ISSN 1518-3548

BANCO CENTRAL DO BRASIL

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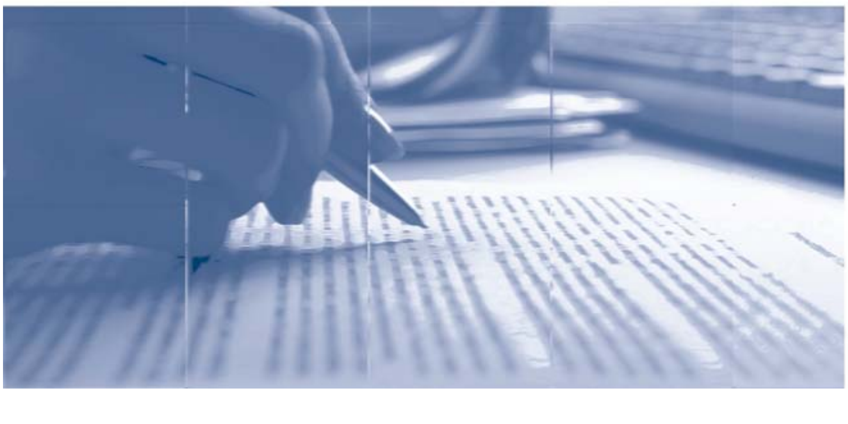
Fabia A. de Carvalho and Marcos R. Castro

December, 2016

Working Papers



453

ISSN 1518-3548
CGC 00.038.166/0001-05

Working Paper Series	Brasília	n. 453	December	2016	p. 1-38

Working Paper Series

Edited by Research Department (Depep) – E-mail: workingpaper@bcb.gov.br

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Macroprudential Policy Transmission and Interaction with Fiscal and Monetary Policy in an Emerging Economy: a DSGE model for Brazil*

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Marcos R. Castro ***

Abstract

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We use a DSGE model with heterogeneous financial frictions and foreign capital flows estimated with Bayesian techniques for Brazil to investigate optimal combinations of simple macroprudential, fiscal and monetary policy rules that can react to the business and/or the financial cycle. We find that the gains from implementing a cyclical fiscal policy are only significant if macroprudential policy countercyclically reacts to the financial cycle. Optimal fiscal policy is countercyclical in the business cycle and slightly procyclical in the financial cycle.

Keywords: DSGE models, Bayesian estimation, financial regulation, monetary policy, macroprudential policy

JEL classification: E4, E5, E6.

*We are grateful to Pierpaolo Benigno, Emanuel Kohlscheen, the participants in the BIS CCA Research Network Conference, and anonymous referees for insightful comments and suggestions. Errors and omissions in the paper are of course the authors' sole responsibility.

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1 Introduction

The Brazilian government implemented a new fiscal regime in the aftermath of the global financial crisis, with public banks stepping in strongly in the credit markets to offset the retraction in private banks' credit origination. The government also introduced tax cuts and increased spending in social and investment programs to help stimulate the economy in a context of unfavorable international conditions.

This had important implications for fiscal accounts. After almost a decade of strong primary surpluses following the implementation of the inflation targeting regime[1], which granted the country an investment grade in 2008, the fiscal accounts deteriorated to the point of posting primary deficits from end-2014 onwards.As a result, the country was sequentially downgraded by rating agencies.

The expansionist stance of fiscal policy created important challenges for monetary policy, affecting the anchoring of inflation expectations. Carvalho and Castro (2015b) show that macroprudential policies (MaP), used in some occasions to loose credit conditions for particular sectors (e.g. rural, automobile industry), further affected inflation expectations [2].

This raises the question: should fiscal policy react to the credit cycle? We use our open-economy DSGE model with heterogeneous financial frictions, detailed in Carvalho and Castro (2015a), to address this question by employing Schmitt-Grohé and Uribe (2007)'s method to find the optimal combination of simple and implementable fiscal, monetary and macroprudential policy rules that are allowed to react to either the credit or the business cycle, or to both.

The results suggest that the gains from implementing a fiscal policy that reacts to both the financial and business cycles are minor if macroprudential policy is not allowed to countercyclically react to the financial cycle. The optimal policy combination[3] is comprised of a fiscal policy that is anticyclical in the business cycle and slightly procyclical in the credit cycle[4], a very aggressive countercyclical response of the CCyB to the financial cycle, and a monetary policy that strongly reacts to inflation and the business cycle.

Since international shocks have been the main justification for loose fiscal policy in

[1]The consolidated public sector primary surplus averaged 3.51% from 2002 to 2008.

[2]For a more detailed discussion of the challenges facing macroprudential and monetary policy in Brazil, please refer to Carvalho and Castro (2015b)

[3]Within the set of implementable policies.

[4]The anticyclical nature of the optimal fiscal response dominates.

the past years in Brazil, we compare the dynamic responses of the optimal simple rules to international shocks. We find that the direction of the optimal fiscal response clearly depends on the specific source of the shock, given that each shock will have a particular influence on bank credit dynamics.

This is a familiar concept for monetary policy in inflation targeting regimes: that it is optimal to react to certain shocks but it is not optimal to react to the first round effect of others. We show that this is also true for fiscal and macroprudential policies that work together towards the objective of attaining financial, economic and price stability.To implement the optimal dynamic policy response, it is essential to identify the source of disturbance. We show that when fiscal policy optimally responds to both the financial cycle and the business cycle, it impacts credit and output through a crowding-out impact on capital investment. In other words, by increasing public consumption, the government crowds out private capital investment. The reduction in capital investment results in less demand for commercial loans, and credit falls. There are other consequences that end up affecting output, putting pressure on inflation. In this case, monetary policy responds accordingly.

The paper is presented as follows. Section 2 describes the theoretical model. Section 3 discusses the stationarization of the model, the computation of the steady state, and the estimation. Section 4 finds the optimal combination of fiscal, macroprudential and monetary policies allowed to react to either credit or business cycles, or to both. The final section concludes.

2 The theoretical model

In this section we show the main features of the theoretical model. A detailed description of the model is available at Carvalho and Castro (2015a).

The model was built to replicate important features of an emerging economy's credit market where risk can build up from developments in real asset prices and in the labor market, and can also be influenced by the international environment. The main innovations in the theoretical framework were the introduction of endogenous default in consumer loans based on labor income, the introduction of foreign direct investment interacting with the financial friction of entrepreneurs and the adjustment cost of foreign debt which results in a modified-UIP. Figure 1 shows a schematic representation of the real sector of the economy and Figure 2 shows the financial flows.

The core features of the model are as follows. With respect to financial variables: 1) banks operate in heterogeneous credit markets; i.e., they extend consumer, housing and commercial loans, each having a different type of borrowing constraint, and all of them facing endogenous default risk; 2) consumer loans are extended based on banks' ex-ante assessment of borrowers' capacity to pay the loans with future labor income; 3) housing loans are subject to a loan-to-value constraint and are senior to consumer loans, thus affecting expected available income; and 4) banks have liquidity preferences and face frictions to optimize balance sheet allocations, and do so in a dynamic framework.

With respect to the open-economy aspects of the model: 1) the non-banking sector of the economy receives inflows of foreign direct and portfolio investment, and issues foreign debt, facing adjustment costs when the rollover rate deviates from the steady state; 2) exporters are price takers, face costs to adjust the export quantum and take working capital loans in foreign currency from domestic banks to finance a share of their exports; and 3) international reserves are a policy instrument that reacts to the exchange rate.

The agents in the economy are households (savers and borrowers), labor unions, entrepreneurs, firms producing intermediate and final goods, import and export firms, retailers, distributors, a retail money market fund, a bank conglomerate, the external sector and the government.

2.1 Households

Households are either savers or borrowers. Both supply labor to a continuum of labor unions that operate under monopolistic competition, consume traditional consumption goods and housing, and have demand deposits. Savers can invest in savings deposits and in quotas of a retail money fund. They receive net-of-tax profits from all business activities in the economy, trade claims to entrepreneurs' net worth with the foreign direct investor, and earn dividends distributed by banks.

Borrowers take risky loans to finance both consumption and housing. Banks extend consumer loans based on their expected future labor income, and this makes them risky since income is subject to unanticipated idiosyncratic shocks. Housing loans are senior to consumer loans.

2.1.1 The borrowers' optimization program

At period t, borrower i gets a one-period retail loan $B^{C}_{B,i,t}$ and a housing loan $B^{H}_{B,i,t}$ at fixed interest rates $R^{L,C}_{B,t}$ and $R^{L,H}_{B,t}$, respectively. Lending rates are set by the bank based on borrowers' expected capacity to pay the loans with labor income.This modeling strategy was adopted to replicate the way consumer loans are extended in Brazil, and in many other countries where these loans are unsecured or weakly collateralized[5].

At every period, borrowers' labor income is subject to unanticipated idiosyncratic shocks $\varpi_{B,i,t} \sim lognormal\left(1, \sigma_{B,t}\right)$, a short-cut for idiosyncratic productivity shocks that do not affect firms' aggregate production but that affect borrowers' available income. Borrowers may default on all their loans (i.e., consumer and housing loans) or only on consumer loans, given that housing loans have seniority over consumer loans[6]. In case of default, the bank seizes a fraction $\gamma_t^{B,C}$ of the borrower's net-of-tax labor income, after incurring proportional monitoring costs $\mu_{B,C}$ and $\mu_{B,H}$, respectively. Hence, at period $t+1$, after the shock $\varpi_{B,i,t+1}$ realizes, the borrower defaults on consumer loans if realized labor income previously committed to pay the loan is less than the face value of the total debt. This threshold value ($\overline{\varpi}_{B,i,t+1}$) is given by

$$R_{B,i,t}^{L,C} B_{B,i,t}^{C} + R_{B,t}^{L,H} B_{B,i,t}^{H} = \gamma_t^{B,C} \overline{\varpi}_{B,i,t+1} \left(1 - \tau_{W,t+1}\right) N_{B,i,t+1} W_{t+1} \tag{1}$$

For convenience, we define another threshold $\overline{\varpi}_{B,i,t+1}^{H}$ which will determine default on housing loans:

$$R_{B,t}^{L,H} B_{B,i,t}^{H} = \gamma_t^{B,C} \overline{\varpi}_{B,i,t+1}^{H} \left(1 - \tau_{W,t+1}\right) N_{B,i,t+1} W_{t+1} \tag{2}$$

The expected zero profit condition of the risk neutral competitive lending bank branch is given by

$$R_{B,t}^{C} B_{B,i,t}^{C} = \gamma_t^{B,C} E_t \left(1 - \tau_{W,t+1}\right) N_{B,i,t+1} W_{t+1} \left(1 - \mu_{B,C}\right) \left[\int_{\overline{\varpi}_B^H}^{\overline{\varpi}_B} \varpi dF\left(\varpi; \sigma_B\right) - \overline{\varpi}_B^H \left[F\left(\overline{\varpi}_B; \sigma_B\right) - F\left(\overline{\varpi}_B^H; \sigma_B\right) \right] \right] \tag{3}$$

$$+ \left(\overline{\varpi}_B - \overline{\varpi}_B^H\right) \left(1 - F\left(\overline{\varpi}_B; \sigma_B\right)\right)$$

where $R_{B,t}^{C}$ is the funding cost for consumer credit operations and $F\left(\cdot; \sigma_{B,t+1}\right)$ and $dF\left(\cdot; \sigma_{B,t+1}\right)$ are log-normal CDF and PDF, respectively.

On average, the expected repayment to retail lending branches is

$$\gamma_t^{B,C} E_t \left(1 - \tau_{W,t+1}\right) N_{B,i,t+1} W_{t+1} \int_{\overline{\varpi}_B^H}^{\overline{\varpi}_B} \varpi dF\left(\varpi; \sigma_B\right) - \overline{\varpi}_B^H \left(F\left(\overline{\varpi}_B; \sigma_B\right) - F\left(\overline{\varpi}_B^H; \sigma_B\right) \right) \tag{4}$$
$$+ \left(\overline{\varpi}_B - \overline{\varpi}_B^H\right) \left(1 - F\left(\overline{\varpi}_B; \sigma_B\right)\right)$$

Monitoring costs are received by the patient households as lump-sum transfers. The expected repayment to the housing lending branch has a similar representation, and total

[5]For more details on the impact of this modeling strategy and a comparison with standard collateral constraints, please refer to Carvalho et al. (2014).

