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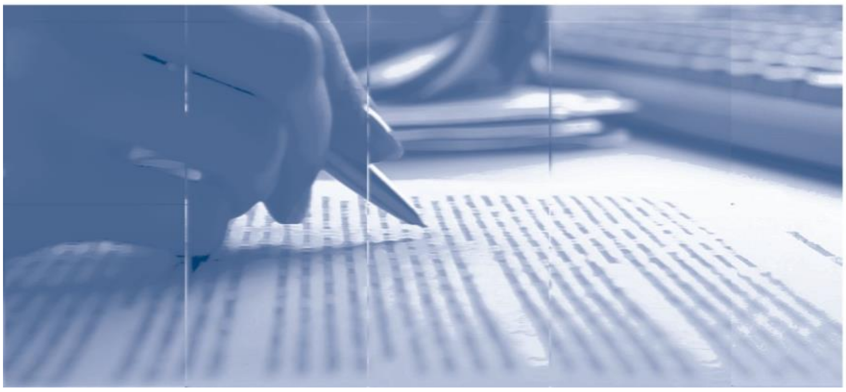

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Traditional and Matter-of-fact Financial Frictions in a DSGE Model for Brazil: the role of macroprudential instruments and monetary policy

Fabia A. de Carvalho *
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Abstract

This paper investigates the transmission channel of macroprudential instruments in a closed-economy DSGE model with a rich set of financial frictions. Banks are exposed to default risk in consumer, housing and investment loans. Consumer loans are extended based on expected borrowers' capacity to pay off debt with labor income. Housing loan extensions are subject to both debt-to-income and loan-to-value constraints. Banks optimally choose balance sheet allocation facing regulatory constraints, risk and frictions. The model is estimated with Brazilian data using Bayesian techniques, and is able to reproduce not only price effects from macroprudential policies, but also quantity effects. The effects of macroprudential instruments on banks' balance sheets can span through the stock and composition of loans, holdings of liquid assets, the share of distributed dividends on total profits, or the composition of bank liabilities. The final impact of shocks to macroprudential instruments on capital buffers is tightly related to the type of regulatory instrument being adjusted. Unanticipated changes in reserve requirements have important quantitative effects, especially on banks' liquid assets and on the choice of funding. This result also holds when required reserves deposited at the central bank are remunerated at the base rate. The magnitude of the impact depends on the size of the incidence base. Changes in required capital substantially impact the real economy and banks' balance sheets. Announcements of changes in capital requirement that precede actual implementation trigger immediate responses from banks, most noticeably with respect to dividend distribution, smoothing out the impact on credit. Capital adequacy ratios improve immediately after the announcement. Countercyclical capital buffers have an important role to mitigate excessive credit growth and to attenuate the recessionary impact of capital impairment.

Keywords: *DSGE models, Bayesian estimation, financial regulation, monetary policy, macroprudential policy*
JEL classification: E4, E5, E6.

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1 Introduction

The literature on DSGE models with credit frictions has been built under a strong assumption with respect to collateral constraints: that loan extensions are tightly related to the value of physical collateral that backs up the operation. The main strands of this literature incorporate agency problems in loan extensions backed up by physical capital (Bernanke, Gertler & Gilchrist (1999), Fiore & Tristani (2013), Glocker & Towbin (2012)), or binding credit constraints based on the value of households' assets, most usually housing (Iacoviello (2005), Gerali *et al.* (2010), Dib (2010), Andrés, Arce & Thomas (2010)) or a mix of both (Pariès, Sørensen & Rodriguez-Palenzuela (2011), Roger & Vlcek (2011), among others). Brzoza-Brzezina, Kolasa & Makarski (2013) provide an extensive comparison of the economic implications of both modeling assumptions.

Secured bank loans might be representative of the credit market in advanced economies, but other types of bank loans delinked from physical collateral have been gaining ground[1]. At the beginning of 2013, for instance, the rating agency Moody's downgraded Canadian banks mostly because of an important exposure of the financial system to unsecured consumer loans, whose performance is tightly related to households' disposable income.

In countries with strong impediments to the execution of collateral warranties, creditors find creative ways to devise contracts that mitigate default risk. In Brazil, for instance, it is common practice for banks to require that borrowers prove to have financial capacity to settle debt installments with labor income. In such cases, debt-to-income or debt service ratios are more relevant than loan-to-value to determine lending rates and debt limits. As a matter of fact, about half the total volume of consumer loans in Brazil are not collateralized by physical assets, and are granted with no constraints on the final destination of borrowed funds. Credit lines linked to purchases of vehicles represent another third part of consumer loans, and although there are constraints with respect to the destination of funds, a share of them are not collateralized.

The way financial frictions are incorporated in the models can substantially affect the model prescriptions. As a matter of fact, important conclusions in the DSGE literature are model-dependent[2]. In BGG-type financial accelerators, fluctuations in the price of physical collateral determine the occurrence of default, generating a strong connection between the external finance premium and borrowers' leverage. In this environment, financial frictions operate mainly through their impact on investment decisions. On the other hand, when loans are extended based on the expected stream of labor income, other sources of bank vulnerability arise. These types of financial frictions might also generate stronger procyclicality in the economy given their feedback effect from labor conditions to credit risk and credit conditions, and hence from

[1] Mendoza (2002) mention cases in which variants of debt-to-income ratios were determinant to establish loan contracts in the US.

[2] Brzoza-Brzezina, Kolasa & Makarski (2013) provide an extensive analysis of model-implied differences in responses of the main economic variables by examining credit constraint and external finance premium financial accelerators vis-a-vis a standard New Keynesian model.

consumption decisions funded by loans to the demand for goods, and back to labor conditions.

In this paper, we build a DSGE model with financial frictions that are suited to reproduce the dynamics of an economy where: 1) households take consumer loans based on their expected future stream of labor income, and can default on these loans if they face bad shocks to their income; 2) housing loans are extended based on loan-to-value and debt-to-income constraints; 3) consumer loans compete against investment loans in bank asset allocation; 4) the perception of significant risk in lending operations makes liquid assets, such as public bonds, an attractive investment choice that competes against bank loans; 5) banks' external funding faces competition from other investment opportunities easily available to bank clients; 4) banks make optimal decisions with respect to their balance sheet allocations and dividend distribution by making non-trivial choices between low-risk-low-return and high-risk-high-return assets, subject to a number of regulatory constraints and macroprudential policies that distort their optimal balance sheet allocation. We use the model to assess the transmission channels of macroprudential policies in Brazil, where all those features are very representative of the commercial and retail banking industry. To this end, we also add a few other frictions that make the model a better fit for Brazil's tightly regulated savings and mortgage market.

The possibility of credit default when labor income is a key factor to extend consumer loans is an assumption with important implications for the model responses. An analogous model where the debt-to-income constraint binds and where there is no default, such as in Mendoza (2002), underestimates the impact of macroprudential instruments on the economy and overestimates the impact of monetary policy on banks' capital adequacy ratios. In contrast, another analogous model where loans to households are fully collateralized by housing, such as in Iacoviello (2005) and Gerali *et al.* (2010), makes the contraction in consumer loans stronger.

The set of macroprudential instruments analyzed in this paper comprises: simplified Basle-1 and Basle-2 core capital requirements, with or without previous announcements of changes in regulation; risk-weights on bank assets to compute capital adequacy ratios; and remunerated and non-remunerated reserve requirements on distinct bank funding sources. We also conduct experiments with countercyclical capital buffers to assess the potential stabilizing effect of these types of macroprudential instruments.

The model is estimated with Bayesian techniques using Brazilian time series during the inflation targeting regime (1999Q3 to 2013Q2). Bayesian IRFs are computed, and counterfactual exercises are reported to help understand the transmission channels of macroprudential instruments and refine the assessment of their economic effects.

We find that monetary policy has a substantially larger impact on the real economy compared to macroprudential instruments[3]. On the other hand, reserve requirements

[3] This result is conditional on the chosen magnitude of policy shocks. Since the estimated variance of reserve requirements is low, given the fact that the required capital ratio has not changed along the period we investigate, we chose the following values for the shocks: 1 p.p. for the monetary policy shock, 1 p.p. for capital requirement, 0.1 p.p. for risk weights on CAR, and 10 p.p. for

on time deposits and capital requirements have a potentially stronger impact on credit. Bank balance sheet adjustments differ according to the macroprudential instrument being shocked. Increased reserve requirements on time deposits trigger a sizable adjustment of bank liquidity, whereas increased capital requirements lead to strong earnings retention. In contrast, when the risk weight of a particular bank asset increases in the computation of capital adequacy ratios, banks show a clear preference for cutting off excess capital instead of building up new capital. The opposite holds for reserve and capital requirements, and for monetary policy shocks. For these instruments, actual Basel ratios improve when policy becomes stricter.

Bank liquidity, which in the model is represented by holdings of riskless public bonds, has an important role in attenuating the impact of reserve requirements on the real economy. The estimated economic impact of non-remunerated reserve requirements on demand deposits is small, but we show that this is a consequence of the small incidence base.

Shocks to core capital requirement have strong effects on banks' funding costs. When the shock hits, banks try to improve their capital adequacy ratios by reshuffling their assets and by change the rate of retained earnings over total profits. If announcements of changes in capital requirements precede actual implementation, banks immediately increase the ratio of retained earnings over total profits thus improving their capital adequacy ratios over the impact period. Previous announcements are more effective in reducing the risk exposure of the economy even after the shock hits.

We simulated scenarios in which bank capital is severely impaired or in which banks reduce their liquidity targets, creating conditions for excessive credit expansion. In these two cases, where shocks originate from the banking system, countercyclical capital buffers can substantially mitigate the impact of the shocks on credit and on the real economy.

Our paper relates to the literature that analyzes the impact of macroprudential policies in a DSGE framework (Glocker & Towbin (2012), Pariès, Sørensen & Rodriguez-Palenzuela (2011), Roger & Vlcek (2011), Montoro & Tovar (2010), Areosa & Coelho (2013)). However, in most of these references housing or capital have a leading role in credit extensions. Our paper also relates to the literature of endogenous bank lending (Andrés, Arce & Thomas (2010), Gerali *et al.* (2010)). Notwithstanding, our model goes beyond introducing monopolistic competition in bank lending. The frictions introduced in banks' optimization problem are particularly suited to endogenously map the main determinants of lending spreads in Brazil: markup, default risk, administrative costs, direct and indirect taxes, and regulatory costs.

The paper is presented as follows. Section 2 describes the theoretical model. Section 3 discusses the stationarization of the model and the computation of the steady state. Section 4 discusses the estimation conducted with Bayesian techniques. Section 4 analyzes the transmission channel of macroprudential policies. Section 5 examines counterfactual exercises and discusses some policy issues. The final section concludes.

reserve requirements.

2 The theoretical model

The economy is composed of households, entrepreneurs, producing firms and a financial sector. Households are distributed in two groups: savers and borrowers. They differ with respect to their intertemporal discount factors, to their access to investment opportunities, and to their ownership of business activities. Both of them supply labor to a labor union. Entrepreneurs engage in risky projects that are financed with their own net worth and with bank debt. Intermediate firms combine labor supplied by unions and capital rented from entrepreneurs to produce inputs that will be assembled and distributed to final goods producing firms. These firms specialize in the production of private and public consumption and investment goods, capital and housing.

The financial sector is composed of a bank conglomerate and a retail money fund. The retail money fund represents an investment opportunity that dominates in return all other financial options available to the household[4]. The fund's portfolio is composed of government bonds and time deposits issued by the bank conglomerate. The bank conglomerate comprises deposit branches, lending branches and a continuum of banks that make optimal choices with respect to dividend distribution and to balance sheet composition, constrained by regulatory requirements on mandatory reserves at the central bank, capital adequacy ratio based on risk-weighted assets, and subject to regulatory constraints on housing loans and on the remuneration of savings accounts. External funding to the bank conglomerate comes from time, savings and demand deposits. The conglomerate can also augment its net worth by retaining profits. Loans are risky since entrepreneurs' projects and households' labor income are subject to idiosyncratic shocks that might reduce their capacity to settle their debt obligations. Banks have preferences over balance sheet components, such as liquid assets and time deposits. We also introduce rigidity in time deposit balances and lending rates, and further assume that bank activities generate administrative costs and are subject to tax incidence.

In this session, we describe the main features of the theoretical model, emphasizing our contributions to existing models and adjustments to Brazilian particularities. The complete derivation of the theoretical model can be obtained from the authors.

2.1 Households

The economy is inhabited by two groups of households: net creditors and net debtors of the financial system. Net creditors, henceforth "savers", have a range of available financial investment opportunities, namely demand and savings deposits issued by the bank conglomerate and quotas of a retail money fund[5]. In addition, savers have right

[4] Notwithstanding, households have preferences over other financial investment opportunities with lower nominal return. This allows the model to find a non-negligible role for assets that are dominated in return and that are important to understand the transmission channel of reserve requirements.

[5] The yield on savings accounts is regulated by the government as a markdown on the base rate of the economy, according to Brazilian practice.

to after-tax-profits from all business activities. Savers derive utility from consumption goods, housing, and liquid financial balances[6].

Net debtors, henceforth "borrowers", also derive utility from consumption goods, housing, and demand deposits. Consumer and housing loans add resources to their budgets so as to finance their purchases of goods and housing. Loans are granted by the bank conglomerate based on expectations with respect to borrowers' capacity to settle debt payments with labor income. Household loans are risky since labor income is subject to idiosyncratic shocks that realize only after loan contracts are made.

In this respect, the model differs from the mainstream macroeconomic literature that introduces financial frictions in consumer loans. Although housing collateral has been the preferred choice in this literature, weakly collateralized or unsecured bank loans are gaining ground in the real world, bringing along concerns about the building up of vulnerabilities in financial systems[7].

Non-corporate loans in Brazil amount to 43% of total bank loans (as of 2013Q2). About half the stock of unsecured consumer loans that are not collateralized with physical capital and are not associated with the purchase of a particular good. Credit lines financing purchases of vehicles represent another third part of consumer loans, but the underlying goods are not necessarily put as collateral. Moreover, regardless of collateral requirements, banks decisions on consumer loans strongly rely on borrowers' capacity to settle their debt obligations with labor income.

Housing loans are about 12% of total bank loans. Although banks establish minimum LTV ratios in these operations, banks attribute great importance to the analysis of debt service-to-income ratios to make their final decisions on whether or not to extend the loan. Interest rates on housing loans that are not regulated by the government are set according to the client's basket of bank products and services, and less so on client's leverage or LTV ratios of those operations.

In this environment, events that affect the labor market potentially spillover to banks' risk taking, with feedback effects to the rest of the economy.

2.1.1 The Saver's program

Savers are uniformly distributed in the continuum $\in (0, \omega_S)$ and choose a stream $\left\{C_{S,t}, H_{S,t}, N_{S,t}, D^S_{S,t}, D^D_{S,t}, D^F_{S,t}\right\}$ of consumption, housing, labor supply, savings de-

[6]Since savings accounts are return-dominated by investment fund quotas during most of the analyzed period in Brazil, we let depositors have preferences for savings.

[7]In 2013, Moody's downgraded Canadian banks strongly based on an important exposure to unsecured consumer loans, whose performance is tightly related to households' disposable income. The Canadian Quarterly Financial Report of the First Quarter 2013 highlights the risks of high debt-service ratios that built up as a result of a prolonged period of low interest rates in Canada. The stress simulation points to a significant increase in loans in arrears should unemployment rise.

posits, demand deposits, and quotas of the retail money fund, to maximize

$$E_0 \left\{ \sum_{t\geq 0} \beta_S^t \left[\begin{array}{c} \frac{1}{1-\sigma_X} \left(\mathcal{X}_{S,t}\right)^{1-\sigma_X} - \frac{\varepsilon_t^L \overline{L}_S}{1+\sigma_L} \left(N_{S,t}\right)^{1+\sigma_L} \\ + \frac{\psi_{S,S}}{1-\sigma_S} \varepsilon_t^{S,S} \left(\frac{D_{S,t}^S}{P_{C,t}C_{S,t}}\right)^{1-\sigma_S} + \frac{\psi_{D,S}}{1-\sigma_D} \varepsilon_t^{D,S} \left(\frac{D_{S,t}^D}{P_{C,t}C_{S,t}}\right)^{1-\sigma_D} \end{array} \right] \varepsilon_t^\beta \right\} \tag{1}$$

subject to the budget constraint

$$\begin{aligned} &\left(1+\tau_{C,t}\right) P_{C,t} C_{S,t} + P_{H,t} \left(H_{S,t} - \left(1-\delta_H\right) H_{S,t-1}\right) + D_{S,t}^F + D_{S,t}^S + D_{S,t}^D \\ &= R_{F,t-1} D_{S,t-1}^F + R_{S,t-1} D_{S,t-1}^S + D_{S,t-1}^D + \left(1-\tau_{w,t}\right)\left(W_t^N N_{S,t}\right) \\ &+ TT_{S,t} + \Pi_{S,t}^{LU} + \Pi_{S,t} + TT_{\Gamma,S,t} + T_{S,t}^{GN} \end{aligned} \tag{2}$$

where

$$\mathcal{X}_{S,t} = \left[\left(1-\varepsilon_t^H \omega_{H,S}\right)^{\frac{1}{\eta_H}} \left(C_{S,t} - \bar{h}_S C_{S,t-1}\right)^{\frac{\eta_H - 1}{\eta_H}} + \left(\varepsilon_t^H \omega_{H,S}\right)^{\frac{1}{\eta_D}} \left(H_{S,t}\right)^{\frac{\eta_H - 1}{\eta_H}} \right]^{\frac{\eta_H}{\eta_H - 1}},$$

ε_t^β, ε_t^L, and ε_t^H are preference shocks, $\overline{L}_S$, $\psi_{S,S}$, and $\psi_{S,D}$ are scaling parameters, $\omega_{H,S}$ is a bias for housing in the consumption basket, $\bar{h}_S$ is group-specific consumption habit, δ_H is housing depreciation, and $\tau_{C,t}$ and $\tau_{w,t}$ are tax rates on consumption and labor income, respectively. Housing is priced at $P_{H,t}$.

Labor is competitively supplied to labor unions at a nominal wage W_t^N. Labor unions distribute their net-of-tax profits $\Pi_{S,t}^{LU}$ from monopolistic competition back to households as lump-sum transfers. Savers also receive lump sum transfers $TT_{S,t}$ from the government, in addition to net-of-tax profits $\Pi_{S,t}$ from firms, entrepreneurs, and the bank conglomerate. $TT_{\Gamma,S,t}$ are costs from capital utilization, which we assume to be distributed as lump-sum transfers to savers and $T_{S,t}^{GN}$ are transfers from entrepreneurs that quit their projects at each period. One-period returns on savings accounts and on retail money fund quotas are $R_{S,t}$ and $R_{F,t}$, respectively.

2.1.2 The Borrower's program

Borrowers are distributed in the continuum $(0, \omega_B)$. They take bank loans against a proportion $\gamma_t^{B,C}$ of expected future labor income. Borrower i's total income from labor is subject to idiosyncratic shocks, $\varpi_{B,i,t} \sim lognormal\,(1, \sigma_B)$, a short-cut for idiosyncratic income shocks that do not affect firms' aggregate production but that have an impact on borrowers' capacity to pay their debt installments. After the realization of the shock, borrower i's net-of-tax nominal labor income is

$$\varpi_{B,i,t} \left[\left(1-\tau_{w,t}\right) N_{B,i,t} W_t\right] \tag{3}$$

where W_t is wage negotiated between firms and unions[8].

[8] It can be shown that the borrower's net-of-tax income from labor $\left(1-\tau_{\omega,t}\right) N_{B,i,t} W_t$ equals the net-of-tax labor income obtained from unions $\left(1-\tau_{\omega,t}\right) N_{B,i,t} W_t^N$ plus her share on unions' net-of-tax profits $\Pi_{S,t}^{LU}$.

At period t, household i gets two types of credit: a consumer loan, with nominal value $B^C_{B,i,t}$, and a housing loan, $B^H_{B,i,t}$. Both loans redeem in the subsequent period and are negotiated at fixed interest rates, $R^{L,C}_{B,i,t}$ and $R^{L,H}_{B,t}$, respectively. The interest rate on housing loans is exogenously set by the government and does not depend on borrowers' leverage. This assumption accords with the tightly regulated market of Brazilian housing loans to low-priced real estate, which represents the bulk of the housing loans market[9]. [10]

In case of an adverse shock to the borrower's labor income that leads to default on bank loans, the bank seizes a fraction $\gamma^{B,C}_t$ of household's net-of-tax labor income, after incurring proportional monitoring costs $\mu_{B,C}$, in case default is on consumer loans, and $\mu_{B,H}$, in case default is on housing loans[11].

Housing loans are senior to consumer loans with respect to income commitment[12]. After labor decisions are made, the shock $\varpi_{B,i,t+1}$ realizes, and the borrower chooses to default if the amount of labor income previously committed to the loan is less than the total debt redeeming[13]. This threshold, $\overline{\varpi}_{B,i,t+1}$, is such that the borrower is indifferent between settling debt obligations or letting the bank seize the committed share of her labor income:

$$\gamma^{B,C}_t \overline{\varpi}_{B,i,t+1} \left(1 - \tau_{w,t+1}\right) N_{B,i,t+1} W_{t+1} = R^{L,C}_{B,i,t} B^C_{B,i,t} + R^{L,H}_{B,t} B^H_{B,i,t} \tag{4a}$$

For convenience, we define another threshold $\overline{\varpi}^H_{B,i,t+1}$ with respect to the housing loan:

$$\gamma^{B,C}_t \overline{\varpi}^H_{B,i,t+1} \left(1 - \tau_{w,t+1}\right) N_{B,i,t+1} W_{t+1} = R^{L,H}_{B,t} B^H_{B,i,t} \tag{5}$$

Since lending branches are risk neutral and operate under perfect competition, for

[9]As of June 2013, the upper bound for the price of houses that qualify for these cheaper credit lines was BRL 500 thousand (approx. USD 250 thousand). Housing loans to low-priced real estate amounted to 76% of total housing loans financed through savings deposits in Brazil. Apart from the loans funded from savings deposits, an important segment of housing loans is funded with resources from the Severance Indemnity Fund (FGTS), managed by Caixa Economica Federal, a state-owned bank. These housing loans represent 36% of total housing loans in Brazil and are granted at low rates that bear little correspondence with the borrower's leverage or collateral.

[10]Housing loans to low-priced real state are subject to an interest rate cap of 12% p.a.. However, the market of loans to low-priced real estate is by far dominated by Caixa Economica Federal (CEF), and the rates charged on these loans are not intimately associated with leverage or LTVs, although minimum LTV applies to the decision of whether or not to extend the loan to each particular proponent. The fact that banks are required to channel a certain share of their savings deposits to mortgage loans makes them closely track CEF's lending rates in order to attract enough demand for their housing loans. Several other regulatory requirements apply to the market of housing loans and savings deposits in Brazil. Our model addresses only the main aspects of this regulatory framework.

[11]These monitoring costs can be regarded as the cost of bankruptcy (including auditing, legal and enforcement costs).

[12]This assumption guarantees that expected default in housing markets is lower than in the market for consumer loans, which conforms with Brazilian empirical evidence.

[13]We rule out strategic default by assuming an implicit clause in the debt contract that if the borrower deviates from the optimal labor supply plan under commitment, she will be ruled out of the debt market in every subsequent period of the model.

each borrower the expected return from loans (left side of the following equation) must equal the funding costs associated with these operations (right side):

$$E_t\left(1-\mu_{B,C}\right)\int_{\overline{\varpi}^H_{B,i,t+1}}^{\overline{\varpi}_{B,i,t+1}}\left[\gamma_t^{B,C}\varpi_{B,i,t}\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}-R^{L,H}_{B,t}B^H_{B,i,t}\right]dF\left(\varpi_{B,i,t}\right) \tag{6}$$

$$+E_t\int_{\overline{\varpi}_{B,i,t+1}}^{\infty}R^{L,C}_{B,i,t}B^C_{B,t}dF\left(\varpi_{B,i,t}\right)=R^C_{B,t}B^C_{B,i,t}$$

or

$$\gamma_t^{B,C}\left[E_t\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}G_{B,C}\left(\overline{\varpi}_{B,i,t+1},\overline{\varpi}^H_{B,i,t+1}\right)\right]=R^C_{B,t}B^C_{B,i,t} \tag{7}$$

where

$$\begin{aligned}G_{B,C}\left(\overline{\varpi}_1,\overline{\varpi}_2\right)=\left(1-\mu_{B,C}\right)&\left[\int_{\overline{\varpi}_1}^{\overline{\varpi}_2}\varpi dF\left(\varpi\right)-\overline{\varpi}_1\left[F\left(\overline{\varpi}_2\right)-F\left(\overline{\varpi}_1\right)\right]\right]\\&+\left(\overline{\varpi}_2-\overline{\varpi}_1\right)\left(1-F\left(\overline{\varpi}_2\right)\right)\end{aligned} \tag{8}$$

The household's expected repayment on the consumer loan is given by

$$\gamma_t^{B,C}E_t\left[\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}_{B,t+1},\overline{\varpi}^H_{B,i,t+1}\right)\right]$$

where

$$\begin{aligned}H\left(\overline{\varpi}_B,\overline{\varpi}^H_B\right)=&\int_{\overline{\varpi}^H_B}^{\overline{\varpi}_B}\varpi dF\left(\varpi\right)-\overline{\varpi}^H_B\left(F\left(\overline{\varpi}_B\right)-F\left(\overline{\varpi}^H_B\right)\right)\\&+\left(\overline{\varpi}_B-\overline{\varpi}^H_B\right)\left(1-F\left(\overline{\varpi}_B\right)\right)\end{aligned} \tag{9}$$

Similarly, the household's expected settlement of the housing loan is

$$\gamma^{B,C}E_t\left[\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}^H_{B,i,t+1},0\right)\right]$$

and the expected settlement of bank loans is

$$\gamma^{B,C}E_t\left[\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}_{B,i,t+1},0\right)\right]$$

Although housing loan rates for low-priced real estate in Brazil are not associated with borrowers' leverage or collateral, banks abide by minimum LTV ratios to meet the demand for housing loans. For this reason, we impose a collateral constraint on this credit segment such that the nominal value of housing loans cannot exceed a fraction $\gamma_t^{B,H}$ of borrower's housing stock.

$$B^H_{B,i,t}\leq\gamma_t^{B,H}P^H_tH^B_{i,t} \tag{10}$$

This helps the model link fluctuations in housing prices to changes in the demand for mortgage loans.

The LTV ratio $\gamma_t^{B,H}$ is time varying, and allows the model to accommodate the recent increase in household indebtedness in Brazil, a trend that seems to be more related to the financial deepening of the economy than to a possible bubble in housing prices.

The representative borrower[14] chooses the stream $\left\{C_{B,t}, N_{B,t}, H_{B,t}, \mathcal{X}_{B,t}, D_{B,t}^D, \varpi_{B,t}, \varpi_{B,t}^H, B_{B,t}^C, B_{B,t}^H\right\}$ to maximize the utility function

$$E_0\left\{\sum_{t\geq 0}\beta_B^t\left[\frac{1}{1-\sigma_X}\left(\mathcal{X}_{B,t}\right)^{1-\sigma_X}-\frac{\varepsilon_t^L\overline{L}_B}{1+\sigma_L}\left(N_{B,t}\right)^{1+\sigma_L}+\frac{\psi_{D,B}}{1-\sigma_D}\varepsilon_t^{D,B}\left(\frac{D_{B,t}^D}{P_{C,t}C_{B,t}}\right)^{1-\sigma_D}\right]\varepsilon_t^\beta\right\} \tag{11}$$

subject to the budget constraint

$$\begin{aligned}&\left(1+\tau_{C,t}\right)P_{C,t}C_{B,t}+P_{H,t}\left(H_{B,t}-\left(1-\delta_H\right)H_{B,t-1}\right)+\gamma_t^{B,C}\left(1-\tau_{w,t}\right)N_{B,t}W_t^N H\left(\varpi_{B,t},0\right)+D_{B,t}^D\\ &\leq B_{B,t}^C+B_{B,t}^H+D_{B,t-1}^D+\left(1-\tau_{w,t}\right)\left(W_t^N N_{B,t}\right)+TT_{B,t}+\Pi_{B,t}^{LU}\end{aligned}$$

and the constraints from the optimal contract

$$\begin{aligned}&\gamma_t^{B,C}E_t\left(1-\tau_{w,t+1}\right)N_{B,t+1}W_{t+1}^N G_{B,C}\left(\varpi_{B,t+1},\varpi_{B,t+1}^H\right)=R_{B,t}^C B_{B,t}^C \qquad (12)\\ &\gamma_t^{B,C}\varpi_{B,t}^H\left(1-\tau_{w,t}\right)N_{B,t}W_t^N=R_{B,t-1}^{L,H}B_{B,t-1}^H\\ &B_{B,t}^H\leq\gamma_t^{B,H}P_{C,t}Q_{H,t}H_t^B\end{aligned}$$

where

$$\mathcal{X}_{B,t}=\left[\left(1-\varepsilon_t^H\omega_{H,B}\right)^{\frac{1}{\eta_H}}\left(C_{B,t}-\bar{h}_B C_{B,t-1}\right)^{\frac{\eta_H-1}{\eta_H}}+\left(\varepsilon_t^H\omega_{H,B}\right)^{\frac{1}{\eta_H}}\left(H_{B,t}\right)^{\frac{\eta_H-1}{\eta_H}}\right]^{\frac{\eta_H}{\eta_H-1}}, \tag{13}$$

and the auxiliary variables $\varpi_{B,t}$ and $\varpi_{B,t}^H$ are defined by

$$\gamma_t^{B,C}\left(\varpi_{B,t}-\varpi_{B,t}^H\right)\left(1-\tau_{w,t}\right)N_{B,t}W_t=R_{B,t-1}^{L,C}B_{B,t-1}^C \tag{14}$$

2.2 Entrepreneurs

Investment loans are modeled as in Christiano, Motto and Rostagno (2010), except that we introduce time varying LTV ratios to account for the fact that the share of capital stock financed through non-earmarked bank loans in Brazil is small and to accommodate changes in leverage that are dissociated from innovations in the value of collateral. The recent financial deepening of the Brazilian economy can be captured

[14] In order to avoid heterogeneity issues that might arise if each household, faced with an idiosyncratic shock to her labor income, is allowed to freely choose her allocations, we assume that there is an insurance contract that evens out any income discrepancy among borrowers. We should impose that every single household follow the same allocation plan that maximizes households' average utility.

through this variable.

