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# MONETARY POLICY AND RESERVE REQUIREMENTS IN A SMALL OPEN ECONOMY

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This paper investigates how a combination of monetary and macroprudential policies might affect the dynamics of a small open economy (SOE) with financial frictions under alternative discretionary shocks. Discretionary shocks in productivity and domestic and foreign monetary policies identify the roles of alternative interest rate and reserve requirement rules to stabilize the economy. The model is calibrated for the Brazilian economy. The exchange rate channel of transmission is relevant for foreign but not for domestic shocks. The interest rate rule should target domestic inflation and should not react to the exchange rate. The countercyclical reserve requirements rule, in its turn, should aggressively react to the credit-gap and not include a fixed component. Under both domestic and foreign shocks, the countercyclical effectiveness of the macroprudential policy improves when the degree of openness increases. There is a complementarity between monetary and macroprudential policy rules to stabilize the SOE.

**Keywords:** Monetary Policy, Macroprudential Policy, Small Open Economy, Financial Frictions

## 1. INTRODUCTION

Over the past few years, since the 2008 financial turmoil, both developed and developing countries have adopted a mix of macroprudential and monetary policy actions as part of a prescription to recover their economies from the negative effects of the crisis. The Central Bank of Brazil, for instance, implemented a reserve requirements policy to prevent the economy from a credit contraction. Later on, following the country's recovery, this policy was used to reduce the

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speed of expansion of the credit market. Other policy instruments such as minimum capital requirements were also applied as countercyclical tools to manage credit fluctuations. These macroprudential measures were adopted simultaneously to other standard monetary policy actions, giving rise to a discussion on whether they are complementary or substitute, and what their combined effects on the real economy are.[1]

The subprime crisis highlighted the role of the financial sector as a source and channel of transmission of crises to the real economy. Since then, many researchers have been looking more carefully at the financial sector and building models with different kinds of financial frictions. The relationship between equity capital of banks and credit flow, for instance, was modeled by Gertler and Karadi (2011), who incorporated financial intermediaries in a *dynamic stochastic general equilibrium* (DSGE) model with nominal rigidities based on Christiano et al. (2005) and Smets and Wouters (2007). The financial friction was incorporated in the closed economy as an agency problem between financial intermediaries and savers, inducing an endogenous restriction on the degree of leverage so that a deterioration in the bank's capital triggers an imbalance between supply and demand and an increase in the cost of credit.

Another element that affects credit flow is reserve requirements by the monetary authority. As argued by Glocker and Towbin (2015), emerging market central banks avoid raising interest rates when facing credit booms and prefer to use reserve requirements as an additional policy instrument. Divino and Kornelius (2015), using the Gertler and Karadi (2011) framework, added policy rules for reserve requirements to the baseline model of a closed economy. By calibrating the model for the Brazilian economy, they found that the macroprudential policy of reserve requirements is not a substitute for conventional monetary policy based on interest rate rules. However, it might be implemented as a complementary tool to stabilize credit conditions and minimize volatility of macroeconomic variables under domestic shocks.

In the open economy environment, the role of the macroprudential policy has not yet been widely explored as in the closed-economy counterpart. Some important contributions have been made by Glocker and Towbin (2012), Agénor et al. (2018), and Mimir and Sunel (2019). A relevant question to answer is whether the macroprudential policy might contribute to stabilize the real side of the economy and to produce higher welfare than the sole use of standard monetary policy instruments. Gali and Monacelli (2005) investigated macroeconomic implications of distinct monetary policy regimes and found a trade-off between exchange rate and terms of trade stabilization on one hand, and domestic inflation and output gap on the other hand. In their setup, domestic inflation targeting emerges as the optimal monetary policy regime relative to both Taylor rules and exchange rate peg, which generate higher welfare losses due to the excessive smoothness in the terms of trade that they entail. Using a similar framework, Divino (2009b) argues that the real exchange rate affects inflation and output gap in opposite directions, yielding an endogenous monetary policy trade-off that makes it impossible for the monetary authority to stabilize both of these variables simultaneously. Furthermore, there is a dirty-floating exchange rate regime because this rate affects both inflation and output gap that enter in the optimal interest rate rule.

Recent studies emphasize that financial stability should be the primary objective of the macroprudential policy, instead of price and output gap stabilization, which are conventional objectives of the monetary policy (Glocker and Towbin (2012), Agénor et al. (2013), Divino and Kornelius (2015), Rubio (2019)). However, macroprudential measures might improve the performance of the monetary policy in the presence of financial frictions and with the goal of financial stability by the central bank, when this objective is explicitly accounted for in the interest rate rule (Glocker and Towbin (2012)), in the reserve requirements rule (Divino and Kornelius (2015)), or in the capital requirements rule (Agénor et al. (2013), Catullo et al. (2019)). Reserve requirements are very effective and easily implemented in practice (Carvalho and Castro (2015b), Agénor et al. (2018)) and should respond to credit growth to some extent (Ferreira and Nakane (2015), Gross and Semmler (2019)).

The objective of this paper is to investigate how a combination of monetary policy based on interest rate rules and macroprudential policy grounded on reserve requirement rules might affect the dynamics of a small open economy (SOE) with financial frictions under alternative discretionary shocks. The external sector is incorporated to a DSGE model with macroprudential policy rules. Domestic households might invest in foreign risk-free bonds, and exchange rate movements are transmitted to domestic prices through wage inflation. Financial intermediaries and frictions are introduced *a la* Gertler and Karadi (2011). Discretionary shocks in domestic monetary policy, productivity, and foreign monetary policy are used to simulate the dynamics and identify the roles of monetary and macroprudential policies to stabilize an SOE under alternative degrees of openness. The monetary policy sets nominal interest rate rules that react to different measures of inflation and exchange rate. The macroprudential policy defines reserve requirement rules that respond to credit gap. The model is calibrated for the Brazilian economy because it is a representative case of an emerging economy that used reserve requirements as a macroprudential tool in several episodes in the post-2000 period, as detailed by Glocker and Towbin (2015).[2] After identifying the best design for the monetary policy rule, we confront it with alternative macroprudential policy arrangements, represented by reserve requirement rules that combine a fixed rate with a varying component that reacts to the credit gap. A welfare analysis compares the performances of these alternative policies to stabilize the SOE.

We contribute to the literature by introducing financial intermediaries and frictions, as in Gertler and Karadi (2011), in an SOE framework that is used to investigate the roles of alternative monetary and macroprudential policy rules to stabilize the economy under domestic and foreign discretionary shocks and different degrees of openness. In Gertler and Karadi (2011), there is an agency problem that leads to an endogenous capital constraint on the financial intermediary ability to acquire assets. They allow the central bank to act as a commercial bank, by expanding its credit intermediation, and interpret this as an unconventional monetary policy. We modify this framework by removing this role from the central bank and introducing an active macroprudential policy based on reserve requirement rules. Financial intermediaries face endogenously determined balance sheet constraints that tighten during adverse periods, raising the net benefits from the credit stabilizing macroprudential policy. We argue that, given a Taylor-type domestic inflation targeting monetary policy, the macroprudential policy might help achieve macroeconomic stability even further. This is because any variation of credit around the steady-state level leads to a movement in reserve requirements to reduce the credit gap, implying a countercyclical supply of credit for the intermediate goods producing firms that strengthens the anti-inflationary feature of the Taylor-type monetary policy at a lower output gap cost. This happens independently of any consideration about the exchange rate, which is characterized by a floating regime.

The model brings together elements of financial frictions, macroprudential policy, and economic opening in a unified environment. The major findings indicate that the exchange rate plays a relevant role only on the transmission of discretionary shocks originated in the foreign sector. For domestic shocks, there are no significant differences between the dynamics of the small open and closed economy. That is because the world economy is exogenous to the SOE and the benchmark degree of openness is small, as is the case of the Brazilian economy. The interest rate rule should not directly respond to the exchange rate after either domestic or foreign shocks. The best choice for the monetary policy is a domestic inflation targeting regime, while for the macroprudential policy a reserve requirements rule that reacts more aggressively to the credit gap is appropriate. Under both domestic and foreign shocks, the countercyclical effectiveness of the reserve requirements rule improves when the degree of openness increases. Reserve requirements should be used as a systematic countercyclical macroprudential instrument instead of an *ad-hoc* policy tool on which policy-makers can rely only during episodes of capital inflows or outflows. The smallest welfare loss was achieved under a countercyclical reserve requirements rule that aggressively stabilizes credit deviations. Thus, there is a complementarity between monetary and macroprudential policies to stabilize the SOE after distinct discretionary shocks.

The paper is organized as follows. The next section describes the baseline model, with emphasis on the new elements represented by financial intermediaries and frictions, macroprudential policy, and openness of the economy. The third section describes the parameters used in calibration, and reports and discusses the results obtained from the simulation exercises. Finally, the fourth section is dedicated to the concluding remarks.

## 2. MODEL

The benchmark consists of a New Keynesian DSGE model with financial friction and reserve requirements. The financial sector is modeled according to Gertler and Karadi (2011), where banks lend funds obtained from households to firms. Financial intermediaries are also a source of financial frictions in the credit market. Reserve requirements follow the setup proposed by Agénor et al. (2018) and Divino and Kornelius (2015). The model is developed for two asymmetric countries represented by an SOE and the rest of the world (ROW). In this configuration, residents of the SOE have access to imported final goods and risk-free bonds denominated in foreign currency.

### 2.1. Households

The representative household is composed of workers and bankers in constant proportions over time. Workers supply labor and earn wages in return. Bankers run financial intermediaries and make *lump sum* transfers of all earnings to their respective households, who might save by buying debt from financial intermediaries and consume final goods. Saving might also be negative, meaning that they are borrowing from financial intermediaries. Assuming that there is a *continuum* of identical households in the unit interval, the problem is to maximize the expected discounted value of the utility function, given by

$$\max \sum_{i=0}^{\infty} \beta^i E_t\big[u(C_{t+i}, L_{t+i})\big],$$

where $C_t$ is consumption and $L_t$ is labor supply. Following Gali (2008), consumption is a composite $C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}}\left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ of domestically produced goods $C_{H,t}$ and imported final goods $C_{F,t}$, where $\alpha$ is referred to as the degree of openness of the SOE ($0 \leq \alpha \leq 1$) and $\eta > 0$ measures the substitutability between domestic and foreign produced goods, from the viewpoint of the domestic consumer. The standard utility function incorporates habit formation and depends on consumption and labor supply as $u(C_t, L_t) = \log(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi}L_t^{1+\varphi}$, where $h$ is the habit formation parameter ($0 < h < 1$), $\chi$ is the relative weight placed on labor supply, and $\varphi$ is the Frisch elasticity of labor supply ($\chi, \varphi > 0$).

Households face a home currency budget constraint[3]:

$$C_t + B_{t+1} + \epsilon_t B^*_{t+1} = W_t L_t + T_t + R_t B_t + \epsilon_t R^*_t B^*_t,$$

where $B_t$ is the quantity of domestic short-term debt, $B^*_t$ is the amount of risk-free foreign bonds (both bonds with maturity in $t$), $\epsilon_t$ is the real exchange rate, $W_t$ is the real wage, $T_t$ denotes lump-sum transfers and pay-offs to the households from ownership of firms, $R_t$ is the risk-free gross real return of domestic bonds, $R^*_t$ is the gross foreign real interest rate paid by the foreign bond, and $\beta$ is the constant intertemporal discount factor ($0 < \beta < 1$).

