Draft as of 31 May 2024

# Estimating the Reserve Demand Curve for the Philippines
## A Time-Varying Parameter VAR approach

Joan Christine S. Allon-Pineda, Jasmin E. Dacio and Shirra Jazel L. de Guia

ABSTRACT

Effective monetary policy requires a good understanding of banks' demand for liquidity also called "reserves" at the central bank. This paper models a reserve demand function for the Philippines with the dual goal of: (i) estimating the slope or the elasticity of rates to reserve shocks; and (ii) identifying transition points that define scarce, ample, and abundant reserves. Results show evidence of a non-linear, time-varying slope for the reserve demand function, as suggested in theory. This elasticity of rates to reserves was found to be generally negative but close to zero throughout the study period, which suggests that Philippine banks have maintained a generally ample level of reserves over time. The slope of the demand function also shifted along with structural changes in both rates (i.e., banks' balance-sheet costs and other frictions limiting arbitrage trading) and reserves (i.e., regulation, supervision, or market functioning). The adoption of the IRC system in 2016 encouraged more active monetary operations by the BSP and more active liquidity management by Philippine banks, which supported a tighter relationship between reserves and rates. Liquidity-enhancing measures deployed during the pandemic pushed reserve levels into abundant territory, which brought elasticity back to near-zero levels. As conditions normalized, the current recovery period saw reserve levels declining and pushed reserve demand back into ample and scarce territory. In terms of policy implications, this paper's methodology can be used in real-time to assess the ampleness of reserves, which in effect, allows policymakers to gauge the extent of their control over short-term market interest rates.

**JEL classification** : E41, E43, E52, E58, G21

**Keywords** : demand for money, interest rates, central bank, monetary policy, banks

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## 1. Introduction

The Philippine financial system continues to be dominated by the banking sector which in 2022, accounts for almost 82 percent of the total resources of the financial system. Bank reserves grew in tandem with the banking sector, with reserve money[1] reaching ₱3.8 trillion as of end-2022, roughly equivalent to 17 percent of nominal GDP. However, the increase in reserves is also associated with the accumulation of foreign assets arising from the surge of capital inflows and stream of remittances from Filipinos abroad in the early 2010s, resulting in a significant structural liquidity overhang. This excess liquidity has implications on monetary policy implementation, especially in a mid-corridor system, where the central bank steers short-term interest rates towards the announced policy rate through its open market operations (OMO) by either increasing or reducing reserve balances in the system.

According to Afonso et al. (2023), the sensitivity of interest rates to changes in reserves is dependent on the total amount of reserves in the system with the reserve regime classified into three categories—namely, abundant, ample, and scarce. In periods of high reserves (i.e., abundant), the demand curve for bank reserves is flat. This suggests that the price, or the interest rate at which banks are willing to trade reserves, is relatively fixed or unresponsive to changes in aggregate supply of reserves. Meanwhile, as reserves decline and enter the ample region, the sensitivity of interest rates to demand for reserves start to increase, marking the beginning of a typical downward-sloping demand curve. Finally, as reserves become scarce, the negative slope further steepens, suggesting that rates are now highly sensitive to changes in reserve levels. Understanding the relationship between rates and reserves is essential to assessing the effectiveness of OMO in implementing the stance of monetary policy.

Structural changes, such as changes due to prudential regulation as well as changes to the central bank's operational framework, have affected bank's demand for reserves over time. For the Philippines, the BSP formally adopted the Inflation Targeting (IT) framework in January 2002. Initially, the BSP operated a passive monetary implementation approach using a set of standing facilities, namely, the Repurchase (RP) facility, Reverse Repurchase (RRP) facility, and the Special Deposit Account (SDA) facility. However, given the limitations of the available instruments and market conditions, this configuration led to the divergence of money market rates to the key policy rate. To address this issue, the BSP enhanced its framework for monetary implementation with the adoption of the Interest Rate Corridor (IRC) system in June 2016. This system provided a formal and coherent framework for steering market interest rates towards the policy rate. It also supported more active liquidity management through the introduction of auction-based OMO and standing facilities, development of the liquidity forecasting framework, and the configuration of the corridor width (BSP Chapter 1, 2019).

[1] Reserve money includes currency issue, liabilities of the BSP to other depository corporations, and liabilities of the BSP to other sectors.

In 2020, the COVID-19 pandemic created a huge shock on the economy, warranting coordinated responses from both fiscal and monetary policy authorities. The BSP deemed it necessary to act decisively and take extraordinary measures to ensure sufficient liquidity to support the economy's funding needs and shore up market confidence to maintain proper functioning of the financial system amid the ongoing crisis. The implementation of the said monetary measures resulted in liquidity injection amounting to almost ₱2.3 trillion or around 13 percent of nominal GDP in 2020, which, in turn, led to an abundant level of excess reserves (BSP, 2020).

In view of the developments mentioned above, this study aims to estimate the daily elasticity of interest rates to changes in level of reserves in the Philippines over time and across different reserve regimes. In particular, we estimate the time-varying elasticity of interest rates with respect to changes in reserves over time, and identify the transitions points that define scarce, ample, and abundant reserves. We do this by estimating a structural time-varying slope of the reserve demand curve for the period 2012 to 2023. The rest of the paper is organized as follows. Sections 2 and 3 of the paper discuss the theory and previous studies on the monetary policy implementation and the reserve demand curve. Section 4 presents the data. Section 5 presents the empirical methodology. Section 6 reports the results of the model. Section 7 summarizes the findings and corresponding policy implications.

## 2. Monetary policy implementation and the reserves market

According to Romer (1990), monetary policy influences macroeconomic activity by setting a short-term interest rate that is expected to influence aggregate demand. In the New Keynesian model, this involves the setting of interest rate in the IS curve while accounting for expectations of future output and inflation (Friedman and Kuttner, 2010). To implement this in the IT framework, most central banks signal their monetary policy stance through their key policy interest rate, which is then transmitted to the financial market through various channels. Often, this transmission begins with the implementation of active OMO which influences short-term interest rates via the reserves market (Kuttner and Mosser, 2002). Put simply, the operating target is steered close to the policy rate by adjusting the quantity of available reserves in the system.

Short-term interest rate is determined by the equilibrium supply and demand of reserves, with central banks assumed to have a monopoly over the supply. However, in practice, the level of reserves is not completely determined by the central bank but is also affected by other autonomous factors, such as the changes in the balances of the national government's treasury department, foreign exchange interventions, as well as changes in currency demand (Afonso et al., 2023). Through the liquidity forecasts, the central bank can monitor and actively estimate the supply of reserves in the system and possibly conduct active OMO to offset the liquidity impact of these other sources of reserves, helping ensure that the operational target is in line with the key policy rate.

Meanwhile, Borio (1997) argued that the demand for reserves by banks is mainly driven by the need to comply with the reserve requirement (RR) as well as to maintain working balances for the payment and settlement of their obligations, such as interbank transfers. While RR ratios have declined generally across the globe with the recognition that RR as a monetary policy is blunt and not market-based, the introduction of new financial regulations, such as the liquidity coverage ratio, has affected the liquidity risk management of banks, altering their demand for reserves and making it more difficult to predict (Afonso et al., 2023). Nonetheless, this demand is assumed to follow a downward-sloping curve where changes in reserves are inversely related to interest rate changes (Poole, 1968). The sensitivity of short-term rates to changes in the reserve supply is also dependent on the tightness of the relationships underpinning reserve demand, determined by the substitutability between reserves and other assets, such as interbank transactions and government securities. Friedman and Kuttner (2010) noted that if overnight funds are decoupled from these other assets, then any changes in the equilibrium overnight rate will not translate to other market interest rates and, in turn, weakens the effectiveness of monetary policy.

Hamilton (1997) opined that the available funds that banks can lend out to customers is dependent on the reserve deposits held by the bank that is more than the required reserve level. In instances wherein banks face a reduction in reserve deposits with the central bank, the bank can either borrow from the central bank or other private banks, or sell off some of its assets. This lower supply of reserve inevitably places an upward pressure on market interest rate, a situation known as the liquidity effect, especially if it becomes systemic that the liquidity position of banks with respect to the central bank shifts from surplus to deficit. Afonso et al. (2019) further posited that this liquidity effect varies depending on the level of reserves in the system. In an environment of scarce reserves, interbank activity is more robust and central banks can easily influence rates by adjusting the supply of reserves via OMO. Meanwhile, in environments where banks are awash with excess reserves, such as those with structural liquidity surplus, interest rates may not be as responsive to changes in the reserve supply owing to lower interbank trading activity. The former environment more accurately captures the liquidity effect, while the latter questions the existence of it.

