Central Bank Bills and the Exchange Rate: The Case of Papua New Guinea

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ABSTRACT

This paper presents a simple model of how the sale of central bank bills (CBBs) serves as an effective tool of exchange rate management in the case of Papua New Guinea. We employ a VAR approach and find that the quantity of CBBs rather than the short-term interest rate elicits the largest movement in the exchange rate. Moreover, we find evidence that banks hold non-remunerated excess reserves at a non-zero lower bound rate of interest. This is indirect evidence that policymakers must sterilize excess reserves not for fear of losing control of interest rate but for exchange rate management. Our model and empirical results make a strong case that the sale of CBBs can simultaneously support exchange rate stability and money-financed fiscal deficits. The CBBs help to quarantine the excess reserves injected through monetary financing.

KEY WORDS: central bank bills, exchange rate, excess reserves, monetary policy

JEL Codes: E40, E42, E50, E58

1. Introduction

This paper contributes to a growing literature which underscores the point that one objective and one instrument may not be appropriate for developing and many emerging economies (Borio 2019, Blanchard 2011, Aizenman 2019). Besides foreign exchange intervention, which has an upper limit, the Bank of Papua New Guinea (BPNG) must also sell central bank bills (CBBs) to stabilize the exchange rate. This finding proposes one transformative opportunity to policymakers; that is, the ability to undertake monetary financing while stabilizing the exchange rate. As long the monetary authority sells CBBs, money-financed fiscal deficits do not generate the standard prediction of uncontrolled inflation. To the best of our knowledge, this is the first article that

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1 The paper benefited from helpful comments and suggestions by Dr. Angus Chu and Dr. Giorgos Gouzoulis. Errors which remain are our responsibility.
formally models and empirically verifies the hypothesis that the sale of central bank bills appreciates the nominal exchange rate. The contemporary literature focuses on shocks emanating from an interest-rate instrument or the required reserve ratio (Primus 2016), as well as from dual instruments: interest rate and foreign exchange reserves (Castillo 2014). Yet, another aspect of the literature looks at interest rate versus a money instrument for attaining financial stability and concludes that the former is better (Goodhart et al. 2011).

Borio (2019) acknowledges that the practice of multiple instruments-one policy goal – e.g. dual instruments of foreign exchange intervention and sterilization to target the exchange rate – is one where monetary policy action has preceded economic theory. Thus, this work is an important step in addressing this topic. The theoretical and empirical analyses explain why central banks in developing countries must ‘mop up’ or swap out persistent non-remunerated excess reserves with an interest-earning domestic security. It is a noteworthy stylized fact that many developing economies have banking systems that are flushed with excess reserves – banks’ holdings of liquidity beyond that imposed by the required reserve ratio (Khemraj 2014). Policy makers in developing economies have employed CBBs or Treasury bills to sterilize excess reserves since the period of financial liberalization from the early 1990s (Gevorkyan 2015, Gray and Pongsaparn 2015, Nyawata 2012). There are essentially two justifications for this operation: (i) the monetarist approach that argues how excess reserves engender credit expansion, excessively low interest rates, currency depreciation and inflation (Saxegaard 2006) and (ii) the policy concern of developing the market-based interest rate instrument (Gray and Pongsaparn 2015).

Based on the stylized facts that bankers in Papua New Guinea (PNG) have a liquidity preference for non-remunerated excess reserves, which becomes perfectly elastic at a non-zero lower bound rate of interest, the fear of losing interest rate control and excessive credit creation is unjustified. It follows that the removal of excess reserves requires new justifications. To this end, we present a simple model that outlines why mopping up excess reserves via one-sided sales of CBBs is a necessary instrument of exchange rate targeting. We envision three basic reasons for the sale of CBBs: (i) the inadequacy of foreign exchange intervention; (ii) to curtail capital outflow, which can undermine exchange rate stability; and (iii) to maintain banks’ satisficing profits in the national currency. During periods of low profitability, banks’ can exercise market influence to

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2 There is no interest paid on excess reserves in Papua New Guinea.
induce a nominal depreciation (a wider bid-ask spread), which increases profitability in foreign currency trading (Khemraj 2014, p. 109). Thus, CBBs maintain banks’ target profits without compromising exchange rate stability.

We use a VAR model to test our hypothesis that the sale of central bank bills appreciates the nominal exchange rate. The data is sourced from the BPNG and the estimation is conducted using monthly data for the period 2000: Jan to 2019: June. We find that the quantity of CBBs elicits the largest movements in the exchange rate as compared to the short-term interest rate. More specifically, our results show that the sale of CBBs appreciates PNG’s currency relative to the US dollar. We conclude that this is evidence of a second instrument that targets the exchange rate. The results also demonstrate that a CBB shock increases the quantity of foreign currencies traded in the domestic market, while the interest-rate shock produces a negative adjustment. These varied results show that the quantity of CBBs serves to save or economize on scarce foreign currencies. It follows that the interest rate may not be the appropriate instrument if the objective is to stabilize the exchange rate and conserve scarce foreign currencies.