At the end of period t, each entrepreneur i purchases capital $K_{E,i,t+1}$ from capital goods producers and, at $t+1$, rents it to the producers of intermediate goods at the rental rate R^K_{t+1}. Capital purchases are financed with entrepreneur's net worth $N^E_{i,t+1}$ and commercial loans $B_{E,i,t+1}$:

$$P_{K,t}K_{E,i,t+1} = N^E_{i,t} + B_{E,i,t} \tag{15}$$

At the beginning of period $t+1$, before capital is rented to domestic goods producers, it is subject to an idiosyncratic shock $\omega_{i,t+1}\tilde{}\ \log normal\left(\mu_{E,t+1}, \sigma_{E,t+1}\right)$, with $E_t\omega_{i,t+1} = 1$, which represents the riskiness of business activity. We assume that $\sigma_{E,t+1}$ follows an AR(1) process and that its realization is known at the end of period t, prior to the entrepreneur's investment decision.

After $\omega_{i,t+1}$ realizes, physical capital becomes $\omega_{i,t+1}K_{E,i,t+1}$. After depreciation at the rate δ_K, capital is sold back to capital goods producers at the market price $P_{K,t+1}$. Therefore, the average nominal return of entrepreneur's capital at period $t+1$ is

$$\begin{aligned} R^{TK}_{t+1} &\equiv \int_0^\infty \omega\left[R^K_{t+1} + P_{K,t+1}\left(1-\delta_K\right)\right] dF\left(\omega, \sigma_{E,t+1}\right) \\ &= R^K_{t+1} + P_{K,t+1}\left(1-\delta_K\right) \end{aligned} \tag{16}$$

The nominal amount $B_{E,i,t}$ is borrowed at the fixed rate $R^{L,E}_{i,t}$. Loans are collateralized by a fraction γ^E_t of entrepreneurs' stock of capital. We define the threshold value $\varpi_{i,t+1}$ such that

$$R^L_{E,i,t}B_{E,i,t} = \varpi_{i,t+1}\gamma^E_t R^{TK}_{t+1}K_{E,i,t} \tag{17}$$

Whenever $\omega_{i,t+1} < \varpi_{i,t+1}$, the entrepreneur goes bankrupt and the bank seizes the collateral by incurring monitoring costs that correspond to a fraction μ_E of recovered assets. Let $R_{E,t}$ be the proportional funding cost of the commercial lending branch. Since the idiosyncratic risk is diversifiable, the interest rate on commercial loans is such that the expected profit of the financial intermediary is zero:

$$R_{E,t}B_{E,i,t} = \gamma^E_t E_t R^{TK}_{t+1}K_{E,i,t}G\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right) \tag{18}$$

where

$$G\left(\varpi_{t+1}, \sigma_{E,t+1}\right) = \left(1-\mu_E\right)\int_0^{\varpi_{t+1}} \omega dF\left(\omega, \sigma_{E,t+1}\right) + \left(1 - F\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right)\varpi_{t+1} \tag{19}$$

The entrepreneur's expected cash flow is:

$$E_t R^{TK}_{t+1}K_{E,i,t}\left[1 - \gamma^E_t H\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right] \tag{20}$$

where

$$H\left(\varpi_{t+1},\sigma_{E,t+1}\right)=\int_{0}^{\varpi_{t+1}}\omega dF\left(\omega,\sigma_{E,t+1}\right)+\left(1-F\left(\varpi_{i,t+1},\sigma_{E,t+1}\right)\right)\varpi_{t+1} \tag{21}$$

The entrepreneur's problem amounts to choosing a sequence of $\{\varpi_{i,t+1}, B_{E,i,t}, K_{E,i,t}\}$ to maximize (20) constrained by (15), (17), (18) and $B_{E,i,t} \geq 0$.

At the end of each period, only a fraction γ_t^N of the entrepreneurs survive. The ones that leave the market have their capital sold and the proceeds are distributed to the households as lump-sum transfers T_t^{GN}. The average nominal value of entrepreneurs' own resources N_t^E at the end of period t is

$$N_t^E=\gamma_t^N R_t^{TK} K_{t-1}\left[1-\gamma_t^E H\left(\overline{\varpi}_{E,t},\sigma_{E,t}\right)\right] \tag{22}$$

where the survival rate γ_t^N is given by

$$\begin{aligned}\gamma_t^N &= \frac{1}{1+e^{-\gamma^N-\widetilde{\gamma}_t^N}}\\ \widetilde{\gamma}_t^N &= \rho_\gamma^N \widetilde{\gamma}_{t-1}^N+\sigma_\gamma^N \varepsilon_{\gamma,t}^N\end{aligned} \tag{23}$$

and

$$T_t^{GN}=\left(1-\gamma_t^N\right)\left(R_t^{KT} K_{t-1}\left[1-\gamma^E H\left(\overline{\varpi}_{E,t},\sigma_{E,t}\right)\right]\right) \tag{24}$$

2.3 Goods producers

Goods producers are modeled according to the standard DSGE literature. There is a continuum $j \in (0,1)$ of competitive intermediate goods producers that combine labor and capital to produce homogeneous goods. The production function is

$$Z_{j,t}^d = A.\varepsilon_t^A\left[u_t K_{j,t-1}\right]^\alpha\left(\epsilon_t L_{j,t}\right)^{1-\alpha} \tag{25}$$

where ε_t^A is a temporary shock to total factor productivity, A is a scaling constant, and ϵ_t is a permanent common shock to labor productivity whose growth rate $g_{\epsilon,t}$ follows

$$g_{\epsilon,t}=\rho_\epsilon . g_{\epsilon,t-1}+\left(1-\rho_\epsilon\right).g_\epsilon+\varepsilon_t^Z \tag{26}$$

Cost minimization is subject to capital utilization adjustment costs $\Gamma_u(u_t) \equiv \phi_{u,1}\left(u_t-1\right)+\phi_{u,2}/2\left(u_t-1\right)^2$.

Intermediate goods producers sell their output to retailers, who operate under monopolistic competition setting prices on a staggered basis à la Calvo. Retailers who are not chosen to optimize set their prices according to the indexation rule:

$$P_t^d(k)=\pi_{t-1}^{d,\gamma_d}\overline{\pi}^{1-\gamma_d}P_{t-1}^d(k) \tag{27}$$

where $\overline{\pi}$ is steady-state inflation. Retailers differentiate the homogeneous goods and sell them to competitive distribution sectors. These, in turn, reassemble the differentiated goods using a CES production function:

$$Y_t^d = \left[\int_0^1 Z_t^d(k)^{\frac{1}{\mu_d}} \, dk \right]^{\mu_d} \tag{28}$$

Distributers sell their output to final goods firms, which specialize in the production of goods for government consumption G, private consumption C, capital investment I_K, and housing investment I_H. Final goods producers are competitive and face no frictions. Therefore, the zero profit condition yields

$$Y_t^{d,J} = \{G, C, I_K, I_H\} \tag{29}$$

$$P_t^J = P_t^d \tag{30}$$

Perfectly competitive firms produce the stock of housing and fixed capital. At the beginning of each period, they buy back the depreciated capital stock from entrepreneurs as well as the depreciated housing stock from households. These firms augment their capital and housing stocks using final goods and facing adjustment costs to investment. At the end of the period, the augmented stocks are sold back to entrepreneurs and households at the same prices.

2.4 Investment Fund

A recent strand of the literature has introduced imperfect competition in the bank deposits market[15]. This has implications for the dynamic responses of changes in reserve requirements. Under this assumption, the impact of shocks to reserve requirements on credit is partially buffered by adjustments in the cost of funding to banks.

In Brazil, banks' time deposits face fierce competition from retail money funds and from domestic federal bonds. About half the outstanding balance of domestic federal bonds are held by bank's non-financial clients, either through holdings of securities or through quotas in mutual funds. Money market funds hold about 30% of domestic federal bonds. In addition, the National Treasury allows private individuals to hold claims to federal bonds negotiated at "Tesouro Direto"[16].

Such competition results in very narrow markdowns of time deposit rates on the base rate of the economy. For instance, in the period analyzed in this paper, the base rate was merely 0.2 p.p higher on average than the effective 90-day time deposits (CDB) rate.

[15] Dib (2010), Pariès, Sørensen & Rodriguez-Palenzuela (2011), Andrés, Arce & Thomas (2010), Roger & Vlcek (2011).

[16] The stock of outstanding debt negotiated at Tesouro Direto is about 1% of the stock outstanding of domestic federal bonds.

We therefore assume that the interest rate on time deposits, R_t^T, and on domestic public bonds, R_t, are equal at every point in time. This assumption has implications to the response of credit conditions given changes in reserve requirements.

Without loss of generality, we let the group of savers in the model hold quotas of a retail money fund, whose portfolio is composed of time deposits D_t^T issued by banks and government bonds B_t^F. Transactions with the retail money funds are free of administrative costs. Since $R_t^T = R_t$, the retail money fund is indifferent with respect to its portfolio composition.

2.5 Banking sector

Our 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.

The bank conglomerate is composed of a continuum $[0, 1]$ of competitive banks that get funding from deposit branches and extend credit to households and entrepreneurs through their lending branches. Banks are the financial vessel of the conglomerate: they channel money market funds to the lending branches while making 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 through retained earnings, but the conglomerate can also choose to distribute dividends and accommodate changes in the regulatory environment by adjusting other balance sheet components. Our adopted segmentation of the bank conglomerate allows the model to endogenously reproduce the most relevant determinants of lending spreads and the effects of regulatory requirements on bank rates and volumes.

2.5.1 Deposit branches

There is one representative deposit branch for each type of deposit. The demand deposit branch costlessly takes unremunerated demand deposits, $D_{S,t}^D$ and $D_{B,t}^D$, which are determined from households' optimization problems. It then costlessly distributes the resources to each bank $j \in [0, 1]$. In the following period, banks return the unremunerated funds to the deposit branch, which, in turn, returns them to households:

$$\omega_S D_{S,t}^D + \omega_B D_{B,t}^D = D_t^D = \int_0^1 \omega_{b,j} D_{j,t}^D dj \tag{31}$$

The savings deposit branch operates analogously, except that savings deposits accrue interest R_t^S that is regulated by the government according to:

$$R_t^S = 1 + \varphi_{R,t}^S (R_t - 1) \tag{32}$$

where $\varphi_{R,t}^S$ follows an AR(1) process around the steady state markdown.

The time deposit branch issues deposit certificates to the retail money fund, at interest rates equal to the base rate $\left(R_t^T = R_t\right)$. The resources are also costlessly distributed to the banks, and, in the following period, returned to the retail money fund with accrued interest .

2.5.2 Lending branches

Lending branches get funding from banks and extend commercial and consumer loans to entrepreneurs and to borrowers, respectively. Without loss of generality, we assume one representative lending branch for commercial loans and another for consumer loans.

The representative commercial lending branch is competitive and seeks to diversify its funding sources. It borrows $B_{E,j,t}^b$ from bank j at the interest rate $R_{E,j,t}$. Total loans $B_{E,t}^{LB,E}$, which are extended to entrepreneurs at the fixed-rate $R_{E,t}^L$, are a CES aggregate of funding resources:

$$B_{E,t}^{LB,E} = \left[\int_0^1 \omega_{b,j} \left(B_{E,j,t}^b\right)^{\frac{1}{\mu_E^R}} dj\right]^{\mu_E^R} \tag{33}$$

where

$$B_{E,t}^{LB,E} = \omega_E B_{E,t} \tag{34}$$

In the following period, the lending branch chooses the amount to borrow from each bank $B_{E,j,t}$ so as to maximize

$$R_{E,t}^L B_{E,t}^{LB,E} - \int_0^1 \omega_{b,j} R_{E,j,t} B_{E,j,t}^b dj \tag{35}$$

subject to (33).

The FOC, together with the zero-profit condition, results in a demand function for commercial loans funding from bank j :

$$B_{E,j,t}^b = \left(\frac{R_{E,j,t}}{R_{E,t}}\right)^{\frac{\mu_E^R}{1-\mu_E^R}} B_{E,t}^{LB,E} \tag{36}$$

As a result, each bank j has some market power in the allocation of available funds, and is free to choose the interest rate that it will charge the lending branches, constrained by Calvo-type interest rate rigidities.

Aggregate funding to the investment lending branch has the following representation:

$$\begin{aligned} B_{E,t}^b &\equiv \int_0^1 \omega_{b,j} B_{E,j,t}^b dj \\ &= B_{E,t}^{LB,E} \Delta_{E,t}^R \end{aligned} \tag{37}$$

where

$$\Delta^R_{E,t} = \int_0^1 \omega_{b,j} \left(\frac{R_{E,j,t}}{R_{E,T}} \right)^{\frac{\mu^R_E}{1-\mu^R_E}} dj \tag{38}$$

From Jensen's inequality, $\Delta^R_{E,t} > 1$. The net cash flow $\Pi^{E,LB}_t$ from the investment lending branch is

$$\begin{aligned} \Pi^{E,LB}_t &= \int_0^1 \omega_{b,j} B_{E,j,t} dj - B^{LB,E}_{E,t} \\ &= B^{LB,E}_{E,t} \left(\Delta^R_{E,t} - 1 \right) > 0 \end{aligned} \tag{39}$$

which is distributed to banks as lump-sum transfers:

$$\Pi^{E,LB}_t = \int_0^1 \omega_{b,j} \Pi^{E,LB}_{j,t} dj \tag{40}$$

The decisions of the representative investment lending branch are analogous to those of the representative consumer lending branch. The demand curve for funding is:

$$B^{C,b}_{B,j,t} = \left(\frac{R^C_{B,j,t}}{R^C_{B,t}} \right)^{-\frac{\mu^R_{B,C}}{\mu^R_{B,C}-1}} B^C_{B,t} \tag{41}$$

2.5.3 Housing loan branch

The Brazilian housing loans market is heavily regulated by the government. The regulatory authority requires that a fraction $\tau_{H,S,t}$ of savings deposits be channeled to housing loans, and regulates on the lending rates[17]. We therefore assume that the final lending rate $R^{L,H}_{B,t}$ is set by the government as a markdown on the base rate:

$$\frac{R^L_{B,H,t}}{R_t} = \left(\frac{R^L_{B,H,t-1}}{R_{t-1}} \right)^{\rho_{R^H}} \left(\frac{R^L_{B,H}}{R} \right)^{1-\rho_{R^H}} \exp\left(\varepsilon_{R^H,t} \right) \tag{42}$$

Consequently, the only role played by the mortgage loan branch is to channel funds from savings deposits to housing loans, not influencing either interest rates or volumes. It follows that

$$\omega_B B^H_{B,t} = B^{H,wb}_{B,t}$$

Since mortgage loans are risky, the actual cash flow received by the mortgage branch is

$$\Pi^H_t = \omega_B \gamma^{B,C}_t \left(1 - \tau_{w,t}\right) N_{B,t} W_t G_{B,H} \left(\overline{\varpi}^H_{B,t}, 0 \right) - R^{H,wb}_{B,t-1} B^{H,wb}_{B,t-1} \tag{43}$$

[17] Banks have discretion to extend loans to finance more expensive real estate. However, the bulk of housing loans in Brazil finance low-priced real estate, which is subject to such regulation.

where

$$G_{B,H}\left(\overline{\varpi}_1,\overline{\varpi}_2\right)=\left(1-\mu_{B,H}\right)\left[\int_{\overline{\varpi}_1}^{\overline{\varpi}_2}\varpi dF\left(\varpi\right)-\overline{\varpi}_1\left[F\left(\overline{\varpi}_2\right)-F\left(\overline{\varpi}_1\right)\right]\right] \\ +\left(\overline{\varpi}_2-\overline{\varpi}_1\right)\left(1-F\left(\overline{\varpi}_2\right)\right) \tag{44}$$

The bank conglomerate absorbs the cost of default of housing loans as a loss that cannot be passed through to volumes or rates in this market.

2.5.4 Banks

Banks act like treasury departments with a mandate on strategic decisions about dividend distribution, bound by regulatory constraints. Each bank j takes demand deposits $D^D_{j,t}$, time deposits $D^T_{j,t}$ and savings deposits $D^S_{j,t}$ from households. After complying with regulation and making strategic decisions on capital accumulation and balance sheet composition, the bank channels the available resources to lending and mortgage branches.

Banks have to comply with a number of regulatory requirements. Although the choice of regulation introduced in the model was made to reflect the regulatory framework faced by banks operating in Brazil, most of them are common place in the world. First, funding in the money market is subject to reserve requirements. In addition to unremunerated reserve requirements, which are commonly addressed in the literature, we introduce remunerated requirements on savings and time deposits, and an "additional" reserve requirement detailed below [18]. Second, the benchmark model introduces a simplified version of Basle 1 and Basle 2-type capital requirement, which is based on the computation of capital adequacy ratios after weighting bank assets according to their risk factors. Third, we introduce tight regulation on housing loans and savings accounts. Finally, we introduce tax collection on specific credit operations in addition to an expense-deductible income tax on conglomerate's activities.

Banks have preferences over some balance sheet components, particularly liquid assets and time deposits. These preferences are introduced in banks' optimization problem as targets to be attained in the balanced growth path. We let the data determine the power of each of these assumptions by estimating cost-elasticity parameters.

Bank $j's$ balance sheet is:

$$B^b_{E,j,t}+B^{C,b}_{B,j,t}+B^{H,b}_{B,j,t}+B_{OM,j,t}+RR^T_{j,t}+RR^S_{j,t}+RR^D_{j,t}+RR^{add}_{j,t}-RR^{S,H}_{j,t}=D^T_{j,t}+D^S_{j,t}+D^D_{j,t}+Bankcap_{j,t} \tag{45}$$

where $Bankcap_{j,t}$ is net worth, $B_{OM,j,t}$ are liquid assets (i.e., public bonds holdings), $RR^T_{j,t}$, $RR^S_{j,t}$, and $RR^D_{j,t}$ are balances of required reserves on time, savings and demand

[18] Reserve requirements in Brazil have been used for a number of reasons: general financial stability concerns, disruptions in specific segments of the credit or bank liquidity market, overall economic stability, or, outside the sample considered for estimation in this paper, for income distribution (Carvalho & Azevedo (2008), Montoro & Moreno (2011), Mesquita & Torós (2011), Tovar, Garcia-Escribano & Martin (2012))

deposits, respectively, and $RR_{j,t}^{add}$ are additional required reserves[19].

Reserve requirements are determined as:

$$RR_{j,t}^{k} = \tau_{RR,k,t} D_{j,t}^{k} \tag{46}$$

$$RR_{j,t}^{add} = \tau_{RR,add,t} \left(D_{j,t}^{D} + D_{j,t}^{T} + D_{j,t}^{S} \right) \tag{47}$$

where $\tau_{RR,k,t}$ are required ratios on deposits of type $k = [Demand, Time, Savings, Additional]$ set by the government and follow AR(1) processes around the steady state. Reserve requirements deposited at the monetary authority accrue the same rate as their incidence base.

Banks that take savings deposits in Brazil have to extend the equivalent of a fraction of their savings deposits as loans to low-priced housing. However, the publicly-owned bank Caixa Economica Federal (CEF) also uses the resources from the Severance Indemninity Fund (FGTS) to fund mortgage loans. For this reason, we introduce the variable $RR_{j,t}^{S,H}$ to represent funding for housing loans obtained from the FGTS. For simplicity, we assume that FGTS funds fill the gap between required and actual destination of savings deposits to housing loans.

$$RR_{j,t}^{S,H} = \left(\tau_{H,S,t} D_{j,t}^{S} - B_{B,j,t}^{H} \right) \tag{48}$$

Banks make no strategic decisions with respect to housing loans or interest rates on savings deposits. On the other hand, the balance of time deposits is chosen by the bank, subject to adjustment costs that introduced to reproduce the strong persistence in the data:

$$\Gamma_T \left(\frac{D_{j,t}^{T}}{D_{j,t-1}^{T}} \right) \equiv \phi_T/2 \left(\frac{D_{j,t}^{T}}{D_{j,t-1}^{T}} \varepsilon_t^{DT} - g_{\epsilon,t} \pi_{C,t} \right)^2 \tag{49}$$

Bank capital can change with net operational results, $FC_{j,t}^{b}$ and dividend distribution, $P_{C,t} C_{B,j,t}$. It is also subject to shocks $\varepsilon_t^{bankcap}$ that can capture changes in market's perception with respect to the quality of bank capital or any other shocks that change the marked-to-market value of banks' net worth[20]. The capital accumulation rule is:

$$Bankcap_{j,t} = Bankcap_{j,t-1} + FC_{j,t}^{b} - P_{C,t} C_{B,j,t} + Bankcap_{j,t} \varepsilon_t^{bankcap} \tag{50}$$

Banks are constrained by a minimum capital requirement, γ_t^{BankK}, modeled as an AR(1) with very high persistence (0.999). The capital adequacy ratio $CAR_{j,t}^{b}$ mea-

[19] In addition to traditional reserve requirements on the main types of bank deposits, the Central Bank of Brazil has often used so called "additional reserve requirements", whose incidence base is the same as 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.

[20] Our modeling choice dispenses with the need to artificially introduce depreciation to bank capital

sures how much of total risk-weighted assets can be backed up by bank's net worth:

$$BI_{j,t} = \frac{Bankcap_{j,t}}{CAR^b_{j,t}} \tag{51}$$

where $CAR^b_{j,t}$ is

$$CAR^b_{j,t} = \tau_{\chi 1} B^{C,b}_{B,j,t} + \tau_{\chi 2} B^b_{E,j,t} + \tau_{\chi 3} B^{H,b}_{B,j,t} + \tau_{\chi 4} B_{OM,j,t} + \epsilon^{CAR}_{j,t} \tag{52}$$

and where $\tau_{\chi\,\bullet}$ are risk weights modeled as AR(1) processes and ϵ^{CAR}_t is an AR(1) process centered on the value of risk-weighted assets that compose actual CAR's in Brazil but that are not included in the model.

The Brazilian financial system operates with high excess of capital (5.4 p.p. above the minimum required as of 4Q2013, and 5.7 p.p. on average since 2000). After the break of the financial crisis in 2008, banks raised excess capital even further (7 p.p. above the minimum required in 2009). Although internal financing is usually costlier than external financing, the capital buffer has a potential signaling effect of banks' soundness, with positive effects on wholesale funding costs and on the probability of sudden stops in funding facilities. In addition, capital buffers can also prevent banks from falling short of the required minimum, an event that could result in undesired supervisory intervention.

We introduce precautionary capital buffer by letting banks face an appropriate cost function when deviating from the minimum capital requirement. Since the model solution is linearized around the balanced-growth path, it suffices to introduce a cost function that fulfills $\Gamma'_{bankK} < 0$, $\Gamma''_{bankK} > 0$, and, at the balanced growth path, $\Gamma_{bankK}\left(\frac{\overline{BI}}{\gamma^{BankK}}\right) = 0$, where $\frac{\overline{BI}}{\gamma^{BankK}} > 1$. For convenience, and w.l.g. since the cost parameters that affect the model dynamics are estimated, we choose the following representation:

$$\Gamma_{bankK}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right) = \frac{\chi_{bankK,2}}{2}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right)^2 + \chi_{bankK,1}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right) + \chi_{bankK,0} \tag{53}$$

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

$$
\begin{aligned}
FC^b_{j,t} = & \left(R_{E,j,t-1} - \tau_{B,E,t-1} - s^{adm,E}_{t-1}\right) B^b_{E,j,t-1} - B^b_{E,j,t} \\
& + \left(R^C_{B,j,t-1} - \tau_{B,B,t-1} - s^{adm,B}_{t-1}\right) B^{C,b}_{B,j,t-1} \\
& - B^{C,b}_{B,j,t} + R^H_{B,t-1} B^{H,b}_{B,j,t-1} - B^{H,b}_{B,j,t} \\
& + R_{t-1} B_{OM,j,t-1} - B_{OM,j,t} - R^T_{t-1} D^T_{j,t-1} + D^T_{j,t} - \Gamma_T \left(\frac{D^T_{j,t}}{D^T_{j,t-1}}\right) D^T_{j,t} \\
& - R^S_{t-1} D^S_{j,t-1} + D^S_{j,t} - D^D_{j,t-1} + D^D_{j,t} \\
& + R^T_{RR,t-1} RR^T_{j,t-1} + R^S_{RR,t-1} RR^S_{j,t-1} + R^D_{RR,t-1} RR^D_{j,t-1} \\
& + R^{add}_{RR,t-1} RR^{add}_{j,t-1} - R^{S,H}_{RR,t-1} RR^{S,H}_{j,t-1} \\
& - RR^T_{j,t} - RR^S_{j,t} - RR^D_{j,t} - RR^{add}_{j,t} + RR^{S,H}_{j,t} \\
& - \Gamma_{bankK} \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t CAR^b_{j,t}}\right) Bankcap_{j,t} \\
& - \frac{\chi_{OM}}{2} \left(\frac{B_{OM,j,t}}{Lb^b_{j,t}} - \nu^{OM}_t\right)^2 L^b_t \\
& - \frac{\chi_{d\_T}}{2} \left(\frac{D^T_{j,t}}{Lb^b_{j,t}} - \nu^{d\_T}_t\right)^2 L^b_t \\
& + \Pi^L_{j,t} + \Xi^b_{j,t}
\end{aligned} \tag{54}
$$

where s^{adm}_t are administrative costs, which we assume to be proportional to the respective loan portfolio, $\tau_{B,t}$ are tax rates on credit, $R_{RR,t}$ is the interest rate paid by the monetary authority on required reserves, χ_{OM} and χ_{d_T} are cost parameters associated with the deviation of bank holdings of liquid assets and time deposits from their targeted paths. We introduce a lump-sum transfer $\Xi^b_{j,t}$ to insure against cash flow variations originating from interest rate rigidity:

$$\Xi^b_{j,t} = \left(R_{E,t-1} - R_{E,j,t-1}\right) B^b_{E,j,t-1} + \left(R^C_{B,t-1} - R^C_{B,j,t-1}\right) B^{C,b}_{B,j,t-1} \tag{55}$$

and $\Pi^L_{j,t}$ are lump sum transfers from conglomerate branches to bank j, introduced to make aggregation straightforward:

$$\Pi^L_{j,t} = \Pi^{E,LB}_{j,t} + \Pi^{C,LB}_{j,t} + \Pi^{L,B,C}_{j,t} + \Pi^{L,B,H}_{j,t} + \Pi^{L,E}_{j,t} \tag{56}$$

$$\Pi^{E,LB}_{j,t} = B_{E,j,t} - \omega_E B_{E,t} \tag{57}$$

$$\Pi^{C,LB}_{j,t} = B^C_{B,j,t} - \omega_B B^C_{B,t} \tag{58}$$

$$\Pi^{L,B,C}_{j,t} = \gamma^{B,C} \left(1 - \tau_{\omega,t}\right) \omega_B N_{B,t} W^N_t G_{B,C} \left(\overline{\varpi}_{B,t}, \overline{\varpi}^H_{B,t}\right) - R^C_{B,t-1} B^C_{j,B,t-1} \tag{59}$$

$$\Pi^{L,B,H}_{j,t} = \gamma^{B,C} \left(1 - \tau_{\omega,t}\right) \omega_B N_{B,t} W^N_t G_{B,H} \left(\overline{\varpi}^H_{B,t}, 0\right) - R^H_{B,t-1} B^H_{j,B,t-1} \tag{60}$$

$$\Pi_{j,t}^{L,E} = \left[\gamma^E \left(R_t^K + P_{K,t}\left(1-\delta_K\right)\right) K_{t-1} G\left(\varpi_{Et}, \sigma_{E,t}\right) - R_{E,t-1} B_{j,E,t-1}\right] \tag{61}$$

Banks choose the stream of real dividend distribution $\{C_{B,j,t}\}$ to maximize

$$E_0 \left\{ \sum_{t\geq 0} \beta_{Bank}^t \left[\frac{1}{1-\sigma_B} \left(\frac{C_{B,j,t}}{\epsilon_t} \right)^{1-\sigma_B} \right] \varepsilon_t^{\beta,B} \right\} \tag{62}$$

subject to (36), (41), and (45) to (55) , where $C_{B,j,t} = div_{j,t}^b / P_{C,t}$, and $div_{j,t}^b$ are banks' nominal dividends. We assume that banks' intertemporal discount factor, β_{Bank}, is lower that of bank stockholders. This is a short-cut to modeling savers' risky investment choices, since, in practice, bank shareholders demand a return on their risky investment in bank operations that is higher than the risk-free opportunity cost R_t.