As the price sensitivity of reserve demand likely changes depending on the aggregate reserve regime, Afonso et al. (2023) developed a method for estimating the aggregate reserve demand curve and determining at what level banks' demand for reserves are deemed to be fully satisfied. Above the satiation point, reserves are abundant, resulting in a flat demand curve where changes in reserve supply do not influence the price of reserves. In contrast, when reserves are scarce, interest rates tend to be very volatile owing to a highly inelastic downward-sloping demand curve. In between these two regions, reserves are considered ample with a less steeper demand curve and less volatile interest rate. In the succeeding sections, we replicate the methodology to estimate the reserve demand curve for the Philippines to better understand its evolution over time as well as its implication on monetary policy implementation.

## 3. Past and current BSP OMO framework

In 2013, the structural overhang stood at around ₱2.5 to ₱3 trillion, or approximately 20 percent of GDP, owing to large increases in banks' reserves associated with the country's accumulation of foreign assets. Hence, BSP monetary operations had to focus on absorbing the structural surplus to steer market rates close to the policy rate. At that time, bulk of system reserves was set aside as required reserves owing to the high RR ratio at 18 percent. The remaining excess liquidity was then siphoned passively using a set of standing facilities. The RRP facility operated in a first-come, first-served basis, with the RRP rate set as the key policy rate. The RP facility offered banks collateralized loans with a fixed margin of 200 basis points (bps) over the RRP rate while the SDA facility offered banks deposits at a fixed margin relative to the RRP rate. However, owing to the limited amount of government securities in the BSP's portfolio, majority of the structural liquidity was absorbed through the SDA window. Moreover, the BSP introduced sterilization tools to ward off the significant capital inflows to the country in 2010 to 2013, which included the setting of the SDA rate to 50 to 150 bps below the RRP rate.[2] These measures resulted in a de facto floor system as the marginal interest rate relevant to banks was the SDA rate. Hence, this led to the weakening of the transmission mechanism and, in turn, the divergence between short-term market rates and the official policy rate.

Given the limitations of the passive approach and distortions arising from the de facto floor system, the BSP decided to move to a mid-corridor implementation regime with the use of active OMO instruments. Through the active approach, the BSP has better grasp of monetary conditions owing to improvements to the transmission mechanism. Consequently, it also provides support to the development of the financial market. Hence, in June 2016, the BSP implemented the IRC system, which is a symmetrical 100-point wide corridor with the policy rate at the mid-point of the corridor and the overnight lending facility (OLF) rate and overnight deposit facility (ODF) rate at plus/minus 50 bps from the policy rate. In addition, the BSP reformed the RRP facility and introduced OMO instruments, such as the term deposit facility (TDF), to actively absorb excess liquidity at yields close to the policy rate. Both facilities followed an auction system with the former under a fixed-volume, fixed-rate setup and the latter designed as a fixed-volume, variable-rate type of auction. Liquidity was gradually mopped up by steady scaling up of the TDF auctions over time. In late 2017, the BSP OMO's began to take hold as market rates began to steer close to the middle or upper half of the IRC.

With the approved amendment of the BSP Charter in 2019, the BSP further enhanced the IRC system through the issuance of BSP securities for sterilizing structural liquidity surplus and aiding the development of interbank markets. BSP securities are designed to be the main structural sterilization or absorption instrument moving forward while the TDF and RRP are used for fine-tuning operations. Moreover, the BSP gradually eased RR ratio to reach single digit levels in line with ratios in the region, reducing the frictions arising from reserve requirements. As of June 2023, the

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[2] Prior to January 2013, the SDA rate was equal to the overnight RRP rate but was charged with a premium. The BSP reduced rates paid on the SDA facility to discourage placements in the said facility.

RR ratio for universal and commercial banks stood at 9.5 percent. These developments culminated better control over domestic interest rates.

## 4. Reserve demand curve

We discuss a stylized model of the downward-sloping demand for reserves of an individual bank following Chen et al (2023):

$$\begin{aligned} r_i &= f\big(g(C_i)\big) \\ C_i &= [R_i \quad X_i] \\ g(C) &= c + Cw_g \end{aligned} \tag{1}$$

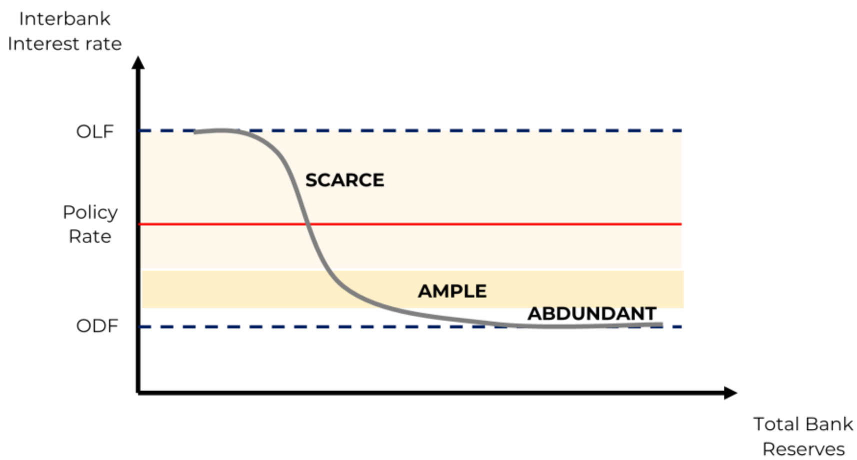
where the short-term interest rate, $r_i$, is a function of excess reserves, $R_i$, and other explanatory variables, $X_i$, while $w_g$ is a column vector of $p+1$ coefficients and $c$ is a constant. The sum of the individual reserve demand curves is the banking system demand for reserves following Afonso et al (2023). According to Chen et al (2023), this aggregate reserve demand equation then depicts the rate at which banks are ready to borrow and lend reserve as a function of aggregate reserves in the banking system.

The stylized representation of the aggregate demand curve in a mid-corridor system is shown in Figure 1. To keep short-term rates closer to the target policy rate, the central bank carefully monitors liquidity conditions and adjusts the availability of funds through its OMO. This assumes that in times of reserve abundance, banks will attempt to limit their excess reserves and choose to earn interest by lending to other banks in the interbank call loan (IBCL) market or depositing at the central bank at rates that are at least equal to the standing deposit facility (or ODF) rate. However, the IBCL rate could get nearer the ODF rate as reserves increase.

Meanwhile, in periods of reserve deficiency, banks would borrow from the central bank at the rate of the standing lending facility (or OLF) or access the IBCL market at rates close to the OLF rate in order to maintain sufficient reserves as well as meet regulatory requirements. It should be noted that access to the IBCL in the Philippines is greatly dependent on existence of credit line given its clean nature. Banks that do not have credit line will have to access the OLF. With the IBCL rate serving as the operating target for many central banks, prolonged periods of the IBCL rate trending above the policy rate could suggest shortage in reserves and tight liquidity conditions, while declining market rates reflect ample excess liquidity, consistent with Poole (1968).

Aside from the position of overnight rates within the corridor, the slope of the curve also provides information on the ability of OMO to influence overnight rates (Figure 1). In particular, the slope indicates the sensitivity of interest rates to changes in reserves, with a flat slope suggesting limited response of interest rate to changes in reserves owing to abundant reserves, while a steeper slope due to scarcer reserves allows interest rates to become more sensitive to movements in overall liquidity conditions (Afonso et al., 2023). This sensitivity of rates to changes in reserve levels then provide insights on the ability of OMO to influence short-term interest rates.

**Figure 1. Demand Curve for Reserves**




## 5. Data

This study uses daily data for the period 6 April 2012 to 30 June 2023, excluding weekends and holidays. While Afonso et al. (2022) used aggregate reserve balances kept with the US Fed for their study, we find the use of excess reserves more appropriate for Philippines, computed as the sum of banks' excess reserves[3] and their placements in the ODF and the RRP window of the BSP. This is then normalized using total assets[4] of the Philippine banking system. This step controls for the changes in reserves driven by the growth of the banking system. As bank assets are reported on a monthly basis, the daily data was derived using linear interpolation. The normalized reserve level is used as the measure of the daily quantity of aggregate reserves.[5]

The spread between the IBCL rate and the floor of the BSP interest rate corridor is used to proxy the price of reserves to take into account the differing opportunity cost of overnight funds along the lower half of the interest rate corridor. The IBCL rate is used as the price for overnight (O/N) funds in the unsecured market for funds among banks.[6] Meanwhile, the floor of the BSP interest rate corridor is represented by either the rate on the BSP SDA window or the ODF. The corridor floor is considered as the implied minimum rate that banks can receive for their excess reserves, as banks will not lend their excess reserves lower than what they can receive from either the SDA or ODF. Prior to the IRC period, the BSP used the SDA rate as the floor of the de facto corridor The SDA rate was set 50 to 150 bps below the policy rate beginning 24 January 2013. Previously, the SDA was pegged to the RRP rate but was charged with a slight premium. The said series is used for the period 6 April 2012 to 2 June 2016. With adoption of the IRC, the BSP used a 100-bp, with the OLF rate as the ceiling and the ODF rate as the floor, both of which are 50-bp away the RRP rate.