In our view, the case of PNG fits a wider group of countries with similar stylized facts: (i) oligopoly banks with a liquidity preference for non-remunerated excess reserves; (ii) exchange rate targeting; and (iii) persistent interest-earning liquid assets in excess of the required macro-prudential level. Though we expect our results to hold in this class of countries, many more empirical studies need to be done before we can confidently derive general implications.

The remainder of the paper is organized as follows. Section 2 provides key stylized facts in PNG and Section 3 develops our theoretical model. In Section 4, we present our empirical results and section 5 discusses the implications of the findings. Section 6 concludes.

2. Institutional Background
In 2001, the Bank of Papua New Guinea (BPNG, the central bank) adopted a policy rate called the Kina Facility Rate (KFR) in order to signal the monetary policy position of the central bank. In practice, adjustments in the KFR have been less frequent with the current rate maintained at 6.25 percent since its last change in 2012. Policymakers expected the KFR to affect market rates, particularly lending and deposit rates. To this end, the BPNG introduced a Repurchase Agreement Facility (RAF) whose interest rate is determined on a margin from the prevailing KFR.
One factor curtailing the use of the interest-rate instrument – the KFR – is the persistence of excess reserves. As a consequence, banks do not borrow from the BPNG and the latter never needs to inject liquidity into the banking system. Therefore, the KFR becomes irrelevant and the interest-rate instrument ineffective. In fact, a BPNG study finds that the interest rate transmission mechanism does not work when there are excess reserves (Vellodi et al. 2012, Ofoi 2018, David and Nants 2006). However, these researchers contend that excess reserves do affect the exchange rate and by extension, the rate of inflation. To effectively target the latter, in 2004 the BPNG introduced the use of Central Bank Bills (CBBs) to sterilize or ‘mop up’ the excess reserves in the banking system. Two pieces of conventional wisdom motivate this action: (i) the notion that excess reserves engender credit expansion, excessively low interest rates, currency depreciation and thereby, inflation (Saxegaard 2006); and (ii) the need to nurture the development of a market-based interest rate rule (Gray and Pongsaparn 2015). The CBBs form part of the liability of the BPNG’s balance sheet and also have maturity features similar to the government’s Treasury bills. Further, the CBBs were introduced at the time when the government refined its debt strategy to offer longer term Inscribed Stocks and less short-term Treasury bills (BPNG 2007).

Figure 1 Central bank bills, exchange rate and excess reserves – 2004: June to 2019: June

Figure 1 presents some stylized facts. First, it illustrates the ratio of CBBs to excess reserves and it has always exceeded 4 throughout the sample period. This implies that there is no
complete sterilization and can partly explain why excess reserves remain persistent. Note carefully that the ratio has exceeded 80 in July 2008, which suggests that the BPNG had undertaken extensive sterilization at the outbreak of the global financial crisis. Why might sterilization be necessary? In a period of global financial stress, many emerging markets and other developing countries experienced significant capital flight – a phenomenon once again being repeated during the COVID-19 shock causing the dollar to appreciate noticeably as we revise this paper. The anomaly in which capital moves from developing to advanced economies during economic stress in the latter can be explained by a world hierarchy of currencies (Hofmann et al. 2020, Fields and Vernengo 2013, McKinnon 2001).

One way of slow down the capital flight is to offer the domestic private sector an interest-earning financial instrument such as CBBs or Treasury bills. This domestic security – a liability to the central bank – is an important tool of foreign exchange management. The ratio of CBBs to excess reserves has since settled on an average of around 5 to 1 since 2012. Notwithstanding the persistent one-sided sterilization, excess reserves averaged 10 percent of the monetary base (MB) for the entire period. Moreover, the scaled exchange rate of the Kina relative to the US dollar (US$/Kina × 100) has fluctuated between 30 and 50. The Kina appreciated relative to the dollar from 2004 to around the second quarter of 2012 and has since depreciated. An increase in the value means the Kina appreciated against the dollar, while a decrease indicates an appreciation.

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3 Observe that our use of the term sterilization is different from its meaning in the Mundell-Fleming world. Mundell, in particular, envisaged the central bank using domestic securities from the asset side of its balance sheet akin to classical open market operations (Moosa and Bhatti 2010). Sterilization in our world means the monetary authority sells a domestic-currency security to the private sector in order to remove excess reserves – most likely injected when the government writes checks on its deposit at the central bank. This official deposit is also on the liability side of the balance sheet.

4 The actual exchange rate, expressed in direct quote, can be obtained by diving the scaled number by 100. The scaling was done for presentation purpose. An increase means the Kina has appreciated while a decrease shows a depreciation.
Figure 2 depicts bankers’ demand for excess reserves or their liquidity preference curve, which becomes perfectly elastic at a non-zero rate of interest – the 28-day rate on CBBs. The plot uses locally weighted regression to extract the banks’ liquidity preference and its negative slope indicates that bankers are prepared to part with excess reserves and purchase CBBs only at higher rates of interest. The demand curve becomes flat around 2.5 percent, which means that CBBs and excess reserves become perfect substitutes at this minimum rate. We call this the non-zero lower bound and it demonstrates the degree of market power bankers hold in the security market.

