ESSAYS ON FOREIGN EXCHANGE INTERVENTION

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Dedication

For my mom and dad,

my lovely wife, Aurora,

and my three amazing children, Nadya, Rey, and Matteo.

Acknowledgments

Thank you to my supervisor, Eric Leeper, for providing guidance and feedback throughout my graduate years. I am extremely grateful to have you as an academic advisor and a good friend. Furthermore, to my friends in Indiana University and University of Virginia, thank you for the friendship that we have. I will never forget you all. I would also like to thank Bank Indonesia for the financial support throughout my study. Lastly, I would like to deeply express my gratitude to my family, my wife Aurora and my three amazing children, for putting up with my ups and downs and for providing a sounding board when required. We made it to the finish line!

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Preface

The Indonesian experience with foreign exchange intervention (FXI) is of interest. Since the adoption of inflation targeting in 2005, Bank Indonesia (BI) uses FXI as an integral part of its policy mix. Consequently, unlike many emerging market economies, BI intervenes in the exchange rate market more frequently.

To intervene in the exchange rate market, BI buys or sells foreign currency in the domestic financial market. An intervention is usually accompanied by sterilization measures to offset changes in the domestic liquidity. If left unsterilized, BI's foreign currency transactions may disrupt monetary policy objectives due to liquidity injections or absorptions they create. BI sterilizes its foreign reserve transactions by selling/buying government bonds, issuing/retiring central bank bills, or raising/reducing reserve requirement ratio. Over time, BI has focused more on the use of government bonds as sterilization instruments. The sales or purchases of bonds for sterilization purposes are done through open market operations.

As stated by Bindseil (2014), it is often found that there is a dichotomy or segregation between monetary policy and monetary operations within a central bank organization. Often the operational aspects of a central bank's policy, including FX intervention, do not have a clear theoretical or a conceptual basis. Using Indonesian experience with FX intervention, this research aims to provide insights into several key issues: How effective are foreign exchange interventions? Indeed, do they work at all? If so, what determines the effectiveness? How much should a central bank intervene and when? Finally, what are the effects of interventions on macroeconomic

conditions? My dissertation will focus on these questions and will be divided into two chapters.

The first chapter reconciles different results found in the literature regarding the effect of foreign exchange interventions. Using a simple FX intervention rule and a Bayesian VAR model estimated on Indonesian data, I find that the heterogeneity can, to a large extent, be traced back to differences in the identification of the policy shock in the VAR model. I show that different identification approaches correspond to different magnitude of interventions which lead to different effects. Lastly, this chapter provides operational insights on how to conduct FX interventions that are deemed effective.

In the second chapter, I conduct an empirical exercise that aims to give understanding on how sterilized foreign exchange intervention affects domestic credit. Conceptually, an important element of this exercise is the direct effect of Bank Indonesia's attempt to sterilize its foreign reserve transactions on commercial banks' balance sheet composition. I find that the sterilization of foreign reserve purchases crowd-out bank lending. Such impacts, however, depend on bank-level characteristics.

Chapter 1

The Effect of Foreign Exchange Intervention on Exchange Rate

1.1 Introduction

Do foreign exchange (FX) interventions affect the exchange rate? The answers have yet to reach a consensus. A review of the extensive empirical literature on foreign exchange intervention shows a wide range of results. Adler and Tovar (2014), Villamizar-Villegas (2016), Rincon and Toro (2010), and de Roure et al. (2013) are a few examples in the literature arguing that sterilized interventions have no effect on the level of exchange rate. Others, such as Lahura and Vega (2013) and, Kohlscheen and Andrade (2014) found a small (less than 0.25 percentage point of appreciation or depreciation) effect of interventions on exchange rate. Finally, Kim (2003), Barroso (2014), Pincheira (2013), Tobal and Yslas (2018), Kuersteiner et al. (2018), and Echavarria et al. (2014) found larger effects, albeit varying.

An important share of the FX intervention literature relies on structural vector autoregression (SVAR). Noteworthy examples include Kim (2003), Echavarria et al. (2009), and Blanchard et al. (2015). The use of SVAR is appealing in a such that it controls for endogenous interactions between variables in the model by imposing a minimal set of assumptions, known as identification schemes. However, the results

depend on whether the model's structure correctly captures the relationship between variables.

Literature on FX intervention mostly focuses on the policy's effectiveness as measured using historical data without explicitly touching on an important policy question: What is the size of an intervention that deemed to be effective? Motivated by this knowledge gap, this chapter reconciles differences regarding the effectiveness of foreign exchange interventions found in the literature and use the results to shed some lights on how to conduct effective interventions.

Using a structural VAR model estimated on Indonesian data, I show that the heterogeneity of FXI's effectiveness found in the literature is caused by differences in the identification of the FXI shocks. Furthermore, using a simple FX intervention rule, in which central bank only responds to pressures in the exchange rate market, the effectiveness of the policy can be characterized by how much the central bank responds to these pressures, also known as the systematic component of the policy rule. Characterizing the systematic component using an FX intervention rule allows me to derive a mapping between FXI shocks and the corresponding systematic components. Next, I use the impulse response function estimated from the VAR parameters to obtain the contemporaneous (impact) effect of FXI on exchange rate. The mapping described before helps me to express the estimated impact effect of interventions in terms of model's parameters and the systematic component of the policy rule.

The main result is the estimated impact effect of FX interventions as a function of the systematic component of the policy rule. It illustrates all possible pairings of impact effects and systematic components that are consistent with the data. Using this result, then I show that the heterogeneity of results in the literature can be linked

to differences in the identification of the policy shock in the VAR model. In fact, a particular identification may correspond to a specific belief related to how much a central bank reacts to exchange rate pressures. Thus, a further implication is that if a policy maker has a certain prior belief related to the exchange rate elasticity of the intervention instrument, her prior belief then can be translated into an estimate of the impact effect of her policy action. This is an important implication of this study since it can provide a novel insight into how much a central bank needs to intervene for it to have an effective impact. Lastly, the estimation of the effect of FX intervention was then extended to the dynamic effect of the intervention for a 24-month horizon.

This study follows the work of Caldara and Kamps (2017), that focuses on the heterogeneity of fiscal multipliers found in the literature. They compared different values of fiscal multipliers corresponding to different systematic components of fiscal policy rules expressed in prominent fiscal literature, including Blanchard and Perotti (2002) and Mountford and Uhlig (2008). They argue that this heterogeneity was related to different restrictions or identification in the VAR model that implicitly results in different business cycle elasticity of tax revenue and government spending.

This work is also related to Baumeister and Hamilton (2015) on how one can impose prior beliefs on a systematic component. Focusing on the oil market, the basis of their work is that the price elasticities of demand and supply can be written as functions of the elements of reduced form VAR parameters. Expressing price elasticities in terms of reduced form parameters allows them to explicitly impose priors to the elasticity values.

The remainder of the chapter is organized as follows. In section 2, I derive the analytical relationship between the systematic component of the policy rule and the

effect of interventions. In section 3, I apply the analytical framework to an SVAR model estimated on Indonesian data. In section 4, I present some policy implications. Lastly, section 5 concludes the chapter.

1.2 Empirical Analysis

Using a structural VAR model, I first characterize the systematic component of an FX intervention rule that relate changes in a policy instrument to changes in exchange rate. Then I show that identifying the systematic component of the policy rule is equivalent to identifying FX intervention shocks. Lastly, I derive an analytical relationship between the parameters characterizing the systematic component and the implied effect of the policy on the exchange rate.

1.2.1 The SVAR model

Consider a structural VAR (SVAR) presented in Equation 1.1 below

$$y_t' A_0 = \sum_{\ell=1}^{k} y_{t-\ell}' A_\ell + c + \varepsilon_t' \quad \text{for } 1 \leq t \leq T \tag{1.1}$$

where y_t is an $n \times 1$ vector of endogenous variables, ε_t is an $n \times 1$ vector of structural shocks, A_ℓ is an $n \times n$ matrix of structural parameters for $0 \leq \ell \leq k$ with A_0 invertible, c is a $1 \times n$ vector of parameters, k is the lag length, and T is the sample size. The vector $\varepsilon_t | y_0, ..., y_{t-k}$ is Gaussian with mean zero and variance I_n.

The SVAR described in Equation 1.1 can be written in the compact form

$$y_t' A_0 = x_t' A_+ + \varepsilon_t' \quad \text{for } 1 \leq t \leq T \tag{1.2}$$

where $A_+' = [A_1' \quad ... \quad A_k' \; c']$ and $x_t = [y_{t-1}' \quad ... \quad y_{t-k}' \; 1]'$. The dimension of A_+ is $m \times n$ where $m = nk + 1$. A_0 and A_+ are the structural parameters.

Furthermore, the model can be written in reduced form as:

$$y_t' = x_t' B + u_t', \quad u_t \sim \mathbb{N}(0, \Sigma) \tag{1.3}$$

which allows the link to the structural representation of the model through $\mathbb{E}[u_t u_t'] = \Sigma = (A_0 A_0')^{-1}$, $B = A_+ A_0^{-1}$ and $\varepsilon_t = A_0 u_t$, where u_t is the vector of reduced-form residuals.

To study the effect of a policy on a particular economic variable, the identification of the structural shocks is necessary. However, structural parameters are not identified. Therefore, to recover the structural shocks, identifying restrictions need to be imposed; we need to select the elements of ε_t that represent this shock.

Consider the partition $\varepsilon_t = [\varepsilon_{p,t}', \varepsilon_{np,t}']'$, where $\varepsilon_{p,t}$ is a $z \times 1$ vector of policy shocks and $\varepsilon_{np,t}$ is a $n - z \times 1$ vector of non-policy shocks, with z denotes the number of policy variables in the SVAR. Specifying $\varepsilon_{p,t}$ is equivalent to specifying the equation that characterizes policy behaviour. Assume $z = 1$, thus, without loss of generality, the 1st equation of the SVAR is the policy equation, such that

$$y_t' A_{0,1} = x_t' A_{+,1} + \varepsilon_{p,t}, \quad \text{for } 1 \leq t \leq T \tag{1.4}$$

with $A_{0,1}$ and $A_{+,1}$ denote the first column of A_0 and A_+, respectively. Rewrite Equation 1.4 in the form of policy rule

$$y_{p,t} = y'_{np,t}\psi_0 + \sum_{\ell=1}^{k} y'_{t-\ell}\psi_\ell + \omega_p \varepsilon_{p,t}, \quad \text{for } 1 \leq t \leq T \tag{1.5}$$

where $\psi_0 = -a_{0,1np}/a_{0,11}$ is a $n - z \times 1$ vector of contemporaneous coefficients, $\psi_\ell = -a_{\ell,1\cdot}/a_{0,11}$ are $n \times 1$ vectors of lagged coefficients, $\omega_p = 1/a_{0,11}$ is a constant scaling factor. $a_{\ell,ij}$ denotes the ijth element of A_ℓ. The first two terms on the right-hand side of Equation 1.5 describe the systematic component of the FXI rule. This systematic component characterizes how the intervention instrument at time t, $y_{p,t}$ responds to contemporaneous and lagged movements of other variables in the model.