[6]This assumption replicates the evidence of higher default rates in consumer loans than in housing loans in Brazil.

expected loan payment is

$$\gamma_t^{B,C} E_t \left(1 - \tau_{W,t+1}\right) N_{B,i,t+1} W_{t+1} \int_0^{\overline{\varpi}_B} \varpi dF\left(\varpi; \sigma_B\right) + \overline{\varpi}_B \left(1 - F\left(\overline{\varpi}_B; \sigma_B\right)\right) \tag{5}$$

We model the demand for housing loans according to a variant of the traditional loan-to-value constraint:

$$B^H_{B,i,t} = \rho^{B,H} B^H_{B,i,t-1} + \left(1 - \rho^{B,H}\right) \gamma_t^{B,H} P_{H,t} H^B_{i,t} \tag{6}$$

Borrowers derive utility from a composite ($\mathcal{X}_{B,t}$) of consumption goods ($C_{B,t}$) and housing ($H_{B,t}$), demand deposits ($D^D_{B,t}$), and worked hours ($\bar{h}_{N,B}$). The representative borrower's utility function is

$$E_0 \left\{ \sum_{t\geq 0} \beta_B^t \left[\frac{1}{1-\sigma_X} \left(\mathcal{X}_{B,t}\right)^{1-\sigma_X} - \frac{\varepsilon_t^L \psi_{N,B}}{1+\sigma_L} \left(\frac{N_{B,t}}{\epsilon_{L,t}} - \bar{h}_{N,B} \frac{N_{B,t-1}}{\epsilon_{L,t-1}} \right)^{1+\sigma_L} + \frac{\psi_{D,B}}{1-\sigma_D} \varepsilon_t^{D,B} \left(\frac{D^D_{B,t}}{P_{C,t}\epsilon_{L,t}\epsilon_{A,t}} \right)^{1-\sigma_D} \right] \varepsilon_t^{\beta,B} \right\} \tag{7}$$

where

$$\mathcal{X}_{B,t} = \left[\left(1 - \varepsilon_t^H \omega_{H,B}\right)^{\frac{1}{\eta_H}} \left(\frac{C_{B,t}}{\epsilon_{L,t}\epsilon_{A,t}} - \bar{h}_{C,B} \frac{C_{B,t-1}}{\epsilon_{L,t-1}\epsilon_{A,t-1}} \right)^{\frac{\eta_H - 1}{\eta_H}} + \left(\varepsilon_t^H \omega_{H,B}\right)^{\frac{1}{\eta_D}} \left(\frac{H_{B,t}}{\epsilon_{L,t}\epsilon_{A,t}} \right)^{\frac{\eta_H - 1}{\eta_H}} \right]^{\frac{\eta_H}{\eta_H - 1}} \tag{8}$$

and $\bar{h}_{C,B}$ is consumption habit, $\omega_{H,B}$ is housing bias in the consumption basket, δ_H is housing depreciation, and $\tau_{C,t}$ and $\tau_{W,t}$ are tax rates on consumption and labor income, respectively. ε_t^L, ε_t^H , $\varepsilon_t^{\beta,B}$, $\varepsilon_t^{D,B}$ are preference shocks, and $\psi_{N,B}$ and $\psi_{B,D}$ are scaling parameters. Housing is priced at $P_{H,t}$. $\epsilon_{L,t}$ and $\epsilon_{A,t}$ are stochastic trends in population and labor productivity. Labor is competitively supplied to labor unions at a nominal wage W_t^N. Labor unions are monopolistically competitive, and distribute their net-of-tax profits (Π_t^{LU}) back to households as lump-sum transfers.

The aggregate budget constraint of the representative borrower[7] is

$$\begin{aligned} &\left(1 + \tau_{C,t}\right) P_{C,t} C_{B,t} + P_{H,t} \left(H_{B,t} - \left(1 - \delta_H\right) H_{B,t-1}\right) + \gamma_{t-1}^{B,C} \left(1 - \tau_{W,t}\right) N_{B,t} W_t H\left(\overline{\varpi}_{B,t}, 0; \sigma_{B,t}\right) + D^D_{B,t} \\ &\leq B^C_{B,t} + B^H_{B,t} + D^D_{B,t-1} + \left(1 - \tau_{W,t}\right) \left(W_t^N N_{B,t}\right) + TT_{B,t} + \Pi^{LU}_{B,t} \end{aligned} \tag{9}$$

where W_t^N is the wage paid by unions to households[8].

The borrower maximizes its utility function (7) subject to constraints (8) to (2.1.1), (6) and (9). For the sake of brevity, we omit the details of the savers' and union's optimization

[7]A representative borrower exists if we assume that an insurance contract homogenizes income available to each borrower after the idiosyncratic shock realizes and after default decisions are made. We impose that every single borrower follows the same allocation plan that maximizes average utility in the group of borrowers.

[8]It is straightforward to show that $\left(1 - \tau_{\omega,t}\right) N_{B,t} W_t = \left(1 - \tau_{\omega,t}\right) \left(W_t^N N_{B,t}\right) + \Pi^{LU}_{B,t}$

programs, which are standard in the literature.

2.2 Entrepreneurs

Entrepreneurs manage productive capital, funding their projects with bank loans and FDI. Banks take capital as collateral for the loans, and given idiosyncratic shocks to the projects, entrepreneurs might default on their loans. This follows Christiano et al. (2010) with time varying LTV ratios. Our main innovation relates to the introduction of FDI.

Domestic savers and foreign investors shares ($N^S_{E,t}$ and $N^{FDI}_{E,t}$, respectively) of entrepreneurs' net worth. Change of ownership is made through FDI flows (FDI_t). Hence

$$N^{FDI}_{E,t} = N_{E,t}\frac{N^{FDI}_{E,t-1}}{N_{E,t-1}} + S_t FDI_t$$

where $N_{E,t}$ is total net worth and FDI inflows are driven by:

$$\frac{FDI_t}{P^*_t \epsilon_{L,t}\epsilon_{A,t}} = -\gamma^{FDI}\left(\frac{N_{E,t-1}}{P_{C,t-1}\epsilon_{L,t-1}\epsilon_{A,t-1}} - n^{FDI}_E\right) + \varepsilon^{FDI}_t \tag{10}$$

where n^{FDI}_E is the steady state stock of FDI and ε^{FDI}_t is a shock[9].

At the end of period t, entrepreneurs get one-period bank loans ($B_{E,t}$) to partially fund capital ($K_{E,t}$). A fraction (γ^E_t) of entrepreneur's capital is put up as collateral. The value of capital is subject to an idiosyncratic shock $\omega_{t+1} \sim lognormal(1, \sigma_{E,t+1})$ which can cause loans to default. In this case, banks will pay monitoring costs (μ_E) to execute collateral. At the end of each period, only a fraction γ^N_t of entrepreneurs survive. The other fraction distributes their wealth (Π^E_t) to patient households and foreign investors, according to their net worth shares.

2.3 Producers and retailers

Domestic intermediate goods producers operate under perfect competition. Output is produced from labor and capital according to:

$$Z^d_{j,t} = A.\varepsilon^A_t \left[u_{j,t}K_{j,t}\right]^\alpha \left(\epsilon_{A,t}L_{j,t}\right)^{1-\alpha} \tag{11}$$

where $j \in (0,1)$, A is a scaling constant, u_t is capital utilization, $L_{j,t}$ is labor demand, ε^A_t is a temporary productivity shock, and $\epsilon_{A,t}$ is a permanent labor productivity shock with growth rate $g_{A,t}$.

[9] Payment for foreign purchases of entrepreneurs' net worth is transferred to savers as a lump sum ($TT^{FDI}_{E,t}$).

Intermediate goods producers maximize profits

$$MC_t Z^d_{j,t} - R^K_t K_{j,t} - \Gamma_u \left(u_{j,t}\right) P_{C,t} K_{j,t} - W_t L_{j,t} \tag{12}$$

subject to (11), where MC_t is the price of domestic intermediate goods, $\Gamma_u(u_t)$ is a quadratic adjustment cost of capital utilization, and W_t are wages.

Final goods producers use domestic and imported intermediate goods in the production of private and public consumption, investment, and exports goods. There are price rigidities in the purchases of both domestic and imported intermediate goods. Capital and housing stock producers make investment decisions.

2.4 Exports and foreign variables

Brazilian exports are relatively well diversified yet still strongly based on commodities. The country is a price taker in the global commodities market but the responses of the export quantum to developments in global prices is sluggish. Taking these facts into account, we model the export firm as a price taker that faces adjustment costs to change export volumes. The export firm purchases export goods (X_t) from domestic producers at the domestic currency price $P_{X,t}$ and sells them abroad at the foreign currency price ($P^{X^*}_t$), which is a function of world prices (P^*_t), the rest-of-the-world output gap (y^*_t) and a shock (Z^{X^*}):

$$\frac{P^{X^*}_t}{P^*_t} = \left(\frac{Z^{X^*}_t}{\alpha_{Y^*} y^*_t}\right)^{-\frac{1}{\epsilon_{Y^*}}} \tag{13}$$

where α_{Y^*} is a proportionality parameter and world price inflation is AR(1).

At the beginning of period t, the exporter gets a loan ($\omega^X_t P^{X^*}_t X_t$) in foreign currency to finance working capital, at the international risk-free rate plus a premium that reflects country risk and operational risk.The loan redeems at the end of the same period.

The exporter chooses X_t to maximize its discounted cash flow:

$$E_0 \sum_{t=0}^{\infty} \beta^t_S \frac{\Lambda_{S,t}}{P_{C,t} \epsilon_{L,t} \epsilon_{A,t}} \Pi^X_t$$

where

$$\Pi^X_t = S_t P^{X^*}_t X_t \left[1 - \left(1 + \tau^{R^{L,f}_X}_t\right) \omega^X_t \left(R^{L,f}_{X,t} - 1\right)\right] - P_{X,t} X_t \left[1 + \Gamma_X \left(X_t / \left(g_{L,t} g_{A,t} X_{t-1}\right); \varepsilon^X_t\right)\right] \tag{14}$$

$R^{L,f}_{X,t}$ is the lending interest rate, Γ_X is a quadratic adjustment cost, ω^X_t is the time-varying share of exports that are financed with bank loans, $\tau_t^{R_X^{L,f}}$ is a proportional tax on export loans' interest payments, and ε_t^X is an adjustment cost shock.

The lending rate is determined by:

$$R_{X,t}^{L,f} = R_t^* \phi_t^* \phi_t^{L,X} \tag{15}$$

where R_t^* is the foreign interest rate, ϕ_t^* is the country risk premium, $\phi_t^{L,X}$ is a lending spread specific to this credit segment. We assume that R_t^* , $\phi_t^{L,X}$, ω_t^X, and ε_t^X are AR(1) processes.

2.5 The retail money market fund

A retail money market fund (RMMF) intermediate savers' financial investment, without transaction costs. This fund invests in bank time deposits (D_t^T) and government bonds ($B_{F,t}$), and issues bonds in international markets ($B_{F,t}^*$), which yield R_t^T, R_t and $R_t^*\phi_t^*$, respectively. Foreign bonds issued by the fund are denominated in foreign currency, while the other assets are denominated in domestic currency.

The RMMF seeks to maximize the total nominal return of its portfolio according to the following optimization program:

$$\max_{\{D_t^T, B_t^F, B_t^*\}} E_t \left\{ R_t^T D_t^T + B_{F,t} R_t - S_{t+1} R_t^* \phi_t^* B_{F,t}^* \right\} - \Gamma_{F,B^*} \left(\frac{B_{F,t}^*}{\pi_t^* g_{L,t} g_{A,t} B_{F,t-1}^*} \right) S_t B_{F,t}^* \tag{16}$$

subject to the balance sheet constraint

$$D_t^F = D_t^T + B_{F,t} - S_t B_{F,t}^*$$

where $\Gamma_{F,B^*}(r) \equiv \phi_{F,B^*}(r-1)^2/2$ is an adjustment cost for rollover rates different from the stationary trend. The parameter ϕ_{F,B^*} influences the size of the impact of foreign capital inflows on the domestic economy and the credit market.

The resulting first order conditions imply a non-arbitrage condition, i.e., $R_t^T = R_t$, and a modified UIP equation:

$$R_t = \frac{P_{C,t}}{S_t P_t^*} E_t \left\{ \frac{S_{t+1} P_{t+1}^*}{P_{C,t+1}} \frac{\pi_{C,t+1}}{\pi_{t+1}^*} R_t^* \phi_t^* \varepsilon_t^{UIP} \right\} + \phi_{F,B^*} \left(\frac{B_{F,t}^*}{\pi_t^* g_{L,t} g_{A,t} B_{F,t-1}^*} - 1 \right) \frac{B_{F,t}^*}{\pi_t^* g_{L,t} g_{A,t} B_{F,t-1}^*} + \phi_{F,B^*} \frac{1}{2} \left(\frac{B_{F,t}^*}{\pi_t^* g_{L,t} g_{A,t} B_{F,t-1}^*} - 1 \right)^2 \tag{17}$$

where ε_t^{UIP} is a shock.

