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* Marcos R. Castro ‡ Silvio M. A. Costa §

May 1, 2013

(PRELIMINARY VERSION)

Please do not cite

Abstract

This paper builds a DSGE model with financial frictions tailored to the Brazilian banking sector. Banks extend risky retail and housing loans based on their expectations about clients' future capacity to pay off their debt out of their labor income. Investment loans are a close variant of standard BGG-type loans. Conforming with empirical evidence on the Brazilian deposits market, interest rates on deposits are unresponsive to supply or demand conditions, a feature that signficantly differs from the literature. In addition to accepting a variety of types of deposits from households, banks operate in the credit market under monopolistic competition with rigidity in lending rates. Further frictions on banks' decisions are incorporated in the management of liquidity and liability. The regulatory environment comprises macroprudential rules and requirements on housing loan concessions and savings accounts management. The frictions introduced in both the demand and supply side of banking operations, together with taxation on banking activity and operational costs, allow the model to endogenously map the main determinants of actual lending spreads in Brazil. The model is estimated with Bayesian techniques and used to investigate the transmission channel of macroprudential policies. The impact of countercyclical capital buffers is also examined. Counterfactual exercises with nonresponsive monetary policy are carried out to isolate the total expected impact of changes in reserve requirements. The model responses imply that reserve requirements importantly affect the composition of banks' balance sheet, even when they are remunerated at the base rate. Open market operations have an important role in buffering the impact of such instruments in the real economy. When the shocks are scaled so as to offset the base-effect of low balances of demand deposits in the economy, the tax-like-effect on banks' profits of increases in non-remunerated reserves outstands in the transmission channel of reserve requirements. Capital requirements enact a stronger and more prolonged impact on credit conditions that a monetary policy shock. However, the transmission to the real economy is dampened by the automatic stabilizer of monetary policy. Countercyclical capital buffers that respond to the credit-to-GDP gap help stabilize output under negative shocks.

Acknowledgement 1 *The views expressed in this work are those of the authors and do not necessarily reflect those of the Central Bank of Brazil or its members.*

*Research Department, Central Bank of Brazil, fabia.carvalho@bcb.gov.br
†Research Department, Central Bank of Brazil, marcos.castro@bcb.gov.br
‡Corresponding author
§Research Department, Central Bank of Brazil, silvio.costa@bcb.gov.br

1 Introduction

Matter-of-fact financial frictions in Brazil significantly differ from those to which the recent DSGE literature has devoted their efforts to detailing and analyzing. Differences strike in both credit and deposits markets.

The literature has been consonant with respect to one aspect of collateral constraints in loan concessions: banks decisions are assumed to be fundamentally based on the value of a physical asset backing up the loan[1] . That might be a good representation of banks' behavior in advanced economies, but it is a very distant reality from the standpoint of retail loans in Brazil. Retail loan concessions in Brazil rely heavily on borrowers' prospects of future labor income. About half of the total volume of bank retail loans are absent of physical collateral, being advanced with little imposition on the final destination of borrowed funds. Credit lines advanced for purchases of vehicles represent another third part of the volume of retail loans, and although the destination of funds is pre-specified, the underlying goods may or may not be put up as collateral.

Even when there is physical collateral involved in the credit operation, banks' decisions on credit concessions are not usually limited to assessments about the physical collateral put forward. Banks' business is not about buying and selling capital or durable goods; in fact they are strongly precautionary against the possibility of having to deal with collateral execution to recover loans in default. The standard modeling strategy of financial frictions cannot reproduce such an environment due to the preponderant importance attributed to the value of physical collateral in defining the amount of loans advanced. In BGG-type financial accelerators, fluctuations in the price of physical collateral pin down the occurrence of default, generating a strong connection between the external risk premium and borrowers' leverage. In Brazil, loan performance is tightly associated with labor market conditions and there seems to be a disconnect between historical arrears and households' leverage.

In an attempt to introduce financial frictions in liability components of banks balance sheets, the literature has adopted the approach of assuming monopolistic competition in the deposits market[2]. This assumption generates a positive spread on the deposit rate. That is in striking difference to empirical evidence in Brazil. After the implementation of the inflation targeting regime, the spread between 90-day certificates of deposits (CDB) and the effective base rate (Selic) has been neglible (0.2 p.p. of a nominal quarterly base rate of 3.6% in average), despite strong movements in volumes.

Financial frictions have important implications for the transmission of shocks to the economy. Notwithstanding, important conclusions in the DSGE literature are model-dependent[3]. As a result, given the discrepancies between these models' theoretical set-up and the Brazilian reality of core banking operations appropriate models should be devised.

The purpose of this paper is twofold. First, we augment a state-of-the-art New Keynesian DSGE model that features nominal and real frictions by introducing financial frictions that more realistically describe core banking operations in Brazil. Second, we examine the transmission channels of monetary and macroprudential policy to the economy.

Conforming with empirical evidence on Brazilian deposits markets, we assume that interest rates on time deposits are unresponsive to supply or demand conditions. In addition to supplying a variety of deposits to households, banks operate in the credit market under monopolistic competition with rigidity in lending rates. Retail loans are based on banks' assessment of borrowers' future capacity to pay off their debt out of labor income. Housing loans are collateralized by the underlying real estate but concessions are also dependent on prospects of future labor income. Investment loans are a close variant of the BGG-financial accelerator. Further frictions on banks' decisions are incorporated in the management of liquidity and liability, through liquidity targets and costs from deviating from the optimal level of time deposits and further adjustment costs. The regulatory environment comprises macroprudential rules and requirements

[1] The main strands of the literature on financial frictions in macroeconomic models incorporate agency problems in loan concessions backed up by physical capital ([1], [5],[6]) or binding credit constraints based on the value of households' assets, most usually housing ([19], [18], [16],[4]) or a mix of both ([3], [11], among others). [14] provide an extensive comparison of the economic implications of both modeling assumptions.

[2] Some examples are [11], [18] and [16].

[3] [14] 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.

on housing loan concessions and savings accounts management. The model is estimated with Bayesian techniques and used to investigate the transmission channel of macroprudential policies.

The frictions introduced in both the demand and supply side of banking operations, together with taxation on banking activity and operational costs, allow the model to endogenously map the main determinants of actual lending spreads in Brazil.

The model responses show that the most important impact of changes in reserve requirement ratios rests on the composition of banks' balance sheet. Open market operations have an important role in buffering the impact of such instrument in the real economy. The estimated impact on the real economy is mild. Upon impact, investment and retail lending rates increase, leading to lower demand for loans and reducing total volume of credit in the economy. Both the labor and the goods markets are mildly affected, resulting in some contraction of output. The literature also finds evidence of a moderate degree of the impact of non-remunerated reserve requirements on the economy[4].

However, contrary to what most of this literature advocates[5], the estimated impulse responses of changes in remunerated reserve requirements on time deposits show stronger effects in the real economy compared to changes in unremunerated reserve requirements on demand deposits, notwithstanding the fact that required reserves on time deposits are fully remunerated in Brazil. This has important implications for policy prediction. Further investigation shows that this result is driven by a base-effect, since the balance of time deposits in Brazil is almost eight times as large as that of demand deposits. After scaling the shocks to enact an equivalent impact in terms of the amount of funds seized by the central bank, we obtain the traditional prediction that reserve requirements on demand deposits have stronger impacts in the economy mostly through the differentiated impact in banks' profits and not so much in banks' balance sheet.

The literature interprets the modest degree of the real impact of reserve requirements to be a consequence of a responsive monetary policy[6]. We conduct a counter-factual exercise in which monetary policy remains nonresponsive to economic conditions while we stress the model with a shock to reserve requirements. The responses of this exercise with respect to aggregate economic variables and banking variables are practically identical to the benchmark estimated response, a result that is also driven by the base-effect. In qualitative terms, the assumption about the type of monetary policy makes a difference for the responses to changes in reserve requirements on demand deposits; however the magnitude of such a difference is negligible.

An increase in the overall target of capital requirement has a more prolonged and stronger impact on the credit-to-GDP ratio than a monetary policy shock. However, the automotatic stabilizer of monetary policy dampens the passthrough of worsened credit conditions to the rest of the real economy.

We also examine possible impacts of countercyclical capital buffers. A countercyclical buffer that reacts to the credit gap is shown to stabilize output in the advent of an unexpected deterioration in bank capital.

The economic agents in our model are almost the same as those in [3]. However, there are important differences with respect to the decision making by households, entrepreneurs and banks. Our paper relates to the literature that analyzes the impact of macroprudential policies in a DSGE framework ([6], [3], *[11],* [12]). However, all of the cited studies have a prominent role for the housing sector or bank capital, focusing mostly on advanced economies. Our paper also relates to the literature on endogeneous bank lending through the introduction of monopolistic competition in bank lending ([4], [18]).

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 under Bayesian techniques. Section 4 presents the impulse responses of the estimated model. Section 5 examines counterfactual exercises and discusses some policy issues, including alternative

[4] [6] find that reserve requirements have a role in supporting price stability if, among other conditions that are somehow addressed in our model, debt is denominated in foreign currency. [8] argue that reserve requirements have smaller impacts if the amount of deposits subject to reserve requirements relative to domestic bank credit is small, yet what "small" means was not qualified. [13] find empirical evidence that higher unremunerated reserve requirements in Brazil increase the mean of lending rates. [10] use event study and dynamic panel VAR on a number of Latin American countries to find that RR have a moderate and transitory effect in private banking growth, playing a complementary role to monetary policy.

[5] [8] claim that partial remuneration of reserve requirements reduce their distortionary tax effect but also lessen the impact of changes in the reserve requirement rate on the banking system.

[6] [6] argue that if interest rate setting is dissociated from decisions on reserve requirements, the former may neutralize the impact of the latter.

countercyclical capital requirement rules. The final section concludes.

2 The theoretical model

In this session, we describe the main features of the theoretical model, emphasizing our contributions to existing models or adjustments to Brazilian particularities.

2.1 Households

Households derive utility from consumption goods, housing goods, and from liquidity. They supply labor to a labor union in a competitive environment.

There are two types of households: net creditors or net debtors of the financial system. A number of financial assets are available to net creditors, henceforth "savers". Savers own demand and savings deposits at the bank and shares of an investment fund whose portfolio is composed of a basket of government bonds and time deposits issued by a bank conglomerate. Liquidity in savers' utility is a combination of resources deposited at demand and savings accounts[7].The yield on savings accounts is regulated by the government as a markdown on the base rate of the economy, in conformity with Brazilian practice.

Net debtors, henceforth "borrowers", obtain loans by offering stakes of their future wages as collateral. These loans represent half the stock of retail loans in Brazil, and are advanced with little imposition on the final destination of the extended funds. Credit lines financing purchases of vehicles represent another third of retail loans, and the underlying goods may or may not be put up as collateral. Regardless of the presence of physical collateral, retail credit concessions by Brazilian banks heavily rely on the assessment about the borrower's capacity to pay future installments of the loan based on her expected stream of labor income.

2.1.1 The Saver's program

Savers are uniformly distributed in the continuum $S \in (0, \omega_S)$ 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 deposits, demand deposits, and investment fund quotas, to maximize

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

subject to the budget constraint

$$\begin{aligned} & (1+\tau_{C,t}) P_{C,t} C_{S,t} + P_{H,t} \left(H_{S,t} - (1-\delta_H) H_{S,t-1}\right) + D^F_{S,t} + D^S_{S,t} + D^D_{S,t} \\ = \; & R_{F,t-1} D^F_{S,t-1} + R_{S,t-1} D^S_{S,t-1} + D^D_{S,t-1} + (1-\tau_{w,t}) \left(W_t^N N_{S,t}\right) \qquad (2) \\ & + TT_{S,t} + \Pi^{LU}_{S,t} + \Pi_{S,t} + TT_{\Gamma,S,t} + T^{GN}_{S,t} \qquad (3) \end{aligned}$$

where

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

[7]The yield on savings deposits is lower than the yield on investment fund quotas. To prevent arbitrage, we let depositors yield some utility from savings. Previous versions of the model attempted to introduce a third type of household who could only invest in savings deposits, with a distinct intertemporal discount factor. However, this modeling strategy failed to pin dow the level of savings deposits, resulting in a overwhelming region of indeterminacy in the model.

and 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 supplied to labor unions at a nominal wage W_t^N. Labor unions transfer their net-of-tax profits $\Pi_{S,t}^{LU}$ obtained from monopolistic competition back to households in a lump-sum manner. Savers also receive lump sum transfers from the government, $TT_{S,t}$, in addition to profits $\Pi_{S,t}$ from firms, entrepreneurs, and banks. Costs from capital utilization and the depreciation of bank capital are lump-sum transfered to savers as $TT_{\Gamma,S,t}$. Profits from entrepreneurial activities are also transfered to savers as $T_{S,t}^{GN}$.

One-period returns on savings accounts and on investment fund quotas are $R_{S,t}$ and $R_{F,t}$, respectively. These are fixed rates negotiated at the moment the deposit is made.

2.1.2 The Borrower's program

Borrowers are distributed in the continuum $(0, \omega_B)$. They can obtain loans by offering future wage assignments as collateral. Borrower i's total income from labor is subject to lognormally distributed 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 affect borrowers' ability to pay their debt installments. After realization of the shock $\varpi_{B,i,t}$, borrower i's net-of-tax nominal labor income is given by

$$\varpi_{B,i,t}\left[\left(1-\tau_{\omega,t}\right)N_{B,i,t}W_t\right] \tag{4}$$

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

At period t, household i borrows a nominal amount of debt $B_{B,i,t}^{C}$ from the bank's retail lending branch to be repaid next period, in addition to a nominal amount $B_{B,i,t}^{H}$ from the bank's mortgage loan branch. The one-period interest rates on these loans, $R_{B,t}^{L,C}$ and $R_{B,t}^{L,H}$, respectively, are set at the moment of the negotiation. Instead of housing or other tangible assets, as is common in the literature for advanced economies, the bank's branches may seize as collateral a fraction $\gamma_t^{B,C}$ of the household's net-of-tax labor income, after incurring proportional monitoring costs $\mu_{B,C}$ and $\mu_{B,H}$, respectively, which can be regarded as the cost of bankruptcy (including auditing, legal and enforcement costs). Collateral proceeds are split between both bank's lending branches, priority given to mortgage loans[9]. Next period, after realization of the shock $\varpi_{B,i,t+1}$, the borrower chooses to default if the amount of labor income commited to the loan is less than the total debt redeeming. This threshold value, $\overline{\varpi}_{B,i,t+1}$, for shock $\varpi_{B,i,t+1}$ is such that

$$\gamma_t^{B,C}\overline{\varpi}_{B,i,t+1}\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1} = R_{B,i,t}^{L,C}B_{B,i,t}^{C} + R_{B,t}^{L,H}B_{B,i,t}^{H} \tag{5a}$$

For convenience, we define another threshold $\overline{\varpi}_{B,i,t+1}^{H}$ such that

$$\gamma_t^{B,C}\overline{\varpi}_{B,i,t+1}^{H}\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1} = R_{B,t}^{L,H}B_{B,i,t}^{H} \tag{6}$$

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

$$\begin{aligned} &E_t\left(1-\mu_{B,C}\right)\int_{\overline{\varpi}_{B,i,t+1}^{H}}^{\overline{\varpi}_{B,i,t+1}}\left[\gamma_t^{B,C}\varpi_{B,i,t}\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1} - R_{B,t}^{L,H}B_{B,i,t}^{H}\right]dF\left(\varpi_{B,i,t}\right) \\ &+E_t\int_{\overline{\varpi}_{B,i,t+1}}^{\infty} R_{B,t}^{L,C}B_{B,t}^{C}dF\left(\varpi_{B,i,t}\right) = R_{B,t}^{C}B_{B,i,t}^{C} \end{aligned} \tag{7}$$

or

$$\gamma_t^{B,C}\left[E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}G_{B,C}\left(\overline{\varpi}_{B,i,t+1},\overline{\varpi}_{B,i,t+1}^{H}\right)\right] = R_{B,t}^{C}B_{B,i,t}^{C} \tag{8}$$

[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 sum of the net-of-tax labor income obtained from unions $\left(1-\tau_{\omega,t}\right)N_{B,i,t}W_t^N$ and her share on unions' net-of-tax profits $\Pi_{S,t}^{LU}$.

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

where

$$G_{B,C}\left(\overline{\varpi}_1,\overline{\varpi}_2\right) = \left(1-\mu_{B,C}\right)\left[\int_{\overline{\varpi}_1}^{\overline{\varpi}_2}\varpi dF\left(\varpi\right)-\overline{\varpi}_1\left[F\left(\overline{\varpi}_2\right)-F\left(\overline{\varpi}_1\right)\right]\right] + \left(\overline{\varpi}_2-\overline{\varpi}_1\right)\left(1-F\left(\overline{\varpi}_2\right)\right) \tag{9}$$

and $R^C_{B,t}$ is the retail lending branch's funding cost.

On average, the household's expected repayment to the retail lending branch is given by

$$\begin{aligned} & \gamma_t^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}\left[\begin{array}{c}\int_{\overline{\varpi}^H_{B,i,t+1}}^{\overline{\varpi}_{B,i,t+1}}\varpi dF\left(\varpi\right)\\ -\overline{\varpi}^H_{B,i,t+1}\left(F\left(\overline{\varpi}_{B,i,t+1}\right)-F\left(\overline{\varpi}^H_{B,i,t+1}\right)\right)\\ +\left(\overline{\varpi}_{B,i,t+1}-\overline{\varpi}^H_{B,i,t+1}\right)\left(1-F\left(\overline{\varpi}_{B,i,t+1}\right)\right)\end{array}\right] \\ = & \gamma_t^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}_{B,t+1},\overline{\varpi}^H_{B,i,t+1}\right) \end{aligned} \tag{10}$$

where

$$H\left(\overline{\varpi}_B,\overline{\varpi}^H_B\right) = \int_{\overline{\varpi}^H_B}^{\overline{\varpi}_B}\varpi dF\left(\varpi\right)-\overline{\varpi}^H_B\left(F\left(\overline{\varpi}_B\right)-F\left(\overline{\varpi}^H_B\right)\right) + \left(\overline{\varpi}_B-\overline{\varpi}^H_B\right)\left(1-F\left(\overline{\varpi}_B\right)\right) \tag{11}$$

Similarly, the household's expected repayment to the mortgage loan branch is

$$\begin{aligned} & \gamma^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}\left[\int_0^{\overline{\varpi}^H_{B,i,t+1}}\varpi dF\left(\varpi\right)+\left(\overline{\varpi}^H_{B,i,t+1}\right)\left(1-F\left(\overline{\varpi}^H_{B,i,t+1}\right)\right)\right] \\ = & \gamma^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}^H_{B,i,t+1},0\right) \end{aligned} \tag{12}$$

and the overall payment flow of bank loans is

$$\begin{aligned} & \gamma_t^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}\left[\int_0^{\overline{\varpi}_{B,i,t+1}}\varpi dF\left(\varpi\right)+\left(\overline{\varpi}_{B,i,t+1}\right)\left(1-F\left(\overline{\varpi}_{B,i,t+1}\right)\right)\right] \\ = & \gamma^{B,C}E_t\left(1-\tau_{\omega,t+1}\right)N_{B,i,t+1}W_{t+1}H\left(\overline{\varpi}_{B,i,t+1},0\right) \end{aligned} \tag{13}$$

The interest rate on housing loans is set by the government and does not depend on borrowers' leverage. This assumption accords with the tightly regulated market of Brazilian housing loans to lower priced real estate, which contitutes the bulk of the housing loans market. These loans are subject to an interest rate cap of 12% p.a., in addition to several other regulatory requirements are also addressed in the model[10]. The following two constraints on housing loans pertain to such requirements.

First, we impose the constraint that housing loans cannot exceed a fraction $\gamma_t^{B,H}$ of borrower's housing stock.

$$B^H_{B,i,t} \leq \gamma_t^{B,H}P^H_tH^B_{i,t} \tag{14}$$

The introduction of $\gamma_t^{B,H}$ an additional source of variation in borrower's leverage with housing loans allows the model to accomodate the recent increase in household indebtness in Brazil that is unrelated with observed movements in the value of collateral.

Additionally, since regulated rates on housing loans are lower than market rates, the central bank requires that the mortgage loan branch extend housing loans at an amount equivalent to a fraction $\tau_{H,S,t}$ of the bank's savings deposits. Therefore, total demand for housing loans will also be constrained by[11]:

$$\omega_B B^H_{B,t} \leq \tau_{H,S,t}\omega_S D^S_{S,t} \tag{15}$$

[10]The upper bound for the price of houses that qualify for these cheaper credit lines is currently BRL 500 thousand (˜USD 250 thousand).