Utilizing the established relationship between the structural form and the reduced form VAR, and concentrating on the problem of identifying the FX intervention shocks, Equation 1.5 can be expressed in terms of reduced form residuals as follows:

$$u_{p,t} = \psi_0 u_{np,t} + \omega_p \varepsilon_{p,t}, \quad \text{for } 1 \leq t \leq T \tag{1.6}$$

The above equation states that unexpected changes in the policy variable (intervention instrument) depend endogenously to the non-policy variable of interest ($u_{np,t}$) and exogenously to the uncorrelated policy shocks ($\varepsilon_{p,t}$). Hence, the vector ψ_0 fully characterizes the systematic component of the policy equation (rule).

1.2.2 Foreign exchange intervention rule

Foreign exchange intervention is defined as an activity of buying or selling foreign currency responding to innovations in the exchange rate. In practice, central banks use different measures to capture innovations in the exchange rate (Patel and Cavallino (2019)). Many countries decide how much to intervene based on the nominal changes of the exchange rate (appreciation or depreciation). Others use measures such as the volatility of the exchange rate or the deviation from a certain target.

The baseline exercise uses a policy rule that responds only to the appreciation or depreciation of the nominal exchange rate (leans-against-the-wind). In this setup, I use the adjusted stock of foreign currency reserve (r) as a proxy of central bank's intervention instrument and nominal exchange rate (s) as the non-policy variables. Later, as a robustness check, I modify the analysis with a policy rule that responds to exchange rate volatility (exchange rate smoothing).

Rewriting Equation 1.6 using the specified variables of choice, we have

$$u_{r,t} = \psi_s^r u_{s,t} + \omega_r \varepsilon_{r,t}, \quad \text{for } 1 \leq t \leq T \tag{1.7}$$

where ψ_s^r is the element of ψ_0 associated to the exchange rate that captures the automatic response of foreign currency reserve to changes in the exchange rate. Specific for this exercise, parameter ψ_s^r is measured as the exchange rate elasticity of foreign currency reserve.

1.2.3 Measuring the (contemporaneous) effect of FXI on exchange rate

To measure the effect of interventions on exchange rate, I use the impulse response function (IRF) estimated from the SVAR parameters. In particular, I look at the exchange rate response to a one-time unanticipated intervention shock at horizon $t = 0$, or in VAR term, $L_0(A_0, A_+) = (A_0^{-1})'$.

As pointed out in Caldara and Kamps (2017), the systematic component of the policy rule also identifies the exogenous FX intervention shocks. This unique mapping allows us to derive an analytical relationship between the parameters characterizing the policy rule and the impact (contemporaneous) effect: Policy shocks uniquely depend on elasticities ψ_s^r and reduced form parameters (B, Σ), so does the impact effect.

Note that we have $u_t = (A_0^{-1})'\varepsilon_t$. Thus, we can obtain the vector of impact IRFs by running a projection of u_t on $\varepsilon_{r,t}$. To express $(A_0^{-1})'$ as function of ψ_s^r, rewrite Equation 1.7 such that

$$\omega_r \varepsilon_{r,t} = u_{r,t} - \psi_s^r u_{s,t}$$

where ψ_s^r is an $(n-1) \times 1$ vector. Omitting the scaling factor and for an arbitrary u_t gives

$$L_0(\psi_s^r, u_t)_{s,r} = [(u_{r,t} - \psi_s^r u_{s,t})(u_{r,t} - \psi_s^r u_{s,t})']^{-1}(u_{r,t} - \psi_s^r u_{s,t})u_{s,t}' \tag{1.8}$$

Lastly, by expressing the reduced-form residuals in terms of the elements of the covariance matrix Σ, Equation 1.8 can be written as:

$$L_0(\psi_s^r, \Sigma)_{s,r} = \frac{\sigma_{s,r} - \psi_s^r \sigma_s^2}{(\psi_s^r \sigma_s)^2 + \sigma_r^2 - 2\psi_s^r \sigma_{s,r}} \tag{1.9}$$

where $\sigma_{s,r}$, σ_s^2, and σ_r^2 are elements of Σ that describe the covariances between the reduced form residuals for exchange rate $u_{r,t}$ and policy variable $u_{s,t}$.

The use of a simple rule greatly simplifies the analysis. Equation 1.9 shows that, under the simple rule, the impact effect solely depends on the systematic component of the policy rule. Meanwhile, the elements of Σ will determine whether the combination of the impact effect and its corresponding systematic component of the policy rule is consistent with the data or not. Notice that the elements of Σ that matter are the ones that related to exchange rate and reserve. Therefore, the co-movement between exchange rate and reserve will be the key to pin down all possible combinations of the impact effect and its respective systematic component of the policy rule that satisfy the data.

The impact effect, L_0, measures the covariance between the exchange rate and the FX reserve residuals, $u_{s,t}$ and $u_{r,t}$, conditional on the realization of a policy (FX intervention) shock. On the other hand, as shown in Equation 1.7, ψ_s^r determines the response of $u_{r,t}$ to a change in $u_{s,t}$ and, consequently, the covariance between $u_{r,t}$ and $u_{s,t}$, conditional on the realization of an exchange rate shock. By construction, these two conditional covariances add up to the unconditional covariance, $\sigma_{s,r}$, observed in the data. Hence, by varying the size of the systematic component, ψ_s^r, the conditional covariance between $u_{r,t}$ and $u_{s,t}$ explained by exchange rate (non-policy) shocks will also change. Therefore, to match the data, the conditional covariance generated by the FX intervention (policy) shock, and thus, the impact effect, needs to adjust. I present the application of this analytics in the next section.

1.3 Application and Results

I apply the framework in Section 1.2 to study the effect of FX intervention on exchange rate. I estimate the VAR model on a monthly data for Indonesia from January 2009 to June 2021 to obtain the reduced form parameters (B, Σ). The estimation will then extend to the dynamic impact of FX intervention.

1.3.1 Data and estimation

Central bank often buys foreign exchange in tranquil times and sells foreign exchange during crisis periods. These activities are easy to describe but difficult to measure. Several issues complicate the measurement. First, many central banks, including BI, do not publish their foreign exchange reserve transactions. Second, the use of a central bank's official foreign reserve asset data is likely to overestimate the actual central bank's foreign reserve transactions. This measurement error most likely comes from changes in interest income and changes in the market value of securities held. Furthermore, official foreign reserve assets held in a central bank also include non-currency asset, such as SDR allocations, golds, reserve position in the IMF, and other reserve assets.

Following Aizenman et al. (2021), I estimate BI's foreign exchange reserve transactions by subtracting non-currency asset components, changes related to interest income, and changes related to valuation from BI's official reserve asset position. The resulting residual will be referred as BI's reserve transactions ($RESTRX$). A detailed explanation of this construction can be found in Appendix A.

Table 1.1: Data description

Variables	Notations	Description	Data Source
Proxy for cumulative FX interventions	r	Stock of FX reserves less non-currency reserve and changes in valuation and interest income, measured in domestic currency	Bank Indonesia & author's calculation
Monetary aggregate	m	Base money (M0), measured in domestic currency	Bank Indonesia
Domestic interest rate	i	Money market rate in percentage per-annum	Bank Indonesia
Exchange rate	s	Nominal exchange rate - IDR/USD	Bank Indonesia

The model consists of the following four endogenous variables: adjusted FX reserve, r, as proxy of cumulative FX interventions; base money (M0), m; interest rate, i; and nominal exchange rate changes, s, where a positive value of s corresponds to a weaker exchange rate (depreciation). Series are end-of-month values. All variables, except interest rates, are logged. Table 1.1 describes the details of the data. The use of monthly series for high-frequency variables is expected to minimize the endogeneity issue between variables. It should be noted that BI intervenes on a daily basis and exchange rates and money market interest rates also change in real time.

The VAR includes twelve lags of the endogenous variables and a constant. I impose a Minnesota prior on the reduced-form VAR parameters by using dummy observations (see del Negro and Schorfheide (2012) for details) and select the hyper-parameters that govern the prior distributions to a relatively weak prior.[1]

[1]No attempt was made to optimally select the hyper-parameters. Using the same notations as in del Negro and Schorfheide (2012), the hyper-parameters are $\lambda_1 = 0.2$, $\lambda_2 = 0.5$, $\lambda_3 = 1$, $\lambda_4 = 0.01$, and $\lambda_5 = 0.01$.

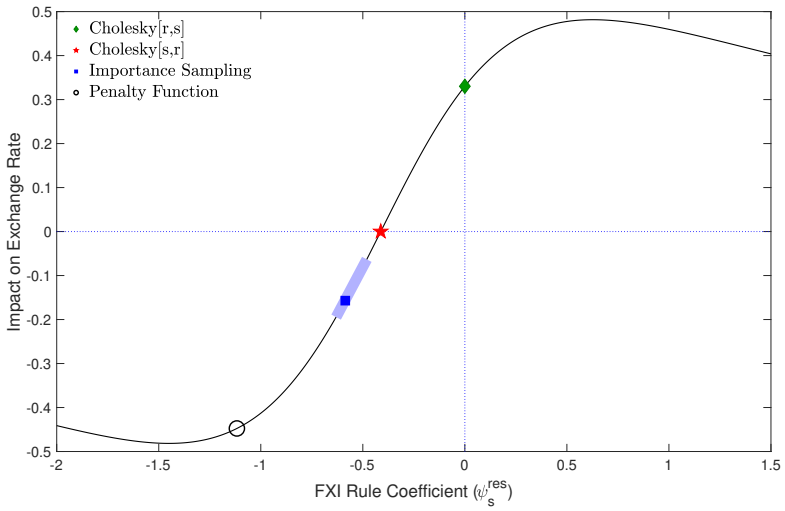


Figure 1.1: Contemporaneous effect on exchange rate changes as function of policy rule coefficient.

1.3.2 Impact effect of foreign exchange intervention

Figure 1.1 illustrates the relationship between impact effects of FX intervention and the exchange rate elasticity of foreign reserve. The effect measured as percentage point changes in nominal exchange rate appreciation or depreciation. A negative effect denotes percentage point reduction in exchange rate depreciation/appreciation and a positive effect means percentage point increase in exchange rate depreciation/appreciation.

To obtain this result, first I used the reduced-form VAR parameters (B and Σ) evaluated at their OLS estimates. Structural coefficients were then recovered using the relationship $B = A_+ A_0^{-1}$ and were used to estimate the impulse response function. Lastly, the mapping between impact effects (L_0) and the elasticity (ψ_s^r) were obtained using Equation 1.9.

Solid line in Figure 1.1 shows all combinations of impact effects and contem-

poraneous elasticities of reserve to exchange rate (ψ_s^r) that are consistent with the data. Based on the data, the set of admissible impact effect is ranging between -0.5 and 0.5 percentage point. To put this result into perspective, the average nominal exchange rate appreciation and depreciation over the sample period is 1.5 and 1.9 percent per month, respectively. Furthermore, negative impact effects are associated with policy rule that feature a larger systematic component in the negative direction. For instance, the more Bank Indonesia sells its foreign exchange reserve when the exchange rate depreciates, the greater the decline in the depreciation rate will be.

