirement successfully reduce excess reserves in several developing countries (Agenor et al., 2004; Aikaeli, 2006; Anderson-Reid, 2011; Primus et al., 2014). On the contrary, Maynard and Moore (2005), Khemraj (2009), Bathaluddin et al. (2012) and Nguyen et al. (2015) found an insignificant relationship between required reserve ratio and excess reserves. Another monetary policy variable that directly influences excess reserve holdings is the penalty rate. A high penalty rate for overdrawing temporary funds in central bank accounts induces commercial banks to hold more precautionary reserves. The penalty rate is commonly represented by the discount rate in the literature. Using an ARDL model, Fielding and Shorthand (2005) found that a positive shock to the discount rate raises the impact on excess reserves in Egypt.

According to Pontes and Murta (2012), involuntary variables that explain the demand for excess reserves are classified into structural and cyclical factors. One of the structural determinants is the low degree of financial market development, which is common in many developing countries including PNG. Saxegaard (2006) asserted that an underdeveloped interbank market, an inefficient payment system, a high cost of financial operations, an insufficient bank credit facility and lack of a secondary market interrupt the efficient flow of liquidity from commercial banks to other agents. Hence, they create a situation of excess liquidity in the banking system. Hamma and Ejbari (2013) represented the underdeveloped financial system with a ratio of private sector deposits to total bank assets in a 2SLS model to capture the depositing behaviour of private sector customers. The finding suggested that an underdeveloped financial system is a key determinant of excess liquidity in Morocco. The other structural factor is the high degree of risk aversion that influences excess reserves through a low credit demand.

Among the cyclical factors, Saxegaard (2006) and Ukeje et al. (2015) used inflation and capital inflows in their studies. Commercial banks charge high risk premiums during inflation to accommodate for uncertainty in the value of collaterals. Consequently, demand for credit falls and banks hold involuntary excess reserves. Using an ordinary least squares (OLS) method, the study by Ukeje et al. (2015) concluded that inflation is one of the fundamental determinants of excess liquidity in Nigeria. Saxegaard (2006) pointed out that foreign capital inflows received from oil exports, foreign direct investments, external loans and foreign aid dominate public revenues in several African countries. This is evident in the balance of payments having large current and capital account surpluses. The public revenues that end up in commercial bank accounts contribute directly to the issue of persistent excess reserves. The other factor is a cyclical downturn in the economy. Maynard and Moore (2005) explained that during a cyclical downturn, commercial banks anticipate a low transaction demand for money and consequently increase their holdings of excess reserves.

Other involuntary factors identified by Saxegaard (2006), Anderson-Reid (2011) and Pontes and Murta (2012) are deposits, loans, government securities, opportunity cost, the lending rate, foreign exchange reserves, the foreign exchange rate, political instability, financial crisis and civil war. In addition, Khemraj (2009) stated that commercial banks in Guyana accumulate excess reserves due to the desire for a minimum rate of interest and an unofficial foreign currency constraint. Using an ARDL model, the author found a highly significant and negative coefficient of foreign currency constraint in line with *a priori* expectations. He concluded that commercial banks hold excess reserves primarily for involuntary purposes.

3 Methodology and data

3.1 Variable definitions

To empirically investigate the determinants of excess reserves, careful consideration is given to the selection of explanatory variables and their relevance to PNG. The variable selection is based on previous studies (Agenor et al., 2004; Saxegaard, 2006; Khremjar, 2009; Anderson-Reid, 2011), data availability and domestic features such as monetary policy, financial system, banking activity and macroeconomic environment. In this study, the choice of the dependent variable is excess reserves (XRS) that commercial banks hold in excess of the required limit in central bank accounts and own vaults. Excess reserves are expressed as a ratio of total bank deposits. The independent variables are precautionary and involuntary factors that potentially influence demand for excess reserves in the banking system.

The precautionary variables used in this study are the cash reserve requirement, discount rate and volatility of demand deposits. The cash reserve requirement (CRR) is proxied by a ratio of required reserves to total bank deposits, which measures the impact of regulatory requirement set by the central bank. The cash reserve requirement is a low-cost monetary policy instrument useful for long-term liquidity management. An increase in the cash reserve requirement neutralizes excess reserves in the banking system. The central bank discount rate (DCR) represents the penalty rate. The central bank imposes a penalty when commercial banks fail to meet their liquidity requirements. A high discount rate encourages commercial banks to hold sufficient reserves in their settlement accounts to avoid penalty payments. Thus, the discount rate is expected to have a positive relationship with excess reserves. To include the role of uncertainty in the model, this study employs a volatility measure of demand deposits similar to that used by Khremraj (2009) and Primus et al. (2014). The volatility of demand deposits (VDD) is defined as a moving standard deviation of the demand deposits to total bank deposits ratio. A rise in the volatility of demand deposits induces commercial banks to hold more excess reserves purposely to meet unexpected customer withdrawals. Hence, a positive relationship is expected between volatility of demand deposits and excess reserves.

Commercial banks also demand excess reserves for involuntary reasons, which are structural and cyclical in nature. The central bank primarily accumulates foreign exchange reserves to support the domestic exchange rate, maintain import cover and service external debt. The accumulation of foreign reserves contributes positively to excess reserves holdings. However, sometimes the central bank sells foreign reserves mainly in US dollars to banks and non-bank traders. Commercial banks use their reserves to buy foreign currencies and invest in safe foreign assets, which in turn lowers the level of excess reserves. The foreign exchange reserves (FER) variable is represented by a ratio of foreign reserves to total central bank assets. A study by Vellodi et al. (2012) stated that one of the possible reasons for commercial banks to hold excess reserves is the weak demand for private sector loans. The ratio of private sector credit to total bank assets (PCR) captures the impact that demand for loans has on bank excess reserves. An increase (decrease) in demand for private sector credit is expected to reduce (increase) excess reserve holdings in the banking system.

In an underdeveloped banking sector, making deposits and accessing loans become equally challenging to private sector customers. The deposit (PSD) component is represented by a ratio of private sector deposits to total bank assets in this study. Commercial banks hold substantial amount of deposits in interest bearing accounts due to limited investment opportunities and high liquidity risk (Pontes and Murta, 2012). Commercial banks are expected to accumulate excess reserves as private sector deposits increase and vice versa. The treasury bill rate (TBR) is the weighted average rate and it captures the opportunity cost of holding excess reserves that would have been invested in safe government securities. Commercial banks find it unattractive to bid for government securities under the falling interest rate regimes because the opportunity cost is low. Hence, the treasury bill rate has a negative relationship with excess reserves. In PNG, the degree of influence that involuntary factors have on excess reserves are closely associated with commercial banks' ability to make domestic loans and to invest in government securities and foreign assets. Full description of the variables and source of the data are provided in Table A1 in the Appendix.