[11]This equation will have no role on defaulting decisions since we assume that the constraint is non-binding at all times. In fact, Brazilian banks' balance sheets give support to this assumption since the amount of housing loans is persistently lower than the mandatory allocation.

After the idiosyncratic shock $\varpi_{B,i,t}$ is observed, the household decides whether to default or not, and $\varpi_{B,i,t} < \overline{\varpi}_{B,t}$ leads to default[12].

The representative borrower chooses the stream $\left\{C_{B,t}, N_{B,t}, H_{B,t}, \mathcal{X}_{B,t}, D^D_{B,t}, \overline{\varpi}_{B,t}, \overline{\varpi}^H_{B,t}, B^C_{B,t}, B^H_{B,t}\right\}$ to maximize the utility function

$$E_0 \left\{ \sum_{t\geq 0} \beta_B^t \left[\frac{1}{1-\sigma_X} \left(\mathcal{X}_{B,t}\right)^{1-\sigma_X} - \frac{\varepsilon_t^L \overline{L}_B}{1+\sigma_L} \left(N_{B,t}\right)^{1+\sigma_L} + \frac{\psi_{D,B}}{1-\sigma_D} \varepsilon_t^{D,B} \left(\frac{D^D_{B,t}}{P_{C,t} C_{B,t}} \right)^{1-\sigma_D} \right] \varepsilon_t^{\beta} \right\} \tag{16}$$

subject to the budget constraint

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

and the constraints from the optimal contract

$$\begin{aligned} & \gamma_t^{B,C} E_t \left(1-\tau_{\omega,t+1}\right) N_{B,t+1} W^N_{t+1} G_{B,C}\left(\overline{\varpi}_{B,t+1}, \overline{\varpi}^H_{B,t+1}\right) = R^C_{B,t} B^C_{B,t} \\ & \gamma_t^{B,C} \overline{\varpi}^H_{B,t} \left(1-\tau_{\omega,t}\right) N_{B,t} W_t^N = R^{L,H}_{B,t-1} B^H_{B,t-1} \\ & B^H_{B,t} \leq \gamma_t^{B,H} P_{C,t} Q_{H,t} H_t^B \\ & \omega_B B^H_{B,t} \leq \tau_{H,S,t} \omega_{CS} D^S_{CS,t} \end{aligned} \tag{17}$$

where

$$\mathcal{X}_{B,t} = \left[\left(1-\varepsilon_t^H \omega_{H,B}\right)^{\frac{1}{\eta_H}} \left(C_{B,t} - \bar{h}_B C_{B,t-1}\right)^{\frac{\eta_H - 1}{\eta_H}} + \left(\varepsilon_t^H \omega_{H,B}\right)^{\frac{1}{\eta_H}} \left(H_{B,t}\right)^{\frac{\eta_H - 1}{\eta_H}} \right]^{\frac{\eta_H}{\eta_H - 1}} \tag{18}$$

where the auxiliary variables $\overline{\varpi}_{B,t}$ and $\overline{\varpi}^H_{B,t}$ are defined by

$$\gamma_t^{B,C} \left(\overline{\varpi}_{B,t} - \overline{\varpi}^H_{B,t}\right) \left(1-\tau_{\omega,t}\right) N_{B,t} W_t = R^{L,C}_{B,t-1} B^C_{B,t-1} \tag{19}$$

2.2 Entrepreneurs

Commercial loans are modeled as in Christiano, Motto and Rostagno (2010), except that we introduce LTV ratios since capital stock in Brazil is hardly financed through bank loans. Changes in LTV ratios will also accomodate changes in leverage that are dissociated from innovations in collateral value.

At the end of period t, each entrepreneur i purchases capital $K_{E,i,t}$ from capital goods producers and, at $t+1$, rents it to the producers of intermediate goods at the rental rate R^K_{t+1}.

Funds to purchase capital are obtained from two sources: entrepreneur's net worth $N^E_{i,t}$ and investment loans $B_{E,i,t}$:

$$P_{K,t} K_{E,i,t} = N^E_{i,t} + B_{E,i,t} \tag{20}$$

At the beginning of period $t+1$, before rental activities, capital is subject to an idiosyncratic shock $\omega_{i,t+1}$, which represents the riskness of business activity. We assume that this shock is lognormally distributed with parameters $\mu_{E,t+1}$ and $\sigma_{E,t+1}$, such that $E_t \omega_{i,t+1} = 1$ and $\sigma_{E,t}$ follows an AR(1) process.

$$E_t \omega_{i,t+1} = e^{\mu_{E,t+1} + 0.5\left(\sigma_{E,t+1}\right)^2} = 1 \Rightarrow \mu_{E,t+1} = -\frac{1}{2}\left(\sigma_{E,t+1}\right)^2 \tag{21}$$

[12] In order to avoid heterogeneity issues that might come up if each household, faced with an idiosyncratic shock to its labor income, is allowed to freely choose its 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 average utility amongst households.

The actual value of $\sigma_{E,t+1}$ is known to the entrepreneur at the end of period t, prior to her investment decision. At the beginning of period $t+1$, $\omega_{i,t+1}$ realizes, and physical capital becomes $\omega_{i,t+1}K_{E,i,t}$. After use, capital depreciates at the rate δ_K and 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

$$\begin{aligned} R_{t+1}^{TK} &\equiv \int_0^{\infty} \omega \left[R_{t+1}^{K} + P_{K,t+1}\left(1-\delta_K\right)\right] dF\left(\omega, \sigma_{E,t+1}\right) \\ &= R_{t+1}^{K} + P_{K,t+1}\left(1-\delta_K\right) \end{aligned} \tag{22}$$

The entrepreneur borrows a nominal amount $B_{E,i,t}$ from the investment lending branch at the fixed rate $R_{i,t}^{L,E}$. Loans are collateralized by a fraction γ_t^E of the entrepreneur's stock of capital. Therefore, the minimum value $\varpi_{i,t+1}$ at which it is still optimal for the entrepreneur to fulfill her debt at $t+1$ is such that

$$R_{E,i,t}^{L} B_{E,i,t} = \varpi_{i,t+1}\gamma_t^E R_{t+1}^{TK} K_{E,i,t} \tag{23}$$

otherwise the entrepreneur goes bankrupt and the bank seizes the collateral while incurring in monitoring costs amounting to a fraction μ_E of the total value of recovered assets.

Commercial lending branches operate in a competitive market, extending loans to many small entrepreneurs. Let $R_{E,t}$ be the proportional funding cost of the lending branch. Since the idiosyncratic risk is diversifiable, the interest rate on investment loans is such that the expected profit of the financial intermediary is zero:

$$R_{E,t}B_{E,i,t} = \gamma_t^E E_t R_{t+1}^{TK} K_{E,i,t} G\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right) \tag{24}$$

where

$$G\left(\varpi_{t+1}, \sigma_{E,t+1}\right) = \left(1-\mu_E\right)\int_0^{\varpi_{t+1}} \omega dF\left(\omega, \sigma_{E,t+1}\right) + \left(1 - F\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right)\varpi_{t+1} \tag{25}$$

If the idiosyncratic shock $\omega_{i,t+1}$ is favorable (i.e., greater than $\varpi_{i,t+1}$), the investment loan is fully redeemed at the value $R_{E,t}^{L}B_{E,i,t}$. Otherwise, when $\omega_{i,t+1} < \varpi_{i,t+1}$, the bank partially recovers the extended funds by executing the collateral and collecting the amount $\gamma_t^E\left(1-\mu_E\right)\left(\omega_{i,t+1}K_{E,i,t}R_{t+1}^{TK}\right)$.

The expected cash flow of the entrepreneur is:

$$E_t R_{t+1}^{TK} K_{E,i,t}\left[1 - \gamma_t^E H\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right] \tag{26}$$

where

$$H\left(\varpi_{t+1}, \sigma_{E,t+1}\right) = \int_0^{\varpi_{t+1}} \omega dF\left(\omega, \sigma_{E,t+1}\right) + \left(1 - F\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right)\varpi_{t+1} \tag{27}$$

The entrepreneur's problem amounts to choosing a sequence of $\{\varpi_{i,t+1}, B_{E,i,t}, K_{E,i,t}\}$ to maximize (26) constrained by (24), (20), (23) and $B_{E,i,t} \geq 0$. We constrain the latter to be strictly greater than zero.

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. Therefore, the average nominal value of entrepreneurs' own resources N_t^E at the end of period t is

$$N_t^E = \gamma_t^N R_t^{TK} K_{t-1}\left[1 - \gamma_t^E H\left(\overline{\varpi}_{E,t}, \sigma_{E,t}\right)\right] \tag{28}$$

where the survival rate is given by

$$\begin{aligned} \gamma_t^N &= \frac{1}{1+e^{-\gamma^N - \widetilde{\gamma}_t^N}} \\ \widetilde{\gamma}_t^N &= \rho_\gamma^N \widetilde{\gamma}_{t-1}^N + \sigma_\gamma^N \varepsilon_{\gamma,t}^N \end{aligned} \tag{29}$$

The net transfer T_t^{GN} of wealth from exiting entrepreneurs to households at the end of period t is

$$T_t^{GN} = \left(1-\gamma_t^N\right)\left(R_t^{KT} K_{t-1}\left[1 - \gamma^E H\left(\overline{\varpi}_{E,t}, \sigma_{E,t}\right)\right]\right) \tag{30}$$

2.3 Goods producers

The modeling of goods producers follows the standard DSGE literature. Details are in the appendix. There is a continuum of intermediate goods producers that combine labor negotiated with unions and capital rented from entrepreneurs to produce homogeneous goods. They operate under perfect competition and face adjustment costs to capital utilization, in addition to temporary shocks to factor productivity and permanent shocks to labor productivity. Their production function is

$$Z_{j,t}^{d} = A.\varepsilon_t^A \left[u_t K_{j,t-1}\right]^{\alpha} \left(\epsilon_t L_{j,t}\right)^{1-\alpha} \tag{31}$$

where ε_t^A is a temporary shock to total factor productiviy, A is a scaling constant, and ϵ_t is a permanent shock to labor productivity that follows

$$g_{\epsilon,t} = \rho_\epsilon . g_{\epsilon,t-1} + \left(1-\rho_\epsilon\right).g_\epsilon + \varepsilon_t^Z \tag{32}$$

$$g_{\epsilon,t} = \epsilon_t / \epsilon_{t-1}$$

and g_ϵ is the steady state of $g_{\epsilon,t}$.

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 their price choices set their prices according to the indexation rule:

$$P_t^d\left(k\right) = \pi_{t-1}^{d,\gamma_d} \overline{\pi}^{1-\gamma_d} P_{t-1}^d\left(k\right) \tag{33}$$

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

$$Y_t^d = \left[\int_0^1 Z_t^d\left(k\right)^{\frac{1}{\mu_d}} dk\right]^{\mu_d} \tag{34}$$

Distributers sell their output to final goods firms. There are 4 firms producing final goods, each of which specializes in the production of one type of good: 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

$$Y_t^{d,J} = \{G, C, I_K, I_H\} \tag{35}$$

$$P_t^J = P_t^d \tag{36}$$

Perfectly competitive firms produce the stock of housing and fixed capital. At the beginning of period t, they buy back the depreciated capital stock $(1-\delta_K)K_{t-1}$ from entrepreneurs as well as the depreciated housing stock $(1-\delta_H)\left(\omega_S H_{S,t-1} + \omega_B H_{B,t-1}\right)$ from households, at nominal prices $P_{K,t}$, and $P_{H,t}$ respectively. These firms augment their capital and housing stocks using final goods and facing quadratic 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

About half of the balance of domestic bonds issued by the Brazilian federal government in the market are held by banks' non-financial clients, either through direct ownership of securities or through apportions in investment funds. Public bonds are substitutes for time deposits issued by banks and for investment fund quotas whose portfolios are combinations of fixed income instruments, including government securities.

Without loss of generality, we let the group of savers in the model hold quotas of the investment fund, whose portfolio is composed of time deposits D_t^T issued by banks and government bonds B_t^F, which yield respectively R_t^T and R_t.

The fund seeks to diversify its portfolio and maximize its return through the following program:

$$\begin{aligned} \max_{\{B_t^F, D_t^T\}} \psi_F \left[(1-\omega_{T,F})^{\frac{1}{\eta_F}} \left(B_t^F\right)^{\frac{\eta_F-1}{\eta_F}} + (\omega_{T,F})^{\frac{1}{\eta_F}} \left(D_t^T\right)^{\frac{\eta_F-1}{\eta_F}} \right]^{\frac{\eta_F}{\eta_F-1}} \\ + R_t B_t^F + R_t^T D_t^T \\ \text{s.t. } D_t^F = B_t^F + D_t^T \end{aligned} \tag{37}$$

where ψ_F is the weight on portfolio diversification vis-a-vis the portfolio return.

First order conditions to this problem yield

$$R_t^T - R_t = \psi_F \left[(1-\omega_{T,F})^{\frac{1}{\eta_F}} \left(B_t^F\right)^{\frac{\eta_F-1}{\eta_F}} + (\omega_{T,F})^{\frac{1}{\eta_F}} \left(D_t^T\right)^{\frac{\eta_F-1}{\eta_F}} \right]^{\frac{\eta_F}{\eta_F-1}-1} \left\{ \left(\frac{1-\omega_{T,F}}{B_t^F} \right)^{\frac{1}{\eta_F}} - \left(\frac{\omega_{T,F}}{D_t^T} \right)^{\frac{1}{\eta_F}} \right\} \tag{38}$$

and the funds' portfolio return is $R_{F,t} = \frac{R_t B_t^F + R_t^T D_t^T}{B_t^F + D_t^T}$.

The rate of return on time deposits in Brazil closely follows the base rate, with a negligible spread between them[13]. We therefore assume that the weight on diversification ψ_F is zero, which results in $R_{F,t} = R_t^T = R_t$.

Transactions with the investment funds are free of administrative costs.

2.5 Banking sector

We model the banking sector as a conglomerate composed of the following branches: wholesale, savings, time deposit, demand deposit, loan book financing, lending and mortgage branches. Overall, the purpose of this segmentation is to clearly mark the determinants of the lending spread that endogenously arises in the model and the effects of regulatory requirements on bank rates and volumes. The wholesale branch is the financial vessel of the conglomerate: it channels the funds obtained both in the money market and in the open market to the loan book financing branches and the mortgage branch. It is also attributed with the task of complying with reserve and capital requirements, deciding on the liquidity buffer and on the demand for time deposits, in addition to paying tax on profits. Profits from imperfect competition and lending rate rigidities are introduced in the scope of loan book financing branches. The risk of default is incorporated in the final lending branches' problem. The mortgage branch and the savings deposits branch are modeled in accordance with the Brazilian regulatory framework.

Although the agents of our bank conglomerate are the same as those in [3], there are substantial differences in the optimization problem of each branch so as to reproduce the core characteristics of the Brazilian banking activity.

2.5.1 Wholesale branch

We model the wholesale branch's optimization problem so that the model can be used to assess not just the impact of macroprudential policy on bank rates but also on volumes through shifts in the composition of banks' balance sheets.

The wholesale branch obtains funding in the money market and in the open market and channels available funds to the rest of the conglomerate. Regulatory requirements are incorporated in this branch's

[13] In the sampled period, the base rate was merely 0.2 p.p higher than the effective 90-day time deposits (CDB) rate, in average.

decisions. First, capital requirements are introduced in the form of a cost of deviating from the legal requirement[14]. Second, funding in the money market is subject to reserve requirements. Third, a fraction of savings deposits are mandatorily channeled to mortgage loans, at the expense of being collected as under-remunerated reserves by the monetary authority. Finally, the wholesale branch collects a tax on profits from the conglomerate's activities.

The recent strand of the literature has been inclined to introducing imperfect competition in the bank deposits market[15]. This implies some degree of price-elasticity in the supply of time deposits. However, the interest rate on time deposits in Brazil tighlty tracks the base rate, with a negligible spread between them. Therefore, the interest rate on time deposits in our model is assumed to be fixed on supply since the saver is indifferent with respect to the share of time deposits in the investment fund's portfolio. The volume will be defined by the wholesale bank. To avoid perfect substitution in the wholesale branch's demand for time deposits and open market operations, we introduce costs of deviating from the optimal balance. We also introduce an adjustment cost of changing the balance of time deposits over time so as to account for the slugishness observed in this market.

The wholesale branch has a liquidity target in terms of the share of government bonds $B_{OM,t}$ in total liabilities. Deviations from the target are costly. These frictions, namely the costs associated with time deposits and with liquidity, shape the model responses to changes in reserve requirements.

The conglomerate's balance sheet is

$$\begin{aligned} & B_{B,t}^{C,wb} + B_{E,t}^{wb} + B_{B,t}^{H,wb} + B_{OM,t} + RR_t^T + RR_t^S + RR_t^D + RR_t^{add} \\ = \quad & D_t^{T,wb} + D_t^{S,wb} + D_t^{D,wb} + Bankcap_t \end{aligned} \tag{39}$$

where superscript wb refers to wholesale branch balances, RR_t^T, RR_t^D, RR_t^S, and RR_t^{add} [16] are required reserves:

$$RR_t^D = \tau_{RR,D,t} D_t^{D,wb} \tag{40}$$

$$RR_t^T = \tau_{RR,T,t} D_t^{T,wb} \tag{41}$$

$$RR_t^S = \tau_{RR,S,t} D_t^{S,wb} \tag{42}$$

$$RR_t^{add} = \tau_{RR,add,t} \left(D_t^{D,wb} + D_t^{T,wb} + D_t^{S,wb} \right) \tag{43}$$

Required reserves are remunerated at the rates $R_{RR,t}^D$, $R_{RR,t}^T$, $R_{RR,t}^S$, and $R_{RR,t}^{add}$ respectively. In our calibration, we set $R_{RR,t}^D = 1$ since reserve requirements on demand deposits in Brazil are not remunerated.

Bank capital evolves according to

$$Bankcap_t = \left(1 - \delta^{wb}\right) Bankcap_{t-1} + \nu^b \left(1 - \tau_{\Pi,t}\right) \Pi_t^b \tag{44}$$

where ν^b is the fraction of net-of-tax profits that are retained by the bank. The coefficient of bank capital depreciation, δ^{wb}, ensures stationarity.

[14] The model is generic enough to encompass Basle 1- and Basle 2-type requirements. We also conduct exercises with rules in line with Basle 3.

[15] [16], [3], [4], [11].

[16] In Brazil, in addition to the traditional reserve requirements on the main types of bank deposits, the monetary authority has often made use of an "additional" reserve requirement that is levied on the same reservable base of the 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 these additional reserve requirements (RR_t^{add}) have a homogeneous rate $\tau_{RR,add,t}$ incident upon the simple average of all deposits.

In Brazil, a share of the funds in savings accounts has to be channeled to housing loans. We model this constraint as:

$$B_{B,t}^{H,wb} \leq \tau_{H,S,t} D_t^{S,wb} \tag{45}$$

where the mandatory ratio of savings deposits $\tau_{H,S,t}$ to be allocated in housing loans is set by the monetary authority.

When the bank does not fulfill the mandatory allocation of savings deposits in housing loans, it is required to deposit the gap at the central bank in the form of required reserves remunerated as a markdown on savings interest rates, $\left(1+\varphi_t^S\left(R_{t-1}^S-1\right)\right)$.

The wholesale branch's profit is

$$\begin{aligned}
\Pi_t^b = \; & R_{B,t-1}^{C,wb} B_{B,t-1}^{C,wb} + R_{E,t-1}^{wb} B_{E,t-1}^{wb} + R_{B,t-1}^{H,wb} B_{B,t-1}^{H,wb} + R_{t-1} B_{OM,t-1} \\
& + \frac{\vartheta}{2}\left(\frac{B_{OM,t-1}}{D_{t-1}^{T,wb}+D_{t-1}^{S,wb}+D_{t-1}^{D,wb}+Bankcap_{t-1}} - \nu_{t-1}^{OM}\right)^2 \left(D_{t-1}^{T,wb}+D_{t-1}^{S,wb}+D_{t-1}^{D,wb}+Bankcap_{t-1}\right) \\
& + \left(1+\varphi_t^S\left(R_{t-1}^S-1\right)\right)\left(\tau_{H,S,t-1} D_{t-1}^{S,wb} - B_{B,t-1}^{H,wb}\right) \\
& + R_{RR,t-1}^T RR_{t-1}^T + R_{RR,t-1}^S RR_{t-1}^S + R_{RR,t-1}^D RR_{t-1}^D + R_{RR,t-1}^{add} RR_{t-1}^{add} \\
& - \frac{\chi_{d_T}}{2}\left(\frac{D_{t-1}^{T,wb}}{D_{t-1}^{T,wb}+D_{t-1}^{S,wb}+D_{t-1}^{D,wb}+Bankcap_{t-1}} - \nu_{t-1}^{d_T}\right)^2 \left(D_{t-1}^{T,wb}+D_{t-1}^{S,wb}+D_{t-1}^{D,wb}+Bankcap_{t-1}\right) \\
& - \Gamma_T\left(D_{t-1}^{T,wb}\right) D_{t-1}^{T,wb} - R_{t-1}^{T,wb} D_{t-1}^{T,wb} - R_{t-1}^S D_{t-1}^{S,wb} - D_{t-1}^{D,wb} \\
& - \frac{\chi_{K,wb}}{2}\left(\frac{Bankcap_{t-1}}{\tau_{\chi 1} B_{B,t-1}^{C,wb} + \tau_{\chi 2} B_{E,t-1}^{wb} + \tau_{\chi 3} B_{B,t-1}^{H,wb} + \tau_{\chi 4} B_{OM,t-1}} - \nu_{t-1}^{BankK}\right)^2 Bankcap_{t-1} \\
& - Bankcap_{t-1}
\end{aligned} \tag{46}$$

where ν_t^{OM} is the target for the liquidity buffer, $\nu_t^{d_T}$ is the target for the share of time deposits in total liability, and ν_t^{BankK} is capital requirement. Associated cost parameters are ϑ, χ_{d_T}, and $\chi_{K,wb}$.