That excess reserves and CBBs are perfect substitutes at around 2.5 percent does not preclude bankers from engaging in credit creation or demanding foreign assets. In other words, given excess reserves, bankers rearrange their portfolios to maximize returns. Given the non-zero lower bound of 2.5 percent, bankers will demand a mark-up on this minimum rate from the loan market or choose to hold excess reserves or CBBs. It follows that foreign assets become the principal outlet for investing the non-remunerated excess reserves. However, transaction cost, risk and shortages of foreign currency can prevent complete portfolio adjustment, thus the stylized fact of persistent excess reserves (Figures 1 and 2). Two implications follow: (i) domestic and foreign
assets are imperfect substitutes and (ii) bankers continually search for foreign currency to unload their holdings of excess reserves. Therefore, a foreign currency shortage or constraint prevents bank and non-bank actors from converting all surplus money balances into foreign assets (Khemraj 2009).

The foreign currency constraint occurs because there could be a contemporaneous mismatch between the stock demand for foreign exchange and the stock supply in the local market. If the stock demand is greater than the stock supply, there is a short-term FX constraint and not everyone who wants hard currencies will get them. When the stock supply is greater than demand, surplus Kina balances (excess reserves) could be exchanged for foreign-currency assets. The BPNG conducts buying and selling operations of foreign exchange in the domestic FX market, thereby actively managing the FX constraint. However, it is crucial to note that the BPNG does not explicitly set a hard exchange rate target but tends to lean against nominal depreciations relative to the US dollar.

When the BPNG buys foreign currency, it injects liquidity into the banking system and ergo, contributes to persistent excess reserves in the banking system. The BPNG increases and decreases its holdings of international reserves when the FX constraint is non-binding and binding respectively. Figure 3 illustrates this stylized fact, where there is an inverse relationship between the foreign exchange constraint and the BPNG’s net intervention in the foreign exchange market. The BPNG sells foreign currency to the domestic market (positive net interventions) when the foreign exchange constraint is binding or negative as shown in Figure 3, and the reverse holds. This indicates that the central bank is pursuing an exchange rate mandate – even if it does not declare a hard peg as in the case of Barbados, the Eastern Caribbean Currency Union, Belize, The Bahamas and others. This policy is understandable given that there is evidence of a strong exchange rate pass-through to inflation in Papua New Guinea (Samson et al. 2006). In addition, Volz (2015) includes PNG in a panel regression of twenty-two countries measuring substantial pass-through from the exchange rate and terms of trade to domestic prices. Moreover, David and Nants (2006) empirically demonstrate that the monetary transmission mechanism is more effective through the exchange rate as opposed to the interest rate channel in Papua New Guinea.
Two conclusions are drawn from this short overview. First, the stylized fact that exchange rate changes have high pass-through to prices necessitates foreign exchange market intervention. Second, persistent excess reserves can compromise credit and exchange rate stability, thus the need for sterilization through CBBs. However, given the stylized fact that banks have a liquidity preference at a non-zero lower bound rate, the fear that excess reserves can lead to excessive credit creation is not likely to hold.

3. Conceptual Framework
In this section, we sketch the basic mechanics of how the sale of CBBs might target the exchange rate through channels unrelated to constraining credit creation. This approach is based on the stylized fact that banks in Papua New Guinea have a liquidity preference, where they choose to hold non-remunerated excess reserves at a non-zero rate of interest. Given banks’ liquidity preference, there is no tendency for excessive credit creation and ergo, little justification for sterilization through the sale of CBBs. However, we present new channels through which the use of CBBs remains a critical tool for exchange rate targeting. We envision three basic reasons for
the sale of CBBs: (i) CBBs become necessary to lean against the tendency of nominal depreciations as the BPNG must maintain a minimum level of international reserves, which proves FX market interventions inadequate in maintaining the exchange rate target; (ii) CBBs are required to curtail capital outflow and conserve on scarce foreign exchange; and (iii) CBBs serve to maintain banks’ satisficing profits. This latter justification becomes critical during periods of foreign currency shortages that prevent banks from investing in foreign assets. Since excess reserves incur an opportunity cost, banks’ can exercise market influence and increase the bid-ask spread (induce a nominal depreciation) in the foreign exchange market to increase profitability from foreign currency trading. The sale of CBBs allows banks to maintain target profits without compromising exchange rate stability (Khemraj 2014, p. 109).