The nominal return of the RMMF from period $t-1$ to period t is given by

$$R_t^F D_{t-1}^F = R_{t-1}^T D_{t-1}^T + R_{t-1} B_{F,t-1} + S_t R_{t-1}^* \phi_{t-1}^* B_{F,t-1}^* - \Gamma_{F,B^*}\left(\frac{B_{F,t-1}^*}{\pi_{t-1}^* g_{L,t-1} g_{A,t-1} B_{F,t-2}^*}\right) S_{t-1} B_{F,t-1}^* \quad (18)$$

2.6 The balance of payments and foreign capital flows

The model has all major balance of payments (BoP) accounts. In addition to exports, imports, and private sector debt, which are traditionally present in open economy models, the balance of payments also includes FDI, foreign portfolio investment (FPI_t), foreign exchange reserve flows, and unilateral transfers (ULT_t). The BoP equation is:

$$\begin{aligned} B_t^f &= R_{t-1}^f B_{t-1}^f + \omega_t^X (R_t^* \phi_t^* - 1) P_t^{X^*} X_t - \left(P_t^{X^*} X_t - P_t^{M,*} Z_t^M\right) - ULT_t \\ &- \left(FDI_t - \frac{\Pi_t^{E,FDI}}{S_t}\right) + \left(B_t^{FER} - R_{t-1}^* \phi_t^{FER} B_{t-1}^{FER}\right) - \left(\frac{B_{FPI,t}}{S_t} - \frac{R_{t-1} B_{FPI,t-1}}{S_t}\right) \end{aligned} \quad (19)$$

where B_t^{FER} is the stock of foreign exchange reserves. The interest rate (R_t^f) on foreign debt (B_t^f) corresponds to the foreign risk free interest rate (R_t^*) multiplied by the country risk premium (ϕ_t^*).

Since foreign portfolio investors traditionally seek for short-term arbitrage opportunities, FPI in the model is driven by expected interest rate differentials:

$$\ln\left(\frac{B_{FPI,t}}{P_{C,t}\epsilon_{L,t}\epsilon_{A,t}} \frac{1}{b_{FPI}}\right) = \gamma^{R,FPI}\left[\ln\left(E_t \frac{R_t}{\pi_{C,t+1}} \frac{\pi_{t+1}^*}{R_t^* \phi_t^*}\right) - \ln\left(\frac{R}{\pi_C} \frac{\pi^*}{R^* \phi^*}\right)\right] + \varepsilon_t^{FPI} \quad (20)$$

where ε_t^{FPI} is a shock and $B_{FPI,t}$ are government bonds held by foreign investors.

The country risk premium (ϕ_t^*) is affected by global risk aversion $risk_t$ and net foreign debt ($B_t^f - B_t^{FER}$). We also introduce FPI as a factor affecting the dynamics of country risk premium, since this type of investment is usually more susceptible to herd behavior and is traditionally seen as a source of vulnerability in the external accounts of emerging economies[10]:

$$\phi_t^* = \phi^* \exp\left(\kappa_{bf}^{\phi^*}\left[\frac{S_t\left(B_t^f - B_t^{FER}\right) + \kappa_{B^{FPI}}^{\phi^*} B_{FPI,t}}{P_{C,t}\epsilon_{L,t}\epsilon_{A,t}} - \left(b^f - b^{FER} + \kappa_{B^{FPI}}^{\phi^*} b_{FPI}\right)\right] + \kappa_{risk}^{\phi^*} \ln\left(\frac{risk_t}{risk}\right)\right) \varepsilon_t^{\phi^*} \quad (21)$$

where $\varepsilon_t^{\phi^*}$ and $risk_t$ are AR(1) processes.

In the model, the only domestic agent that borrows from abroad is the retail money market

[10]FDI flows will also affect the risk premium through indirect channels. For instance, when the flows affect the exchange rate, they country may become less attractive to foreign portfolio investors, and if they withdraw their positions, the country risk premium can be directly affected.

fund. Therefore

$$B_t^f = B_{F,t}^* \tag{22}$$

Foreign exchange reserves are managed by the monetary authority. They are remunerated at the foreign risk free rate R_t^* plus an additional exogenous premium (ϕ_t^{FER}) to reflect actual returns on Brazilian foreign reserves investment. Unilateral transfers (ULT_t) are modeled as an AR process.

2.7 The banking sector

The modeling strategy for the banking sector is adequate to assess the impact of macroprudential policy instruments not only on bank rates (prices) but also on quantities, through shifts in the composition of banks' balance sheets.

There is one bank conglomerate composed of a continuum of competitive banks that get funding from deposit branches and extend credit to households, entrepreneurs, and export firms through lending branches. Banks channel money market funds to the lending branches and make all important decisions with respect to the composition of the conglomerate's balance sheet. The conglomerate is subject to regulatory requirements and can only accumulate capital by retaining profits. The share of profits to be distributed or reinvested is a choice variable in the intertemporal optimization program of the bank. Our adopted segmentation of the bank conglomerate allows the model to endogenously reproduce the most relevant determinants of lending spreads in the main credit segments in Brazil and the effects of regulatory requirements on bank rates and volumes.

2.7.1 Deposit branches

There is one representative deposit branch for each type of deposit. The demand deposit branch costlessly takes unremunerated demand deposits, $\omega_S D_{S,t}^D$ and $\omega_B D_{B,t}^D$, which are determined from households' optimization problems. It then costlessly distributes this funding to each bank $j \in [0, 1]$. In the following period, these resources return to households. The savings and time deposit branches operate analogously, except that these deposits accrue interest (R_t^S), which is regulated by the government according to:

$$\ln\left(\frac{R_t^S}{R^S}\right) = \varphi_R^S \ln\left(\frac{R_t}{R}\right) + \ln\left(\varepsilon_t^{R,S}\right) \tag{23}$$

where $\varepsilon_t^{R,S}$ is a shock.

The time deposit branch issues deposit certificates to the retail money market fund, at an interest rate equal to the base rate (i.e., $R_t^T = R_t$). This is motivated by the fact that in Brazil banks' time deposits face fierce competition from domestic federal bonds[11] and this results in very narrow markdowns of time deposit rates on the base rate of the economy[12].

2.7.2 Lending branches

Lending branches are specialized in commercial, retail or housing loans. The representative commercial lending branch is competitive in the market of credit to entrepreneurs and seeks to diversify its funding sources. It borrows $B^b_{E,j,t}$ from bank j at the interest rate $R_{E,j,t}$. Total loans extended to entrepreneurs are a CES aggregate of funding resources:

$$B_{E,t} = \left[\int_0^1 \omega_{b,j} \left(B^b_{E,j,t} \right)^{\frac{1}{\mu^R_{E,t}}} dj \right]^{\mu^R_{E,t}} \tag{24}$$

where the markup $\mu^R_{E,t}$ is an AR(1).

The lending branch chooses the amount to borrow from each bank ($B_{E,j,t}$) so as to minimize total funding costs $\int_0^1 \omega_{b,j} R_{E,j,t} B^b_{E,j,t} dj$ subject to the aggregation technology in (24). The FOC yields:

$$B^b_{E,j,t} = \left(\frac{R_{E,j,t}}{R_{E,t}} \right)^{\frac{\mu^R_{E,t}}{1-\mu^R_{E,t}}} B^{LB,E}_{E,t} \tag{25}$$

Total funding collected from banks $j \in [0, 1]$ at period t is:

$$B^b_{E,t} = B_{E,t} \Delta^R_{E,t} \tag{26}$$

where

$$\Delta^R_{E,t} = \int_0^1 \omega_{b,j} \left(\frac{R_{E,j,t}}{R_{E,t}} \right)^{\frac{\mu^R_{E,t}}{1-\mu^R_{E,t}}} dj > 1$$

[11] About half the outstanding balance of domestic federal bonds are held by non-financial clients of the banking system, either through direct ownership of securities or through quotas of mutual funds. In fact, domestic federal bonds held by money market funds account for about 30% of domestic federal bonds. Private individuals can also hold claims to federal bonds negotiated at National Treasury's facility 'Tesouro Direto'

[12] For instance, in the period analyzed in this paper, the quarterly base rate was merely 0.2 p.p higher on average than the effective 90-day time deposits (CDB) rate. This assumption has (desired) implications for the response of credit conditions after changes in reserve requirements. If these rates were not equal, the impact of reserve requirements shocks on credit would be partially attenuated by adjustments in the cost of funding to banks, a feature that is not perceived in Brazilian banks.

2.7.3 Housing loan branch

The Brazilian housing credit market is heavily regulated by the government. The regulatory authority requires that a fraction of savings deposits be channeled to housing loans, most of which at regulated lending rates[13]. We therefore assume that the final lending rate ($R^{L,H}_{B,t}$) is set by the government as a markup on the savings deposits rate. Consequently, the only role played by the housing loan branch is to channel housing loans from banks to households, making no strategic decisions with respect to lending rates or volumes. The bank conglomerate absorbs the cost of default on housing loans as a loss. The volume of housing loans in banks' assets will impact capital adequacy ratios, hence banks' decisions with respect to their positions on non-regulated credit segments will be affected by their balance sheet exposure to housing loans.

2.7.4 Working capital loans to exporters

Export credit lines in the Brazilian banking system represent only a small fraction of the total volume of non-earmarked loans[14]. Most of these export credit lines is short term, with very low default rates. As a result, w.l.g. we modeled them as working capital loans[15]. We assume that the banking sector makes no strategic decisions with respect to export loans. Lending rates are set with a premium over the rate applicable to foreign debt, and volumes are decided by the exporters.

2.7.5 Banks

Banks' operations are funded with resources from the deposit branches and from retained earnings. They optimally choose the composition of their balance sheet, constrained by regulation on reserve requirements, capital requirements, risk weights on capital adequacy ratio (CAR), and facing nominal frictions in addition to operational and fiscal costs. They are allowed to choose the amount of profits to be distributed to their owners (i.e., savers) or to be retained as capital.

The regulatory environment has the following features. First, funding from time deposits is subject to reserve requirements, which can be remunerated or non-remunerated. Second,

[13] Housing loans that finance expensive real estate are less tightly regulated. However, the bulk of housing credit in Brazil finances low-priced real estate, which is subject to regulation.

[14] As of December 2013, they amounted to 4.4% of total bank credit.

[15] The Brazilian Development Bank (BNDES) has important credit lines intended to foster the export sector. Both working capital and investment loans are extended at subsidized rates. Decisions on subsidies and quantities follow a development-oriented strategy that tightly adheres to the principles guiding fiscal policy. However, since our intention was to model a channel of contagion from adverse international conditions to the banking system, we focused only on non-regulated loans.

the benchmark model introduces a simplified version of Basel I and Basel II-type capital requirement, which is based on CAR after weighting bank assets according to their risk factors. Third, there are regulatory requirements on savings deposits and housing loans. Finally, there is tax incidence on specific credit operations and on banks' profits. Bank *j*'s balance sheet can be represented as:

$$\begin{aligned} &B_{Bank,j,t} + B^{b}_{E,j,t} + B^{C,b}_{B,j,t} + B^{H,b}_{B,j,t} - RR^{S,H}_{j,t} + RR^{T}_{j,t} + RR^{S}_{j,t} + RR^{D}_{j,t} + RR^{add}_{j,t} \\ &= D^{T}_{j,t} + D^{S}_{j,t} + D^{D}_{j,t} + Bankcap_{j,t} \end{aligned} \tag{27}$$

where $B_{Bank,j,t}$ are liquid assets (i.e., public bonds held by the bank), $B^{b}_{E,j,t}$, $B^{C,b}_{B,j,t}$, and $B^{H,b}_{B,j,t}$ are funds to commercial, consumer and housing lending branches, $Bankcap_{j,t}$ is net worth, $RR^{T}_{j,t}$, $RR^{S}_{j,t}$, and $RR^{D}_{j,t}$ are required reserves on time, savings and demand deposits, respectively, and $RR^{add}_{j,t}$ are additional required reserves[16], and $RR^{S,H}_{j,t}$ is an exogenous source of funding to housing loans that fulfills[17]:

$$RR^{S,H}_{j,t} + \tau_{H,S,t} D^{S}_{j,t} = B^{H,b}_{B,j,t} \tag{28}$$

Export credit does not show in banks' balance sheet equation because it redeems within the same period at which it was extended. It will only show in banks' cash flows.

Reserve requirements are determined according to:

$$\begin{aligned} RR^{D}_{j,t} = \tau_{RR,D,t} D^{D}_{j,t} \,, RR^{S}_{j,t} = \tau_{RR,S,t} D^{S}_{j,t} \,, RR^{T}_{j,t} = \tau_{RR,T,t} D^{T}_{j,t} \\ RR^{add}_{j,t} = \tau_{RR,add,t} \left(D^{D}_{j,t} + D^{T}_{j,t} + D^{S}_{j,t} \right) \end{aligned} \tag{29}$$

where $\tau_{RR,D,t}$, $\tau_{RR,S,t}$, and $\tau_{RR,T,t}$ are required ratios set by the government on demand, savings and time deposits, respectively, and follow AR(1) processes. Required reserves deposited at the monetary authority accrue the same rate paid by banks to their clients on each of these deposits.

Banks have preferences over some balance sheet components, particularly liquid assets and time deposits. Deviation from the steady state allocation is costly. These frictions are necessary for the model to pin down the balances of public bonds and time deposits at the

[16]In addition to traditional reserve requirements on the main types of bank deposits, the Central Bank of Brazil has often used the so called "additional reserve requirements", whose incidence base is the same as of standard required reserves. However, these additional reserve requirements can be remunerated differently from their standard counterparts or have a different form of compliance. For simplicity, we assume in our model that they have a homogeneous incidence rate upon the simple average of all deposits. Other types of reserve requirements have been eventually introduced in Brazil, such as requirements on marginal changes in deposits, among others, but we focused on the ones that have lasted longer.