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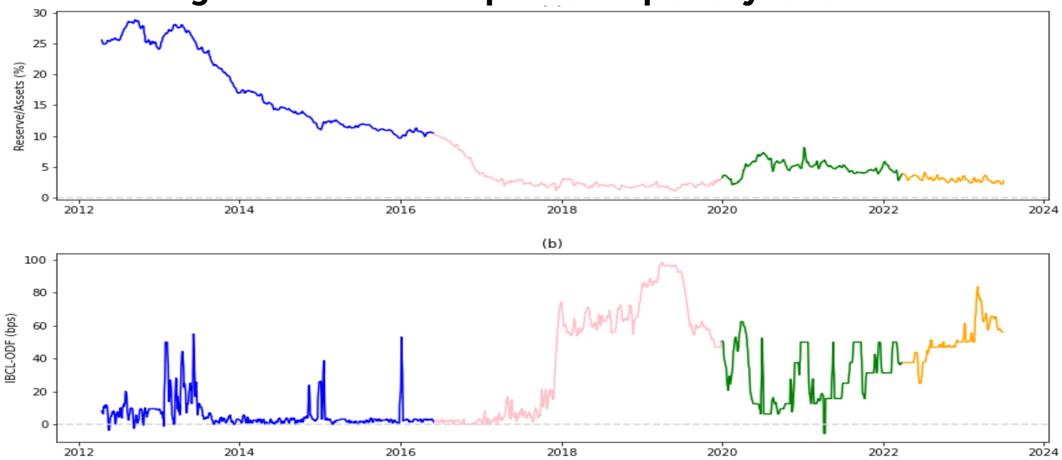
[3] Excess reserves held by banks is the level of reserves kept with the central bank above the required level.
[4] This is the sum of all assets net of accounts due from head office/branches/agencies and due to head office/branches/agencies of foreign banks.
[5] This formulation is consistent with recent theoretical derivations of the demand curve (Bigio and Sannikov, 2021; Bianchi and Bigio, 2022; Lagos and Navarro, 2023) and has been recently adopted by empirical papers (Lopez-Salido and Vissing, Jorgensen, 2022; Acharya et al., 2023).
[6] For days with no IBCL transactions, the rate of the most recent transaction is used.

The main variables used in the model are shown in Figure 2. The normalized reserves fall within 0.7 to 25.0 percent of bank assets. The ratio started to decline from 2013 to 2017 as the banking system outgrew stagnant reserves, coupled with the decrease in ODF/SDA volumes. The decline continued in 2017 amid the structural changes brought about by the IRC implementation and remained flat at low levels for the period 2018 to 2019 following the series of government bond issuances, which helped siphon excess liquidity from the financial system. The ratio increased anew at the onset of the pandemic (March 2020) as the BSP implemented extraordinary liquidity measures to help restore the proper functioning of Philippine financial markets. This included the reduction of RR ratio of universal and commercial banks to 12.0 percent from 14.0 percent, participation of the BSP in the secondary market for government securities, and the use of new loans to Micro, Small, Medium Enterprises as alternative compliance with the RR. Normalized reserves remained elevated throughout 2021 and returned to pre-pandemic levels in 2022 onwards.

Meanwhile, the rate spread was generally narrow pre-IRC, coinciding with the abundant level of reserves during that period. IBCL rates approached the bottom of the de facto corridor as most of BSP absorption took place at the SDA rate. The spread started to widen when aggregate reserves declined especially in early 2018. During this period, the BSP had already transitioned to a mid-corridor framework and liquidity was mopped up using OMO instruments as TDF volumes were gradually raised to siphon the excess liquidity. Moreover, the national government issued more securities, which further tightened liquidity conditions. As a result, market rates, as proxied by the IBCL in this study, started to climb towards the middle and upper half of the IRC, reflecting the higher cost of borrowing due to lower excess liquidity. However, in late 2018 up to 2019, the spread again declined as reserves increased owing to the successive reduction in the RR ratio. As part of the plans to reduce the RR ratio to single digit, the BSP started reducing the 20 percent RR ratio in 2018 to 14 percent in December 2019. This continued during the pandemic period as the BSP implemented extraordinary liquidity measures to help support the economy. Nonetheless, by the middle of 2021, the rate spread began to rise following the BSP's implementation of its exit strategy from the liquidity-enhancing measures, as well as the subsequent aggressive contractionary monetary policy stance implemented to address elevated inflation.

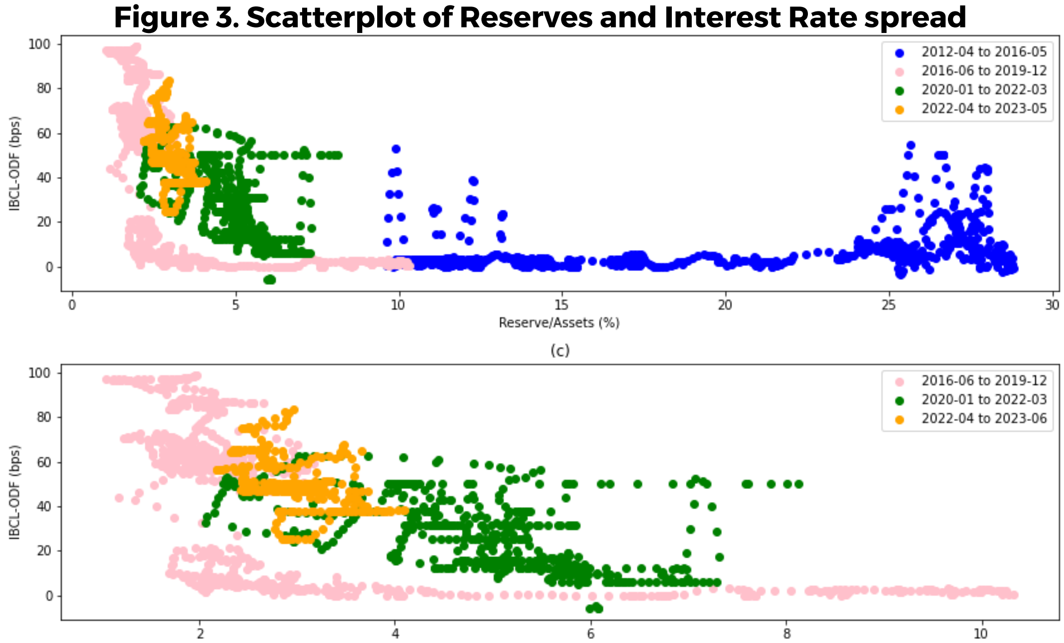
**Figure 2. Evolution of price and quantity variables**




Note: The color coding matches the regimes discussed in Section 6.2 onwards.
Source: Authors' calculations

A scatterplot of reserves and the interest rate spread is provided in Figure 3 to visualize better the relationship between the two variables. Prior to the IRC period (blue dots), it appears that there is no inverse relationship between the quantity and price of reserves. By contrast, we can linearly fit the expected downward-sloping reserve demand curve after the adoption of the IRC framework (pink dots). Moreover, we can observe a slight shift in the demand curve in 2019 (green dots), wherein the curve moved up and to the right, but has relatively flattened during the pandemic (yellow dots).

**Figure 3. Scatterplot of Reserves and Interest Rate spread**




Note: The color coding matches the regimes discussed in Section 6.2 onwards.
Source: Authors' calculations

## 6. Methodology

Afonso, et al. (2022) outlines the empirical model and estimation strategy used to derive the aggregate demand curve for reserves. The study writes aggregate demand as:

$$p_t = p_t^* + f(q_t - q_t^*;\ \theta_t), \tag{2}$$

where $p$ and $q$ are the price and quantity of reserves as defined in Section 4, $p^*$ is the demand curve's lower asymptote, $f(x;\ \theta)$ is a decreasing non-linear function parameterized by $\theta_t$ that goes to zero as $x$ goes to infinity, and $q^*$ is the horizontal location of the curve relative to a normalization point. Changes in the curve's lower asymptote $p_t^* < 0$ arises from structural changes in banks' balance-sheet costs and other frictions limiting arbitrage trading. Changes in the horizontal location of the curve $q_t^*$ comes from structural changes in regulation, supervision, or market functioning that affect banks' demand for reserves.