Let Λ_{jt}^{Bank} be the Lagrange multiplier associated with the capital accumulation constraint (50), $\nu_{j,t}^{Bank}$ be the Lagrange multiplier of the balance sheet constraint, and $\eta_{j,t}^{Bank,\bullet}$ be the Lagrange multiplier of the lending branches' demand for loans. First order conditions to bank j's optimization problem are:

$$\frac{1}{\epsilon_t} \left(\frac{C_{B,j,t}}{\epsilon_t} \right)^{-\sigma_B} \varepsilon_t^{\beta,B} = \Lambda_{j,t}^B \tag{63}$$

$$\begin{aligned} \Lambda_{j,t}^{Bank}\left(1-\varepsilon_t^{bankcap}\right) = & \\ \beta_{Bank} E_t \frac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}} + \nu_{j,t}^{Bank} & \\ -\Lambda_{j,t}^{Bank} \Gamma_{bankK}\left(\frac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^b}\right) - \Lambda_{j,t}^{Bank} \Gamma_{bankK}'\left(\frac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^b}\right) \frac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^b} & \\ + \Lambda_{j,t}^{Bank} \frac{\chi_{OM}}{2}\left(\frac{B_{OM,j,t}}{Lb_{j,t}^b} - \nu_t^{OM}\right)\left(\frac{B_{OM,j,t}}{Lb_{j,t}^b} + \nu_t^{OM}\right) & \\ + \Lambda_{j,t}^{Bank} \frac{\chi_{d\_T}}{2}\left(\frac{D_{j,t}^T}{Lb_{j,t}^b} - \nu_t^{d\_T}\right)\left(\nu_t^{d\_T} + \frac{D_{j,t}^T}{Lb_{j,t}^b}\right) & \end{aligned} \tag{64}$$

$$
\begin{aligned}
&\beta_{Bank} E_t \frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} \left(R^T_t - R^T_{RR,t} \tau_{RR,T,t} - R^{add}_{RR,t} \tau_{RR,add,t} \right) \\
&= \beta_{Bank} E_t \frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} \Gamma'_T \left(\frac{D^T_{j,t+1}}{D^T_{j,t}} \right) \left(\frac{D^T_{j,t+1}}{D^T_{j,t}} \right)^2 + \nu^{Bank}_{j,t} \left(1 - \tau_{RR,T,t} - \tau_{RR,add,t}\right) \\
&+ \Lambda^{Bank}_{j,t} \left[\begin{array}{c} (1 - \tau_{RR,T,t} - \tau_{RR,add,t}) - \Gamma_T \left(\frac{D^T_{j,t}}{D^T_{j,t-1}} \right) - \Gamma'_T \left(\frac{D^T_{j,t}}{D^T_{j,t-1}} \right) \frac{D^T_{j,t}}{D^T_{j,t-1}} \\ + \frac{\chi_{OM}}{2} \left(\frac{B_{OM,j,t}}{Lb^b_{j.t}} - \nu^{OM}_t \right) \left(\frac{B_{OM,j,t}}{Lb^b_{j,t}} + \nu^{OM}_t \right) \\ + \frac{\chi_{d\_T}}{2} \left(\frac{D^T_{j,t}}{Lb^b_{j,t}} - \nu^{d\_T}_t \right) \left(\frac{D^T_{j,t}}{Lb^b_{j,t}} + \nu^{d\_T}_t - 2 \right) \end{array} \right]
\end{aligned} \tag{65}
$$

$$
\begin{aligned}
\Lambda^{Bank}_{j,t} &= \beta_{Bank} E_t \frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} R_t - \nu^{Bank}_{j,t} \\
&+ \gamma^{BankK}_t \tau_{\chi 4} \Lambda^{Bank}_{j,t} \Gamma'_{bankK} \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_t} \right) \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_t} \right)^2 \\
&- \Lambda^{Bank}_{j,t} \chi_{OM} \left(\frac{B_{OM,j,t}}{L^b_t} - \nu^{OM}_t \right)
\end{aligned} \tag{66}
$$

$$
\begin{aligned}
\Lambda^{Bank}_{j,t} &= \beta_B E_t \frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} \left(R_{E,j,t} - \tau_{B,E,t} - s^{adm,E}_t \right) - \nu^{Bank}_{j,t} - \eta^{Bank,E}_{j,t} \\
&+ \Lambda^{Bank}_{j,t} \tau_{\chi 2} \gamma^{BankK}_t \Gamma'_{bankK} \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_t} \right) \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_t} \right)^2
\end{aligned} \tag{67}
$$

$$
\begin{aligned}
\Lambda^{Bank}_{j,t} &= \beta_{Bank} E_t \frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} \left(R^C_{B,j,t} - \tau_{B,B,t} - s^{adm,B}_t \right) - \nu^{Bank}_{j,t} - \eta^{Bank,BC}_{j,t} \\
&+ \Lambda^{Bank}_{j,t} \gamma^{BankK}_t \tau_{\chi 1} \Gamma'_{bankK} \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_{j,t}} \right) \left(\frac{Bankcap_{j,t}}{\gamma^{BankK}_t \ CAR^b_{j,t}} \right)^2
\end{aligned} \tag{68}
$$

$$
\begin{aligned}
&R^O_{E,j,t} \beta_B E_t \sum_{i \geq 0} \xi^i_E \beta^i_{Bank} \frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}} \frac{B^b_{E,j,t+i}}{P_{C,t+i}} \\
&= \frac{\mu^R_E}{\mu^R_E - 1} E_t \sum_{i \geq 0} \xi^i_E \beta^i_{Bank} \eta^{Bank,E}_{j,t+i} \frac{B^b_{E,j,t+i}}{P_{C,t+i}}
\end{aligned} \tag{69}
$$

$$R^{C,O}_{B,j,t}\beta_{Bank}E_t\sum_{i\geq 0}\xi^i_{B,C}\beta^i_{Bank}\frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}}$$
$$= \frac{\mu^R_{B,C}}{\mu^R_{B,C}-1}E_t\sum_{i\geq 0}\xi^i_{B,C}\beta^i_{Bank}\eta^{Bank,BC}_{j,t+i}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}} \tag{70}$$

First order conditions for consumer lending rates can be recursively represented as:

$$R^{C,O}_{B,j,t}\beta_{Bank}\aleph^{R,BC,2}_{j,t} = \frac{\mu^R_{B,C}}{\mu^R_{B,C}-1}\aleph^{R,BC,1}_{j,t} \tag{71}$$

$$\aleph^{R,BC,1}_{j,t} = E_t\sum_{i\geq 0}\xi^i_{B,C}\beta^i_{Bank}\eta^{Bank,BC}_{j,t+i}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}}$$
$$= \eta^{Bank,BC}_{j,t}\frac{B^{C,b}_{B,j,t}}{P_{C,t}} + \xi_{B,C}\beta_{Bank}E_t\aleph^{R,BC,1}_{j,t+1}$$

$$\aleph^{R,BC,2}_{j,t} = E_t\sum_{i\geq 0}\xi^i_{B,C}\beta^i_{Bank}\frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}}$$
$$= \frac{B^{C,b}_{B,j,t}}{P_{C,t}}E_t\frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} + \xi_{B,C}\beta_{Bank}\aleph^{R,BC,2}_{j,t+1}$$

Commercial lending rates have analogous representations.

The FOCs show that the relevant opportunity cost for the bank is not just the base rate. Holding fixed the impact in the following period, higher capital buffers and deviations from optimal time deposit balances increase banks' opportunity cost. For small deviations of the liquidity buffer from the target, greater liquidity decreases the opportunity cost so that loans can have more appealing rates to banks' clients. On the other hand, when there is shortage of liquidity, the opportunity cost increases and loans get more expensive, which will generate some asset reshuffling. Since $\beta_{Bank} < \beta_S$, the shadow price of one additional unit of bank capital in the balanced-growth path is higher than one unit of external funds.

2.5.5 Aggregating the bank conglomerate

The insurance $\Xi^b_{j,t}$ eliminates the heterogeneity that arises from interest rate rigidity, and allows for a uniform representation of banks' decisions. Aggregate variables are:

$$Bankcap_t = \int_0^1 \omega_{b,j} Bankcap_{j,t} dj \tag{72}$$

$$B^b_{E,t} = \int_0^1 \omega_{b,j} B^b_{E,j,t} dj; \quad B^{C,b}_{B,t} = \int_0^1 \omega_{b,j} B^{C,b}_{B,j,t} dj \tag{73}$$

$$D^T_t = \int_0^1 \omega_{b,j} D^T_{j,t} dj; \quad D^D_t = \int_0^1 \omega_{b,j} D^D_{j,t} dj; \quad D^S_t = \int_0^1 \omega_{b,j} D^S_{j,t} dj; \tag{74}$$

$$\frac{1}{\epsilon_t}\left(\frac{C_{B,t}}{\epsilon_t}\right)^{-\sigma_B} \varepsilon^{\beta,B}_t = \Lambda^B_t \tag{75}$$

$$\begin{aligned}\Lambda^{Bank}_t\left(1-\varepsilon^{bankcap}_t\right) &= \beta_{Bank} E_t \frac{\Lambda^{Bank}_{t+1}}{\pi_{C,t+1}} + \nu^{Bank}_t \\ &- \Lambda^{Bank}_t \Gamma_{bankK}\left(\frac{Bankcap_t}{\gamma^{BankK}_t CAR^b_t}\right) \\ &- \Lambda^{Bank}_t \Gamma'_{bankK}\left(\frac{Bankcap_t}{\gamma^{BankK}_t CAR^b_t}\right)\frac{Bankcap_t}{\gamma^{BankK}_t CAR^b_t} \\ &+ \Lambda^{Bank}_t \frac{\chi_{OM}}{2}\left(\frac{B_{OM,t}}{Lb^b_t} - \nu^{OM}_t\right)\left(\frac{B_{OM,t}}{Lb^b_t} + \nu^{OM}_t\right) \\ &+ \Lambda^{Bank}_t \frac{\chi_{d\_T}}{2}\left(\frac{D^T_t}{Lb^b_t} - \nu^{d\_T}_t\right)\left(\nu^{d\_T}_t + \frac{D^T_t}{Lb^b_t}\right)\end{aligned} \tag{76}$$

$$\beta_{Bank} E_t \frac{\Lambda^{Bank}_{t+1}}{\pi_{C,t+1}}\left(R^T_t - R^T_{RR,t}\tau_{RR,T,t} - R^{add}_{RR,t}\tau_{RR,add,t}\right) \tag{77}$$

$$\begin{aligned}&= \beta_{Bank} E_t \frac{\Lambda^{Bank}_{t+1}}{\pi_{C,t+1}} \Gamma'_T\left(\frac{D^T_{t+1}}{D^T_t}\right)\left(\frac{D^T_{t+1}}{D^T_t}\right)^2 + \nu^{Bank}_t\left(1-\tau_{RR,T,t}-\tau_{RR,add,t}\right) \\ &+ \Lambda^{Bank}_{j,t}\left[\begin{array}{c}\left(1-\tau_{RR,T,t}-\tau_{RR,add,t}\right) - \Gamma_T\left(\frac{D^T_t}{D^T_{t-1}}\right) - \Gamma'_T\left(\frac{D^T_t}{D^T_{t-1}}\right)\frac{D^T_t}{D^T_{t-1}} \\ +\frac{\chi_{OM}}{2}\left(\frac{B_{OM,t}}{Lb^b_t} - \nu^{OM}_t\right)\left(\frac{B_{OM,t}}{Lb^b_t} + \nu^{OM}_t\right) \\ +\frac{\chi_{d\_T}}{2}\left(\frac{D^T_t}{Lb^b_t} - \nu^{d\_T}_t\right)\left(\frac{D^T_t}{Lb^b_t} + \nu^{d\_T}_t - 2\right)\end{array}\right]\end{aligned} \tag{78}$$

$$\Gamma_T\left(\frac{D^T_t}{D^T_{t-1}}\right) \equiv \phi_T/2\left(\frac{D^T_t}{D^T_{t-1}}\varepsilon^{DT}_t - g_{\epsilon,t}\pi_{C,t}\right)^2 \tag{79}$$

$$\Gamma'_T\left(\frac{D_t^T}{D_{t-1}^T}\right) \equiv \phi_T\left(\frac{D_t^T}{D_{t-1}^T}\varepsilon_t^{DT} - g_{\epsilon,t}\pi_{C,t}\right)\varepsilon_t^{DT} \tag{80}$$

$$\begin{aligned}\Lambda_t^{Bank} &= \beta_{Bank}E_t\frac{\Lambda_{t+1}^{Bank}}{\pi_{C,t+1}}R_t - \nu_t^{Bank} \\ &+ \gamma_t^{BankK}\tau_{\chi 4}\Lambda_t^{Bank}\Gamma'_{bankK}\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)^2 \\ &- \Lambda_t^{Bank}\chi_{OM}\left(\frac{B_{OM,t}}{Lb_t^b} - \nu_t^{OM}\right)\end{aligned} \tag{81}$$

$$\begin{aligned}\Lambda_t^{Bank} &= \beta_B E_t\frac{\Lambda_{t+1}^{Bank}}{\pi_{C,t+1}}\left(R_{E,j,t} - \tau_{B,E,t} - s_t^{adm,E}\right) - \nu_t^{Bank} - \eta_t^{Bank,E} \\ &+ \Lambda_t^{Bank}\tau_{\chi 2}\gamma_t^{BankK}\Gamma'_{bankK}\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)^2\end{aligned} \tag{82}$$

$$\begin{aligned}\Lambda_t^{Bank} &= \beta_{Bank}E_t\frac{\Lambda_{t+1}^{Bank}}{\pi_{C,t+1}}\left(R_{B,j,t}^C - \tau_{B,B,t} - s_t^{adm,B}\right) - \nu_t^{Bank} - \eta_t^{Bank,BC} \\ &+ \Lambda_t^{Bank}\gamma_t^{BankK}\tau_{\chi 1}\Gamma'_{bankK}\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t^b}\right)^2\end{aligned} \tag{83}$$

$$R_{E,t}^O\beta_{Bank}\aleph_t^{R,E,2} = \frac{\mu_E^R}{\mu_E^R - 1}\aleph_t^{R,E,1} \tag{84}$$

$$\aleph_t^{R,E,1} = \eta_t^{Bank,E}\frac{B_{E,t}^b}{P_{C,t}} + \xi_E\beta_{Bank}E_t\aleph_{t+1}^{R,E,1}$$

$$\aleph_t^{R,E,2} = \frac{B_{E,t}^b}{P_{C,t}}E_t\frac{\Lambda_{t+1}^{Bank}}{\pi_{C,t+1}} + \xi_E\beta_{Bank}E_t\aleph_{t+1}^{R,E,2}$$

$$R_{B,t}^{C,O}\beta_{Bank}\aleph_t^{R,BC,2} = \frac{\mu_{B,C}^R}{\mu_{B,C}^R - 1}\aleph_t^{R,BC,1} \tag{85}$$

$$\aleph_t^{R,BC,1} = \eta_t^{Bank,BC}\frac{B_{B,t}^{C,b}}{P_{C,t}} + \xi_{B,C}\beta_{Bank}E_t\aleph_{t+1}^{R,BC,1}$$

$$\aleph_t^{R,BC,2} = \frac{B_{B,t}^{C,b}}{P_{C,t}}E_t\frac{\Lambda_{t+1}^{Bank}}{\pi_{C,t+1}} + \xi_{B,C}\beta_{Bank}E_t\aleph_{t+1}^{R,BC,2}$$

$$\Pi_t^L = \int_0^1 \omega_{b,j} \Pi_{j,t}^L dj \tag{86}$$

Interest rates on commercial loans can be recursively represented as

$$1 = \left(1 - \xi_E^R\right) \left(\frac{R_{E,t}^O}{R_{E,t}} \right)^{\frac{1}{1-\mu_E^R}} + \xi_E^R \left(\frac{R_{E,t-1}}{R_{E,t}} \right)^{\frac{1}{1-\mu_E^R}}$$

Similarly, for consumer loans:

$$1 = \left(1 - \xi_{B,C}^R\right) \left(\frac{R_{B,t}^{C,O}}{R_{B,t}^C} \right)^{\frac{1}{1-\mu_{B,C}^R}} + \xi_{B,C}^R \left(\frac{R_{B,t-1}^C}{R_{B,t}^C} \right)^{\frac{1}{1-\mu_{B,C}^R}}$$

In addition,

$$\Delta_{E,t}^R = \left(1 - \xi_E^R\right) \left(\frac{R_{E,t}^O}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} + \xi_E^R \left(\frac{R_{E,t-1}}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} \Delta_{E,t-1}^R$$

$$\Delta_{B,C,t}^R = \left(1 - \xi_{B,C}^R\right) \left(\frac{R_{B,t}^{C,O}}{R_{B,t}^C} \right)^{-\frac{\mu_{B,C}^R}{\mu_{B,C}^R - 1}} + \xi_{B,C}^R \left(\frac{R_{B,t-1}^C}{R_{B,t}^C} \right)^{-\frac{\mu_{B,C}^R}{\mu_{B,C}^R - 1}} \Delta_{B,C,t-1}^R$$

$$\begin{aligned} B_{E,t}^b &= \omega_E B_{E,t} \Delta_{E,t}^R \\ B_{B,t}^{C,b} &= \omega_B B_{B,t}^C \Delta_{B,C,t}^R \\ \Pi_t^{E,LB} &= B_{E,t}^b - \omega_E B_{E,t} \\ \Pi_t^{C,LB} &= B_{B,t}^{C,b} - \omega_B B_{B,t}^C \end{aligned}$$

Banks' balance sheets and dividends are aggregated as:

$$\begin{aligned} &B_{E,t}^b + B_{B,t}^{C,b} + B_{B,t}^{H,b} + B_{OM,t} + RR_t^T + RR_t^S + RR_t^D + RR_t^{add} + RR_t^{S,H} \\ &= D_t^T + D_t^S + D_t^D + Bankcap_t \end{aligned} \tag{87}$$

$$
\begin{aligned}
P_{C,t}C_{B,j,t} = {} & Bankcap_{t-1} - \left(1-\varepsilon_t^{bankcap}\right) Bankcap_t \\
& - R^T_{t-1}D^T_{t-1} - R^S_{t-1}D^S_{t-1} - D^D_{t-1} - \Gamma_T\left(\frac{D^T_t}{D^T_{t-1}}\right) D^T_t \\
& + R^T_{RR,t-1}RR^T_{t-1} + R^S_{RR,t-1}RR^S_{t-1} + RR^D_{t-1} + R^{add}_{RR,t-1}RR^{add}_{t-1} - R^{S,H}_{RR,t-1}RR^{S,H}_{t-1} \\
& + D^T_t + D^S_t + D^D_t + R_{t-1}B_{OM,t-1} \\
& + \gamma^{B,C}\left(1-\tau_{\omega,t}\right)\omega_B N_{B,t}W^N_t G_{B,C}\left(\overline{\varpi}_{B,t}, \overline{\varpi}^H_{B,t}\right) \\
& + \gamma^{B,C}\left(1-\tau_{\omega,t}\right)\omega_B N_{B,t}W^N_t G_{B,H}\left(\overline{\varpi}^H_{B,t}, 0\right) \\
& + \gamma^{E}\left(R^K_t + P_{K,t}\left(1-\delta_K\right)\right) K_{t-1}G\left(\varpi_{Et}, \sigma_{E,t}\right) \\
& - RR^T_t - RR^S_t - RR^D_t - RR^{add}_t + RR^{S,H}_t \\
& - \Gamma_{bankK}\left(\frac{Bankcap_t}{\gamma_t^{BankK}CAR_t}\right) Bankcap_t \\
& - \frac{\chi_{OM}}{2}\left(\frac{B_{OM,t}}{Lb_t} - \nu^{OM}_t\right)^2 Lb_t - \frac{\chi_{d\_T}}{2}\left(\frac{D^T_t}{Lb_t} - \nu^{d\_T}_t\right)^2 Lb_t \\
& - \left(\tau_{B,E,t-1} + s^{adm,E}_{t-1}\right) B^b_{E,t-1} - \left(\tau_{B,B,t-1} + s^{adm,B}_{t-1}\right) B^{C,b}_{B,t-1} \\
& - B_{OM,t} - \omega_B B^C_{B,t} - \omega_B B^H_{B,t} - \omega_E B_{E,t}
\end{aligned} \tag{88}
$$

Finally, aggregation of reserve requirements results in

$$RR^D_t = \tau_{RR,D,t}D^D_t$$

$$
\begin{aligned}
RR^T_t &= \tau_{RR,T,t}D^T_t \\
RR^S_t &= \tau_{RR,S,t}D^S_t \\
RR^{add}_t &= \tau_{RR,add,t}\left(D^D_t + D^T_t + D^S_t\right) \\
RR^{S,H}_t &= \left(\tau_{H,S,t}D^S_t - B^H_{B,t}\right)
\end{aligned}
$$

2.6 Government

The government is composed of a monetary and a fiscal authority. The monetary authority makes the following decisions: 1) the base rate of the economy; 2) ratios and the remuneration of reserve requirements; 3) capital requirement ratio; 4) housing loans lending rate. The fiscal authority purchases goods, issues public bonds, levies taxes, and makes lump sum transfers to households.

2.6.1 The monetary authority

The base interest rate is set by the monetary authority according to:

$$R_t^4 = \left(R_{t-1}^4\right)^{\rho_R} \left[\left(E_t \frac{P_{C,t+4}}{P_{C,t}} \frac{1}{\overline{\pi}_t^4} \right)^{\gamma_\pi} \left(\frac{gdp_t}{gdp} \right)^{\gamma_Y} R^4 \right]^{1-\rho} \varepsilon_t^R \tag{89}$$

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 $gdp_t = \frac{GDP_t}{\epsilon_t}$ is the stationary level of output that excludes banking costs:

$$GDP_t = Y_t - T_{bank,t} \tag{90}$$

$$\begin{aligned} T_{bank,t} = {} & s_{t-1}^{adm,E} \omega_E B_{E,t-1} + s_{t-1}^{adm,B} \omega_B B_{B,t-1}^C \\ & + \frac{\chi_{OM,t-1}}{2} \left(\frac{B_{OM,t-1}}{Lb_{t-1}} - \nu_{t-1}^{OM} \right)^2 \times L_{t-1}^b \\ & + \Gamma_T \left(D_{t-1}^T \right) D_{t-1}^{T,wb} \\ & + \frac{\chi_{d\_T}}{2} \left(\frac{D_{t-1}^T}{L_{t-1}^b} - \nu_{t-1}^{d\_T} \right)^2 L_{t-1}^b \\ & + \gamma_t^E \ \mu_E \ \left(R_t^K + P_{K,t} \left(1 - \delta_K\right) \right) \omega_E K_{E,t-1} J\left(\overline{\varpi}_{E,t}\right) \\ & + \gamma_t^{B,C} \left(1 - \tau_{w,t}\right) \omega_B N_{B,t} W_t \ \mu_{B,C} \ \left[J\left(\overline{\varpi}_{B,t}\right) - J\left(\overline{\varpi}_{B,t}^H\right) - \overline{\varpi}_{B,t}^H \left(F\left(\overline{\varpi}_{B,t}\right) - F\left(\overline{\varpi}_{B,t}^H\right) \right) \right] \\ & + \gamma_t^{B,C} \left(1 - \tau_{w,t}\right) \omega_B N_{B,t} W_t \ \mu_{B,H} \ J\left(\overline{\varpi}_{B,t}^H\right) \end{aligned} \tag{91}$$

where

$$J\left(\overline{\varpi}_{B,t}\right) = \aleph_{cdf} \left(\frac{\log\left(\overline{\varpi}_{B,t}\right)}{\sigma_B} - \frac{\sigma_B}{2} \right)$$

$$J\left(\overline{\varpi}_{B,t}^H\right) = \aleph_{cdf} \left(\frac{\log\left(\overline{\varpi}_{B,t}^H\right)}{\sigma_B} - \frac{\sigma_B}{2} \right)$$

$$\left(\overline{\varpi}_{E,t}\right) = \aleph_{cdf} \left(\frac{\log\left(\overline{\varpi}_{E,t}\right)}{\sigma_E} - \frac{\sigma_E}{2} \right)$$

The time varying inflation target follows

$$\overline{\pi}_t^4 = \left(\overline{\pi}_{t-1}^4\right)^{\rho_{\overline{\pi}^4}} \left(\overline{\pi}^4\right)^{1-\rho_{\overline{\pi}^4}} \varepsilon_t^{\overline{\pi}^4} \tag{92}$$

The rules for the other instruments set by the monetary authority are described in (32), (42), (46), (47), (48), and (52).

2.6.2 The fiscal authority

The fiscal authority consumes final goods according to the rule:

$$\frac{G_t}{\epsilon_t} = \rho_g \left(\frac{G_{t-1}}{\epsilon_{t-1}}\right) + (1-\rho_g)\left(g - \mu_{B,G}\left(\frac{B_{t-1} + RR^D_{t-1} + RR^T_{t-1} + RR^S_{t-1} + RR^{add}_{t-1}}{P_{C,t-1}\epsilon_{t-1}} - \left(b + rr^D + rr^T + rr^S + rr^{add}\right)\right)\right) + \varepsilon^G_t \tag{93}$$

where lower-case variables denote stationary variables, and g is the steady state value of stationary government consumption. Government consumption has a role in stabilizing gross public sector debt, which incorporates central bank's liabilities.

Public debt issued by the government meets the demand from the retail money fund and the wholesale bank:

$$B_t = B_{OM,t} + B_{F,t} \tag{94}$$

Tax rates $\tau_{C,t}, \tau_{w,t}, \tau_{\Pi,t}$,and $\tau_{B,B,t}$ follow AR(1) processes around their steady states[21].

The joint public sector budget constraint is

$$\begin{aligned} &P_{G,t}G_t + TT_t \\ &- R^{S,H}_{t-1}RR^{S,H}_{t-1} \\ &+ RR^D_{t-1} + R^{RR,T}_{t-1}RR^T_{t-1} + R^{RR,S}_{t-1}RR^S_{t-1} + R^{RR,add}_{t-1}RR^{add}_{t-1} + R_{t-1}B_{t-1} \\ &= \tau_{w,t}\Pi^{LU}_t + \tau_{\Pi,t}\Pi_t + \tau_{\Pi,t}\nu^b\Pi^b_t + \tau_{w,t}W^N_t N_t + \tau_{C,t}P_{C,t}C_t \\ &+ \omega_E\tau_{B,E,t-1}B_{E,t-1} + \omega_B\tau_{B,B,t-1}B^C_{B,t-1} \\ &+ RR^D_t + RR^T_t + RR^S_t + RR^{add}_t - RR^{S,H}_t + B_t \end{aligned} \tag{95}$$

2.7 Market clearing

Market clearing requires that the following equalities hold:

$$Y^d_t = Y^{C,d}_t + Y^{G,d}_t + Y^{I_K,d}_t + Y^{IH,d}_t \tag{96}$$

$$Y^{G,d}_t = G_t \tag{97}$$

$$Y^{IH,d}_t = I_{H,t} \tag{98}$$

$$Y^{IK,d}_t = I_{K,t} \tag{99}$$

[21] Due to lack of time series of tax levied on financial intermediation, disaggregated into private individuals and firms, we assume that $\tau_{B,E,t}$ is a fixed proportion of $\tau_{B,B,t}$.

$$Y_t^C = C_t \tag{100}$$

3 The steady state and calibrated parameters

The model variables were stationarized by dividing real variables by the technology shock ϵ_t and nominal variables by both the technology shock and the consumer price level, P_t^C.

Pinning down the steady state of the Brazilian economy is an exercise that involves a great amount of judgement. Most series have trends, and long series are the exception, not the rule. In addition, some markets have been deepening over the past years, adding uncertainty about what is trend, what is transition, or what is structural change. The prescription of using filtered series when trends are an issue does not apply indistinctly to Brazilian data. Filtered series in many cases give the wrong idea of where economic variables are in the business cycle.

With that in mind, we followed two different strategies to calibrate the steady state. The main economic ratios were fixed according to their average during the inflation targeting period (Table 1)[22]. GDP growth and the base rate were also fixed according to the average in this period.

We chose to calibrate credit and deposits as a share of GDP, as well as lending rates and the markdown of savings rates, according to the most recent observations in the data. The reasons for this choice are as follows. Bank series in Brazil show serious trends and possible issues related to transition (Figure 1). Over the past decade, credit-to-GDP ratios have accelerated. Much of this acceleration is attributed to the financial deepening of the economy, a consequence of greater social inclusion and a prolonged period of macroeconomic stability with low inflation. Yet, the current levels of credit-to-GDP are still low compared to the rest of the world, and credit growth has been strongly financed stable funding. In fact, credit-to-time deposits has declined during most part of the credit acceleration period. We expect the financial deepening of the economy to continue allowing for further rounds of sustainable credit expansion.

The ex-ante default ratios in the steady state were set at 2.9% for investment loans and 7% for consumer loans, in line with recent available data on actual default. We fixed steady state lending rates and balances as shares of GDP, in addition to banking spread components. We set the variance of the idiosyncratic shock to entrepreneur's collateral value (σ_E) to 0.58 to calibrate capital depreciation at 1.5% per quarter. The variance of the idiosyncratic shock to borrower's committed income (σ_B) was fixed at 0.2[23]. From these assumptions, all the remaining variables related to finan-

[22]In this table, GDP ratios are expressed in terms of yearly GDP. In the implementation of the model, the ratios were all computed in terms of quarterly GDP.

[23]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.

cial 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 at the actual average of the Brazilian Financial System[24] from the beginning of the series on December 2000. Required capital was set at 11%, the regulatory rate for tier-1 capital since the implementation of Basle 1. Risk weights on bank assets were set at the actual values reported by Brazilian banks on portfolios that are related to the ones included in our 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 which would represent a 17.5% nominal return on banks' dividends[25].

Reserve requirement ratios were fixed at the average of their 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 2013. Average additional reserves were calculated from the series starting on 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[26].

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[27].

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[28]. We also assumed that the government does not make transfers to borrowers[29].

[24]The reported capital adequacy ratio does not include development banks, such as the National Development Bank (BNDES).

[25]The impulse responses are not sensitive to this parameterization as long as $0.9 << \beta_{Bank} < \beta_S$. Values near the lower bound generate unlikely responses to monetary policy shocks.