In Figure 4, we illustrate the basic rationale for the sale of CBBs in maintaining an exchange rate target. The demand curve for the local currency (monetary base) – the Kina – is inversely related to its price in the US dollar relative to the Kina, where a currency appreciation is indicated by an increase in the exchange rate (direct quote: $/Kina). As the Kina appreciates, economic agents can purchase larger quantities of US-denominated currencies and thereby, demand less of the local currency or monetary base. Conversely, the supply of the monetary base is positively related to the nominal exchange rate, where a currency appreciation relative to the dollar encourages economic agents to increase their supply of the local currency in exchange for the US dollar. When the demand and supply for the monetary base are in equilibrium – point A – the expected exchange rate ($^e$) is equal to the central bank’s long-term target ($\bar{S}$).

Countries like Papua New Guinea face a long-term foreign currency constraint that engenders a tendency for nominal depreciations. In the long run, the demand for the national currency decreases, which creates a long-term expectation of depreciation against the dollar from $S_1^e$ to $S_2^e$ (where $S_2^e < \bar{S}$) – the demand curve shifts inward from $D_1$ to $D_2$. Moreover, governments tend to increase the supply of reserve money (or base money) by writing checks on their deposit at the central bank. This process injects surplus money balances into the banking system and shifts the supply curve outward from $S_1$ to $S_2$, thus inducing a further expected depreciation from $S_2^e$ to $S_3^e$ (where $S_3^e < S_2^e < \bar{S}$).
One way to return market expectation to $S_1^e = \overline{S}$ is to intervene into the local FX market and sell hard currencies. This intervention contracts the supply of Kina and shifts the supply curve from $S_2$ to $S_1$ and reaches equilibrium at point B. However, this does not bring expectation in line with the initial target – the market is at point B but we need to be at point-C equilibrium. Crucially, the monetary authority does not have an unlimited amount of international reserves to steer the market to the initial equilibrium exchange rate at point C. Further sale of international reserves relative to its purchase can undermine the target exchange rate and financial stability (Obstfeld et al. 2010). We contend that the central bank can steer expectations toward point-C equilibrium through the sale of CBBs – an interest-earning security in the national currency. When this policy is implemented, the supply curve shifts from $S_1$ to $S_3$ and restores the initial equilibrium exchange rate ($S_1^e = \overline{S}$) with a lower monetary base. It is important to emphasize that the sale of CBBs to quarantine excess reserves is not the same as open market operations. As a matter of fact, in most developing economies the central bank never does reverse repurchase agreements, just continual one-sided sale of the central bank security.

To present our insights more clearly, we sketch the basics through a formal but simple model. Equation (1) represents the condition for exchange rate adjustment under portfolio-balance equilibrium. The nominal exchange rate is expressed as a direct quote, where one local currency
unit buys the US$. An increase in the spot rate \( S_t \) indicates an appreciation of the Kina and a decrease signals a depreciation. This approach extends Dooley and Isard (1983, p. 687) and involves the introduction of a transaction-cost component \( v_t \). There are transaction costs associated with finding the foreign currency before investing in an asset overseas.

\[
\Delta S / S_{t-1} + r_{F,t} = r_{B,t} + v_t
\]  

(1)

The return on the foreign asset for investing a unit of money is given by \( \Delta S / S_{t-1} + r_{F,t} \), where \( r_{F,t} \) is the foreign rate of return. It follows that the amount earned on the foreign asset has an exchange rate component \( \Delta S / S_{t-1} \) and the foreign interest rate \( r_{F,t} \). Moreover, \( r_{B,t} + v_t \) is the return on the domestic asset \( r_{B,t} \) plus the friction cost.

Rearranging Equation (1) produces an adjustment equation for the nominal exchange rate – Equation (2). Note carefully that Equation (2) shows that the domestic and foreign interest rate differential, plus the transaction costs associated with acquiring foreign exchange determine the exchange rate adjustment. The latter point demonstrates why the uncovered interest parity condition may not produce immediate exchange rate adjustments – given interest rate differential, economic agents must first acquire foreign exchange to restore interest rate parity. Further, given persistent excess reserves in developing economies’ banking systems, capital flight or investment in overseas assets is only worthwhile if transaction costs are low. In plain terms, this simple model illustrates how the transaction cost of acquiring foreign exchange is an important determinant of exchange rate adjustment.

\[
\Delta S / S_{t-1} = r_{B,t} + v_t - r_{F,t}
\]  

(2)

Noting that \( \Delta S = S_t - S_{t-1} \) and further rearranging produces a non-linear difference equation below.

\[
S_t = [1 + (r_{B,t} + v_t - r_{F,t})]S_{t-1}
\]  

(3)

To derive an analytical solution, we assume that the central bank targets an average exchange rate, \( S \). This target does not have to be a hard peg but an average over a period of time such that Equation (4) is satisfied.

\[
S_t = S_{t-1} = \bar{S}
\]  

(4)
Substitution of Equation (4) into (3) produces an implicit function that determines the average exchange rate target.

$$\bar{S}[1-(1+(r_{B,t}+v_t-r_{F,t}))]=0$$ \hspace{1cm} (5)

After further simplification, the average exchange rate target is derived as shown below.