[17]The motivation to introduce this exogenous source of funding is the following: In Brazil, banks that take savings deposits are required to extend a fraction $\tau_{H,S,t}$ of their savings deposits to finance low-priced housing. However, the estate-owned bank Caixa Economica Federal (CEF), which is the main player in the mortgage loan market in Brazil, also funds mortgage loans from resources deposited at the Severance Indemnity Fund (FGTS). We represent funding from this external source as $RR^{S,H}_{j,t}$, which is assumed to fill the gap between required and actual destination of savings deposits to housing loans

retail money fund's portfolio and play an important role in the dynamic responses of the model, particularly in financial variables. We let the data determine the power of each of these frictions by estimating cost-elasticity parameters.

Banks make no strategic decisions with respect to housing loans or interest rates on savings deposits, although their exposure to housing loans affects their capital adequacy requirements.Time deposit volume is chosen by the bank, subject to quadratic adjustment costs $\Gamma_T\left(\frac{D^T_{j,t}}{g_{\epsilon,t}\pi_{C,t}D^T_{j,t-1}}\varepsilon^{DT}_t\right)$, introduced in the model to reproduce the strong persistence in the data.

Banks accumulate capital from the net flow of resources from bank operations, $CF^b_{j,t}$, net of distributed dividends, $div^b_{j,t}$. Capital accumulation is subject to shocks ($\varepsilon^{bankcap}_t$) that can capture changes in market perception about bank capital quality or any other shocks that change the marked-to-market value of banks' net worth. The capital accumulation rule is:

$$Bankcap_{j,t} = Bankcap_{j,t-1} + CF^b_{j,t} - div^b_{j,t} + Bankcap_{j,t}\varepsilon^{bankcap}_t \tag{30}$$

Banks are constrained by a minimum capital requirement, γ^{BankK}_t. We model γ^{BankK}_t as an AR(1) with very high persistence implying that when the regulatory authority changes the capital requirement, agents hardly foresee the moment when another change will occur.

Compliance with the minimum requirement is assessed through the computation of the capital adequacy ratio $CAR^b_{j,t}$, which measures how much of risk-weighted assets can be backed up by the bank's net worth:

$$CAR^b_{j,t} = \frac{Bankcap_{j,t}}{\tau_{\chi 1,t}B^{C,b}_{B,j,t} + \tau_{\chi 2,t}B^b_{E,j,t} + \tau_{\chi 3,t}B^{H,b}_{B,j,t} + \tau_{\chi 4,t}B_{Bank,j,t} + \varepsilon^{CAR}_t} \tag{31}$$

where τ_χ is the risk weight factor modeled as an AR(1) and ε^{CAR}_t account for risk-weighted assets that are not explicitly included in the model but that exist in the actual computation of CAR's in Brazil. They are introduced as AR(1).

We introduce a precautionary capital buffer by letting banks face an appropriate cost function when deviating from the minimum capital requirement

$$\Gamma_{bankK}\left(\frac{CAR^b_{j,t}}{\gamma^{BankK}_t}\right) = \frac{\chi_{bankK,2}}{2}\left(\frac{CAR^b_{j,t}}{\gamma^{BankK}_t}\right)^2 + \chi_{bankK,1}\left(\frac{CAR^b_{j,t}}{\gamma^{BankK}_t}\right) + \chi_{bankK,0} \tag{32}$$

Let $Lb^b_{j,t}$ be bank j's total liabilities:

$$Lb^b_{j,t} = D^T_{j,t} + D^S_{j,t} + D^D_{j,t} + Bankcap_{j,t} \tag{33}$$

The one-period cash flow from bank j's operations is:

$$CF^b_{j,t} = \left(R_{E,j,t-1} - \tau_{B,E,t-1} - s^{adm,E}_{t-1}\right) B^b_{E,j,t-1} - B^b_{E,j,t} + \left(R^C_{B,j,t-1} - \tau_{B,B,t-1} - s^{adm,B}_{t-1}\right) B^{C,b}_{B,j,t-1} - B^{C,b}_{B,j,t} \tag{34}$$

$$+ R^H_{B,t-1} B^{H,b}_{B,j,t-1} - B^{H,b}_{B,j,t} + R_{t-1} B_{Bank,j,t-1} - B_{Bank,j,t} - R^T_{t-1} D^T_{j,t-1} + D^T_{j,t} - \Gamma_T \left(\frac{D^T_{j,t}}{g_{L,t} g_{A,t} \pi_{C,t} D^T_{j,t-1}} \varepsilon^{DT}_t\right) D^T_{j,t}$$

$$- R^S_{t-1} D^S_{j,t-1} + D^S_{j,t} - D^D_{j,t-1} + D^D_{j,t} + R^{RR,T}_{t-1} RR^T_{j,t-1} + R^{RR,S}_{t-1} RR^S_{j,t-1} + RR^D_{j,t-1} + R^{RR,add}_{t-1} RR^{add}_{j,t-1} - R^{S,H}_{t-1} RR^{S,H}_{j,t-1}$$

$$- RR^T_{j,t} - RR^S_{j,t} - RR^D_{j,t} - RR^{add}_{j,t} + RR^{S,H}_{j,t} + S_t P^{X^*}_t X_t \omega^X_t \left(R^{L,f}_{X,t} - R^*_t \phi^*_t\right) - \Gamma_{bankK} \left(\frac{CAR^b_{j,t}}{\gamma^{BankK}_t}\right) Bankcap_{j,t}$$

$$- \frac{\chi_{B,Bank}}{2} \left(\frac{B_{Bank,j,t}}{Lb^b_{j,t}} - \nu^{B,Bank}_t\right)^2 Lb^b_{j,t} - \frac{\chi_{d\_T}}{2} \left(\frac{D^T_{j,t}}{Lb^b_{j,t}} - \nu^{d\_T}_t\right)^2 Lb^b_{j,t} + \Pi^L_{j,t} + \Xi^b_{j,t}$$

where $\tau_{B,t}$ is a tax on bank credit transactions, s^{adm}_t are administrative costs, assumed to be proportional to bank credit volumes[18], R^{RR}_t are the interest rates paid by the monetary authority on bank reserves, $\nu^{B,Bank}_t$ and $\nu^{d\_T}_t$ are targets for liquidity and time deposits, modeled as AR(1), and $S_t P^{X^*}_t X_t \omega^X \left(R^{L,f}_{X,t} - 1\right)$ is the cash flow from working capital loans to exporters. $\Pi^L_{j,t}$ are lump sum transfers from lending branches to bank j and $\Xi^b_{j,t}$ is an insurance against differentials in individual banks' lending rates to lending branches and the aggregate lending rate. This allows for a representative bank.

Banks optimize an intertemporal plan of real dividend distribution $\left\{C_{Bank,j,t}\right\}$

$$E_0 \left\{\sum_{t\geq 0} \beta^t_{Bank} \left[\frac{1}{1-\sigma_B} \left(\frac{C_{Bank,j,t}}{\epsilon_{L,t}\epsilon_{A,t}}\right)^{1-\sigma_B}\right] \varepsilon^{\beta,Bank}_t\right\} \tag{35}$$

subject to (25) and its analogous representation for the demand for consumer loans, and to (27) to (34), where $\varepsilon^{\beta,Bank}_t$ is a shock affecting banks' intertemporal preferences. We assume that banks' intertemporal discount factor, β_{Bank}, is lower than that of banks' stockholders. This is a short-cut to risk-to-return considerations, so as to account for the fact that in practice bank shareholders demand a higher return on their portfolio than the risk-free opportunity cost R_t. Since $\beta_{Bank} < \beta_S$, in the balanced-growth path the shadow price of one additional unit of bank capital is higher than one unit of external funds.

[18] Administrative costs on borrowers' loans ($s^{adm,B}_t$) are AR(1). Administrative costs on entrepreneurs' loans ($s^{adm,E}_t$) are proportional to those of consumer loans.

2.8 The public sector

The public sector is composed of a monetary, a regulatory, and a fiscal authority. The monetary authority sets the base rate of the economy and manages international reserves. The regulatory authority sets: 1) ratios and remuneration of reserve requirements; 2) minimum capital requirement; 3) risk weight of banks' assets to compute capital adequacy ratios; 4) lending rates of housing loans; 5) required allocation of savings deposits on housing loans; and 6) interest rate on savings deposits. The fiscal authority purchases goods, issues public bonds, levies taxes, and makes lump sum transfers to households.

2.8.1 The monetary and regulatory authorities

The base interest rate is set by the monetary authority according to a forward looking rule:

$$R_t^4 = \left(R_{t-1}^4\right)^{\rho_R} \left[\left(E_t \frac{P_{C,t+4}}{P_{C,t}} \frac{1}{\overline{\pi}_t^4}\right)^{\gamma_\pi} \left(\frac{gdp_t}{gdp}\right)^{\gamma_Y} R^4\right]^{1-\rho} \upsilon_t^R \tag{36}$$

where unsubscribed R is the equilibrium nominal interest rate of the economy given the steady state inflation $\overline{\pi}$, $\overline{\pi}_t^4$ is a time-varying inflation target, and $gdp_t = \frac{GDP_t}{P_{C,t}\epsilon_t\epsilon_{A,t}}$ is the stationary level of nominal output, given by:

$$GDP_t = P_{C,t}C_t + P_{IH,t}I_{H,t} + P_{IK,t}I_{K,t} + P_{G,t}G_t + S_t P_t^{X^*} X_t - S_t P_t^{M,*} Z_t^M \tag{37}$$

Foreign exchange interventions with international reserves are an instrument used by the monetary authority to dampen fluctuations of the real exchange rate. The intervention rule is given by:

$$\ln\left(\frac{B_t^{FER}}{P_t^* \epsilon_{A,t}\epsilon_{L,t}} \frac{1}{\overline{b}^{FER}}\right) = -\gamma^{S,FER} \ln\left(\frac{S_t P_t^*}{P_{C,t}} \frac{1}{s}\right) + \varepsilon_t^{FER} \tag{38}$$

where ε_t^{FER} is a shock, s is the steady state value of the real exchange rate, and $\overline{b}^{FER}$ is the steady state amount (in the balanced growth path) of foreign exchange reserves.

The regulatory authority sets the interest rate on savings accounts according to (23) and its remaining policy instruments are modeled as AR(1) processes with high persistence.

2.8.2 The fiscal authority

The fiscal policy instrument is government consumption. It follows a standard rule with a term that stabilizes net public sector debt, defined as the sum of public sector liabilities (i.e., public bonds and banks' required reserves deposited at the central bank) net of public sector assets (i.e., international reserves):

$$\frac{G_t}{\epsilon_{A,t}\epsilon_{L,t}} = \left(1-\rho_g\right)\left[\overline{g} - \mu_{B,G}\left(netdebt_{t-1}\right)\right] + \rho_g\left(\frac{G_{t-1}}{\epsilon_{A,t-1}\epsilon_{L,t-1}}\right) + \upsilon_t^G \tag{39}$$

where $netdebt_{t-1} = \frac{B_{t-1}+RR^D_{t-1}+RR^T_{t-1}+RR^S_{t-1}+RR^{add}_{t-1}-S_{t-1}B^{FER}_{t-1}}{P_{C,t-1}\epsilon_{A,t-1}\epsilon_{L,t-1}} - \left(b + rr^D + rr^T + rr^S + rr^{add} - b^{FER}\right)$, lower-case variables are stationary and g is stationary government consumption.

The amount of public debt issued by the government meets the demand for public bonds from the retail money market fund, the foreign portfolio investors and the wholesale bank:

$$B_t = B_{Bank,t} + B_{F,t} + B_{FPI,t} \tag{40}$$

The joint public sector budget constraint can be expressed as:

$$\begin{aligned} & P_{G,t}G_t + TT_t - R^{S,H}_{t-1}RR^{S,H}_{t-1} + RR^D_{t-1} + R^{RR,T}_{t-1}RR^T_{t-1} \\ & + R^{RR,S}_{t-1}RR^S_{t-1} + R^{RR,add}_{t-1}RR^{add}_{t-1} + R_{t-1}B_{t-1} - S_tR^*_{t-1}\phi^{FER}_t B^{FER}_{t-1} \\ & = \tau_{W,t}\Pi^{LU}_t + \tau_{\Pi,t}\Pi_t + \tau_{W,t}W^N_t N_t + \tau_{C,t}P_{C,t}C_t + \tau_t^{R^{L,f}_X} S_t P^{X^*}_t X_t \omega^X_t \left(R^{L,f}_{X,t} - 1\right) \\ & + \tau_{B,E,t-1}B^b_{E,t-1} + \tau_{B,B,t-1}B^{C,b}_{B,t-1} \\ & + RR^D_t + RR^T_t + RR^S_t + RR^{add}_t - RR^{S,H}_t + B_t - S_tB^{FER}_t \end{aligned} \tag{41}$$

where TT_t are AR(1) lump-sum transfers distributed to savers and borrowers at a fixed proportion and tax rates $\tau_{C,t}$, $\tau_{W,t}$, $\tau_{\Pi,t}$, $\tau_t^{R^{L,f}_X}$ and $\tau_{B,B,t}$ are AR(1).