Estimating the sensitivity of the IBCL rate to reserve shocks poses three main challenges, namely: (i) non-linearity; (ii) structural shifts; and (iii) endogeneity. First, the aggregate demand curve is nonlinear since the slope of the curve itself is a function of aggregate reserves, as discussed in Section 4. Second, the curve may have moved over time due to persistent structural changes caused by major economic events like the 2008 global financial crisis, or changes in the operating environment like the 2016 IRC implementation. Third, the problem of endogeneity comes from two types of reserve fluctuations: the BSP buying or selling assets from banks or the transfer of funds between reserves and non-reserve accounts at the BSP. The first type of endogeneity is due to the BSP's actions, while the second type is due to the activity of non-reserve accounts that are correlated with money-market conditions and ultimately, the demand for reserves.

To address the first two challenges, Afonso, et al. (2022) empirically estimates the demand curve with time-varying coefficients and at a daily frequency:

$$p_t = \alpha_t + \beta_t q_t + \sigma_t v_t, \tag{3}$$

where $p$ and $q$ are the price and quantity of reserves, $v$ is a daily demand shock, $\sigma$ is a daily shock variance and $\beta_t$ is the time-varying slope that measures the elasticity of rates to reserves on each day. Equation 3 is expanded into a time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility based on Primiceri (2005) and Del Negro and Primiceri (2015):

$$q_t = c_{q,t} + b_{q,q,1,t}q_{t-1} + b_{q,p,1,t}p_{t-1} + \ldots + b_{q,q,m,t}q_{t-m} + b_{q,p,m,t}p_{t-m} + u_{q,t}, \tag{4}$$

$$p_t = c_{p,t} + b_{p,q,1,t}q_{t-1} + b_{p,p,1,t}p_{t-1} + \ldots + b_{p,q,m,t}q_{t-m} + b_{p,p,m,t}p_{t-m} + u_{s,t},$$

where $q$ and $p$ are the quantity and price of reserves, the $c$'s and $b$'s are the time-varying coefficients, and the $u$'s are serially uncorrelated, heteroskedastic and jointly normally distributed errors with mean zero and time-varying covariance matrix $\Omega_t$, i.e., $(u_{q,t}, u_{p,t})' \sim N(0, \Omega_t)$.

The TVP-VAR model is estimated at a daily frequency using Bayesian methods, with each parameter being modeled as a stochastic process. The vectorized form of Equation 4 is:

$$y_t = c_t + B_{1,t} y_{t-1} + \cdots + B_{m,t} y_{t-m} + u_t \qquad \text{with } t = 1, \ldots . T \tag{5}$$

where $y_t$ is a 2 × 1 stacked vector of observables $(q_t, p_t)$'; $c_t$ is a 2 × 1 vector of stacked constant terms $(c_{q,t}, c_{p,t})$'; $B_{i,t}$, with $i = 1, \ldots, m$ lags, are the following 2×2 matrices of time-varying coefficients:

$$B_{i,t} = \begin{bmatrix} b_{q,q,i,t} & b_{q,p,i,t} \\ b_{p,q,i,t} & b_{p,p,i,t} \end{bmatrix}. \tag{6}$$

To model time variation in the covariance matrix of the errors, the term $\Omega_t$ is reparametrized as follows:

$$A_t \Omega_t A_t' = \Sigma_t \Sigma_t', \tag{7}$$

where $\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 \\ 0 & \sigma_{2,t} \end{bmatrix}$ is a diagonal matrix, and $A_t = \begin{bmatrix} 1 & 0 \\ \alpha_{21,t} & 1 \end{bmatrix}$ is a lower triangular matrix. It follows that:

$$\begin{aligned} y_t &= c_t + B_{1,t} y_{t-1} + \cdots + B_{m,t} y_{t-m} + A_t^{-1} \Sigma_t \varepsilon_t, \\ Var(\varepsilon_t) &= I_n, \end{aligned} \tag{8}$$

where $\varepsilon_t$ is a 2 × 1 vector of reserve and rate shocks that are uncorrelated with each other at each point in time by construction. Stacking all the time-varying coefficients in a vector $B_t$, the model can be represented in the following companion form:

$$\begin{aligned} y_t &= X_t' B_t + A_t^{-1} \Sigma_t \varepsilon_t, \\ X_t' &= I_n \otimes [1, y_{t-1}', \ldots, y_{t-m}'], \end{aligned} \tag{9}$$

where ⊗ denotes the Kronecker product.

Like Primiceri (2005), the parameters are assumed to follow slow-moving random walks which evolve more slowly than the daily errors,[7] and whose innovations are uncorrelated with the $u$ errors at all leads and lags. The parameters are modeled as follows:

$$B_t = B_{t-1} + v_t, \tag{10}$$

$$\alpha_t = \alpha_{t-1} + \zeta_t, \tag{11}$$

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t, \tag{12}$$

[7] Prior densities of covariances (QSW) are kept low for less time variation in the dynamic parameters, which are assumed to move more slowly than daily errors and liquidity shocks.

where $\alpha_t = \alpha_{21,t}$ is the non-zero off-diagonal term in $A_t$, and $\sigma_t = (\sigma_{1,t}, \sigma_{2,t})'$ is the 2×1 vector of diagonal terms in $\Sigma_t$. $B$ and $\alpha$ are modeled as random walks; $\sigma_t$ is modeled as a geometric random walk. All innovations in the model ($\varepsilon_t$, $v_t$, $\zeta_t$, $\eta_t$) are assumed to be jointly normally distributed with covariance matrix:

$$V = Var\left(\begin{bmatrix}\varepsilon_t\\ v_t\\ \zeta_t\\ \eta_t\end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0\\ 0 & Q & 0 & 0\\ 0 & 0 & S & 0\\ 0 & 0 & 0 & W\end{bmatrix} \tag{13}$$

where $I_n$ is the $n$×$n$ identity matrix, $S$ is the variance of $\zeta_t$, and $Q$ and $W$ are positive-definite matrices.

To address the third challenge of endogeneity, Afonso, et al. (2022) uses an instrumental variable (IV) approach in the estimation of reserve demand elasticity. The TVP-VAR model with stochastic volatility simultaneously estimates the forecast errors $u$ and their time-varying covariances, with the observable variables $q$ and $p$. In this exercise, the instrumental variable is the past forecast errors of reserves $u$ from a forecasting model based on the estimated TVP-VAR model which captures the joint dynamics of the quantity and price of reserves. Specifically, using the forecast error for reserves $h$ days ago, $u_{q,t-h}$, as an instrument for reserves today, $q_t$, the IV estimate of $\beta_t$ in Equation 3 can be written as:

$$\beta_t^{IV} = \frac{cov(p_t, u_{q,t-h})}{cov(qt\ ,uq,t-h)}. \tag{14}$$

A more accessible equivalent of the above ratio of covariances is used to estimate elasticity —that is, the ratio of the $h$-day-ahead impulse responses of rates and reserves to a reserve shock under a Cholesky decomposition with reserves ordered first.[8] It is important to note that the choice of forecast horizon $h$ presents a trade-off between instrument exogeneity and estimate precision. The longer is the horizon, the more plausible is the exogeneity assumption. However, a longer horizon implies larger estimate uncertainty.

The skeleton codes for TVP-VAR with stochastic volatility come from a MATLAB program written by Dimitri Korobilis,[9] which is further revised to produce an elasticity estimate using an IV approach, $\beta_t^{IV}$. The VAR is set to a 10-day lag and the Bayesian estimation is set to 5,500 iterations with the first 500 iterations as burn-ins. Informative priors are generated based on the Primiceri (2005) sub-routine also written by Dimitri Korobilis, which derives initial values from an Ordinary Least Square (OLS) model estimated using a training sample that consists of the first year of data (roughly 220 observations). Hyperparameters are set as per reference to ensure that model

[8] The ratio of impulse response functions as an IV estimator was used by Christiano et al. (1999) to estimate the interest elasticity of money demand and more recently, by Del Negro et al. (2020) and Barnichon and Mesters (2021) to estimate the Phillips curve.

[9] Code for TVP-VAR using the Carter and Kohn (1994) algorithm as implemented in Primiceri (2005) with multivariate stochastic volatility is available at https://sites.google.com/site/dimitriskorobilis/matlab/code-for-vars.

parameters move more slowly than the daily errors and liquidity shocks affecting banks' demand for reserves. The priors for Q, S and W in Equation 13 are set to smaller values at $\lambda_1$ = 0.04, $\lambda_2$ = 0.1, and $\lambda_3$ = 0.01, respectively. Also, as per reference, the forecast horizon $h$ is set to five (5) days ahead to satisfy the exogeneity requirement, while keeping the estimates sufficiently precise.