This result highlights two important properties of the policy effectiveness. First, the immediate impact of an intervention is symmetrically bounded, and the boundaries have reversing signs. An important implication of this is if policy makers do not have sufficient information to limit the range of plausible values of reserve elasticities, then the impact of the policy becomes difficult to determine. If policy makers take an agnostic view of plausible values for the exchange rate elasticity of reserve, the impact effect lies within a range between -0.5 and 0.5 percentage point. However, policymakers typically utilize additional information or impose some restrictions to the model to narrow down plausible elasticity values.

Second, the impact of intervention on the exchange rate is exactly zero if and only if exchange rate elasticity of foreign reserve (ψ_s^r) is around -0.45. If we define an effective intervention is the one that can reduce the intensity of exchange rate changes, then it is safe to say that -0.45 is the threshold elasticity for an effective intervention.

1.3.2.1 Recursive identification

The exchange rate elasticity threshold of -0.45 explained before is an example of how to apply restrictions to model parameters. In this application, the elasticity threshold can be obtained by assuming that the policy does not have a direct impact on the exchange rate. In VAR terms, this is a recursive (Cholesky) identification that orders the exchange rate variable before the foreign exchange reserve. This identification sets up a rule so that exchange rate shocks explain all the unconditional covariances between reserve and exchange rate residuals. Conversely, if the exchange rate variable is ordered after the foreign exchange reserve, the result is a point (depicted as diamond) in Figure 1.1 where the exchange rate elasticity of foreign reserve is zero and corresponds to an impact effect of positive 0.35 percentage point.

It is natural to limit the analysis to negative elasticity values to be in line with the conventional rule-of-thumb in central banks' practices. Specifically, central banks want to sell (decumulate) or buy (accumulate) reserve when the exchange rate depreciate or appreciate, respectively. For ψ_s^r larger than -0.45 (larger elasticity in negative direction), the impact effect is negative for the following reason. Under the simple policy rule, a larger (more negative) elasticity than 0.45 implies that the non-policy shocks (exchange rate shocks) generate larger (more negative) conditional covariances between reserve and exchange rate compared to the Cholesky identification, which also larger than the unconditional covariances observed in the data. Therefore, for the model to match the data, the (negative) policy shocks (FX intervention shocks) need to generate positive conditional covariances, and that translates into negative impact effects.

From this application alone, one can see that the impact of an intervention on

the exchange rate can vary according to the identification or restriction assumptions used in the model. For example, ruling out positive values may be useful to narrow down the set of plausible assumptions about the exchange rate elasticity of reserve. Yet, excluding positive elasticity values would still be insufficient to identify the sign, let alone the size of the impact effect. In the next subsection, I apply a sign restriction to the VAR's parameters to isolate the sign of impact effects to be consistent with conventional wisdom in central banks' practices.

1.3.2.2 Sign restriction

A widely used VAR identification is imposing sign restrictions on impulse responses. Prominent examples are Mountford and Uhlig (2008) and Arias et al. (2019). Built on their work, I use the following set of restrictions on impulse responses to identify foreign exchange intervention shocks. First, I assume that foreign exchange interventions react contemporaneously solely to the exchange rate. This assumption is consistent with the evidence provided by the leaning-against-the-wind literature and follows closely Kim (2003) and Echavarria et al. (2009)'s approach for the cases of the US and Colombia, respectively. Second, the response of exchange rate is restricted to have a particular sign to comply with the conventional wisdom on the effects of interventions. In particular, central bank interventions are expected to reduce exchange rate pressure (appreciation/depreciation). Third, I impose a fully sterilized intervention assumption by restricting the contemporaneous responses of monetary aggregate and policy rate to be zero (zero restrictions). I apply these assumptions using a Bayesian technique with two sampling methods, namely the penalty function approach (PFA) of Mountford and Uhlig (2008) and importance sampling as in Arias et al. (2019).

The penalty function approach (PFA) involves the use of a loss function to obtain an optimal orthogonal matrix that satisfies the zero restrictions while also satisfies (or come close to satisfying) the sign restriction. First, an orthogonal matrix is drawn from a distribution. Then this matrix is evaluated for its conformity with the restrictions that have been set. PFA penalizes the drawn matrix if it does not satisfy the restrictions. The objective is to obtain an optimal orthogonal matrix that satisfies the restriction or has the smallest penalty over a certain number of draws.

The second method is the importance sampling. Similar to the PFA, this method also works within the scope of the orthogonal reduced-form parameterization. However, unlike PFA, the inference under importance sampling method were drawn from a distribution of orthogonal matrices conditional on the sign and zero restrictions. The importance sampling method discards draws that do not comply the restrictions but keeps the ones that satisfy them. Therefore, while the PFA results in a single optimum orthogonal matrix, importance sampling produces a distribution of orthogonal matrices that satisfy the restrictions.

The circle in Figure 1.1 depicts the combination of the systematic component of foreign exchange reserve and the associated impact effect on exchange rate implied by the penalty function approach. Meanwhile, the square in Figure 1.1 shows the result obtained from the importance sampling approach, presented as a posterior median value within its 68% probability band.

Evaluated at the OLS estimate, the penalty function approach results in an impact effect of -0.44 percentage point. This means that, based on historical data, when estimated using the PFA, Bank Indonesia's FX interventions were able to reduce the intensity of exchange rate depreciation/appreciation by 0.44 percentage point.

This impact effect corresponds to an exchange rate elasticity of reserve around -1.1. Meanwhile, the posterior median of the impact effect obtained from the importance sampling method is -0.16 percentage point, implying an elasticity value of -0.59. There are a couple of things that can be discussed from the results: the first is related to the differences in the magnitude of the impact effect and the second is related to the inference that can be drawn from the two methodologies.

First, the relatively larger impact effect generated by the penalty function approach is not surprising. As stated in Chapter 13 of Kilian and Lutkepohl (2017), the penalty function approach not only punishes violations of sign restrictions more than it rewards VAR models with the correct signs, but also rewards responses with larger magnitudes. Thus, it may implicitly correspond to an individual belief of a relatively large systematic component of the policy rule or the exchange rate elasticity of reserve. In Uhlig's words (see Uhlig (2005)), "one is, in effect, imposing somewhat more than just sign restrictions".

Subjective beliefs on an elasticity value was also studied by Baumeister and Hamilton (2015). They provided an explicit characterization of the influence of prior beliefs on posterior distributions for structural parameters in set identified SVARs. Focusing on oil market VAR models, the central premise of their work is that priors can be imposed explicitly on the price elasticities of demand and supply. However, this work is different in the sense that I do not impose specific priors on the exchange rate elasticities of reserve. In fact, as mentioned at the beginning of this section, a relatively weak set of priors are imposed on the reduced-form parameters. Nevertheless, the exercise performed in this research shows that the two widely used sampling methods, even when applied using the same set of priors, can produce different results that may implicitly link to a certain prior belief.

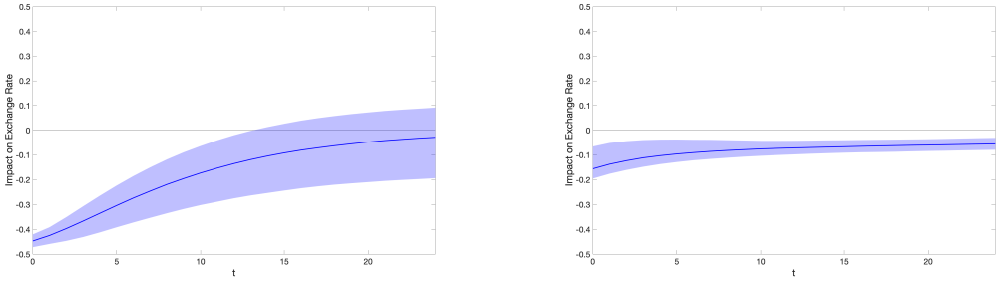
Second, the result under the importance sampling method is set identified since they were drawn from a distribution of rotation matrices and impulse responses that satisfy the restrictions. Meanwhile, the result coming from the PFA is not set identified since they were drawn from a single optimal rotation matrix. On the one hand, the robustness of a set identification is an appealing motivation for using sign and zero restrictions since it covers a wider set of structural parameters. On the other hand, however, this set may include values that are questionable.

It is natural to compare these results with existing literature. However, estimates on exchange rate elasticity of reserve for Indonesia, especially in the context of FX intervention policy, are uncommon in the literature. Pontines and Rajan (2011) is perhaps the only one that specifically estimate this measure in the form of a central bank intervention policy function. Using monthly data from January 2000 to July 2009, they estimate the exchange rate elasticity of reserve of -0.894 when using bilateral exchange rate data and -0.722 when using trade weighted exchange rate data. These two estimates lie between the results from the PFA and the importance of sampling method.

1.3.3 Dynamic effect of foreign exchange intervention

In this subsection, I extend the estimation of the impact effect in the previous subsection to a full Bayesian estimation of the dynamic effect. VAR's reduced-form parameters (B, Σ) are now drawn from a posterior distribution that belong to a family of conjugate distributions.

Results are shown in Figure 1.2. The PFA and the importance sampling method



(a) Penalty function (b) Importance sampling

Figure 1.2: Median responses of exchange rate to FXI shock identified using sign restriction. Shaded areas are the 68% probability bands from 20,000 draws.

result in median effects that are within the 68-percent credible sets for 24-month horizon. The median short-term exchange rate responses to an exogenous intervention shock are consistent with the contemporaneous (impact) effects described in the previous subsection. Using the penalty function approach, the median impact effect is -0.44 percentage point; under the importance sampling approach, the median response is around -0.16 percentage point. Evaluated at the whole horizon, the penalty function approach results in an exchange rate response that lasted for about 12 months before going back to its initial value. In the meantime, importance sampling results in a more persistent exchange rate response; the negative exchange rate responses lasted for the entire estimation horizon (24 months). To summarize, when estimated using importance sampling method, FX intervention has smaller but more persistent effect compared to the PFA method. Aligned with results in the previous subsection, these differences may also correspond to a specific belief on the relative persistency of the effect.

The results are also in line when compared to existing research, although it is relatively difficult to find empirical literature that specifically uses Indonesian data. Using instrumental variable on a panel data covering 52 developing countries which

includes Indonesia, Adler et al. (2015) found that interventions have economically meaningful and persistent effect on exchange rate.[2] Meanwhile, Blanchard et al. (2015) found that countries that intervened in the exchange rate market, in which the sample includes Indonesia, were able to ease the effect of capital flows shocks to exchange rate. They also pointed out that the effectiveness lasts for 3 to 4 quarters, supporting the persistency observed in our result.

1.3.4 Alternative policy rule: Exchange rate smoothing

In this subsection, I investigate the robustness of the results presented in this section using an alternative intervention policy rule: exchange rate smoothing. Under this rule, a central bank's FX intervention responds to an increase in the exchange rate volatility and aims to reduce the volatility of the exchange rate without any specific intentions to weaken or strengthen the nominal exchange rate.