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

[27]www.bcb.gov.br/?spread

[28]Since the LTV ratio in housing loans was 0.6 in 2012, we assumed that the value of the collateral in this market was twice the stock of loans divided by the LTV ratio.

[29]By the time we finished this version of the paper, we had not had access to data on debt

From the assumed ratios of banks' balance sheet components, we obtained the steady state balance of public bonds at banks' assets, and consequently pinned down banks' liquidity target. From the assumed ratio of public debt, we calibrated the total stock of public bonds in the economy and at the retail money fund's portfolio.

4 Estimation

The model was linearized by Dynare around the steady state and estimated using Bayesian techniques. We used the following time series as observables, sampled from the inflation targeting regime in Brazil (1999:Q3 to 2013:Q4)[30]:

- Consumer inflation $\left(\pi_{C,t}^{obs}\right)$: inflation index used to assess compliance with the inflation target (IPCA - Índice de Preços ao Consumidor Amplo – IBGE).
- Inflation target $\left(\bar{\pi}_{C,t}^{obs}\right)$: 4-quarter-ahead actual inflation target.
- Nominal interest rate $\left(R_t^{obs}\right)$: quarterly effective nominal base rate (Selic).
- Aggregate private consumption $\left(c_t^{obs}\right)$: share of seasonally adjusted private consumption in nominal values to the seasonally adjusted proxy for a closed economy nominal GDP. The proxy for a closed economy GDP was calculated as the sum of the nominal values of private and public consumption and fixed capital formation.
- Government consumption $\left(g_t^{obs}\right)$: share of seasonally adjusted government consumption in nominal values to the seasonally adjusted proxy for a closed economy nominal GDP.
- Unemployment $\left(U_t^{obs}\right)$: Brazilian National Statistics Institute (IBGE)'s new unemployment series with missing values filled up by an interpolation of a series econometrically built from IBGE's discontinued series of unemployment. The resulting series was detrended by its mean from 1999Q1 to 2012Q1.
- Real wage change $\left(\Delta w_t^{obs}\right)$: quarterly change in IBGE's seasonally adjusted real wage series with missing values filled up by an interpolation of a series econometrically built from IBGE's discontinued series of real wages.
- GDP $\left(\widehat{gdp}_t^{obs}\right)$: HP cycle of the log of the proxy for the real GDP of the closed economy. This proxy was constructed by deflating the proxy for the closed economy nominal GDP by a composite of consumer and producer price inflation, to proxy for the quarterly GDP deflator.
- Installed capacity utilization $\left(u_t^{obs}\right)$: quarterly capacity utilization published by Fundação Getúlio Vargas, demeaned by the average from 1999Q1 to 2012Q2.

commitment by indebted households. We thus fixed borrowers' participation in the labor market under the arbitrary assumption that indebted households in Brazil have a debt commitment of 50% of their annual labor income.

[30]Missing variables were filled up with standard Dynare routines.

- Bank capital $\left(bankcap_t^{obs}\right)$: Brazilian financial system's core capital as defined by the Central Bank of Brazil, as a share of quarterly nominal GDP. Both series are seasonally adjusted.

- Capital adequacy ratio $\left(CAR_t^{obs}\right)$: actual average capital adequacy ratio of the Brazilian financial system

- Commercial loans $\left(b_{E,t}^{obs}\right)$: stock outstanding of investment loans granted by banks with freely allocated funds as a share of quarterly nominal GDP. Both series are seasonally adjusted.

- Consumer loans $\left(b_{B,t}^{C,obs}\right)$: stock outstanding of consumer loans granted by banks with freely allocated funds as a share of quarterly nominal GDP. Both series are seasonally adjusted.

- Housing loans $\left(b_{B,t}^{H,obs}\right)$: stock outstanding of regulated mortgage loans to households as a share of quarterly nominal GDP. Both series are seasonally adjusted.

- Lending spread for commercial loans $\left(\check{R}_{E,t}^{L,obs}\right)$: Ratio between the quarterly effective nominal interest rate on investment loans granted with freely allocated funds and the base rate. The lending rates on each type of loan are weighted by their respective stock outstanding. Missing observations at the beginning of the series were filled up by an interpolation of the series of lending rates on consumer loans.

- Lending spread for consumer loans $\left(\check{R}_{B,C,t}^{L,obs}\right)$: Ratio between the quarterly effective nominal interest rate on consumer loans granted with freely allocated funds and the base rate. The lending rates on each type of loan are weighted by their respective stock outstanding.

- Lending spread for housing loans $\left(\check{R}_{B,H,t}^{L,obs}\right)$: Ratio between the quarterly effective nominal interest rate on housing loans granted with freely allocated banks' funds and the base rate. The lending rates on each type of loan are weighted by their respective stock outstanding. Although the bulk of housing loans in Brazil are granted with mandatorily allocated funds, the series for lending rates on these loans is only available from September 2000 onwards.

- Default rate on commercial loans $\left(default_{E,t}^{obs}\right)$: investment loans in arrears for over 90 days as a share of total outstanding investment loans.

- Default rate on consumer loans $\left(default_{B,t}^{obs}\right)$: consumer loans in arrears for over 90 days as a share of total outstanding consumer loans.

- Time deposits $\left(d_t^{T,obs}\right)$: quarterly average of the total stock of non-financial institutions' and households' time deposits held by the Brazilian financial system as a share of nominal quarterly GDP. Both series are seasonally adjusted.

- Demand deposits $\left(d_t^{D,obs}\right)$: quarterly average of the total stock of non-financial institutions' and households' demand deposits held by the Brazilian financial system as a share of nominal quarterly GDP. Both series are seasonally adjusted.

- Savings deposits $\left(d_t^{S,obs}\right)$: quarterly average of the total stock of non-financial institutions' and households' savings accounts in the Brazilian financial system as a share of nominal quarterly GDP. Both series are seasonally adjusted.
- Markdown on savings rates $\left(\mu_t^{R^S,obs}\right)$: Ratio between the quarterly effective nominal interest rate on savings accounts and the base rate.
- Required reserve ratio on time deposits $\left(rr_t^{T,obs}\right)$: quarterly average balance of required reserves on time deposits held at the central bank as a share of the total balance of non-financial institutions' and households' time deposits held by the Brazilian financial system.
- Required reserve ratio on demand deposits $\left(rr_t^{D,obs}\right)$: quarterly average balance of non-remunerated required reserves on demand deposits held at the central bank as a share of the total balance of non-financial institutions' and households' demand deposits held by the Brazilian financial system.
- Required reserve ratio on savings deposits $\left(rr_t^{S,obs}\right)$: quarterly average balance of required reserves on savings accounts held at the central bank as a share of the total balance of non-financial institutions' and households' savings deposits held by the Brazilian financial system.
- Additional required reserves ratio $\left(rr_t^{add,obs}\right)$: quarterly average balance of supplementary required reserves on demand, time and savings deposits held at the central bank as a share of the total balance of demand, time and savings deposits held by the Brazilian financial system on behalf of non-financial institutions and households. Although the incidence base of additional required reserves singles out each type of deposit, we choose a simplified approach to calculate the aggregate effective required reserve ratio.
- Civil construction $\left(const_t^{obs}\right)$: quarterly change in IBGE's seasonally adjusted index of civil construction.

Employment in the model was mapped into the unemployment series according to:

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

$$\Delta w_t^{obs} = \frac{W_t/P_t^C\epsilon_t}{W_{t-1}/P_{t-1}^C\epsilon_{t-1}}/\Delta n \tag{101}$$

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

For the choice of prior means, we used information from Brazilian-specific empirical evidence, whenever available, or followed the related literature. We tried to compensate for the arbitrariness in the choice of some priors by setting large confidence intervals. Table 2 shows the results of the estimation, including prior and posterior moments[31].

5 The Transmission Channel of Macroprudential Policies

5.1 Reserve requirement shocks

To analyze the transmission channel of reserve requirements (RR), their ratios were shocked at 10 p.p., a reasonable magnitude considering Brazil's recent history. This implies that RR on demand deposits rise on impact to 59.6%, from the steady state level of 49.6%, RR on time deposits rise to 21% from 11%, RR on savings accounts rise to 28% from 18%, and the additional RR rises to 17.7% from 7.7%.

Figure 6 shows the 10 p.p. shock to (unremunerated) RR on demand deposits $\left(\left(\tau^{D}_{RR,t}\right)\right)$ [32]. This instrument has a small contractionist impact on the real economy. Although this might seem at odds with the literature, we argue below that the small base of incidence has an important contribution to this result. The most important effects are restricted to banks' balance sheets, with some spillover to capital and housing investment decisions. On impact, banks immediately unleash liquidity and cut down on dividend distribution to alleviate the burden of strained liquidity. Funding from time deposits increases only gradually due to nominal rigidities. The liquidity strain causes an important increase in banks' funding cost, which is only partially passed through to final lending rates, since leverage is not put under great pressure in the real economy. Higher lending rates of commercial loans reduce the demand for investment goods, which drives down the price of capital, further constraining credit conditions in the commercial segment. The overall impact of this shock on banks' balance sheet slightly improves the capital adequacy ratio.

A shock to (remunerated) RR on time deposits (Figure 7) has a much stronger impact on the economy. The transmission channel differs with respect to banks' dividend distribution. Since this reserve is remunerated at the base rate, the loss of revenues from interest rate accrued on bank assets is not as in the case of an increase in unremunerated RR. As a result, banks choose not to retain dividends. A shock to (remunerated) RR on savings accounts (Figure 8) is qualitatively similar, yet the amplitude of the responses is lower given the smaller incidence base.

The total balance of time deposits in Brazil is almost eight times as large as that of demand deposits. A fair comparison of the potential impact of RR needs to take into account the size of their incidence base. After scaling the shocks to generate an equivalent impact in terms of the amount of funds seized by the central bank, we

[31] We ran 2 chains of 180,000 draws of the Metropolis Hastings to estimate the posterior.

[32] We computed Bayesian impulse responses to the shocks in the model using the standard Dynare toolkit. 95% confidence intervals are plotted in Bayesian IRFs alongside the estimated mean response.

obtain the traditional prediction that reserve requirements on demand deposits have stronger marginal impact on the economy mostly through the direct impact on banks' profits and less so on banks' balance sheet allocations. In particular, we applied a 50 p.p. shock to RR on demand deposits, a 7 p.p. shock to RR on time deposits, and a 15 p.p. shock to RR on savings deposits. Figure 12 compares the impulse responses [33]. In all cases, monetary policy was kept unresponsive so that we could evaluate the full impact of RR.

In Brazil, reserve requirements on time deposits have been the instrument of choice when the central bank needs to drain liquidity from the economy. There is an implicit assumption that this would be the least distortionary instrument for this purpose. However, the frictions introduced in the optimal bank balance sheet allocation in our model, and that are validated by the estimation, imply that an exogenously imposed asset allocation is costly to the bank, and thus higher funding costs translate into higher lending rates. This has important policy implications[34].

The literature interprets the modest degree of the real impact of reserve requirements as a consequence of a responsive monetary policy. Glocker & Towbin (2012), for instance, argue that if interest rate setting is dissociated from decisions on reserve requirements, the former may neutralize the impact of the latter. We conduct a counterfactual exercise in which monetary policy remains nonresponsive to economic conditions while we stress the model with a shock to reserve requirements. Figure 11 shows the responses[35]. When monetary policy is unresponsive, the impact of changes in reserve requirements on GDP is stronger and more prolonged. In that situation, when banks increase lending rates to accommodate the increase in funding costs, households' consumption and investment demand are no longer stimulated by monetary policy. As such, the impact on the demand for goods is not alleviated, and consequently the drop in the demand for labor curtails borrowers' capacity to take loans. As a result, borrowers' consumption is more severely affected. The shock is further reinforced since the cost of funding rises. Banks reduce their positions in risky assets (i.e., loans) and the capital adequacy ratio further improves. In sum, our results are in line with the literature. When monetary policy does not relieve the contractionist impact of shocks to reserve requirements, the economy faces a more significant downturn.

The analysis of the responses to changes in the ratios of remunerated RR, either on time deposits or savings accounts, when monetary policy is kept unchanged, yields the same conclusions outlined above (Figures 9 and 10).

[33]All counterfactual exercises use the mean of the posterior estimation to produce impulse responses

[34]Montoro & Moreno (2011) claim that if RR are partially remunerated, the distortionary tax effect is reduced, but their overall impact on the banking system is also lessened. In our model, the estimated impulse responses of changes in remunerated reserve requirements on time deposits can have non-negligible effects on the real economy notwithstanding the fact that there is no mismatch between the interest rate paid on bank deposits and that accrued on required reserves.

[35]To do this exercise, we perturbed the model with unexpected shocks to the interest rate rule such that the nominal base rate would remain at the steady state level over the response period.

5.1.1 A brief note on the literature

The international literature finds evidence of a moderate degree of the impact of non-remunerated RR on the economy. The assumptions underlying these conclusions are manifold. Tovar, Garcia-Escribano & Martin (2012) use event study and dynamic panel VAR on a number of Latin American countries to find that RR have a moderate and transitory effect on private banking growth, playing a complementary role to monetary policy. Montoro & Moreno (2011) argue that RR have smaller impacts if the amount of deposits subject to RR relative to domestic bank credit is small. Glocker & Towbin (2012) find that RR have a role in supporting price stability if, among other conditions that are to some extent addressed in our model, debt is denominated in foreign currency.

Few studies analyze the aggregate impact of RR in Brazil. Souza-Rodrigues & Takeda (2004) find empirical evidence that higher unremunerated reserve requirements in Brazil increase the mean of lending rates. Areosa & Coelho (2013) build a DSGE model with agency problems in banks' funding and find that RR have qualitatively equivalent (yet weaker) impact on the economy compared to the monetary policy instrument. Our model differs from Areosa & Coelho (2013) in several important ways. Apart from a more comprehensive description of the financial sector, our model features default in loans to the real sector, whereas Areosa & Coelho (2013) introduce default in bank deposits. An immediate consequence of their assumption is that there will be a wedge between banks' cost of funding from deposits and the base rate, driven by solvency concerns. We choose not to adhere to this assumption since the spread between 90-day bank certificates of deposits (CDB) and the effective base rate (Selic) has been negligible after the implementation of the inflation targeting regime (0.2 p.p. from a nominal quarterly base rate of 3.6% on average), despite strong movements in volumes. This evidence also challenges the assumption extensively used in the literature[36] that banks have monopolistic power in setting deposit rates. In this respect, there are a number of investment opportunities that compete with demand deposits in Brazil. Another important difference from Areosa & Coelho (2013) is that in their model RR can only affect the economy through price effects, since they are dominated in return by public bonds. Instead, if RR were fully remunerated, as is the case with time deposits in Brazil, reserve requirements would be neutral to the economy. In our model, we find important quantitative effects of these instruments.

5.2 Capital requirement shocks

An unanticipated 1 p.p. increase in required capital, from 11% to 12% (Figure 13), has important real effects that are triggered by changes in banks' balance sheet composition and in their decisions with respect to the share of profits to be distributed to bank owners.

The transmission mechanism is as follows. Given that deviations from the required capital are costly to the banks, the shadow cost of banks' operations increases, and is passed through to lending rates. More expensive consumer loans reduce income

[36] Some examples are Roger & Vlcek (2011), Gerali *et al.* (2010) and Dib (2010).

available for consumption. The drop in consumption and capital investment that follows from consumer and commercial credit contraction is enough to drag down GDP. The impact on the labor market is such that even though housing lending rates fall – and that results from our assumption that these rates are decided by the government and are tightly linked to the base rate of the economy – the demand for housing loans also falls.

Since banks can decide how much of their earnings will be distributed and how much will be retained, they also accommodate part of the cost implied by higher capital requirements by retaining profits. This, together with the drop in risky assets, allows them to improve their net worth position, and liquid assets increase. However, since banks hold a large amount of excess capital in the steady state, final compliance with the capital requirement comes mostly from reducing this capital buffer, and not so much from increasing the actual Basel ratio.

With respect to the impact of changes in capital requirement on different types of loans, we find that the demand for collateralized loans is more sensitive to changes in lending rates. This, together with the fact that the risk weight of commercial loans in the CAR is lower than that of unsecured loans, causes the increase in lending rates of commercial loans to be less than that of consumer loans and also to show less persistence.

These conclusions were obtained from the baseline model, where monetary policy is responding to economic conditions by lowering the base rate. However, this response is not strong enough to offset the impact of tighter capital regulation on the shadow price of banks' operations. Hence, even if monetary policy is kept unchanged after a shock to capital requirement ratios (Figure 14), bank funding costs, capital accumulation, and liquidity are not substantially changed compared to the baseline scenario. However, since monetary policy cannot alleviate the burden of tighter credit conditions on the real economy, a more pronounced drop in collateral value and in labor income causes lending rates to increase further. The final drop in GDP is therefore much more severe as the impact of the shock builds up.

5.2.1 Anticipated vs. unanticipated announcements of changes in capital requirements

The baseline model assumes that changes in capital requirements are not anticipated. However, regulatory changes of this nature are usually announced with a substantial lag to the implementation. To investigate whether announcements made in advance of the implementation trigger any anticipatory behavior, we compare the impulse responses of the model in two alternative scenarios: one in which the macroprudential authority announces a 1 p.p. increase in required capital to be implemented only 4 quarters after the announcement, and the other in which the announcement is made together with the implementation. Figure 15 shows the results.

Announcements trigger an anticipatory behavior of banks: they immediately start to retain earnings and improve their capital adequacy ratios over the entire period. As a matter of fact, the announcement is more effective in reducing the banks' risk exposure even after the shock hits. Economic agents also anticipate the impact of the shock and the demand for loans becomes more sensitive to lending rates. As a result, lending rates do not need to rise as much to curtail credit as when the shock is unanticipated. Real variables, such as GDP and inflation are impacted from start, but show smoother trajectories.

5.2.2 Countercyclical capital buffer

In the baseline model, capital requirement decisions are represented by an autoregressive process with very strong persistence (0.999). This is a fair representation of the Brazilian regulatory framework during our sampled period, in which Brazil had adhered to either Basel I or Basel II accords, and when capital requirement ratios remained practically invariable. [37]

However, the Basel III regulatory framework introduces a countercyclical capital buffer that has been more commonly interpreted as a rule that requires banks to build up capital during expansionary credit cycles and loosens up in downturns. The purpose of this buffer is to dampen excessive oscillations in credit supply, which are commonly associated with financial system distress.

We compare the impact of countercyclical capital buffers and traditional capital requirement under two different scenarios. In the first, we assume that banks reduce their liquidity target to simulate a supply-driven credit expansion associated with loosened risk-taking standards. In the second, we simulate a severe bank capital impairment that can potentially depress the economy. The capital buffers can react either to contemporaneous ($\chi_E = 0$) or expected ($\chi_E = 1$) deviations of credit-to-GDP from its stationary trend:

$$\begin{aligned}\gamma_{t,cc}^{BankK} &= (1-\rho_{BankK,cc})\left(\begin{array}{c}(1-\chi_E)\left(\omega_{BankK,cc}^{B}\left(\frac{B_t^{C,wb}+B_t^{C,wb}+B_t^{C,wb}}{b^{C,wb}+b^{C,wb}+b^{C,wb}}\frac{gdp}{GDP_t}\right)\right)\\ +\chi_E\left(\omega_{BankK,cc}^{B}E_t\left(\frac{B_{t+4}^{C,wb}+B_{t+4}^{C,wb}+B_{t+4}^{C,wb}}{b^{C,wb}+b^{C,wb}+b^{C,wb}}\frac{gdp}{GDP_{t+4}}\right)\right)\end{array}\right) \\ &\quad +\rho_{BankK,cc}\gamma_{t-1,cc}^{BankK}+\varepsilon_{t,cc}^{BankK}\end{aligned} \tag{102}$$

and $\gamma_t^{BankK,total} = \gamma_t^{BankK} + \gamma_{t,cc}^{BankK}$

Figures 16 and 17 show the model responses to a drop in bank's liquidity target (ν_t^{OM}) such that total credit-to-GDP rises on impact by 1% from its stationary trend when traditional capital requirements are in effect[38]. To better isolate the effect of macroprudential policies, we shut down monetary policy by assuming that the base rate remains constant. Compared with traditional capital requirements, if the countercyclical capital buffer can be immediately adjusted to react to credit expansion

[37] Although Basel II includes operational and market risk in the computation of capital adequacy ratios, we believe credit risk was the most preponderant factor in capital requirement rules, so that our rule is a reasonable approximation when associated with the CAR equation (52).

[38] For this exercise, we set $\rho_{BankK,cc} = 0.8$ and $\omega_{BankK,cc}^{B} = 20$, which implies a 1 p.p. rise in total capital requirement ($\gamma_t^{BankK,total}$) on impact.

(Figure 16), it drives down the variance of GDP by over 80% when the regulatory authority responds to contemporaneous credit conditions and by about 75% when the rule is forward looking, reacting to credit conditions four-periods ahead. The countercyclical capital buffers also mitigate the expansionist impact of the liquidity shock on the real economy. We performed the same exercise but now assuming that the countercyclical buffer can only be altered 4 periods after the shock (Figure 17). This simulates the framework to be adopted in Brazil, which requires the regulatory authority to announce changes in the instrument one year in advance. In this case, the drop in the variance of credit-to-GDP is a little smaller but the proportionality between the contemporaneous and the forward-looking rule is maintained.

The second exercise makes a strong case in favor of the countercyclical capital buffer. Figure 18 shows the model responses to a shock to dividend distribution that severely impairs bank capital, such that credit-to-GDP falls by 1% from its stationary trend under traditional capital requirements. Using the same rules as in the previous exercise, the introduction of countercyclical capital buffers drop the variance of credit-to-GDP by over 90%, and the difference in the types of countercyclical rules is not so relevant with respect to credit stabilization. If the implementation of the countercyclical buffer is lagged (Figure 19), the forward looking rule is a little more efficient in driving down credit variance. The countercyclical capital buffers also substantially mitigate the effect of the negative shock to bank capital on the real economy.

In the particular case of Brazil, required capital buffers cannot exceed 2.5 p.p. above the standard capital requirement. Assuming the same smoothing coefficient, if we constrained the maximum hike in required capital to 2.5 p.p., the variance of credit-to-GDP would drop by about 75%.

5.3 Risk weight shocks

Figures 20 and 21 show the impact of 10 a p.p. hike in the risk weight of consumer and commercial loans, respectively. The shocks have an immediate impact on the lending rate of their specific credit segment, reducing credit. Banks choose to retain dividends so as to avoid further deterioration in capital adequacy ratios. Net funds released from the drop in loans are redirected to bank liquidity. Altogether, banks accommodate the overall impact of risk weight shocks on their balance sheet by releasing part of the capital buffer, which implies that the Basle ratio remains below pre-shock values for a prolonged period of time. Tighter credit conditions impact consumption and capital investment, depressing output.

With respect to risk weights of housing loans (Figure 22), the over regulation of the lending rate in this market shifts the main burden of the adjustment to the other credit segments. Hence, banks increase lending rates of commercial and consumer loans and cut dividends so as to improve capital adequacy ratios. The contractionist impact that follows worsens labor market conditions in such a way that the demand for housing loans also drops, notwithstanding the fact that the lending rate falls by tracking the base rate.

5.4 Monetary policy under financial frictions

The estimated model features traditional shapes of the responses of the key macroeconomic variables to a monetary policy shock (Figure 23)[39]. Notwithstanding, the financial frictions of the model imply more elaborate transmission channels. A 100 bp shock to the nominal base rate reduces consumption, hours worked and output through the traditional channels. Financial frictions reinforce the responses. The reduction in labor income puts pressure on the delinquency rates of consumer loans, increasing final lending rates. Hence, the demand for consumer loans falls, and borrower's consumption further adjusts to accommodate tighter funding conditions.

Worsened demand conditions reduce prices. In particular, the fall in the price of capital reduces the value of collateral put up for commercial loans, putting pressure on default rates and, consequently, on lending rates. This reduces the demand for investment loans, further depressing investment.

The monetary policy shock has important implications for the composition of banks' balance sheets. The increase in the base rate puts pressure on external and internal bank funding costs. The reduction in the stock of loans resulting from higher funding costs is accommodated through an expansion in bank liquidity and an increase in the share of retained earnings. The recomposition of banks' balance sheet towards safer assets and greater capital accumulation improve the capital adequacy ratio. The price of housing falls with depressed demand conditions, therefore lower collateral values reduce housing loans.

6 Comparative Analysis

6.1 Macroprudential vs. Monetary Policy Shocks

To better understand the differences in the responses of macroprudential instruments compared with monetary policy, we simulated scenarios in which the regulatory and monetary authorities tighten macroprudential and monetary policy in the first four quarters, phasing them out in the subsequent 4 periods. The magnitude of each shock on impact was the same used to plot the impulse response functions in the previous session[40]. Figure 27 shows the results, and each response corresponds to a full-blown simulation of the model given one particular shock.

Monetary policy has a stronger impact on the labor market and, consequently, on consumption. Here, among the many policies considered in this exercise, only the monetary policy shock affects housing lending rates. This causes a strong drop in

[39] We present the IRFs of temporary technology and price markup shocks in the appendix (Figures 24 and 25)

[40] Although this choice is arbitrary, we believe it is better than using the estimated variance of macroprudential shocks since over the sampled period, there have not been changes to capital requirements and we do not have aggregate series of risk weights applied to compute capital adequacy ratios that would conform to the credit segmentation that we used in this paper. Our choice seems reasonable considering our understanding of policy choices in Brazil

housing investment, further depressing the demand for intermediate goods, and hence the labor market. The final impact on GDP is stronger than any of the macroprudential policies considered.

Capital requirements have the strongest impact on non-regulated credit markets (i.e., consumer and commercial), followed by reserve requirements on time deposits[41]. Increased reserve requirements on time deposits trigger a sizable adjustment of bank liquidity, whereas increased capital requirements bring about a strong cut in bank dividend distribution. Moreover, when the weight of a particular risky bank asset increases in the computation of capital adequacy ratios, banks show a clear preference for cutting off excess capital instead of building up new capital; hence the capital adequacy ratio deteriorates. The opposite holds for reserve and capital requirements, and for monetary policy shocks. For these instruments, banks prefer to accumulate capital, and actual Basel ratios improve.

6.2 Reserve requirements and the role of bank liquidity preferences

The model features two transmission channels through which reserve requirements impact banking costs and the rest of the economy: the cost channel and the liquidity preference (or targeted liquidity) channel. The first one emerges from the gap between the remuneration of required reserves at the central bank and the opportunity cost of banks' internal funds. If remuneration is lower than the opportunity cost, any increase in reserve requirement ratios will produce higher funding costs to banks, which will be partially passed on to firms and households through higher lending rates. This reserve requirement transmission channel is traditionally mentioned in the literature (e.g., Areosa & Coelho (2013)). However, if reserve requirement remuneration matches the bank's opportunity costs, this channel might be muted, and the impact of the instrument through this channel becomes negligible.

Nonetheless, some categories of reserve requirements in Brazil are remunerated at the short term policy rate, reducing banks' opportunity cost of keeping reserves at the central bank. However, other types of liquid assets have analogous remuneration but give banks more flexibility to manage their portfolios. This is introduced in our model through a liquidity target in the form of public bonds. By introducing liquidity targets in bank's optimization problem, the model is able to produce relevant responses to policy changes in reserve requirements, even when they are remunerated. This can be seen in Figures 28 and 29, which compare the impact of a permanent 10 p.p. increase in reserve requirements on time and demand deposits in the baseline model and in an alternative version of the model with no role for liquidity targets (i.e., by imposing $\chi_{OM} = 0$).

In the absence of liquidity targets, the shock to reserve requirements on time deposits causes no impact on the economy or on banks' balance sheets, except for the fact that liquidity falls so as to cope with the new requirements without creating any further

[41]We did not include RR on demand and savings deposits in this exercise, since we have shown that in the baseline model, RR on time deposits have the strongest impact

costs to the bank. With respect to reserve requirements on demand deposits, since they do not accrue interest, only the cost channel is present in the alternative model. The responses of the alternative model are considerably smaller than those of the baseline model. Hence, we can conclude that most of the impact on lending rates and on the real economy comes from the liquidity target channel.

6.3 Alternative borrowing constraints

Our model incorporates debt-to-income borrowing constraints associated with the possibility of delinquency in consumer loans, which, in fact, exists in equilibrium. In this respect, the model follows Bernanke, Gertler & Gilchrist (1999) except that wage income replaces physical assets – capital or housing – as collateral for loans to households. We single out the differences in the responses of our model, compared to the main strands of the macroeconomic literature that incorporates financial frictions in household decisions by simulating two variants of our model: one in which only housing can serve as collateral for consumer loans (HM) and another in which debt-to-income constraints bind (WM)[42].

In the version where housing is put up as collateral for consumer loans (HM), the form of borrowing constraints follows Iacoviello (2005) and Gerali *et al.* (2010) [43]:

$$R^{L,C}_{B,t} B^{C}_{B,t} + R^{L,H}_{B,t} B^{H}_{B,t} \leq \gamma^{B,C}_{t} E_t P_{H,t+1} \left(1 - \delta_H\right) H_{B,t}$$

In the second alternative version of the model, (WM), debt constraints are strictly tied to current wage income. This formulation follows Mendoza (2002):

$$R^{L,C}_{B,t} B^{C}_{B,t} + R^{L,H}_{B,t} B^{H}_{B,t} \leq \gamma^{B,C}_{t} \left(1 - \tau_{w,t}\right) N_{B,t} W^{N}_{t}$$

There is no default on household loans in Iacoviello (2005), Gerali *et al.* (2010) and Mendoza (2002); hence, we rule out the possibility of default in the alternative versions of our model presented in this exercise.

Figures 30, 31, and 32 show each model's impulse responses of shocks to capital requirement, reserve requirement on demand deposits, and monetary policy.