The first-order condition (FOC) for labor supply is

$$UMgC_t W_t = \chi L_t^{\varphi}, \tag{1}$$

where the marginal utility of consumption ($UMgC_t$) is

$$UMgC_t = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1}. \tag{2}$$

The FOC for domestic short-term bond ($B_{t+1}$) yields the Euler equation:

$$E_t[\beta \Lambda_{t,t+1} R_{t+1}] = 1, \tag{3}$$

where the stochastic discount factor ($\Lambda_{t,t+1}$) is defined as

$$\Lambda_{t,t+1} \equiv \frac{UMgC_{t+1}}{UMgC_t}. \tag{4}$$

Finally, the FOC for risk-free foreign bond $B^*_{t+1}$ yields

$$E_t\left[\beta \Lambda_{t,t+1} \frac{\epsilon_{t+1}}{\epsilon_t} R^*_{t+1}\right] = 1. \tag{5}$$

## 2.2. Non-financial Firms

Non-financial firms are categorized in three groups, represented by intermediate goods producing firms, capital producing firms, and final goods producing firms. Intermediate goods firms borrow from financial intermediaries, buy capital from capital producing firms, and sell intermediate goods to final goods firms, receiving $P_m$ for each unit sold. Capital producing firms buy capital from intermediate goods firms, repair this depreciated capital, build new capital, and sell new and refurbished capital to intermediate goods firms. Final goods firms buy intermediate goods, repackage, and sell them to the final consumers.

*2.2.1. Intermediate goods producing firms.* Intermediate goods firms are competitive firms that produce and sell intermediate goods to final goods firms, using labor supplied by households and capital produced by capital producing firms. To buy capital, intermediate goods firms obtain loans from financial intermediaries. At the end of each period, they sell depreciated capital back to capital producing firms and buy a new one for use in production in the subsequent period.

The loans are completely used to buy capital:

$$Q_t S_t = Q_t K_{t+1}, \tag{6}$$

where $S_t$ is the amount of financial claims, $K_{t+1}$ is the capital acquired at the end of period $t$ for use in production in the next period, and $Q_t$ is the value of each unit of loan as well as the price of each unity of capital.[4] There are no financial frictions such as collateral restrictions for firms to obtain loans from financial intermediaries. It is assumed that financial intermediaries have complete information about the firms and there is no problem regarding enforcing payouts as in Gertler and Karadi (2011).

The technology of intermediate goods firms is described by the production function[5]:

$$Y_{mt} = A_t (U_t K_t)^{\alpha_c} L_t^{1-\alpha_c}, \tag{7}$$

where $Y_{mt}$ is the aggregate production of intermediate goods, $A_t$ is the total factor productivity, $U_t$ is the utilization rate of capital, $K_t$ is the available capital to the firm, and $\alpha_c$ is the share of capital in the Cobb–Douglas function. Productivity $A_t$ is subject to a discretionary shock modeled as a stationary log-linear first-order autoregressive process:

$$\log A_t = \rho_A \log A_{t-1} + \varepsilon_{At}, \tag{8}$$

where $\rho_A \in (0, 1)$ and $\varepsilon_{At} \sim iid(0, \sigma_A^2)$.

Capital evolves from the addition of net investment to the effective quantity of capital held from the previous period:

$$K_{t+1} = K_t + I_{nt}. \tag{9}$$

Suppose that at the end of period $t$, capital producing firms repurchase remaining capital $K_t$ under the current price $Q_t$ ($Q_t K_t$) and discounted by depreciation. Hence, the profit of the firm is the total income minus costs of labor and financial claims plus remaining capital, as follows:

$$Profit_{mt} = P_{mt} Y_{mt} - W_t L_t - Q_{t-1} S_{t-1} R_{kt} + [Q_t - \delta(U_t)] K_t, \tag{10}$$

where $P_{mt}$ is the price of the intermediate good, $\delta(U_t)$ is the depreciation rate, $R_{kt}$ is the gross return of the financial claims $Q_{t-1}S_{t-1}$ with maturity in $t$, $P_{mt}Y_{mt}$ is the income, and $[Q_t - \delta(U_t)]K_t$ is the stock of capital that is left over, discounting the depreciation rate. The depreciation rate is a crescent and convex function of the utilization rate of capital $U_t$, such that

$$\delta(U_t) = \delta_a + \delta_b \frac{U_t^{1+\zeta}}{1+\zeta}, \tag{11}$$

where $\delta_a$ is the depreciation even if capital was not used, $\delta_b$ and $\zeta > 0$ are parameters of the function.

In a monopolistic competitive market, prices of goods and quantities of inputs (labor and utilization rate of capital) are chosen by private agents in order to maximize profit subjected to the production technology described in equation (7), for $t = 0, 1, \ldots$. The FOCs for profit maximization are

$$P_{mt}(1 - \alpha_c) \frac{Y_{mt}}{L_t} = W_t \tag{12}$$

and

$$P_{mt} \alpha_c \frac{Y_{mt}}{U_t} = \delta_b U_t^{\zeta} K_t, \tag{13}$$

using equation (11) to replace $\delta'(U_t)$. In order to endogenously determine the return of financial claims, it is assumed that financial intermediaries have perfect information about the firm so that they charge the *ex-post* return on capital in an amount that exactly offsets profits in $t+1$. Substituting equations (6) and (12) in (10), and rearranging, we obtain

$$R_{kt+1} = \frac{\left[P_{mt+1}\alpha_c \frac{Y_{mt+1}}{K_{t+1}} - \delta(U_{t+1}) + Q_{t+1}\right]}{Q_t}. \quad \textbf{(14)}$$

2.2.2. *Capital producing firms.* The capital producing firms buy capital from intermediate goods firms at the end of the period, repair what was depreciated, and build new capital. New and refurbished capital form the gross capital or gross investment of the economy. Then, capital producing firms sell the gross capital stock to the same intermediate goods firms. They face adjustment costs associated with new capital, but not with refurbished capital, which has unity cost. Profits are distributed to the respective owners of the firms via *lump sum* transfers.

The net capital created, or net investment $I_{nt}$, is defined as the difference between gross investment $I_t$ and refurbished capital $\delta(U_t)K_t$:

$$I_{nt} \equiv I_t - \delta(U_t)K_t. \quad \textbf{(15)}$$

Adjustment cost of the net investment $I_{nt}$ fulfills the properties $f(1)=f'(1)=0$ and $f''(1)>0$, and has functional form as

$$f\left(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}\right) = \frac{\eta_i}{2}\left(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} - 1\right)^2,$$

where $I_{ss}$ is the steady-state investment and $\eta_i > 0$ is the inverse of net investment elasticity with respect to capital price in the steady state.

The profit of capital producing firms is the expected value of income from the net capital at price $Q_t$ minus the unit cost of produced capital and adjustment cost, represented by

$$Profit_{kt} = E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i}\left[Q_{t+i}I_{nt+i} - I_{nt+i} - f\left(\frac{I_{nt+i}+I_{ss}}{I_{nt+i-1}+I_{ss}}\right)(I_{nt+i}+I_{ss})\right]. \quad \textbf{(16)}$$

Profit only comes from created net capital, given that refurbished capital is sold by unity price, which is the same price of cost, to intermediate goods firms.

The problem of capital producing firms is to choose the optimal level of net investment $I_{nt}$ in order to maximize profits subject to the definition of net capital created (15). The price $Q_t$ is given because one assumes a competitive market. The FOC yields

$$\begin{aligned} Q_t = {} & 1 + f(\cdot) + \frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} f'(\cdot) \\ & - E_t\left[\beta\Lambda_{t,t+1}\left(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}}\right)^2 \eta_i\left(\frac{I_{nt+1}+I_{ss}}{I_{nt}+I_{ss}} - 1\right)\right]. \end{aligned} \quad \textbf{(17)}$$

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*2.2.3. Final goods producing firms.* Non-differentiated goods produced by intermediate goods firms are inputs used in the production process of final goods. Final goods firms repackage these intermediate goods as differentiated goods and sell them to the final consumers. There is friction in nominal prices as long as final goods firms have market power due to the production of differentiated goods. Final good price is adjusted above marginal cost according to a time-dependent rule proposed by Calvo (1983).

The production is a constant elasticity of substitution (CES) function of a *continuum* of unit mass of final goods firms, where each firm produces a sole differentiated final good. Specifically, we have that $Y_t = \left( \int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df \right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $Y_t$ is the aggregate final output, $Y_{ft}$ is the output of firm $f$, and $\varepsilon$ is the CES, with $\varepsilon > 1$. The price of the final goods is $\int_0^1 P_{ft} Y_{ft} df$, where $P_{ft}$ is the price of firm $f$ output. The final consumer's problem is to minimize the cost subject to the firm's production. The solution yields $Y_{ft} = \left( \frac{P_{ft}}{P_{H,t}} \right)^{-\varepsilon} Y_t$, where the final goods price level is $P_{H,t} = \left( \int_0^1 P_{ft}^{1-\varepsilon} df \right)^{\frac{1}{1-\varepsilon}}$.

Nominal price rigidity is added to the model in the price of final goods. During each period, firms have a constant probability $(1-\gamma)$ of freely adjusting their price to an optimal level $P_t^o$ and a probability $\gamma$ of passively realigning its price using a lagged inflation rate. Hence, final prices evolve according to

$$P_{H,t} = \left[ (1-\gamma)(P_t^o)^{1-\varepsilon} + \gamma(\pi_{H,t-1}^{\gamma_P} P_{H,t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \quad (18)$$

where $\pi_{H,t} \equiv \frac{P_{H,t}}{P_{H,t-1}}$ is the gross domestic inflation rate and $\gamma_P$ is the measure of price indexation. Dividing equation (18) by $P_{H,t-1}$ and defining $\pi_t^o \equiv \frac{P_t^o}{P_{H,t-1}}$ as an optimal price correction factor, the following relation emerges:

$$\pi_{H,t}^{1-\varepsilon} = (1-\gamma)(\pi_t^o)^{1-\varepsilon} + \gamma \pi_{H,t-1}^{\gamma_P(1-\varepsilon)}. \quad (19)$$

Because of nominal price rigidity, the firm's problem is to choose an optimal price, $P_t^o$, which is the same chosen by other firms that are able to realign price in time $t$, in order to maximize the expected discounted value of profit subject to the result of cost minimization by the final consumers:

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^o}{P_{H,t+i}} \prod_{k=1}^{i} (\pi_{H,t+k-1})^{\gamma_P} - P_{mt+i} \right] Y_{ft+i}$$

$$s.a. \; Y_{ft+i} = \left( \frac{P_{ft+i}}{P_{H,t+i}} \right)^{-\varepsilon} Y_{t+i},$$

remembering that because of price realignment to $P_t^o$, firm $f$ price at time $t+i$ is

$$P_{ft+i} = P_t^o \prod_{k=1}^{i} \left( \pi_{H,t+k-1} \right)^{\gamma_p} = P_t^o \prod_{k=1}^{i} \left( \frac{P_{H,t-1+k}}{P_{H,t-2+k}} \right)^{\gamma_P} = P_t^o \left( \frac{P_{H,t+i-1}}{P_{H,t-1}} \right)^{\gamma_P}.$$

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The FOC of this problem is

$$\pi_t^o = \frac{\varepsilon}{\varepsilon - 1}\frac{NN_t}{DD_t}\pi_{H,t}, \tag{20}$$

where

$$NN_t = Y_t P_{mt} + E_t\left[\gamma\beta\Lambda_{t,t+1}\left(\frac{\pi_{H,t+1}}{\pi_{H,t}^{\gamma P}}\right)^{\varepsilon} NN_{t+1}\right] \tag{21}$$

and

$$DD_t = Y_t + E_t\left[\gamma\beta\Lambda_{t,t+1}\left(\frac{\pi_{H,t+1}}{\pi_{H,t}^{\gamma P}}\right)^{\varepsilon-1} DD_{t+1}\right]. \tag{22}$$

## 2.3. Financial Intermediaries

Reserve requirements are introduced in the model with bankers as financial intermediaries between households (lenders) and non-financial firms (borrowers). There is an obligation for bankers to keep a fraction of their assets deposited with the monetary authority. A banker has a probability $\theta$ to remain a banker next period, and a probability $(1-\theta)$ to become a worker and take all the gains with him. Assuming that the proportion between bankers and workers is constant, the same quantity of workers become bankers, receiving funds from households in order to start business. Both financial flows are included as *lump sum* transfers in the household's budget constraint.