The exogeneity assumption underlying the IV estimation strategy posits that an error in the forecast of reserves today $u_{q,t}$, is uncorrelated with future demand shocks, $v_t$, in Equation 3 and as such, can serve as an instrument for future demand for reserves, $q_{t+h}$. The time-varying covariance of reserves five (5) days ahead with their forecast error today (i.e., the denominator in the IV estimate) is used to assess the relevance of the chosen instrument. This covariance is interpreted as the result of the first-stage regression in a two-stage least-squares (2SLS) model and as reported in the following section, has been found to be always above zero, suggesting that the instrument is strong throughout the sample. In addition, the Bayesian posterior distributions of elasticity, $\beta_t^{IV}$ automatically ensures robustness to weak instruments, as it already reflects the uncertainty in both the numerator (i.e., the reduced-form coefficient) and the denominator (i.e., the first-stage coefficient). This directly accounts for possible non-normality of the IV estimate, which could occur if the denominator is close to zero. Finally, the IV estimation is robust to autocorrelation and heteroskedasticity of the demand shocks, because elasticity $\beta_t^{IV}$ is derived as a function of time-varying covariances estimated from a VAR model with ten (10) lags and stochastic volatility.

## 7. Results

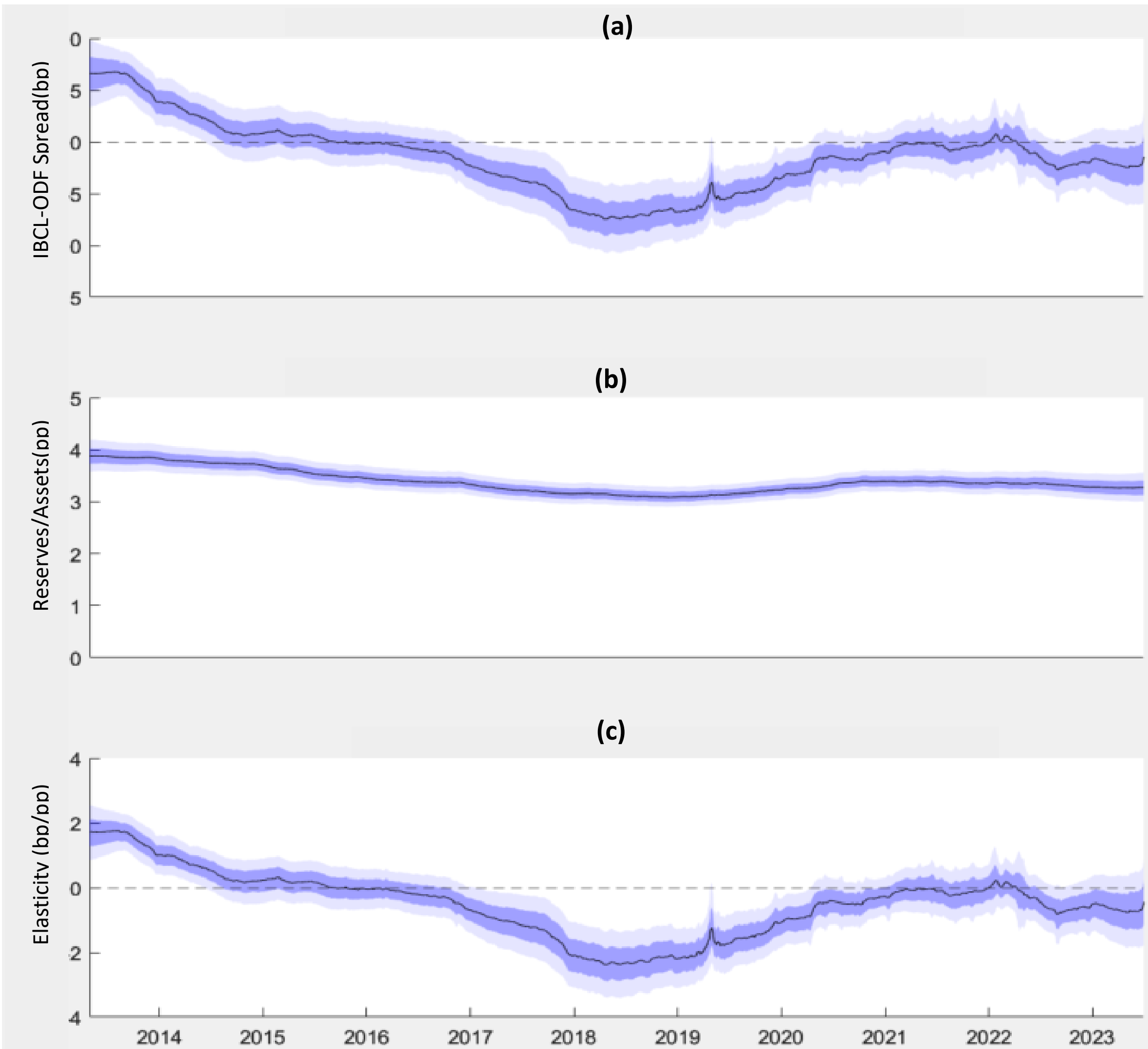
### 7.1 Beta Estimates

Figure 4 shows the elasticity of the IBCL rate to reserves estimated using the IV approach discussed in the previous section. The IV estimate (Panel (c)) is derived from the ratio of the 5-day ahead impulse response of the IBCL rate to reserves shocks (Panel (a)) and the 5-day ahead impulse response of reserves to reserve shocks (Panel (b)). The solid line represents the posterior median, while the dark and light blue shaded areas correspond to the 70 percent and 85 percent confidence bands, respectively, based on 5,000 iterations.

Panel (b) shows the 5-day ahead impulse response of reserves to reserve shocks, which is equivalent to the time-varying covariance of reserves and their past forecast errors (i.e., denominator in Equation 14). As mentioned in the previous section, this measure can also be interpreted as the result of the first-stage regression in a 2SLS model. The impulse response function (IRF) of reserves is more stable than the IRF of rates, and ranges from one to three percentage points (pp). As discussed in the previous section, confidence bands around this measure are entirely within positive territory, suggesting that the instrument is strong throughout the sample.

Finally, the estimate of elasticity in Panel (c) confirms the non-linearity of the slope of the aggregate reserve demand function for the Philippines. The estimate mirrors the impulse response of rates in Panel (a) in terms of both sign and statistical significance, which supports of the validity of the inference. The measure is mostly negative and ranges from 2 to -4 bps per pp. Confidence bands around this measure cross the zero upper bound for some periods, which according to Afonso, et al. (2022), indicate periods of abundant reserves. An assessment of the regions of reserve demand over time is discussed in Section 7.4.