Compared to WM, the possibility of default on consumer loans in the benchmark model produces a stronger impact of macroprudential instruments on the real economy. It also reflects on bank capital and dividend distribution. The assumption about the existence of default also has implications for the responses to a monetary

[42] To perform this exercise, we set the model parameters at the mean of the estimated posterior distribution of our benchmark model. The modifications in the model were restricted to the equations that we present in this subsection and to the consequent changes that these equations imply in first order conditions of borrower's optimization program. The financial frictions incorporated in commercial loans (which are a tight variant of Bernanke, Gertler & Gilchrist (1999)) were maintained in all exercises.

[43] In the original works, $\gamma^{B,C}_{t}$ is set to 1. In this exercise, we need to relax this constraint so as to pin down a reasonable value for the steady state of housing in the economy.

policy shock. In WM, the absence of default allows banks to both accumulate capital and increase dividend distribution. This overestimates the impact of a contractionist monetary policy stance on actual Basel ratios.

HM generates much stronger impact of macroprudential policy on housing investment. This leads to a sharper decline in credit-to-GDP, most especially in the segment of consumer credit. Notwithstanding, since the labor market is now only weakly connected to credit decisions and since we did not introduce habit in housing decisions– which has an important impact on the responses of aggregate consumption – the impact of macroprudential policies on consumption, on the labor market and on GDP is substantially less contractionist in HM. Although HM implies a greater sensitivity of the value of housing collateral to lending rates, and that results in stronger responses of credit to macroprudential policy, the spillover effect of strained credit conditions on the economy is much more subdued given the low linkages with the labor market.

7 Conclusion

This paper builds a DSGE model with matter-of-fact financial frictions to assess the transmission channel of a set of selected macroprudential policy instruments. Banks' decisions on consumer loans are based on expectations with respect to borrowers' labor income. These loans are risky, and default exists even in equilibrium. This entails stronger impact of macroprudential policies on the real economy as compared to traditional models of collateral constraints in consumer loans that do not consider the possibility of default in this credit segment.

The model also features frictions in the optimal composition of banks' balance sheet. Banks are assumed to have liquidity targets, and this amplifies the impact of macroprudential policies in the credit market and in the real sector. Banks can also accommodate the impact of changes in the regulatory framework by deciding on the share of profits to be distributed or retained.

The model is estimated with Bayesian techniques using Brazilian data from the inflation targeting regime. We analyze the transmission channel of the following policy instruments: 1) traditional (Basle 1 and 2) core capital requirements, with anticipated or unanticipated implementation, 2) Basle 3 capital buffers, 3) reserve requirements on demand deposits, savings deposits, time deposits, and "additional" deposits, and 4) risk-weights that are used in the computation of capital adequacy ratios.

We find that monetary policy has a substantially larger impact on the real economy than macroprudential instruments. On the other hand, reserve requirements on time deposits and capital requirements have a potentially stronger impact on bank credit-to-GDP. Adjustment in bank balance sheets are very different depending on the macroprudential instrument being shocked. Increased reserve requirements on time deposits trigger a sizable adjustment of banks' liquid assets, whereas increased capital requirements bring about a strong retention of bank earnings. When the weight of a particular risky bank asset increases in the computation of capital adequacy ratios, banks show a clear preference for cutting off excess capital instead of building up new capital. The opposite holds for reserve and capital requirements, and for monetary policy shocks. For these instruments, actual Basel ratios improve.

Shocks to reserve requirements can have important effects on the real economy. We show that even when required reserves at the central bank are remunerated, they have a non-neutral effect on bank aggregates and on the economy. In particular, the size of deposits in the economy is a key variable to determine the magnitude of the impact of the shock to the financial sector and to the real economy. If incidence bases are equal in size, the opportunity cost of maintaining reserve requirements that do not accrue interest rate dominates the magnitude of the impact.

When the implementation of new capital requirements is preceded by an announcement, banks anticipate the impact of the new regulation by immediately improving capital adequacy. As a result, the economic effects of the shock can be seen long before the shock hits.

We simulated scenarios in which bank capital is severely impaired or in which banks reduce their liquidity targets, creating conditions for excessive credit expansion. In these two cases, countercyclical capital buffers can substantially mitigate the impact of the shocks on credit and on the real economy. We also analyze cases in which announcements precede the actual implementation of countercyclical capital buffers.

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A Tables

Table 1: Steady state calibrations

	Description	Value
	Values	
g_{ϵ}	GDP growth (% per annum)	3.4
π_C	CPI Inflation (% per annum)	4.5
i_H	Investment in housing (% of GDP)	3.0
i_K	Investment in capital (% of GDP)	14.4
g	Government spending (% of GDP)	20.4
D^D	Demand deposits (% of GDP)	3.4
D^T	Time deposits (% of GDP)	20.9
D^S	Savings deposits (% of GDP)	10.7
$B^{B,C}$	Retail loans outstanding(% of GDP)	12.5
$B^{B,H}$	Housing loans outstanding (% of GDP)	5.5
B^{B^E}	Commercial loans outstanding (% of GDP)	13.8
$R_{L,B,c}$	Nominal retail lending rate (% per annum)	34.3
$R_{L,B,h}$	Nominal housing lending rate (% per annum)	7.4
$R_{L,E}$	Nominal commercial lending rate (% per annum)	21.1
τ_C	Consumptio tax(%)	16.2
τ_W	Tax on labor income (%)	15.0
τ_{π}	Tax on profits (%)	15.0
bankcap	Bank capital (% of GDP)	13.0
$\tau_{RR,T}$	Reserve requirement ratio on time deposits (%)	11.0
$\tau_{RR,S}$	Reserve requirement ratio on savings deposits (%)	18.1
$\tau_{RR,D}$	Reserve requirement ratio on demand deposits (%)	49.6
τ_{adic}	Additional reserve requirement on total deposits (%)	7.7
τ_H	Mininum required allocation of savings deposits in housing loans (%)	34.0
γ^{bankK}	Capital requirement (%)	11.0
	Parameters	
σ_{bank}	Bank's inverse elasticity of intertemporal substitution	1.00
β_{bank}	Bank's discount factor	0.98
δ_H	Housing depreciation (% per annum)	4.00
$\tau_{\chi 1}$	Risk weight of retail loans	1.50
$\tau_{\chi 2}$	Risk weight of commercial loans	1.00
$\tau_{\chi 3}$	Risk weight of housing loans	0.90
$\tau_{\chi 4}$	Risk weight of bank's liquid assets	0.00
τ_B	Tax on retail loans (%)	0.3
τ_E	Tax on commercial loans (%)	0.1
$\mu_{B,H}$	Monitoring cost of housing loans	0.00
$\mu_{b,G}$	Productivity growth rate	0.06
μ_W	Wage markup	1.1
μ_D	Price markup	1.1
$s^{adm,B}$	Adm. costs in retail lending (%)	0.6
$s^{adm,E}$	Adm. costs in commercial lending (%)	0.3
σ_B	Std of the shock to borrowers' labor income	0.2
σ_E	Std of the shock to entrepreneur's collateral	0.6
$\mu_{B,g}$	Response to debt in government spending rule	0.06
CAR	Basle index (%)	16.8

Table 2: Estimated Parameters and Shocks

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
Preference and Technology							
$\bar{h}_S$	Habit persistence	Beta	0.75	0.05	0.626	0.561	0.694
σ_L	Inverse Frisch elasticity of labor	Gamma	1.50	0.10	1.445	1.278	1.608
σ_S	EoS of savings deposits	Gamma	4.00	3.00	23.509	16.254	30.331
σ_D	EoS of demand deposits	Gamma	4.00	3.00	8.968	4.780	12.928
η_H	EoS between consumption and housing	Gamma	1.00	0.25	2.113	1.371	2.903
$\phi_{u,2}$	Capital utilization cost	Gamma	0.20	0.15	0.099	0.040	0.154
ξ_E	Adj. cost of employment to hours	Beta	0.75	0.10	0.621	0.569	0.675
ϕ_K	Adj. cost of capital investment	Gamma	3.00	0.50	3.870	2.981	4.730
ϕ_H	Adj. cost of housing investment	Gamma	3.00	0.50	3.941	3.065	4.820
Nominal Rigidities							
ξ_D	Calvo - prices	Beta	0.75	0.05	0.818	0.756	0.881
α_W	Calvo - wages	Beta	0.75	0.05	0.837	0.789	0.886
γ_D	Price indexation	Beta	0.50	0.20	0.238	0.051	0.405
γ_W	Wage indexation	Beta	0.50	0.20	0.265	0.055	0.466
ξ^{R_E}	Calvo - commercial credit interest rate	Beta	0.50	0.20	0.276	0.065	0.470
$\xi^{R_{B,c}}$	Calvo - retail credit interest rate	Beta	0.50	0.20	0.361	0.124	0.588
Policy rules							
ρ_R	Interest rate smoothing	Beta	0.70	0.03	0.807	0.779	0.837
γ_π	Inflation coefficient	Gamma	2.00	0.05	1.963	1.881	2.044
γ_Y	Output gap coefficient	Gamma	0.20	0.10	0.089	0.022	0.152
ρ_g	Government spending smoothing	Beta	0.70	0.20	0.709	0.571	0.843
Financial Frictions							
$\chi_{bankK,2}$	Cost w.r.t. capital buffer	Gamma	0.06	0.01	0.064	0.048	0.080
$\chi_{b_{OM}}$	Cost w.r.t. liquidity buffer	Gamma	0.10	0.05	0.054	0.030	0.076
$\chi_{d,T}$	Cost w.r.t. time deposits/bank liabilities	Gamma	0.10	0.05	0.087	0.032	0.138

Continued on next page

Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
ϕ_T	Adjustment cost of time deposits	Gamma	0.20	0.10	0.292	0.135	0.448
Autoregressive shocks							
$\rho_{\varepsilon^{I_K}}$	Adj. cost of capital investment	Beta	0.50	0.10	0.482	0.326	0.634
$\rho_{\varepsilon^{I_H}}$	Adj. cost of housing investment	Beta	0.50	0.10	0.443	0.300	0.595
$\rho_{\varepsilon^{B,S}}$	Savers' preference	Beta	0.50	0.10	0.757	0.639	0.868
$\rho_{\varepsilon^{B,B}}$	Borrowers' preference	Beta	0.50	0.10	0.530	0.343	0.712
$\rho_{\varepsilon^{A}}$	Temporary technology	Beta	0.50	0.10	0.779	0.703	0.852
$\rho_{\varepsilon^{u}}$	Capital utilization	Beta	0.50	0.10	0.733	0.635	0.828
ρ_{μ_D}	Price markup	Beta	0.50	0.10	0.473	0.316	0.630
ρ_{μ_W}	Wage markup	Beta	0.50	0.10	0.383	0.264	0.500
ρ_{ϵ}	Permanent technology	Beta	0.95	0.03	0.968	0.941	0.995
Autoregressive financial shocks							
$\rho_{\varepsilon^{S,S}}$	Preference for savings deposits	Beta	0.50	0.20	0.958	0.930	0.988
ρ_{R_H}	Housing loans IR smoothing	Beta	0.50	0.20	0.878	0.807	0.960
$\rho_{\mu^R_E}$	Markup on commercial loans	Beta	0.50	0.10	0.609	0.502	0.720
$\rho_{\mu^R_{B,C}}$	Markup on retail loans	Beta	0.50	0.10	0.891	0.846	0.944
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.20	0.679	0.497	0.864
ρ_{σ_B}	S.D. of risk in retail loans	Beta	0.50	0.20	0.536	0.257	0.807
ρ_{σ_E}	S.D. of risk in commercial loans	Beta	0.50	0.20	0.660	0.578	0.744
$\rho_{d,D}$	Preference for demand deposits	Beta	0.70	0.20	0.914	0.850	0.983
$\rho_{d,T}$	Adj. cost in time deposits	Beta	0.70	0.20	0.799	0.693	0.904
$\rho_{\gamma_{B,H}}$	Housing loans debt-to-income	Beta	0.90	0.05	0.974	0.959	0.992
ρ_{γ_E}	LTV of commercial loans	Beta	0.90	0.05	0.988	0.980	0.997
$\rho_{\gamma_{B,C}}$	Retail loans debt-to-income	Beta	0.90	0.05	0.973	0.959	0.986
$\rho_{IB^{rem}}$	CAR exogenous component	Beta	0.50	0.20	0.957	0.929	0.989
$\rho_{\phi^{R_S}}$	Markdown on savings IR	Beta	0.50	0.20	0.961	0.935	0.990
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.20	0.679	0.497	0.864

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Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
Traditional shocks							
ϵ^{R}	Monetary policy shock	Inv. Gamma	0.01	Inf	0.016	0.013	0.019
ϵ^{G}	Government spending shock	Inv. Gamma	0.01	Inf	0.007	0.006	0.008
ϵ^{I_K}	Capital invest. adj. cost	Inv. Gamma	0.05	Inf	0.081	0.063	0.098
ϵ^{I_H}	Housing invest. adj. cost	Inv. Gamma	0.05	Inf	0.035	0.027	0.042
ϵ^{β_S}	Savers' preference shock	Inv. Gamma	0.05	Inf	0.063	0.040	0.085
ϵ^{β_B}	Borrowers' preference shock	Inv. Gamma	0.05	Inf	0.089	0.046	0.134
ϵ^{A}	Temporary technology shock	Inv. Gamma	0.02	Inf	0.017	0.014	0.020
ϵ^{u}	Capital utilization shock	Inv. Gamma	0.02	Inf	0.018	0.014	0.022
ϵ^{μ_D}	Price markup shock	Inv. Gamma	0.03	Inf	0.046	0.029	0.062
ϵ^{μ_W}	Wage markup shock	Inv. Gamma	0.03	Inf	0.102	0.068	0.135
ϵ^{Z}	Permanent technology shock	Inv. Gamma	0.00	Inf	0.001	0.001	0.002
$\epsilon^{\overline{\pi}}$	Inflation target	Inv. Gamma	0.01	Inf	0.005	0.004	0.006
Financial shocks							
$\epsilon^{S,S}$	Preference for savings deposits	Inv. Gamma	0.10	Inf	0.672	0.472	0.875
ϵ^{R_H}	Markup on housing loans	Inv. Gamma	0.01	Inf	0.005	0.004	0.006
$\epsilon^{\mu^{R_E}}$	Markup on commercial loans	Inv. Gamma	0.02	Inf	0.005	0.004	0.006
$\epsilon^{\mu^{R_{B,C}}}$	Markup on retail loans	Inv. Gamma	0.02	Inf	0.008	0.006	0.009
ϵ^{bankK}	Dividend distribution	Inv. Gamma	0.02	Inf	0.036	0.030	0.042
ϵ^{σ_B}	S.D. of risk in retail loans	Inv. Gamma	0.10	Inf	0.071	0.053	0.090
ϵ^{σ_E}	S.D. of risk in commercial loans	Inv. Gamma	0.10	Inf	0.160	0.128	0.189
$\epsilon^{D,S}$	Preference for demand deposits	Inv. Gamma	0.10	Inf	0.328	0.177	0.466
$\epsilon^{d,T}$	Adj. cost in time deposits	Inv. Gamma	0.05	Inf	0.043	0.026	0.060
$\epsilon^{\gamma_{B,H}}$	Housing loans debt-to-income	Inv. Gamma	0.05	Inf	0.043	0.033	0.052
ϵ^{γ_E}	LTV of commercial loans	Inv. Gamma	0.05	Inf	0.212	0.168	0.254
$\epsilon^{\gamma_{B,C}}$	Retail loans debt-to-income	Inv. Gamma	0.05	Inf	0.041	0.033	0.050
$\epsilon^{IB,rem}$	CAR exogenous component	Inv. Gamma	0.10	Inf	0.099	0.082	0.115

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Table 2 – (cont.)

	Description	Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
$\epsilon^{\phi^{R_S}}$	Markdown on savings IR	Inv. Gamma	0.01	Inf	0.066	0.055	0.077
$\epsilon^{\tau_{RR,T}}$	RR on time deposits	Inv. Gamma	0.02	Inf	0.029	0.024	0.033
$\epsilon^{\tau_{RR,add}}$	RR on additional deposits	Inv. Gamma	0.02	Inf	0.012	0.010	0.014
$\epsilon^{\tau_{RR,S}}$	RR on savings deposits	Inv. Gamma	0.02	Inf	0.007	0.006	0.008
$\epsilon^{\tau_{RR,D}}$	RR on demand deposits	Inv. Gamma	0.02	Inf	0.040	0.034	0.046

B Figures

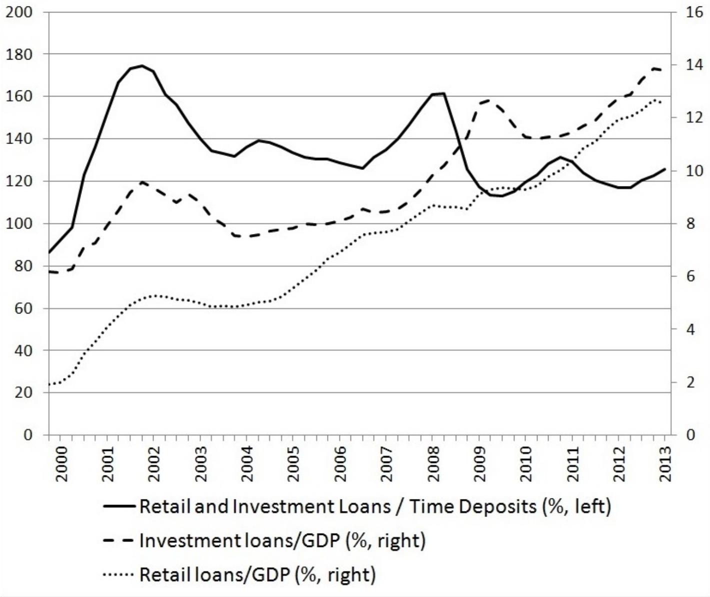


Figure 1: Consumer and Commercial Loans as a share of GDP and Time Deposits

Note: Retail and Commercial Loans in this graph are outstanding balances of non-mandatory loans in the Brazilian financial system, excluding BNDES.