The balance sheet of each financial intermediary is

$$Q_t S_{jt} + \tau_t B_{jt+1} = N_{jt} + B_{jt+1},$$

where $S_{jt}$ is the amount of loans that banker $j$ holds, $N_{jt}$ is the amount of net worth at the end of period $t$, $B_{jt+1}$ is the deposits from households in $t$ with maturity in $t+1$, and $\tau_t$ is the rate of reserve requirements over deposits in $t$. Reserve requirements follow Divino and Kornelius (2015), where the monetary authority establishes an obligation for financial intermediates to keep a time-varying fraction of the household's deposits as reserve requirements with the central bank.

Banker $j$ equity capital evolves according to the difference between interests on assets and liabilities, yielding

$$N_{jt+1} = R_{kt+1} Q_t S_{jt} + R_{RRt+1}\tau_t B_{jt+1} - R_{t+1} B_{jt+1},$$

where $R_{RRt}$ is the fraction of market interest rate paid by the monetary authority on the reserve requirements. Using the previous equation, $B_{jt+1}$ might be substituted and

$$N_{jt+1} = (R_{kt+1} - R_{\tau t+1}) Q_t S_{jt} + R_{\tau t+1} N_{jt},$$

in which the cost of deposits, including reserve requirements, is

$$R_{\tau t+1} \equiv \frac{R_{t+1} - \tau_t R_{RRt+1}}{1-\tau_t} = R_{t+1} + \frac{\tau_t}{1-\tau_t}(R_{t+1} - R_{RRt+1}). \tag{23}$$

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Taking into account the probability that the banker will remain a banker for $i$ periods, the expected terminal wealth is

$$V_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(N_{jt+1+i}).$$

Considering the definition of $N_{jt}$, the sum might be split into two terms, one related to deposits and the other to equity capital, allowing for a solution by using recursive substitution as

$$V_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt},$$

where $\nu_t$ and $\eta_t$ are shadow prices of assets and equity capital, defined as

$$\nu_t \equiv E_t[(1-\theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{\tau t+1}) + \theta\beta\Lambda_{t,t+1}x_{t,t+1}\nu_{t+1}] \quad \textbf{(24)}$$

and

$$\eta_t \equiv E_t[(1-\theta)\beta\Lambda_{t,t+1}R_{\tau t+1} + \theta\beta\Lambda_{t,t+1}z_{t,t+1}\eta_{t+1}], \quad \textbf{(25)}$$

with $x_{t,t+i} \equiv \frac{Q_{t+i}S_{jt+i}}{Q_t S_{jt}}$ is the gross growth rate of assets between $t$ e $t+i$ and $z_{t,t+i} \equiv \frac{N_{jt+i}}{N_{jt}}$ is the gross growth rate of net worth between $t$ and $t+i$.

Gertler and Karadi (2011) incorporated a financial friction that prevents financial intermediaries from expanding their assets indefinitely. The banker, at the end of each period, might choose to divert a fraction $\lambda$ of available funds to his/her household. Hence, lenders are willing to supply funds to the financial intermediaries as long as the diverted funds don't surpass the expected terminal wealth. That is, the banker has enough assets to repay all lenders, so that the constraint $V_{jt} \geq \lambda Q_t S_{jt}$ must be satisfied.

In case of positive spreads, financial intermediaries are supposed to obtain deposits from households until the constraint is binding in order to optimize the expected value of equity capital. Hence, since the constraint binds, we might derive the financial intermediary $j$'s demand for assets $Q_t S_{jt} = \phi_t N_{jt}$, where $\phi_t$ is the maximum leverage ratio for bankers in $t$:

$$\phi_t \equiv \frac{\eta_t}{\lambda - \nu_t}. \quad \textbf{(26)}$$

We can replace $Q_{t+i}S_{jt+i}$ in the definition of $x_{t,t+1}$ and, using definition of $z_{t,t+1}$, find the relation between the gross growth rates of assets and equity capital:

$$x_{t,t+1} = \frac{\phi_{t+1}}{\phi_t} z_{t,t+1}. \quad \textbf{(27)}$$

Demand for assets $Q_t S_{jt}$ might also be replaced in the evolution of banker $j$'s net worth, which produces

$$N_{jt+1} = [(R_{kt+1} - R_{\tau t+1})\phi_t + R_{\tau t+1}]N_{jt}.$$

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Since $N_{jt+1}$ is the numerator of $z_{t,t+1}$, the following relation between rates of equity capital growth, return on assets, and interest on liabilities might be derived:

$$z_{t,t+1} = (R_{kt+1} - R_{\tau t+1})\phi_t + R_{\tau t+1}. \quad \textbf{(28)}$$

The aggregate demand for assets is

$$Q_t S_t = \phi_t N_t. \quad \textbf{(29)}$$

In order to obtain an equation for aggregate net worth, $N_t$, first consider it as $N_{et} + N_{nt}$, where $N_{et}$ is the fraction of existing bankers and $N_{nt}$ is the fraction of new ones. For $N_{et}$, it is assumed a *continuum* of unit mass of intermediaries $N_{et} = \int_0^1 N_{ejt} dj$. Hence, the aggregate is

$$N_{et} = \int_0^1 N_{ejt} dj = \int_0^1 [(R_{kt} - R_{\tau t})\phi_t + R_{\tau t}] N_{ejt-1} dj,$$

where $N_{ejt}$ is the equity capital of intermediary $j$ at time $t$. Considering that

$$\int_0^1 N_{ejt-1} dj = N_{et-1} = \theta N_{t-1},$$

and using equation (28), we obtain

$$N_{et} = \theta z_{t-1,t} N_{t-1}.$$

For $N_{nt}$, it is assumed that households transfer a fraction $\frac{\omega}{(1-\theta)}$ of exiting bankers' assets net of reserve requirements as funds to new bankers. The assets of exiting bankers is $(1-\theta)Q_t S_{t-1}$, which yields $N_{nt} = \omega Q_t S_{t-1}$, where $\omega$ is a parameter of the fraction. The outcome is the law of motion for $N_t$:

$$N_t = \theta z_{t-1,t} N_{t-1} + \omega Q_t S_{t-1}. \quad \textbf{(30)}$$

Lastly, it is worth noticing that although there is no friction in the intermediate goods firms' borrowing, the friction in bankers' funding might affect the availability of lending for non-financial firms, and therefore, the return on capital the firms have to pay.

## 2.4. Monetary Authority and the World Economy

The monetary authority might obligate financial intermediaries to maintain reserve requirements, deciding the level and the remuneration of this reserve. We consider two alternative rules for the reserve requirements $\tau_t$ over total deposits, represented by a fixed rate and a countercyclical rule as follows:

$$\tau_t = \begin{cases} \overline{\tau}, & \text{for fixed rate rule,} \\ \overline{\tau} + \kappa_\tau (\log Q_t S_t - \log QS_{ss}), & \text{for countercyclical rule,} \end{cases} \quad \textbf{(31)}$$

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where $\overline{\tau}$ is the steady-state value of the required reserves ratio, and $\kappa_\tau$ is the weight placed by the monetary authority on the credit gap, with $\kappa_\tau > 0$ and $QS_{ss}$ being the steady-state level of credit. The parameters are calibrated in order to keep $\tau_t$ within the interval (0, 1). As in Mimir et al. (2013) and Montoro and Tovar (2010), the reserve requirements rule includes a fixed component $\overline{\tau}$ to address model's distortions represented by real rigidities, price rigidity, and financial frictions. Since credit gaps are a measure of intertemporal distortions in this economy, the overall welfare level is expected to be higher when the countercyclical macroprudential policy rule is in place as opposed to fixing $\tau_t = \overline{\tau}$.

The remuneration, $R_{RRt}$, whenever paid by monetary authority over reserve requirements is specified as a fraction of $R_t$:

$$R_{RRt+1} = 1 + \kappa_{RR}(R_{t+1} - 1), \qquad \textbf{(32)}$$

where $\kappa_{RR}$ is the fraction of the market rate. The Fisher equation links nominal and real interest rates:

$$1 + i_t = R_{t+1}E_t\pi_{t+1}. \qquad \textbf{(33)}$$

Assuming no arbitrage in international financial markets and that the ROW has the same preferences as the SOE, a real version of the uncovered interest rate parity (UIP) might be derived. Equations (3) and (5) might be combined to produce: $E_t[\beta\Lambda_{t,t+1}R_{t+1}] = E_t\left[\beta\Lambda_{t,t+1}\frac{\epsilon_{t+1}}{\epsilon_t}R^*_{t+1}\right]$. Substituting domestic and foreign real interest rates for nominal interest rates and inflations according to the Fisher equation (33) and assuming that $\frac{\Lambda_{t,t+1}}{\pi_{t+1}}$ and $\frac{\Lambda_{t,t+1}\epsilon_{t+1}}{\pi^*_{t+1}}$ have log-normal distributions, the real version of UIP arises:

$$q_t - E_tq_{t+1} = (i^*_t - E_t\log\pi^*_{t+1}) - (i_t - E_t\log\pi_{t+1}) + \sigma_t, \qquad \textbf{(34)}$$

where $q_t$ is the logarithm of the real exchange rate and $\sigma_t$ is the risk premium.