$$\bar{S}(r_{F,t}-r_{B,t}-v_t)=0$$ \hspace{1cm} (6)

Given that banks’ have a liquidity preference that becomes perfectly elastic at a non-zero lower bound rate, we model $r_{B,t}$ as follows. Equation (7) represents banks’ liquidity preference, where the negative slope is differentiable over $r_0-\beta R_t$ but flat at the non-zero lower bound rate (the minimum reservation rate: $r_{min}$). The intensity of the liquidity effect is given by the parameter $\beta$ when the level of excess reserves ($R_t$) changes.

$$r_{B,t} = \begin{cases} 
  r_0 - \beta R_t & \text{if } r_{B,t} > r_{min} \\
  r_{min} & \text{otherwise}
\end{cases} \hspace{1cm} (7)$$

In this simple set-up, we model two important determinants of excess reserves: (i) Government spending from its account at the central bank ($\bar{G}$) and (ii) the long-run average accumulation of international reserves ($\bar{F}$). Fiscal expenditure finds its way into the banking system and thereby, adds to excess reserve holdings. The latter also increases when $\bar{F}$ rises and vice versa. The symbol ($\phi$) expresses the percentage of each source of non-remunerated excess reserves and sum to unity.

$$R_t = \phi \bar{F} + (1-\phi)\bar{G}$$ \hspace{1cm} (8)

Substitution of Equation (8) into (7) derives the extended domestic interest rate shown below. To keep the model simple and tractable, we only focus on the $r_{B,t} > r_{min}$ segment of banks’ liquidity preference curve.

$$r_{B,t} = r_0 - \beta[\phi \bar{F} + (1-\phi)\bar{G}]$$ \hspace{1cm} (9)

Earlier discussions noted that the foreign exchange constraint is related to the central bank’s intervention in the domestic FX market. When the central bank accumulates international reserves it not only injects liquidity into the banking system, but also quarantines hard currencies that would otherwise be available to the private sector. In this case, banks and other economic
agents incur an opportunity cost in holding excess reserves. We posit that the sale of CBBs can serve to reduce the transaction costs associated with operating in the foreign exchange market, as economic participants stop searching for foreign currency and invest in CBBs. Thus, we model the transaction cost as follows.

\[ v_t = v_0 + d \bar{F} - c \bar{B} \] (10)

Equation (10) shows that an increase in the average international reserves (\( \bar{F} \)) over some period increases transaction costs in the foreign exchange market. On the other hand, an increase in the average sales of CBBs (\( \bar{B} \)) reduces the transaction cost and vice versa. The term \( v_0 \) represents a measure of exogenous risk as is typical in portfolio-balance models.

Substitution of Equations (10) and (9) into (6) produces the implicit function that determines the exchange rate target.

\[ \bar{S} \{ r_{F,t} - r_0 + \beta[\phi \bar{F} + (1-\phi)\bar{G}] - v_0 - d \bar{F} + c \bar{B} \} = 0 \] (11)

We are specifically interested in several partial and cross-partial derivatives. The following partials explain the initial impact of each exogenous variable on the exchange rate target: \( \partial \bar{S} / \partial r_{F,t} \), \( \partial \bar{S} / \partial \bar{F} \) and \( \partial \bar{S} / \partial \bar{G} \). We do not examine the initial impact of an increase in \( \bar{B} \) since the sale of CBBs is a reaction variable or instrument that is not sold for its own sake but for neutralizing the impact of other exogenous shocks. In order to fully assess the impact of CBBs on exchange rate management, we must also consider the following second-order cross-partial derivatives:

\[ \partial^2 \bar{S} / \partial r_{F,t} \partial \bar{B}, \partial^2 \bar{S} / \partial \bar{F} \partial \bar{B} \text{ and } \partial^2 \bar{S} / \partial \bar{G} \partial \bar{B}. \] These three cross-partials demonstrate the idea that the sale of CBBs can be employed as a reaction variable to exogenous shocks.

Equation (12) depicts the first result, where \( \Omega = r_{F,t} - r_0 + \beta[\phi \bar{F} + (1-\phi)\bar{G}] - v_0 - d \bar{F} + c \bar{B} \) and is positive given the values of \( r_{F,t} + \beta[\phi \bar{F} + (1-\phi)\bar{G}] + c \bar{B} \) as compared to \( r_0 + v_0 + d \bar{F} \). It shows that an increase in the foreign interest rate depreciates the exchange rate. However, the positive cross-partial derivative given by Equation (13) suggests that CBBs play a stabilizing role when there is foreign interest rate pressure.

\[ \partial \bar{S} / \partial r_{F,t} = -\bar{S} / \Omega < 0 \] (12)

\[ \partial^2 \bar{S} / \partial r_{F,t} \partial \bar{B} = -[-c \bar{S}] / \Omega^2 > 0 \] (13)
Next, we explore the effect of the long-term accumulation of FX reserves by the monetary authority; then we examine the outcome when the central bank sells CBBs to bankers and other economic agents.