3.2 Data

This study uses monthly time-series data covering the period from January 2002 to December 2017, a total of 192 observations per variable. The selected sample period is constrained by data availability, particularly the exposure of excess reserves in the banking system. All variables are expressed as ratios except the discount rate and treasury bill rate, which are in percent. The volatility of demand deposits is measured as the moving standard deviation of the logarithm of demand deposits. Thereafter, all variables are transformed to natural logarithmic form except the volatility of demand deposits, which is already in logarithmic form through the volatility conversion (see, Aikaeli, 2006; Hamma and Ejbari, 2013; Primus et al., 2014). This allows estimated coefficients to be interpreted in terms of elasticities. Table 1 provides some descriptive statistics of the variables employed in the study. The Jarque-Bera statistics show that all variables except excess reserves and private sector credit are not normally distributed at the 5 percent significance level. The small standard deviation values indicate that all variables are generally less volatile relative to their respective mean values. The data for each variable is fairly symmetric and moderately skewed as indicated by values of skewness. The data is sourced from various Quarterly Economic Bulletin publications of the Bank of Papua New Guinea (BPNG), the central bank.

Table 1: Descriptive statistics of variables, Jan 2002 to Dec 2017
All variables are expressed in natural logarithms.

Variable	Syb	Mean	SD	Max	Min	Skew	JB
Excess Reserves	XRS	-2.892	0.375	-2.005	-4.046	-0.303	2.969
Cash reserve requirement	CRR	-2.944	0.504	-2.231	-3.863	0.086	21.570**
Discount rate	DCR	2.170	0.251	2.862	1.946	0.916	64.166**
Volatility demand deposits	VDD	0.031	0.016	0.082	0.007	0.994	36.159**
Foreign exchange reserves	FER	-0.244	0.182	-0.062	-0.671	-0.868	29.315**
Private sector credit	PCR	-1.096	0.062	-0.924	-1.244	0.272	2.567
Private sector deposits	PSD	-1.108	0.273	-0.598	-1.619	-0.130	8.455**
Treasury bill rate	TBR	1.663	0.521	2.995	0.531	0.778	21.249**

Note: ** represents significance at 5 percent level. Syb, SD, Max, Min, Skew and JB stand for symbol, standard deviation, maximum, minimum, skewness and Jarque-Bera, respectively.

3.3 Model specification

A few studies have been conducted to estimate the demand functions for bank excess reserves in developing countries. This study specifically provides an empirical assessment of precautionary and involuntary variables on excess reserves. The empirical specification employed in the study was developed by Agenor et al. (2004) and has been applied in several other studies, such as Saxegaard (2006), Khremraj (2009), Primus et al. (2014), Nguyen et al. (2015) and Ukeje et al. (2015). The demand function for excess reserves is specified in a linear form as follows:

$$XRS_t = \gamma_0 + \gamma_1 CRR_t + \gamma_2 DCR_t + \gamma_3 VDD_t + \gamma_4 FER_t + \gamma_5 PCR_t + \gamma_6 PSD_t + \gamma_7 TBR_t + \varepsilon_t \quad (1)$$

where XRS_t is the dependent variable, CRR_t, DCR_t and VDD_t are precautionary variables, FER_t, PCR_t, PSD_t and TBR_t are involuntary variables, γ_0 is the constant term, γ_1, γ_2, γ_3, γ_4, γ_5, γ_6 and γ_7 are coefficients to be estimated, and ε_t is the error term. According to the literature, the expected coefficient signs of γ_2, γ_3 and γ_6 are positive while that of coefficients γ_1, γ_5 and γ_7 are negative (see, Saxegaard, 2006; Khremraj, 2009; Pontes and Murta, 2012; Ukeje et al., 2015). γ_4 is expected to be either positive or negative. In order to effectively measure the relationships between excess reserves and their determinants, the ARDL cointegration procedure proposed by Pesaran et al. (2001) is applied in equation (1). The choice of ARDL model is based on stationary properties of the time series (see Section 4.1), previous studies (see Section 3.4) and own expectations (short-run and long-run results).

3.4 ARDL estimation method

The ARDL model is a dynamic single equation that contains lagged values of the dependent variable and current and lagged values of the explanatory variables (Pesaran et al., 2001). The model examines the cointegrating relationship between variables through the work of Pesaran et al. (1996). In order to empirically analyze the long-run relationships and short-run dynamic interactions among variables of interest, the studies of Pesaran and Smith (1998) and Pesaran et al. (2001) have introduced the ARDL cointegration procedure. The procedure is employed in a series of papers, such as Fielding and Shorthand (2005), Aikaeli (2006), Khemraj (2009) and Anderson-Reid (2011), to conduct empirical assessments on demand for excess reserves in their respective countries. This study also employs the ARDL cointegration procedure to estimate the determinants of excess reserves in PNG.

The ARDL model has several advantages as compared to that of other cointegrated regression models. Firstly, the time series variables are to be integrated of order zero, I(0) or integrated of order one, I(1) or a combination of both to enter the model (Pesaran et al., 2001). Secondly, the model is flexible in accepting different optimal lag lengths in different variables. The appropriate lag selection eliminates the residual correlation problem, which mitigates the endogeneity issue among the regressors and thus, provides unbiased estimates (Menegaki, 2019). Thirdly, the model avoids concerns on the number of choices such as the number of endogenous and exogenous variables to be included, the treatment of deterministic elements, and the order of variables. Finally, the error correction model can be derived from the ARDL model through a simple linear transformation. The inclusion of short-run dynamics in the long-run equation through the error correction mechanism corrects the endogeneity bias problem among the regressors (Pesaran and Smith, 1998).

Given these advantages, the ARDL cointegration procedure is considered appropriate for time series analysis. Thus, in this study, following the estimation procedure proposed by Pesaran et al. (2001) and based on equation (1), the ARDL framework is specified as follows:

$$\Delta XRS_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta XRS_{t-i} + \sum_{i=1}^{q} \alpha_{2i} \Delta CRR_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta DCR_{t-i} + \sum_{i=1}^{q} \alpha_{4i} \Delta VDD_{t-i} + \sum_{i=1}^{q} \alpha_{5i} \Delta FER_{t-i} + \sum_{i=1}^{q} \alpha_{6i} \Delta PCR_{t-i} + \sum_{i=1}^{q} \alpha_{7i} \Delta PSD_{t-i} + \sum_{i=1}^{q} \alpha_{8i} \Delta TBR_{t-i} + \beta_1 XRS_{t-1} + \beta_2 CRR_{t-1} + \beta_3 DCR_{t-1} + \beta_4 VDD_{t-1} + \beta_5 FER_{t-1} + \beta_6 PCR_{t-1} + \beta_7 PSD_{t-1} + \beta_8 TBR_{t-1} + \delta_1 DUM_{XRS} + \varepsilon_t \quad (2)$$