Capital requirement is introduced through the time-varying target ν_t^{BankK} that represents the optimal share of bank capital over risk-weighted assets. We assume that this variable follows an AR(1) process around an optimal target. Risk-weights on bank assets are $\tau_{\chi 1}$, $\tau_{\chi 2}$, $\tau_{\chi 3}$, and $\tau_{\chi 4}$, where $\tau_{\chi 1}$, $\tau_{\chi 2}$, $\tau_{\chi 3}$ are strictly positive.

The adjustment cost on time deposit balances $\Gamma_T\left(D_t^{T,wb}\right)$ is given by

$$\Gamma_T\left(D_t^T\right) \equiv \phi_T/2\left(\frac{D_t^T}{D_{t-1}^T}\varepsilon_t^{DT} - g_{\epsilon,t}\pi_{C,t}\right)^2 \tag{47}$$

The wholesale branch chooses $\left\{B_{B,t}^{C,wb}, B_{E,t}^{wb}\ ,\ B_{OM,t}\ ,\ D_t^{T,wb},\ RR_t^T\right\}$ [17] to maximize (46) subject to (39) to (45).

Let total liabilities be defined as

$$Lb_t = D_t^{T,wb} + D_t^{S,wb} + D_t^{D,wb} + Bankcap_t \tag{48}$$

First order conditions to the wholesale branch's problem yield

[17] The wholesale branch has no decisions to make on housing loans, since these are completely determined after the level of savings deposits is established. Since the remuneration on savings deposits is exogenously set by the government, the level of deposits is unilaterally determined by depositors.

$$R_{B,t}^{C,wb} - \Lambda_t^{WB} = -\tau_{\chi 1}\chi_{K,wb}\left(\frac{Bankcap_t}{\tau_{\chi 1}B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}} - \nu_t^{BankK}\right) \times \left(\frac{Bankcap_t}{\chi 1 B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}}\right)^2 \tag{49}$$

$$R_{E,t}^{wb} - \Lambda_t^{WB} = -\tau_{\chi 2}\chi_{K,wb}\left(\frac{Bankcap_t}{\chi 1 B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}} - \nu_t^{BankK}\right) \times \left(\frac{Bankcap_t}{\chi 1 B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}}\right)^2 \tag{50}$$

$$R_t - \Lambda_t^{WB} = \vartheta_t\left(\frac{B_{OM,t}}{Lb_t} - \nu_t^{OM}\right) -\tau_{\chi 4}\chi_{K,wb}\left(\frac{Bankcap_t}{\chi 1 B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}} - \nu_t^{BankK}\right) \times \left(\frac{Bankcap_t}{\chi 1 B_{B,t}^{C,wb} + \tau_{\chi 2}B_{E,t}^{wb} + \tau_{\chi 3}B_{B,t}^{H,wb} + \tau_{\chi 4}B_{OM,t}}\right)^2 \tag{51}$$

$$\begin{aligned} & R_t^{T,wb} - \Lambda_t^{WB} - \tau_{RR,T}\left(\Lambda_t^{WB} - R_{RR,t}^T\right) - \tau_{RR,add}\left(\Lambda_t^{WB} - R_{RR,t}^{add}\right) \\ = \; & \frac{\vartheta_t}{2}\left(\frac{B_{OM,t}}{Lb_t} - \nu_t^{OM}\right)\left(\frac{B_{OM,t}}{Lb_t} + \nu_t^{OM}\right) \\ & -\Gamma_T^{'}\left(D_t^{T,wb}\right) - \Gamma_T\left(D_t^{T,wb}\right) \\ & -\frac{\chi_{d_T}}{2}\left(\frac{D_t^{T,wb}}{Lb_t} - \nu_t^{d_T}\right)\left[2 - \frac{D_t^{T,wb}}{Lb_t} - \nu_t^{d_T}\right] \end{aligned} \tag{52}$$

where Λ_t^{WB} is the Lagrange multiplier of the balance sheet constraint (39) and represents the bank's opportunity cost.

The bank's opportunity cost is not just the base rate (51). If government bonds were thought to bear risk, the bank's opportunity cost would have to cover this risk. In line with our current capital requirement regulation, we set $\tau_{\chi 4}$ to zero in our baseline calibration. Notwithstanding, liquidity still impacts the bank's opportunity cost. When there is excess liquidity, the opportunity cost of the bank is lower than the base rate so as that loans can have more appealing rates to banks' clients. On the other hand, when there is shortage of liquidity, the opportunity cost exceeds the base rate, loans get more expensive favoring asset reshuffle.

(49) and (50) make explicit two ways in which capital requirements affect the rates charged upon bank loans. First, when the bank is over capitalized, it has incentives to increase its loan book, which reflects in the rates it charges to channel funds for the other branches to lend (i.e., the rate on funds for lending is lower than the opportunity cost). Second, the intensity at which the rate for lending departs from the opportunity cost is tuned by the risk weight on the respective asset.

The dynamics of time deposits in the economy is ruled by (52). It implies that the volume of time deposits is affected by the wedge between the remuneration of its required reserves and the funding cost of the bank. The level of deposits will also bear a strong relationship with bank's liquidity, tuned by the value of cost parameters. The wholesale branch will be more willing to accept time deposits when liquidity exceeds the optimal. The other frictions that affect the level of deposits are, by construction, the costs of deviating from the optimal and the adjusment cost.

Reserve requirements on time deposits therefore have an impact on banks' optimality conditions, although their remuneration perfectly matches the base rate.

2.5.2 Time deposit branch

The time deposit branch issues deposit certificates to the investment fund[18]. These balances are then transfered to the wholesale branch at the price $R_t^{T,wb} = R_t$. Since there are no frictions,

$$D_t^T = D_t^{T,wb} \tag{53}$$

The imposition of equality between the base rate and the rate of return on deposits actually paid for by the time deposit branch forces the wholesale bank to fulfill its optimality condition in (52) by adjusting deposit levels instead of the rate.

2.5.3 Demand deposits and savings accounts branches

The demand deposit branch collects unremunerated demand deposits, $D_{S,t}^D$ and $D_{B,t}^D$, completely determined by households' demand. It then aggregates these deposits and channels them to the wholesale branch:

$$D_t^{D,wb} = \omega_S D_{S,t}^D + \omega_B D_{B,t}^D \tag{54}$$

The savings deposits branch is assumed to have no market power, since interest rates on savings accounts in Brazil are regulated by the government. The savings deposits branch thus collects all savings deposits supplied by savers and transfers them to the wholesale branch:

$$D_t^{S,wb} = \omega_S D_{S,t}^S \tag{55}$$

Since there are no frictions in either of these operations,

$$D_t^D = D_t^{D,wb} \tag{56}$$

and

$$D_t^S = D_t^{S,wb} \tag{57}$$

2.6 Loan book financing and final lending branches

The main determinants of lending spreads in Brazil are bank markups, default rates, administrative costs, direct and indirect tax charges, and reserve requirements[19]. The latter belongs to the wholesale's optimization problem. They will reflect in the interest rates charged by the wholesale branch to channel funds to the other branches. They will also reflect on its decisions on volumes. Apart from default, the other components of the lending spread are incorporated in the optimization problems of the loan book financing branches. Transmission to the final lending branch's cost of funding is subject to rigidities.

Loan book financing branches provide funds to investment and retail lending branches. They face administrative costs proportional to the volume of funds they extend, and are also charged with a direct tax on financial intermediation, $\tau_{B,t}$.

Commercial lending branches collect differentiated financial resources from the continuum of loan book financing branches and aggregate them using a CES technology

$$B_{E,t} = \left[\int_0^1 B_{E,t}(j)^{\frac{1}{\mu_E^R}} dj \right]^{\mu_E^R} \tag{58}$$

[18] As previously mentioned, the rate of return of time deposit certificates is assumed to equal the base rate of the economy, a feature that is observed in Brazilian data.

[19] Refer to the BCB's annual report on Banking and Credit, at http://www.bcb.gov.br/?spread

at the corresponding average interest rate

$$R_{E,t} = \left[\int_0^1 R_{E,t}(j)^{\frac{1}{1-\mu_E^R}} dj \right]^{1-\mu_E^R} \tag{59}$$

It follows that the demand curve for loan book branch j's funds is given by

$$B_{E,t}(j) = \left(\frac{R_{E,t}(j)}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} B_{E,t} \tag{60}$$

where $\mu_E^R / \left(\mu_E^R - 1\right) > 1$.

Each loan book branch is subject to Calvo price rigidity, and the fraction ξ_E^R of branches not allowed to choose their rates keep them unchanged from the previous period. Therefore, the optimization problem of branches allowed to choose their rates is

$$\max_{\{R_{E,t}(j)\}} E_t \sum_{k=0}^{\infty} \left(\beta_S \xi_E^R\right)^k \frac{\Lambda_{S,t+k}}{\Lambda_{S,t}\pi_{C,t,t+k}} \left(\begin{array}{c} \left[R_{E,t}(j) - \left(R_{E,t+k}^{wb} + \tau_{B,E,t+k} + s_{t+k}^{adm,E} \right) \right] \\ \times \left(\frac{R_{E,t}(j)}{R_{E,t+k}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} B_{E,t+k} \end{array} \right) \tag{61}$$

where $R_{E,t}^{wb}$ is the funding cost.

First order conditions to this problem yield

$$\begin{aligned} & \frac{R_{E,t}^O}{R_{E,t}} E_t \sum_{k=0}^{\infty} \left(\beta_S \xi_E^R\right)^k \frac{\Lambda_{S,t+k}}{\Lambda_{S,t}} \left(\frac{R_{E,t}}{R_{E,t+k}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} \frac{B_{E,t+k}}{P_{C,t+k}} \\ = \; & \mu_E^R E_t \sum_{k=0}^{\infty} \left(\beta_S \xi_E^R\right)^k \frac{\Lambda_{S,t+k}}{\Lambda_{S,t}} \left(\frac{R_{E,t}}{R_{E,t+k}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1} - 1} \frac{B_{E,t+k}}{P_{C,t+k}} \frac{R_{E,t+k}^{wb} + \left(\tau_{B,E,t+k} + s_{t+k}^{adm,E} \right)}{R_{E,t+k}} \end{aligned} \tag{62}$$

where $R_{E,t}^O$ is the optimal rate. This equation shows that the optimal rate will be a markup over the sum of the funding rate, operational costs, and tax expenses.

Total funding from the wholesale branch $B_{E,t}^{wb}$ for investment loans corresponds to the sum of funds channeled to each loan book financing branch:

$$\begin{aligned} B_{E,t}^{wb} &= \int B_{E,t}(j)\, dj \\ &= B_{E,t} \Delta_{E,t}^R \end{aligned} \tag{63}$$

where $\Delta_{E,t}^R$ is the funding rate dispersion:

$$\begin{aligned} \Delta_{E,t}^R &= \int \left(\frac{R_{E,t}(j)}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} dj \\ &= \left(1 - \xi_E^R\right) \left(\frac{R_{E,t}^O}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} + \xi_E^R \left(\frac{R_{E,t-1}}{R_{E,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} \Delta_{E,t-1}^R \end{aligned} \tag{64}$$

Period t's expected nominal profits from loan book financing branches' operations are

$$\begin{aligned} E_t \Pi_{t+1}^{b,E} &= \omega_E \int_0^1 \left[R_{E,t}(j) - \left(R_{E,t}^{wb} + \tau_{B,E,t} + s_t^{adm,E} \right) \right] \\ & \quad \times \left(\frac{R_{E,t}(j)}{R_{E,t}} \right)^{-\frac{\mu_{E,t+k}^R}{\mu_{E,t+k}^R - 1}} B_{E,t} dj \\ &= \omega_E \left[R_{E,t} - \left(R_{E,t}^{wb} \Delta_{E,t}^R + \tau_{B,E,t} + s_t^{adm,E} \right) \right] B_{E,t} \end{aligned} \tag{65}$$

The optimization problem for loan book financing branches that channel their resources to retail lending branches is analogous.

Commercial and retail lending branches collect funds from the loan book financing branches at the rates $R_{E,t}$ and $R^{C}_{B,t}$ and competitively lend to entrepreneurs and households at the final rates $R^{L}_{E,t}$ and $R^{L,C}_{B,t}$. The wedge between final lending rates and funding rates for final lending branches will correspond to the expected loss from default. This problem is detailed in 2.2 and 2.1.2.

2.6.1 Mortgage loan branch

The Brazilian housing loans market is heavily regulated by the government. The regulatory authority mandates that a fraction $\tau_{H,S,t}$ of savings deposits be channeled to housing loan concessions. Housing loans are also subject to regulated lending rates[20]. We therefore assume that the final lending rate $R^{L,H}_{B,t}$ is set by the government.

Interest rates R^{S}_{t} on savings deposits are also highly regulated. We also assume them to be set by the government.

As a result, the only role of the mortgage loan branch is to channel funds from savings deposits to housing loans, having no say on 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

$$\Pi^{H}_{t} = \omega_B \gamma^{B,C}_{t} \left(1-\tau_{w,t}\right) N_{B,t} W_t G_{B,H}\left(\overline{\varpi}^{H}_{B,t}, 0\right) - R^{H,wb}_{B,t-1} B^{H,wb}_{B,t-1} \tag{66}$$

where

$$\begin{aligned} G_{B,H}\left(\overline{\varpi}_1, \overline{\varpi}_2\right) &= \left(1-\mu_{B,H}\right)\left[\int_{\overline{\varpi}_1}^{\overline{\varpi}_2} \varpi dF\left(\varpi\right) - \overline{\varpi}_1\left[F\left(\overline{\varpi}_2\right) - F\left(\overline{\varpi}_1\right)\right]\right] \\ &\quad + \left(\overline{\varpi}_2 - \overline{\varpi}_1\right)\left(1 - F\left(\overline{\varpi}_2\right)\right) \end{aligned} \tag{67}$$

The cost of default on mortgage loans is absorbed as losses since they cannot be passed through to volumes or rates in this market.

2.7 Government

The government is composed of a monetary and a fiscal authority. The monetary authority sets the base rate of the economy, regulates on reserve requirements, capital requirements, and housing loan concessions, and engages in open market operations with government bonds. The fiscal authority decides on government consumption, issues public debt to central bank's portfolio, levies taxes, and makes lump sum transfers to households.

[20] There is room for strategic decisions by banks, especially in concessions for pricier real estate. However, the bulk of loan concessions in Brazil fincance low-valued real estate, which is subject to such regulation.

2.7.1 The monetary authority

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

$$R_t^4 = \left(R_{t-1}^4\right)^{\rho_R} \left[\left(E_t \frac{P_{C,t+4}}{P_{C,t}} \frac{1}{\overline{\pi}_t^4}\right)^{\gamma_\pi} \left(\frac{gdp_t}{gpd}\right)^{\gamma_Y} R^4\right]^{1-\rho} \left(\frac{\pi_{C,t}}{\pi_{C,t-1}}\right)^{\gamma_{\Delta\pi}} \varepsilon_t^R \tag{68}$$

where unsubscripted 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 stationarized level of output that excludes banking costs:

$$GDP_t = Y_t - T_{bank,t}$$

$$\begin{aligned}
T_{bank,t} \quad = \quad & s_{t-1}^{adm,E} \omega_E B_{E,t-1} + s_{t-1}^{adm,B} \omega_B B_{B,t-1}^C && (69)\\
& + \frac{\chi_{K,wb}}{2} \left(\frac{Bankcap_{t-1}}{\tau_{\chi 1} B_{B,t-1}^{C,wb} + \tau_{\chi 2} B_{E,t-1}^{wb} + \tau_{\chi 3} B_{B,t-1}^{H,wb} + \tau_{\chi 4} B_{t-1}} - \nu_t^{BankK} \right)^2 \\
& \times Lb_{t-1} \\
& + \frac{\vartheta_{t-1}}{2} \left(\frac{B_{OM,t-1}}{Lb_{t-1}} - \nu_{t-1}^{OM} \right)^2 \times Lb_{t-1} \\
& + \Gamma_T \left(D_{t-1}^{T,wb} \right) D_{t-1}^{T,wb} \\
& + \frac{\chi_{d_T}}{2} \left(\frac{D_{t-1}^{T,wb}}{Lb_{t-1}} - \nu_{t-1}^{d_T} \right)^2 Lb_{t-1} && (70)\\
& + \gamma_t^E \ \mu_E \ \left(R_t^K + P_{K,t} \left(1 - \delta_K\right) \right) \omega_E K_{E,t-1} J\left(\overline{\varpi}_{E,t}\right) \\
& + \gamma_t^{B,C} \left(1 - \tau_{W,t}\right) \omega_B N_{B,t} W_t \ \mu_{B,C} \ \left[J\left(\overline{\varpi}_{B,t}\right) - J\left(\overline{\varpi}_{B,t}^H\right) - \overline{\varpi}_{B,t}^H \left(F\left(\overline{\varpi}_{B,t}\right) - F\left(\overline{\varpi}_{B,t}^H\right) \right) \right] \\
& + \gamma_t^{B,C} \left(1 - \tau_{W,t}\right) \omega_B N_{B,t} W_t \ \mu_{B,H} \ J\left(\overline{\varpi}_{B,t}^H\right) \\
& + \delta^{wb} Bankcap_{t-1}
\end{aligned}$$

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

$$\overline{\pi}_t^4 = \left(\overline{\pi}_{t-1}^4\right)^{\rho_{\overline{\pi}^4}} \left(\overline{\pi}^4\right)^{1-\rho_{\overline{\pi}^4}} \varepsilon_t^{\overline{\pi}^4} \tag{71}$$

The monetary authority sets the remuneration of savings accounts according to

$$R_t^S = 1 + \left(\alpha_{1,R}^S\right) R_t + \varepsilon_t^{R^S} \tag{72}$$

and housing loan rates are fixed as

$$\frac{R^L_{B,H,t}}{R_t} = \left(\frac{R^L_{B,H,t-1}}{R_{t-1}}\right)^{\rho_{R^H}} \left(\frac{R^L_{B,H}}{R}\right)^{1-\rho_{R^H}} \exp\left(\varepsilon_{R^H,t}\right) \tag{73}$$

Interest rates on reserve requirements, as a ratio over the base rate, follow AR(1) processes around the respective steady state ratio. Reserve requirement ratios and the mandatory percentage allocation of savings accounts on housing loans also follow AR(1) processes around their steady states.

For ease of exposition, we let the monetary authority costlessly manage the open market by supplying whatever demand for government bonds from banks and the investment fund. Since debt tenure in this model is only one period, open market operations and outright purchases of government debt are indistinct, so we opt to use the term "open market" to refer to any transaction with public bonds.

2.7.2 The fiscal authority

The fiscal authority decides on its consumption of final goods according to the rule:

$$\begin{aligned} & \frac{G_t}{\epsilon_t} \\ = \; & \rho_g \left(\frac{G_{t-1}}{\epsilon_{t-1}}\right) \\ & + \left(1-\rho_g\right)\left(g - \mu_{B,G}\left(\frac{B_{t-1} + RR^D_{t-1} + RR^T_{t-1} + RR^S_{t-1} + RR^{add}_{t-1}}{P_{C,t-1}\epsilon_{t-1}} - \left(b + rr^D + rr^T + rr^S + rr^{add}\right)\right)\right) \\ & + \varepsilon^G_t \end{aligned} \tag{74}$$

where lower-case variables denote stationary functions of their trending counterparts, and g is the steady state value of stationarized 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 by the investment fund and the wholesale bank:

$$B_t = B_{OM,t} + B_{F,t} \tag{75}$$

Tax rates $\tau_{C,t}, \tau_{w,t}, \tau_{\Pi,t}$,and $\tau_{B,B,t}$ follow AR(1) processes around their steady state. Since we could not find time series of tax levied on financial intermediation disaggregated by individuals and firms, we assume that $\tau_{B,E,t}$ is a steady proportion of $\tau_{B,B,t}$.