**Figure 4. Elasticity of Rates to Reserves using IV approach**

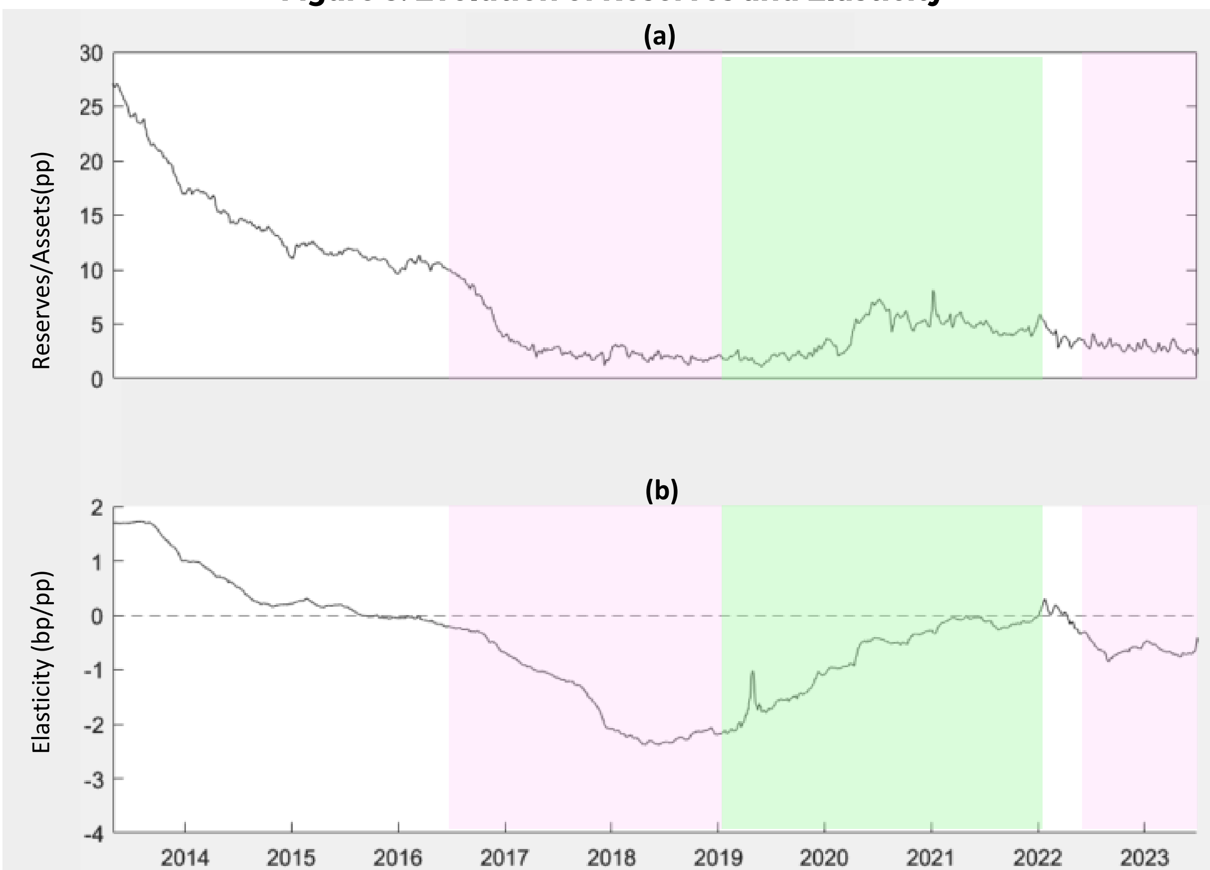



Source: Authors' calculations

### 7.2 Historical Analysis

Comparing the elasticity estimate alongside reserve levels over time (Figure 5) confirms that the movement of the slope aligns with theory. Positive elasticity is seen early in the study period which is evidence of the disconnect between reserves and rates before the implementation of the IRC system. During this period, the BSP introduced measures designed to ward off capital inflows. In particular, the BSP shifted to an asymmetric corridor as it rationalized the SDA facility and reduced the SDA rate by 50 to 150 bps below the RRP rate while maintaining the RP rate at 200 bps above the RRP rate in 2013. These events resulted in a de facto floor system that weakened the relationship between market rates and reserves. Hence, the BSP decided to abandon the de facto floor system and eventually move to a mid-corridor system. Episodes of reserve scarcity (in red) like with the start of IRC in mid-2016, or recovery from the COVID-19 pandemic by the second quarter of 2022, show a stronger relationship between rates and reserves with elasticity falling into deeper negative territory. Meanwhile, episodes of reserves rising or settling at stable levels (in green) like the series of RR ratio cuts in 2019 and the liquidity-enhancing measure implemented during the COVID-19 pandemic show a weaker relationship with the estimate approaching the zero-bound.

**Figure 5. Evolution of Reserves and Elasticity**




Source: Authors' calculations

Given the non-linearity of the slope of the aggregate reserve demand curve, the level of reserves that define what is "scarce," "ample" and "abundant" may have shifted over time. These shifts are marked by significant horizontal and vertical movements in the rate spread and the reserve-asset ratio. Four regimes are identified, namely: (i) pre-IRC period from Q2 2013 to Q2 2016; (ii) early IRC period from Q3 2016 to Q4 2019; (iii) COVID-19 pandemic period from Q1 2020 to Q1 2022; and (iv) post-pandemic period from Q2 2022 to latest. Table 1 shows the average rate spread $\boldsymbol{p}^{*}$, reserve-asset ratio $q^{*}$, and elasticity $\beta_t^{IV}$ for each identified regime.

**Table 1. Horizontal ($q^*$) and Vertical ($p^*$) Shifts in the Reserve Demand Curve**

| | All | Pre-IRC | IRC | Pandemic | Recovery |
|---|---|---|---|---|---|
| Rate Spread (p*) | 26.922 | 5.439 | 49.667 | 32.182 | 61.570 |
| Reserve-Asset Ratio (q*) | 8.834 | 16.521 | 2.208 | 4.432 | 2.752 |
| IV Elasticity ($\beta_t^{IV}$) | -0.497 | -0.388 | -1.699 | -0.362 | -0.637 |

Source: Authors' calculations

First, a significant shift in the three averages coincides with the implementation of the IRC system. The adoption of the IRC framework was intended to strengthen monetary policy transmission in the Philippines by fostering money market transactions and active liquidity management by Philippine banks (BSP, 2022). Peak elasticity is seen during this period which suggests that changes in bank behavior and market structures brought about by the IRC tightened the relationship between rates and reserves. Meanwhile, the pandemic period saw a fall in average rate spread and a rise in average reserves, possibly due to the BSP's deployment of various liquidity-enhancing measures. To infuse liquidity and stimulate domestic economic activity, the BSP implemented a cumulative 200-bp cut in the key policy rate, regulatory relief measures to BSP-supervised financial institutions (BSFIs), reduction in the RR ratios,[10] among others. As a result, reserve demand elasticity weakened during the period as liquidity infusions created a situation of "abundant" reserve supply.

The current regime saw a return to pre-pandemic averages —that is, higher rate spread and lower reserves ratios. Average elasticity, however, only increased slightly and has remained stable at present. The partial approach may be due to reserve levels still remaining above pre-pandemic averages. As of end-June 2023, estimated elasticity is at -0.45 bps which means a one percentage-point increase in normalized reserves leads to a median decline in the IBCL spread of 0.45 bps. This elasticity value is lower relative to the average of the current regime, which may indicate movement away from scarce reserve territory.

### 7.3 Non-linear Least Squares Fit

This section discusses the non-linear least squares (NLLS) fit of the forecasts of the reserve demand function developed in the earlier sections. This analysis identifies the thresholds of the reserve demand curve, which corresponds to the level of reserves that define the territories of abundant, ample, and scarce reserves. This post-processing exercise uses the estimated TVP-VAR model to generate one hundred (100) forecasts for each day of the sample period drawn from the in-sample five-day-ahead joint posterior distribution of the IBCL-ODF spread (p) and normalized reserves (q). A sigmoid function is then fitted onto the resulting forecasts to estimate the time-invariant non-linear parameters of the function, for the entire study period and for the above identified regimes (Figure 6).

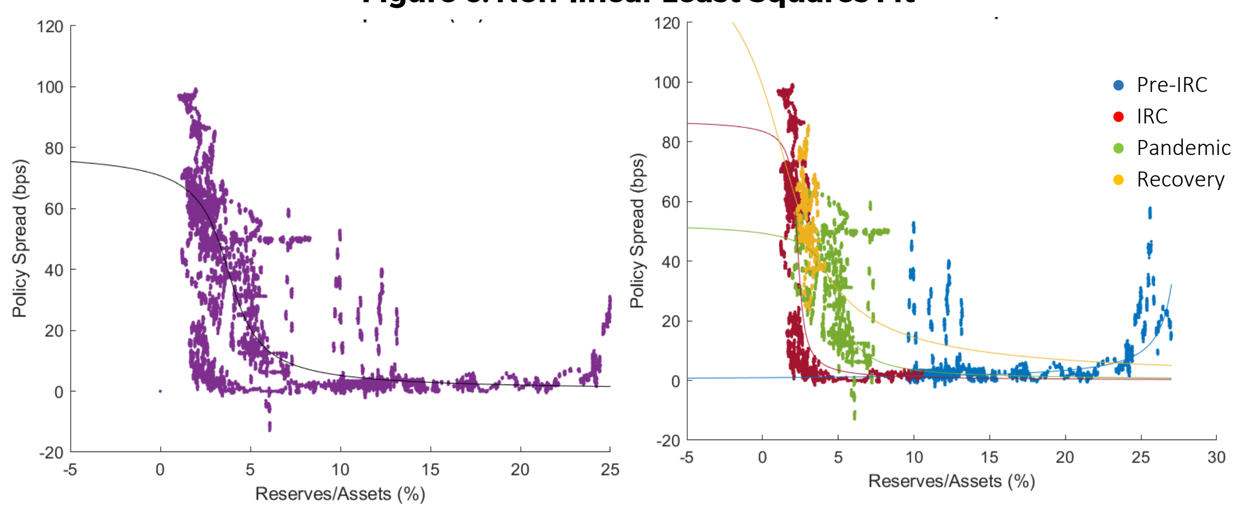
[10] The BSP reduced the RR ratio by 200 bps effective on 3 April 2020 for universal and commercial banks and non-bank financial institutions with quasi-banking licenses; and by 100 bps effective on 31 July 2020 for thrift banks and rural/cooperative bank.