where α_0 is the constant term, α_{1i}, α_{2i}, α_{3i}, α_{4i}, α_{5i}, α_{6i}, α_{7i} and α_{8i} are short-run dynamic elasticities, β_1, β_2, β_3, β_4, β_5, β_6, β_7 and β_8 are long-run coefficients, ε_t is a serially uncorrelated error term, $t-1$ is the lag structure, p and q are optimal lag orders of the dependent and independent variables respectively, t is a time script for the month, Δ is the first difference operator, and δ_1 is a coefficient on the dummy variable (DUM_{XRS}) which captures the structural break induced by capital inflows received from high commodity prices and resources boom on excess reserves. The dummy variable is derived from the breakpoint unit root analysis of the variables as shown in Section 4.1. The dummy variable takes 0 until December 2005 and 1 from January 2006 onwards. Equation (2) accounts for short-run and long-run effects and contemporaneous and lagged effects of the regressors.

In the framework described in equations (2), the ARDL bounds cointegration test is performed to determine the existence of a long-run relationship among the variables, assuming that all variables are endogenous. The bounds F-statistic developed by Pesaran et al. (2001) is used to test the joint significance of the coefficients. If the computed F-statistic is above the upper bound critical value, reject the null hypothesis of no cointegration. Similarly, if the computed F-statistic is below the lower bound critical value, do not reject the null hypothesis. However, if the computed F-statistic lies between lower and upper bounds, the test is considered inconclusive. The null hypothesis of a no long-run cointegration against the alternative of a long-run relationship is defined by

H_0: β_1= β_2= β_3= β_4= β_5= β_6= β_7=β_8= 0 (the long-run relationship does not exist)
H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$ (the long-run relationship exists)

Once the long-run relationship between variables under investigation is established (that is, by rejecting the null hypothesis of no cointegration), equation (2) can be reparametrized to include the error correction term (ECT). That is, the short-run dynamics are incorporated in the long-run equation without losing long-run information. This in turn, makes endogeneity bias inconsequential in the model and generates consistent estimates. The error correction representation of the ARDL model is expressed as follows:

$$\Delta XRS_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta XRS_{t-i} + \sum_{i=i}^{q} \alpha_{2i} \Delta CRR_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta DCR_{t-i} + \sum_{i=1}^{q} \alpha_{4i} \Delta VDD_{t-i} + \sum_{i=1}^{q} \alpha_{5i} \Delta FER_{t-i} + \sum_{i=1}^{q} \alpha_{6i} \Delta PCR_{t-i} + \sum_{i=1}^{q} \alpha_{7i} \Delta PSD_{t-i} + \sum_{i=1}^{q} \alpha_{8i} \Delta TBR_{t-i} + \delta_1 DUM_{XRS} + \lambda ECT_{t-1} + \varepsilon_t \quad (3)$$

where the coefficient (λ) of the error correction term indicates the speed of adjustment and long-run causality. The coefficient must be negative and statistically significant to assure that the system converges towards the long-run equilibrium. According to Menegaki (2019), the highly significant coefficient on the error correction term confirms the existence of a long-run relationship between variables under study. The reparameterized equation (3) estimates the short-run dynamic interactions and the long-run relationship of the underlying variables through the OLS procedure.

4 Empirical results

4.1 Unit root tests

The ARDL estimation procedure starts with the unit root tests. There are several unit root testing techniques available in the literature, and in this study, Augmented Dickey-Fuller (ADF), Philips-Perron (PP) and Dickey-Fuller generalized least squares (DF-GLS) unit root tests are employed to check the stationary properties of the variables. The trend and intercept term is included for a unit root test of each variable in level and first difference (Menegaki, 2019). The maximum lag lengths for ADF and DF-GLS are selected using Schwarz information criterion (SIC) while the bandwidth for PP is determined using Bartlett Kernel. Table 2 presents a summary of the results. The ADF and DF-GLS unit root test results suggest that all variables are integrated of order one at the 5 percent level of significance. The PP test results indicate that the volatility of demand deposits is stationary in level while the other variables are stationary at their first difference. The unit root analysis concludes that variables used in the model are integrated of order I(0) and I(1). The ARDL model is suitable when variables under study are integrated of different orders. In addition, unit root tests are performed to ensure that no underlying variable is integrated of order two, I(2) or above.

Table 2: ADF, PP and DF-GLS unit root test results, Jan 2002 to Dec 2017

Variable	ADF test statistic		PP test statistic		DF-GLS test statistic	
	Level	1st difference	Level	1st difference	Level	1st difference
XRS	-2.947	-15.820**	-2.473	-32.289**	-2.959	-18.499**
CRR	-2.437	-10.042**	-2.851	-26.046**	-1.727	-9.243**
DCR	-1.351	-11.538**	-1.592	11.786**	-1.326	-11.521**
VDD	-3.101	-9.317**	-4.204**	-12.378**	-3.096	-9.362**
PSD	-2.028	-17.399**	-2.577	-17.066**	-1.896	-16.226**
FER	-1.133	-11.657**	-1.243	-16.937**	-0.999	-11.270**
PCR	-3.049	-15.995**	-2.898	-15.974**	-3.200	-15.782**
TBR	-1.952	-14.548**	-1.951	-14.551**	-1.941	-14.490**

Note: ** represents significance at 5 percent level.

The conventional unit root tests are weak in the presence of structural breaks in the time series, which may produce spurious results in regression (Assamoi et al., 2020). In order to identify structural breaks, this study applies the breakpoint unit root test developed by Zivot and Andrews (1992), which endogenously determines one structural breakpoint. The test results show that a structural change in excess reserves occurred in January 2006. This structural break might be induced by high commodity prices and resources boom. To verify the detected break date, the structural breakpoint test proposed by Chow (1960) is also performed. The breakpoint unit root test results are reported in Table B1 and Table B2 in the Appendix. For the purpose of regression analysis, a dummy variable is introduced in the model to account for the structural break in the dependent variable of excess reserves.

4.2 Cointegration tests

The next step in ARDL analysis is to perform cointegration tests. Since unit root test results confirm a mixture of I(0) and I(1) variables, the ARDL bounds cointegration test proposed by Pesaran et al. (2001) is applied to examine the long-run relationship between the variables. Prior to performing the bounds cointegration test, the conventional ARDL model specified in equation (2) is estimated. Given the use of monthly data series, the maximum lag length is set to 12 (see, Pesaran and Pesaran, 1997). The general to specific approach suggested by Perron (1997) is applied to reduce the model to a parsimonious representation. The Akaike information criterion (AIC) and SIC are used to identify the optimal lag structure of the model. The SIC automatically selects an optimal lag order of the model as (1,0,4,1,0,0,0,0). The SIC based model is chosen ahead of the AIC case because it has superior predictive power. In addition, the SIC based model is structurally stable and efficient. Table 3 presents the results of the bounds cointegration test.