Following Gali (2008), consumer price index (CPI) is defined as $P_t \equiv \left[(1-\alpha)P^{1-\eta}_{H,t} + \alpha P^{1-\eta}_{F,t}\right]^{\frac{1}{1-\eta}}$, where $P_{H,t}$ is the domestic price index of domestically produced goods—or producer price index (PPI)—and $P_{F,t}$ is the domestic price index of foreign produced goods. Assuming that local and foreign goods are perfect substitutes in steady state and the law of one price holds, one might derive a log-linear equation that relates CPI inflation $\pi_t$ and PPI inflation $\pi_{H,t}$ as

$$\log\pi_t = \log\pi_{H,t} + \frac{\alpha}{1-\alpha}\Delta q_t. \qquad \textbf{(35)}$$

It is assumed that the monetary authority follows a flexible Taylor rule with interest rate smoothing, choosing either PPI or CPI inflation as targeting rate and reacting or not to exchange rate movements. In this context, four possible configurations arise:

$$i_t = \begin{cases} (1-\rho_i)[i_{ss} + \kappa_\pi \log \pi_{H,t} + \kappa_y(\log Y_t - \log Y_t^n)] + \rho_i i_{t-1} + \varepsilon_t, \\ (1-\rho_i)[i_{ss} + \kappa_\pi \log \pi_{H,t} + \kappa_y(\log Y_t - \log Y_t^n) + \kappa_q q_t] + \rho_i i_{t-1} + \varepsilon_t, \\ (1-\rho_i)[i_{ss} + \kappa_\pi \log \pi_t + \kappa_y(\log Y_t - \log Y_t^n)] + \rho_i i_{t-1} + \varepsilon_t, \\ (1-\rho_i)[i_{ss} + \kappa_\pi \log \pi_t + \kappa_y(\log Y_t - \log Y_t^n) + \kappa_q q_t] + \rho_i i_{t-1} + \varepsilon_t, \end{cases} \quad \textbf{(36)}$$

where $\rho_i$ is a smoothing parameter (with $0 < \rho_i < 1$), $i_{ss}$ is the steady-state nominal interest rate, $Y_t^n$ is the natural level of output (under flexible price equilibrium), $\kappa_\pi$, $\kappa_y$, and $\kappa_q$ measure the reaction of the nominal interest rate to inflation, output gap, and exchange rate movements, respectively, and $\varepsilon_{it} \sim iid(0, \sigma_i^2)$ is a discretionary monetary policy shock. Notice that the closed-economy Taylor rule is a particular case of the previous rules, with $\kappa_q = 0$ and $\pi_{H,t} = \pi_t$ when $\alpha = 0$.

The choice of inflation measure (either CPI or PPI) and the inclusion or not of the exchange rate allow to investigate which interest rate rule presents the best performance to stabilize the economy against alternative discretionary shocks. Then, these interest rate rules are combined with alternative reserve requirement rules in order to identify the best matching for the SOE.

We do not intent to derive optimal policy rules for interest rate and reserve requirements. This would require an approximation of a social welfare function that should be optimized subject to the economy equilibrium conditions as in Woodford (2003) for instance. Some authors, including Glocker and Towbin (2012), Agénor et al. (2018), and Mimir and Sunel (2019), assume alternative policy rules for interest rate and reserve requirements and optimize over coefficients. This approach also does not result in optimal policy rules because the variables assumed to enter in the rules and functional forms might not correspond to the optimal ones derived from a social welfare optimization problem. Here, we consider alternative Taylor-type interest rate rules that have shown good empirical performances to represent the monetary policy of the Brazilian economy according to Palma and Portugal (2014), Castro et al. (2015), among others. We investigate how combinations of these rules with a countercyclical macroprudential policy of reserve requirements might contribute to stabilize the economy under alternative discretionary shocks.

To close the model and without loss of generality, we assume that the foreign interest rate, foreign inflation rate, and risk premium all follow stationary AR(1) processes given by

$$i_t^* = \rho_{i*} i_{t-1}^* + \varepsilon_{i*t} \ , \quad \textbf{(37)}$$

$$\log \pi_t^* = \rho_{\pi*} \log \pi_{t-1}^* + \varepsilon_{\pi*t}, \quad \textbf{(38)}$$

and

$$\sigma_t = (1-\rho_\sigma)\sigma_{ss} + \rho_\sigma \sigma_{t-1} + \varepsilon_{\sigma t}, \quad \textbf{(39)}$$

where $\sigma_{ss}$ is the steady-state risk premium, $\rho_{i*} \in (0, 1)$, $\rho_{\pi*} \in (0, 1)$, $\rho_\sigma \in (0, 1)$, $\varepsilon_{i*t} \sim iid(0, \sigma_{i*t}^2)$, $\varepsilon_{\pi*t} \sim iid(0, \sigma_{\pi*t}^2)$, and $\varepsilon_{\sigma t} \sim iid(0, \sigma_{\sigma t}^2)$.

Risk premium and foreign inflation shocks enter the model through the UIP (34). Thus, their transmission channels and effects on the SOE endogenous variables are similar. This happens because, under the SOE hypothesis, the ROW economy is exogenous and unaffected by discretionary shocks to the SOE variables. On the other hand, shock to the ROW variables is fully transmitted to the SOE domestic variables. For comparison purposes with the domestic monetary policy shock and following the practice in the literature, we consider only the effects of a foreign monetary policy shock represented by equation (37) in the simulation exercises. This shock also enters the model through equation (34).

## 2.5. Equilibrium

Output is divided into consumption and investment, which includes adjustment cost, according to the economy-wide resource constraint:

$$Y_t = C_t + I_t + \frac{\eta_i}{2}\left(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}} - 1\right)^2 (I_{nt}+I_{ss}). \quad \mathbf{(40)}$$

Labor market clearing implies that labor supply should be equal to labor demand. Hence, the same wage $W_t$ is earned by workers and paid by firms. Combining (1) and (12) yields

$$\frac{\chi L_t^{\varphi}}{UMgC_t} = P_{mt}(1-\alpha_c)\frac{Y_{mt}}{L_t}. \quad \mathbf{(41)}$$

Goods market clearing requires that intermediate and final goods production are adjusted by a price dispersion $D_t$ given by

$$Y_{mt} = D_t Y_t, \quad \mathbf{(42)}$$

where

$$D_t = \gamma D_{t-1}\left(\frac{\pi_{H,t}}{\pi_{H,t-1}^{\gamma_p}}\right)^{\varepsilon} + (1-\gamma)\left[\frac{1-\gamma\left(\frac{\pi_{H,t}}{\pi_{H,t-1}^{\gamma_p}}\right)^{\gamma-1}}{1-\gamma}\right]^{\frac{-\varepsilon}{1-\gamma}}. \quad \mathbf{(43)}$$

Total deposits by domestic households, $B_t$, are equal to the sum of the deposits received by each one of the $j$ financial intermediaries, $B_{jt}$. The aggregate balance sheet of the financial intermediaries is $Q_t S_t + \tau_t B_{t+1} = N_t + B_{t+1}$. Rearranging this equation and using (29), we might express $B_{t+1}$ as

$$B_{t+1} = \frac{1}{1-\tau_t}(\phi_t - 1)N_t. \quad \mathbf{(44)}$$

All financial claims held by financial intermediaries are used to finance acquisition of capital by intermediate goods firms, which is implicitly expressed in equation (6).

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## 3. RESULTS

The model is calibrated for the Brazilian economy in order to simulate the dynamics of the economy after discretionary shocks in domestic monetary policy, productivity, and foreign monetary policy. Initially, we investigate which measure of inflation, represented by either CPI or PPI, should enter the interest rate rule, and whether this rule should respond to the exchange rate. Then, we combine this monetary policy with alternative macroprudential rules for reserve requirements and investigate the role of the degree of openness. We evaluate the performance of these policy rules to stabilize the economy and perform a welfare analysis.

### 3.1. Calibration

The values of the parameters used in the simulations are, for the most part, equivalent to those commonly found in the literature. Most of the parameter values were also used by Divino and Kornelius (2015), Gertler and Karadi (2011), and Castro et al. (2015). Table 1 displays the calibrated values along with the respective sources.

The values of $\delta_a$ and $\delta_b$ are calibrated according to the functional form of the depreciation rate $\delta(U_t)$ so that the steady-state values of the depreciation rate, $\delta$, and the rate of capital utilization, $U$, are equal to 0.025 and 1, respectively. The fraction of capital transferred to new bankers, $\omega$, is calibrated to allow for the ratio of equity to loans to be $\frac{1}{\phi} = 0.175$, which is close to the Brazilian data. The reserve requirement, $\overline{\tau}$, the coefficient of credit gap in the countercyclical macroprudential rule, $\kappa_\tau$, and the fraction of market rate paid by the monetary authority on reserve requirement, $\kappa_{RR}$, are calibrated according to the data for the Brazilian economy. For other parameters, we use the values estimated by Castro et al. (2015) for the Brazilian economy. When this is not possible, we choose the same values set by Gertler and Karadi (2011).

For the parameter $\alpha$, which measures the degree of openness of the economy, we found values of 0.25 in Glocker and Towbin (2012), 0.3 in Divino (2009a), and 0.4 in Araújo (2016), Gali and Monacelli (2005). However, these studies refer to developed countries where the degree of openness is greater than that of Brazil. Thus, we approximate this parameter by the average value in the last 10 years of the ratio of imports to GDP in the Brazilian economy, which is 0.12 according to the data from the Brazilian Institute of Geography and Statistics (IBGE).

The coefficient of real exchange rate in the interest rate rule varies according to the exchange rate regime. We include the real exchange rate in the policy rule as an alternative to simulate a dirty floating exchange rate regime.[6] Araújo (2016) used a value of 0.6, but on the relative variation of the nominal exchange rate. For the relative variation of the real exchange rate, Ferreira (2015) estimates a value close to 0.47 for the Brazilian economy. West (2003) used a coefficient lower than 0.1, which is consistent with the fact that it is applied only on the contemporaneous value of the log real exchange rate. Thus, we also decide to use 0.1 for this parameter along with an interest rate smoothing of 0.79.

**Table 1.** Parameter values

| Par. | Value | Description | Source |
|---|---|---|---|
| Households | | | |
| $\beta$ | 0.989 | Intertemporal discount factor | Castro et al. (2015) |
| $h$ | 0.74 | Consumption habit persistence | Castro et al. (2015) |
| $\chi$ | 3.409 | Labor weight in the utility function | Gertler and Karadi (2011) |
| $\phi$ | 0.276 | Inverse of the Frisch labor-supply elasticity | Gertler and Karadi (2011) |
| Intermediate goods firms | | | |
| $\alpha_c$ | 0.33 | Capital share in the production function | Divino and Kornelius (2015) |
| $\delta_a$ | 0.020392 | Depreciation rate | Calibrated by the authors |
| $\delta_b$ | 0.037787 | Slope of the depreciation rate in relation to the capital utilization rate | Calibrated by the authors |
| $\zeta$ | 7.2 | Capital utilization rate | Gertler and Karadi (2011) |
| Capital goods firms | | | |
| $I_{ss}$ | 0.112175 | Steady-state investment | Calculated by the authors |
| $\eta_i$ | 3.42 | Inverse of the investment elasticity in relation to the capital price | Gertler and Karadi (2011) |
| Final goods firms | | | |
| $\varepsilon$ | 4.1667 | Constant elasticity of substitution | Gertler and Karadi (2011) |
| $\gamma$ | 0.74 | Calvo probability of not changing prices | Castro et al. (2015) |
| $\gamma_P$ | 0.33 | Inflation decay factor | Castro et al. (2015) |
| Financial intermediates | | | |
| $\theta$ | 0.975 | Banker survival probability | Divino and Kornelius (2015) |
| $\overline{\lambda}$ | 0.28 | Fraction of available funds that the banker diverts to his family | Divino and Kornelius (2015) |
| $\omega$ | 0.000875 | Fraction transferred to the new bankers | Divino and Kornelius (2015) |
| Monetary authority and aggregate restrictions | | | |
| $i_{ss}$ | 0.011122 | Nominal interest rate in steady state | Calculated by the authors |
| $QS_{ss}$ | 4.487004 | Credit level in steady state | Calculated by the authors |
| $\kappa_\pi$ | 2.43 | Inflation coefficient in the Taylor rule | Castro et al. (2015) |
| $\kappa_y$ | 0.16 | Output gap coefficient in the Taylor rule | Castro et al. (2015) |
| $\kappa_q$ | 0.4762 | Real exchange rate coefficient in the Taylor rule | West (2003) |
| $\rho_i$ | 0.79 | Interest rate smoothing in the Taylor rule | Castro et al. (2015) |
| $\overline{\tau}$ | 0.45 | Fixed level of reserve requirements | Divino and Kornelius (2015) |