Consistent with the reserve demand curve implied by the theory in Equation 2, the reserve demand function is specified as follows:

$$p_t = p_t^* + f(q_t - q_t^*;\theta) \qquad \text{with} \qquad f(x;\theta) = \left(\arctan\left(\frac{\theta_1 - x}{\theta_2}\right) + \frac{\pi}{2}\right)\theta_3 \tag{16}$$

where $p^*$ and $q^*$ are the vertical and horizontal locations, $\theta_1$ is a location parameter, $\theta_2$ is a scale parameter, and $\theta_3$ is a normalization factor. The arctan function is chosen for its smooth and decreasing sigmoid shape that goes to zero as $x \to \infty$, which is consistent with the theory discussed in Section 4. The location parameter, $\theta_1$, represents the point of maximum absolute slope, or the reserve level at which the negative slope of the curve is the steepest. As such, the region around $\theta_1$ is considered the region of scarce reserves, where the IBCL rate is highly sensitive to even small reserve shocks. The point of maximum slope growth, $k$ given by $k = \theta_1 + \theta_2/\sqrt{3}$, is where the curve's absolute slope increases at the highest rate as reserves decrease. This is interpreted as the threshold between ample and scarce reserves. A transformation of the normalization factor, $\pi\theta_3$ measures the vertical distance between the upper and lower asymptotes of the nonlinear time-invariant function in Equation 16—that is, $\lim_{x\to-\infty} f(x;\theta) - \lim_{x\to+\infty} f(x;\theta) = \pi\theta_3$. The theory predicts that, as reserves decline, the IBCL rate should converge (from below) to the OLF rate plus a spread capturing balance-sheet costs and other frictions.[11] As a result, $\pi\theta_3$ should be (at least) of the same order of magnitude as the OLF-IBCL spread.

**Figure 6. Non-linear Least Squares Fit**




Source: Authors' calculations

Table 2 shows the parameters of the nonlinear function derived from the procedure discussed above. Considering the entire study period, estimates show that the region of scarce reserves ($\theta_1$) occurs when reserves are around 3.8 percent of bank assets. Meanwhile, the level of reserves that mark the transition between ample and

[11] Stigma or borrowing caps may also push the IBCL rate towards the OLF rate. This may explain the tighter OLF-IBCL spread during the IRC period given complementary efforts to de-stigmatize the overnight lending facility.

scarce reserve territory ($k$) is more than half a point higher at 4.5 percent of bank assets. Looking at regimes, parameter estimates are much higher for the pre-IRC period (Q2 2013 to Q2 2016) which saw historically high levels of reserves (q*). The implementation of the IRC system shifted reserve levels down, which led to tighter estimates at 2.3 percent for the region of scarcity and 2.5 percent for the threshold. With the release of liquidity during the pandemic period, the parameters rose by more than two percentage points to 4.9 percent for the region of scarcity and 5.5 percent for the transition point. For the current recovery period, the region of scarcity has fallen to 1.3 percent of bank assets—below pre-pandemic levels—while the threshold of scarce and ample has fallen to 2.8 percent. Finally, the normalization parameter $\theta_3$ is around 79 bps, which is in the same order of magnitude as the average OLF-IBCL spread of 99.5 bps, confirming that our results are reasonable.

**Table 2. Non-Linear Time Invariant Parameters, θ**

| | All | Pre-IRC | IRC | Pandemic | Recovery |
|---|---|---|---|---|---|
| Region of Scarce Reserves ($\theta_1$) | 3.736 | 25.638 | 2.308 | 4.768 | 1.500 |
| Threshold between Ample and Scarce ($k$) | 4.489 | 26.596 | 2.524 | 5.274 | 3.026 |
| Normalization Factor ($\theta_3$) | 79.77 | 108.137 | 89.833 | 53.128 | 116.600 |

Source: Authors' calculations

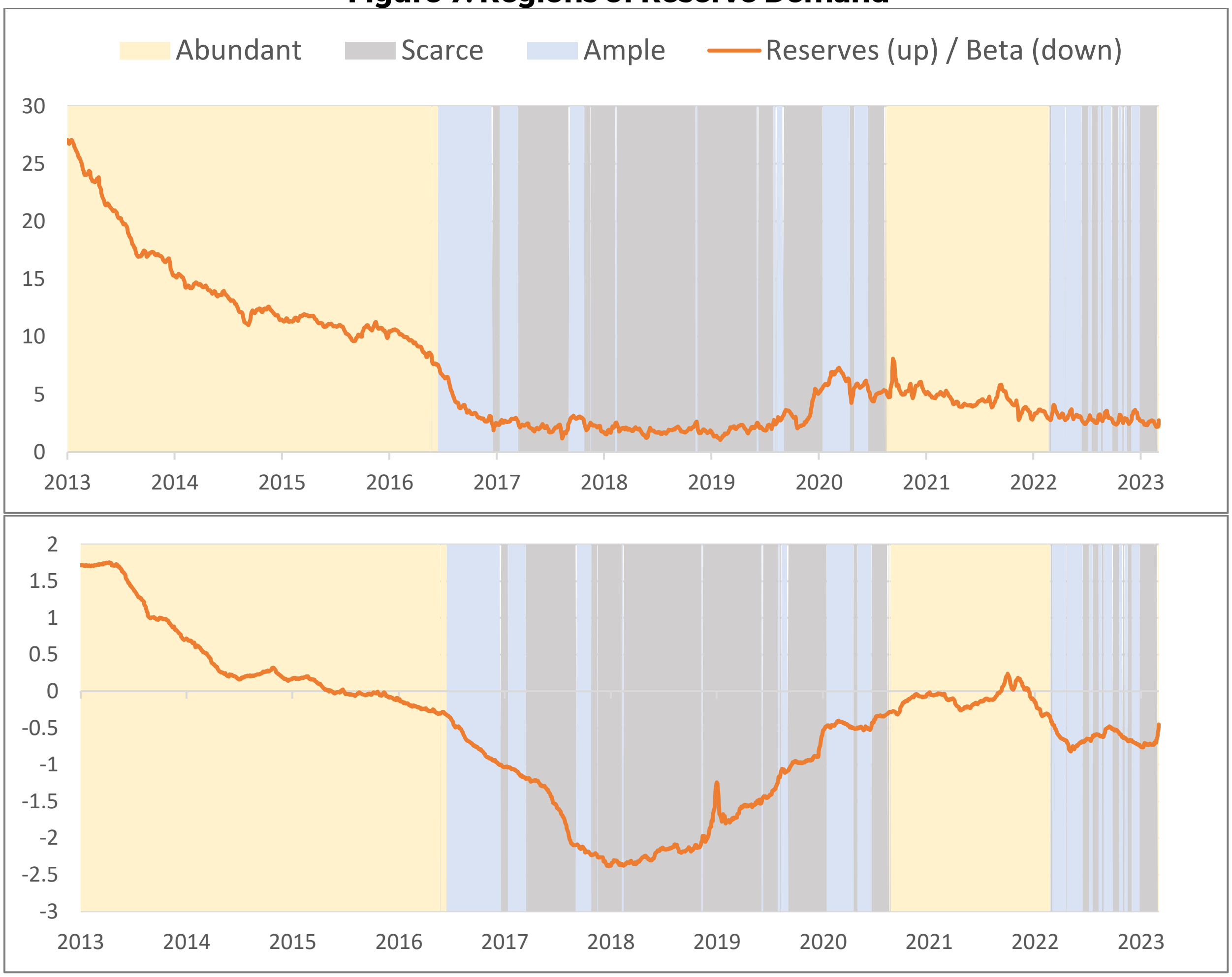
### 7.4 Regions of Reserve Demand over Time

This section identifies episodes of scarce, ample, and abundant reserve levels by dividing the sample period into its corresponding reserve region (i.e., scarce, ample, abundant). To be classified as scarce reserve territory, actual reserve levels should be below the threshold parameter $k$ for their respective regime as specified in Table 2. To be classified as abundant reserve territory, the elasticity estimate for the period should not be significant—that is, the confidence interval shown in Figure 4 crosses the zero-bound. Finally, periods that are defined as neither scarce nor abundant automatically falls under ample reserve territory.