Table 3: F-bounds test results

Test statistic	Value	Optimal lag structure
F-statistic	13.817**	(1,0,4,1,0,0,0,0)
Significance level	Lower bound critical value I(0)	Upper bound critical value I(1)
10 percent	2.03	3.13
5 percent	2.32	3.50
2.5 percent	2.60	3.84
1 percent	2.96	4.26

Note: ** represents significance at 5 percent level.

The bounds F-statistic is calculated for the case of unrestricted intercept and no trend. According to the results, the computed F-statistic value (13.817) exceeds the upper bound critical values at all significance levels, implying that there is a cointegrating relationship between variables in the presence of a structural break. Hence, short-run elasticities and long-run coefficients of the ARDL model can be estimated.

For sensitivity reasons, since all variables are I(1) in the ADF and DF-GLS unit root tests, the Johansen (1988) cointegration test is performed to ascertain the existence of a long-run relationship between variables. The test specification allows for a linear deterministic trend in data with the selection of intercept term in cointegrating equations. The lag intervals are determined according to information criteria. The trace statistic and maximum eigenvalue statistic discover two cointegrating equations, each at the 5 percent level of significance. Thus, the Johansen cointegration test confirms the F-bounds test results. The Johansen cointegration test results are presented in Table B3 in the Appendix.

4.3 Estimation results and discussion

After confirming the existence of a long-run relationship in the cointegration analysis, this section proceeds with the estimation and analysis of the results. The estimation aims to obtain long-run relationships and short-run dynamic reactions of excess reserves with precautionary and involuntary factors. Using equation (2), a parsimonious representation is determined by SIC in an eight-variable model as (1,0,4,1,0,0,0,0). This specification generates unbiased estimates and explains about 66.0 percent of the variation in demand for excess reserves.

4.3.1 Long-run results

The long-run coefficients of the variables are estimated using equation (2) and results are presented in Table 4. Most of the long-run coefficients are statistically significant and have the expected signs. The exceptions are in the case of cash reserve requirement, volatility of demand deposits and dummy variable. The coefficient of cash reserve requirement is correctly signed but not significant in explaining the demand for excess reserves. The finding conforms to that of Khemraj (2009) and Nguyen et al. (2015), who found that the required reserve ratio has an insignificant impact on excess reserve holdings in Guyana and China, respectively. The finding suggests that a change in the cash reserve requirement does not successfully influence excess reserves in the banking system, making this policy variable ineffective in PNG. In contrast, the studies of Agenor et al. (2004) and Saxegaard (2006) found that the cash reserve requirement effectively reduces excess reserves in commercial banks. The coefficient associated with volatility of demand deposits is statistically insignificant and incorrectly signed. The insignificant result suggests that liquidity risk is not a concern in an environment of persistent excess reserves like PNG. This finding is supported by Khemraj (2009) who concluded in his paper that the volatility of demand deposits is not a significant determinant of excess reserves. Furthermore, the coefficient on the dummy variable representing the structural break induced by high commodity prices and resources boom is found to have no real effect on demand for excess reserves in the long run.

Table 4: Determinants of excess reserves (long-run ARDL estimation results), Jan 2002 to Dec 2017

Variable	Coefficient	SE	t-statistic	p-value
Dependent variable: excess reserves (XRS)				
CRR	-0.032	0.110	-0.294	0.769
DCR	0.986*	0.312	3.160	0.002
VDD	-0.626	1.954	-0.320	0.749
FER	-0.528**	0.245	-2.152	0.033
PCR	-1.125**	0.547	-2.057	0.041
PSD	1.051*	0.222	4.743	0.000
TBR	-0.185***	0.096	-1.925	0.056
DUM_{XRS}	0.099	0.093	1.071	0.286
Constant	-5.218*	0.999	-5.220	0.000
R-squared		0.660		
Adjusted R-squared		0.632		
SE of regression		0.229		
F-statistic		23.976*		
DW statistic		1.997		
Serial correlation LM		0.287(0.751)		
Heteroskedasticity ARCH		1.794(0.169)		
Normality Jarque-Bera		4.647(0.098)		
Specification Ramsey		0.891(0.412)		

Note: *, ** and *** indicate significance levels at 1 percent, 5 percent and 10 percent, respectively. The values in brackets are p-values. The optimal lags are selected by SIC. SE, DW, LM and ARCH stand for standard error, Durbin-Watson, Langrage multiplier and autoregressive conditional heteroscedasticity, respectively. The long-run estimates are based on the levels data.

In line with theoretical expectations, the estimated coefficient of discount rate is found to be positive and statistically significant at a 1 percent level. More specifically, a one percent increase in the discount rate is associated with nearly a 0.99 percent increase in excess reserves. The finding is well in line with previous studies such as Fielding and Shorthand (2005), Bathaluddin et al. (2012) and Kigabo and Gichondo (2018). The finding suggests that commercial banks are highly responsive to a change in penalty rate associated with the liquidity shortfall in central bank accounts. The banks act in such a responsible manner to avoid high penalty costs for illiquidity. The discount rate is the only precautionary variable that significantly influences excess reserves in the long run.

The coefficient associated with private sector deposits is found to have a statistically significant and positive effect on excess reserves at a 1 percent level. As expected, a percent increase in private sector deposits leads to a 1.05 percent increase in excess reserves. The finding is consistent with those of Pontes and Murta (2012) and Ukeje et al. (2015), who discovered that bank deposits contribute positively to excess reserves in Cape Verde and Nigeria, respectively. The significant finding suggests that risk-averse depositors in PNG hold greater portion of their deposits in commercial bank accounts than other deposit-taking institutions. While demand for credit is not a generalized phenomenon in PNG, the estimated coefficient confirms a highly significant correlation with excess reserves. For example, a one percent increase in demand for private sector credit causes a significant reduction in excess reserves by about 1.13 percent. This finding suggests that private sector credit can ease the liquidity pressure in the banking system, where demand for credit is generally low. Similar findings were reported by Saxegaard (2006), Hamma and Ejbari (2013) and Ukeje et al. (2015) that provision of private sector loans by commercial banks significantly lowers excess reserve holdings.