I define a daily volatility of the exchange rate as the percentage deviation of a daily exchange rate (s_t) from its 10-day average ($\bar{s}$). I present this volatility in an annualized term by multiply each day's value to the squared root of 260 (see Equation 1.10) and obtain its daily average for each month of observation to be used in the estimation. Similar volatility measure was used by Fratzscher et al. (2019).[3]

$$dailyvolatility = \frac{|s_t - \bar{s}|}{\bar{s}} \times 100 \times \sqrt{260} \tag{1.10}$$

[2]The persistency in their result was backed-up with half-life of around 12 to 23 months.

[3]In many empirical study, volatility is often associated with variations in exchange rate shocks or standard deviations of exchange rate changes. I define volatility this way because authorities are often concerned with drastic exchange rate movements–a risk that is better measured by the deviation of the exchange rate from a certain value, such as the fundamental exchange rate or the average over a period.

Unlike changes in the exchange rate, exchange rate volatility, by construction, is always positive. Thus, I need to modify the SVAR identification. First, I do not differentiate between buy or sell interventions. In other words, all intervention activities have the same sign. The sign restriction is then intended to capture the effect of interventions on exchange rate volatility. Either buy or sell, FX interventions are expected to reduce volatility. Second, I still assume that foreign exchange interventions react contemporaneously solely to the volatility of the exchange rate. Lastly, contemporaneous responses of the interest rate and the monetary base are set to be zero to reflect fully sterilized interventions.

Results under the alternative policy rule are shown in Figure 1.3. In general, the use of exchange rate smoothing rule still produces a combination of impact effects and policy rule coefficients that are in line with the baseline results, especially regarding how the impact of the intervention is symmetrically bounded. Based on the data, the set of admissible impact effects is ranging between -1.1 and 1.1 percentage point. Notice that in this exercise, under the alternative policy rule, I do not distinguish between buy and sell interventions. Therefore, it makes sense to limit the elasticity of foreign exchange reserve to exchange rate volatility to positive values. If so, then the acceptable effect is within the range of 0.19 to -1.1 percentage point. To put this into perspective, the monthly daily-average volatility over the sample period is 9%.

If an effective intervention is the one that can reduce exchange rate volatility, then this policy is effective if and only if the elasticity value is greater than 0.04. This elasticity value coincides with the result coming from a Cholesky identification that places the exchange rate volatility variable before reserve. Compared to the baseline exercise, this elasticity value is relatively smaller, even close to zero. This means that if BI wants to influence the exchange rate volatility, the intervention that needs

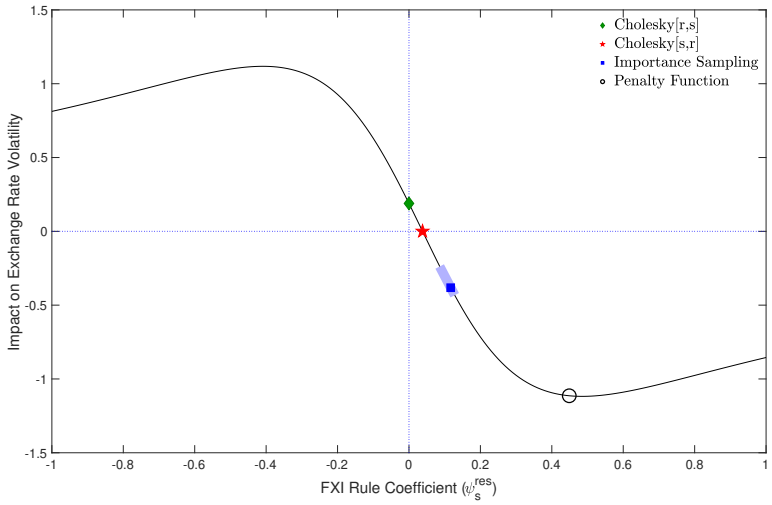


Figure 1.3: Contemporaneous effect on volatility of S as function of FXI rule coefficient under alternative policy rule.

to be taken does not need to be large. This is certainly different from the baseline result under lean-against-the-wind policy rule, where BI needs to intervene at a larger minimum amount for the policy to have impact on the exchange rate.

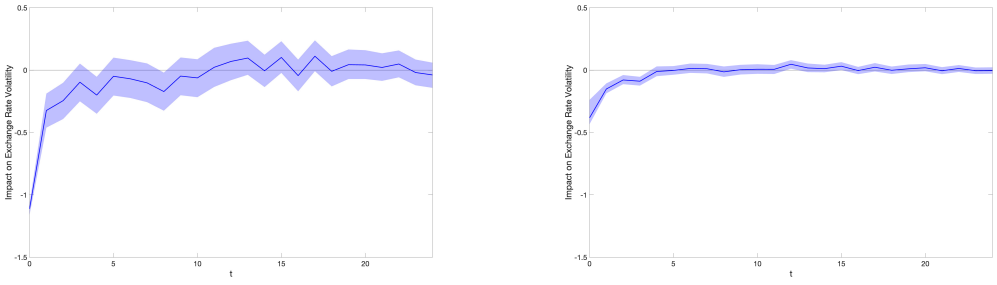
Next, I apply sign restriction on the impact of the policy shock. Evaluated at the OLS estimate, the penalty function approach results in an impact effect of 1.1 percentage point reduction in the volatility, which corresponds to an elasticity around 0.45. Meanwhile, the posterior median of the impact effect from the importance sampling method is 0.38 percentage point reduction in the volatility, implying an elasticity value of 0.12. Under the alternative policy rule, sign restriction gives results that are in line with the baseline result. That is, the use of the importance sampling approach corresponds to a combination of elasticity and impact effect that are relatively smaller compared to the penalty function approach (see Table 1.2).

Lastly, I extend the analysis to the dynamic effect of FX intervention. In contrast to the baseline result, under the alternative policy rule, a central bank intervention

Table 1.2: Result comparison between baseline and alternative policy rule

Sampling Method	(1) Baseline policy rule	(2) Alternative policy rule
PFA		
Impact	-0.44	-1.1
Elasticity	-1.13	0.45
Importance sampling		
Impact	-0.16	-0.38
	(-0.07; -0.20)	*(-0.23; -0.43)*
Elasticity	-0.59	0.12
	(-0.49; -0.64)	*(0.09; 0.13)*

Notes: Numbers in the brackets are the 68% credible sets from the posterior distributions.



(a) Penalty function (b) Importance sampling

Figure 1.4: Median responses of exchange rate to FXI shock identified using sign restriction under the alternative policy rule. Shaded areas are the 68% probability bands from 20,000 draws.

has no long-term impact. The two sampling methods used in this analysis produce less persistence effects. The effect of FXI only lasts for 3 months. The most striking difference between the two sampling methods is the magnitude of the short-term effects, while the mid- and long-term dynamics are not significantly different from zero (Figure 1.4).

Literature studying the effect of FXI on the exchange rate volatility find similar results. Adler and Tovar (2014), in their study covering 15 countries (including Indonesia), finds that the purchase of FX reserve by an authority effectively reduces the pace of appreciation which then limit the deviation of the exchange rate from its

equilibrium value. Using a wider sample, Fratzscher et al. (2019) argues that FXI is effective to smoothen exchange rate movements. Regarding the persistency of the effect, not many studies have shown this. To name a few, Echavarria et al. (2014) and Villamizar-Villegas (2016) find that the effect of FXI on the exchange rate volatility in Colombia persists for about one month.

1.4 Policy implications

A couple of important questions when it comes to implementing foreign exchange intervention is: How much and when should a central bank intervene? The empirical results presented in this chapter can shed some lights on these important policy issues.

1.4.1 The size of FX intervention

This chapter explores how the effect of FX intervention can be explicitly linked to the systematic component in the FXI rule. Under a simple rule, this systematic component can be interpreted as the exchange rate elasticity of foreign exchange reserve. Since Bank Indonesia fully controls foreign reserve, then the elasticity value can be translated into an operational-level indicator to shed some lights on how much should central bank intervene to be effective.

Using the baseline policy rule, the threshold elasticity value for an effective FX intervention is -0.45. In other words, for each 1% appreciation/depreciation of the exchange rate, the central bank must respond by buying/selling 0.45% of the total foreign exchange reserve. Using the IDR value of the adjusted FX reserve as of June

2021 (IDR 1,821 trillion), Bank Indonesia needs to intervene at least IDR8.2 trillion (±USD570 million) for its to be effective.

Considering that FX intervention is costly, which is not the scope of this research, then it is also necessary to consider the persistency of its effect when designing the operational framework of the policy. The question of persistency is very important from a policy standpoint. If a central bank suffers costs to intervene, any cost-benefit analysis will depend on how durable those benefits are. Even if intervention is effective on impact, it may not be worthwhile if the costs are persistent while the benefits are transitory. Of the two alternative policy rules presented in this chapter, the FX intervention rule that responds to movements in nominal exchange rate have more persistent effect compared to policy rule that responds to exchange rate volatility.

1.4.2 The timing of FX intervention

Drawing on a survey of 21 central banks, Patel and Cavallino (2019) argues that more than two thirds of their respondents normally intervene after the market has moved in a certain direction, while only three central banks occasionally intervene pre-emptively. Many central banks that carry out FX intervention also set an undisclosed range in which the exchange rate may move, called the intervention band. The exchange rate will be determined according to market mechanism if it remains within the range of the band. If the exchange rate penetrates the upper or lower limit of the range, the central bank will intervene in the foreign exchange market so that the exchange rate moves back into the intervention band.

The limited impact of the policy can be used as a guide in determining the inter-

vention band. Notice that based on the exercise under the baseline policy rule, the impact of an FX intervention is bounded within a 0.5 percentage point appreciation and a 0.5 percentage point depreciation. Knowing this, Bank Indonesia certainly does not want to wait for the exchange rate to move too far from its benchmark value before intervening, otherwise it will be more difficult to bring the exchange rate back to the benchmark.[4]

1.4.3 Rules, discretion, and flexibility

The choice of an optimal policy rule is an interesting topic for further study, but the empirical results in this study can provide some insight. Despite the limited effect, the two policy rules analyzed in this chapter indicate that an FX intervention is effective in responding to exchange rate pressures, either measured by nominal changes or increasing volatility. In this research, the use of these two policy rules seems mutually exclusive. However, in practice both are equally important, especially for central banks that adopt inflation targeting. While expected inflation dynamics are determined by the nominal trend path of the exchange rate, higher volatility might affect the firms' price-setting behaviour and cause imported inflation to fluctuate (see Devereux and Yetman (2010)).

In the case of appreciation trends, Bank Indonesia should lean against the wind in the exchange rate market to accumulate reserve. The negative elasticity threshold of 0.45 not only ensures that the intervention is effective in reducing the appreciation pressure, but also ensures that Bank Indonesia earn additional foreign reserve which can be useful in the future.

[4]One example of a benchmark value is the level of the exchange rate that is considered in line with the fundamentals of the economy, often known as the fundamental exchange rate.