2.9 Market clearing, aggregation, and the resource constraint of the economy

Market clearing requires that the following supply and demand equalities hold:

$$\begin{aligned} & Y^M_t = Y^{C,M}_t + Y^{G,M}_t + Y^{IK,M}_t + Y^{IH,M}_t + Y^{X,M}_t \\ & Q^G_t = G_t \ , Q^{IH}_t = I_{H,t} \ , Q^{IK}_t = I_{K,t} \ , Q^C_t = C_t \\ & Q^X_t = \left(1 + \Gamma_X\left(X_t/\left(g_{L,t}g_{A,t}X_{t-1}\right); \varepsilon^X_t\right)\right)X_t \end{aligned} \tag{42}$$

We assume that the costs that do not deplete final goods, in addition to bank adjustment and monitoring costs, are transferred as a lump sum to savers:

$$TT_{\Gamma,t} = \omega_S TT_{\Gamma,S,t} \quad , TT_{bank,t} = \omega_S TT_{bank,S,t}$$

where $TT_{\Gamma,t} = \Gamma_u(u_t) P_{QQ,t} K_{t-1}$.

Hence, the resource constraint of the economy is

$$Y_t^D = Y_t^{C,D} + Y_t^{IH,D} + Y_t^{IK,D} + Y_t^{G,D} + Y_t^{X,D} \tag{43}$$

3 Taking the model to the data

3.1 The steady state and calibration

The model variables were stationarized by dividing real variables by both the technology trend $\epsilon_{A,t}$ and the populational trend $\epsilon_{L,t}$. Nominal variables were divided by both these trends and also by consumer price, P_t^C. We calibrated the steady state by fixing the main economic ratios, GDP growth and the base rate according to their average during the inflation targeting period (Table 1). The share of credit- and deposits-to-GDP, as well as lending rates and the markdown of savings rates, were calibrated according to the most recent observations in the data.

The ex-ante default ratios in the steady state were set at 3.72% for commercial loans and 7.45% for retail loans, in line with the average default rate from 2009 to 2013. We fixed steady state lending rates and stocks as shares of GDP, in addition to banking spread components. The variance of the idiosyncratic shock to entrepreneur's collateral value (σ_E) was set at 0.2 to calibrate capital depreciation at 2% per quarter. The variance of the idiosyncratic shock to borrower's committed income (σ_B) was fixed at 0.2 so as to find an intertemporal discount factor of 0.94 for the borrower. This parameter has an important effect on the model's impulse responses. Higher values drive the responses of consumer loans to monetary policy rate shocks to a very unlikely region. From these assumptions, all the remaining variables related to financial accelerators, including threshold levels of idiosyncratic shocks, LTV-ratios, and monitoring costs are obtained after evaluating the model at the steady state. The stock of capital is then determined from the entrepreneur's financial accelerator.

The capital adequacy ratio was fixed according to the actual average value for the Brazilian Financial System in most recent quarters. Required capital was set at 11%, the regulatory rate for Tier-1 capital since the implementation of Basel I in Brazil. Risk weights on bank assets were set at the actual values reported by Brazilian banks on portfolios with a direct correspondence to the ones included in the model (i.e., 1.5 for consumer loans, 1 for investment loans, 0.9 for housing loans, and 0 for government bonds). Given the capital adequacy ratio and banks' intertemporal discount factor, we calibrated the intercept and the slope parameter of the cost function associated with deviations from the capital requirement. Hence, the curvature parameter could be estimated.

We assumed a log-linear utility function for banks' optimization problem, and set banks' intertemporal discount factor at 0.98 to represent a 17.5% nominal return on banks' dividends. Reserve requirement ratios were fixed at their average effective ratios, which were calculated as the share of reserves deposited at the central bank to the volume of deposits in the economy. For time deposits, the average ratio was taken from December 2001, when this requirement was last reintroduced, to December 2012. Average additional reserves were calculated from the series starting in December 2002, when they were introduced. Requirements on savings accounts and demand deposits are averages of the entire inflation targeting period. The minimum required allocation of funds from savings deposits in housing loans was set according to actual compliance[19]. The tax on financial transactions was calibrated to match the share of indirect tax on banking spreads, as reported by the Central Bank of Brazil in its Banking Reports.

The participation of each group of households in labor, consumption goods and housing has important implications for the model dynamics. As a result, we attempted to find out-of-the-model relations that could help pin down this participation. We fixed the share of housing consumed by borrowers in the steady state as the ratio between the approximate value of collateral put up in housing loans and the model's implied value of real estate in the economy[20]. We also assumed that the government does not make transfers to borrowers[21].

From the banks' balance sheet credit- and required reserves-to-asset ratios, we obtained the steady state balance of public bonds in banks' total assets, and consequently pinned down banks' liquidity target. This allowed us to obtain the retail money fund's portfolio.

3.2 Estimation and empirical moments

The model was estimated using Brazilian data from the inflation targeting period (1999:Q3 to 2013:Q4). We used Bayesian techniques, after linearizing the model around the balanced-growth path. We observed all components of the Brazilian balance of payments, in addition to several series from the real economy and from the banking sector. The list of observables is detailed in the appendix.

For the choice of prior means, we used empirical evidence for Brazil, whenever available, or drew from the related literature. We tried to compensate the arbitrariness in the choice of some priors by setting large confidence intervals. Table 2 shows the results of the estimation,

[19]The actual compliance does not include compliance in the form of securitized debt (FCVS) or other instruments that alleviate the burden of the requirement.

[20]Since the LTV ratio in housing loans was 0.73 in 2013, we assumed that the value of the collateral in this market was twice the stock of loans divided by the LTV ratio.

[21]We fixed borrowers' participation in the labor market according to the actual value of debt commitment in Brazil (50% of annual labor income).

including prior and posterior moments[22].

The variance decomposition (Table 3) shows that private consumption, government consumption and capital investment are strongly impacted by shocks related to the open economy. Shocks to the share of households' income committed to unsecured loans also have some power to explain the variance of output and government spending. The variance decomposition also suggests an important participation of international shocks to commercial loans. Shocks to the LTV ratio, productivity and bank capital preferences also drive the variance of commercial loans. Unsecured consumer loans are importantly impacted not only by shocks to debt commitment but also by leverage in housing loans. This indicates that the seniority of housing loans over the other types of consumer credit really poses a restriction on the latter.

4 Policy interaction

MaP policies are concerned with financial stability. However, depending on factors such as the mismatch of business and financial cycles, they can have pose important challenges for other economic policies. Carvalho and Castro (2015b) show, for instance, that expansionist MaP implemented during a contractionist monetary policy cycle had undesirable impact on inflation expectations in Brazil.

On the other hand, economic policies can challenge financial stability. CGFS (2016) notes, for instance, that the tax treatment of debt can have an important role in giving stimulus to debt funding to the detriment of equity.

In Brazil, loose fiscal policy, translated in increased primary expenditures and accelerated credit extension by public banks, was the major driver of the fast credit growth seen after 2011. Loose fiscal policies can also challenge financial stability through its impact on market perception of public solvency, with possible spillovers to the banking activity.

Given the importance of fiscal policy to the recent financial cycle in Brazil and in the world in general, we use our model to assess the optimal behavior of fiscal policy in this context of an open economy with financial frictions and macroprudential regulatory constraints on banking activities. We apply Schmitt-Grohé and Uribe (2007)'s method to find optimal combinations of simple and implementable monetary, macroprudential and fiscal policy rules that can react to the business and/or the financial cycle.

For each of the exercises we perform, the optimal policies are obtained from the minimization of a loss function comprising the volatility of output, inflation, policy interest

[22] We used Dynare to conduct the linear approximation of the model to the calibrated steady state and to perform all estimation routines. We ran 2 chains of 700,000 draws of the Metropolis Hastings to estimate the posterior.

rate and total credit. The weights of output, inflation and interest rate in this cost function are obtained in such a way that the minimization of a cost function comprising only these three variables would result in an optimal monetary policy rule just equal to the one estimated in the benchmark model, using the model structure that exactly matches the benchmark. The weight attributed to credit is arbitrary.

Optimization takes into account all sources of exogenous shocks in the model, an approach that is also adopted by Lambertini et al. (2013). Since the model is estimated, the influence of each shock in the optimal solution will rely on realistic values of the stochastic processes governing the shocks. Although several studies address the optimal responses to a few selected shocks, given the fact that in practice a lot of judgment is involved in assessing real-time sources of shocks driving economic variables, it is equally important to find an optimal rule that could be transparent to and predictable by the public, especially in countries where coordination of market expectations is challenging.

We gradually introduce cyclical responses in the policy rules so as to understand the role each one has on the optimal solution. Table 4 shows the result of optimal simple implementable policy rules, comparing the social losses obtained in the optimization routine[23] with the loss predicted in the benchmark model, where neither MaP nor fiscal policies react to the either the business or the financial cycle and monetary policy follows its estimated rule.

The results suggest that there are substantial welfare gains from implementing optimal policies. Cyclical fiscal policy only results in substantial welfare gain if the macroprudential policy countercyclically reacts to the financial cycle. In this case, the optimal fiscal policy will be countercyclical in the business cycle and slightly procyclical in the credit cycle, but the anticyclical nature of the optimal response dominates[24] The best policy combination, within the set of implementable policies, predicts a stronger countercyclical reaction of monetary policy in addition to a stronger response to inflation.

Since fiscal expansion in Brazil after 2011 had the purpose of deterring the impact of international shocks on the economy, and particularly on specific credit segments, we use our model to apply international shocks and compare the dynamic responses under optimal simple policy rules and the benchmark model, where policies are not cyclical with respect to the financial cycle. Figures 3, 4,and 5 plot the results of this exercise, with shocks to FDI, world output, export prices and foreign interest rates, respectively.

The dynamic responses show the stabilizing power of optimal fiscal policy to these

[23]We use Dynare's OSR routine, but constrain some parameters to reasonable values. If the routine is unconstrained, the reaction of monetary policy to inflation or the reaction of the countercyclical capital requirement to credit can reach very high values which are very unlikely to be ever implemented in practice. This procedure of constraining the support of the maximizing variables is also used in Schmitt-Grohé and Uribe (2007).

[24]We believe this slight procyclicality in the financial cycle comes from a marginal adjustment of the optimization rule.

sources of imbalances, when fiscal policy is allowed to react to business and financial cycles. The exercises also show that since each type of shock has a particular transmission to the economy, and more specifically to the credit market, the policy response will depend on the source of the shock. This is a familiar concept for monetary policy in inflation targeting regimes, that it is optimal to react to certain shocks but it is not optimal to react to the first round effect of others. We show that this is also true for fiscal and macroprudential policies that work together towards the objective of minimizing a particular loss function. For these policies (fiscal and macroprudential), it is essential to identify the source of disturbance to properly calibrate the direction and intensity of the policy response.

When fiscal policy optimally responds to the financial cycle and the business cycle, it impacts credit and output through a crowding-out impact on capital investment. In other words, by increasing public consumption, the government crowds out private capital investment. By reducing capital investment, there is less demand for commercial loans, and credit falls. Other consequences end up affecting output, and that presses inflation and monetary policy responds accordingly.

5 Conclusion

This paper uses a small open economy DSGE model with matter-of-fact financial frictions to assess the optimal behavior of fiscal policy in face of international shocks that have played an important role in the recent Brazilian history. First, we obtain an optimal combination of monetary, macroprudential and fiscal policy, allowing all of them to respond to the financial cycle and/or the business cycle.

The results suggest that the gains from implementing a fiscal policy that reacts to both the financial and business cycle are minor if macroprudential policy is not allowed to react to the financial cycle. In all cases, optimal fiscal policy should be anticyclical in the business cycle and slightly procyclical in the credit cycle, but the anticyclical nature of the optimal response dominates.

The best policy combination predicts a stronger countercyclical reaction of monetary policy together with a stronger response to inflation. The optimal countercyclical capital buffer shows a very aggressive response to the credit gap.

With respect to the dynamic responses of optimal policies under specific shocks, since each type of shock has a particular transmission to the economy, and more specifically to the credit market, the optimal dynamic response depends on the source of the shock. We find that when fiscal policy optimally responds to the financial cycle and the business cycle, it impacts credit and output through this crowding-out impact on capital investment. In other words, by increasing public consumption, the government crowds out private capital investment. By reducing capital investment, there is less demand for commercial loans, and credit falls. There are other consequences that end up affecting output, with subsequent impacts on inflation and on monetary policy responses.