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**TABLE 1.** Continued

| Par. | Value | Description | Source |
|---|---|---|---|
| $\kappa_\tau$ | 0 | Credit gap coefficient in the reserve requirements rule | Divino and Kornelius (2015) |
| $\kappa_{RR}$ | 0 | Fraction of the market interest rate paid over reserve requirements | Divino and Kornelius (2015) |
| Rest of the world | | | |
| $\alpha$ | 0.12 | Degree of openness | Calculated by the authors |
| $\sigma_{ss}$ | 0.011122 | Risk premium in steady state | Calculated by the authors |

**TABLE 2.** Calibration of the discretionary shocks

| Par. | Value | Description | Source |
|---|---|---|---|
| $\rho_A$ | 0.95 | Persistence of technology shock | Gertler and Karadi (2011) |
| $\rho_i$ | 0.90 | Persistence of domestic monetary policy shock | Castro et al. (2015) |
| $\rho_{i*}$ | 0.90 | Persistence of foreign monetary policy shock | Castro et al. (2015) |
| $\varepsilon_A$ | 0.01 | Technology shock | Gertler and Karadi (2011) |
| $\varepsilon_i$ | 0.0025 | Domestic monetary policy shock | Castro et al. (2015) |
| $\varepsilon_{i*}$ | 0.0025 | Foreign monetary policy shock | Castro et al. (2015) |

The list of parameters is completed by the steady-state values of total investment, $I_{ss}$, domestic nominal interest rate, $i_{ss}$, credit level, $Q_{ss}S_{ss}$, and risk premium, $\sigma_{ss}$. These values were calculated along with the other endogenous variables in the steady state.

For the experiments performed ahead, we use persistence and disturbances reported in Table 2. As explained earlier, we only consider shocks in domestic monetary policy, productivity, and foreign monetary policy, for comparison purposes and because this is standard in the literature.[7] Basically, these shocks are characterized by high persistence. The relative importance of each one, however, varies according to other studies. We followed Gertler and Karadi (2011) for the technology shock and Castro et al. (2015) for the domestic and foreign monetary policy shocks. In addition, the domestic monetary policy shock of 0.25 percentage point corresponds to a typical increase in the interest rate adopted by the Central Bank of Brazil under a restrictive monetary policy within the inflation-targeting regime.

### 3.2. Impulse Response Functions

We applied a discretionary shock in the domestic monetary policy, $\varepsilon_i$, given by an unexpected increase of 0.25 percentage point (pp) in the nominal interest rate. Figure 1 illustrates the dynamics of the economy in a horizon of 20 quarters after

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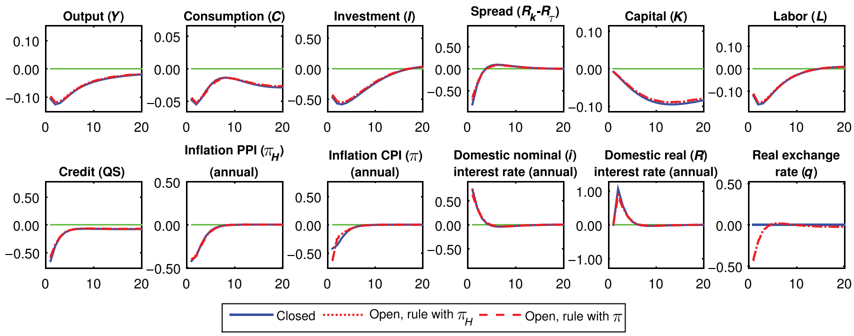


**FIGURE 1.** Responses to domestic monetary policy shock: Interest rate rule with either $\pi_H$ or $\pi$.

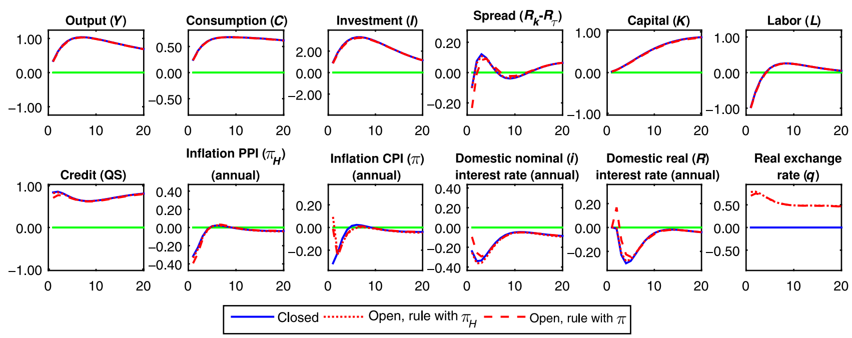


**FIGURE 2.** Responses to productivity shock: Interest rate rule with either $\pi_H$ or $\pi$.

this shock with either $\pi_H$ or $\pi$ in the policy rule. This contractionary shock leads to the standard results of reduction in investment, consumption, output, inflation, and credit, and to appreciation of the real exchange rate. Basically, there is no significant difference in the pattern of the variables between these two specifications of the interest rate rule and the closed-economy counterpart because the world economy is completely exogenous to the SOE and the degree of openness is low ($\alpha = 0.12$). In this scenario, domestic shocks do not affect foreign variables and changes in the real exchange rate only marginally affect CPI inflation, $\pi$, according to equation (35). The openness of the economy does not play any relevant role on the dynamics of the variables. This result replicates some of the findings by Gali and Monacelli (2005), but in a richer environment.

A similar analysis applies to the productivity shock, represented by a 1% increase in the total factor productivity, $A_t$. Figure 2 illustrates the results by using either $\pi_H$ or $\pi$ in the interest rate rule. As in the previous shock, the endogenous variables evolved as expected and the openness of the economy did not play a relevant role to differentiate the dynamics of the variables. The productivity shock leads to an increase in output and a decrease in inflation, which reduces the

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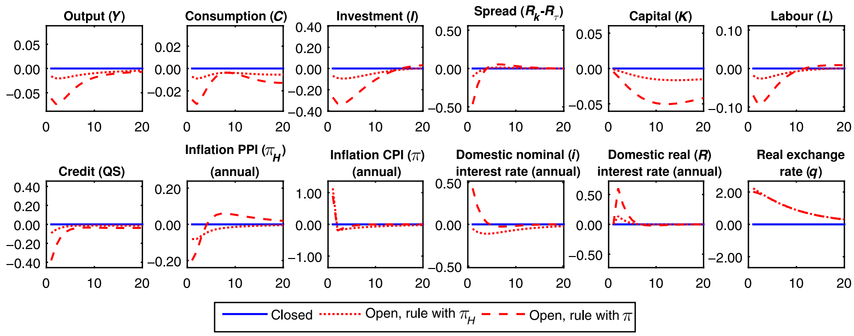


**FIGURE 3.** Responses to foreign monetary policy shock: Interest rate rule with either $\pi_H$ or $\pi$.

nominal interest rate according to the interest rate rule. The real exchange rate depreciates due to capital outflows. Again, the inclusion of either $\pi$ or $\pi_H$ in the interest rate rule does not differentiate the dynamics of the variables from a small open to a closed economy.

The environment, however, is quite different when the discretionary shock has a foreign source. We consider an unexpected increase of 0.25 pp in the foreign nominal interest rate, which is the monetary policy instrument of the world economy. Figure 3 reports trajectories of the impulse-responses, using either $\pi_H$ or $\pi$ in the domestic interest rate rule.

The increase of the foreign interest rate encourages the purchase of foreign securities by the domestic households, increasing the demand for foreign currency and reducing the volume of domestic deposits. The higher demand for foreign currency depreciates the home currency, making imported goods more expensive and causing a momentary increase in $\pi$. There is a reduction in $\pi_H$ because of the decrease in labor, which reduces the firm's marginal cost and dominates the effects of $\pi$ on $\pi_H$ through the wage reduction. The monetary policy reacts by raising the nominal interest rate above the increase in inflation according to the Taylor principle. As a consequence, the domestic real interest rate increases and induces falls in output, consumption, investment, capital, labor, and credit. The real exchange rate, $q$, gradually moves down towards equilibrium, leading the convergence of the economy to the equilibrium.

The dynamics of the variables are sharply affected by the presence of $\pi$ instead of $\pi_H$ in the interest rate rule. This result is quite different from those obtained for the domestic shocks, which did not yield significant differences in the dynamics of the domestic variables when compared to a closed economy. The CPI inflation rate, $\pi$, is strongly impacted by the foreign shock through the real exchange rate depreciation. The jump in CPI inflation affects both the nominal interest rate, through the Taylor rule, and the real interest rate, through the Fisher equation, which in turn reinforces the effects on the real side of the economy. Using $\pi$ instead of $\pi_H$ in the interest rate rule contributes even further to import the

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external volatility to the domestic variables. This does not happen when the interest rate rule targets $\pi_H$ as a measure of inflation. Thus, under a foreign shock, it is advisable for the monetary policy to target domestic inflation in the interest rate rule.

Taking these results as a whole, the model responds to discretionary shocks in a way that is consistent with empirical findings for the Brazilian economy. Minella and Souza-Sobrinho (2013) developed and estimated a medium-size, semi-structural model for Brazil during the inflation targeting period to investigate the transmission mechanisms of monetary policy. They found that interest rate channel plays an important role in explaining output dynamics after a monetary policy shock. In the case of inflation, however, both the interest rate and the exchange rate channels are the main transmission mechanisms. Castro et al. (2015) estimated a large-scale DSGE model by Bayesian techniques for the Brazilian economy in the recent inflation targeting period. Their monetary policy shock, technology shock, and foreign shock to the exchange rate closely resembled the dynamics of the domestic monetary policy, productivity, and foreign monetary policy previously reported from Figures 1–3, respectively. The dynamic responses are quite similar especially when considering the effects of these shocks on real side variables, inflation, nominal interest rate, and exchange rate. Thus, the current model is able to adequately reproduce empirical dynamics estimated from the data for the Brazilian economy in the recent period.

### 3.3. Interest Rate Rules

In order to analyze the performance of alternative interest rate rules to stabilize the SOE, we consider the effects of shocks in the domestic monetary policy using four different configurations. They combine two measures of inflation ($\pi$ or $\pi_H$) and include or not the real exchange rate ($q$) in the monetary policy rule. The macroprudential policy rule is also allowed to change across these alternative interest rate configurations. In the benchmark case, the macroprudential policy is given by only a fixed component, $\tau_t = \overline{\tau} = 0.45$. This value corresponds to the average rate of reserve requirements charged from different types of deposits by the Central Bank of Brazil. The two other cases are for no macroprudential policy at all, with $\overline{\tau} = 0$ and $\kappa_\tau = 0$, and a countercyclical reserve requirements rule that includes a varying component in addition to the fixed one, with $\overline{\tau} = 0.45$ and $\kappa_\tau = 1.5$ in equation (31).