On the other hand, when depreciation pressure increases, Bank Indonesia should intervene by responding to volatility increases for the following reason. The limited effectiveness of the policy indicates that the market mechanism remains the main determinant that drives the exchange rate. However, the empirical result also shows that a relatively small amount of intervention will be effective in reducing exchange rate volatility. Furthermore, when depreciation pressures intensifies a decrease in exchange rate volatility will prevent speculators from taking larger positions (Chutasripanich and Yetman (2015)).

Regardless the choice of the policy rule, deciding the size and timing of an intervention still needs to be supported by a comprehensive practical and operational knowledge of the functioning of global and domestic exchange rate markets. This underpins the flexibility to calibrate intervention mechanisms to maximize its effectiveness. Policy makers can also use extra-model information, such as market intelligence, to narrow the set of empirically plausible exchange rate elasticity of reserve values, allowing for sharper inference on the effect of FXI.

1.5 Conclusion

This chapter examines the heterogeneity of foreign exchange intervention effectiveness found in the literature. Using a simple intervention policy rule, first I show that the effect of foreign exchange intervention on exchange rate can be expressed as a function of the systematic component that characterize the policy rule. Second, I apply the analytical framework on Indonesian data and able to characterize the set of impact effect of interventions and its implied systematic component on the policy rule. I

argue that each point in the set, a pair consist of intervention's impact effect and its implied systematic component of the policy rule, are the only set of pairings that are consistent with the data.

Then I apply sign restrictions using two Bayesian VAR sampling methods, namely the penalty function approach and the importance sampling. I find that the two approaches, even if estimated using the same set of priors, resulted in a significantly different values which may implicitly correspond to a subjective belief on the magnitude of the systematic component of the policy rule.

Lastly, I extend the exercise into a full Bayesian estimation to estimate the dynamic effects of the foreign exchange intervention. I find that foreign exchange interventions that respond to nominal exchange rate changes (leans against the wind) have more persistent effect compared to the ones that respond to exchange rate volatility (exchange rate smoothing).

The empirical results presented in this chapter can shed some lights on how central banks can effectively carry out their foreign exchange interventions. Particularly, insights were drawn on the size and the timing of the interventions, as well as the flexibility of the policy.

Chapter 2

Foreign Exchange Intervention and Banking Intermediation: Evidence from Indonesia

2.1 Introduction

This chapter examines the effects of a central bank's foreign reserve transaction on banking intermediation and aims to shed light on the possible crowding-out effect from official reserve accumulation on lending in Indonesia. I find that such impact also depends on individual bank's balance sheet components and types of banks. For instance, the crowding-out effect is stronger for banks with higher leverage ratio. The effect is also stronger on state-owned banks relatively to private-owned ones.

Foreign exchange intervention is Bank Indonesia's (BI) policy initially aimed at coping with exchange rate pressure. However, in line with the changes in the global environment after the 2008 global financial crisis, especially the liquidity glut, this policy also served as a measure to minimize the negative effect of volatile foreign capital flows on the domestic economy. Hence, under a flexible exchange rate regime, BI intervenes on the foreign exchange market to dampen the pressure in exchange rate market and/or to accumulate foreign exchange reserve (precautionary measure). This has been evidenced by the growing foreign exchange reserve assets over the past

two decades (Figure 2.1).

BI started to accumulate foreign reserve since 2009. Prompted by the excessive global liquidity flowing into developing countries after the financial crisis in 2008, Indonesia was faced with excessive exchange rate appreciation risk which then followed by the significant absorption of foreign reserve ever since. Thus, it can be said that the accumulation of foreign exchange reserve in Indonesia occurs as part of exchange rate management through the intervention in the exchange rate market.

Reserve accumulation is usually accompanied by sterilization measures to offset changes in domestic liquidity. It is documented that nearly all foreign reserve purchases are sterilized in emerging and developing economies. For instance, Aizenman and Glick (2008) report that the monetary base for most central banks does not change after foreign reserve purchases, implying that they were offset by sterilization. In line with their paper, Figure 2.1 shows that the growing trend of Indonesia's foreign exchange reserve, especially in the last four years, has not been followed by expansion in the monetary base, indicating that the central bank has generally sterilized the reserve accumulation.

To accumulate reserve, BI buys foreign currency in the domestic financial markets. If left unsterilized, the reserve purchases may disrupt monetary policy objectives due to liquidity injections it creates. Thus, BI needs to sterilize foreign reserve purchases by selling government bonds, issuing central bank bills, or raising reserve requirements. Over time, BI has focused more on the use of government bonds as sterilization instruments. The sale or purchase of bonds for sterilization purposes are done through open market operations.

Whether it is done through the sales of government bonds, issuance of central

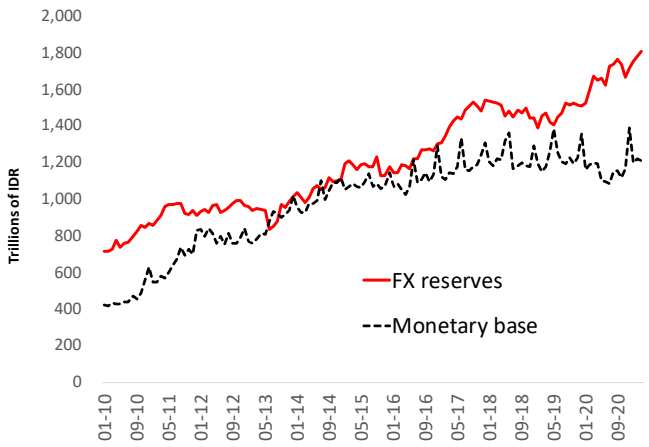


Figure 2.1: FX reserve and monetary base

bank bills or increase in reserve requirements, the sterilization aspect of reserve accumulation is equivalent to domestic borrowing (central bank borrows from domestic market). Assuming private borrowers compete with central banks in the domestic credit markets, then sterilized FX interventions have the potential to distort the proper functioning of the domestic credit markets.

Research interests in foreign reserve regained its traction in mid 2000s following the dramatic increase in foreign reserve levels, especially in developing countries. Literature in this field is concentrated on the motivation and costs or benefits of reserve accumulation. This study attempts to enrich the literature by analyzing the impact of foreign reserve accumulation on bank lending, with a focus on Indonesia.

The study of bank lending has attracted the attention of many researchers given its ability to influence resource allocation, productivity, and growth. Many factors influence the behavior of bank lending. Some that are directly related to my study are as follows: Buch and Goldberg (2014) showed how liquidity risk affects bank lending behavior in various emerging market countries while Baskaya et al. (2017) argued on

how capital flows affect bank lending in Turkey. The contribution of my work to this strand of literature is that I investigate a previously less studied shock in banking sector, that is central bank's reserve accumulation.

The core of this study is the balance sheet effect of foreign reserve transactions conducted by the central bank. In particular, foreign reserve transactions by central banks can affect the economy by changing the composition of banks' balance sheets, hence the name "balance sheet effect". Cespedes et al. (2017) argues that, when the economy is financially constrained, a central bank's intervention in foreign exchange market matters. They claim that foreign exchange interventions can affect the quantity of loans, especially foreign currency loans. For instances, when a central bank sells reserve, they also increase the supply of foreign currency lending to the economy.

The empirical study in this chapter assumes that private borrowers compete with central banks in the domestic credit markets, hence sterilized reserve purchases have the potential to distort the proper functioning of the domestic credit markets. Similar assumptions also form the basis of Cook and Yetman (2012). They found that foreign reserve accumulation in five Asian countries was accompanied by lower credit growth. Furthermore, Hofmann and Shin (2019) and Yun (2020) found a similar result for Colombia and South Korea, respectively. Chang (2018) also found that sterilized purchases of official reserve can be contractionary when domestic banks are binding by collateral or leverage constraints. On the other hand, Gadanecz et al. (2014) argues that commercial banks can easily sell short-term central bank securities to finance new lending, which in turn can stimulate aggregate demand. In line with their paper, Garcia (2011) argues that, in the presence of a credit channel, sterilized foreign exchange purchases may raise aggregate demand through an expansion of bank credit. This study contributes to this strand of literature by documenting

the heterogenous effect of sterilized reserve accumulation on bank lending. Unlike previuously mentioned studies, I use bank-level balance sheet in a panel data setting and exploit how cross-sectional heterogoneity can lead to different effects of reserve accumulation on bank lending.

The remainder of the chapter is organized as follows. In section 2, I present evidence and facts that build my hypotheses. In section 3, I develop the empirical framework to test the hypotheses developed in Section 2. Section 4 extends the analysis to capture the effects of bank-level balance sheet compositions and types of banks. In section 5, I present some policy implications. Lastly, section 6 concludes the chapter.

2.2 Motivating evidence and hypotheses

This section first discusses an overview of banking in Indonesia. Second, it explains how Bank Indonesia (BI) conduct its sterilized foreign exchange intervention, including how this policy affects commercial banks' balance sheet. Based on these observations, I develop the main hypotheses.

2.2.1 Banking environment in Indonesia

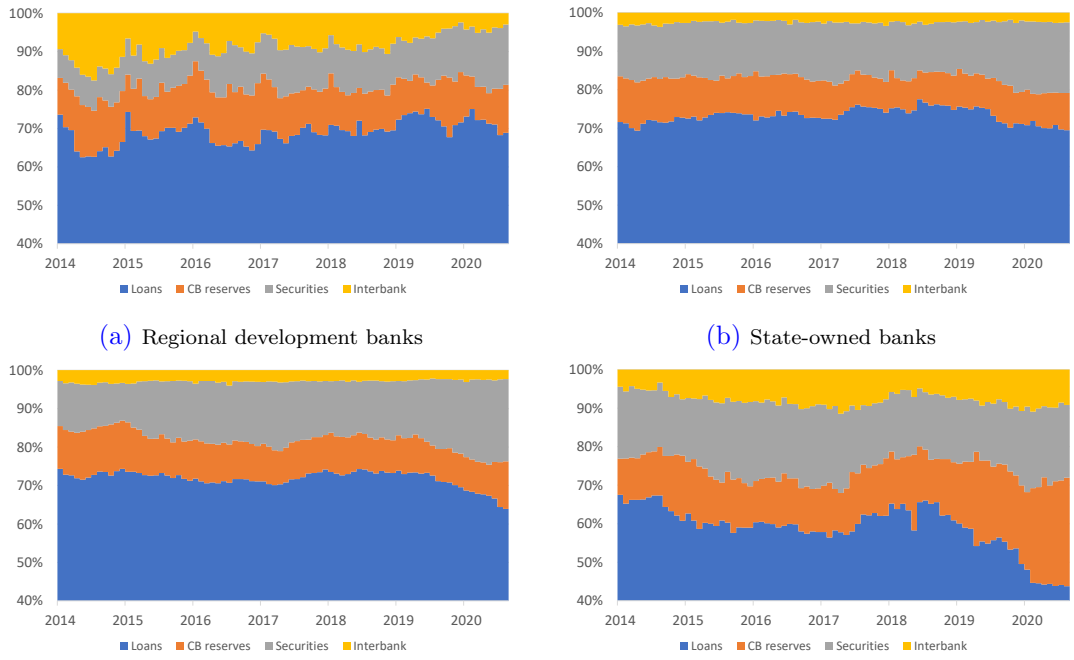
Based on their business activities, banks in Indonesia, which supply approximately 90% of private funding in Indonesia, can be divided into two categories: conventional banks and sharia-based banks. Conventional banks can be further categorized into

two more categories, namely commercial banks and rural credit banks.[1] This research will focus on (conventional) commercial banks.