C Observable Variables

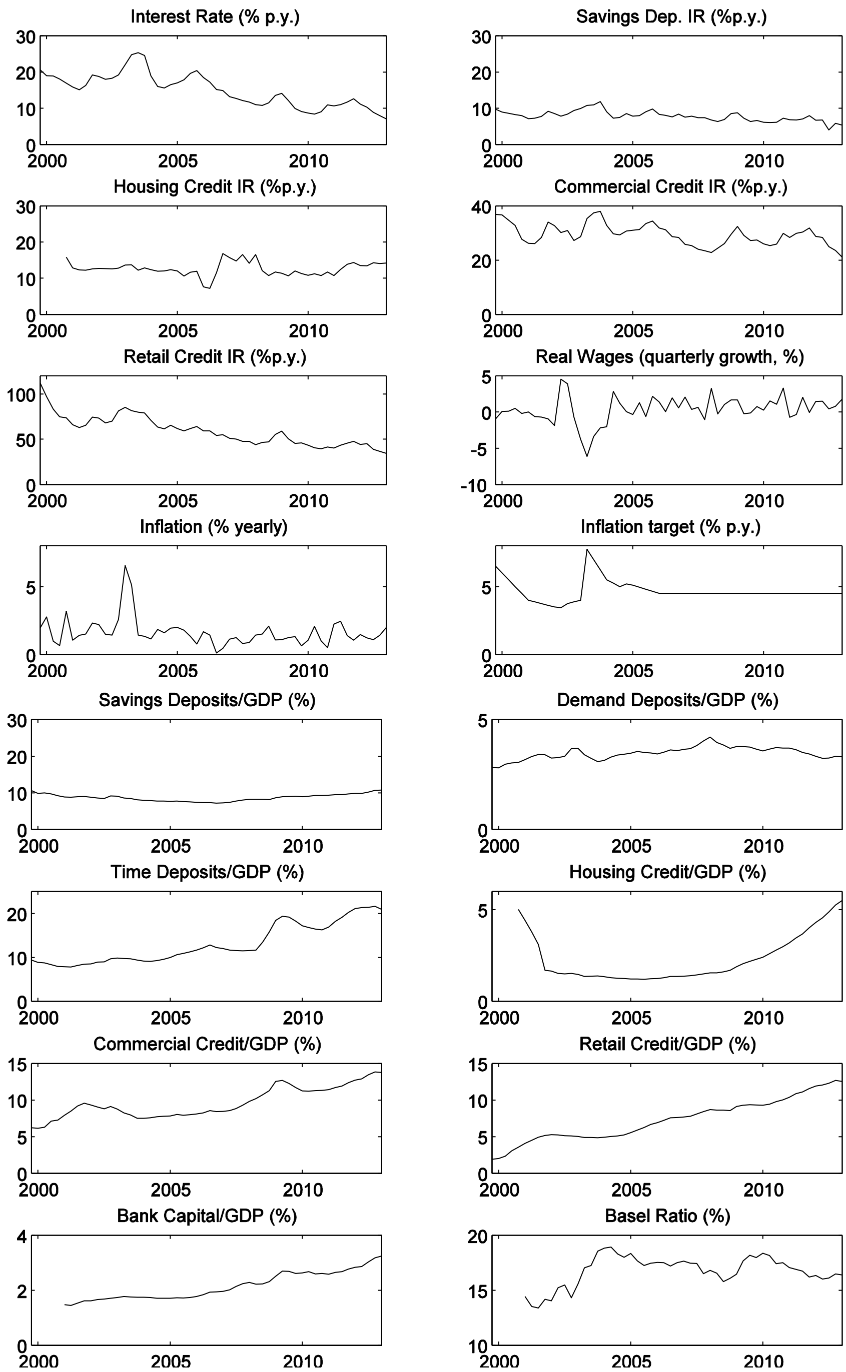


Figure 2: Observable Variables

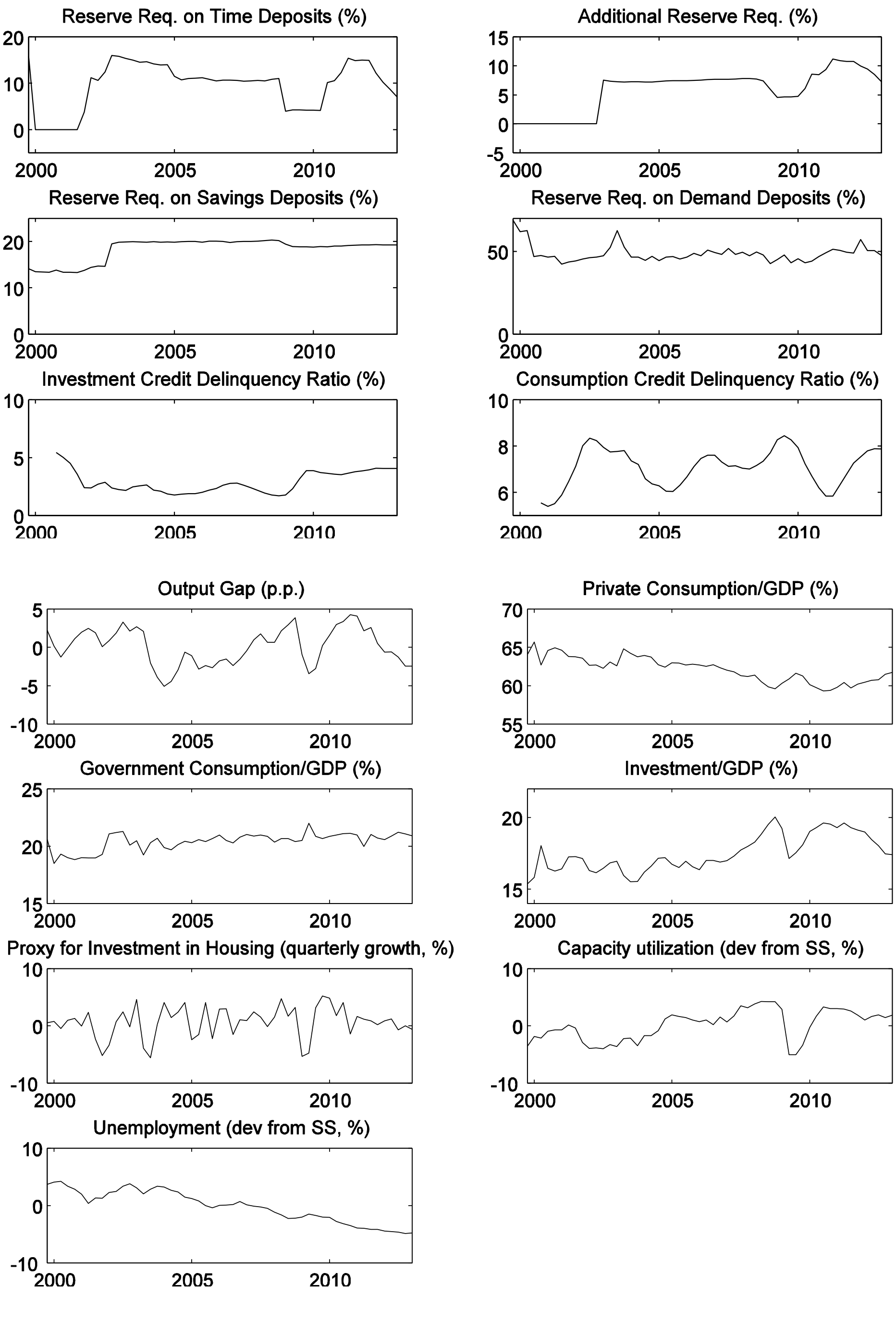


Figure 3: Observable Variables

D Priors and Posteriors

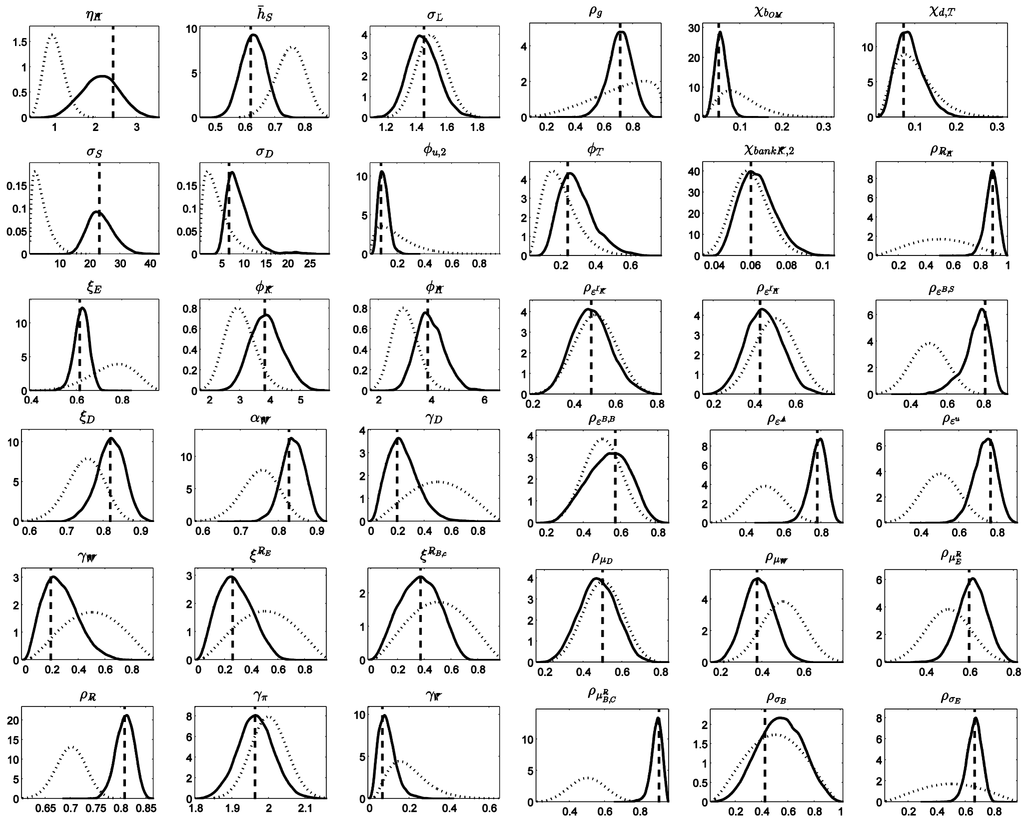


Figure 4: Priors and Posteriors

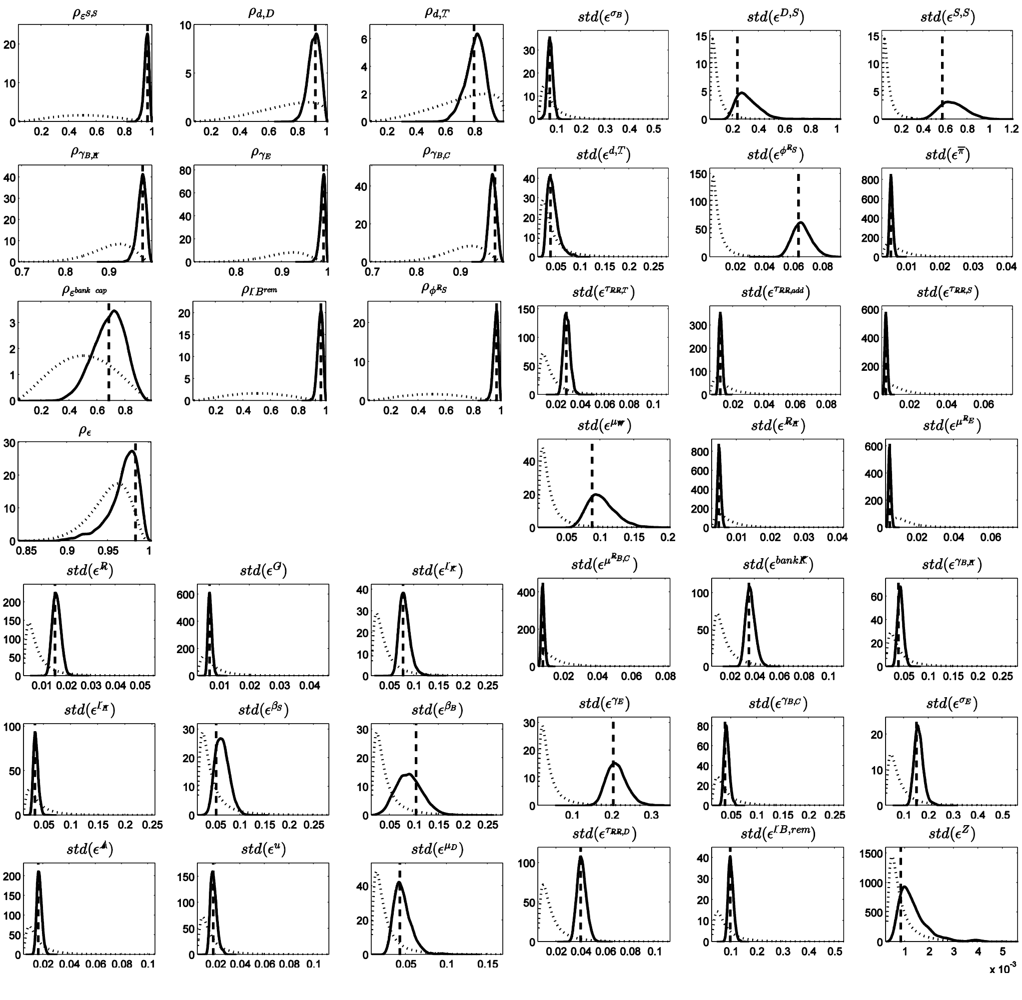


Figure 5: Priors and Posteriors

E The Transmission of Macroprudential and Monetary Policy

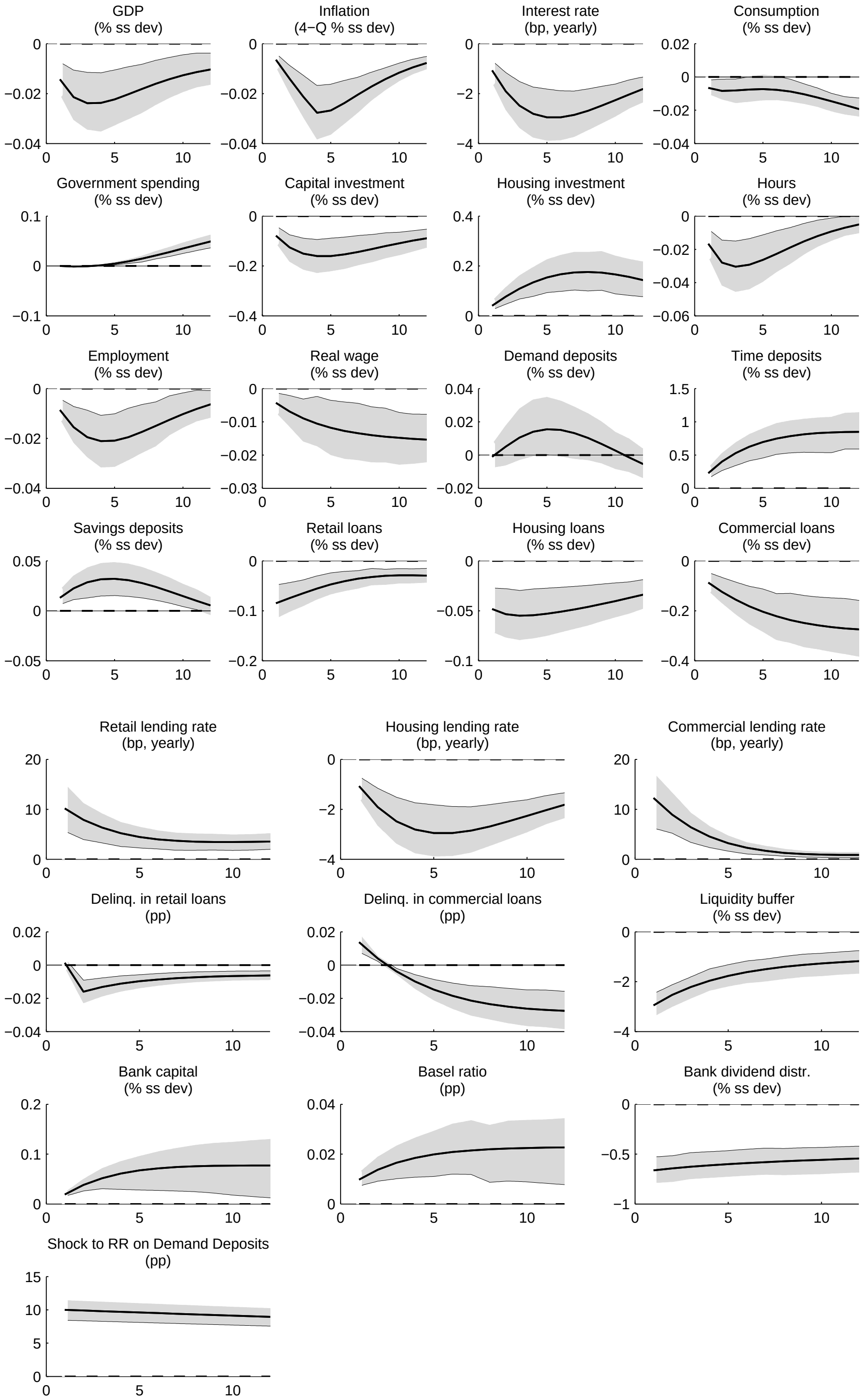


Figure 6: Shock to Reserve Requirement Ratio on Demand Deposits

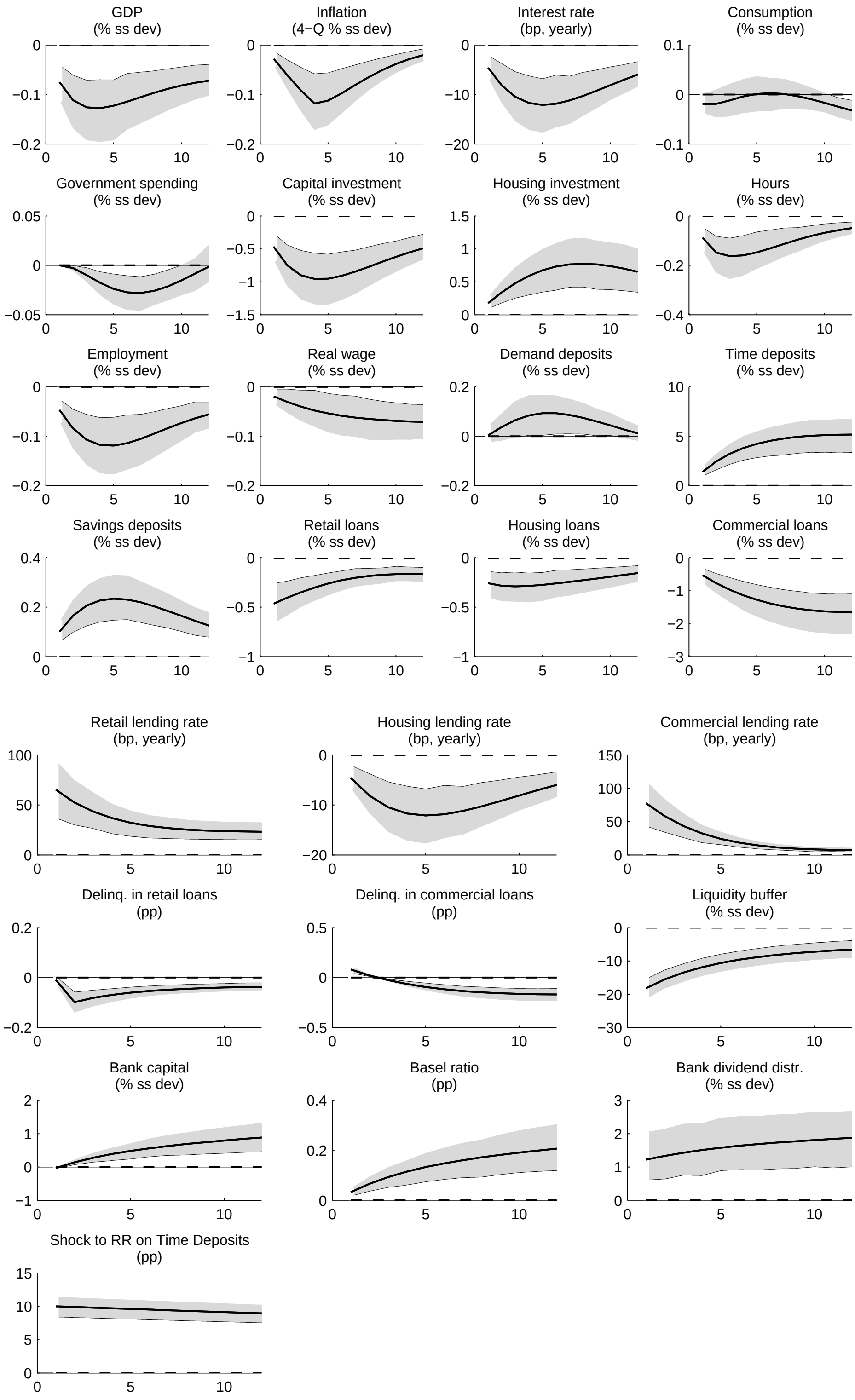


Figure 7: Shock to Reserve Requirement Ratio on Time Deposits

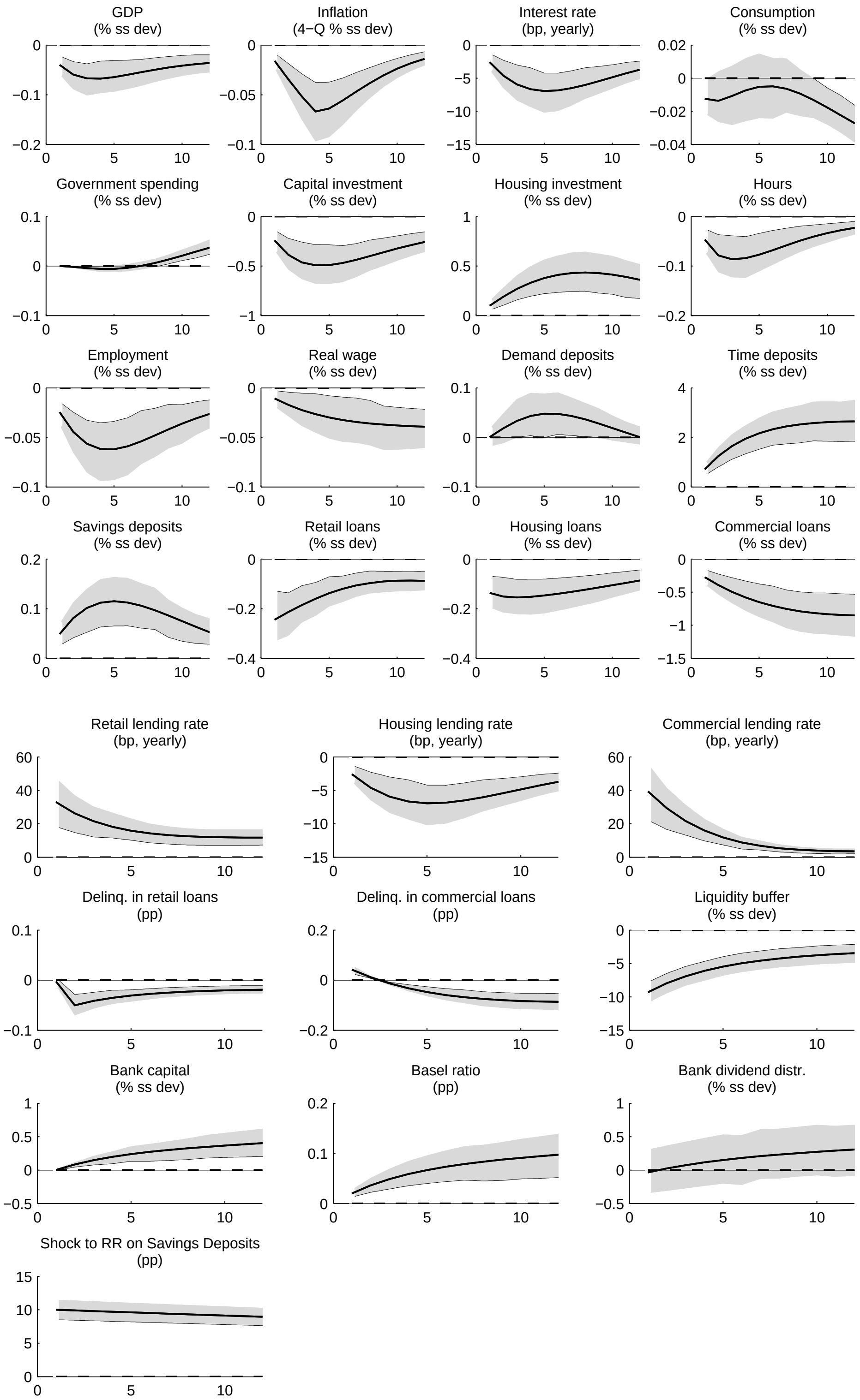


Figure 8: Shock to Reserve Requirement Ratio on Savings Deposits

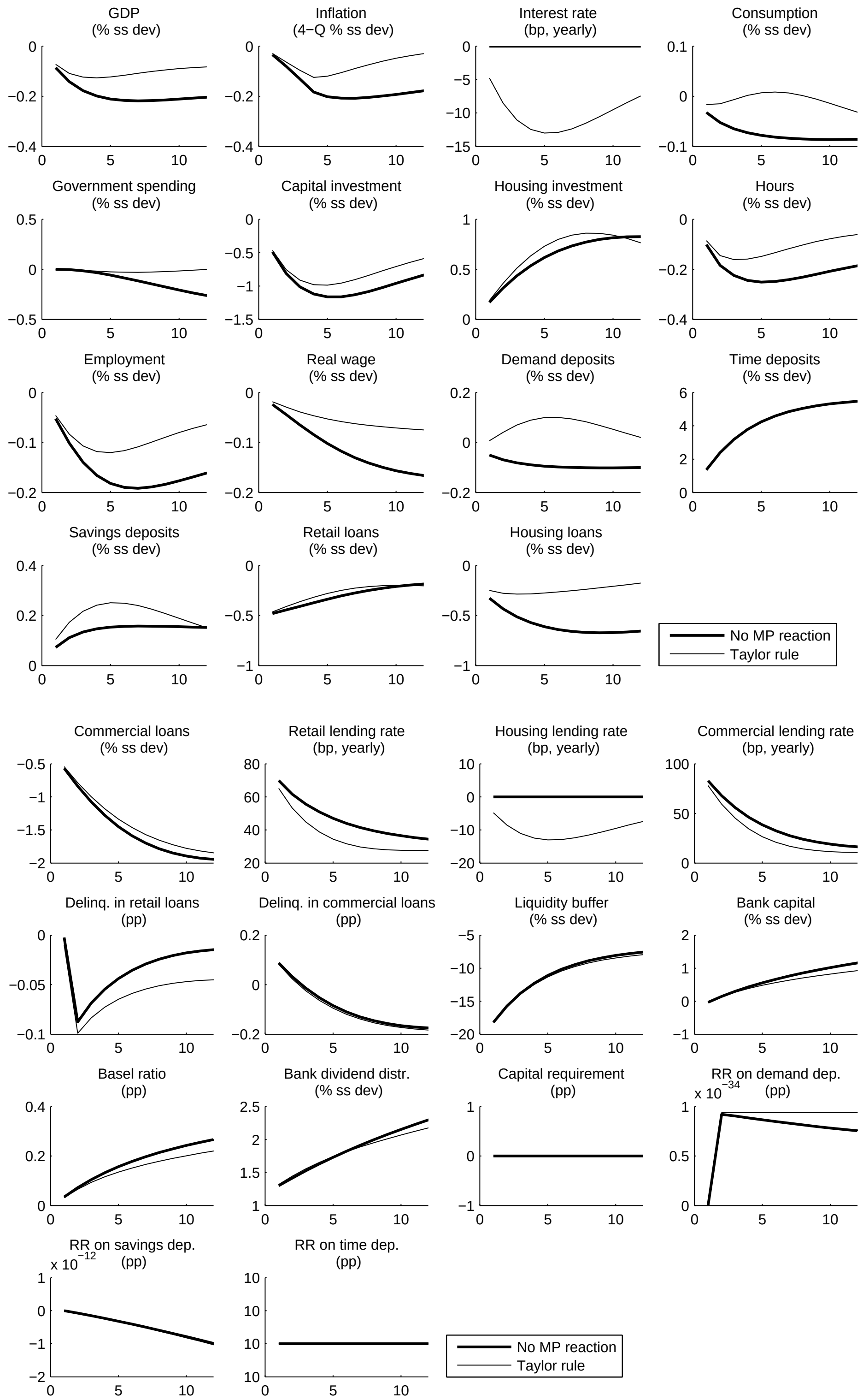


Figure 9: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Time Deposits

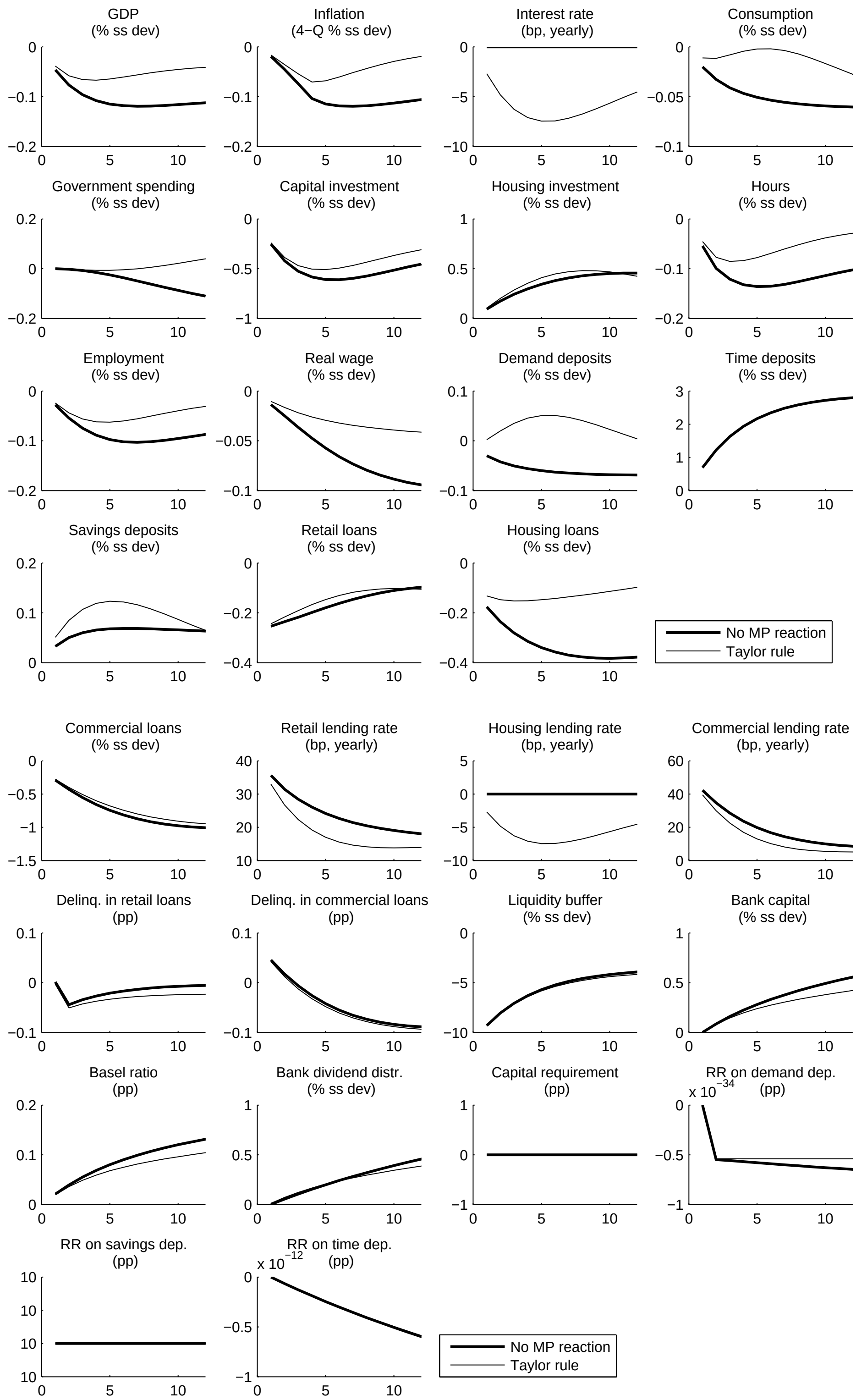


Figure 10: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Saving Deposits

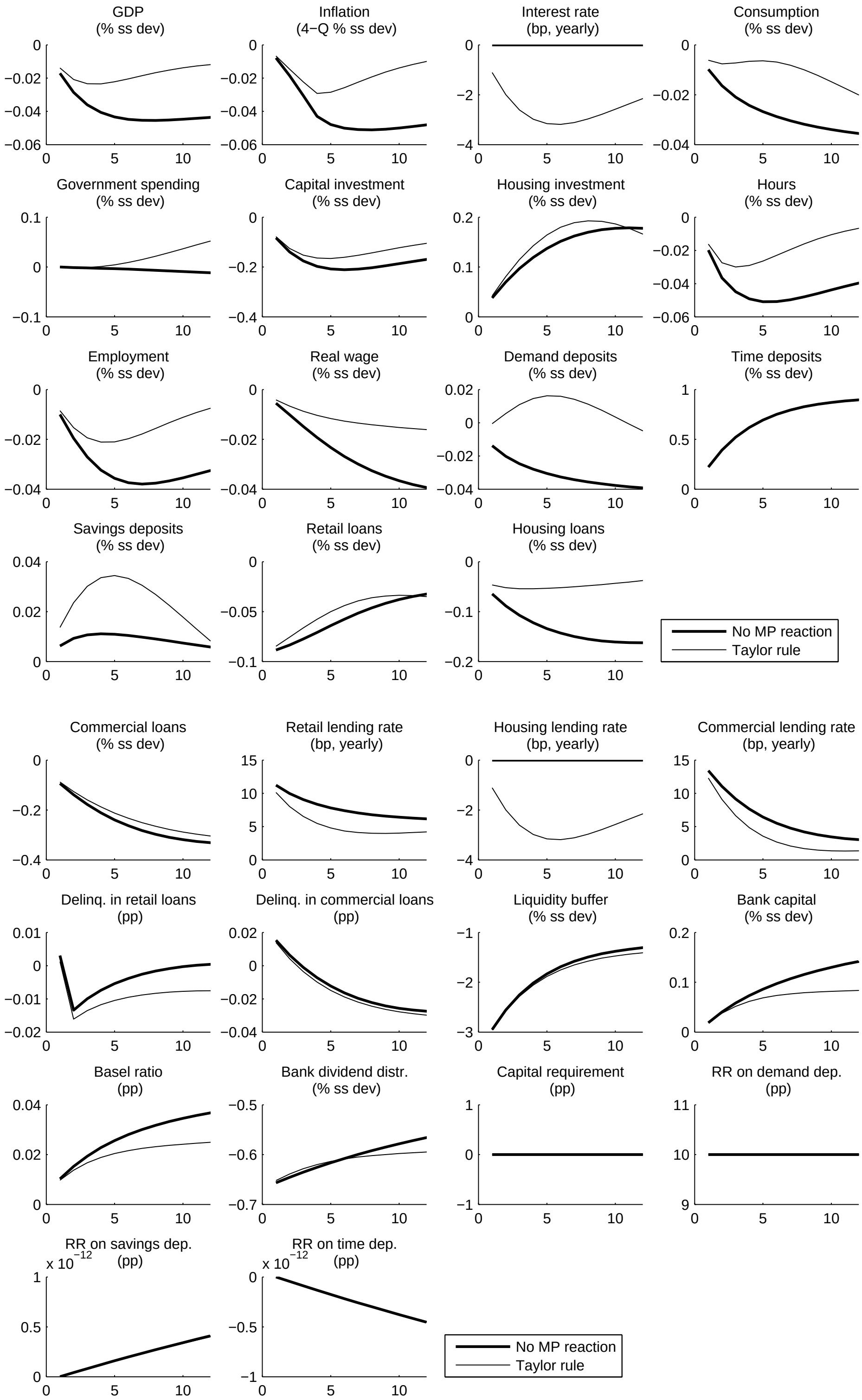


Figure 11: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Demand Deposits