The joint public sector budget constraint is

$$\begin{aligned} & P_{G,t}G_t + TT_t \\ & + \left(1 + \varphi^S\left(R^S_{t-1} - 1\right)\right)\left(\tau_{H,S,t-1}\omega_{CS}D^S_{CS,t-1} - \omega_B B^H_{B,t-1}\right) \\ & + R^{RR,D}_{t-1}RR^D_{t-1} + R^{RR,T}_{t-1}RR^T_{t-1} + R^{RR,S}_{t-1}RR^S_{t-1} + R^{RR,add}_{t-1}RR^{add}_{t-1} + R_{t-1}B_{t-1} \\ = \; & \tau_{w,t}\Pi^{LU}_t + \tau_{\Pi,t}\Pi_t + \tau_{\Pi,t}\nu^b\Pi^b_t + \tau_{w,t}W^N_t N_t + \tau_{C,t}P_{C,t}C_t \\ & + \omega_E\tau_{B,E,t-1}B_{E,t-1} + \omega_B\tau_{B,B,t-1}B^C_{B,t-1} \\ & + RR^D_t + RR^T_t + RR^S_t + RR^{add}_t + B_t \end{aligned} \tag{76}$$

2.8 Market clearing

Market clearing requires:

$$Y_t^d = Y_t^{C,d} + Y_t^{G,d} + Y_t^{I_K,d} + Y_t^{IH,d} \tag{77}$$

$$Y_t^{G,d} = G_t \tag{78}$$

$$Y_t^{IH,d} = I_{H,t} \tag{79}$$

$$Y_t^{IK,d} = I_{K,t} \tag{80}$$

$$Y_t^C = C_t \tag{81}$$

Further details on aggregation and market clearing are in the appendix.

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.

For any model that one might consider, 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 for Brazilian data. Filtered series in many cases give the wrong idea of where the investigated economic variable is in the business cycle.

With that in mind, we took the stance of using two different strategies to calibrate the steady state. The main economic ratios were fixed according to the average of their respective series over the inflation targeting period (Table 1)[21]. The base rate and GDP growth were also fixed according to the average in this period. These series show little evidence of trend or transition. Banking series show more serious trend and transition issues. Although credit expansion has been strong in Brazil over the past few years, the absolute levels as a share of GDP are still low compared to international evidence. We therefore chose to calibrate the shares of loans and deposits to GDP, as well as lending rates and the markdown of savings rates, according to the most recent observations in the data.

The ex-ante steady state default ratios were set at 2.4% for investment loans and 7% for retail loans, in line with recent available data on actual default. We also fixed steady state lending rates and levels, in addition to banking spread components. We let the model estimate the variance of the idiosyncratic shock to the collateral value. From that the model obtains the remaining variables of the financial accelerator, including LTV ratios.

The steady state capital requirement was fixed as the mean capital adequacy ratio actually observed by Brazilian banks since the beginning of the series in December 2000. Although required capital has been kept at 11% throughout the sample, banks have found it desirable, in average, to maintain a capital buffer in excess of the minimum required. We introduce this buffer in the steady state as part of banks' target capital. Risk weights on bank assets were set as in Basle 1. According to current prudential regulation,

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

we set the risk weight on housing loans to half of the other loans. Bank capital was set as the mean of banks' core capital in 2011.

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 onwards, which was when the requirement was last reintroduced. For additional reserves and requirements on savings accounts, the average was taken from December 2002, when the former was introduced and the latter was more actively used. For demand deposits, the average was taken from the entire inflation targeting period. The autoregressive parameters of shocks to reserve requirement ratios were set at 0.99 to assume that agents have a very hard time trying to anticipate future changes in this instrument[22].

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 on its Banking Reports[23].

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 such participation. We fixed the share of housing consumed by borrowers in the steady state as the ratio between the approximate value of collaterals put up in housing loans[24] and the model's implied value of real estate in the economy. The borrowers' participation in the labor market was fixed under the assumption that indebted households in Brazil have a debt commitment of 50% of their annual labor income[25]. The participation in consumption was implied by the former assumptions.

Parameters whose values could not be obtained from Brazilian data were fixed according to Pariès et al (2011).

4 Estimation

The model was estimated using Bayesian techniques, after log-linearization around the steady state. The following time series were used as observables:

- Consumer inflation $\left(\pi_{C,t}^{obs}\right)$: quarterly inflation of the 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 public 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.

[22] 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, for income distribution ([17], [8], [9], [10])

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

[24] 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.

[25] Although there are some indicators of household indebtedness in Brazil, they are based on the entire population, and not only indebted households.

- 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.

- 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.

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

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

- Lending spread for investment 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 retail loans.

- Lending spread for retail loans $\left(\check{R}_{B,C,t}^{L,obs}\right)$: Ratio between the quarterly effective nominal interest rate on retail 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 not publicly available.

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

The data were sampled from the inflation targeting period in Brazil (1999:Q1 to 2012:Q1). Missing variables were filled up with standard Dynare routines. The following equations relate the observables with the variables in the model, where untimed barred variables denote steady states:

$$\pi_{C,t}^{obs} = \pi_{C,t} \tag{82}$$

$$\bar{\pi}_{C,t}^{obs} = \bar{\pi}_{C,t} \tag{83}$$

$$R_{C,t}^{obs} = R_{C,t} \tag{84}$$

$$U_t^{obs} = 1 - \mathrm{E}_t \tag{85a}$$

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

$$\widehat{gdp}_t^{obs} = \log\left(GDP_t/\epsilon_t\right) - \log\left(\overline{gdp}\right) \tag{86}$$

$$\Delta w_t^{obs} = \frac{W_t/P_t^C\epsilon_t}{W_{t-1}/P_{t-1}^C\epsilon_{t-1}}/\Delta n \tag{87}$$

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

$$c_t^{obs} = C_t/GDP_t \tag{88}$$

$$g_t^{obs} = G_t/GDP_t \tag{89}$$

$$b_{E,t}^{obs} = B_{E,t}/GDP_t \tag{90}$$

$$b_{B,t}^{C,obs} = B_{B,t}^{C}/GDP_t \tag{91}$$

$$b_{B,t}^{H,obs} = B_{B,t}^{H}/GDP_t \tag{92}$$

$$\check{R}_{E,t}^{L,obs} = R_{E,t}^{L}/R_t \tag{93}$$

$$\check{R}_{B,C,t}^{L,obs} = R_{B,C,t}^{L}/R_t \tag{94}$$

$$\check{R}_{B,H,t}^{L,obs} = R_{B,H,t}^{L}/R_t \tag{95}$$

$$default_{B,t}^{obs} = F\left(\bar{\varpi}_{B,t}\right) \tag{96}$$

$$default_{E,t}^{obs} = F\left(\bar{\varpi}_{E,t}\right) \tag{97}$$

$$d_t^{T,obs} = D_t^T/GDP_t \tag{98}$$

$$d_t^{D,obs} = D_t^D/GDP_t \tag{99}$$

$$d_t^{S,obs} = D_t^S/GDP_t \tag{100}$$

$$\mu_t^{R^S,obs} = R_t^S/R_t \tag{101}$$

$$const_t^{obs} = i_{H,t}/i_{H,t-1} - 1$$

For the choice of prior means, we used information from Brazilian-specific empirical evidence, whenever available, or drew from the related literature. We tried to compensate the arbitrariness in the choice of some priors by setting large confidence intervals in their distribution. Table 2 shows the results of the estimation, including prior and posterior moments[26]. Most parameters were well identified and converged over the chains.

5 Impulse Responses

To study the model's features, we computed Bayesian impulse responses to the shocks in the model using the standard Dynare toolkit. 95% confidence intervals are plotted alongside the estimated mean response. The discussion below focuses on policy shocks.

The estimated model features traditional shapes of the responses of the key macroeconomic variables to a monetary policy shock (Figure 1)[27]. Notwithstanding, the financial frictions of the model entail more

[26] We use Dynare to conduct the log-linear approximation of the model to the calibrated steady state and to perform all estimation routines. We run 2 chains of 1,003,000 draws of the Metropolis Hastings to estimate the posterior

[27] We present the IRFs of temporary technology and price markup shocks in the appendix (Figures 2 and 3). The focus of the paper is on macroprudential shocks, so we drop the discussion of those shocks.

elaborate transmission channels. A 100 bp shock to the nominal base rate depresses consumption, labor and output through the traditional channels. Financial frictions reinforce the responses. The reduction in labor income puts pressure on the level of non-performing loans for borrowers, to which banks respond by increasing final lending rates. The same happens with entrepreneurs since the value of collateral falls. The increase in lending rates leads to a reduction in the total volume of loans, further depressing investment. The increase in the base rate immediately impacts the funding cost of the wholesale bank. The reduction in credit is accommodated through an expansion in the liquidity buffer. This leads to an increase in the capital adequacy ratio, in spite of the negative impact in actual bank profits.

The price of housing falls with the depressed demand, therefore the amount of banking debt to purchase real estate also falls. This more than offsets the fall in the labor income and creates an opportunity for borrowers to increase their leveraging. Since lending rates do not follow the increase in funding costs one-to-one, due to rigidities in price-setting, borrowers find it advantageous to increase their balances of retail loans. Therefore, the monetary policy shock entails an anticyclic behavior of consumer loans in this environment where labor income, and not a durable good, is given as collateral for loans.

The entrepreneur faces a drop in capital prices, and thus on collateral value, which drives down the volume of investment loans. On impact, the drop in overall demand for loans triggers a realignment of bank's assets towards liquid assets.

Reserve requirement ratios were shocked at the magnitude of 10 p.p.. This implies that reserve requirements on demand deposits rise on impact to 59%, from the steady state level of 49%, while reserve requirements on both time deposits and savings accounts rise to 21% from 11%. The average additional requirement rises to 17.6% from 7.6%

The shock to unremunerated reserve requirements on demand deposits (Figure 5) has a small contractionist impact on output and on prices. The most important impacts are restrained to banks' balance sheet. On impact, banks reshuffle their assets to comply with increased reserves. To this end, they unleash liquidity in the open market. However, the gap between the actual liquidity buffer and the target triggers an increase in the bank's funding cost, which is passed through to final lending rates, yet gradually due to rate rigidities incorporated in the model. Higher rates lead to a cut to the volume of loans, most noticeably to retail loans on impact, since these loans are responsive to flows (labor income) whereas investment loans respond to stocks (capital). The rise in lending rates is not enough to offset profit losses from the increased unremunerated reserves, and profits fall.

Since borrowers are faced with a shortage of financing, they cut down on consumption, with an aggregate negative impact on output and labor market conditions. This puts further pressure on the demand for investment loans, and capital investment falls. Monetary policy reacts to dampened economic conditions by lowering rates, which stimulates savers' consumption. This leads to an increase in savings accounts from the steady state, due to the high estimated elasticity of savings in the utility function. Notwithstanding, and as expected, lower return on financial investment that is not directly associated with utility results in a divestment of investment fund's quotas. The bank, in turn, decides to reshuffle the investment funds' portfolio by increasing the stake of time deposits. The overall impact on bank capital is practically mute, with a slight increase in the capital adequacy ratio.

A shock to (remunerated) reserve requirements on time deposits (Figure 6) has a similar transmission. However, the magnitude of the impact is noticeably higher mainly as a result of a base-effect, as we should discuss below. The main distinction in the transmission of this shock to that on requirements on demand deposits rests on bank's profit. Since this reserve is remunerated at the base rate, the pressure on asset remuneration is not as strong as that enacted by increased unremunerated reserves, and so the gains from higher final lending rates are enough to offset the increase in the funding cost. As the liquidity buffer is gradually recomposed, bank's profits and capital rise.

A shock to underremunerated reserve requirements on savings accounts (Figure 7) is qualitatively analogous to that on reserve requirements on time deposits. The amplitude of the responses is lower for two reasons: 1) the remuneration of required reserves on savings accounts is lower than that on time deposits, which implies some profit loss when the bank sells off liquidity to comply with increased required reserves, and 2) the incidence base of reserve requirements on savings accounts is about half of that on time deposits.

The model was also shocked with a 1 p.p. increase in capital requirement, implying that the optimal capital adequacy ratio targeted by banks rises to 17.8% (Figure 8) [28]. This shock enacts a stronger and more prolonged impact on the credit-to-GDP ratio than a monetary policy shock. However, the automatic stabilizer of monetary policy dampens the pass through of worsened credit conditions to the rest of the real economy through its impact on savers' consumption. Faced with lower rates of return on their assets, the saver increases consumption and, consequently, savings deposits, since the latter have a strong elasticity in savers' utility function.

The increase in the target for the capital adequacy ratio triggers an increase in bank's demand for liquidity. The liquidity buffer in excess of the optimal target reduces funding costs. Notwithstanding, this cannot be passed through to lending rates since the bank needs to cut down on its credit position to comply with the new target for capital adequacy. Since adjustments in the liability side of the bank's balance sheet are costly, a shrinkage of the overall balance sheet cannot be straightforwardly implemented. Lending rates rise to allow for a cut-down on loans.

Figures 9 and 10 show the impact of a 10 p.p. to the risk weights on retail loans and investment loans. These shocks spread to other classes of banks' assets. To improve on the capital adequacy ratio, banks increase their liquidity buffer and raise lending rates on both retail and investment loans to cut on the stock of credit. Tighter credit conditions impact households' consumption with a contractionist impact on output and the labor market. Figure 11 shows the impact of a shock to the risk weight on housing loans. The responses are qualitatively similar to those on the other risk weights, yet the magnitude is small since the initial value of was half the others.

6 Counterfactual exercises

We set the model parameters at the estimated mean of the posterior distribution to conduct counterfactual exercises on different set-ups of macroprudential tools.This allows us to deepen the understanding of the transmission channels operating in the modeled economy[29].

6.1 Removing the base-effect of reserve requirements

In order to single out the marginal impact of the distinct types of reserve requirements, we neutralized the base-effect on the responses of changes in required ratios. To this end, we shocked each required ratio at such a magnitude that the respective balances of required reserves would increase all at the same amount upon impact. Figure 16 shows the comparative impulse responses.

The responses show that reserve requirements on demand deposits have a stronger impact on the real economy. The qualitative effects of the shocks are similar for most variables, and are in accordance with the IRFs discussed above. Qualitative differences rest mainly on the reaction of savers' consumption and to the pass through of the shock to bank's profits. In case of shocks to ratios of remunerated required reserves, the saver divests to consume. That buffers some of the contractionist impact in output arising from tighter credit conditions. With respect to bank's assets, the requirement of an increased allocation of funds to non-remunerated required reserves, in the case of reserve requirements on demand deposits, cuts down on banks' profits. The fact that savers are bank's shareholders and that banks in the model are not entitled with the choice of adjusting the share of retained earnings, savers' income flow is negatively impacted, translating into a reduction in their consumption. Therefore, the final impact in output and labor conditions is accentuated.

[28] In spite of capital requirement in Brazil being set at 11%, banks have kept capital buffers in average throughout the sample. We assume that a 1 p.p. in the required ratio would be entirely passed through to banks' own targets.

[29] The results from counterfactual exercises should not be taken as undisputable evidence to the analyzed problems since fixing parameters that had been jointly estimated does not guarantee that the final set of parameters used in the exercises is likely to come out from the data.

6.2 Nonresponsive monetary policy

We also carried out an exercise in which monetary policy is not allowed to react to economic conditions after a shock to reserve requirement ratios. That is to reproduce a situation in which reserve requirements were auxiliary instruments to monetary policy.

Figure 12 compares the responses to a 10 p.p. increase in the ratio of reserve requirements on demand deposits in both environments, one in which the monetary policy is responsive to economic conditions, and the other where the base rate is kept unchanged throughout the perturbed period[30]. When monetary policy is unresponsive, the impact of changes in the macroprudential instrument is reinforced mainly through the reaction of savers' consumption. The buffering impact of savers' anticipation of consumption that would arise from lower interest rates is not present when monetary policy is unresponsive. As a result, output and labor conditions are more affected by the shock to the macroprudential instrument. Further reinforcement to the shock comes from the higher cost of funding (since the baseline scenario implies an expansionist monetary policy). Higher funding costs are passed through to lending rates, further depressing credit. As a result of bank's asset reshuffling, capital adequacy ratio rises more when monetary policy is unresponsive.

The analysis of the responses to changes in the ratios of remunerated reserve requirements, either on time deposits or savings accounts, when monetary policy is kept unchanged, yields the same conclusions outlined for the case of reserve requirements on demand deposits (Figures 13 and 14).

6.3 Simulation of a counter-cyclical buffer

The baseline model features a simple constant capital requirement, represented as an autoregressive process with null variance driving shock and high autoregressive coefficient (0.99). This representation is convenient because in most of the sample period - from its beginning up to 2008 - prudential regulation was compliant to the Basel I accord. Even afterwards, when Basel II framework prevailed, credit risk still was the preponderant factor in capital requirements, so that not considering operational and market risks in this period is still a reasonable approximation. However, the forthcoming implementation of the Basel III framework entails the introduction of a discretionary counter-cyclical buffer which will build up during expansionary credit cycles and will be loosened out along downturns. The purpose of this buffer is to dampen excessive oscillations in credit supply and to reduce the likelihood of bankruptcies in the financial system.

In order to simulate the implementation of this counter-cyclical buffer in the Brazilian banking market, we performed a slight modification to the representation of the capital requirement process. Instead of a simple autoregressive setup, capital requirements are now assumed to be a function of credit-to-GDP ratio:

$$\nu_t^{BankK} = \rho_{BankK}\nu_{t-1}^{BankK} + (1-\rho_{BankK})\left(\nu^{BankK} + \omega_{BankK}^{B}\left(\frac{B_t^{C,wb} + B_t^{h,wb} + B_t^{E,wb}}{GDP_t}\frac{gdp}{b^{C,wb} + b^{h,wb} + b^{E,wb}}\right)\right) + \varepsilon_t^{Bank}$$

The larger the credit-to-GDP ratio, the higher is the capital requirement. We maintain the autoregressive parameter ρ_{BankK} to prevent excessive oscillations of capital requirements, so that the bank has enough time to build up its capital buffer in expansionary times.

We performed two exercises using this alternative rule. First, we set $\rho_{BankK} = 0.5$, so that reserve requirement responses to credit cycles are swift. This might be the case during downturns and financial crises, when macroprudential authorities have to respond quickly to deterioration in credit supply conditions. In the second exercise, $\rho_{BankK} = 0.5^{1/4}$, so that reserve requirements response to the cycle is more gradual. In order to simulate distress in banking conditions, we generate a 10% decrease in total bank capital through a sudden temporary shock to bank profit distribution. We calibrate the parameter $\omega_{BankK}^{B} = 16$ so that the response of the required capital ratio ν_t^{BankK} to this shock when $\rho_{BankK} = 0.5$ does not exceed 2.5 p.p., which will be the maximum size allowed for the counter-cyclical buffer in Brazil.

[30] 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 perturbed period.

Figure 18 compares the impulse responses implied by these two rules to the impulse response generated by the baseline model with no counter-cyclical buffer.

In all cases, bank capital decreases by 10% after the shock, and slowly increases back towards its steady state value. The homogeneity in the response stems from the assumption that profit accumulation is exogenous, a feature that results from the short (one-period ahead) horizon considered in banks' optimization problem. However, the response of capital requirement is considerably different. In the baseline model, it remains constant, but decreases substantially in the other two cases, especially in the model with lower auto-regressive coefficient. As a result of less constraining capital requirements, interest rates on consumption and investment credit increase by much less than in the baseline scenario, and the impact on consumption and capital expenditures is smaller. The overall impact on GDP is also milder, decreasing by up to two thirds.

Although this very simplistic exercise does not take into account other channels by which a negative financial market shock might affect the economy (such as shocks to idiosyncratic risks of entrepreneurs and borrowers), it illustrates the potential stabilizing effects of a counter-cyclical buffer against negative shocks in financial and credit markets.

6.4 Further considerations

We also carried out and exercise to assess whether the mere existence of reserve requirements in the economy implies any different impact of monetary policy in the economy. Figure 17 shows the comparison of responses to a monetary policy shock under different reserve requirement regimes. The results contrast to [12], who show that the presence of reserve requirements in the economy helps the interest rate policy to better stabilize the economy. In our model, the impact of removing each one of the reserve requirements or all of them on the economy's responses to a monetary policy shock are restrained to the response of the liquidity buffer, and, to a lesser extent, on banks' profits and the capital adequacy ratio.