The estimation results indicate that a one percent increase in the purchase of foreign reserves by commercial banks significantly reduces excess reserve holdings by about 0.53 percent. This outcome is possible when the central bank actively sells foreign currencies to commercial banks. The finding is consistent with that of Pontes and Murta (2012) and Ukeje et al. (2015), who established in their papers that international reserves significantly determine excess reserves in the banking system. The coefficient of treasury bill rate, which represents the opportunity cost of holding excess reserves is statistically significant and negative. As expected, excess reserves are reduced by almost 0.19 percent with a one percent increase in the treasury bill rate. The result of this study is supported by findings from previous papers on demand for excess reserves. For example, Maynard and Moore (2005) and Primus et al. (2014) found that the treasury bill rate is a significant determinant of excess reserve holdings. The finding implies that a high rate attracts commercial banks to buy more treasury bills since the opportunity cost of holding excess reserves is high. Of the involuntary variables, the estimated results indicate that private sector deposits and credit have greater impacts on excess reserve holdings than policy-related variables of foreign exchange reserves and treasury bill rate in the long run.

4.3.2 Short-run results

The short-run dynamic coefficients associated with the long-run relationship are computed using equation (3) and results are reported in Table 5. The estimated coefficient of lagged error correction term is correctly signed and statistically significant at a 1 percent level, implying there is a system convergence towards the long-run equilibrium over time. To be precise, the error correction coefficient of -0.651 suggests that at least 65 percent of the disequilibrium between the underlying variables in the previous month is corrected back to the long-run equilibrium in the current month. The coefficient also confirms the existence of a stable long-run relationship between excess reserves and their determining factors.

The short-run results are generally consistent with the long-run estimates in terms of sign and significance for most of the explanatory variables. The short-run dynamic results indicate that the cash reserve requirement, current value of discount rate and dummy variable have no real effect on demand for excess reserves. Even though the Wald test confirms the existence of a joint significance between contemporaneous and lagged coefficients of the discount rate, the summed coefficient (-3.051) has a negative sign. The finding suggests that commercial banks are willing to pay a small increase in the penalty rate and make loans at a higher lending rate since the opportunity cost of holding excess reserves is high. In this case, commercial banks benefit from the difference between the two rates, but most importantly, the provision of loans significantly reduces excess reserves pressure in the banking system. A similar analysis of the penalty rate was made in Primus et al. (2014) for Trinidad and Tobago. The Wald test results are reported in Table B4 in the Appendix.

Contrary to the long-run result, the coefficient on volatility of demand deposits is found to be positively and significantly correlated with excess reserves. More specifically, the estimated coefficient reveals that a one percent increase in demand deposits leads to a 4.50 percent increase in excess reserves. The result is highly consistent with standard banking practice in PNG where short-term drawdowns of government and private sector deposits are common.

Hence, commercial banks normally hold sufficient reserves in their short-term checking accounts to meet unexpected currency withdrawals over the counter and at the automatic teller machine. This finding is in line with the findings of Maynard and Moore (2005), Saxegaard (2006) and Bathaluddin et al. (2012), who established that the volatility of demand deposits positively influences excess reserves in commercial banks. Moreover, the volatility of demand deposits has a greater impact on excess reserves than all other variables in the short run.

Table 5: Determinants of excess reserves (short-run ARDL estimation results), Jan 2002 to Dec 2017

Variable	Coefficient	SE	t-statistic	p-value
Dependent variable: excess reserves (ΔXRS)				
ΔCRR	-0.056	0.163	-0.340	0.734
ΔDCR	0.047	0.620	0.076	0.940
ΔDCR(-1)	-0.846	0.619	-1.366	0.174
ΔDCR(-2)	-0.489	0.625	-0.783	0.435
ΔDCR(-3)	-1.763*	0.615	-2.868	0.005
ΔVDD	4.504**	2.221	2.028	0.044
ΔFER	-0.781***	0.417	-1.873	0.063
ΔPCR	-2.045*	0.677	-3.021	0.003
ΔPSD	1.141**	0.470	2.428	0.016
ΔTBR	-0.352*	0.131	-2.694	0.008
DUM_{XRS}	-0.128	0.231	-0.555	0.579
ECT(-1)	-0.651*	0.069	-9.405	0.000

Note: *, ** and *** indicate significance levels at 1 percent, 5 percent and 10 percent, respectively. Δ is the first difference operator. The short-run estimates are based on the first differenced data except the dummy variable.

Similar to the long-run findings, the estimated coefficients of involuntary variables are statistically significant and have expected signs in line with the *a priori* expectations. The results show that a one percent increase in foreign exchange reserves, private sector credit and the treasury bill rate reduce excess reserves by about 0.78 percent, 2.05 percent and 0.35 percent, respectively. The private sector deposits, on the other hand, significantly adds excess reserves in the banking system. For instance, a one percent increase in private sector deposits increases excess reserves by about 1.14 percent in the short run. These empirical results suggest that involuntary variables are essential in an environment of persistent excess reserves like PNG. Furthermore, it is important to note that the magnitudes of the short-run estimates are slightly greater than the long-run effects for all variables under study. A similar analysis on the magnitude of coefficient was made in Anderson-Reid (2011) for Jamaica. The overall findings reveal that the principal determinants of excess reserve holdings in PNG are variables representing involuntary factors.

4.4 Causality tests

The existence of a cointegrating relationship between variables under investigation suggests the presence of causality in at least one direction. However, it does not indicate the direction of causality between variables. Therefore, it is essential to perform causality tests using standard econometric procedures. This study uses three approaches namely regressors' t-statistic, Wald coefficient test and Granger causality test to detect short-run causality (see, Tursoy and Faisal, 2016). These tests have the advantage of exposing the underlying causal relationships between variables in line with theoretical considerations. The full results of the Wald coefficient test (Table B4) and Granger causality test (Table B5) are reported in the Appendix while t-statistic values are reported in Table 5. The summary results are presented in Table 6.

Table 6: Summary results of short-run causality tests

Variable	t-statistic	Wald F-test	Granger F-test
Dependent variable: excess reserves (XRS)			
CRR	Insignificant	Insignificant	Unidirectional Granger causality
DCR	Significant	Significant	Unidirectional Granger causality
VDD	Significant	Significant	Bidirectional Granger causality
FER	Significant	Significant	Unidirectional Granger causality
PCR	Significant	Significant	Unidirectional Granger causality
PSD	Significant	Significant	Unidirectional Granger causality
TBR	Significant	Significant	Bidirectional Granger causality
DUM_{XRS}	Insignificant	Insignificant	No Granger causality

Note: t-statistics of explanatory variables and F-statistics from Wald and Granger tests indicate short-run causal effects at 1 percent, 5 percent and 10 percent significance levels. Each of these tests can at least serve as robustness for one another.

The test results show that most independent variables indicate unidirectional causality to excess reserves except the volatility of demand deposits and treasury bill rate, which have bidirectional causality. Furthermore, there is no significant causality from the cash reserve requirement and dummy variable to excess reserves in the short run. The long-run causal effects, on the other hand, can be identified through the t-statistic of the error correction term. According to estimation results reported in Table 5, the lagged error correction term coefficient (-0.651) is highly significant, indicating a unidirectional long-run causality running from all other variables to excess reserves through the error correction term. Generally, both long-run and short-run causality tests strengthen the ARDL estimation results. To illustrate, all causality tests show that foreign exchange reserves have a causal effect on excess reserve holdings at the 10 percent significance level.