Figure 4 compares the magnitudes of the nominal interest rate increases that are required to generate a fixed decrease of 0.39 pp per year in domestic inflation, $\pi_H$, in the first quarter under the benchmark macroprudential policy ($\overline{\tau} = 0.45$). This 0.39 pp decrease in $\pi_H$ requires a raise of 0.25 pp in the nominal interest rate under the policy rule that targets $\pi_H$ and does not react to the real exchange rate, $q$. When the policy rules include the real exchange rate, $q$, the same 0.39 pp decrease in $\pi_H$ demands a higher increase of 0.32 pp in the nominal interest rate. This is because the world economy is not affected by the domestic shock and

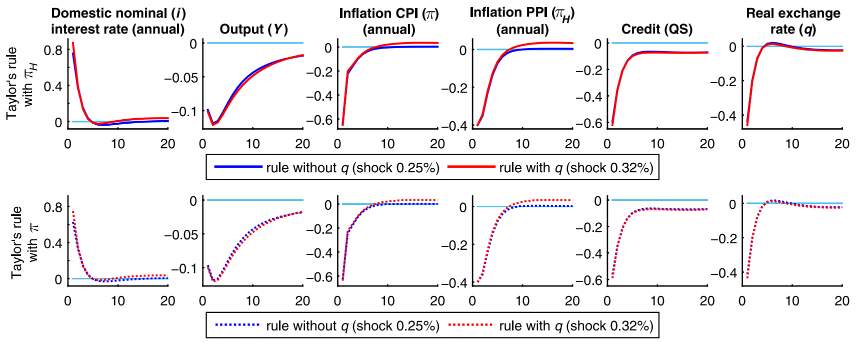


**FIGURE 4.** Responses to a domestic monetary policy shock that is required to reduce $\pi_H$ in 0.39 pp (fixed reserve requirements: $\tau_t = \overline{\tau} = 45\%$).

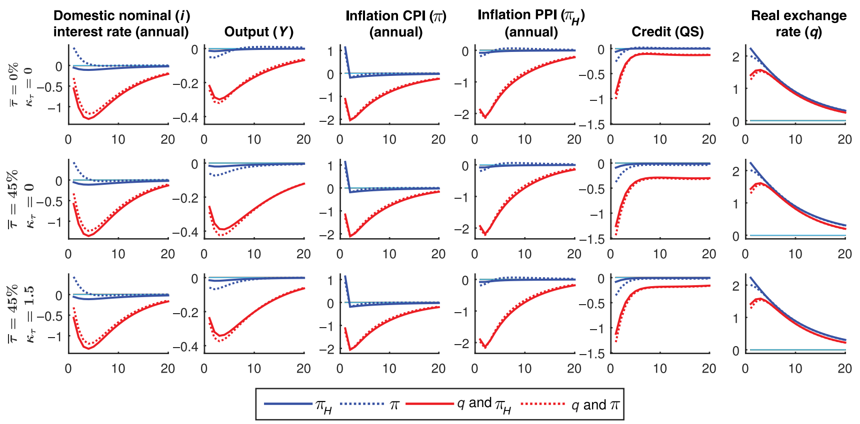


**FIGURE 5.** Responses of selected variables to a foreign monetary policy shock and alternative reserve requirement rules.

the degree of openness of the SOE is low. The first row of responses in Figure 4 reports interest rate rules that target $\pi_H$ while the second row refers to rules that react to $\pi$. In either case, it is a better choice for the monetary policy not to directly respond to the exchange rate in the monetary policy rule.[8]

Under a foreign monetary policy shock, as illustrated in Figure 5, the evidence in favor of domestic inflation targeting remains, independently of the macroprudential policy configuration. Policy rules that target PPI inflation ($\pi_H$) instead of CPI inflation ($\pi$) are more successful to stabilize output and interest rate. The inclusion of $q$ in these rules substantially amplifies volatility of the series. The effects are bigger on the shock impact and responses are more persistent when $q$ is included in the interest rate rules. Only the real exchange rate itself seems to benefit from this inclusion because the effects of the shock on impact are smaller. This finding suggests that stabilization of the real exchange rate might be achieved

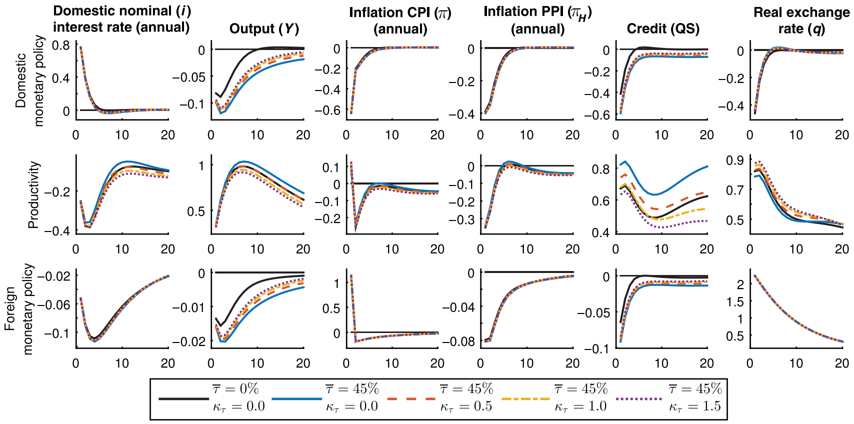


**FIGURE 6.** Responses of selected variables under alternative reserve requirement rules.

at a cost of higher instability in other domestic variables. Considering rules without $q$, the monetary authority is better off by targeting PPI instead of CPI inflation, which amplifies volatilities of the nominal interest rate and output gap.

This result is reminiscent of Gali and Monacelli (2005), who showed that, under some simplifying assumptions, a simple SOE New Keynesian model is isomorphic to a closed-economy counterpart in the sense that the exchange rate plays no role in model equilibrium conditions. Here, the environment is richer as it features capital accumulation, banking sector, and financial frictions. However, the result on the optimal policy given by a PPI inflation targeting is similar to Gali and Monacelli (2005) because it crucially depends on the hypothesis of full pass-through, as emphasized by Gali and Monacelli (2005) and Monacelli (2013). Even after including the macroprudential policy in this framework, targeting PPI inflation with no response to the real exchange rate is still the best choice for the monetary policy.

This finding is in line with Cordella et al. (2014), who provided empirical evidence on the use of reserve requirements as a countercyclical monetary policy tool in developing countries. Due to the pro-cyclical behavior of the exchange rate on the business cycle in developing countries, the countercyclical use of interest rates proves to be complicated because of its impacts on the exchange rate. Reserve requirements can be useful as a second policy tool in response to capital inflows or outflows. We operationalize such a countercyclical reserve requirements rule that smooths fluctuations in the credit gap and contributes to stabilize the SOE over the business cycle.

### 3.4. Reserve Requirement Rules

Following the approach by Agénor et al. (2018) and Divino and Kornelius (2015), we perform simulations for different reserve requirement rules and discretionary shocks. Figure 6 reports impulse-responses under alternative values

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for the parameters $\overline{\tau}$ and $\kappa_\tau$ when the SOE is hit by shocks in the domestic monetary policy, productivity, and foreign monetary policy. The shocks still follow the specifications described in Table 2. The monetary policy targets $\pi_H$ and the real exchange rate does not enter in the interest rate rule. This specification was identified as the best choice for the monetary policy in the previous section. The degree of openness is $\alpha = 0.12$, corresponding to the case of the Brazilian economy.

In general, according to Figure 6, in the case where there is no reserve requirement, given by $\overline{\tau} = 0$ and $\kappa_\tau = 0$, the effects of shocks in both domestic and foreign monetary policies are smoother when compared to the other situations where there is a countercyclical macroprudential policy. After the introduction of the fixed component of reserve requirements, represented by $\overline{\tau} = 0.45$, the deviations of the variables are higher at the impact of the shocks. However, the inclusion of the varying component that reacts to the credit gap reduces volatilities and leads to a faster convergence to the steady state. In some cases, the higher the value of the parameter $\kappa_\tau$, the faster is the convergence to the equilibrium.

The volatilities reported in Table 3, represented by the variables' standard deviations, indicate that the economy without reserve requirements ($\kappa_\tau = 0$ and $\overline{\tau} = 0$) is less volatile in the occurrence of shocks in both domestic and foreign monetary policies. After the inclusion of the varying component in the macroprudential rules, the volatilities decrease as $\kappa_\tau$ increases, suggesting that a more aggressive countercyclical policy to stabilize credit deviations performs best. This is the case for all variables except the nominal interest rate and the real exchange rate after a domestic monetary shock and the inflation rates after a foreign monetary policy shock.

For the productivity shock, the results are mixed. A fixed rule decreases the volatilities of $i$, $\pi$, and $\pi_H$, but increases the volatilities of $Y$, $QS$, and $q$ when compared to the case without reserve requirements. The varying component increases the volatilities of $i$, $\pi$, and $\pi_H$ and decreases the volatilities of $Y$, $QS$, and $q$. Thus, under a productivity shock, the countercyclical macroprudential policy seems to be more effective to stabilize real side variables, as it was originally designed for. Nevertheless, taking all variables and discretionary shocks as a whole, for the vast majority, there is a stabilizing effect on the series volatilities coming from flexible as opposed to fixed rules for reserve requirements. In addition, the macroprudential policy is more effective to stabilize the SOE under financial shocks (domestic and foreign monetary policies) than real shocks (productivity shock).

Given these divergent results in terms of series volatilities, suggesting that alternative policy rules might have different stabilizing effects on distinct variables under a productivity shock, we perform a welfare analysis in the next section in order to identify which effect dominates. The welfare function is represented by the expected utility of the households, which depends on consumption and labor supply. Based on Gertler and Karadi (2011), we compute the welfare loss as the negative deviation of the expected utility from steady-state utility.

Lastly, we analyze the interaction between the monetary and macroprudential policies by comparing magnitudes of nominal interest rate increases that

**TABLE 3.** Volatilities under alternative policy rules for reserve requirements

| Policy rule | $i$ | $\log(Y)$ | $\log(\pi)$ | $\log(\pi_H)$ | $\log(QS)$ | $q$ |
|---|---|---|---|---|---|---|
| Domestic monetary policy shock($\epsilon_i$) | | | | | | |
| $\overline{\tau}=0.0$, $\kappa_\tau=0.0$ | 0.0087 | 0.0016 | 0.0069 | 0.0057 | 0.0046 | 0.0053 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.0$ | 0.0086 | 0.0029 | 0.0071 | 0.0060 | 0.0084 | 0.0050 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.5$ | 0.0086 | 0.0027 | 0.0071 | 0.0060 | 0.0077 | 0.0050 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.0$ | 0.0086 | 0.0025 | 0.0070 | 0.0060 | 0.0073 | 0.0050 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.5$ | 0.0086 | 0.0024 | 0.0070 | 0.0059 | 0.0070 | 0.0051 |
| Productivity shock ($\epsilon_A$) | | | | | | |
| $\overline{\tau}=0.0$, $\kappa_\tau=0.0$ | 0.0099 | 0.0418 | 0.0041 | 0.0051 | 0.0422 | 0.0315 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.0$ | 0.0092 | 0.0462 | 0.0039 | 0.0048 | 0.0576 | 0.0324 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.5$ | 0.0099 | 0.0416 | 0.0042 | 0.0050 | 0.0430 | 0.0324 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.0$ | 0.0103 | 0.0389 | 0.0044 | 0.0052 | 0.0350 | 0.0324 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.5$ | 0.0107 | 0.0371 | 0.0046 | 0.0053 | 0.0298 | 0.0324 |
| Foreign monetary policy shock($\epsilon_{i*}$) | | | | | | |
| $\overline{\tau}=0.0$, $\kappa_\tau=0.0$ | 0.0031 | 0.0003 | 0.0120 | 0.0015 | 0.0007 | 0.0521 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.0$ | 0.0032 | 0.0006 | 0.0120 | 0.0015 | 0.0014 | 0.0522 |
| $\overline{\tau}=0.45$, $\kappa_\tau=0.5$ | 0.0032 | 0.0005 | 0.0120 | 0.0015 | 0.0013 | 0.0522 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.0$ | 0.0032 | 0.0005 | 0.0120 | 0.0015 | 0.0012 | 0.0521 |
| $\overline{\tau}=0.45$, $\kappa_\tau=1.5$ | 0.0031 | 0.0004 | 0.0120 | 0.0015 | 0.0011 | 0.0521 |

are required to produce a given reduction in domestic inflation under alternative configurations of the macroprudential policy. As in the previous section, we seek to generate a decrease of 0.39 pp per year in $\pi_H$ in the first quarter. This requires an increase of 0.25 pp in the nominal interest rate under no macroprudential policy ($\kappa_\tau=0$ and $\overline{\tau}=0$). When the fixed rate is introduced ($\overline{\tau}=0.45$), Figure 7 and Table 4 indicate that the required rise in the nominal interest rate reduces to 0.24 pp. The volatilities of $i$, $\pi$, and $q$ decreases, while those of $Y$, $\pi_H$, and $QS$ increases. The required raise in the nominal interest rate is still smaller than 0.25 pp when the varying component is included in the reserve requirement rules. Thus, the required increase in the nominal interest rate to produce a given reduction in domestic inflation is smaller when a countercyclical macroprudential policy is in place.