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6 Appendix

The observable series used in the estimation of the model were:

Real sector observables: National accounts (private consumption, government consumption, gross fixed capital formation); IBGE's Civil construction index, unemployment, nominal wages, working age population trend, GDP HP cycle, FGV capacity utilization. To match the unemployment series with the employment variable, we used:

$$\left(1+\beta^{S}\right)\mathrm{E}_t = \beta^{S}\mathrm{E}_{t+1} + \mathrm{E}_{t-1} + \left(1-\beta^{S}\xi_{\mathrm{E}}\right)\frac{(1-\xi_{\mathrm{E}})}{\xi_{\mathrm{E}}}\left(N_t - \mathrm{E}_t\right)$$

where

$$\Delta w_t^{obs} = \frac{W_t/P_t^C\epsilon_t}{W_{t-1}/P_{t-1}^C\epsilon_{t-1}}/\Delta n$$

and Δn is the steady state growth of the employed population.

Balance of payments and the rest of the world: National accounts (exports and imports); FDI; FPI; unilateral transfers; international reserves stock and flows; BRL/USD exchange rate; JP Morgan's EMBI Brazil index; CBOE Market Volatility Index; Fed Funds rate; US CPI; trade partners GDP growth.

Inflation and monetary policy rate: IPCA inflation; inflation target; Funcex import and export price indexes; Selic rate.

Banking sector: Brazilian banks core capital; capital adequacy ratio; balances of commercial, consumer, housing and export loans; lending rate on export loans; lending interest spread on commercial and consumer loans; delinquency rate of commercial and consumer loans; balances of time, demand and savings deposits; markdown on savings rates; required reserve ratio on time, demand, savings, and additional deposits; administrative costs; indirect taxes.

Table 1: Steady state and calibrated parameters

	Description	Value
	Steady State Values	
g_A	Productivity growth (% p.a.)	1.98
g_L	Labor force growth (% p.a.)	1.21
c	Consumption (% of GDP)	60.12
i^H	Housing investment (% of GDP)	3.00
i^K	Capital investment (% of GDP)	14.8
g	Government consumption (% of GDP)	20.3
x	Exports (% of GDP)	13.9
m	Imports (% of GDP)	12.5
$w.N$	Labor income (% of GDP)	55.0
π_C	CPI (% p.a.)	4.50
R	NIR (% p.a.)	10.20
R^S	Savings IR (% p.a.)	7.22
R^T	Time deposits IR (% p.a.)	10.20
$R^{L,X}$	Export loans IR (% p.a.)	11.50
$R^{RR,D}$	IR demand deposits RR (% p.a.)	0.00
$R^{RR,S}$	IR savings deposits RR (% p.a.)	7.22
$R^{RR,T\&adic}$	IR time and additional dep RR (% p.a.)	10.20
D^D	Demand deposits (% annual GDP)	3.4
D^T	Time deposits (% annual GDP)	20.1
D^S	Savings deposits (% annual GDP)	11.2
$B^{B,C}$	Retail loans (% of annual GDP)	14.9
$B^{B,H}$	Housing loans (% of annual GDP)	6.2
$B^{B,E}$	Commercial loans (% of annual GDP)	12.6
$bankcap$	Bank capital (% of annual GDP)	12.9
CAR	CAR	16.9
$\gamma^{bankcap}$	CR ratio	11.0
$R^{L,B,c}$	IR retail loans (% p.a.)	39.0
$R^{L,B,h}$	IR housing loans (% p.a.)	8.2
$R^{L,E}$	IR commercial loans (% p.a.)	25.6
σ_B	STD wage income idiosyncratic shock	0.200
σ_E	STD entrepreneurs' idiosyncratic shock	0.595
	Borrowers default probability (%)	7.45
	Entrepreneurs' default probability (%)	3.72

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Table 1 – (cont.)

	Description	Value
τ^C	Consumption tax (%)	16.2
τ^W	Wage tax (%)	15.0
τ^π	Profits tax (%)	15.0
$\tau^{R_X^{L,f}}$	Tax on export loans IR (%)	3.0
$\tau^{RR,T}$	RR ratio time deposits (%)	10.7
$\tau^{RR,S}$	RR ratio savings deposits (%)	22.0
$\tau^{RR,D}$	RR ratio demand deposits (%)	49.2
τ^{adic}	Additional RR ratio (%)	7.5
g^{F^*}	World output growth (% p.a.)	3.2
R^*	Foreign IR (% p.a.)	3.6
π^*	Foreign CPI (% p.a.)	2.4
$risk$	Foreign risk (VIX)	11.0
ω^X	Financed fraction of exports (%)	66.86
b_{FER}	Foreign Exchange Reserves (in % of annual GDP)	12.50
b_{FPI}	FPI Stock (in % of annual GDP)	9.15
b^f	Foreign debt (in % of annual GDP)	17.75
b	Government debt (in % of annual GDP)	53.81
ULT	Unilateral transfers (in % of GDP)	0.16
	Calibrated Parameters	
$\omega_S \omega_B$	Relative size of agents	1.0
η_H	EoS housing and consumption	1.001
$\sigma_\varkappa$	Inverse intertemporal EoS	1
$\sigma_S \sigma_D$	IR elast. of savings and demand deposits	100
$h_B/(h_B + h_S)$	Borrowers' share of housing stock (%)	40.4
$N_B/(N_B + N_S)$	Borrowers' share in total labor force (%)	76.8
$LTV_{B,H}$	Borrowers' LTV ratio housing loans (%)	73.0
DTI_B	Borrowers' DTI (%)	50.0
δ_H	Housing depreciation (% p.a.)	4.0
ν_G	Domestic bias government goods	0.99
ν_{IK}	Domestic bias capital goods	0.75
ν_{IH}	Domestic bias housing goods	0.99
ν_X	Domestic bias export goods	0.90
$\gamma_{YMC}\gamma_{YMG}$	Import adjust. cost private and public cons. goods	0.76
$\gamma_{YMIH}\gamma_{YMIK}$	Import adjust. cost capital and housing goods	1.97
γ_{YMX}	Adjust. costs of imports for export goods	3.12

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Table 1 – (cont.)

	Description	Value
μ_W, μ_D	Wage and domestic price markup	1.1
μ_M	Imported goods price markup	1.0
$\rho_{B,H}$	Housing loans persistence	0.95
β_{bank}	Bank discount factor	0.975
σ_{bank}	Bank's inverse elasticity of intert. substitution	1.00
$\tau_{\chi 1}$	RWF retail loans	1.50
$\tau_{\chi 2}$	RWF commercial loans	1.00
$\tau_{\chi 3}$	RWF housing loans	0.90
$\tau_{\chi 4}$	RWF public bonds	0.00
$\rho_{\gamma bankcap}\rho_{\tau RR}$	Persist. of capital req. and RR ratios	0.999
ρ_{τ_χ}	Persist. of RWF	0.990
$\kappa^{\phi^*}_{B^{FPI}}$	FPI coeff. in risk premium equation	1.0
γ_{FDI}	Mean revertion in FDI equation	0.01
ρ_{gL}	Persistence of labor force growth	0.9961

Table 2: Estimated Parameters and Shocks

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
	Preference and Technology						
$\bar{h}_{C,S}$	Savers' Consumption Habit persistence	Beta	0.80	0.10	0.876	0.837	0.916
$\bar{h}_{C,B}$	Borrowers' Consumption Habit persistence	Beta	0.80	0.10	0.750	0.604	0.902
$\bar{h}_{N,S}$	Savers' Labor Habit persistence	Beta	0.50	0.25	0.136	0.002	0.271
$\bar{h}_{N,B}$	Borrowers' Labor Habit persistence	Beta	0.50	0.25	0.823	0.754	0.894
σ_L	Inverse Frisch elasticity of labor	Gamma	1.00	0.25	0.721	0.359	1.084
$\phi_{u,2}$	Capital utilization cost	Gamma	0.20	0.15	0.142	0.076	0.204
ξ_E	Adjustment cost of employment to hours	Beta	0.75	0.10	0.700	0.656	0.744
ϕ_K	Adjustment cost of capital investment	Gamma	3.00	1.00	2.664	1.261	4.006
ϕ_H	Adjustment cost of housing investment	Gamma	10.00	1.00	10.638	8.997	12.284
μ_C	EoS between domesti and imported goods	Gamma	1.00	0.99	1.324	0.806	1.833
γ_X	Adjustment cost of Exported goods	Gamma	35.00	10.00	35.730	21.543	49.250
	Nominal Rigidities						
ξ_D	Calvo - domestic goods price	Beta	0.80	0.03	0.865	0.829	0.902
ξ_W	Calvo - wages	Beta	0.80	0.10	0.898	0.873	0.924
ξ_M	Calvo - imported goods price	Beta	0.80	0.10	0.700	0.610	0.784
γ_D	Domestic Price indexation	Beta	0.50	0.20	0.139	0.021	0.248
γ_W	Wage indexation	Beta	0.50	0.20	0.063	0.017	0.106
γ_M	Imported goods price indexation	Beta	0.50	0.20	0.490	0.135	0.830
ξ^{R_E}	Calvo - investment credit interest rate	Beta	0.50	0.25	0.136	0.002	0.269
$\xi^{R_{B,c}}$	Calvo - consumption credit interest rate	Beta	0.50	0.25	0.303	0.027	0.547
	Policy rules						
ρ_R	Interest rate smoothing	Beta	0.70	0.10	0.825	0.791	0.862
γ_π	Taylor rule Inflation coefficient	Gamma	2.00	0.05	1.966	1.888	2.046
ρ_g	Government spending smoothing	Beta	0.80	0.10	0.829	0.729	0.938
	Financial Frictions						
$\chi_{bankK,2}$	Capital buffer deviation cost	Gamma	0.10	0.05	0.092	0.062	0.121
$\chi_{b_{bank}}$	Liquidity buffer deviation cost	Gamma	0.10	0.05	0.049	0.034	0.065
$\chi_{d,T}$	Time deposits to loans deviation cost	Gamma	0.10	0.05	0.119	0.064	0.174
ϕ_T	Adjustment cost of time deposits	Gamma	0.20	0.10	0.332	0.161	0.498
	Risk Premium and External Financial Flows						
$\kappa^{\phi^*}_{bf}$	Risk Premium debt coefficient	Gamma	0.05	0.00	0.050	0.048	0.051
$\kappa^{\phi^*}_{risk}$	Risk Premium risk coefficient	Gamma	0.01	0.00	0.002	0.001	0.004
$\gamma_{FER,S}$	FER REER coefficient	Normal	0.00	1.00	1.293	1.025	1.545
$\gamma_{FPI,R}$	FPI Interest Rate coefficient	Normal	0.00	2.00	0.703	-0.817	2.159
ϕ_{F,B^*}	UIP Foreign Debt coefficient	Gamma	1.00	0.90	0.216	0.126	0.301
	Autoregressive shocks						
$\rho_{\varepsilon^{I_K}}$	Adjustment cost of capital investment	Beta	0.50	0.20	0.250	0.105	0.396
$\rho_{\varepsilon^{I_H}}$	Adjustment cost of housing investment	Beta	0.50	0.20	0.546	0.269	0.796
$\rho_{\varepsilon^{B,S}}$	Savers' preference	Beta	0.50	0.25	0.189	0.030	0.327
$\rho_{\varepsilon^{B,B}}$	Borrowers' preference	Beta	0.50	0.25	0.997	0.993	1.000
ρ_{ε^A}	Temporary technology	Beta	0.50	0.20	0.874	0.801	0.949
ρ_{ε^u}	Capital utilization	Beta	0.50	0.10	0.719	0.620	0.813
$\rho_{\epsilon,X}$	Exporters adjust. cost	Beta	0.50	0.25	0.074	0.001	0.145
$\rho_{\epsilon,M}$	Importers adjust. cost	Beta	0.50	0.25	0.238	0.013	0.441
ρ_{μ_D}	Domestic Goods Price markup	Beta	0.50	0.20	0.542	0.297	0.797
ρ_{μ_W}	Wage markup	Beta	0.50	0.20	0.111	0.018	0.202
ρ_{μ_M}	Imported Goods Price markup	Beta	0.50	0.20	0.568	0.240	0.888
ρ_ϵ	Permanent technology	Beta	0.50	0.28	0.015	0.000	0.034
$\rho_{\bar{\pi}}$	Inflation target	Beta	0.70	0.10	0.797	0.701	0.896
ρ_{ϕ^*}	Risk Premium	Beta	0.50	0.28	0.812	0.679	0.954

Continued on next page

Table 2 – (cont.)