4.5 Diagnostic and stability tests

Following the ARDL estimation and cointegration analysis, various diagnostic and stability tests are performed to ascertain the fitness of the model. The residual diagnostic test results indicate that the model is free from serial correlation and heteroscedasticity at the 5 percent significance level. The Ramsey and normality test results confirm that the model has no misspecification problem and errors are normally distributed, respectively (see Table 4). To assess the parameter stability of equation (2), this study employs cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests developed by Brown et al. (1975) based on the recursive residuals. As shown in Figure 1, the plots of CUSUM and CUSUMQ of recursive residuals lie within the 5 percent critical bounds, indicating that the model is structurally stable over time. Hence, the relationships estimated between excess reserves and their determinants appear to be plausible.

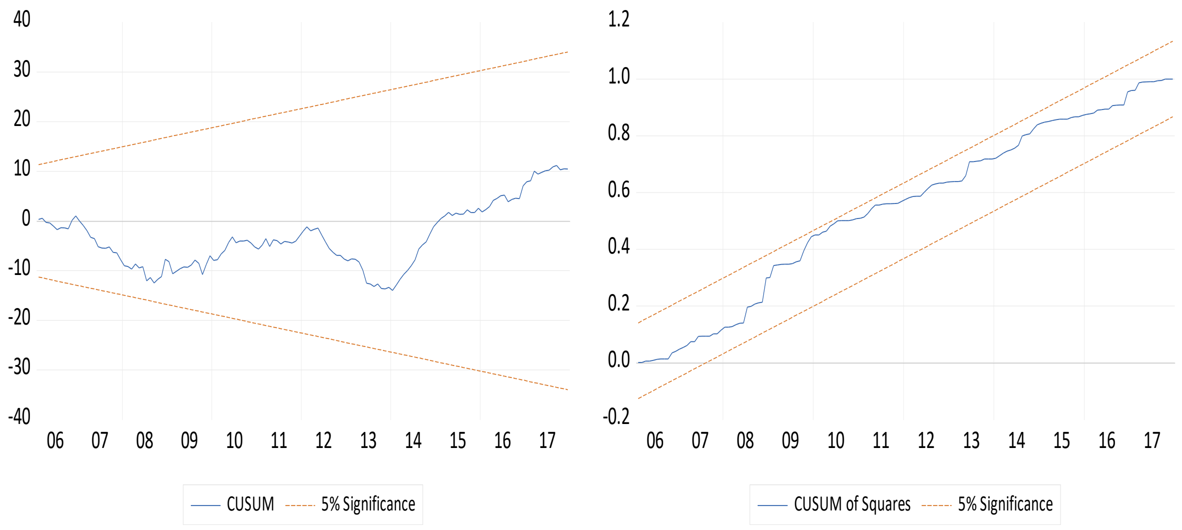

Figure 1: Plots of CUSUM and CUSUMQ of recursive residuals

5 Robustness checks

This study employs the dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) estimation methods developed by Stock and Watson (1993) and Phillips and Hansen (1990) to check the consistency of long-run parameters derived from the ARDL estimation. Some of the past studies that applied the DOLS and FMOLS estimation techniques to check the robustness of ARDL estimation results are that of Priyankara (2018), Menegaki (2019) and Assamoi et al. (2020). The order of integration and long-run relationship established under the ARDL framework are applicable in the DOLS and FMOLS methods since the sample size, sample period and variables remain the same. Hence, no separate stationarity and cointegration tests are required for these cointegrating procedures.

5.1 DOLS method

DOLS is a parametric technique that considers I(1) variables or a mixture of I(0) and I(1) regressors (Stock and Watson, 1993). This cointegrating method deals with the potential serial correlation, endogeneity and simultaneity bias problems by including leads and lags of explanatory variables as additional regressors in the model (Menegaki, 2019). The appropriate selection of leads and lags is essential as it defines the mechanics of DOLS estimation to generate efficient long-run parameters. In this study, the lag selection criterion of SIC chooses leads and lags using a maximum length of 12 consistent with the ARDL estimation. Following Stock and Watson (1993) and based on equation (1), the DOLS model is expressed as follows:

$$XRS_t = c_i + \beta_i X_{it}{}' + \sum_{i=-m}^{i=+m} \pi_i \Delta X_{it+j} + \rho_1 DUM_{XRS} + \varepsilon_{it} \qquad (4)$$

where XRS_t is the dependent variable, X_{it}= $CRR_t, DCR_t, VDD_t, FER_t, PCR_t, PSD_t, TBR_t$ are cointegrating regressors, $\beta_i = \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6, \gamma_7$ are long-run elasticities obtained from least-squares estimates, m represents lengths of leads (+) and lags (-) of the regressors, π_i denotes the estimated coefficients of the led and lagged regressors, $\rho_1$is the coefficient on the dummy variable, c_i is the constant term, ε_{it} is the constant component of the error term, and Δ is the first difference operator. The standard errors are calculated using the Newey-West bandwidth. The long-run dynamic parameters are obtained by estimating regression equation (4) and full results are reported in Table 7.

5.2 FMOLS method

FMOLS is a nonparametric procedure that applies only in the I(1) case for all variables under investigation (Phillips and Hansen, 1990). In this study, the ADF and DF-GLS unit root test results support the use of FMOLS method to check the robustness of the main model. The method modifies both data and parameters to overcome the problems of serial correlation, endogeneity and omitted variable bias (Priyankara, 2018). The inclusion of autocorrelation and endogeneity correction terms in the FMOLS framework generates unbiased long-run parameters. Following Phillips and Hansen (1990) and based on the model given in equation (1), the cointegrated system of FMOLS estimator is expressed as follows:

$$\widehat{\theta_{it}} = \left(\sum_{t=1}^{T} X_{it} X_{it}{'}\right)^{-1} \left(\sum_{t=1}^{T} X_{it}{'} XRS_t{}^{+} - \mathrm{T} \begin{bmatrix} \hat{\lambda}_{it}{}^{+\prime} \\ 0 \end{bmatrix}\right) \quad (5)$$

where XRS_t is the dependent variable, $X_{it} = CRR_t, DCR_t, VDD_t, FER_t, PCR_t, PSD_t, TBR_t$ are cointegrating regressors, DUM_{XRS} is included in X_{it} as a fixed regressor, $XRS_t{}^{+} = XRS_t - \widehat{\omega}_{it}\widehat{\Omega}_{it}{}^{-1}\hat{\mu}_{it}$ is the modified data that corrects endogeneity, $\hat{\lambda}_{it}{}^{+} = \hat{\lambda}_{it} - \widehat{\omega}_{it}\widehat{\Omega}_{it}{}^{-1}\widehat{\Lambda}_{it}$ refers to modified parameters that correct serial correlation, $\widehat{\omega}_{it}$, $\widehat{\Omega}_{it}$ and $\widehat{\Lambda}_{it}$ are long-run covariance matrices of the residuals ($\hat{\mu}_{it}$) computed using the Newey-West automatic bandwidth, and T is the number of time periods. The optimal long-run parameters (θ_{it}) are estimated by running equation (5) and full results are presented in Table 7.