7 Conclusion

This paper presents a DSGE model with both standard and matter-of-fact financial frictions for Brazil. In this model, consumers put up a fraction of their labor income as a guarantee to obtain bank loans, and there is no requirement that these loans be channeled to the purchase of capital goods. This feature is intended to portray the bulk of the retail credit market in Brazil. Loans for unspecific destination prevail in the Brazilian financial system, and even for the case of loans where some sort of capital good is put up as collateral, banks' credit concession is strongly grounded on prospective analysis of their clients' labor income.

Investment credit features a very close variant of BGG-financial accelerator. We include further frictions in banks' decisions, such as liquidity buffers, adjustment costs to time deposits, tight regulatory requirements on loan concessions and savings deposits, among others, so as to better account for the particularities of the Brazilian banking sector.

We introduce macroprudential policy in the form of a variety of reserve requirements, capital requirements, and risk weight on assets. Each instrument enacts a qualitatively different response of bank and real economy variables.

Changes in reserve requirements have a strong impact on banks' liquidity buffer. What the buffer cannot neutralize passes through to the credit market. Tighter credit conditions finally affect the real economy.

The estimated responses of a shock to reserve requirement ratios on remunerated time deposits are relevant, and stronger in magnitude than the unremunerated counterpart. We show that this is mainly due to a base effect, since the balance of time deposits in the Brazilian economy is almost eight times as large as the volume of demand deposits.

When reserve requirements are shut down from the model, the impact of a monetary policy shock on the real economy remains unaltered. The only differences in the IRFs are restrained to banks' liquidity

buffer, profits and subsequently capital.

Capital requirements have a more prolonged impact on the credit-to-GDP ratio than a monetary policy shock; notwithstanding the transmission to the real economy after an increase in the required capital adequacy ratio is dampened by the response of monetary policy rule. We also show that countercyclical buffers have the potential to stabilize output.

Isolated changes in the risk weight of each category of banks' assets contaminate the entire bank portfolio. Overall credit conditions are impacted, with a subsequent spillover to output.

References

[1] B. S. Bernanke, M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. volume 1 of Handbook of Macroeconomics, pages 1341–1393. Elsevier, 1999.

[2] L. J. Christiano, R. Motto, and M. Rostagno (2010). Financial factors in economic Fluctuations. Technical Report 1192, European Central Bank, May 2010.

[3] M. D. Pariès, C. K. Sørensen, and D. Rodriguez-Palenzuela (2011). Macroeconomic Propagation under Different Regulatory Regimes: Evidence from an Estimated DSGE Model for the Euro Area, 2011.

[4] Andrés, J., O. Arce and C. Thomas (2010). Banking Competition, Collateral Constraints and Optimal Monetary Policy. Documentos de Trabajo n. 1001. Banco de España, 2010

[5] De Fiore, F. and O. Tristani (2010). Optimal Monetary Policy in a Model of the Credit Channel. The Economic Journal. doi: 10.1111/j.1468-0297.2012.02558.x, 2012

[6] Glocker, C. and P. Towbin (2012). Reserve Requirements for Price and Financial Stability: When are They Effective? International Journal of Central Banking, 2012.

[7] Queiroz, M. Comportamento Diário do Mercado Brasileiro de Reservas Bancárias – Nível e Volatilidade – Implicações na Política Monetária. Proceedings of the 32nd Brazilian Economics Meeting, 2004.

[8] Montoro, C. and R. Moreno. The Use of Reserve Requirements as a Policy Instrument in Latin America (2011). BIS Quarterly Review, (1), 2011.

[9] Mesquita, M. and M. Torós (2010). Brazil and the 2008 panic, BIS Papers, n. 54, 2010.

[10] Tovar, C., M. Garcia-Escribano, and M. Martin (2012). Credit Growth and the effectiveness of Reserve Requirements and Other Macroprudential Instruments in Latin America. IMF Working Paper 12/142, 2012.

[11] Roger, S. and J. Vlcek. Macroeconomic Costs of Higher Bank Capital and Liquidity Requirements (2011). IMF Working Paper 11/103, 2011.

[12] Montoro, C. and C. Tovar (2010). Macroprudential tools: assessing the implications of reserve requirements in a DSGE model. Incomplete draft. Cemla, 2010.

[13] Souza-Rodrigues, E. and T. Takeda (2004). Reserve Requirements and Bank Interest Rate Distribution in Brazil. Proceedings of the 32nd Brazilian Economics Meeting, 2004

[14] Brzoza-Brzezina, Kolasa and Makarski (2013). The anatomy of standard DSGE models with financial frictions. Journal of Economic Dynamics and Control, v 37(1), 2013.

[15] Jiménez, G., S. Ongena, J. Peydró and J. Saurina. Macroprudential policy, countercyclical bank capital buffers and credit supply : Evidence from the Spanish dynamic provisioning experiments (2012). National Bank of Belgium Working Paper 231, 2012.

[16] Dib, A (2010). Capital Requirement and Financial Frictions in Banking: Macroeconomic Implications . Bank of Canada Working Paper 2010-26, 2010.

[17] Carvalho, F. and C. Azevedo (2008). The incidence of reserve requirements in Brazil: Do bank stockholders share the burden?. Journal of Applied Economics, 2008.

[18] Gerali et al. (2010) : Gerali, A., Neri, S., Sessa, L., Signoretti, F. M.. Credit and Banking in a DSGE Model of the Euro Area, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 42(s1), pages 107-141, 2010.

[19] Iacoviello (2005) : Iacoviello, M. House prices, borrowing constraints, and monetary policy in the business cycle. American Economic Review, 95(3), 739-764, 2005.

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
R	Nominal interest rate (% per annum)	10.2
i_H	Investment in housing (% of GDP)	3
i_K	Investment in capital (% of GDP)	15.85
g	Government spending (% of GDP)	20.9
D^D	Demand deposits (% of GDP)	3
D^T	Time deposits (% of GDP)	21.6
D^S	Saving deposits (% of GDP)	10.35
$B^{B,C}$	Credit for consumption (% of GDP)	12.28
$B^{B,H}$	Credit for housing (% of GDP)	4.87
B^E	Credit for investment (% of GDP)	13.42
$R_{L,B,c}$	Nominal interest rate on consumption credit (% per annum)	39
$R_{L,B,H}$	Nominal interest rate on housing credit (% per annum)	14.2
$R_{L,E}$	Nominal interest rate on investment credit (% per annum)	32.1
τ_C	Tax ratio on consumption (%)	16.2
τ_W	Tax ratio on wages (%)	15
τ_π	Tax ratio on profits (%)	15
τ_B	Tax ratio on financial transactions (%)	0.3
bankcap	Bank capital (% of GDP)	10.75
ν^{bankK}	Optimal bank capital level (%)	10.94
$\tau_{RR,T}$	Reserve requirement ratio on time deposits (%)	11.2
$\tau_{RR,S}$	Reserve requirement ratio on saving deposits (%)	11.7
$\tau_{RR,D}$	Reserve requirement ratio on demand deposits (%)	49
τ_H	Mininum required allocation of saving deposits funds in housing loans (%)	65
$\tau_{RR,\text{adic}}$	Additional reserve requirement on time deposits (%)	7.6
	Parameters	
φ^S	Relative remuneration of non-allocated saving deposits to housing credit	0.90
$\alpha^S_{1,R}$	Coefficient of the savings rate rule	0.70
$\omega_S, \omega_B, \omega_E$	Relative size of agents	1
μ_w	Wage markup	1.1
δ_H	Housing depreciation (% per annum)	4

Continued on next page

Table 1 – (cont.)

	Description	Value
ψ^F	Weight on investment fund's diversification	0
η^F	Elasticity of substitution of fund's portfolio	1.1
v^b	Share of bank's retained earnings (%)	70
$\tau_{\chi 1}$	Risk weight on consumption credit	1
$\tau_{\chi 2}$	Risk weigth on investment credit	1
$\tau_{\chi 3}$	Risk weigth on housing credit	0.5
$\tau_{\chi 4}$	Risk weight on open market positions	0
$\mu_{B,H}$	Monitoring cost for housing credit	0

Table 2: Estimated Parameters and Shocks

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
Preference and Technology							
h_S	Habit persistence	Beta	0.75	0.05	0.64	0.58	0.70
σ_L	Inverse Frisch elasticity of labor	Gamma	1.50	0.10	1.40	1.25	1.56
$\phi_{u,2}$	Capital utilization cost	Gamma	0.20	0.15	0.48	0.26	0.70
ξ_{E}	Adjustment cost of employment to hours	Beta	0.75	0.15	0.80	0.77	0.83
ϕ_K	Adjustment cost of capital investment	Gamma	3.00	2.00	8.88	4.52	13.17
ϕ_H	Adjustment cost of housing investment	Gamma	20.00	16.00	23.48	4.98	42.88
Nominal Rigidities							
ξ_D	Calvo - prices	Beta	0.75	0.05	0.77	0.71	0.83
α_W	Calvo - wages	Beta	0.75	0.05	0.88	0.87	0.90
γ_D	Price indexation	Beta	0.70	0.20	0.13	0.02	0.22
γ_W	Wage indexation	Beta	0.70	0.20	0.24	0.06	0.40
ξ_E^R	Calvo - investment credit interest rate	Beta	0.75	0.15	0.61	0.34	0.87
$\xi_{B,C}^R$	Calvo - consumption credit interest rate	Beta	0.75	0.15	0.40	0.24	0.57
Policy rules							
ρ_R	Interest rate smoothing	Beta	0.70	0.20	0.88	0.84	0.92
γ_π	Inflation coefficient	Gamma	2.00	1.00	1.22	1.08	1.36
γ_Y	Output gap coefficient	Gamma	0.25	0.10	0.16	0.08	0.24
ρ_g	Government spending smoothing	Beta	0.70	0.20	0.69	0.57	0.81
$\mu_{B,G}$	Government debt coefficient	Beta	0.01	0.01	0.01	0.01	0.02
Financial frictions							
σ_S	Saving deposits EoS	Gamma	4.00	3.00	20.22	12.94	27.27
σ_D	Demand deposit EoS	Gamma	4.00	3.00	3.67	1.75	5.67
σ^B	Risk distribution s.d. in consumption credit	Gamma	0.30	0.10	0.06	0.05	0.06
σ^E	Risk distribution s.d. in investment credit	Gamma	0.30	0.10	0.93	0.75	1.10
$\chi_{K_{wb}}$	Capital buffer deviation cost	Gamma	10.00	10.00	3.93	0.00	8.76
$\chi_{b_{OM}}$	Liquidity buffer deviation cost	Beta	0.50	0.28	0.09	0.04	0.15
$\chi_{d,T}$	Time deposits to loans ratio cost	Beta	0.50	0.28	0.20	0.02	0.38
ϕ_T	Adjustment cost of time deposits	Beta	0.50	0.28	0.26	0.05	0.52
ν^{wb}	Retained bank profits	Beta	0.70	0.10	0.72	0.58	0.87
Autoregressive shocks							
$\rho_{\varepsilon^{I_K}}$	Adjustment cost of capital investment	Beta	0.50	0.25	0.37	0.18	0.56
$\rho_{\varepsilon^{I_H}}$	Adjustment cost of housing investment	Beta	0.50	0.25	0.26	0.05	0.45
$\rho_{\varepsilon^{B,S}}$	Saver preference	Beta	0.50	0.28	0.98	0.97	0.99
$\rho_{\varepsilon^{B,B}}$	Borrower preference	Beta	0.50	0.28	0.90	0.88	0.94
ρ_{ε^A}	Temporary technology	Beta	0.50	0.25	0.78	0.72	0.84
ρ_{ε^u}	Capital utilization	Beta	0.50	0.25	0.68	0.57	0.79
ρ_{μ_D}	Price markup	Beta	0.50	0.25	0.95	0.91	1.00
ρ_{μ_W}	Wage markup	Beta	0.50	0.25	0.12	0.01	0.21
Autoregressive financial shocks							
$\rho_{\varepsilon^{S,B}}$	Saving deposit preference	Beta	0.50	0.28	0.94	0.88	1.00
ρ_{R_H}	Housing credit interest rate smoothing	Beta	0.50	0.28	0.94	0.90	0.99
$\rho_{\mu_E^R}$	Investment credit interest rate markup	Beta	0.50	0.25	0.38	0.06	0.73
$\rho_{\mu_{B,C}^R}$	Consumption credit interest rate markup	Beta	0.50	0.25	0.89	0.79	0.99
$\rho_{\nu^{wb}}$	Retained bank profits	Beta	0.50	0.25	0.60	0.38	0.83
ρ_{σ_B}	Risk distribution s.d. in consumption credit	Beta	0.50	0.25	0.96	0.93	0.99
ρ_{σ_E}	Risk distribution s.d. in investment credit	Beta	0.50	0.25	0.96	0.92	1.00
$\rho_{d,D}$	Demand deposit preference	Beta	0.70	0.20	0.96	0.92	0.99
$\rho_{d,T}$	Adjustment cost in time deposits	Beta	0.70	0.20	0.73	0.57	0.90
$\rho_{\gamma_{B,H}}$	Collateral value in housing credit	Beta	0.90	0.05	0.96	0.94	0.99

Continued on next page

Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
ρ_{γ_E}	Collateral value in investment credit	Beta	0.90	0.05	0.89	0.81	0.98
$\rho_{\gamma_{B,C}}$	Collateral value in consumption credit	Beta	0.90	0.05	0.98	0.97	0.99
ρ^{Basel}	Basel ratio	Beta	0.90	0.05	0.93	0.89	0.98
$\rho_{\phi^{R_S}}$	Saving deposit interest rate spread	Beta	0.50	0.28	0.97	0.95	1.00
Traditional shocks							
ϵ^R	Monetary policy shock	Inverse Gamma	0.01	Inf	0.01	0.01	0.01
ϵ^G	Government spending shock	Inverse Gamma	0.01	Inf	0.01	0.01	0.01
ϵ^{I_K}	Capital investment adjustment cost shock	Inverse Gamma	0.05	Inf	0.06	0.05	0.08
ϵ^{I_H}	Housing investment adjustment cost shock	Inverse Gamma	0.05	Inf	0.03	0.02	0.03
ϵ^{β_S}	Saver preference shock	Inverse Gamma	0.05	Inf	0.13	0.07	0.20
ϵ^{β_B}	Borrower preference shock	Inverse Gamma	0.05	Inf	1.67	1.16	2.17
ϵ^A	Temporary Technology shock	Inverse Gamma	0.02	Inf	0.02	0.02	0.02
ϵ^u	Capital utilisation shock	Inverse Gamma	0.02	Inf	0.02	0.01	0.02
ϵ^{μ_D}	Price markup shock	Inverse Gamma	0.03	Inf	0.04	0.03	0.05
ϵ^{μ^W}	Wage markup shock	Inverse Gamma	0.03	Inf	0.12	0.10	0.15
Financial shocks							
ϵ^{R_H}	Housing credit interest rate shock	Inverse Gamma	0.01	Inf	0.00	0.00	0.01
$\epsilon^{\mu^{R_E}}$	Investment interest rate shock	Inverse Gamma	0.02	Inf	0.01	0.00	0.02
$\epsilon^{\mu^R_{B,C}}$	Consumption interest rate shock	Inverse Gamma	0.02	Inf	0.01	0.01	0.02
$\epsilon^{\nu^{wb}}$	Bank capital accumulation shock	Inverse Gamma	0.20	Inf	0.27	0.22	0.32
$\epsilon^{\gamma_{B,H}}$	Housing collateral shock	Inverse Gamma	0.05	Inf	0.06	0.05	0.07
ϵ^{γ^E}	Investment collateral shock	Inverse Gamma	0.05	Inf	0.03	0.01	0.06
$\epsilon^{\gamma_{B,C}}$	Consumption collateral shock	Inverse Gamma	0.05	Inf	0.04	0.03	0.05
ϵ^{σ_E}	Investment credit risk shock	Inverse Gamma	0.10	Inf	0.03	0.02	0.04
ϵ^{σ_B}	Consumption credit risk shock	Inverse Gamma	0.10	Inf	0.06	0.05	0.07
ϵ^{Basel}	Basel ratio shock	Inverse Gamma	0.10	Inf	0.09	0.07	0.10
$\epsilon^{D,S}$	Demand deposit preference shock	Inverse Gamma	0.10	Inf	0.15	0.07	0.23
$\epsilon^{S,S}$	Saving deposit preference shock	Inverse Gamma	0.10	Inf	0.62	0.41	0.83
$\epsilon^{d,T}$	Time deposit adjustment cost shock	Inverse Gamma	0.05	Inf	0.03	0.02	0.03
$\epsilon^{\phi^{R_S}}$	Saving deposit interest rate spread shock	Inverse Gamma	0.01	Inf	0.05	0.04	0.06