As of October 2021, commercial banks in Indonesia consists of 107 active institutions which can be further categorized based on their ownership and size of their core capital. Based on their ownership, commercial banks can be divided into regional development banks, state-owned banks, domestic private-owned banks, and branch offices of foreign banks. Apart from being different in terms of ownership, the four types of banks are also different in terms of their business. Regional development banks focus on banking services in a specific area while other banks operate nationally. State-owned banks, compared to private-owned ones, have the privilege of being the government's agents, which allow them to transact securities directly with the government, including Bank Indonesia. Lastly, for foreign bank branch offices, lending is not their main business, rather more on the channeling of foreign investment. Figure 2.2 shows the composition of assets by type of bank. Panel (d) shows that the portion of loan to assets of foreign banks is not as large as other types of banks.

Next, based on the size of the core capital, banks in Indonesia can be categorized into large banks (core capital above IDR70 trillion), medium banks (core capital between IDR14 trillion to IDR70 trillion) and small banks (core capital below IDR14 trillion). Further details regarding the distribution of these banks can be seen in Table 2.1.

[1]The banking classification in this study follows the Indonesian Financial Services Authority (Otorita Jasa Keuangan/OJK).



(a) Regional development banks

(b) State-owned banks

(c) Private-owned banks

(d) Foreign banks

Figure 2.2: Asset composition by types of bank

Table 2.1: Number of commercial banks in Indonesia based on Indonesian FSA's classification (as of October 2021)

	Size of core capital			**TOTAL**
	<IDR14 Trillion	IDR14 - IDR70 Trillion	>IDR70 Trillion	
Regional development bank	26	1		**27**
State-owned bank		1	3	**4**
Domestic private-owned bank	61	9	1	**71**
Branch offices of foreign banks	4	1		**5**
TOTAL	**91**	**12**	**4**	**107**

Table 2.2: Stylized banking system's balance sheet

Central bank		Commercial banks	
Assets	**Liabilities**	**Assets**	**Liabilities**
Net foreign assets	**Monetary liabilities**	**Reserve with CB**	**Deposits**
Net domestic assets	Currency		
Govt. securities	Bank reserve	**Loans**	**Market borrowings**
	Equity	**Investments**	**Equity**
		Govt. securities	
		Private securities	
		Foreign currency assets	

2.2.2 Mechanism

Bank Indonesia's foreign currency transactions change domestic currency liquidity in the banking system. To maintain the liquidity in the economy, these transactions need to be sterilized, otherwise it would jeopardize monetary policy operational targets. Table 2.2 below provides a highly stylized version of a monetary system (consisting of a central bank and commercial banks) balance sheet, shown in terms of net amounts. In practice, for example, when the central bank purchases foreign currency (shown as foreign assets in the balance sheet), it automatically credits commercial banks' reserve accounts, which leads to an expansion in the monetary base. To minimize risks of increasing money supply and the associated inflationary pressures, the central bank must issue instruments to sterilize the local currency liquidity it injected through the purchases of foreign currency. While Bank Indonesia buys/sells foreign exchange reserve outright from the market, the sterilization process is carried out through auctions in open market operations, mostly through the sale/purchase of government bonds or central bank bills. By doing this, the central bank neuters the effect of their foreign reserve transactions on domestic liquidity.

2.2.3 Hypotheses

Following the scheme laid out in Table 2.2, depending on an individual bank's strategy, the purchase/sale of foreign reserve by Bank Indonesia financed (sterilized) by the sale/purchase of sterilization securities may affect a commercial bank's loans for any given level of deposits. The empirical analysis presented next will provide a test of two competing hypotheses. First, the crowding-out hypothesis, based on Bernanke and Blinder (1988). This hyphotesis assumes that money and bonds are imperfect substitutes. Their model shows that loanable funds can be used to purchase loans, bonds or excess foreign reserve. Therefore, an increase in government bonds holding would diminish the amount of loanable funds available for lending, thus crowding-out loans. On the other hand, the second hypotheses states that the supply of government bonds can be expansionary. The substitutability of liquid securities with excess reserve, or the use of short-term government securities as a liquidity buffer, will lead commercial banks to increase lending (see Gadanecz et al. (2014)).

2.3 Empirical framework

I empirically investigate and formally quantify the effect of central bank's foreign reserve transactions on commercial banks' lending. The core of this analysis is monetary system balance sheet, which involves the balance sheet of both Bank Indonesia, the central bank, and the commercial banks. According to theory (see Gabaix and Maggiori (2014) and Blanchard et al. (2015)), government's sterilized foreign exchange interventions can affect the real economy through its ability to change the composition of bank balance sheets.

2.3.1 Identification

The identification scheme starts with a specification of a baseline model in which two competing hypotheses explained before are tested. To begin with, I use a reduced-form representation of an equilibrium condition in supply and demand of bank lending similar as in Gadanecz et al. (2014) and Pazarbaşioğlu (1997).

2.3.1.1 Loan supply

Bank's aggregate loan supply (L^s) is modelled as a function of the net interest margin, the state of the overall economic environment, and bank's lending capacity (LC). Net interest margin is measured as the difference between lending rates and cost of funds ($r^l - r^d$). The higher the net interest margin, the more motivated banks will be to provide loans. Furthermore, two proxies represent the state of the economy. First, the expected inflation (π^e) is assumed to negatively affect L^s as higher inflation is associated with higher uncertainty. Second, the economic output (y) is expected to have a positive effect on L^s. To complete the loan supply equation, I define lending capacity as a variable that can be measured by banks' holdings of liquid assets, leverage factor (the ability to create supply of loanable funds), banking capital flows, and the quality of banks' loan books. Equation 2.1 below summarizes this.

$$L^s = f(r^l - r^d, \pi^e, y, LC) \tag{2.1}$$

2.3.1.2 Loan demand

Equation 2.2 below captures aggregate demand for lending. Aggregate demand for lending (L^d) can be assumed to negatively depend on the lending rates (r^l) as consumer are likely to delay investment plans during periods in which lending rates are relatively high. Like the effect on loan supply, higher economic output (y) is expected to have a positive effect on L^d. The expected inflation rate (π^e) is also assumed to have a positive effect on L^d as higher inflation would erode the nominal value of consumer's debt. Lastly, stock market price (s) is included as proxy for future income and is expected to have a positive effect on consumer's lending.

$$L^d = f(r^l, y, \pi^e, s) \tag{2.2}$$

2.3.1.3 Macroprudential policy

Bank Indonesia began implementing macroprudential policy in 2008. This policy focuses on addressing systemic risks in the financial sector caused by deteriorating financial conditions, sectoral imbalances, and imprudent behavior. This policy is implemented using instruments such as Loan to Value (LTV) ratio, Countercyclical Capital Buffer (CCB), Macroprudential Intermediation Ratio (MIR), and Macroprudential Liquidity Buffer (MPLB).

The implementation of the above policies can directly affect the balance sheet of commercial banks. Conventional wisdom in central banking argues that loosening macroprudential policies can increase loanable funds. Thus, BI's macroprudential policy should also be considered in measuring the impact of BI's foreign exchange

reserve transactions on banking intermediation.

2.3.2 Baseline specification

Summarizing Equation 2.1 and Equation 2.2, the baseline model specification can be written as:

$$Y_{i,t} = \alpha + \delta Y_{i,t-1} + \beta_1 RESTRX_t + \beta_2 X_t + \beta_3 Z_{i,t} + \beta_4 mpru_t + \theta_i + \tau_t + \varepsilon_{i,t} \quad (2.3)$$

The dependent variable $Y_{i,t}$ is banking intermediation indicator measured either with the change in the ratio of loan-to-assets, difference in log of loans, or difference in the value of loans for bank i's at period t. The loan-to-asset ratio is used in Buch and Goldberg (2014). Gabriel Jimenez and Saurina (2017) used loan growth (changes in log of loans), while Baskaya et al. (2017) used changes in the level of loans. On the other hand, Yun (2020) use both changes in log loans and log loans as the dependent variables. The regressions also include a lagged dependent variable $Y_{i,t-1}$ in order to capture the persistence of the dependent variable.[2]

$RESTRX$ is Bank Indonesia's quarterly reserve transactions in trillions IDR. Matrix X includes macro-level control variables that characterize the equilibrium in supply-demand of loan as described before. These variables are lending rates, net interest margin, output growth, expected inflation rate, capital flows, and stock market price growth.[3] For higher frequency variables, such as interest rate and stock market index, I use end-of-period values. The matrix Z is included to control for differences

[2]Since the time-series dimension is sufficiently large (T=46), the Nickell bias is not a problem and I can proceed with estimating the panel model by OLS.

[3]Expected inflation index is obtained from Bank Indonesia's retail sales survey in the form of consumers' 3-month ahead general price estimates.

in individual banks' lending due to their liquidity, their ability to create loans, and their credit risk. For this matter, I use variables such as liquidity growth, leverage ratio, and provision ratio. I measure liquidity of each bank with the amount of cash and other assets available to quickly meet short-term obligations. Furthermore, the definition of leverage in this study follows Bruno and Shin (2015): more debt relative to each unit of equity means a higher level of leverage. Lastly, provision ratio is the portion of capital set aside to anticipate losses from risky loans. This ratio is usually used to measure a bank's risk assessment of its loan book. Bank-level data are obtained from individual bank's balance sheet.

The baseline regression includes a dummy variable ($mpru$) with a value of 1 for each period in which Bank Indonesia adopted a loose macroprudential policy stance and a value of 0 for periods of a tight macroprudential policy stance. The assessment of Bank Indonesia's macroprudential policy stance is taken from Agung et al. (2022).

The baseline specification utilizes two fixed effects: bank-specific fixed effect, θ_i, and time fixed effect τ_t. The bank-specific fixed effect absorbs different trends in dependent variable for individual banks and absorbs more variation that were not captured by bank-specific controls. The time fixed effect τ_t controls unobservable time-varying characteristics at the macro level that could affect lending, for example development in technology or globalization. Lastly, standard errors are clustered by banks.