\[
\frac{\partial S}{\partial F} = -S(\beta \phi - d) / \Omega < 0 \tag{14}
\]

\[
\frac{\partial S^2}{\partial FB} = -[-cS(\beta \phi - d)] / \Omega^2 > 0 \tag{15}
\]

Equation (14) shows that quarantining FX from the private sector depreciates the currency if the liquidity effect (\(\beta\)) times the ratio of excess reserves (\(\phi\)) is greater than the FX constraint created (\(d\)). The liquidity preference curve presented earlier (Figure 2) indicates that the liquidity effect is quite strong given the steep downward-sloping part of the curve. Therefore, it is reasonable to assume that \(\beta \phi > d\). The other scenario of \(\beta \phi < d\) is not that interesting, but it does hint at what might be needed if the policy objective is to weaken the exchange rate. If the latter condition holds, then accumulating international reserves appreciates the currency. However, in the case where \(\beta \phi > d\), the cross-partial derivative in Equation (15) is positive, which illustrates that the sale of CBBs stabilizes the exchange rate given the initial removal of foreign currency from the private sector.

The following results explore the outcome of government spending using its deposit account at the central bank. Equation (16) shows that government expenditure depreciates the exchange rate. However, the second cross partial derivative in Equation (17) indicates that the sale of central bank securities stabilizes the exchange rate when government spending increases excess reserves in the banking system.

\[
\frac{\partial S}{\partial G} = -\beta S(1 - \phi) / \Omega < 0 \tag{16}
\]

\[
\frac{\partial S^2}{\partial GB} = -[-c\beta S(1 - \phi)] / \Omega^2 > 0 \tag{17}
\]

These comparative static results derive a fundamental testable hypothesis: the sale of central bank bills appreciates the nominal exchange rate. This twist to exchange rate targeting allows monetary authorities to economize on scarce international reserves. Moreover, our results in Equations (16) and (17) demonstrate that money financed fiscal deficits need not undermine exchange rate stability and induce inflationary effects. Monetary authorities can lean against these macroeconomic pathologies through the sale of CBBs, while funding fiscal deficits. This insight is particularly noteworthy with the outbreak of the global pandemic – COVID-19. Governments
in developing countries can respond to the accompanying social and economic crises through money-financed expenditure and safeguard inflation and exchange rate stability with the use of central bank securities.

4. Empirical Analysis

4.1 Empirical Strategy

In this section, we empirically verify our testable hypothesis. We are particularly interested in isolating how CBBs or interest-rate shocks influence the FX market given its importance for price and overall macroeconomic stability. Moreover, these two shocks indicate whether an interest rate or quantity instrument is better for stabilizing the FX market. Our empirical approach involves connecting the CBB and FX markets using a vector auto-regression (VAR). VARs are particularly useful for the task at hand given that the price and quantity in the two markets are endogenous to each other. The interest rate and the quantity of CBBs indicate the security market, while quantity of FX and the spot exchange rate (direct quote: $/Kina) indicate the domestic FX market.

The following time-series conventions are followed. First, the four variables are pre-tested to determine whether they are stationary or non-stationary. The variables of interest are: (i) quantity of central bank securities ($B^{CBB}$), (ii) the 28-day interest rate on the CBBs ($r^{CBB}$), (iii) the quantity of foreign exchange traded by the licenced dealers or cambio system ($Q^{FX}$), and (iv) the nominal exchange rate ($S^{$/Kina}$). The Phillips-Perron and ADF unit root tests indicate that all four series are non-stationary or I (1). The unit root results are robust across different specifications considering trend and drift terms. The lag selections were chosen to minimize the Schwartz information criterion (SIC). Second, following established conventions in time-series econometrics, an unrestricted VAR model, in levels, is first estimated to determine the optimal lag length using the two information criteria – Akaike information criterion (AIC) and SIC. The two information criteria suggest that the unrestricted VAR should be three lags. The variables were estimated in logarithms\(^5\).

Third, for the model to be estimated in levels when all the variables are I (1), there must be at least one co-integration relationship; otherwise, we could be estimating a system of spurious regressions. If there is no long-run relationship (co-integration), then the VAR has to be estimated in differences, providing they are all stationary in their first difference. Both the Trace and the

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\(^5\) The impulse response functions are similar to when the variables are not in logarithms.
Max-eigenvalue co-integration tests indicate a single long-term level relationship among the said variables at the 5 percent level of statistical significance. Also, the co-integration results indicate there is a level relationship between the CBB and the FX markets. Finally, since there is a long-term relationship in the level of the variables, we estimate a vector error correction model (VECM) to determine the impulse response functions.