B Impulse Response Functions

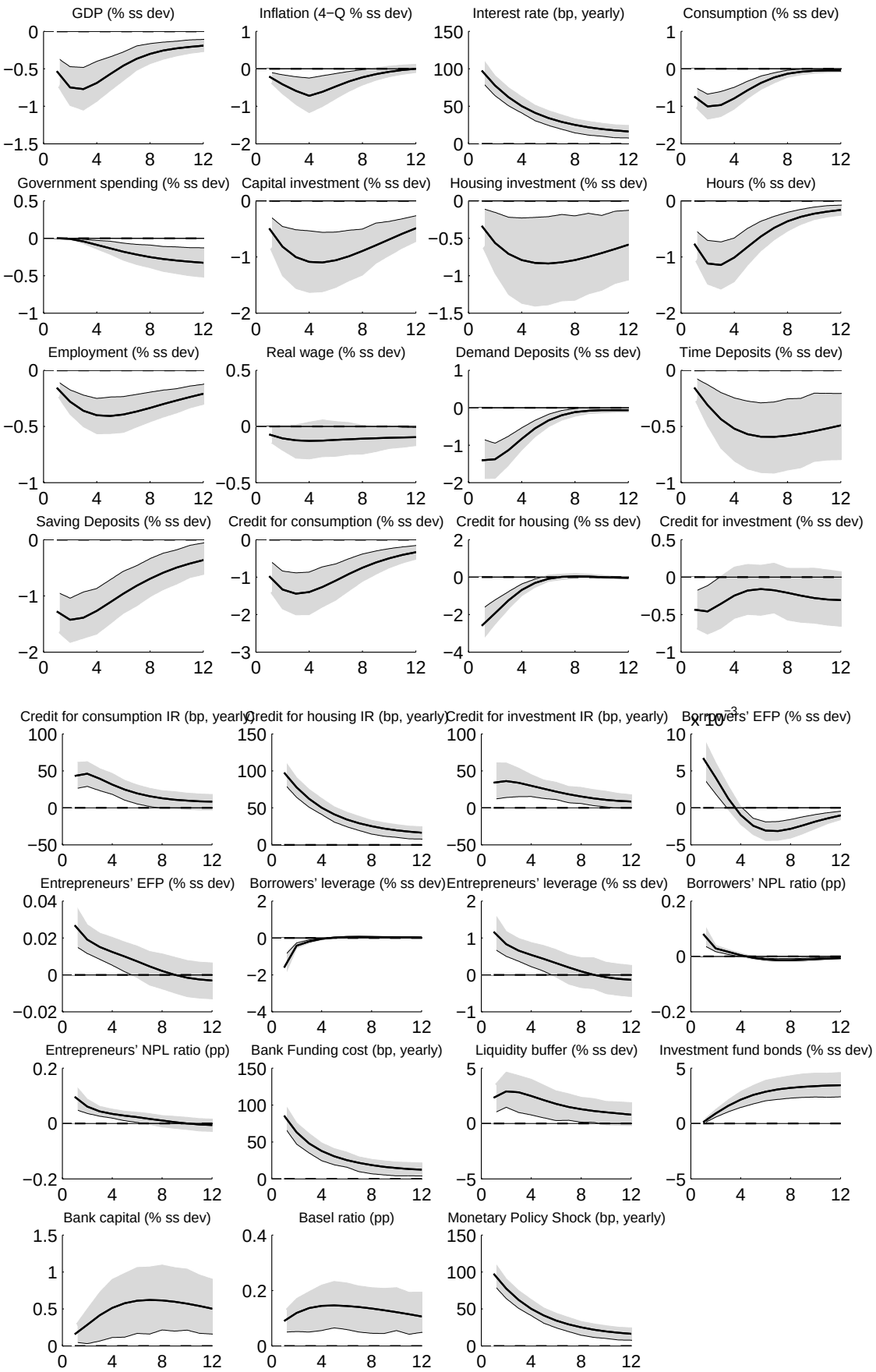

Figure 1: Monetary Policy Shock

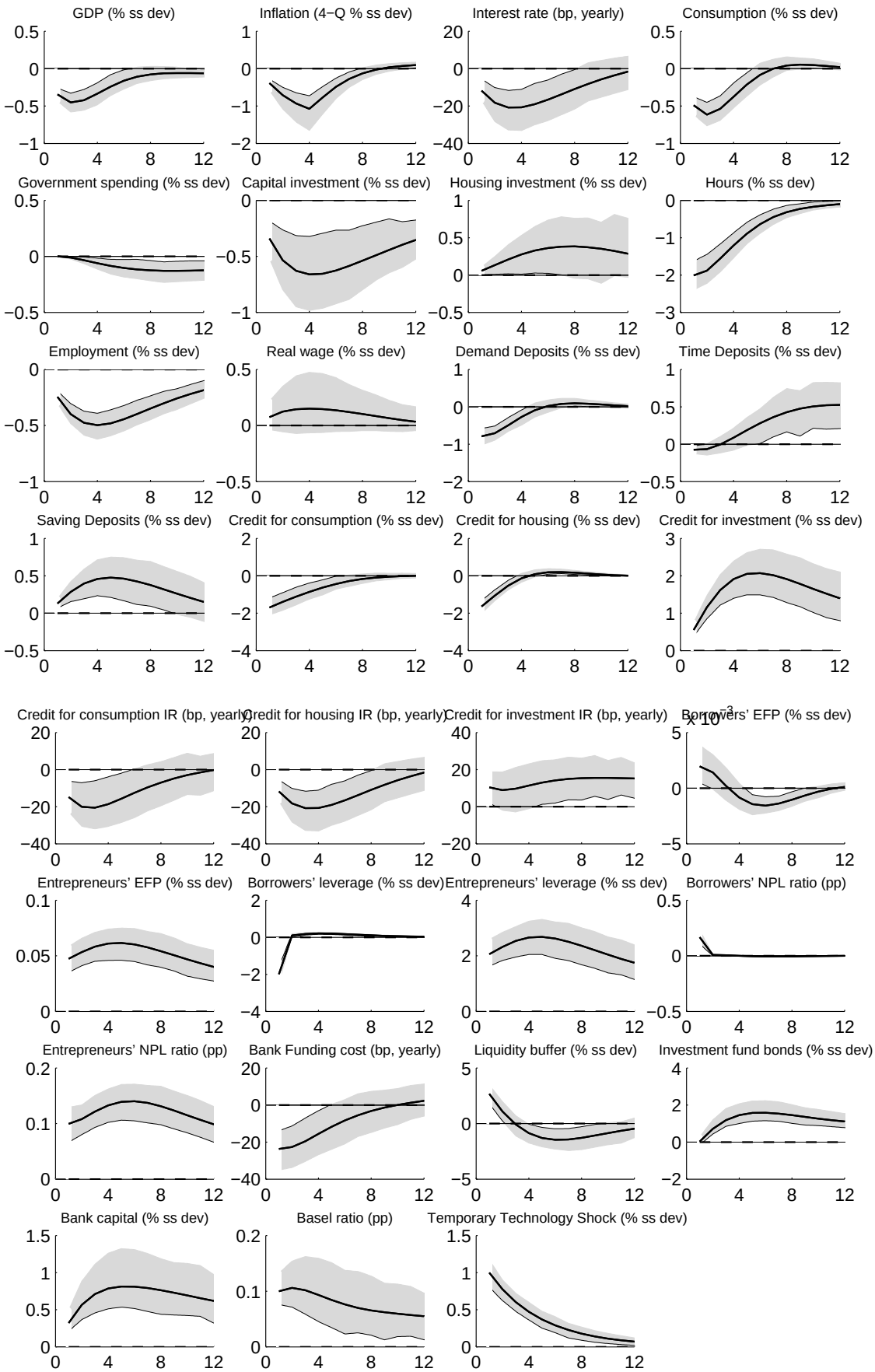

Figure 2: Temporary Technology Shock

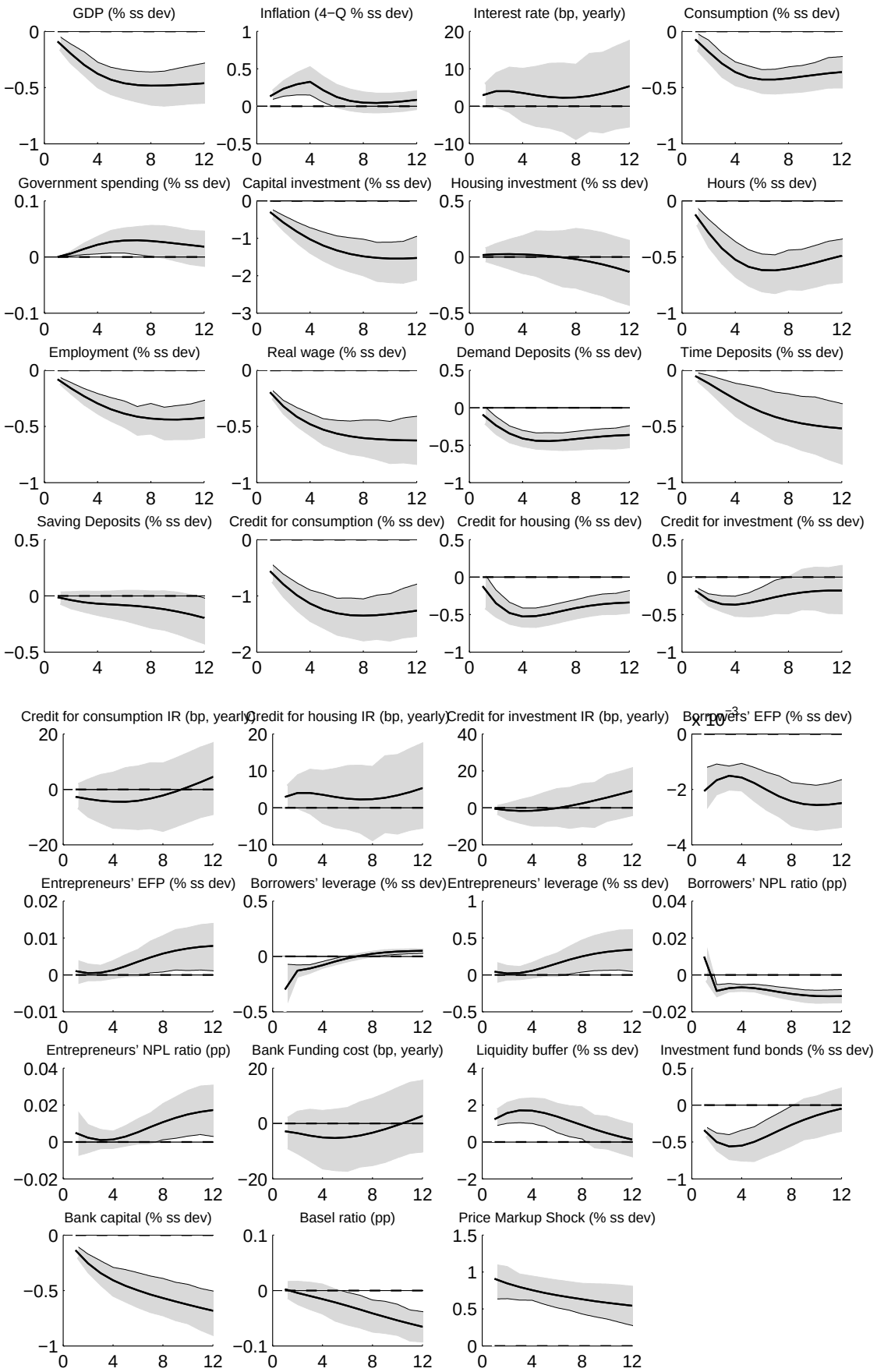

Figure 3: Price Markup Shock

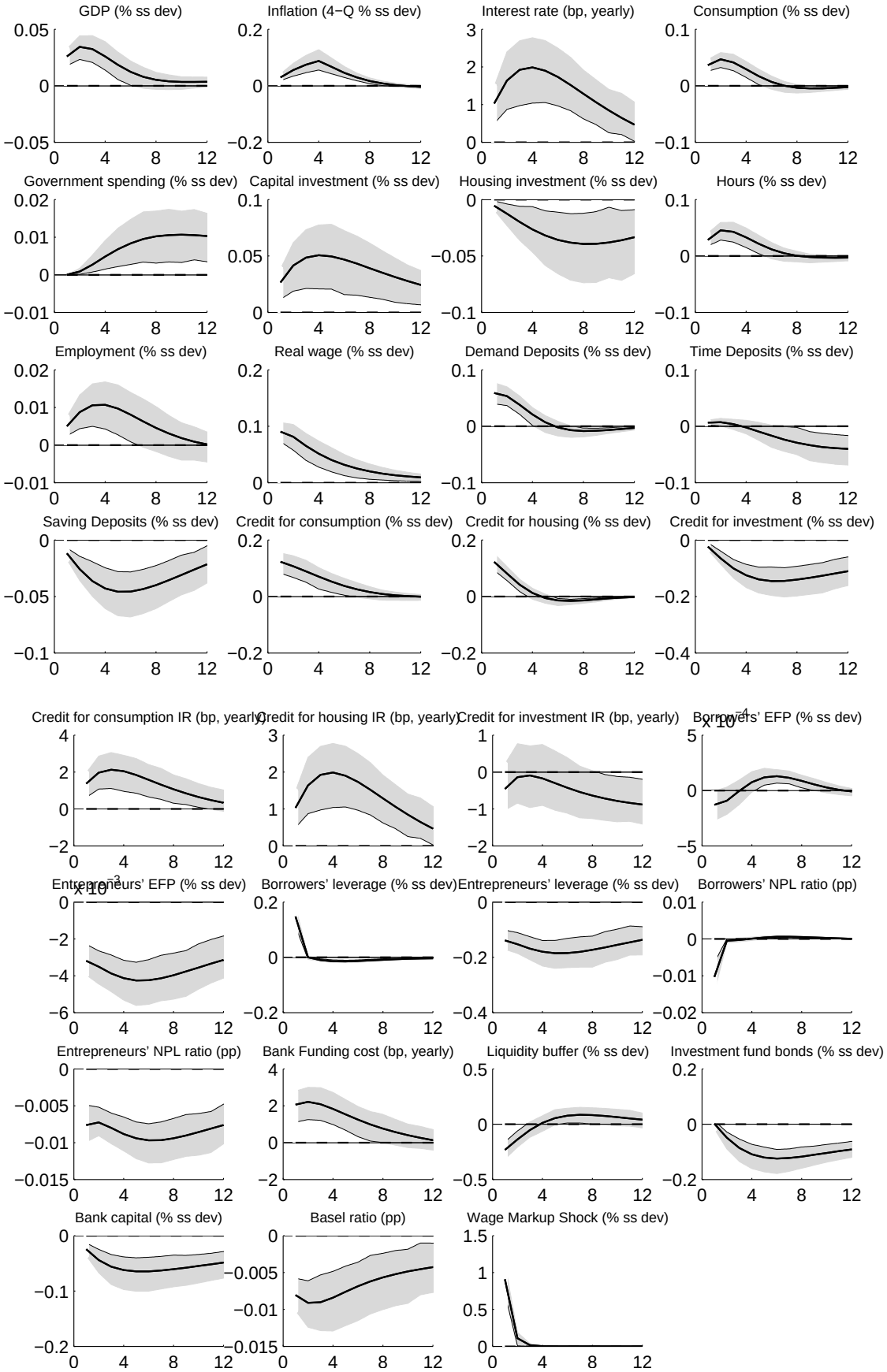

Figure 4: Capital Requirement Shock

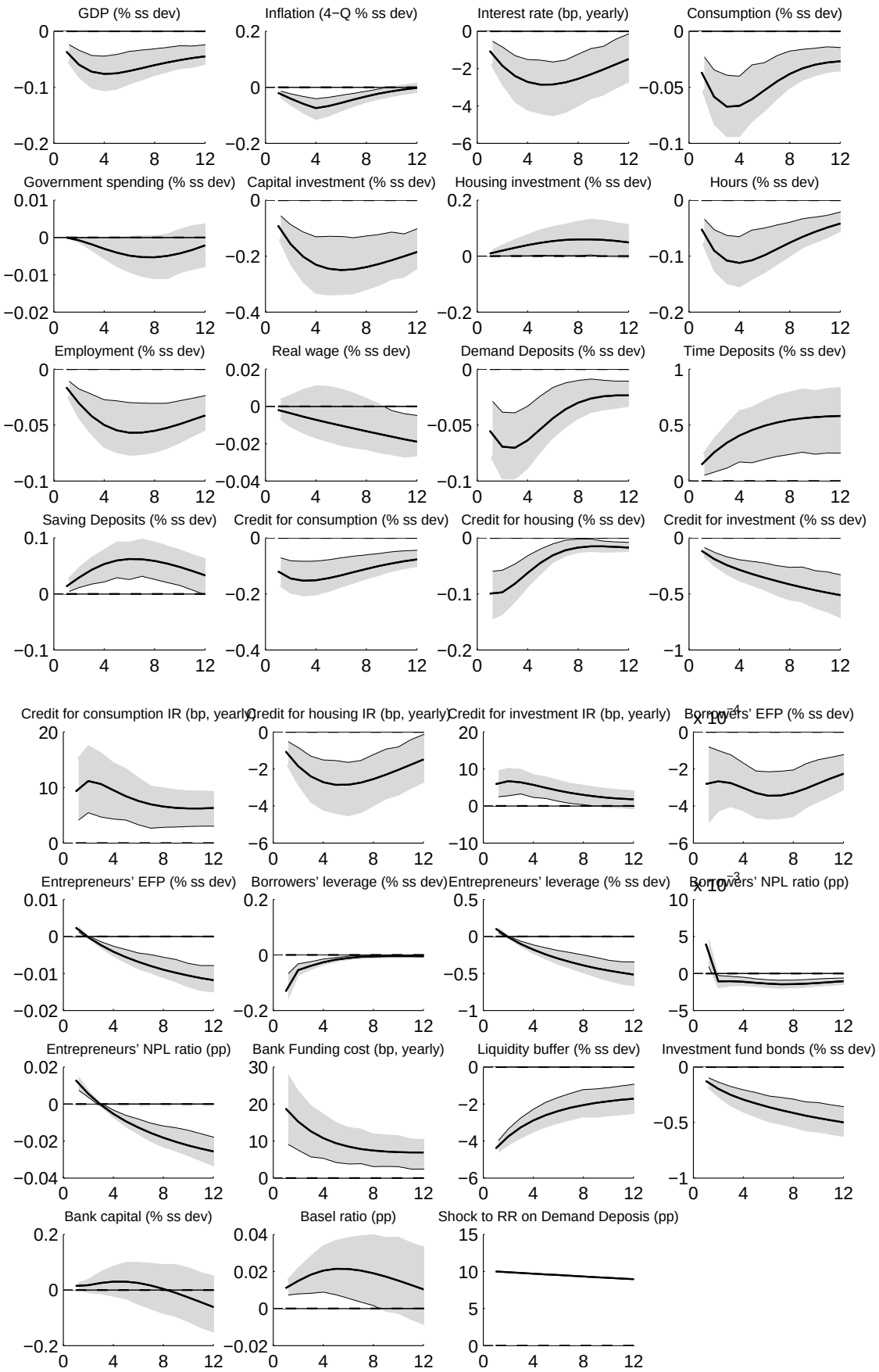

Figure 5: Shock to Reserve Requirement Ratio on Demand Deposits

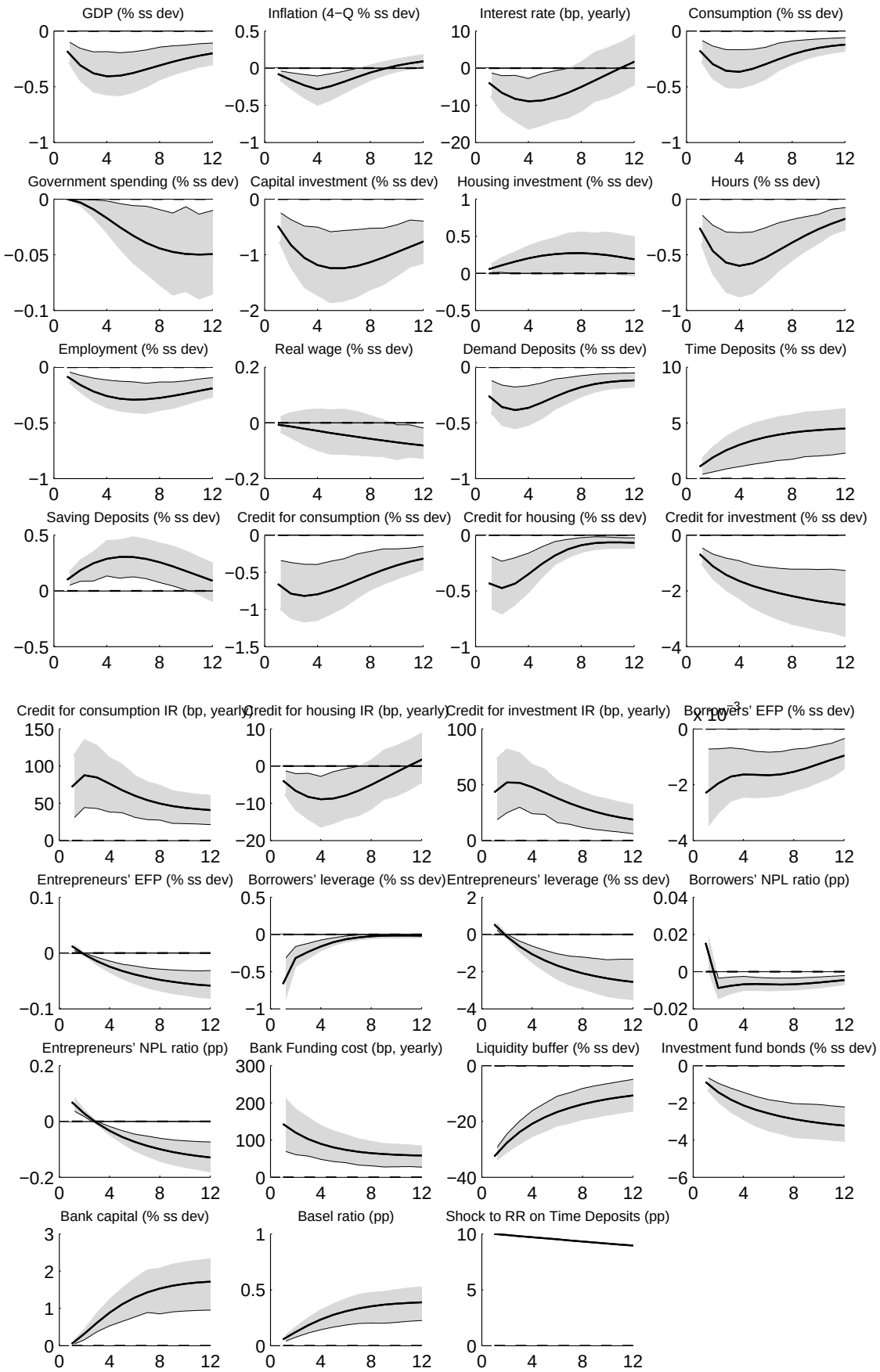

Figure 6: Shock to Reserve Requirement Ratio on Time Deposits

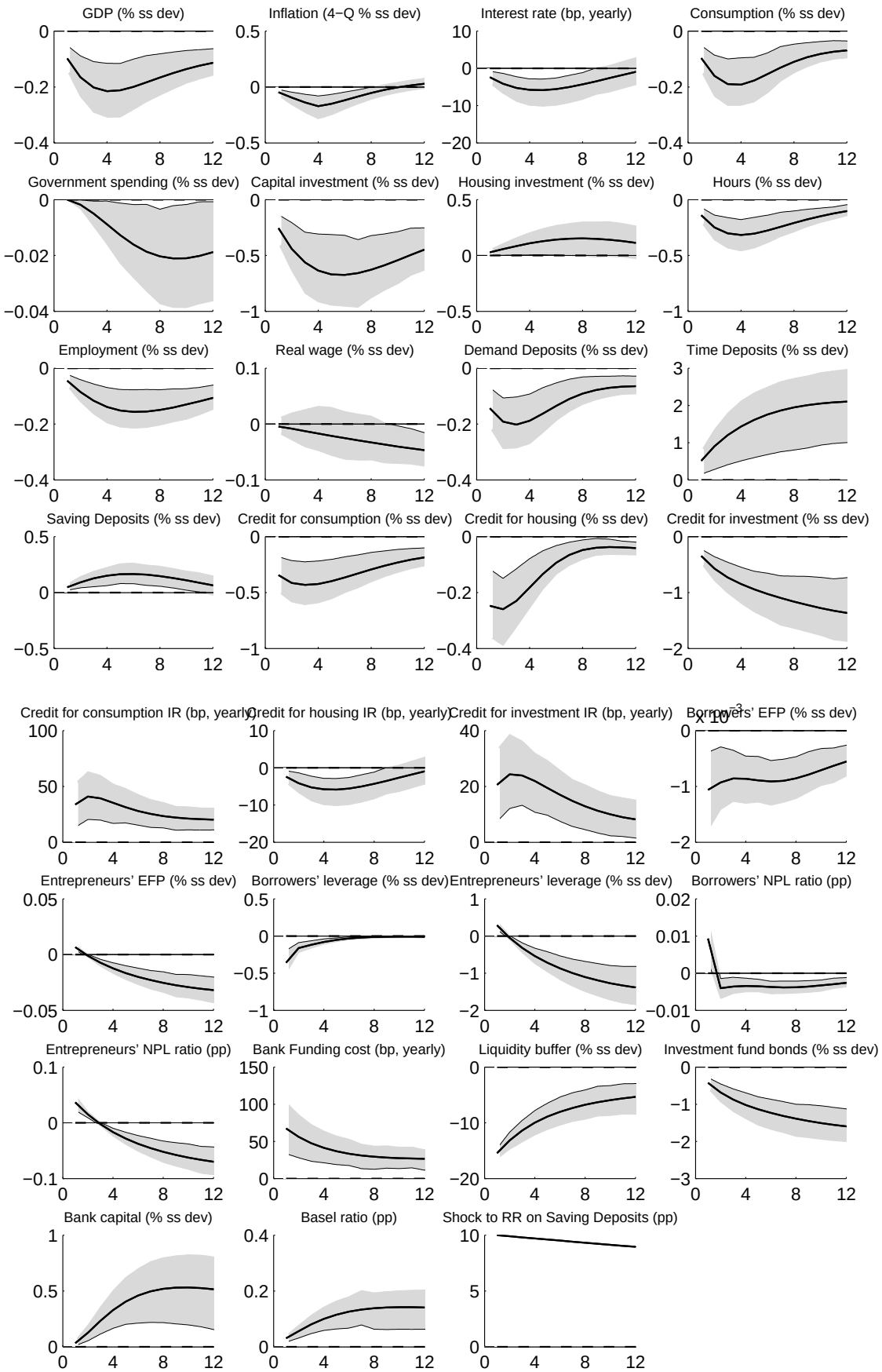

Figure 7: Shock to Reserve Requirement Ratio on Saving Deposits