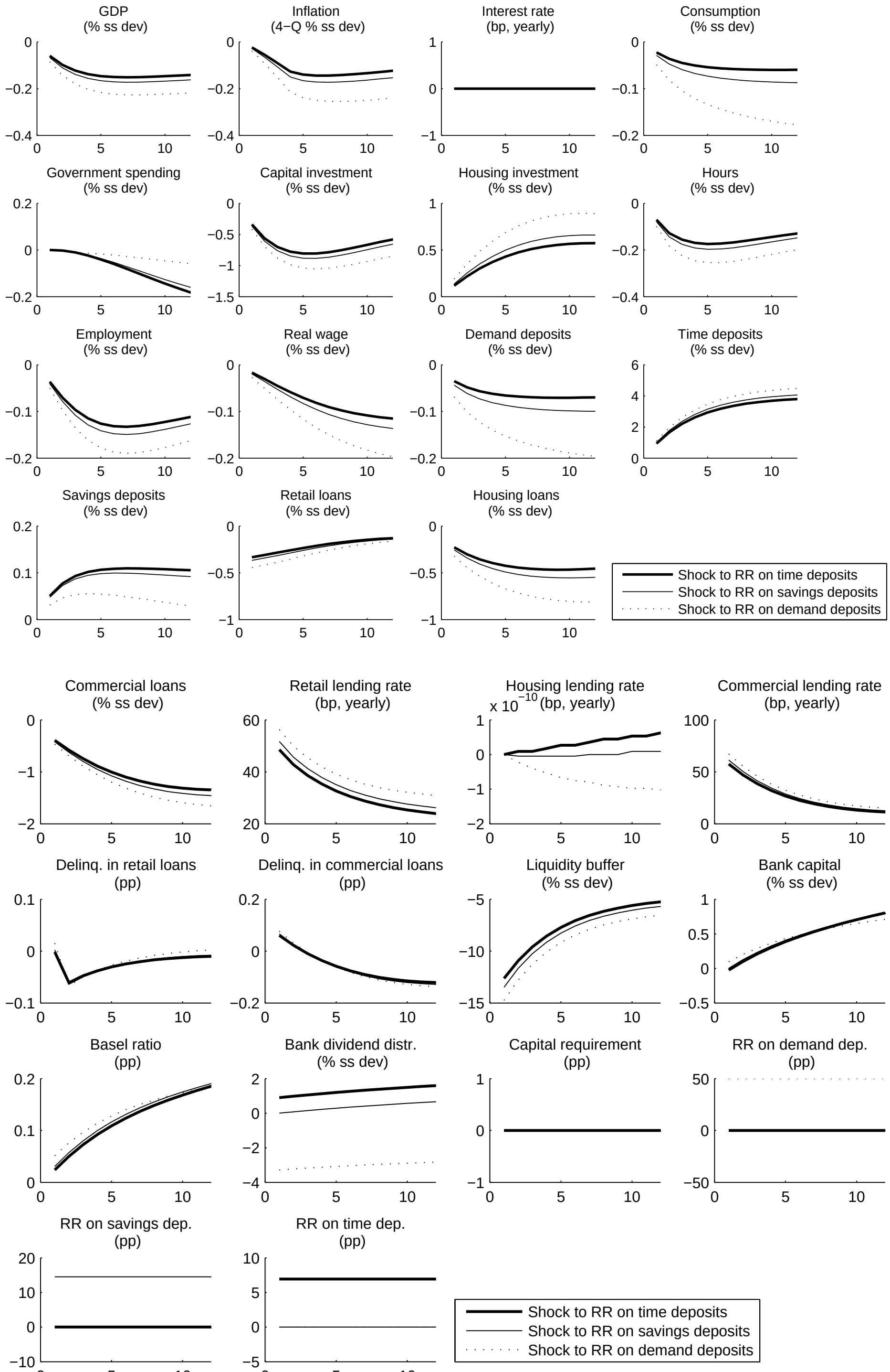


Figure 12: Comparing same scale shocks to Reserve Requirement Ratios

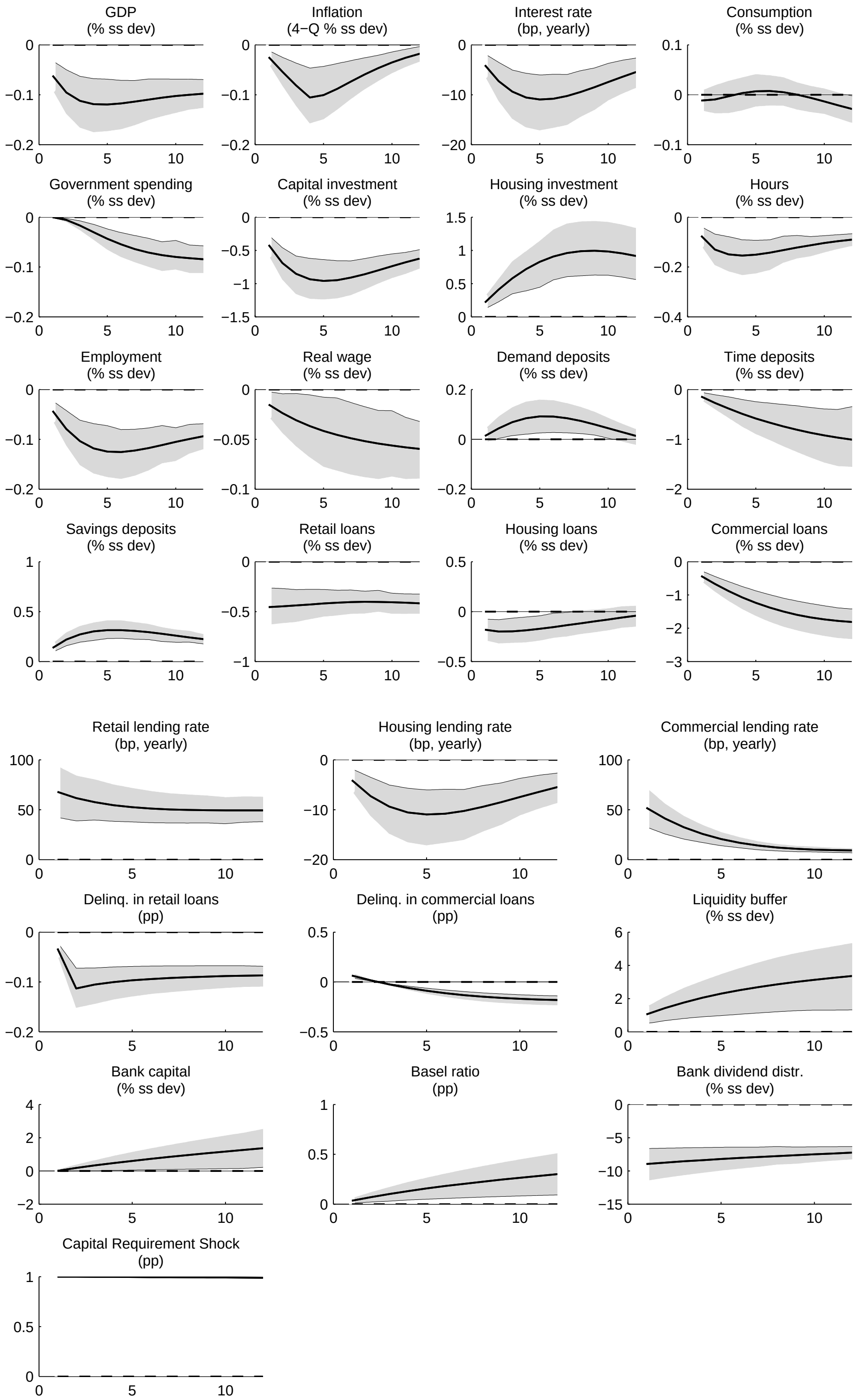


Figure 13: Capital Requirement Shock

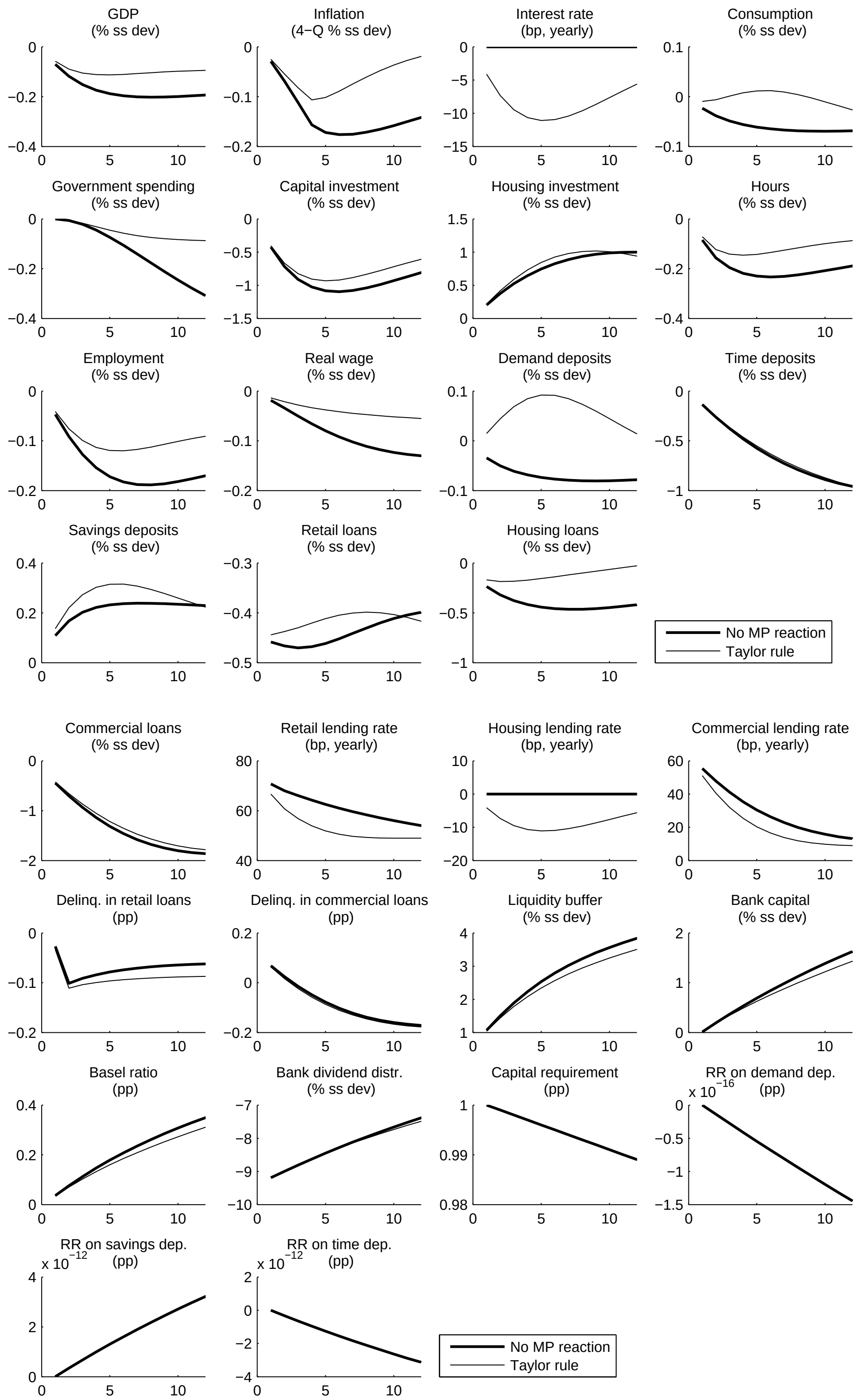


Figure 14: The role of Monetary Policy behavior on the transmission mechanisms of a Capital Requirement Shock

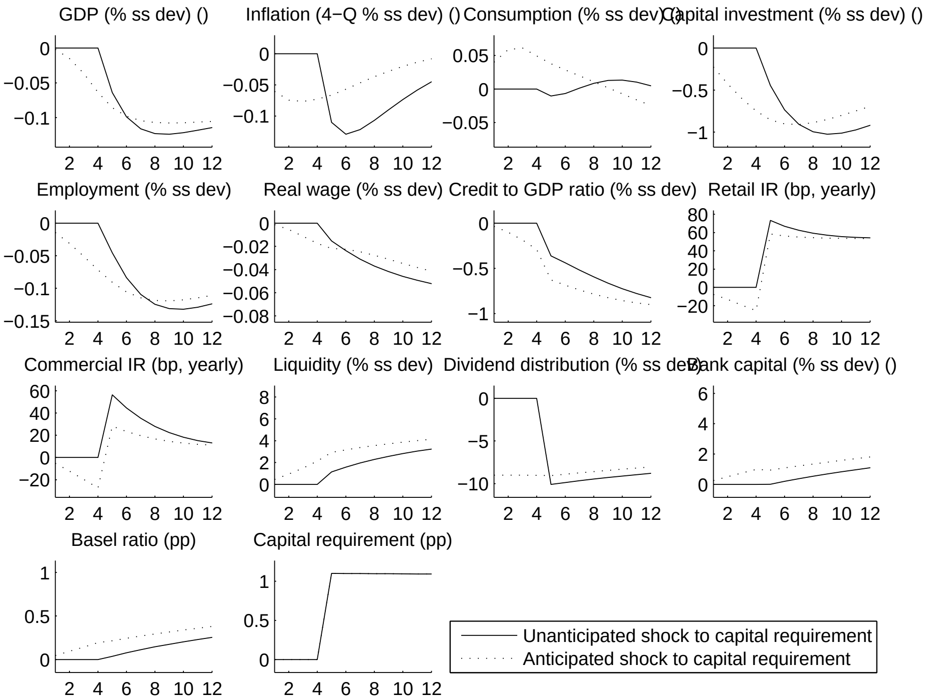


Figure 15: Anticipated x Non-anticipated capital requirement shocks

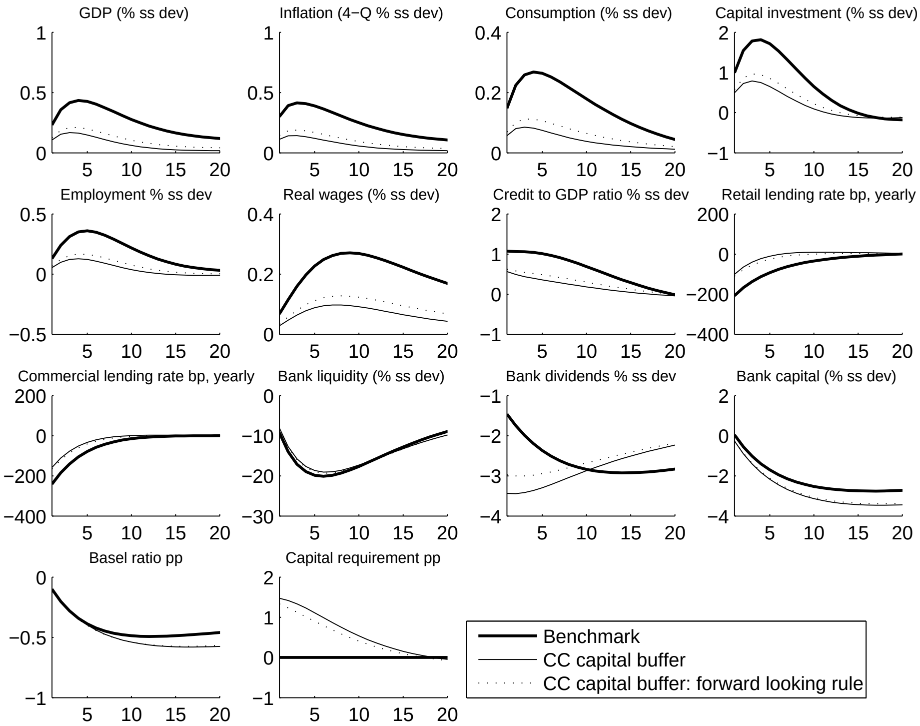


Figure 16: Comparing Countercyclical Capital Buffers after a Shock to Bank Liquidity Target

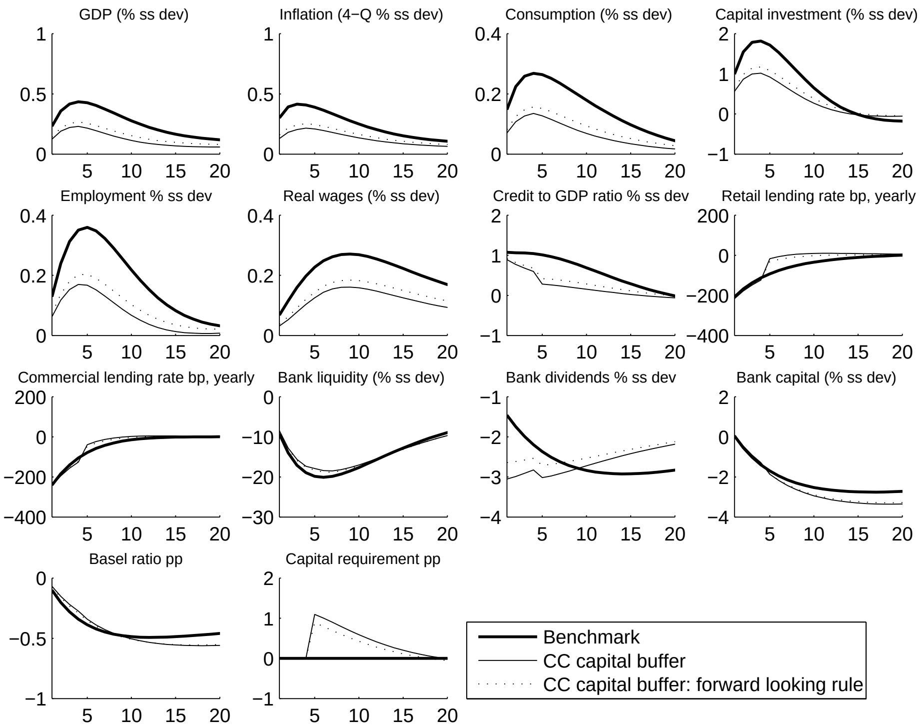


Figure 17: Delayed Implementation of Countercyclical Capital Buffers after a Shock to Bank Liquidity Target

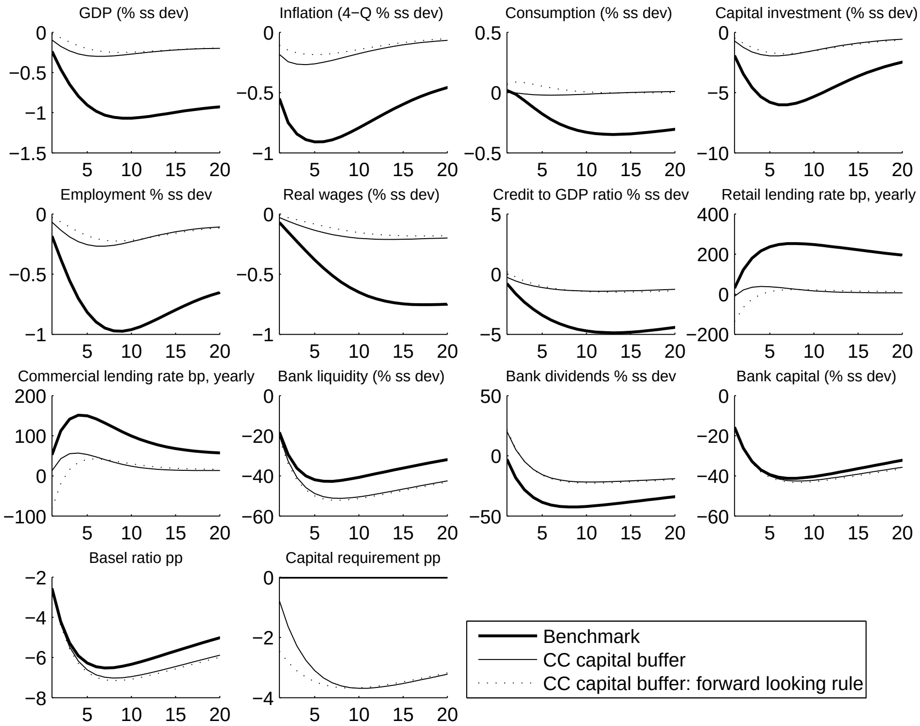


Figure 18: Comparing Countercyclical Capital Buffers after a Negative Shock to Bank Capital

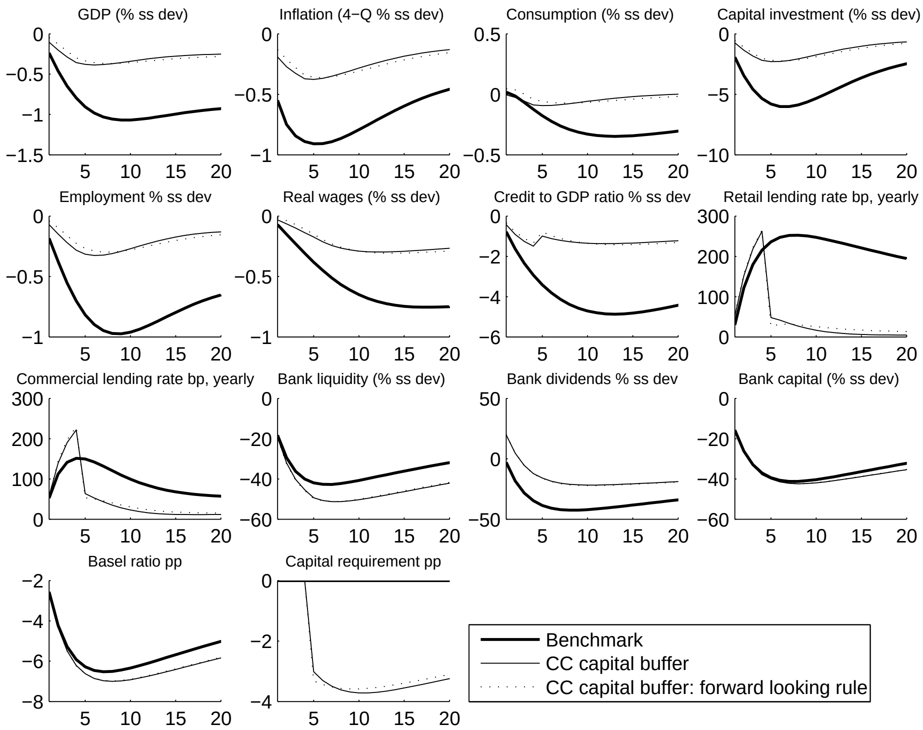


Figure 19: Delayed Implementation of Countercyclical Capital Buffers after a Negative Shock to Bank Capital