β_1 is the main coefficient of interest in this baseline specification. This coefficient gives Equation 2.3 an interpretation in terms of changes: $\beta_1 < 0$ implies that a one unit purchase of foreign reserve by Bank Indonesia reduces commercial bank's loan-to-asset ratio or loan growth or nominal loan. By controlling for some bank-specific

Table 2.3: Data description

	Measure	Obs	Mean	Std. Dev	Min	Max	P25	P50	P75
Reserve transactions	IDR Tn	46	-5.89	93.52	-205.97	252.44	-62.99	4.08	58.07
Reserve purchases (+)	IDR Tn	24	63.74	52.45	0.98	252.44	23.81	56.56	86.38
Reserve sales (-)	IDR Tn	22	-81.84	64.40	-205.97	-0.22	-126.08	-64.03	-28.56
Expected inflation rate	%	46	0.29	11.17	-24.77	17.28	-7.75	4.27	8.31
Real GDP growth	%	46	1.13	1.30	-4.19	5.05	1.21	1.26	1.41
Net interest margin changes	p.p.	46	-0.03	0.44	-0.95	0.68	-0.20	-0.01	0.27
Lending rate changes	p.p.	46	-0.10	0.17	-0.53	0.30	-0.22	-0.10	0.03
Cross-border capital flows	IDR Tn	46	0.27	0.16	0.06	1.01	0.18	0.21	0.31
Stock mkt index growth	%	46	2.09	8.48	-27.95	22.77	-1.27	3.06	5.78
Loan-to-asset changes	p.p.	4410	-0.07	4.80	-41.20	32.90	-2.30	-0.10	2.10
Loan growth	p.p.	4410	0.04	0.11	-2.13	2.82	0.00	0.03	0.06
Nominal loan changes	IDR Tn	4410	0.81	3.48	-33.22	48.46	0.00	0.15	0.54
Liquidity growth	%	4410	0.04	0.33	-2.20	3.55	-0.12	0.03	0.19
Leverage ratio changes	p.p.	4410	-0.06	3.45	-80.46	95.03	-0.48	0.04	0.53
Provision ratio changes	p.p.	4410	0.01	0.66	-8.35	26.90	-0.08	0.00	0.08

and macroeconomic variables, coefficient β_1 reflects the average effect of a national level foreign reserve transactions on commercial banks' lending behaviour.

2.3.3 Data

Table 2.3 provides descriptive statistics for our main variables. The top panel of Table 2.3 contains of variables on the national level, while the bottom panel comprises bank-level variables.

2.3.3.1 Sample period

I estimate the regression model using quarterly data of Indonesian commercial banks' balance sheets and some macroeconomic variables from first quarter of 2010 to second quarter of 2021. This period was chosen to eliminate the effect of the global financial crisis in 2008. Excluding merged banks and new entrants, this period corresponds to

98 commercial banks in Indonesia and an increase in the official foreign reserve asset of around USD40 billion.

2.3.3.2 Measuring BI's foreign exchange reserve transactions

Central bank often buys foreign exchange in tranquil times and sells foreign exchange during crisis periods. These activities are easy to describe but difficult to measure. Several issues complicate the measurement. First, many central banks, including BI, do not publish their foreign exchange reserve transactions. Second, the use of a central bank's official foreign reserve asset data is likely to overestimate the actual central bank's foreign reserve transactions. This measurement error most likely comes from changes in interest income and changes in the market value of securities held. Furthermore, official foreign reserve assets held in a central bank also include non-currency asset, such as SDR allocations, golds, reserve position in the IMF, and other reserve assets.

Following Aizenman et al. (2021), I estimate BI's foreign exchange reserve transactions by subtracting non-currency asset components, changes related to interest income, and changes related to valuation from BI's official reserve asset position. The resulting residual will be referred as BI's reserve transactions ($RESTRX$). A detailed explanation of this construction can be found in Appendix A.

2.3.4 Baseline results

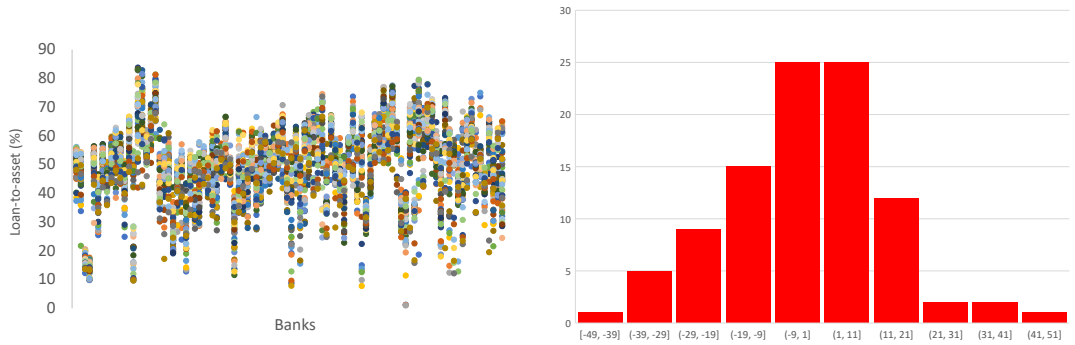
Table 2.4 reports the baseline result. It shows that BI's reserve transactions is negatively associated with bank lending ($\beta_1 < 0$) and suggests an association of sterilized

Table 2.4: Baseline results

VARIABLES	(1) Δ Loan/assets	(2) Δ log(Loan)	(3) Δ Loan
RESTRX	-0.003*** (0.000)	-0.0002*** (0.000)	-0.004*** (0.000)
Bank FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
R-squared	0.2816	0.1255	0.1150
Bank-level controls	Yes	Yes	Yes
Macro-level controls	Yes	Yes	Yes

Notes: Significance levels are indicated as * 0.10, ** 0.05, *** 0.01. Driscoll-Kraay standard errors that allow for heteroscedastic, autocorrelated, and cross-sectionally dependent disturbances are shown in parentheses.

reserve accumulation with significant crowding out of bank lending. This result inlines with Yun (2020), Cook and Yetman (2012), Chang (2018), and Hofmann and Shin (2019). To better interpret the result, the regression coefficients in Table 2.4 can be multiplied by the amount of foreign exchange reserve transactions conducted by Bank Indonesia. The average reserve purchase by Bank Indonesia over the sample period is IDR63.7 trillion (see Table 2.3). Based on the estimated coefficients, if Bank Indonesia purchases foreign exchange reserve at this amount, on average, loan-to-asset ratio drops 0.21 percentage point, loan growth decreases by 0.01 percentage point, and nominal loan goes down by IDR0.26 trillion. To put this result into perspective, the median loan-to-asset ratio change is -0.1 percentage point, the median loan growth is 0.03 percentage point, and the median nominal loan change is IDR0.15 trillion.



(a) Distribution of loan-to-asset ratio across banks for the entire sample period

(b) Loan-to-asset ratio changes between 2010-Q2.2021 across banks

Figure 2.3: Heterogeneity in loan-to-asset ratio dynamics

2.4 Panel evidence across banks

In this section I provide evidences that the effect of BI's foreign exchange reserve transactions on bank lending varies across banks, depending on bank-specific heterogeneity. Focusing on the loan-to-asset ratio, this analysis is motivated by the observed variation of this ratio in the data. Panel (a) of Figure 2.3 shows the variation in the distribution of the loan-to-asset ratios across 98 banks for the whole sample period. Meanwhile, panel (b) of Figure 2.3 depicts the variation in loan-to-asset ratio changes between 2010 to 2021. It shows that some banks experienced a decline in the loan-to-asset ratio while some exhibited an increase in the loan-to-asset ratio.

There are three questions that will be the focus in this section. The first is whether the baseline result changes for banks with different balance sheet structures? Second, what is the effect of different bank sizes? Finally, I test whether different types of bank's businesses will affect the baseline result. In this section, I focus the empirical analysis on loan-to-asset ratio as the dependent variable.

2.4.1 The effect of banks' balance sheet compositions

The banking literature has widely analyzed how the composition of a bank's balance sheet, especially on the asset side, can affect the amount of lending a bank is likely to provide. Banks with a larger value of liquid assets are expected to supply more lending in normal times. Studies such as Kim and Sohn (2017), Berrospide (2013), Cornett et al. (2011), and Kashyap and Stein (2000) argue that more liquid banks are likely to increase their loans since their liquidity levels are well maintained above the minimum level recommended by regulators. Meanwhile, Bouvatier and Lepetit (2012) argues that there is a procyclicality between loan-loss provisions and lending. They argue that banks who set aside a larger portion of their capital to anticipate losses from risky loans have the incentive to expand their lending.

To examine the effect of differences in banks' balance sheet compositions on the baseline result, I modify the baseline regression by including an interaction component between $RESTRX$ and the vector Z. The vector Z contains individual banks' balance sheet characteristics such as liquidity growth, changes in the leverage ratio, and changes in the loan-loss provision ratio. The modified panel regression model takes the form:

$$\begin{aligned} loantoasset_{i,t} =& \alpha + \delta loantoasset_{i,t-1} + \beta_1 RESTRX_t + \beta_2 Z_{i,t} + \beta_3 (RESTRX_t * Z_{i,t}) + \\ & \beta_4 X_t + \beta_5 mpru + \theta_i + \tau_t + \varepsilon_{i,t} \end{aligned} \tag{2.4}$$

The baseline result shows that, on average, the sterilized purchase of foreign exchange reserve by Bank Indonesia negatively impacts lending. This effect, when examined further using Equation 2.4, turned out to be significantly depend by bank-

specific balance sheet composition. As shown in column (1) of Table 2.5, banks that increase their liquid asset in their balance sheets can offset the negative impact of BI's sterilized reserve purchase on their lending. Likewise with banks that set aside higher loan-loss provision in their balance sheets. Nevertheless, the crowding-out effect is stronger on highly leveraged banks.

The liquidity-to-asset ratio measures the amount of cash and other assets banks have available to quickly pay bills and meet short-term business and financial obligations, divided by total asset. Column (1) of Table 2.5 confirms that by increasing the liquidity-to-asset ratio by 1 percentage point, reserve accumulation will have a positive overall impact on bank lending (-0.009 + 0.01 = 0.001). Based on the estimated coefficients, the overall impact of BI's IDR 63.7 trillion purchase of foreign reserve is an increase in the loan-to-asset ratio by 0.06 percentage point.

The second balance sheet component of interest is the loan-loss provision. Loan-loss provision ratio is a portion of capital set aside to anticipate credit losses from risks such as, but not limited to, non-performing loans and customer bankruptcies. The result in Table 2.5 column (1) suggests that a 1 unit increase in a bank's loan-loss provision ratio can overturn the negative impact of BI's foreign exchange reserve transaction on their lending (-0.009 + 0.015 = 0.006). Based on the estimated coefficients, the total impact of Bank Indonesia's IDR 63.7 trillion purchase of foreign reserve for such bank is an increase in the bank's loan-to-asset ratio of 0.38 percentage point.

Lastly, the crowding-out effect of Bank Indonesia's reserve purchase is stronger on banks with higher leverage ratio. The empirical result suggests that for 1 unit increase in a bank's leverage ratio, the total impact of BI's IDR 63.7 trillion purchase

Table 2.5: The effect of bank's characteristics

VARIABLES	(1) All banks	(2) All banks	(3) Reg. Dev.	(4) State-owned	(5) Priv-owned	(6) Fgn. branch
RESTRX	-0.009***	-0.003**	-0.004	-0.006***	-0.002*	-0.001
	(0.001)	(0.001)	(0.005)	(0.002)	(0.001)	(0.005)
*RESTRX**leverage	-0.003***					
	(0.001)					
*RESTRX**provision	0.015***					
	(0.005)					
*RESTRX**liquidity	0.01*					
	(0.005)					
*RESTRX**big banks		-0.002				
		(0.004)				
*RESTRX**medium banks		0.001				
		(0.003)				
*RESTRX**small banks		-0.000				
		(0.002)				
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.3083	0.2820	0.501	0.6076	0.2300	0.3278
Observations	4214	4214	1144	176	2772	220
Number of banks	98	98	26	4	63	5

Notes: Significance levels are indicated as * 0.10, ** 0.05, *** 0.01. Driscoll-Kraay standard errors that allow for heteroscedastic, autocorrelated, and cross-sectionally dependent disturbances are shown in parentheses.

of foreign reserves is a decrease in the loan-to-asset ratio of 0.76 percentage point, or roughly 0.6 percentage point stronger than the average impact.