The ordering of the matrix of contemporaneous parameters is essential for identifying the impulse response functions (IRFs). The following ordering of the variables is proposed: (i) The quantity of FX is assumed to be contemporaneously affected the by exchange rate but not the other way around. The rationale is based on the fact that the BPNG manages the exchange rate in a particular direction. Hence, the exchange rate ought to be more exogenous contemporaneously as compared to the quantity traded in the domestic FX market. (ii) The liquidity preference of banks produces a lower bound interest rate and as a result, the central bank does not possess complete control of the short-term interest rate. However, the central bank can control the quantity of CBBs. Therefore, we restrict the contemporaneous parameters to make the interest rate endogenous to the quantity. The overall ordering from most exogenous to endogenous is as follows: 

\[ B^{CBB} \rightarrow r^{CBB} \rightarrow S^{Kina/USS} \rightarrow Q^{FX} \]

We call this ordering the institutional identification strategy of the IRFs since it is based on features of PNG’s economy. We also explore how shocks to excess reserves would influence the exchange rate, the quantity of FX traded in the domestic market and the domestic interest rate. In this case, we combine the markets for bank reserves and foreign currency. Previously, we combined the market for a domestic security and the FX market. The variable ordering is identical to the outline given above, but CBB is replaced with the level of excess reserves. By combining the money and FX markets, we are able to test whether the liquidity effect holds in a dynamic setting. The model is estimated with three lags as is suggested by the SIC and AIC. It should be noted that the co-integration test for the long-run relationship between the money and FX markets produced mixed results. The Trace test found no level relationship (long run), while the Maximum Eigenvalue test found one cointegrating relationship at the 5 percent level of significance. Nevertheless, we think

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6 As a robustness check, the a-theoretical and non-institutional generalized IRFs were also estimated and they were found to be virtually identical to the institutional IRFs described herein. The generalized IRFs are independent of the ordering of the variables and the technique was proposed by Pesaran and Shin (1996).

7 Carpenter and Demiralp (2008) tested the liquidity effect using a VAR methodology. They found strong evidence in favor of the liquidity effect in the federal funds market when monthly data were utilized.
it is appropriate to estimate a VECM in levels in order to preserve the intuitive interpretation of connecting the price and quantity variables. We do not believe stationary variables give the same intuitive economic interpretation of the IRFs. We also estimated the generalized IRFs (not reported) and the results are identical to the IRFs from the institutional ordering reported.

As it relates to the dataset, it is sourced from the Bank of Papua New Guinea and the estimation is conducted using monthly data for the period 2000: Jan to 2019: June. The quantity of foreign exchange traded in the cambio system is calculated by taking the average of the stock of purchases and the stock of sales.

4.2 Results

In Figure 5, we illustrate the response of $Q^{FX}$ and the exchange rate given a standard deviation (SD) shock to CBBs and interest rate. The impact response and dynamic adjustment given a one unit CBB shock is on the left panel, while the response and adjustment to the interest-rate shock are on the right panel of Figure 5. First, $Q^{FX}$ is muted in period $t = 0$ (the impact response) given the one SD shock to both CBB and interest rate; however, the dynamic adjustments are very different in the next eighteen months. The CBB shock results in a positive adjustment for the next eighteen months, while the interest-rate shock produces a negative adjustment for the same forecast horizon. These varied results show that the quantity of CBBs serves to save or economize on scarce foreign currency, while the interest-rate shock possibly indicates an expectation channel, whereby the private sector is anticipating a future depreciation when interest rate rises in period $t = 0$. This likely induces hoarding of hard currencies, thereby diminishing the quantity traded in the local market. It follows that the interest rate may not be the appropriate instrument if the objective is to stabilize the exchange rate and conserve scarce foreign currencies.

As shown by Figure 5, there is a noticeable difference in the adjustment of the exchange rate given the one SD shock to CBB and interest rate. The initial response in the US$/Kina rate is small in period $t = 0$ (the values are logarithms), but the rate continually appreciates over the following eighteen months for the CBB shock. The appreciation from the CBB shock is stronger as compared to the interest-rate shock. The 95 percent bootstrap confidence interval is overall slightly narrower for the CBB shock in both cases. These results provide strong evidence that the one-sided sale of CBBs produces greater exchange rate stability as compared to the interest rate.
In Figure 6, we demonstrate the effects of excess reserves on the exchange rate, quantity of FX traded in the domestic market and the domestic interest rate. The IRF in the left panel shows that a positive shock to excess reserves depreciates the exchange rate over the forecast horizon of nineteen months, which includes $t = 0$. Moreover, the same shock elicits a small impact response in FX-quantity in period $t = 0$. However, the dynamic adjustment turns negative until month 2 ($t = 3$). From the third month, the market turns positive and eventually settles on a new equilibrium level of foreign exchange. We also find dynamic evidence of banks’ liquidity preference and a non-zero lower bound interest rate. The dynamic liquidity effect (see middle panel) shows that the interest rate tends to decline given the one SD shock to excess reserves. On average, the results indicate that the interest rate settles at a new long-run equilibrium after month eight ($t = 9$). In other words, it takes about nine months for the liquidity shock in period $t = 0$ to drive the interest rate towards its long-term non-zero lower bound rate.
5. Discussion