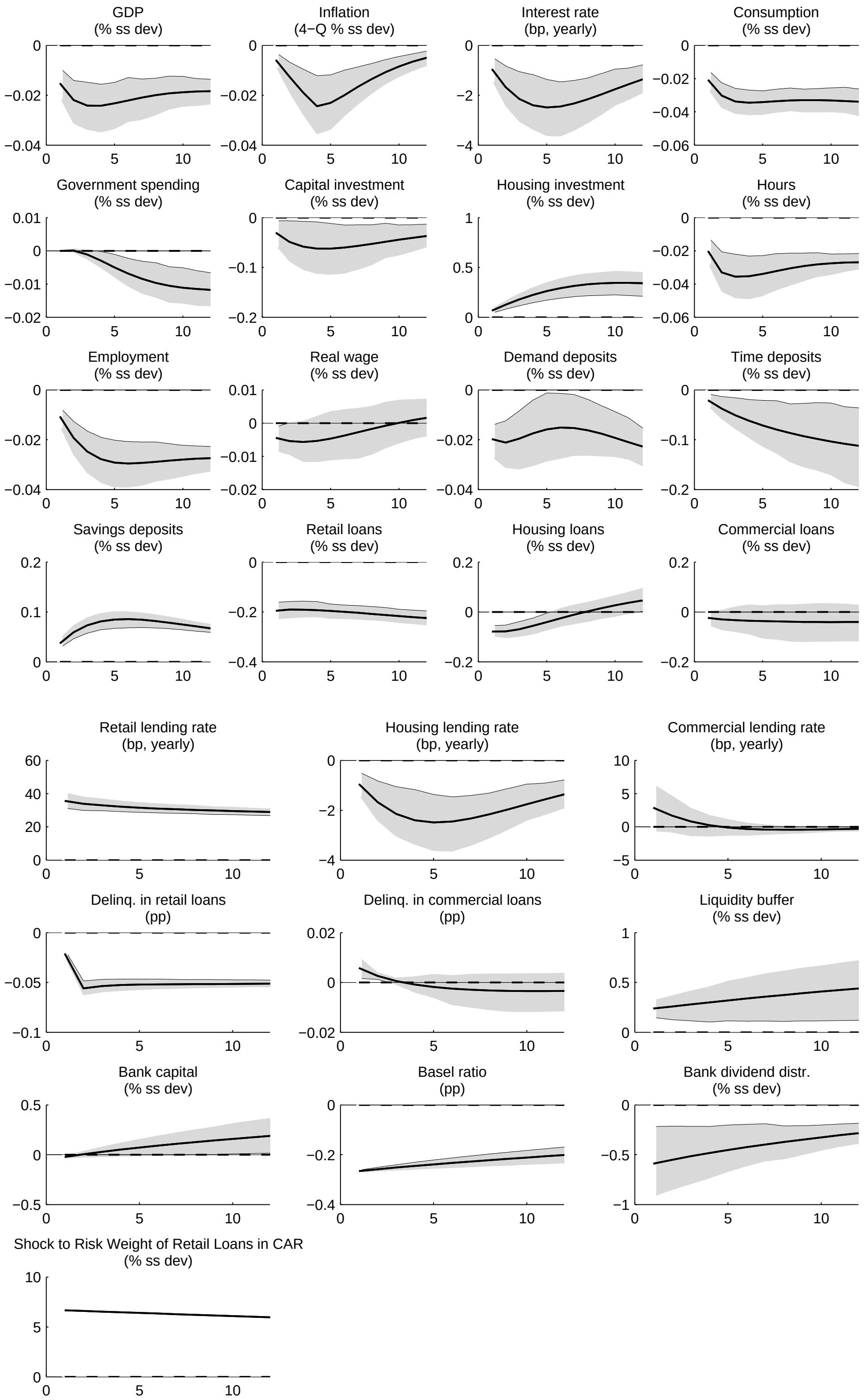


Figure 20: Sectoral Risk Weight Shock to Credit for Consumption

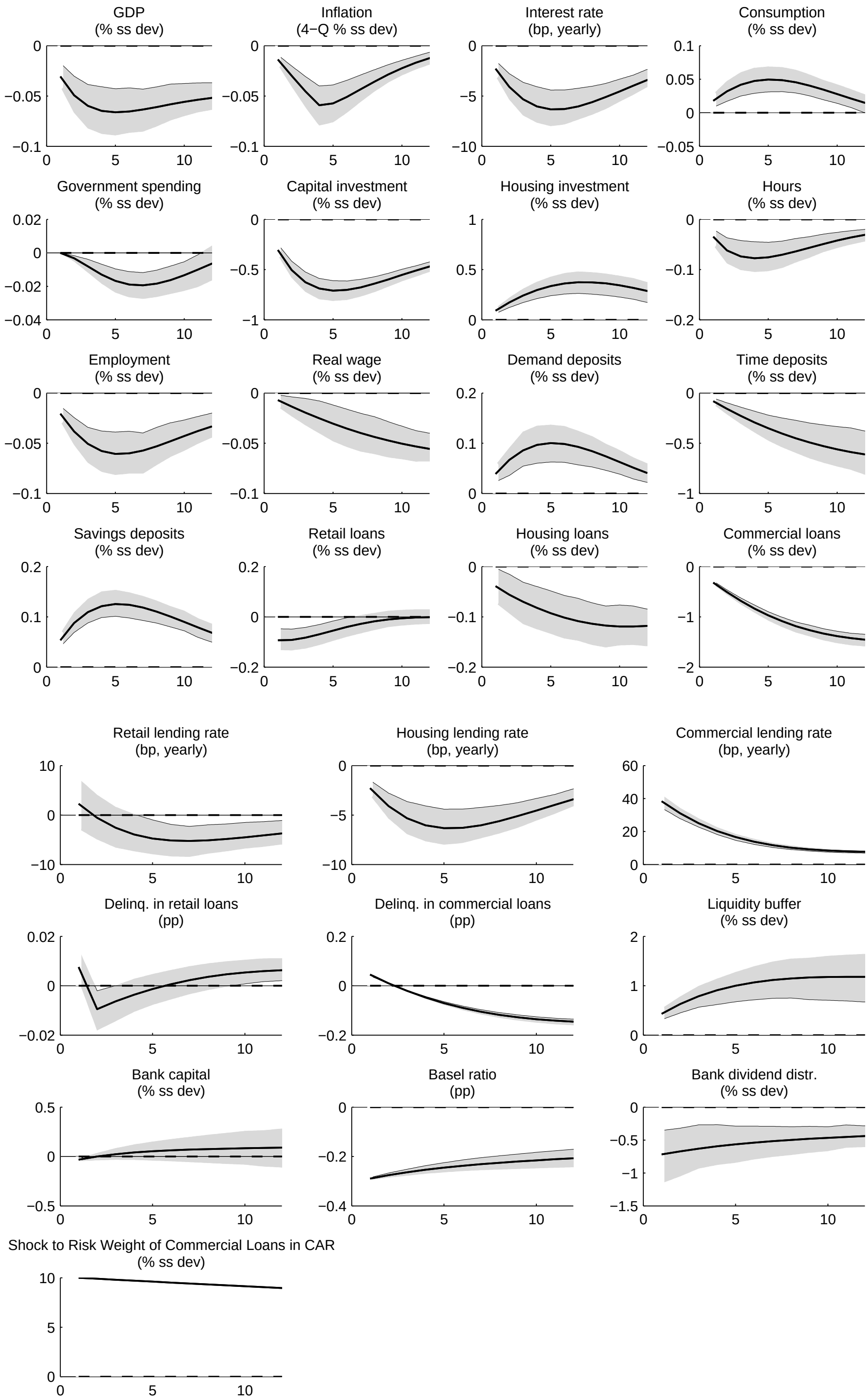


Figure 21: Sectoral Risk Weight Shock to Credit for Investment

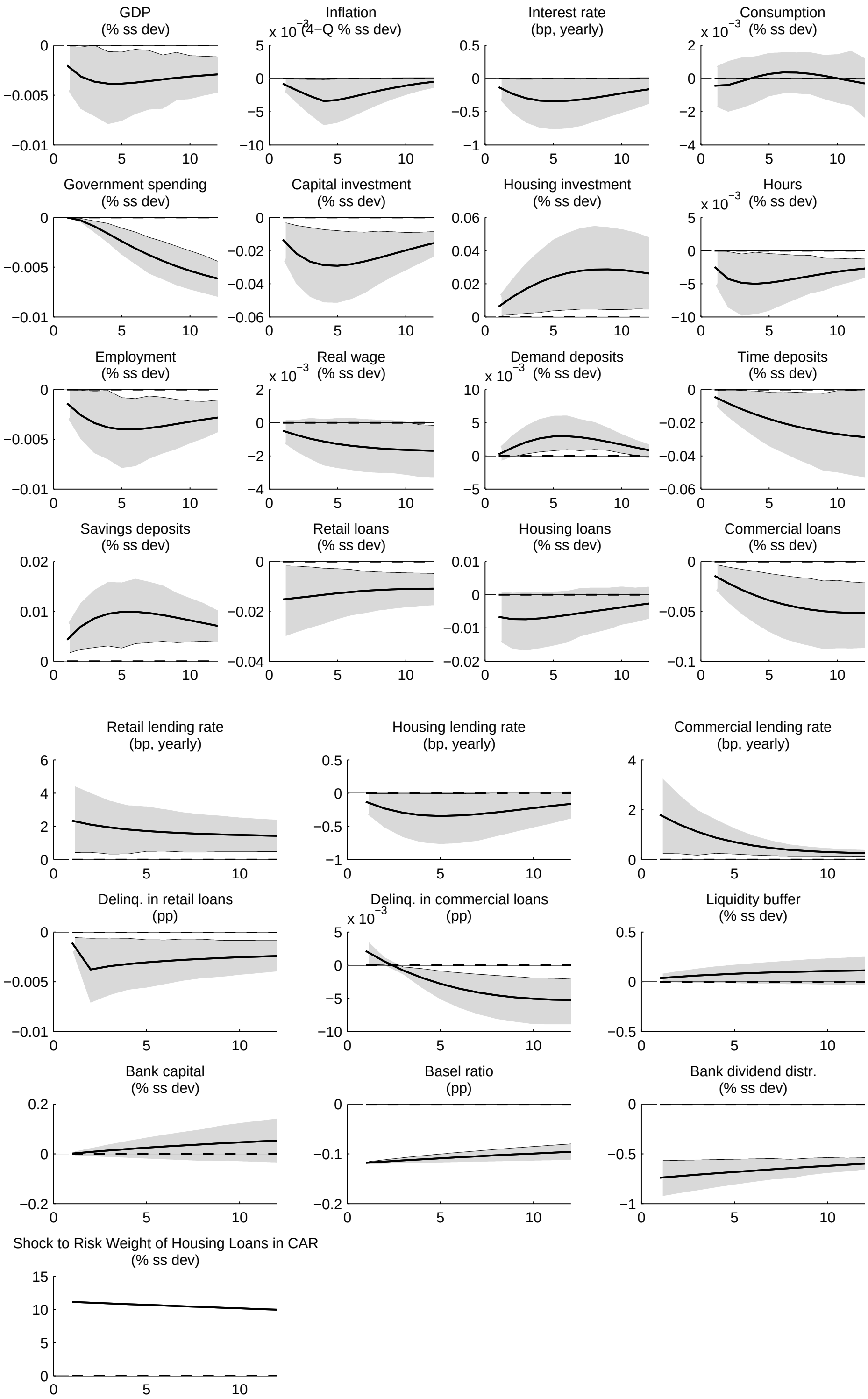


Figure 22: Sectoral Risk Weight Shock to Credit for Housing

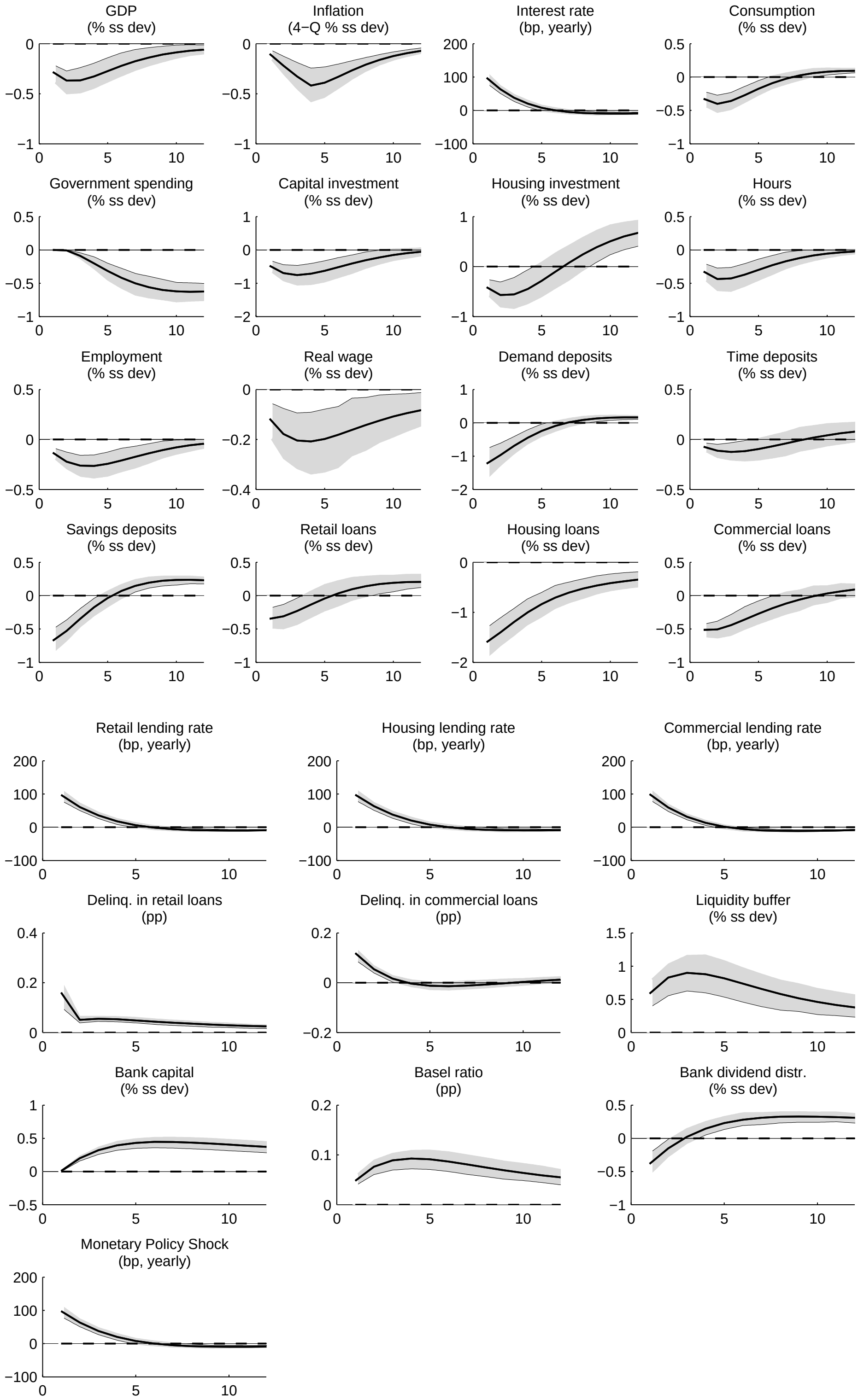


Figure 23: Monetary Policy Shock

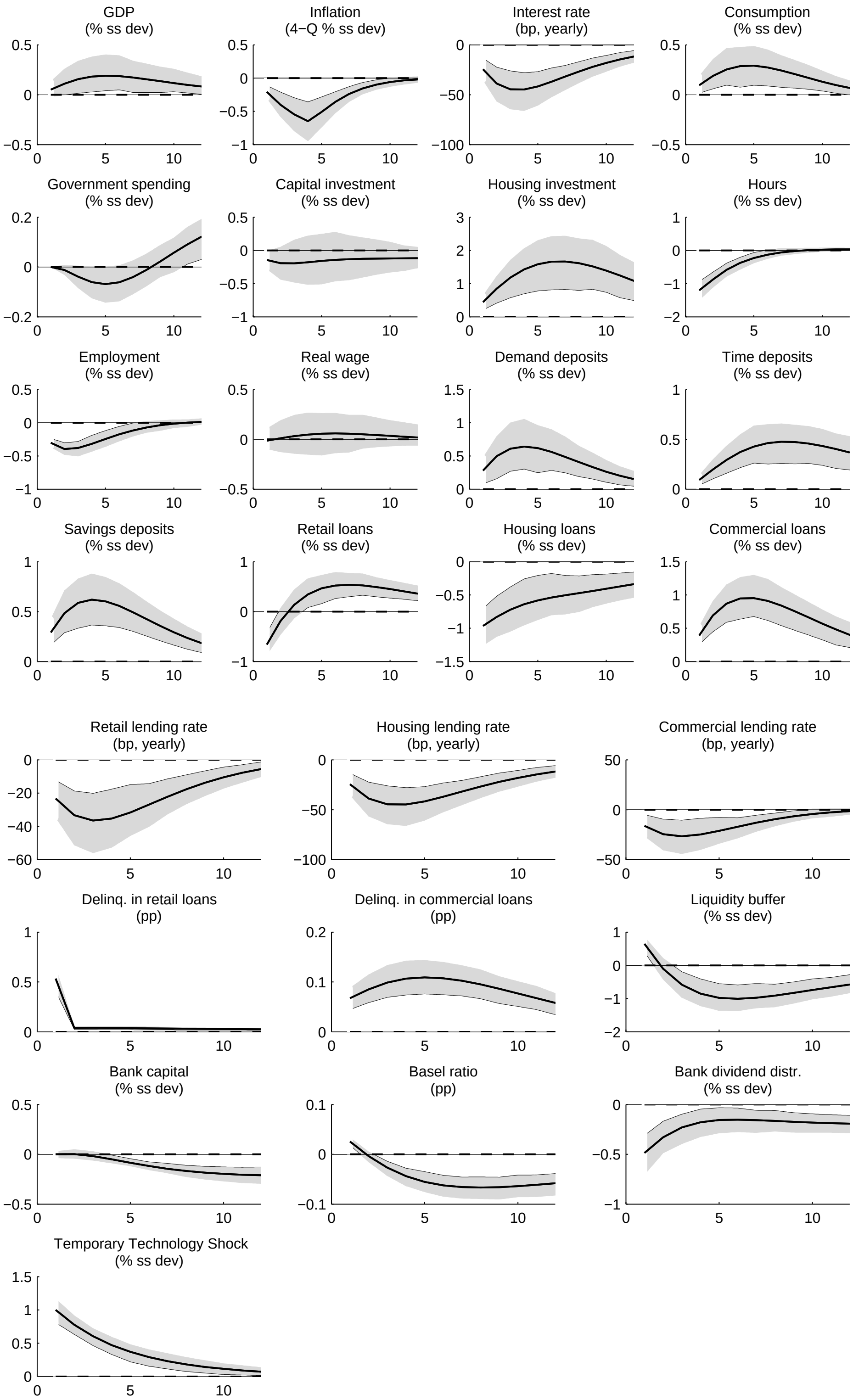


Figure 24: Temporary Technology Shock

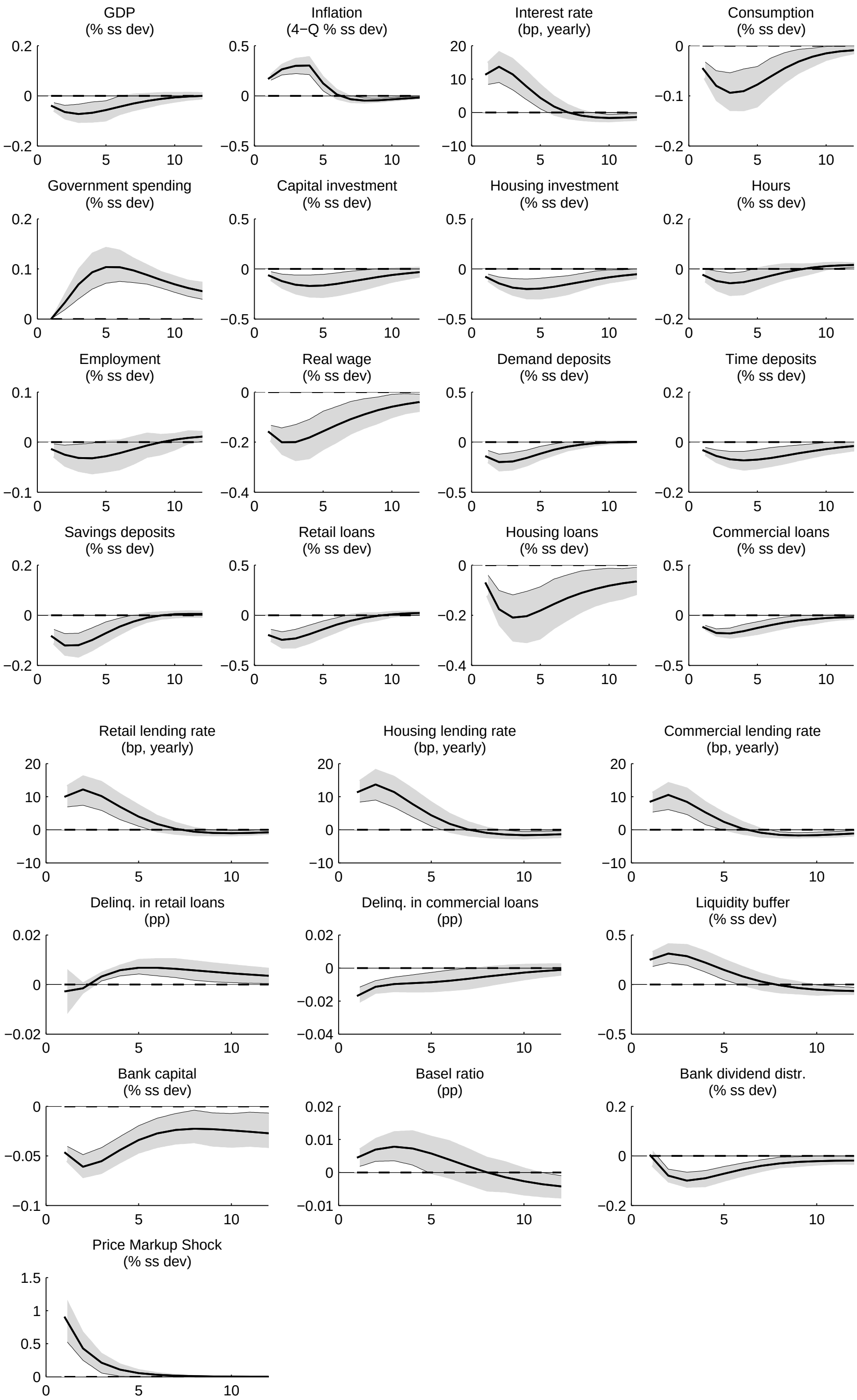


Figure 25: Price Markup Shock

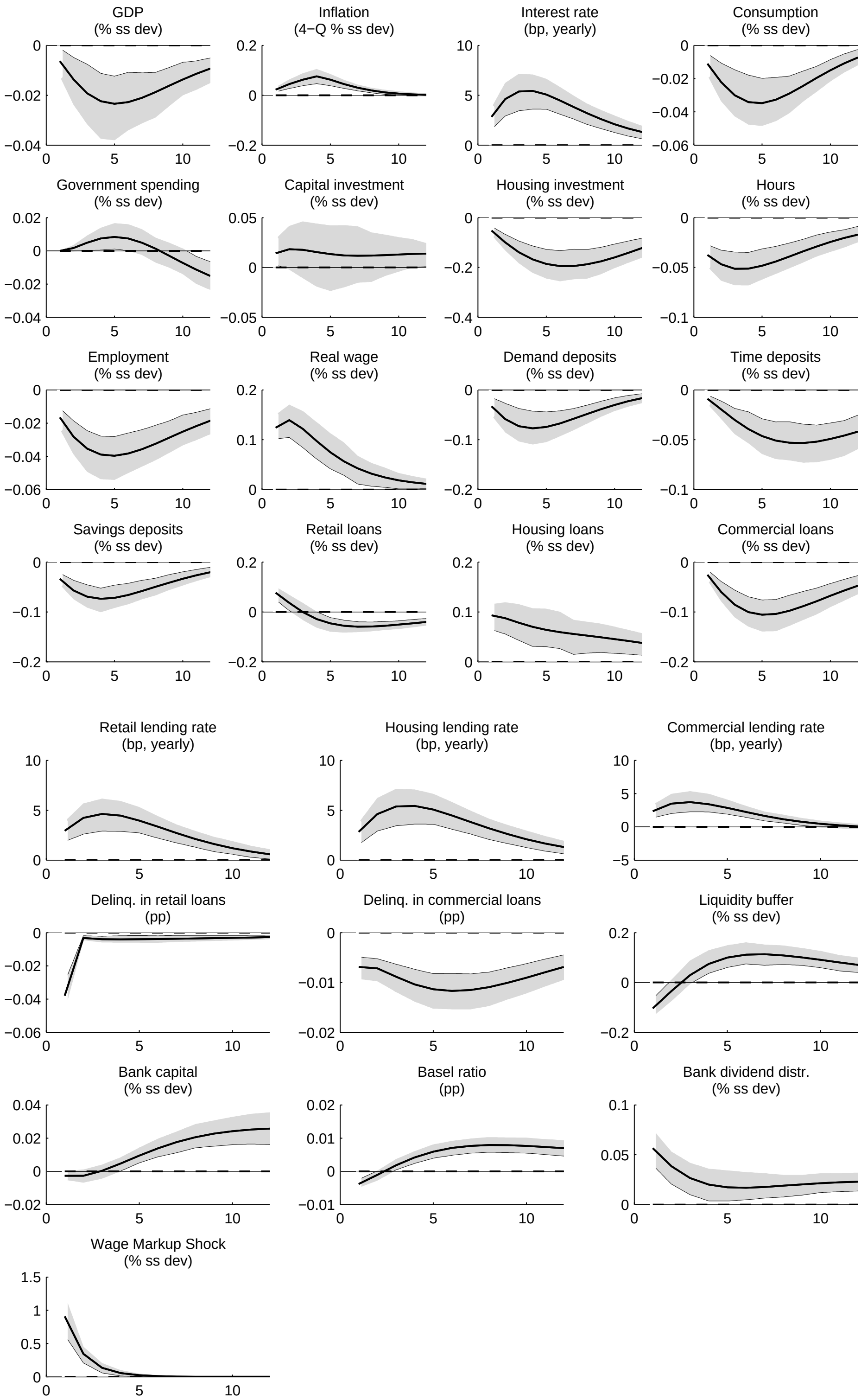
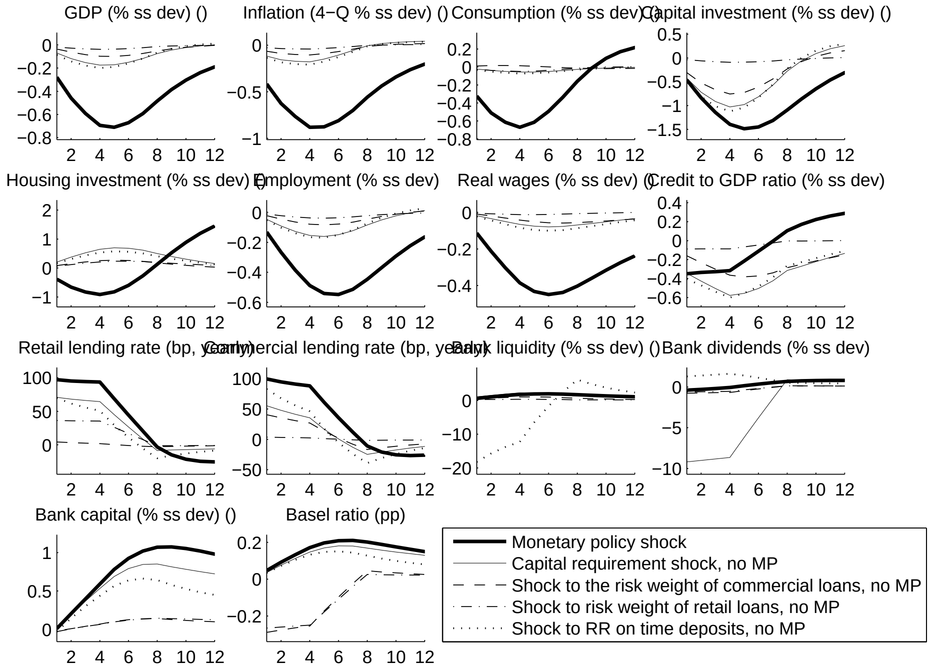


Figure 26: Wage Markup Shock

F Macroprudential Policy vs Monetary Policy Shocks



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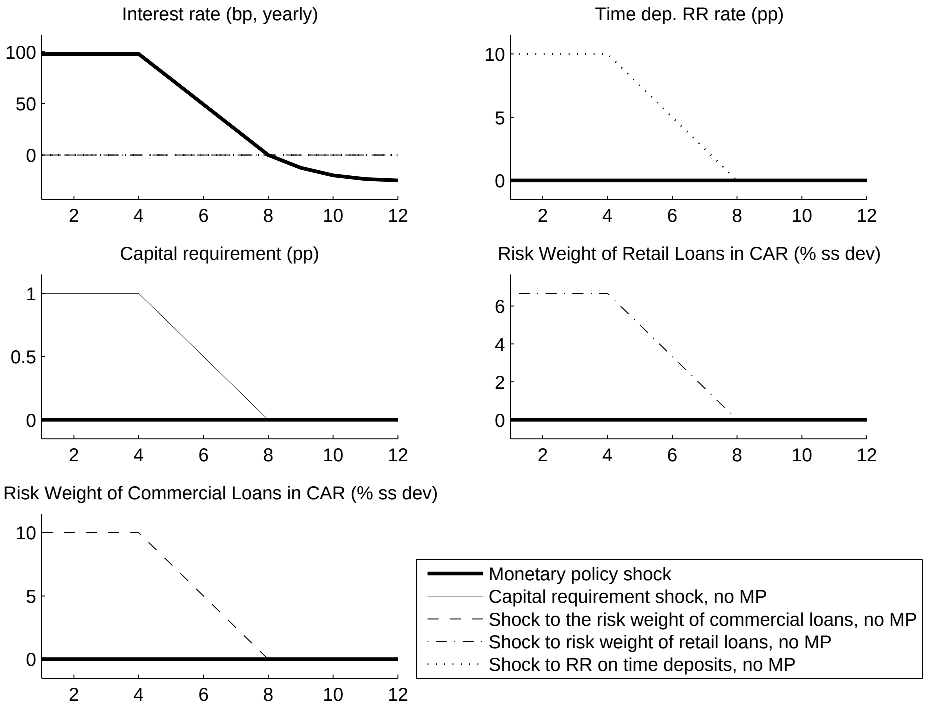

Figure 27: Comparing the Impact of Macroprudential Instruments and Monetary Policy

G Reserve Requirements and the Liquidity Target

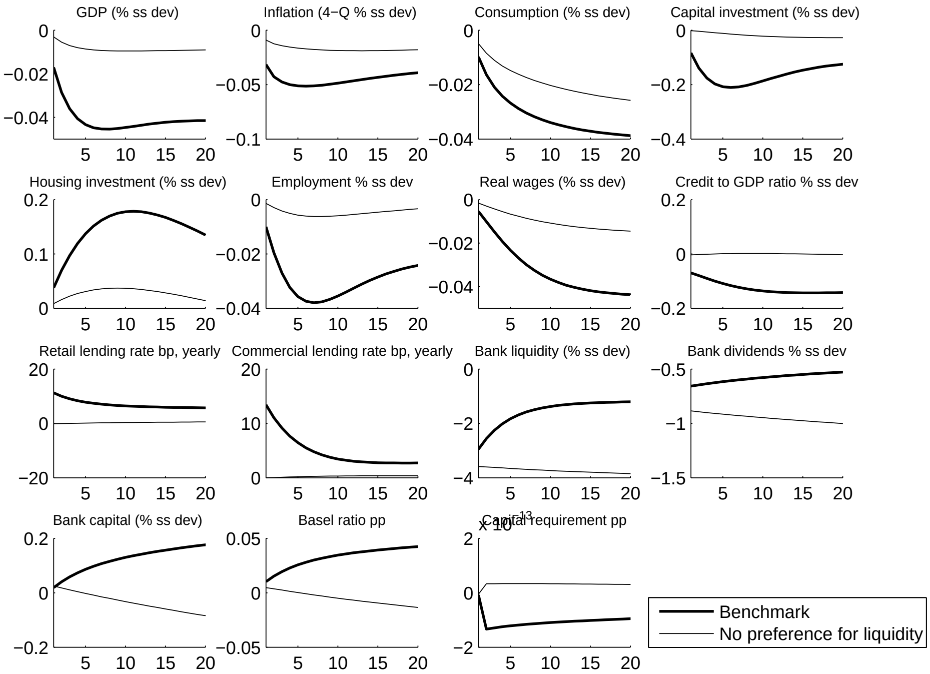

Figure 28: Removing the target for liquidity: permanent shock to reserve requirements on time deposits

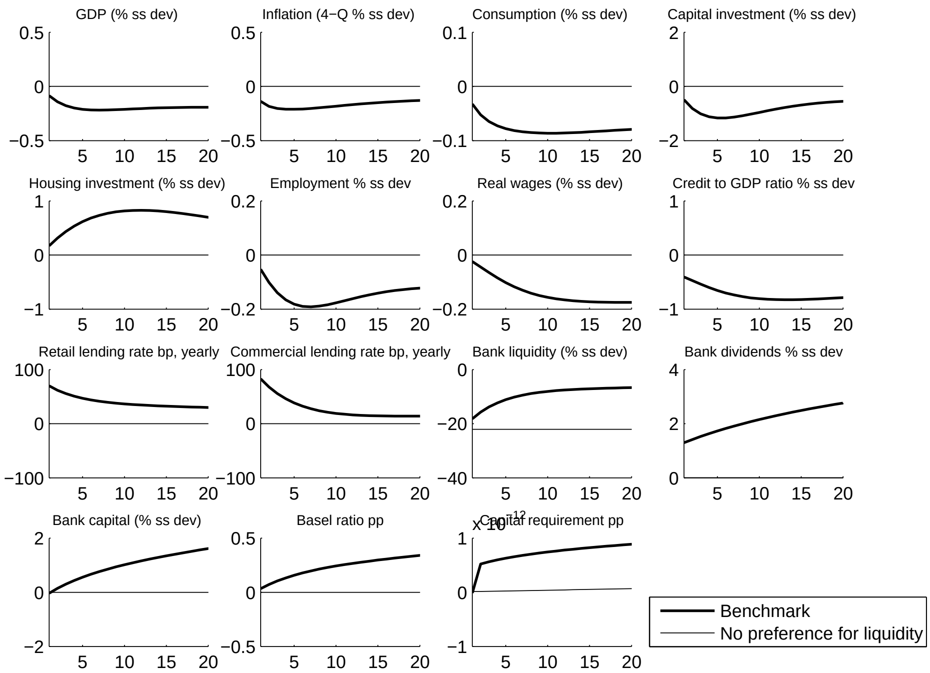

Figure 29: Removing the target for liquidity: permanent shock to reserve requirements on demand deposits

H Comparing Collateral Constraints

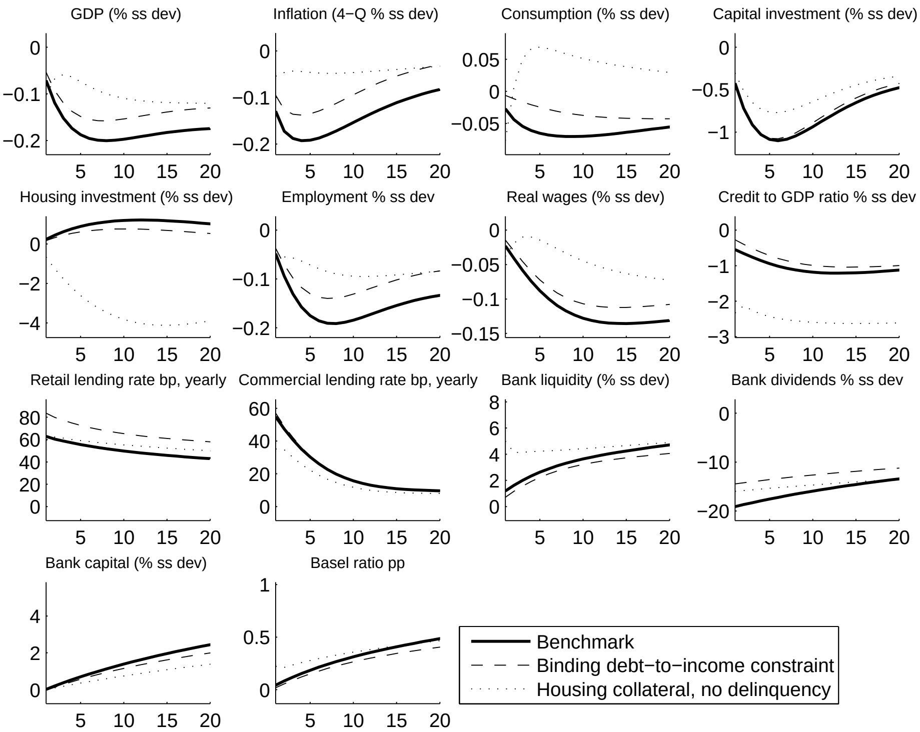

Figure 30: Alternative Collateral Constraints: Capital Requirement Shock, Unresponsive Monetary Policy

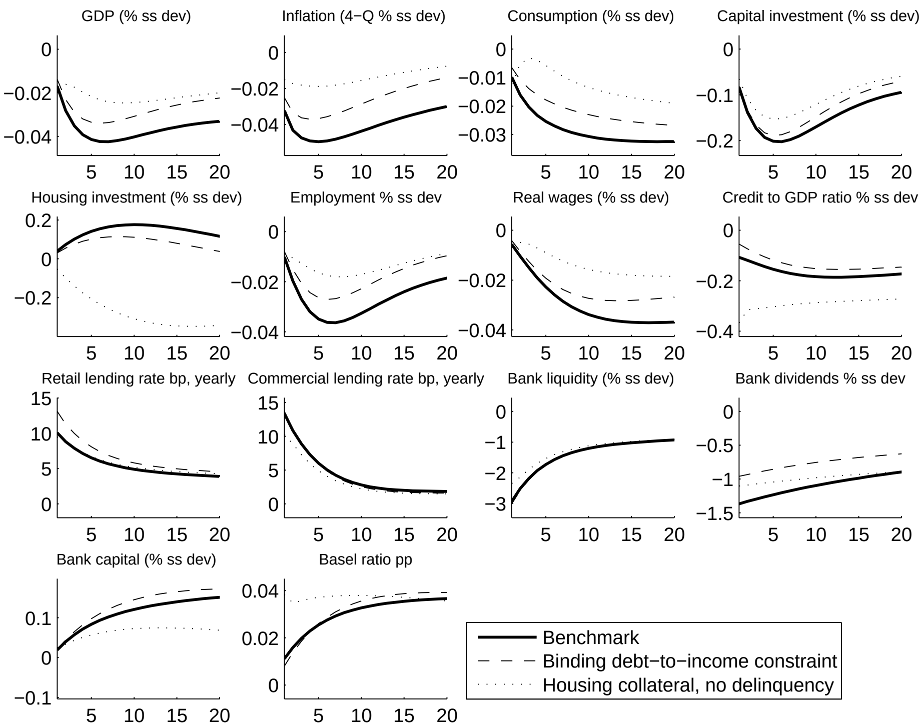

Figure 31: Alternative Collateral Constraints: Shock to Reserve Requirement on Demand Deposits, Unresponsive Monetary Policy

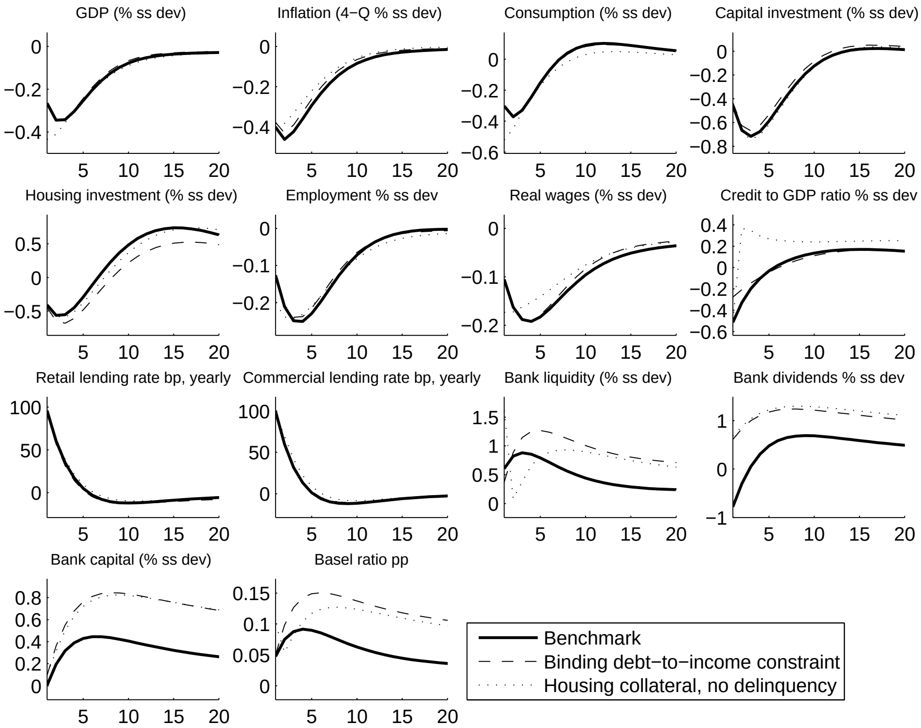

Figure 32: Alternative Collateral Constraints: Monetary Policy Shock