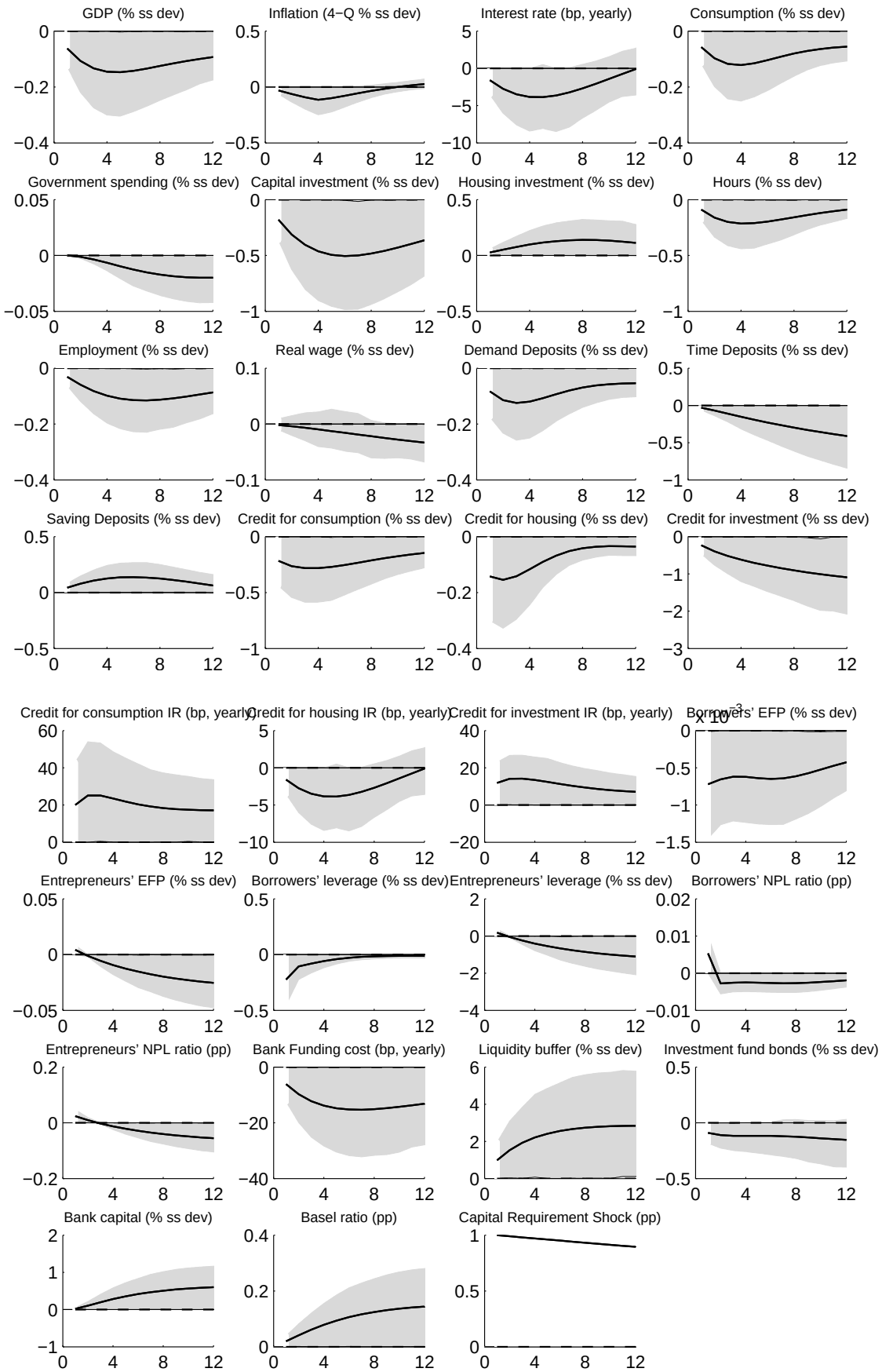

Figure 8: Capital Requirement Shock

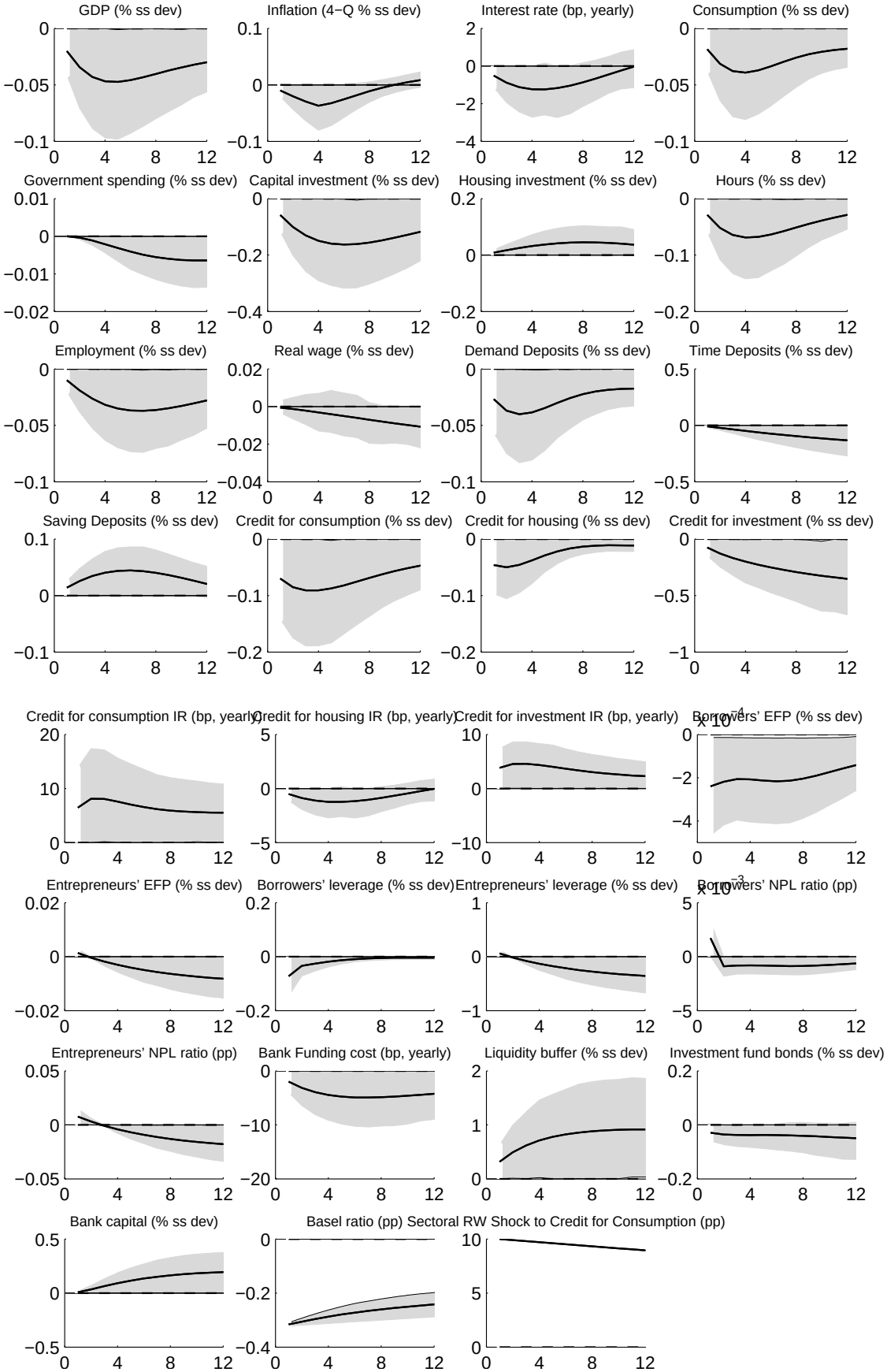

Figure 9: Sectoral Risk Weight Shock to Credit for Consumption

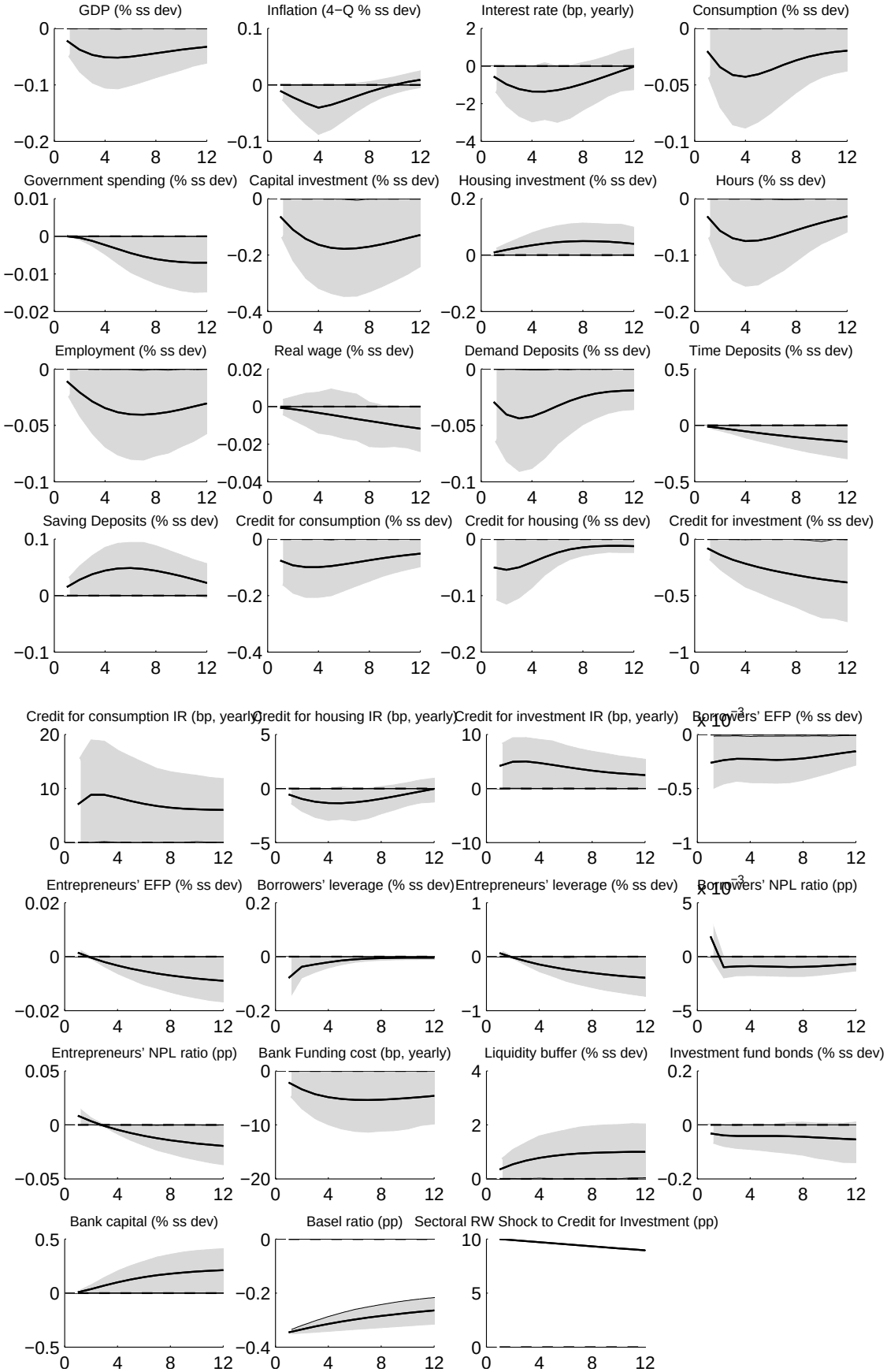

Figure 10: Sectoral Risk Weight Shock to Credit for Investment

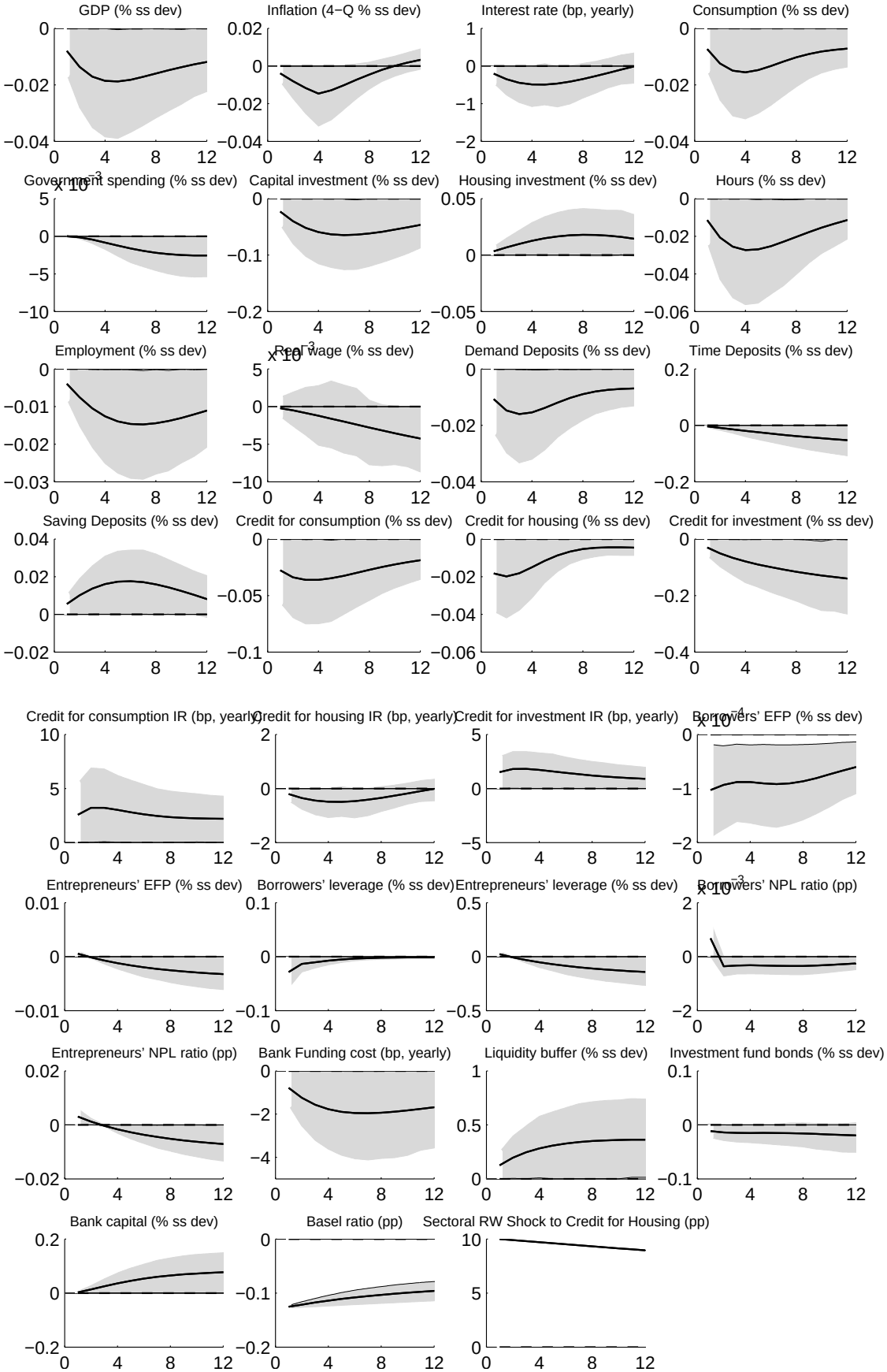

Figure 11: Sectoral Risk Weight Shock to Credit for Housing

C Reserve Requirement exercises

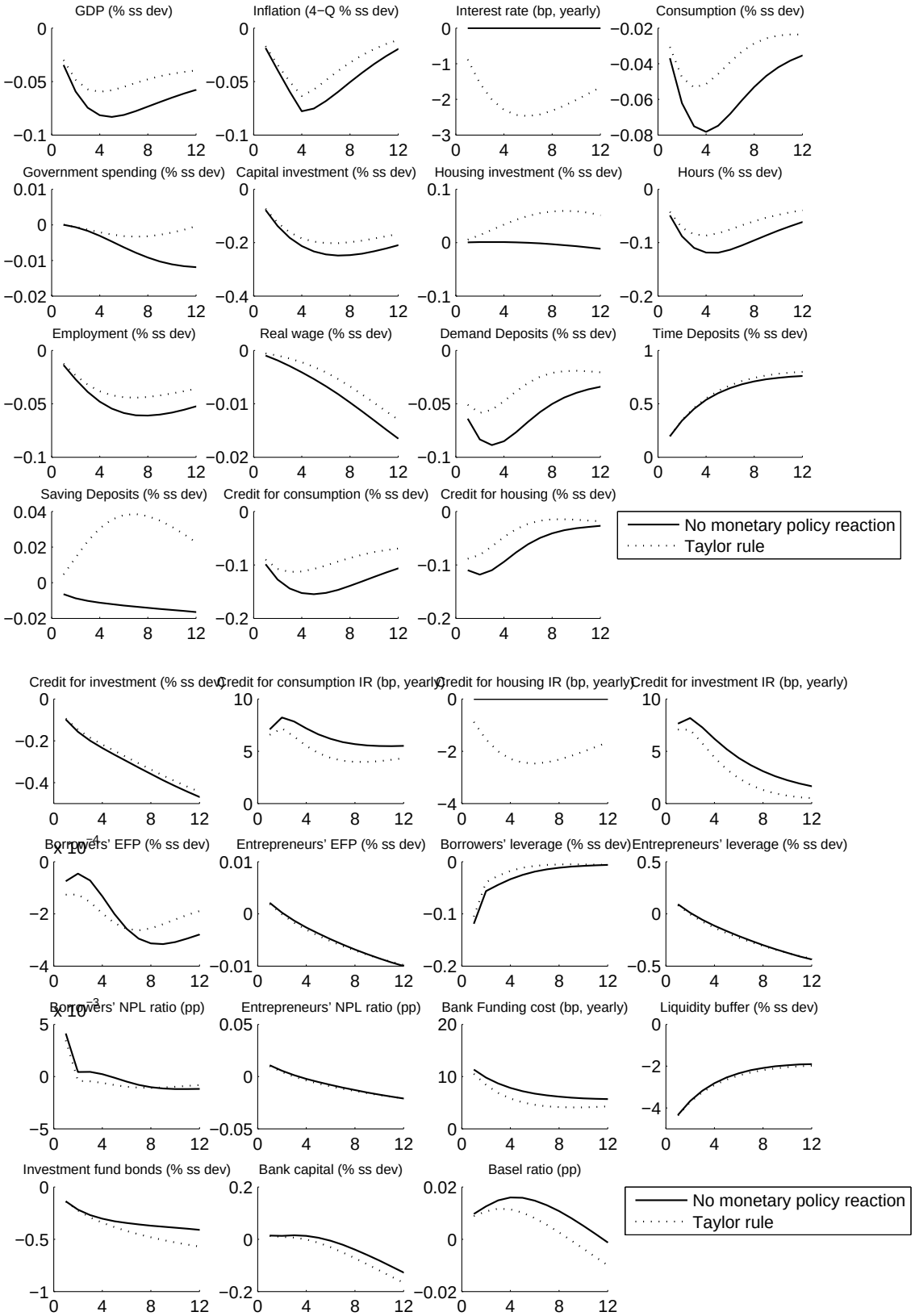

Figure 12: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Demand Deposits

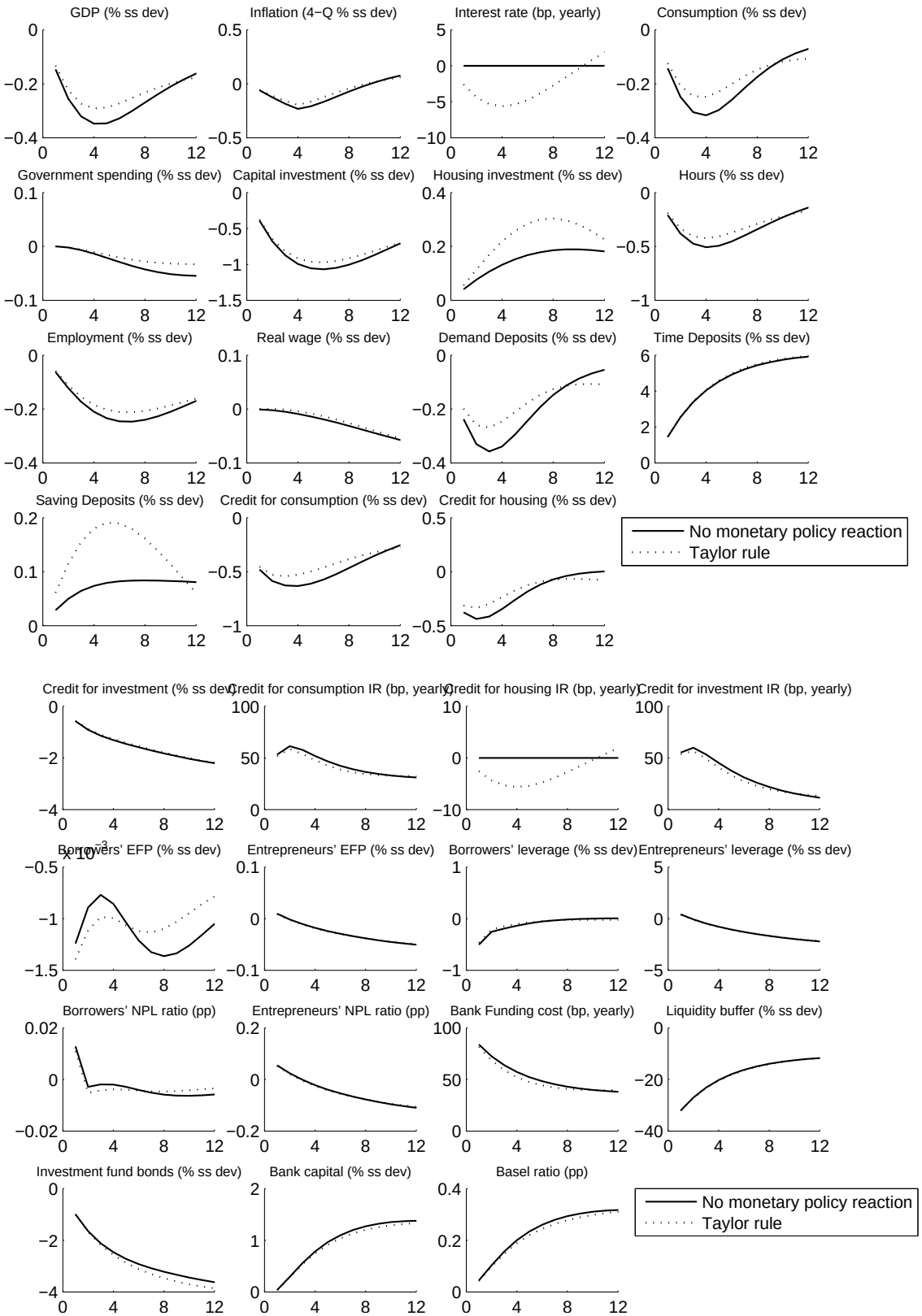