The overall results indicate that there might be complementarity between the macroprudential policy and the monetary policy in the SOE. The increase in the nominal interest rate reduces the credit level, which leads to a decrease in reserve requirements according to the countercyclical macroprudential rule responding to the credit gap. The decrease in credit below the equilibrium level leads to a reduction in reserve requirements according to the countercyclical rule given in equation (31). The aggressiveness of the reaction depends on the response parameter $\kappa_\tau$. The drop in reserve requirements increases the credit supply to the intermediate goods producing firms, allowing the production of final goods at a lower cost. Thus, the macroprudential policy contributes to reduce the initial

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**TABLE 4.** Volatilities under a domestic monetary policy shock that is required to reduce $\pi_H$ in 0.39 pp

| Policy rule | $i$ | $\log(Y)$ | $\log(\pi)$ | $\log(\pi_H)$ | $\log(QS)$ | $q$ |
|---|---|---|---|---|---|---|
| $\overline{\tau}=0.0, \kappa_\tau=0.0$ | 0.0087 | 0.0016 | 0.0069 | 0.0057 | 0.0046 | 0.0053 |
| $\overline{\tau}=0.45, \kappa_\tau=0.0$ | 0.0083 | 0.0028 | 0.0068 | 0.0058 | 0.0081 | 0.0048 |
| $\overline{\tau}=0.45, \kappa_\tau=0.5$ | 0.0084 | 0.0026 | 0.0068 | 0.0058 | 0.0075 | 0.0049 |
| $\overline{\tau}=0.45, \kappa_\tau=1.0$ | 0.0084 | 0.0024 | 0.0069 | 0.0058 | 0.0071 | 0.0049 |
| $\overline{\tau}=0.45, \kappa_\tau=1.5$ | 0.0084 | 0.0023 | 0.0069 | 0.0058 | 0.0068 | 0.0049 |

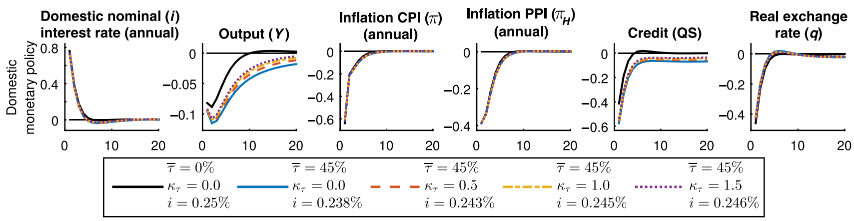


**FIGURE 7.** Responses to a domestic monetary policy shock that is required to reduce $\pi_H$ in 0.39 pp.

impact of the rise in the nominal interest rate on the output gap and to bring the SOE more quickly to the steady-state equilibrium.

The response of reserve requirements, partially neutralizing the effects of the variation in the nominal interest rate, is in accordance with Areosa and Coelho (2013). However, different from their experiment, the macroprudential policy in our model is endogenous and interacts with the monetary policy through the credit channel to stabilize the economy. Carvalho and Castro (2015a,b) and Areosa and Coelho (2013) argue that, in isolation, a monetary policy has a stronger impact on output and inflation than a macroprudential policy. The inclusion of the endogenous macroprudential policy rule makes reserve requirements respond in opposite direction of the monetary policy, and thus, partially offsets its effects in the economy.

Glocker and Towbin (2015) estimate a structural VAR for the Brazilian economy and compare the macroeconomic effects of interest rate and reserve requirement shocks. They find that both policies result in credit decline under an exogenous tightening. However, contrary to an interest rate shock, a positive shock in reserve requirements leads to exchange rate depreciation and increase in prices, with the bank lending channel being the main transmission mechanism. They interpret these different effects as evidence that a reserve requirement policy is a complement to rather than a substitute for the interest rate policy.

Accordingly, our results suggest that a countercyclical reserve requirements rule that reacts to credit gap contributes to reduce the series volatility and to

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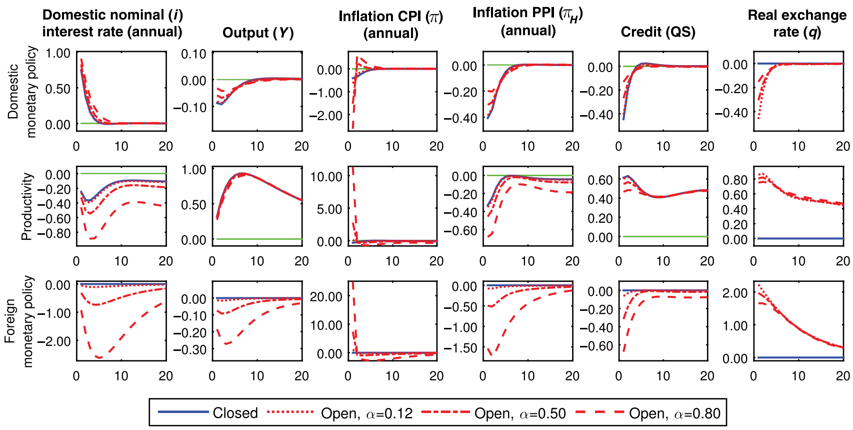


**FIGURE 8.** Sensitivity to the degree of openness under alternative discretionary shocks.

speed convergence to the equilibrium after a domestic monetary policy shock. This finding is confirmed by the welfare analysis reported in section 3.6.

## 3.5. Sensitivity to the Degree of Openness

The relationship between openness of the economy and macroprudential policy in an environment of financial frictions has not yet been extensively explored as in the closed-economy counterpart. Some contributions on this issue have been made by Glocker and Towbin (2012), Agénor et al. (2018), and Mimir and Sunel (2019). An interesting question to address is whether the degree of openness plays any additional role in amplifying and propagating shocks in an SOE with financial frictions when compared to a closed economy. We address this issue by changing the degree of openness from closed to highly open and considering the dynamic effects of discretionary shocks in domestic monetary policy, productivity, and foreign monetary policy, as illustrated in Figure 8. Given the previous findings, the interest rate rule targets PPI inflation and does not respond to the exchange rate while the reserve requirements rule countercyclically reacts to the credit gap with $\overline{\tau} = 0.45$ and $\kappa_\tau = 1.5$.

In the first row of Figure 8, the unexpected increase in the policy interest rate yields the standard effects of a contractionary monetary policy, with decreases in output, inflation, and credit. There is an appreciation of the real exchange rate due to the rise in the domestic interest rate in relation to the foreign rate, stimulating capital inflows. The countercyclical macroprudential policy enters in scene to improve credit conditions by reducing reserve requirements. This policy increases credit supply to intermediate goods producing firms, raising capital and the production of final goods at a lower cost, and reducing inflation. The countercyclical reserve requirements rule reduces the impact of the nominal interest rate increase on output and brings the SOE more quickly to the equilibrium. The

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impact and propagation of the monetary policy shock are smaller in the highly open economy because higher capital inflows contribute with the countercyclical macroprudential policy to smooth credit deviations resulting from the monetary policy shock.

The effects of the productivity shock are displayed in the second row of Figure 8. On impact, output increases because of the higher total factor productivity, inflation decreases due to higher supply of final goods, and nominal interest rate decreases according to the Taylor-type monetary policy rule. Exchange rate depreciates due to the lower domestic rate in relation to the foreign interest rate. The increase in the credit gap leads to a rise in reserve requirements to stabilize the credit market. This reduces credit supply for the intermediate goods producing firms, decreasing capital and final goods production and bringing the economy back to the equilibrium. Impact and propagation of the productivity shock on credit and real exchange rate are smaller in the highly open economy. The effects of the interest rate on domestic inflation are also more pronounced in the more open economy. The role of the countercyclical macroprudential policy is still evident to stabilize the real side of the economy through the credit channel under a higher degree of openness, as was the case in the domestic monetary policy shock.

The last row of Figure 8 reports dynamics responses resulting from a foreign monetary policy shock. On impact, the increase in the foreign interest rate leads to capital outflows and depreciation of the real exchange rate. Domestic households prefer to invest in risk-free foreign bonds that pay higher interest rate than the domestic bonds. There is a decrease in credit that funds the production of intermediate goods and, as a consequence, reduction in the production of final goods. Domestic inflation decreases because of the economic downturn. The nominal interest rate reduces according to the Taylor-type monetary policy rule. The countercyclical macroprudential policy lowers reserve requirements to recover the credit conditions and stimulates the economic activity. Now, however, the impact and propagation of the shock are directly affected by the openness of the economy. The transmission of the foreign shock to the SOE is directly affected by its degree of openness. In the limits, there is no transmission under a closed economy and full transmission under a fully open economy. Nevertheless, the countercyclical macroprudential policy is still having a relevant role to stabilize the real side of the economy through the credit channel.