2.4.2 The effect of bank size

The banking literature has analyzed the impact of bank size on lending with varying results. Banks with larger capital have comparative advantages, in terms of funding and technology, to provide loans to consumers (see Kim and Sohn (2017)). On the other hand, smaller banks tend to have advantages in providing loans to small businesses, mainly through relationship lending (Berger and Udell (1995)). However, Cook and Yetman (2012) found no evidence that banks' relative sizes are associated with differences in loan-to-asset ratio.

This study provides a new dimension in the existing literature by analyzing the

impact of a bank's size on lending in the presence of a central bank's foreign reserve transactions. I modified the baseline regression by including an interaction component between $RESTRX$ and a dummy variables that correspond to large-, medium-, and small-sized banks as described in Section 2.

Looking at column (2) of Table 2.5, the coefficients on the interaction terms suggest no relative significant effects of bank sizes on the effect of BI's foreign reserve transaction on bank lending. In fact, the coefficient on $RESTRX$ is similar in magnitude and sign to the baseline result.

2.4.3 The effect on different types of banks

Next, I apply the baseline specification of Equation 2.3 on sub-samples of four groups of banks: regional development banks, state-owned banks, private-owned banks, and foreign banks. Column (3) to (6) of Table 2.5 show that both state-owned and private-owned banks significantly reduce their loan portions from their total asset within the quarter after Bank Indonesia's sterilized purchase of reserve. On the other hand, there are no evidences for rural and foreign banks to reduce their loans after Bank Indonesia's sterilized reserve purchase.

Regional development banks ultimate mission is to promote economic development of certain regions; therefore, securities investment is not their main business. Thus, sterilized purchases of foreign reserve by Bank Indonesia do not affect the lending activities of this type of banks. On the other hand, foreign bank branches are more focused on making profit through investment in securities. However, not much of the funds they get from these investments are channeled into loans, because finan-

cial intermediary is not the primary business of these banks. Thus, Bank Indonesia's foreign exchange reserve policy does not have a significant influence on foreign banks' lending as well.

Column (4) and (5) of Table 2.5 indicate that state-owned banks reduce their loan portion out of their total asset more than private banks. This is again related to state-owned banks privileges as Bank Indonesia's agents in implementing the central bank's policy, which includes the purchase and/or sale of foreign exchange reserve.[4] Therefore, the impact of BI's foreign exchange reserve transactions are more pronounced for this type of banks. This last result echoes what Yun (2020) finds in his paper. Using Korean data, he shows that the decline in loan growth rates is larger in primary dealer banks. Compared to non-primary dealers, these banks have price incentives based on their securities transactions with the central bank. Therefore, they are more prone to reduce loans.

2.5 Policy implications

The empirical results in this chapter raise several policy implications, including the association of foreign exchange intervention as a mean of macroprudential policy and the link with the impossible trinity theory which lead to the need of a policy mix between foreign exchange reserve management and other macroeconomic policies.

[4]State-owned banks can transact with BI directly in the primary market.

2.5.1 Foreign exchange intervention as macroprudential policy in the midst of volatile capital inflows

As documented in this chapter, the purchases of foreign reserve lean against credit development and have a prudential element that can counter the size of an economic boom. Thus, this study supports the open economy policy to use foreign reserve management as a tool for managing domestic financial stability in the midst of volatile capital flows. Recent theoretical literature demonstrates that capital inflows are expansionary in emerging markets through the credit channel (see Blanchard et al. (2017) and Cerutti et al. (2017)). This view is also supported by empirical evidence. For example, Baskaya et al. (2017) found that capital inflows to Turkey lead to growth in commercial bank credit, especially for domestic banks with more non-core liabilities.

The use of foreign exchange reserve as a tool to minimize macroeconomic risk has also received considerable attention recently. Arce et al. (2019) proposes a theory of foreign reserve accumulation as a macroprudential policy. Using an open economy model of financial crises, in which pecuniary externalities lead to overborrowing, they show that by accumulating foreign reserve, a government can achieve the constrained efficient allocation. Diamond et al. (2020) build on corporate finance models on how collateral values and liquidity interact in influencing leverage, and show how currency appreciation elicits similar effects in an open economy setting. They argue that foreign reserve management has attributes of a prudential tool that leans against credit booms.

2.5.2 The impossible trinity and policy mix

This chapter explores the balance sheet effects of a central bank's sterilized foreign reserve transactions in the context of Indonesia. Even if the central bank holds banking system reserve constant, changes in the stock of liquid securities held by individual banks may affect bank lending in ways that maybe counter-productive to the central bank's ultimate monetary policy goals. The results in this chapter thus support the "impossible trinity" theory in which a central bank's intervention in the foreign exchange market may weakens its authority over domestic financial conditions. Therefore, for an economy that depends highly on its banking system, Bank Indonesia's foreign reserve policy should be accompanied or adapted to policies in the financial sector, particularly in the banking sector.

Bank Indonesia's foreign reserve management is a policy carried out to minimize the impact of foreign capital flows into the domestic economy. Foreign capital flows affect not only exchange rates and prices of financial assets, but also on domestic liquidity conditions and credit growth. In the context of a small open economy, one policy challenge is how to manage capital flows by maintaining a competitive rate of return. Here the role of exchange rates, interest rates (and yields) become important. Therefore, the integration of exchange rate policy with monetary policy, capital flow management and macroprudential policy is essential to strengthen monetary and financial system resilience in the face of increasingly integrated global finance.

2.6 Conclusion

This chapter tests the potential distortionary effect of a central bank's sterilized foreign reserve transaction on bank lending in Indonesia. I find that the sterilization of foreign reserve purchases crowd-out bank lending. Such impact, however, depend on bank-level characteristics. For banks with more liquid asset and banks with less riskier loan portfolios, the negative impact of a central bank's sterilized foreign reserve purchase on their lending provision can be minimized or even reversed. However, the crowding-out effect is stronger on more leveraged banks. The effect is also stronger on state-owned banks, relatively to private-owned ones. However, I find no relative significant effects of bank sizes (measured with the size of a banks' core capital) on the effect of Bank Indonesia's foreign reserve transactions on bank lending.

The empirical results also raise some important policy implications. My findings suggest a dual role of foreign reserve management policy in the context of "leaning versus cleaning". The ability of reserve accumulation to leans against credit development can act as a complement to its original cleaning function. In many policy discussions, building up reserve is seen as a second best to a more comprehensive financial safety net. However, as documented in this chapter, reserve accumulation may have prudential element that minimizes the risk of economic overheating. The results also support the monetary policy "trilemma" of open economy in which rapid reserve accumulation may weakens a central bank's control over domestic monetary policy. Therefore, reserve accumulation should also be accompanied or adapted to other macroeconomic policies, such as monetary policy, macroprudential policy, and capital flows management.

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Appendices

Appendix A

Data construction for Bank Indonesia's FX intervention

Official (foreign) reserve assets (ORA) held in Bank Indonesia include foreign exchange currencies (CR) and other non-currency assets ($nonCR$). This non-currency assets comprises of SDR allocations, reserve position in the IMF, and other reserve assets. Foreign currency reserve can be further divided into two categories of financial assets: securities (SEC) and currency deposits ($DEPO$)[1]. Changes to the SEC and $DEPO$ can occur due to three things. First, they may change as a result of Bank Indonesia's transaction (sale/purchase) of the two assets. Second, changes can also occur as a result of interest income on investments in these two assets. Finally, changes in SEC and $DEPO$ positions can also occur due to changes in the exchange rates (valuation effect).

To calculate *interestincome*, I need to know the composition of the currencies covered in the SEC and $DEPO$. Unfortunately, no country specific information about the currency composition of these reserve assets are available. Therefore, I use the aggregate currency composition of international reserve assets in "emerging and developing economy" as a proxy. For simplicity, I use four major reserve currency shares, namely the US dollar, Euro, UK pound, and Yen, which account for more than 90% of total reserve in EMEs.[2] Together with the interest rates of SEC and

[1]Data on Official Reserve Assets and are components is obtained from Bank Indonesia.

[2]This series are obtained from Currency Composition of Official Foreign Exchange Reserve

$DEPO$, I can pin down the $interestincome$ based on Equation A.1 below

$$interest\,income = r_i^s * \sum_{i=1}^{n} SEC + r_i^d * \sum_{i=1}^{n} DEPO \tag{A.1}$$

where r_i^s is the return to treasury securities of currency i proxied by 10-year bond yields and r_i^d is the deposit rate of currency i proxied by 3-month LIBOR rates.

For the valuation effect, I follow the approach used by Dominguez et al. (2012) by using Balance of Payment (BOP) Statistics. To be precise, I utilize the reserve and related items category in the BOP (RES_{BOP}) that records the market value purchases and sales of reserve assets. The valuation effect then can be obtained as follows:

$$valuation = \Delta ORA - RES_{BOP} \tag{A.2}$$

Finally, the actual foreign exchange reserve transactions conducted by Bank Indonesia ($RESTRX$) can be proxied as follows

$$RESTRX = \Delta ORA - income\,income - valuation - \Delta nonCR \tag{A.3}$$

This foreign exchange reserve transaction is then accumulated and converted into an index basing on the value of foreign exchange reserve at the end of 2008 (end of 2008 value = 100).

(COFER) database

Appendix B

Sampling algorithm for SVAR identification using sign restrictions

B.1 Penalty function approach

1. Draw (B,Σ) from the posterior distribution of the reduced-form parameters.
2. Draw an orthogonal matrix Q from a uniform distribution.
3. Compute L_0Q for each (B, Σ, Q).
4. Following Mountford and Uhlig (2008), evaluate L_0Q using a penalty function that assigns a large numerical penalty if it does not satisfy sign restriction. Repeat as desired and obtain an optimal Q.
5. Recompute IRF with L_0Q replacing L_0. Retain the draw if zero restriction is satisfied.
6. Repeat step 1 to 5 until desired number of draws has been obtained.

B.2 Importance sampling

1. Draw (B,Σ) from the posterior distribution of the reduced-form parameters.
2. Draw an orthogonal matrix Q from a uniform distribution.
3. Compute L_0Q for each (B, Σ, Q).
4. Following Arias et al. (2018), if L_0Q satisfies sign restriction, then set an importance weight to it. Otherwise, set its importance weight to zero.
5. Return to step 1 until the required number of draws has been obtained.
6. Re-sample as desired from drawn objects with replacement using the importance weights.