5.3 Estimation results and discussion

The DOLS and FMOLS estimation results support the long-run coefficients of ARDL estimation in terms of sign and significance for most variables. For the case of magnitude, the coefficients of DOLS and FMOLS estimations are slightly larger than the long-run coefficients of the main model. However, one noticeable difference is that the dummy variable, unlike in the ARDL estimation, becomes positive and statistically significant at the 5 percent level in both the DOLS and FMOLS estimations. To illustrate, the DOLS estimation results indicate that a one percent increase in capital inflows received from high commodity prices and resources boom leads to a nearly 0.35 percent rise in excess reserve holdings. This finding is supported by Saxegaard (2006), who found that aid and oil currency inflows are positively correlated with excess liquidity. The diagnostic tests indicate that residuals are normally distributed and serially uncorrelated at the 5 percent significance level in both the DOLS and FMOLS estimations.

Table 7: Determinants of excess reserves (long-run DOLS and FMOLS estimation results), Jan 2002 to Dec 2017

	(i) DOLS method			(ii) FMOLS method		
Variable	Coefficient	SE	p-value	Coefficient	SE	p-value
Dependent variable: excess reserves (XRS)						
CRR	-0.073	0.121	0.545	-0.138	0.106	0.192
DCR	0.625***	0.363	0.086	0.827*	0.314	0.009
VDD	-1.248	2.180	0.568	-1.714	1.904	0.369
FER	-0.571**	0.287	0.048	-0.798*	0.252	0.002
PCR	-1.127***	0.657	0.088	-1.219**	0.561	0.031
PSD	0.967*	0.240	0.000	0.961*	0.217	0.000
TBR	-0.243**	0.113	0.032	-0.316*	0.097	0.001
DUM_{XRS}	0.348**	0.140	0.014	0.270**	0.123	0.030
Constant	-6.213*	1.433	0.000	-6.917*	1.241	0.000
R-squared		0.583			0.544	
Adjusted R-squared		0.545			0.524	
SE of regression		0.254			0.259	
Long-run variance		0.127			0.109	
Serial Correlation LM		0.138(0.711)			0.035(0.628)	
Normality Jarque-Bera		3.860(0.145)			5.720(0.057)	

Note: *, ** and *** indicate significance levels at 1 percent, 5 percent and 10 percent, respectively. The values in brackets are p-values.

6 Other fundamental factors influencing excess reserves

Apart from the variables included in the empirical model, there are other important factors influence excess reserves in the banking system. First, demand for loans is weak in PNG due to high cost of borrowing and stringent credit requirements. Commercial banks use their oligopolistic market power to charge high lending rates that compensate for risks and marginal transaction costs. In situations where the customers cannot afford the desired minimum interest rates, commercial banks hold surplus funds. Commercial banks also manage lending risk by imposing strict requirements such as clearly registered collaterals and high equity contributions but these requirements make difficult for marginal customers to access loans. As loans become unattractive, commercial banks accumulate excess reserves. Furthermore, big companies mainly of foreign origin are well capitalized and do not require domestic loans to fund projects especially in the resources sector (Vellodi et al., 2012). Second, PNG government receives its revenues from various sources such as taxes, dividends and interest payments. The government normally keeps the revenues in domestic accounts at the central bank and commercial banks. However, in recent years, the government has held most of the funds in commercial bank accounts (BPNG, 2017). These funds contribute directly to accumulation of excess reserves. Moreover, public revenues that are not efficiently utilized by the three levels of government in PNG also reach commercial bank accounts. The transfer of government deposits to its accounts at the central bank is a cheap option to reduce excess reserves in the banking system. Third, PNG has experienced foreign exchange shortages since 2014 (IMF, 2017). Hence, BPNG has rationed foreign reserves that caused a large backlog of foreign exchange orders. This implies that businesses cannot fully buy foreign goods, invest in foreign assets, repatriate profits and dividends or repay foreign loans. As firms continue to hold most of the funds intended for foreign payments in domestic commercial bank accounts, the stock of excess reserves increases.

7 Conclusion

Commercial banks in developing countries hold sufficient cash reserves to manage liquidity risk. However, holding substantial reserves beyond the regulatory requirements poses several undesirable implications on the economy. This paper provides some insights into the demand for excess reserves by commercial banks in PNG. Specifically, using the ARDL model, the paper has empirically investigated the potential determinants of excess reserves for the period January 2002 to December 2017. The short-run and long-run coefficients of precautionary and involuntary variables were estimated to determine their respective impacts on excess reserves. In the long run, the discount rate and private sector deposits indicate significantly positive effects while foreign exchange reserves, private sector credit and the treasury bill rate have significantly negative influences on excess reserves. In the short run, the findings reveal that the discount rate, volatility of demand deposits, foreign exchange reserves, private sector deposits, private sector credit and the treasury bill rate significantly influence excess reserves in commercial banks. However, the cash reserve requirement has an insignificant impact on excess reserve holdings. The findings strongly conclude that commercial banks hold unremunerated excess reserves for involuntary purposes, which supports the results of previous studies such as Saxegaard (2006), Khemraj (2009), Pontes and Murta (2012), Hamma and Ejbari (2013) and Ukeje et al. (2015). In the robustness analysis, the estimated results of the DOLS and FMOLS methods support the long-run dynamic estimates of the ARDL model.

Moreover, the alternative results establish that during the period of high commodity prices and resources boom, commercial banks hold more excess reserves.

There are several policy implications can be drawn from the findings of this paper. An interesting finding worth considering is the insignificant coefficient of cash reserve requirement. The empirical evidence clearly indicates that the cash reserve requirement does not perform effectively to achieve sound reserves management in the banking system. The data from BPNG confirms that although the cash reserves requirement was increased several times during the sample period, the level of excess reserves continued to remain high. Hence, further adjustment to the cash reserve requirement may distort the banking system. To make this policy variable effective in controlling excess reserves, this study supports a policy suggestion made by Vellodi et al. (2012) for BPNG to pay interest on the balances that commercial banks hold above the required limit, which will encourage banks to voluntarily transfer excess funds to their required reserves accounts at the central bank. Others such as Nguyen et al. (2015) suggested that if the cash reserve requirement fails to reduce excess reserves, commercial banks may alternatively increase credit supply. However, in PNG, the demand for loans is extremely weak due to high cost of borrowing and stringent credit requirements. The monetary authority may consider reviewing the lending rates and relaxing loan requirements to stimulate domestic borrowings.