Figure 7 shows the variation in the classification of reserve demand regions over time. Pre-IRC is mostly a period of abundant reserves where the IBCL rate was less sensitive to changes in reserve levels. The IRC period shows a gradual shift into scarce reserve territory as structural changes in BSP monetary operations led to a tighter relationship between rates and reserves. Meanwhile, the pandemic period displays a gradual shift to abundant territory given the deployment of various liquidity-enhancing measures meant to spur economic activity. As conditions normalize in the current recovery period, reserve levels have declined and have pushed reserve demand back into ample and scarce territory.

In terms of policy implications, this analysis can be used in real-time to monitor the market for reserves and assess the ampleness of reserve levels (Afonso, et al., 2022). As an example, average elasticity for the last month of the study period (June 2023) is at -0.7 bps and is significant at a 70 percent confidence interval. In addition, the average reserve level for the past month is at 2.5 pp of bank assets, which is below the regime's threshold between ample and scarce $k$ of 2.8 pp. These numbers support the assessment of a transition from ample to scarce reserve territory. As such, monetary policy operations during this period are expected to have some influence on the IBCL rate, and in effect, other short-term market interest rates. To some degree, knowing which region applies to the current level of reserves allows policymakers to assess the extent of their control over short-term market interest rates.

**Figure 7. Regions of Reserve Demand**




Source: Authors' calculations

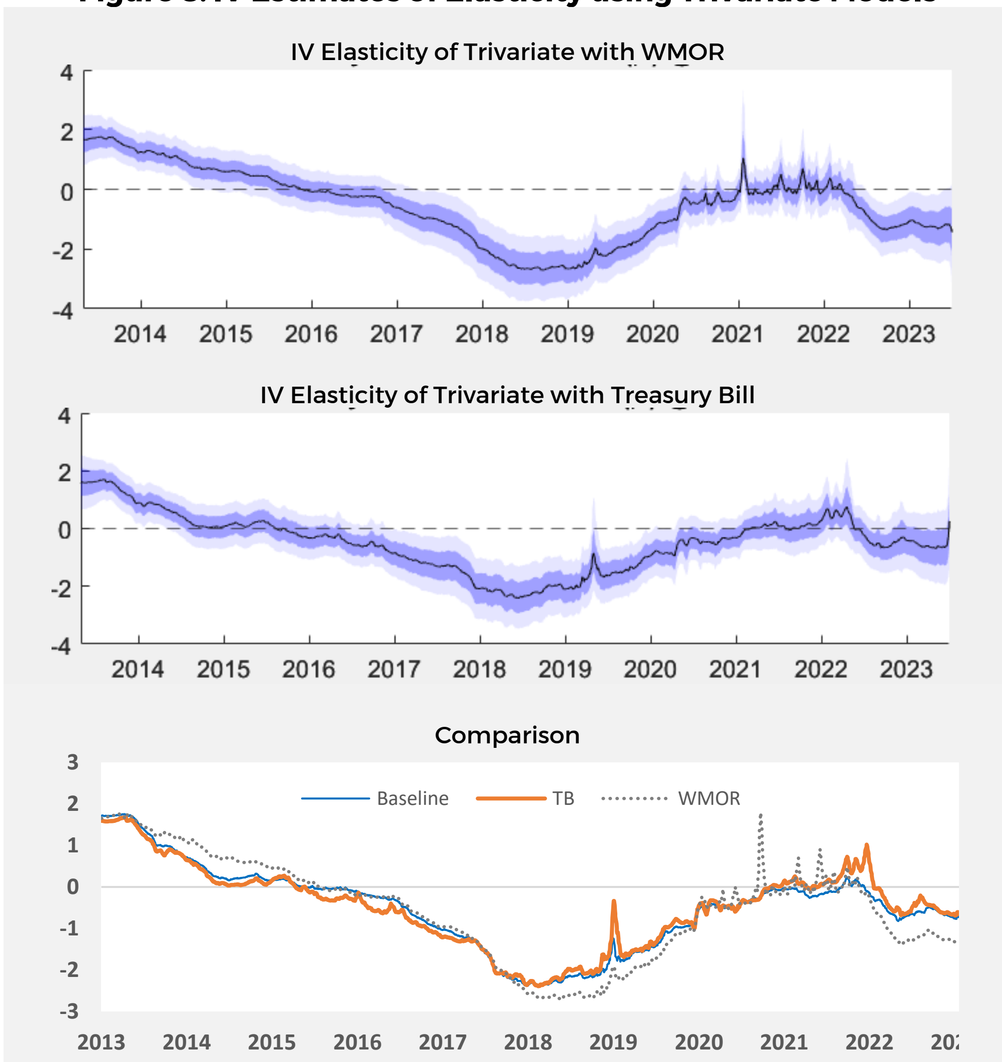
### 7.5 Robustness

Literature suggests that other factors could potentially affect the relationship between the money market rates and central bank reserves. To explicitly control for these confounding factors, two trivariate models were estimated with the weighted monetary operations rate (WMOR)[12] to account for BSP monetary operations and with the 91-day Treasury bill rate to account for Treasury market conditions. Following

[12] The WMOR is the combined rate of the BSP's various deposit facilities. Currently, it is the weighted average of the RRP rate, ODF rate, TDF rate and BSP Securities (BSPB) rate.

Afonso, et. al. (2022), the baseline model is extended to include the spread of the WMOR or the spread of the Treasury bill rate relative to the ODF rate. The elasticity for each model is estimated via the same IV estimation procedure used in the baseline bivariate model.

**Figure 8. IV Estimates of Elasticity using Trivariate Models**




Source: Authors' calculations

Figure 8 shows the results of the trivariate models alongside the baseline estimates. The elasticity derived from the trivariate models appear to be consistent with the estimates obtained from the bivariate model, which confirms the validity of the baseline bivariate estimate. All estimated elasticity falls and turns significant with the introduction of IRC, as aligned with scarcer reserves during the period. All estimates are also mostly insignificant in times of high reserve levels such as during the pandemic and the pre-IRC period. However, compared to the other specifications, the model with WMOR shows greater volatility during the pandemic period possibly due to the series of rate cuts intended to cushion the economic impact of lockdown measures and mobility restrictions. Meanwhile, stronger elasticity is observed during the recovery period possibly due to the series of rate hikes intended to address persistently elevated inflation during that time.

## 8. Conclusion

In an IT framework, central banks need to steer short-term interest rates towards the announced policy rate to implement the monetary policy stance. This is done through active OMO that either increases or reduces the available funds in the system to influence the level of the short-term rate. However, the effectiveness of OMO in influencing market rates is regime dependent. Specifically, Afonso et al. (2022) classifies regimes based on the available level of reserves in the system, namely, abundant levels characterized by high reserve balances that lead to unresponsive short-term rates, ample levels where rates start to become responsive, and scarce levels where low reserve holdings lead to highly sensitive rates.

This paper models a reserve demand function for the Philippines from April 2012 to May 2023 with the dual goal of: (i) estimating the slope or the elasticity of rates to reserve shocks over time; and (ii) identifying transition points that define scarce, ample, and abundant reserves. Specifically, this paper uses time-varying parameter vector autoregression (TVP-VAR) with stochastic volatility (SV) to model the reserve demand function, and an instrumental variable (IV) approach to estimate elasticity. This methodology addresses issues of non-linearity, structural shifts and endogeneity which are inherent in modelling monetary policy. As a post-processing exercise, non-linear least squares fit is applied to the forecasts of the resulting TVP-VAR model to identify the thresholds of the reserve demand curve or level of reserves that define the territories of abundant, ample, and scarce reserves.

Results show evidence of a non-linear, time-varying slope for the reserve demand function, as suggested in theory. This elasticity of rates to reserves was found to be generally negative but close to zero throughout the study period, which suggests that Philippine banks have maintained a generally ample level of reserves over time. The slope of the demand function also shifted along with structural changes in both rates (i.e., banks' balance-sheet costs and other frictions limiting arbitrage trading) and reserves (i.e., regulation, supervision, or market functioning). The adoption of the IRC system in 2016 encouraged more active monetary operations by the BSP and more active liquidity management by Philippine banks, which supported a tighter relationship between reserves and rates. Liquidity-enhancing measures deployed during the pandemic pushed reserve levels into abundant territory, which brought elasticity back to near-zero levels. As conditions normalized, the current recovery period saw reserve levels declining and pushed reserve demand back into ample and scarce territory.

In terms of policy implications, this paper's methodology can be used in real-time to assess the ampleness of reserves, which in effect, allows policymakers to gauge the extent of their control over short-term market interest rates. Looking at the last month of the study period, the significance of average elasticity (-0.7 bps) and an average reserve level (2.5 pp of bank assets) that is below the regime's threshold support the assessment of a transition from ample to scarce reserve levels. As such, monetary policy operations during this period are expected to have some influence on the IBCL rate, and in effect, other short-term market interest rates.

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