Our conceptual framework and empirical evidence that the sale of CBBs is an effective instrument of exchange rate targeting have several implications for PNG. First, we show that quantity dominates price adjustments in terms of stabilizing the foreign exchange rate. This is an important insight given the keen interest in developing market based monetary policy instruments that rely on price adjustments. For example, Nyawata (2012) and indeed the advice from the International Monetary Fund, is keen about using CBBs to sterilize excess reserves in order to develop a functioning money market, which enhances the monetary transmission mechanism through the interest rate operating procedure, i.e., price adjustments. However, our results demonstrate that price adjustments have marginal effects on the exchange rate in the best-case scenario, but
contracts the quantity of foreign currency traded in the worst-case scenario. Our finding is an important note of caution to policymakers.

Second, our results make the case that the fear of excess reserves leading to lower interest rates and rapid credit expansion might be unjustified. We find evidence that banks hold non-remunerated excess reserves at a non-zero lower bound rate of interest. This is indirect evidence that excess reserves engender currency depreciations through non-credit channels. In plain terms, policymakers must sterilize excess reserves not in fear of losing interest rate control, but to prevent capital flight and ensure a satisficing level of bank profits to prevent an increase in the bid-ask spread in the foreign exchange market. Due to banks’ liquidity preference, excess reserves matter for exchange rate management through new channels.

Third, given the necessity of one-sided sterilization for exchange rate management and the inverse relationship between interest rate and banks’ demand for excess reserves, exchange rate management traps economies in a relatively high interest rate environment (Khemraj 2013). However, flexible exchange rate does not necessarily present a better alternative, since the non-zero lower bound rate is also relatively high. In other words, PNG is caught between ‘a rock and a hard place’ in terms of designing developmentalist interest and exchange rate policies.

Finally, we wish to emphasize that the rock and a hard place presents one transformative opportunity to policymakers, i.e., the ability to money finance fiscal expenditures while maintaining stable exchange rates. In other words, so as long monetary authority sells CBBs, money financed fiscal deficits do not generate the standard prediction of uncontrolled inflation. This opportunity space can be relied upon to maintain macroeconomic stability and fund emergencies like social expenditures during pandemics (e.g. COVID-19). If this opportunity space is well utilized, it can overcome the adverse effects of the high interest rate environment that accompanies sterilization and banks’ liquidity preference with a non-zero lower bound rate of interest.

In our view, the case of PNG fits a wider group of countries with similar stylized facts: (i) Oligopoly banks with a liquidity preference for non-remunerated excess reserves; (ii) exchange rate targeting; and (iii) persistent sterilization via one-sided sales of a central bank security from the liability side of its balance sheet. We encourage the reader to consult Khemraj (2014) for an appreciation of the analytics of money, banking and foreign exchange in small open economies.
that fit these stylized facts. Though we expect our results to hold in this class of countries, many more empirical studies need to be done before we can confidently generalize our implications.

6. Conclusion
This paper presents a simple model of how the sale of central bank bills serves as an effective tool of exchange rate management and provides empirical support in the case of Papua New Guinea. The standard literature contends that persist excess reserves in developing economies’ banking systems can ignite rapid credit creation, lower interest rates, currency depreciations and inflationary outcomes. Thus, the traditional rationale for sterilization is credit control and fine-tuning of the policy interest rate. However, we present empirical evidence that banks in Papua New Guinea hold non-remunerated excess reserves at a non-zero lower bound rate of interest; ergo, the fear of excess reserves leading to lower interest rates and rapid credit expansion might be unjustified. Instead, we argue that sterilization targets the exchange rate through two channels: (i) to curtail capital outflow and (ii) maintain banks’ satisficing profits. Since excess reserves incur an opportunity cost, banks’ can exercise market influence and induce a nominal depreciation in the foreign exchange market to increase profitability from foreign currency trading. The sale of CBBs allows banks to maintain target profits without compromising exchange rate stability.

Two key insights emerge from our work. First, price adjustments through the interest-rate operating procedure have marginal effects on the exchange rate in the best-case scenario, but contracts the quantity of foreign currency traded in the worst-case scenario. This finding is an important note of caution to policymakers that aim to enhance the monetary transmission mechanism through the interest rate operating procedure. We show that quantity dominates price adjustments (sale of central bank bills) in terms of stabilizing the foreign exchange rate. Second, our simple theoretical framework and empirical evidence make a strong case that the sale of central bank securities can simultaneously support exchange rate stability and money financed fiscal deficits. When the latter adds to excess reserves in the banking system, these can be quarantined with central bank securities for exchange rate management. In our view, this insight presents a plausible channel through which developing economies can respond to the COVID-19 global pandemic and maintain economic stability. At the time of revising this paper, Wolf (2020) flirts with the utility of monetary financing by the Bank of England during the global pandemic.
we call for further empirical research to determine the importance of central bank securities in exchange rate management in a broader cross-section of developing economies.

References