	Description	Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
$\rho_{\epsilon UIP}$	UIP shock	Beta	0.50	0.25	0.861	0.819	0.904
	Autoregressive financial shocks						
$\rho_{\varepsilon^{S,S}}$	Preference for savings deposits	Beta	0.90	0.05	0.974	0.958	0.991
$\rho_{\mu^R_E}$	Markup on commercial loans	Beta	0.50	0.20	0.606	0.436	0.773
$\rho_{\mu^R_{B,C}}$	Markup on retail loans	Beta	0.50	0.20	0.916	0.857	0.977
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.25	0.049	0.000	0.103
ρ_{σ_B}	Risk distrib. s.d. in retail loans	Beta	0.50	0.20	0.637	0.329	0.940
ρ_{σ_E}	Risk distrib. s.d. in commercial loans	Beta	0.50	0.20	0.975	0.958	0.995
$\rho_{d,D}$	Preference for demand deposits	Beta	0.90	0.05	0.921	0.870	0.972
$\rho_{d,T}$	Adjustment cost in time deposits	Beta	0.50	0.25	0.684	0.539	0.834
$\rho_{\gamma_{B,H}}$	Debt-to-Income in housing loans	Beta	0.90	0.05	0.737	0.615	0.857
ρ_{γ_E}	LTV in commercial loans	Beta	0.90	0.05	0.911	0.842	0.983
$\rho_{\gamma_{B,C}}$	Debt-to-income in retail loans	Beta	0.90	0.05	0.988	0.980	0.997
$\rho_{IB^{rem}}$	Exogenous component in CAR	Beta	0.90	0.05	0.942	0.905	0.979
ρ_{R_S}	Savings Deposits interest rate	Beta	0.50	0.25	0.684	0.532	0.841
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.25	0.049	0.000	0.103
$\rho_{\tau_{B,E}}$	Credit taxes	Beta	0.90	0.05	0.941	0.903	0.981
$\rho_{s_{adm,B}}$	Bank admin. costs	Beta	0.90	0.05	0.928	0.882	0.976
ρ_{FER}	Foreign Exchange Reserves	Beta	0.50	0.25	0.956	0.920	0.994
ρ_{FPI}	Foreign Portfolio Investment	Beta	0.50	0.25	0.971	0.945	0.999
ρ_{FDI}	Foreign Direct Investment	Beta	0.50	0.25	0.740	0.633	0.852
	Traditional shocks						
ϵ^R	Monetary policy	Inv. Gamma	0.02	Inf	0.014	0.011	0.016
ϵ^G	Government spending	Inv. Gamma	0.01	Inf	0.007	0.006	0.008
ϵ_{I_K}	Capital invest. adjustment cost	Inv. Gamma	0.05	Inf	0.119	0.097	0.141
ϵ_{I_H}	Housing invest. adjustment cost	Inv. Gamma	0.05	Inf	0.090	0.064	0.114
ϵ_{β_S}	Savers' preference	Inv. Gamma	0.05	Inf	0.267	0.179	0.355
ϵ_{β_B}	Borrowers' preference	Inv. Gamma	0.05	Inf	1.661	0.646	2.669
ϵ^A	Temporary technology	Inv. Gamma	0.02	Inf	0.023	0.019	0.028
ϵ_u	Capital utilisation	Inv. Gamma	0.02	Inf	0.016	0.013	0.019
ϵ_X	Exporters adjust. cost	Inv. Gamma	0.10	Inf	0.061	0.052	0.071
ϵ_M	Importers adjust. cost	Inv. Gamma	0.10	Inf	0.081	0.061	0.100
ϵ_{μ_D}	Domestic Goods price markup	Inv. Gamma	0.10	Inf	0.064	0.045	0.082
ϵ_{μ_W}	Wage markup	Inv. Gamma	0.10	Inf	0.129	0.090	0.164
ϵ_{μ_M}	Importers markup	Inv. Gamma	0.10	Inf	0.055	0.028	0.081
ϵ^Z	Permanent technology	Inv. Gamma	0.10	Inf	0.044	0.037	0.051
ϵ_{g_L}	Labor force growth rate	Inv. Gamma	0.00	Inf	0.000	0.000	0.000
$\epsilon_{\overline{\pi}}$	Inflation target	Inv. Gamma	0.01	Inf	0.005	0.004	0.006
ϵ_{ϕ^*}	Risk Premium	Inv. Gamma	0.01	Inf	0.004	0.003	0.004
ϵ_{UIP}	UIP shock	Inv. Gamma	0.10	Inf	0.017	0.014	0.020
$\epsilon_{Y,me}$	GDP share meas. error	Inv. Gamma	0.01	Inf	0.003	0.002	0.003
ϵ_{risk}	Foreign Risk aversion index	Inv. Gamma	1.00	Inf	0.601	0.514	0.689
ϵ_{π^*}	Foreign inflation	Inv. Gamma	0.02	Inf	0.008	0.006	0.009
$\epsilon_{P^{M^*}}$	Foreign imported goods price	Inv. Gamma	0.05	Inf	0.030	0.025	0.034
$\epsilon_{\phi^{R^L_X}}$	Exported goods IR markup	Inv. Gamma	0.01	Inf	0.004	0.003	0.004
ϵ_{ω^X}	Share of Financed Exports	Inv. Gamma	0.15	Inf	0.072	0.061	0.083
ϵ_{ZF^*}	World demand	Inv. Gamma	0.01	Inf	0.005	0.004	0.005
	Financial shocks						
$\epsilon_{S,S}$	Preference for savings deposits	Inv. Gamma	0.02	Inf	0.023	0.019	0.026
$\epsilon_{\mu^{R_E}}$	Markup on commercial loans	Inv. Gamma	0.02	Inf	0.004	0.003	0.004
$\epsilon_{\mu^{R_{B,C}}}$	Markup on retail loans	Inv. Gamma	0.02	Inf	0.005	0.004	0.006
ϵ_{bankK}	Dividend distribution	Inv. Gamma	0.02	Inf	0.090	0.076	0.105

Continued on next page

Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
ϵ_{σ_B}	Risk shock to retail loans	Inv. Gamma	0.10	Inf	0.049	0.028	0.068
ϵ_{σ_E}	Risk shock to commercial loans	Inv. Gamma	0.10	Inf	0.035	0.027	0.042
$\epsilon_{D,S}$	Preference for demand deposits	Inv. Gamma	0.05	Inf	0.037	0.031	0.042
$\epsilon_{d,T}$	Time deposit adjustment cost	Inv. Gamma	0.05	Inf	0.042	0.029	0.055
$\epsilon_{\gamma_{B,H}}$	Housing debt-to-income	Inv. Gamma	0.05	Inf	1.241	1.048	1.431
ϵ_{γ_E}	Collateral in commercial loans	Inv. Gamma	0.05	Inf	0.023	0.012	0.034
$\epsilon_{\gamma_{B,C}}$	Retail debt-to-income	Inv. Gamma	0.05	Inf	0.045	0.037	0.053
$\epsilon_{IB,rem}$	Exogenous component in CAR	Inv. Gamma	0.10	Inf	0.117	0.098	0.136
ϵ_{R_S}	Savings Deposits interest rate	Inv. Gamma	0.01	Inf	0.001	0.001	0.002
$\epsilon_{\tau_{B,E}}$	Credit taxes	Inv. Gamma	0.00	Inf	0.000	0.000	0.000
$\epsilon_{S_{adm,B}}$	Bank admin. costs	Inv. Gamma	0.00	Inf	0.001	0.001	0.002
ϵ_{FER}	Foreign Exchange Reserves	Inv. Gamma	0.10	Inf	0.087	0.074	0.100
$\epsilon_{FER,me}$	FER	Inv. Gamma	0.20	Inf	0.094	0.080	0.107
ϵ_{FDI}	Foreign Direct Investment	Inv. Gamma	0.02	Inf	0.012	0.010	0.014
ϵ_{FPI}	Foreign Portfolio Investment	Inv. Gamma	0.10	Inf	0.074	0.062	0.085
ϵ_{ULT}	Unilateral Transfers	Inv. Gamma	0.50	Inf	0.340	0.287	0.390

Table 3: Variance Decomposition of Selected Variables

Shock	Output Gap	Inflation	Interest Rate	Private Consumption	Government Consumption	Capital Investment
$\epsilon_{\gamma_{B,C}}$	7.48	1.02	1.5	3.62	8.5	1.27
$\epsilon_{\gamma_{B,H}}$	0.31	0.25	0.62	0.15	0.77	0.58
ϵ_{σ_E}	0.21	0.02	0.03	0.03	0.02	0.87
ϵ_{bankK}	0.66	0.05	0.08	0.22	0.16	1.08
Other financial shocks	0.36	0.07	0.17	0.28	0.15	0.75
ϵ_{FDI}	0.38	1.41	2.47	1.06	0.75	0.25
ϵ_{PM^*}	3.13	6.23	6.45	7.77	3.91	10.36
ϵ_{R^*}	0.05	0.2	0.37	0.08	1.49	0.04
ϵ_{UIP}	0.69	5.08	12.57	2.42	2.34	1.75
ϵ_X	4.84	0.37	0.73	1.64	0.44	4.39
$\epsilon_{Z_X^*}$	14.62	6.22	6.13	26.3	14.81	23.93
ϵ_{ZF^*}	0.14	1.35	1.37	0.96	0.36	1.38
Other foreign sector shocks	0.93	0.99	1.34	0.24	0.51	0.44
ϵ^G	2.39	0.38	0.9	0.15	15.13	0.34
ϵ^R	1.57	0.79	9.19	0.82	2.48	1.1
$\epsilon_{\overline{\pi}}$	1.15	0.87	0.41	0.56	0.98	0.66
ϵ^A	1.04	21.09	22.81	1.31	1.3	1.41
ϵ^Z	14.26	3.23	4.02	21.3	5.28	2.24
ϵ_{β_B}	19.94	1.88	2.17	10.7	29.75	2.22
ϵ_{β_S}	12.85	5.07	11.13	16.38	0.06	1.98
ϵ_{μ_D}	1.89	34.84	3.41	0.64	0.14	2.58
ϵ_{μ_M}	0.18	1.54	0.21	0.06	0.11	0.1
ϵ_{μ_W}	0.08	2.68	3.05	0.11	0.15	0.21
ϵ_{g_L}	2.72	1.37	3.44	1.53	5.7	0.04
ϵ_{I_H}	1.2	0.31	0.87	0.15	0.01	0.19
ϵ_{I_K}	6.43	0.36	0.29	0.71	0.61	39.06
ϵ_u	0.08	0.16	0.17	0.01	0.01	0.22
Measurement errors	0.41	2.15	4.08	0.77	4.06	0.55

Shock	Commercial Loans	Retail Loans	Housing Loans	Commercial Lending Rate	Retail Lending Rate	Housing Lending Rate
$\epsilon_{\gamma_{B,C}}$	4.19	45.54	0.16	2.49	3.82	1.24
$\epsilon_{\gamma_{B,H}}$	2.04	22.22	72.11	0.23	21.17	0.51
$\epsilon_{\mu^{R_{B,C}}}$	2.5	0.16	0.03	0.17	14.89	0.12
$\epsilon_{\mu^{R_E}}$	0.18	0	0	10.24	0.02	0
ϵ_{σ_E}	17.06	0	0	10.02	0.11	0.02
ϵ_{bankK}	6.85	0.07	0.02	0.95	2.68	0.06
ϵ_{R_S}	0	0	0	0	0	17.15
$\epsilon_{s_{adm,B}}$	0.79	0.02	0.01	0.4	1.19	0.02
Other financial shocks	1.76	0.06	0	1.19	1.62	0.01
ϵ_{FDI}	0.86	0.02	0.02	0.85	0.98	2.05
ϵ_{PM^*}	5.29	0.12	0.48	2.88	2.73	5.34
ϵ_{UIP}	3.45	0.09	0.19	5.29	4.76	10.41
$\epsilon_{Z_X^*}$	8.49	0.6	1.12	4.55	2.81	5.08
ϵ_{ZF^*}	0.87	0.01	0.06	0.5	0.68	1.14
Other foreign shocks	1.48	0.1	0.13	1.3	1.33	2.03
ϵ^G	0.4	0.02	0	0.08	0.18	0.75
ϵ^R	0.59	0.03	0.02	7.41	4.2	7.62
$\epsilon_{\overline{\pi}}$	0.29	0.04	0	0.13	0.09	0.34
ϵ^A	8.46	0.16	0.1	5	6.56	18.9
ϵ^Z	15.42	0.14	3.68	23.09	4.35	3.33
ϵ_{β_B}	1.65	30.04	21	2.11	17.36	1.8
ϵ_{β_S}	3.22	0.17	0.02	1.91	2.29	9.22
ϵ_{μ_D}	0.97	0.17	0.27	2.47	1.49	2.83
ϵ_{μ_W}	0.95	0.06	0	0.71	0.65	2.52
ϵ_{g_L}	2.7	0	0.43	3.95	1.69	2.85
ϵ_{I_K}	7.57	0.04	0.06	10.2	0.25	0.24
Other real economy shocks	0.49	0.06	0.02	0.64	0.46	1.04
Measurement errors	1.5	0.02	0.05	1.24	1.64	3.38

Table 4: Optimal Simple Rules

Policy Reaction Parameter	Definition	Rule A	Rule B	Rule C	Rule D	Rule E
γ_π	MoP reaction to inflation	1.963	1.976	3.80	1.961*	3*
γ_y	MoP reaction to output	0.185	0.185*	0.185*	0.185*	0.522
γ_{cred}	MoP reaction to credit		-0.10	0.338		-0.356
$\omega_{BankK,cc}$	MaP reaction to credit		0.011	6.106	14.932	15*
$\omega_{G,y}$	Fiscal reaction to output	-0.003	-0.03		-0.096	-0.082
$\omega_{G,cred}$	Fiscal reaction to credit	-0.023			-0.065	-0.055
Objective function	Benchmark = 0.00251	0.00245	0.00237	0.00159	0.00140	0.00126

* Fixed parameter

Cyclical rules:

1) Monetary Policy

$$R_t^4 = \left(R_{t-1}^4\right)^{\rho_R} \left[\left(E_t \frac{P_{C,t+4}}{P_{C,t}} \frac{1}{\overline{\pi}_t^4}\right)^{\gamma_\pi} \left(\frac{gdp_t}{gdp}\right)^{\gamma_Y} R^4 \left(creditgap_t\right)^{\gamma}_{cred}\right]^{1-\rho} \upsilon_t^R$$

where $creditgap_t = \frac{b_{E,t}+b_{B,c,t}+b_{B,H,t}}{b_E+b_{B,c}+b_{B,H}}$.