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Appendix A: Data

Table A1: Variable descriptions and data sources

Variable	Symbol	Description	Source
Excess reserves	XRS	Ratio of bank excess reserves to total bank deposits. Both excess reserves and total deposits are denoted in millions of kina.	BPNG and author
Cash reserve requirement	CRR	Ratio of required reserves to total bank deposits. The required reserves are derived using the cash reserve requirement and total bank deposits, and are denoted in millions of kina.	BPNG
Discount rate	DCR	The rate at which commercial banks borrow under the central bank's repurchase agreement facility and is directly linked to the policy signalling rate (in percent). The discount rate is a proxy for penalty rate.	BPNG
Volatility of demand deposits	VDD	Ratio of demand deposits to total bank deposits. The demand deposits are denoted in millions of kina. The ratio is transformed to a volatility measure as the moving standard deviation. Equation (6) defines the volatility of demand deposits with an averaging period (n) of 12 months. $\text{vol}VDD_t = \left[\left(\frac{1}{n}\right)\sum_{i=1}^{n}(VDD_{t-i} - \overline{VDD})^2\right]^{1/2}$ (6)	BPNG and author
Foreign exchange reserves	FER	Ratio of foreign exchange reserves to total central bank assets. Both foreign reserves and central bank assets are denoted in millions of kina.	BPNG
Private sector credit	PCR	Ratio of private sector credit to total bank assets. Both private sector credit and total bank assets are denoted in millions of kina.	BPNG
Private sector deposits	PSD	Ratio of private sector deposits to total bank deposits. The private sector deposits are denoted in millions of kina.	BPNG
Treasury bill rate	TBR	Treasury bill rate is the weighted average rate for treasury bills auctioned at the open market operations (in percent). It accounts for opportunity cost of holding excess reserves in the government security market.	BPNG
Dummy	DUM	Dummy variable represents the structural break induced by high commodity prices and resources boom in the dependent variable (excess reserves).	Author

Table A2: Correlation between variables, Jan 2002 to Dec 2017
All variables are expressed in natural logarithms.

	XRS	CRR	DCR	VDD	FER	PCR	PSD	TBR
XRS	1.000							
CRR	-0.427	1.000						
DCR	0.151	-0.205	1.000					
VDD	-0.344	-0.555	0.119	1.000				
FER	-0.377	-0.664	-0.163	0.303	1.000			
PCR	-0.178	0.132	0.586	0.039	-0.323	1.000		
PSD	0.426	-0.667	0.733	0.368	0.322	0.306	1.000	
TBR	-0.213	-0.107	0.746	0.178	-0.406	0.644	0.522	1.000

Note: The correlation analysis indicates that the strength of association between excess reserves and independent variables ranges from 15 percent to 43 percent. Furthermore, the independent variables show either a positive or negative correlation with excess reserves. In particular, the correlation coefficient of discount rate exhibits a weaker association with excess reserves compared to other variables.

Appendix B: Empirical tests

Table B1: The structural breakpoints of Zivot-Andrews unit root test

Variables	t-statistic	Break date	Result
XRS	-5.053***	2006M01	Stationary
CRR	-3.026	2010M10	Non-Stationary
DCR	-5.134**	2008M06	Stationary
VDD	-5.426**	2008M01	Stationary
FER	-3.202	2006M05	Non-stationary
PCR	-4.885***	2008M01	Stationary
PSD	-3.149	2005M12	Non-stationary
TBR	-3.180	2006M07	Non-stationary

Note: ** and *** represent significance levels at 5 percent and 10 percent, respectively. The results show one structural breakpoint for each variable.

Table B2: Structural change for Jan 2006 using Chow breakpoint test

Chow Breakpoint Test: 2006M01		
Statistic		p-value
F-statistic	5.523	0.000
Log likelihood ratio	43.005	0.000
Wald Statistic	44.185	0.000

Note: The null hypothesis is: no breaks at specified breakpoints. The study rejects the null hypothesis since the F-statistic is statistically significant. This implies that a structural break exists in January 2006 for excess reserves.

Table B3: Johansen cointegration test results

Null hypothesis	Trace statistic	p-value	Eigenvalue statistic	p-value
None ($r = 0$)	204.730**	0.000	62.031**	0.004
At most 1 ($r \leq 1$)	142.699**	0.003	51.768**	0.012
At most 2 ($r \leq 2$)	90.931	0.103	32.521	0.275
At most 3 ($r \leq 3$)	58.410	0.287	19.577	0.785

Note: r indicates number of cointegrating vectors. **denotes rejection of the null hypothesis at 5 percent significance level.

Table B4: Wald test results of short-run ARDL estimation

Variable	Coefficient	F-statistic	p-value
ΔCRR	-0.056	0.115	0.734
ΔDCR	-3.051**	3.136	0.016
ΔVDD	4.504**	4.113	0.044
ΔFER	-0.781***	3.10	0.063
ΔPCR	-2.045*	9.122	0.003
ΔPSD	1.141**	5.896	0.016
ΔTBR	-0.352*	7.258	0.008
DUMXRS	-0.128	0.308	0.579

Note: *, ** and *** indicate significance levels at 1 percent, 5 percent and 10 percent, respectively.

Table B5: Pairwise Granger causality test results

Null Hypothesis:	Obs	F-statistic	Probability
CRR does not Granger Cause XRS	191	8.003	0.005*
XRS does not Granger Cause CRR		0.057	0.812
DCR does not Granger Cause XRS	191	7.269	0.008*
XRS does not Granger Cause DCR		0.052	0.820
VDD does not Granger Cause XRS	191	9.271	0.003*
XRS does not Granger Cause VDD		4.879	0.028**
FER does not Granger Cause XRS	191	5.399	0.021**
XRS does not Granger Cause FER		0.070	0.792
PCR does not Granger Cause XRS	191	7.113	0.006*
XRS does not Granger Cause PCR		1.229	0.269
PSD does not Granger Cause XRS	191	5.847	0.017*
XRS does not Granger Cause PSD		0.338	0.562
TBR does not Granger Cause XRS	191	3.061	0.080***
XRS does not Granger Cause TBR		3.870	0.051**
DUM_{XRS} does not Granger Cause XRS	191	0.874	0.351
XRS does not Granger Cause DUM_{XRS}		0.278	0.598

Note: *, ** and *** indicate significance levels at 1 percent, 5 percent and 10 percent, respectively. Lag length is 2. Obs stands for observations.