## 3.6. Welfare Analysis

In order to evaluate the optimal level of reserve requirements, we compute a welfare loss as a function of different values of parameters $\overline{\tau}$ and $\kappa_\tau$ in the macroprudential policy rule for reserve requirements. The model is solved by a first-order local approximation around the steady state. The welfare function, following the literature, is defined by the expected intertemporal utility function as[9]:

$$\mathbb{W}_t = \sum_{i=t}^{\infty} \beta^{i-t} E_t[u(C_i, L_i)], \tag{45}$$

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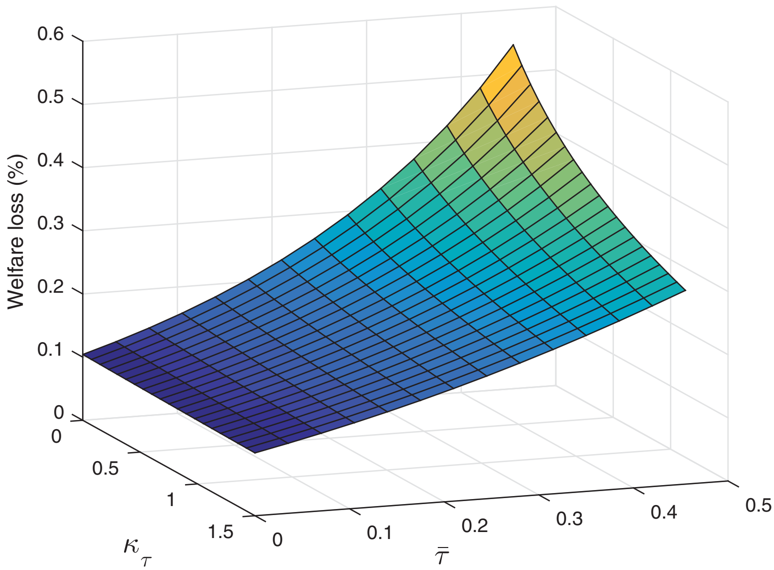


**FIGURE 9.** Welfare loss under alternative configurations of the reserve requirements rule.

where $\mathbb{W}_t$ represents the welfare measure in period $t$. Based on Gertler and Karadi (2011), welfare loss is given by the negative deviation of expected discounted utility from steady-state utility. In Figure 9, simulations are for $\overline{\tau}$ ranging from 0.0 to 0.45 and $\kappa_\tau$ varying from 0.0 to 1.5, with the welfare loss expressed in percent values.[10]

The results suggest that the smaller the fixed component $\overline{\tau}$, the lower the welfare loss is. Moreover, given a fixed value for $\overline{\tau}$, a policy rule with a higher response to the credit gap (higher $\kappa_\tau$) reduces the welfare loss after a shock in the domestic monetary policy. This finding is in line with the previous results. With a higher $\kappa_\tau$, the reduction in credit due to the increase in the domestic interest rate is compensated by a decrease in reserve requirements. In this scenario, the countercyclical performance of the macroprudential policy contributes to bring the credit level quickly to equilibrium and so to stabilize the real side of the SOE. The opposite occurs under an unexpected decrease in the domestic interest rate, which drives credit above the steady-state level. This requires an increase in reserve requirements to stabilize the credit market and pull the economy back to equilibrium. Thus, a combination of an interest rate rule that targets domestic inflation and does not respond directly to the exchange rate with a reserve requirement rule that reacts aggressively to the credit gap yields the smallest welfare loss to the SOE. Considering the Brazilian case, where $\overline{\tau} = 0.45$, there is a significant reduction of about 50% in the welfare loss by moving from no macroprudential policy rule, where $\kappa_\tau = 0$, to a more aggressive rule, with $\kappa_\tau = 1.5$, in the countercyclical response of reserve requirements to the credit gap.

In a wider macroprudential environment, other policy instruments, such as capital requirements (Ferreira and Nakane (2015)), capital regulation in the format of Basel III-type rules (Clancy and Merola (2017)), and central bank loans to nonfinancial firms (Gertler and Karadi (2011)), also yielded smaller welfare losses under more aggressive policy rules. Kiley and Sim (2017), however, warn that countercyclical macroprudential instruments might enhance welfare, but simple-rule approaches must be cautious not to limit credit expansions associated with efficient investment opportunities.

## 4. CONCLUSION

The objective of this paper was to investigate how a combination of monetary policy based on interest rate rules and macroprudential policy grounded on reserve requirements might affect the dynamics of an SOE with financial frictions under alternative discretionary shocks. The proposed DSGE model brought together elements of financial frictions, monetary policy, and macroprudential policy in an open economy environment. The model was calibrated for the Brazilian economy as a representative case of an emerging economy that actively used macroprudential policy in the recent period. We analyzed the effects of discretionary shocks in domestic monetary policy, productivity, and foreign monetary policy under alternative configurations for the interest rate and requirements policy rules. A sensitivity analysis to the degree of openness and a welfare loss evaluation were performed to assess the performance of these alternative policy rules.

Under domestic perturbations, represented by monetary policy and productivity shocks, there were no significant differences between the dynamics of an SOE and a closed economy. This is because the world economy is exogenous to the SOE, preventing the transmission of domestic shocks to foreign variables, and the degree of openness was low, as is the case of the Brazilian economy. In the case of foreign monetary policy shock, however, the effects on the domestic variables were more pronounced, leading to drops in both real and financial sector variables. The impacts were weaker and convergence to the equilibrium was faster when the interest rate rule targeted domestic inflation, as opposed to CPI inflation, and did not respond directly to the exchange rate.

The inclusion of the exchange rate in the interest rate rule reduced the effectiveness of the monetary policy, demanding a higher increase in the nominal interest rate in order to achieve a given decrease in the domestic inflation when compared to the case where the exchange rate did not enter the policy rule. Under a foreign monetary policy shock, the performance of domestic inflation targeting was also better than the CPI inflation targeting. These results are in line with Divino (2009a), who argued that domestic inflation targeting yielded the smallest volatilities for most endogenous variables under a foreign shock, but showed no significant differences in relation to CPI inflation targeting after domestic shocks. The low degree of openness might contribute to explain this apparent divergence.

Taken as a whole, our results suggest that domestic inflation targeting is a more appropriate monetary policy regime for the SOE.

A reserve requirements rule with an aggressive response to the credit gap contributed to smooth variations in output, credit, inflation, and interest rate in the event of a domestic monetary policy shock. This performance was also observed under a foreign monetary policy shock, when the real exchange rate was included in the previous set of smoother variables. Under a productivity shock, however, only output, credit, and real exchange rate displayed smoother trajectories. In this case, economic stability was quickly achieved under no macroprudential policy of reserve requirements. By increasing the degree of openness in a sensitivity analysis, however, the countercyclical role of the macroprudential policy stood out because of its stabilizing effects on the credit gap. The impact and propagation of domestic shocks were smaller in a highly open economy because capital flows contributed with the countercyclical rule of reserve requirements to stabilize credit conditions and real side of the economy.

The absence of a fixed component in the reserve requirement rule reduced volatility of most domestic variables under domestic and foreign shocks. In addition, a higher response to the credit gap in the countercyclical policy rule further reduced volatilities of the variables and led to faster convergence to the steady-state equilibrium after both domestic and foreign monetary policy shocks. The drop in reserve requirements under these shocks increased the credit supply to the intermediate goods producing firms and allowed the production of final goods at a lower cost. According to the welfare analysis, a combination of an interest rate rule that targets domestic inflation and a countercyclical reserve requirement rule that reacts more aggressively to the credit gap yielded the smallest welfare loss to the SOE. This evidence, as in Glocker and Towbin (2015) for the Brazilian economy, highlights the role of the reserve requirements tool as a complement to the traditional monetary policy based on interest rate rule. Thus, reserve requirements should be used as a countercyclical macroprudential instrument instead of an *ad-hoc* policy tool that is only applied during specific episodes of economic instability.

Finally, it is worth mentioning that the exchange rate was incorporated in a simple way in an SOE with financial frictions and reserve requirements. Future research should enrich this environment by including foreign savings funding by banks, presence of international reserves managed by the central bank, and interactions with the fiscal policy. Some of these suggestions are object of ongoing research.

## *NOTES*

1. See Glocker and Towbin (2015) for a detailed discussion on the macroprudential and monetary policies adopted by the Central Bank of Brazil under the inflation targeting regime.

2. Actually, in advanced economies, the conventional monetary policy tool is the short-term interest rate and central banks no longer use reserve requirements as monetary policy instruments (Montoro and Moreno (2011), Brei and Moreno (2018)).

3. There is no fiscal policy in the economy, as our focus is on monetary and macroprudential policies.

4. The prices of the financial claim and capital are equal to simplify the problem. To make this feasible, one only needs to adjust either the value of financial claims or the price of capital, so that the unity values are the same.

5. We abstract from a discretionary shock in the quality of capital, $\xi_t$, that appears in Gertler and Karadi (2011) because it plays no role in our setup.

6. Other forms of dirty floating exchange rate include direct and indirect interventions in the currency market.

7. See for instance Agénor et al. (2018), Mimir and Sunel (2019), and Glocker and Towbin (2012).

8. In the Appendix, Figures A.1 and A.2 illustrate that this finding is not affected by other configurations of the macroprudential policy, given by either $\overline{\tau} = 0$ and $\kappa_\tau = 0$ or $\overline{\tau} = 0.45$ and $\kappa_\tau = 1.5$ in equation (31).

9. Glocker and Towbin (2012) used a exogenously given quadratic loss function that depends on inflation and output gap, $L_t = (\log \pi_t)^2 + \lambda_y(\log Y_t - \log Y_t^n)^2$, as originally derived by Woodford (2003) from a second-order approximation of the utility function in a closed-economy environment without government. We also applied this loss function and the results were very similar to the ones reported in Figure 9. See also Agénor (2019) for an alternative approach that combines growth and welfare.

10. We also computed welfare loss as deviations in consumption instead of utility. The welfare-loss surface was essentially the same, but under a slightly higher scale at the vertical axis. Thus, our conclusions do not depend on whether welfare loss is measured in terms of utility or consumption.

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# APPENDIX

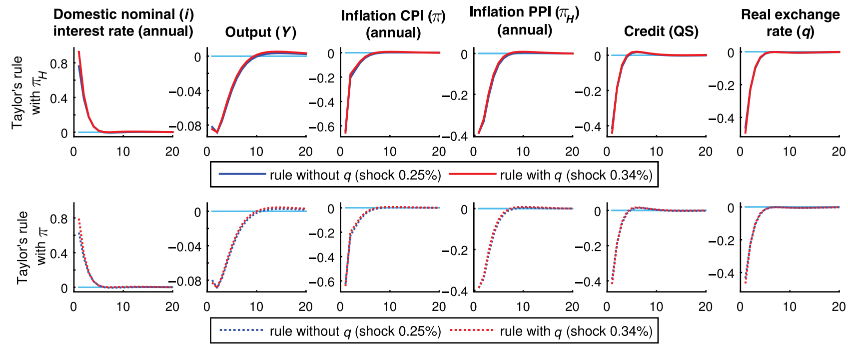


**FIGURE A.1.** Responses to a domestic monetary policy shock that is required to reduce $\pi_H$ in 0.39 pp (no reserve requirements: $\overline{\tau} = 0\%$ and $\kappa_\tau = 0$).

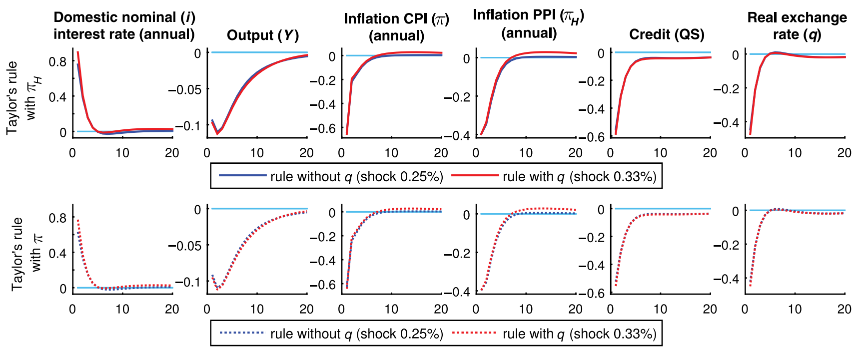


**FIGURE A.2.** Responses to a domestic monetary policy shock that is required to reduce $\pi_H$ in 0.39 pp (countercyclical reserve requirements: $\overline{\tau} = 45\%$ and $\kappa_\tau = 1.5$).

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