2) Fiscal Policy

$$\frac{G_t}{\epsilon_{A,t}\epsilon_{L,t}} = \left(1-\rho_g\right)\left[\overline{g} - \mu_{B,G}\left(netdebt_{t-1}\right)\right] - \omega_{G,cred} ln\left(creditgap_t\right) + \omega_{G,y} ln\left(\frac{gdp_t}{gdp}\right) + \rho_g\left(\frac{G_{t-1}}{\epsilon_{A,t-1}\epsilon_{L,t-1}}\right) + \upsilon_t^G$$

where $netdebt_{t-1} = \frac{B_{t-1}+RR_{t-1}^D+RR_{t-1}^T+RR_{t-1}^S+RR_{t-1}^{add}-S_{t-1}B_{t-1}^{FER}}{P_{C,t-1}\epsilon_{A,t-1}\epsilon_{L,t-1}} - \left(b + rr^D + rr^T + rr^S + rr^{add} - b^{FER}\right)$.

3) Countercyclical Capital Buffer

$$\ln(\gamma_{t,cc}^{BankK}) = \rho_{BankK,cc}\left(\ln\left(\gamma_{t-1,cc}^{BankK}\right)\right) + \left(1-\rho_{BankK,cc}\right)\left(\omega_{BankK,cc}^B \ln\left(creditgap\right)\right) + \varepsilon_{t,cc}^{BankK}$$

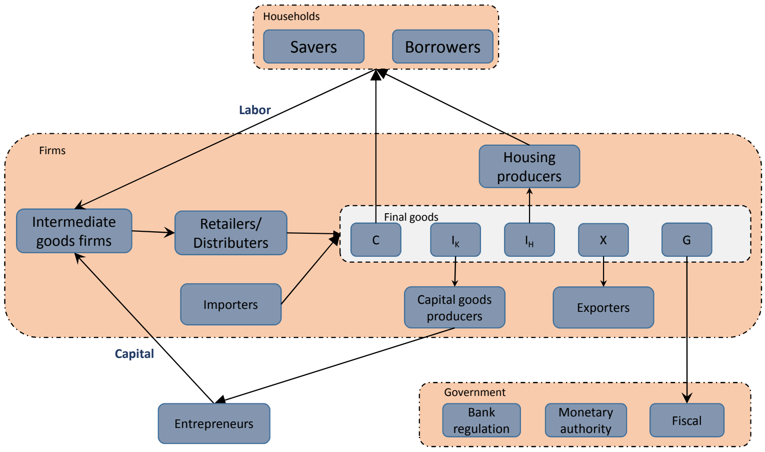

Figure 1: The Real Economy

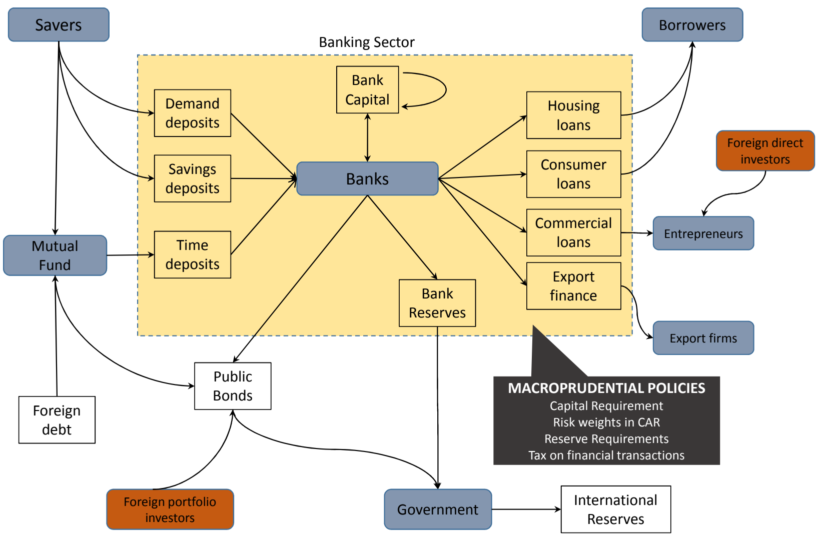

Figure 2: Financial Flows

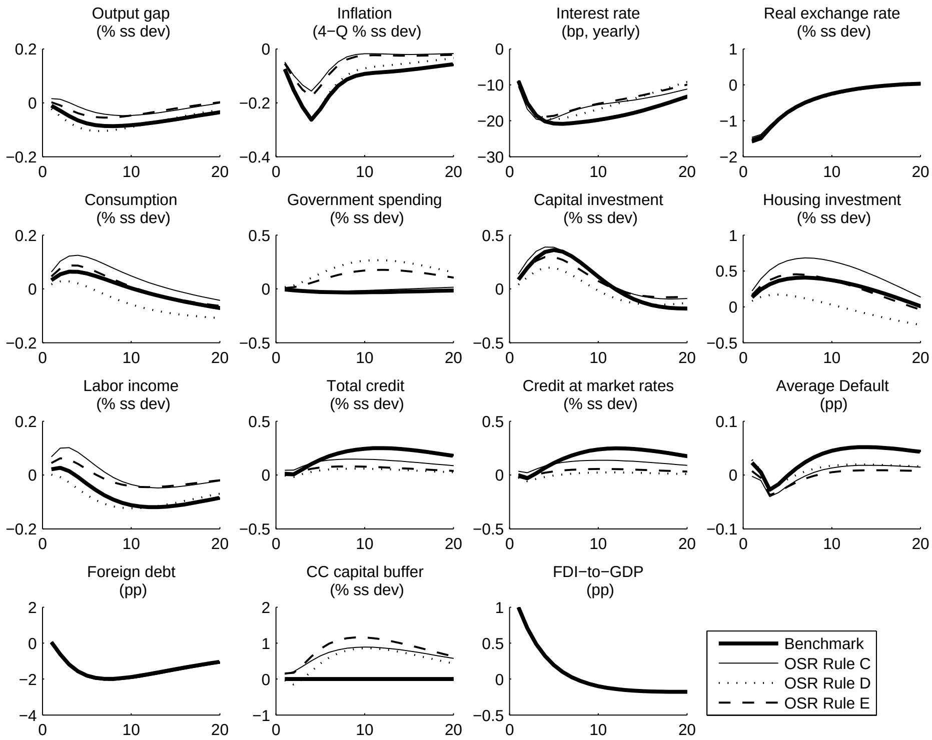

Figure 3: Foreign Direct Investment Shock and OSR Rules

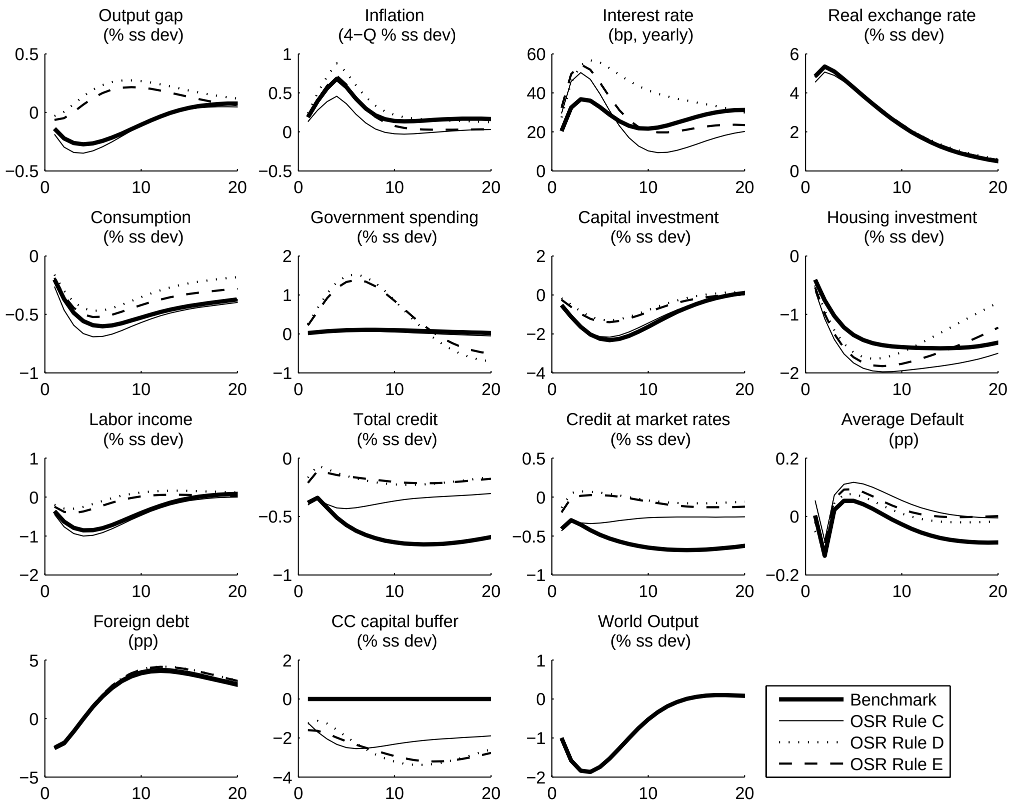

Figure 4: World Output Shock and OSR Rules

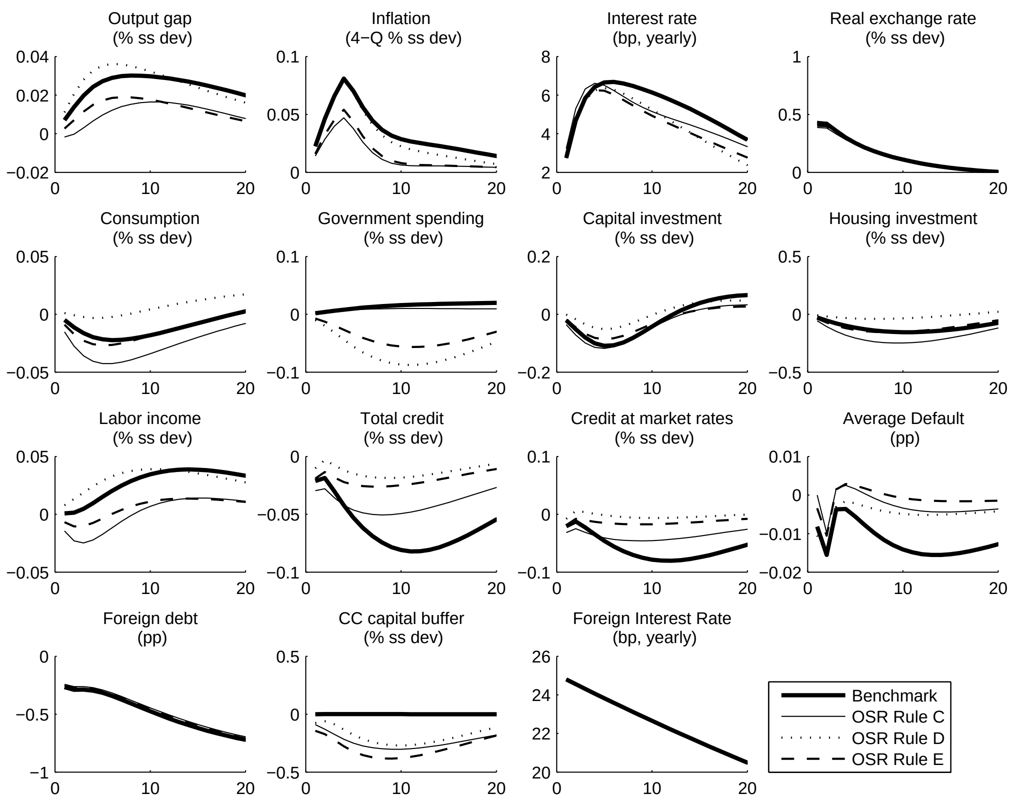

Figure 5: World Interest Rate Shock and OSR Rules