Figure 13: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Time Deposits

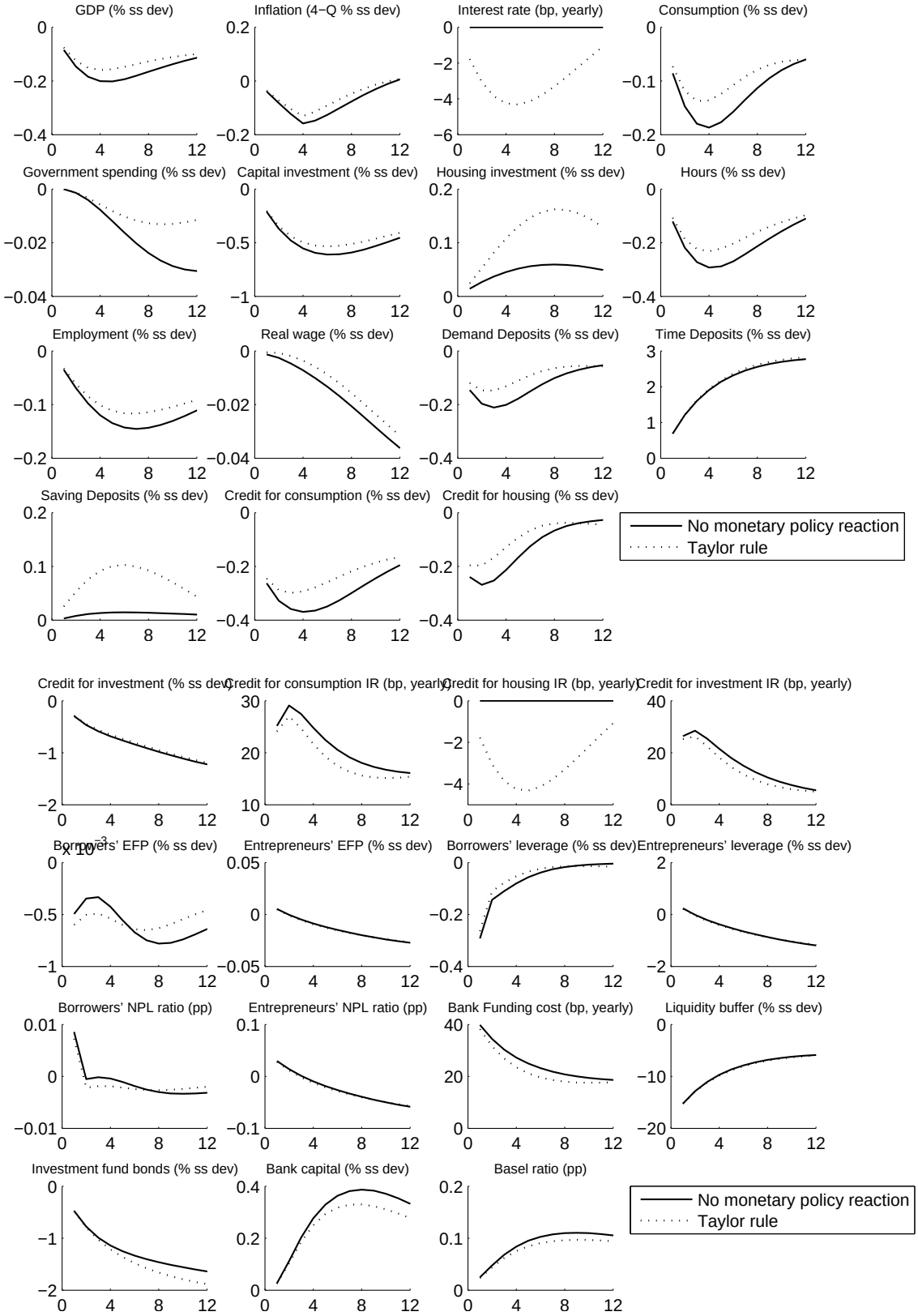

Figure 14: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Saving Deposits

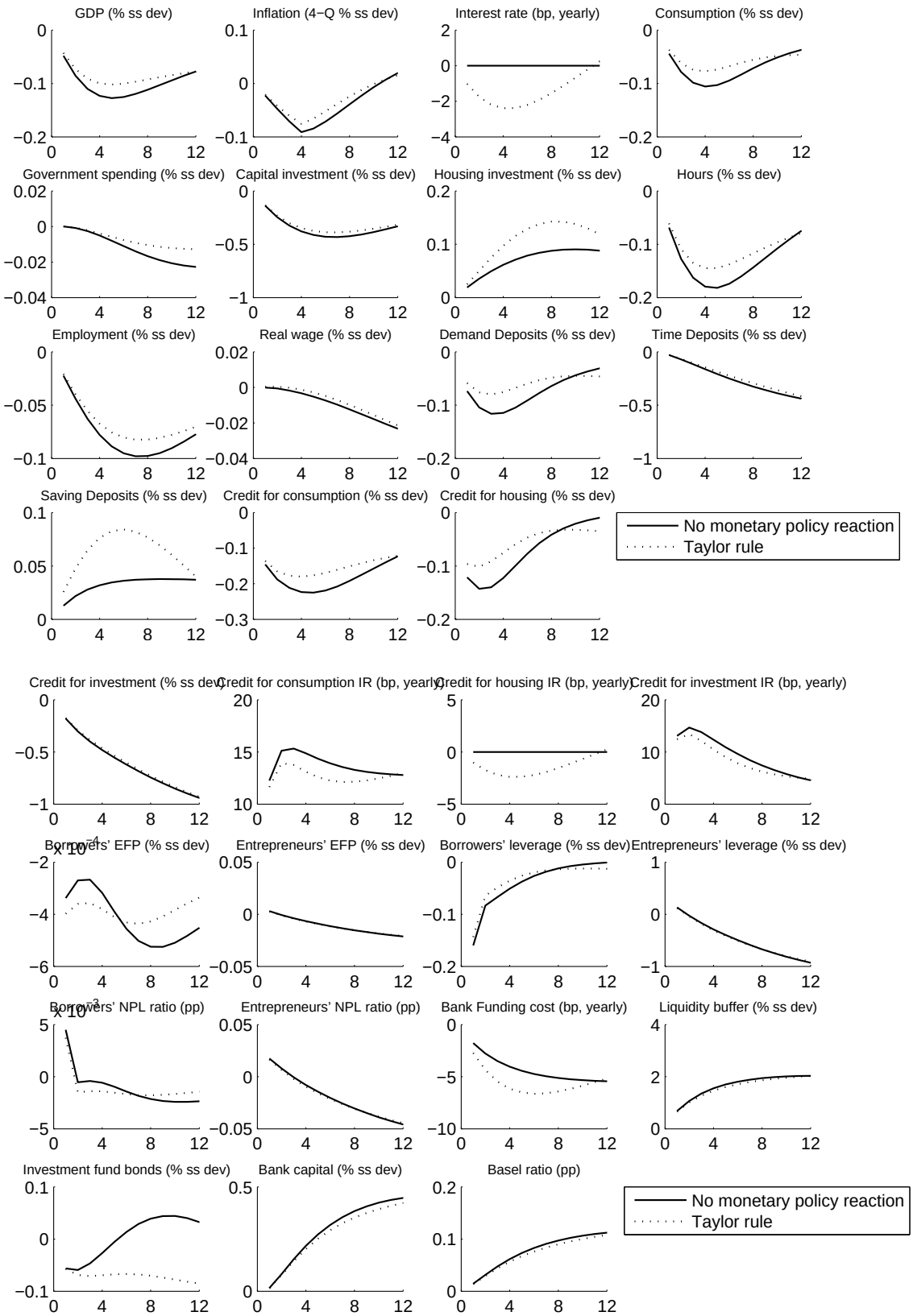

Figure 15: The role of Monetary Policy behavior on the transmission mechanisms of a Capital Requirement Shock

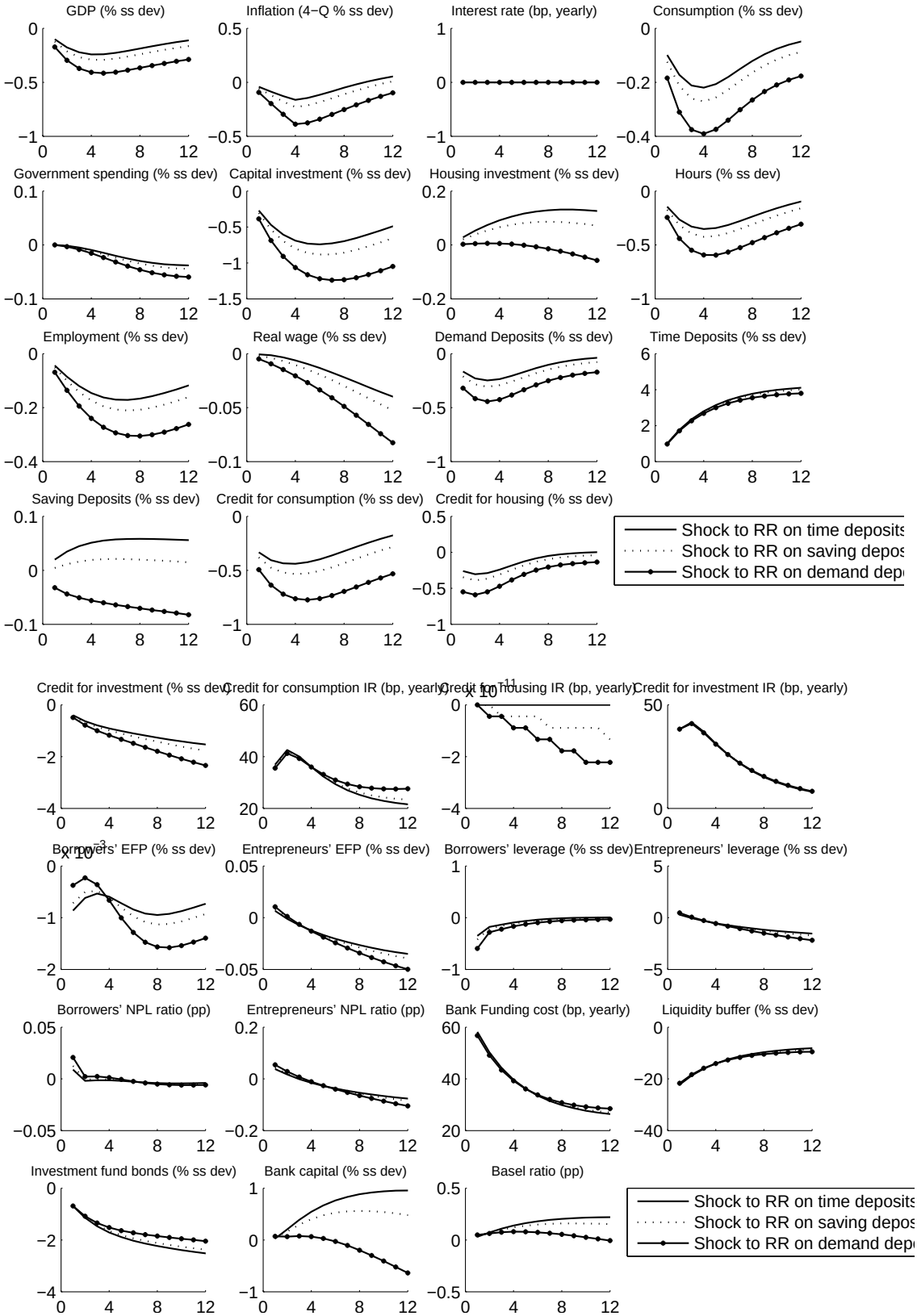

Figure 16: Comparing same scale shocks to Reserve Requirement Ratios

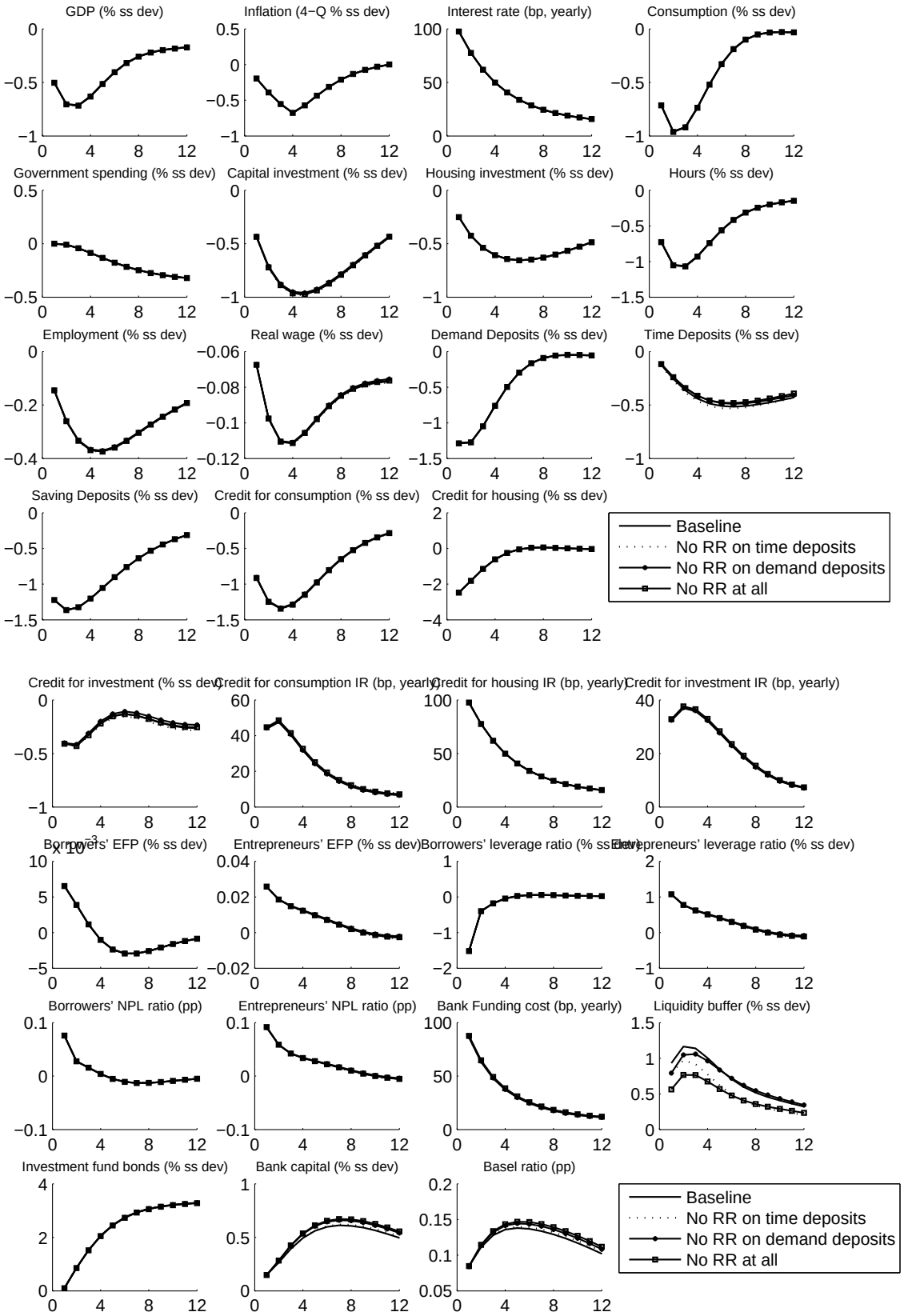

Figure 17: Monetary Policy Shock under different reserve requirement regimes

D Countercyclical Capital Buffer exercises

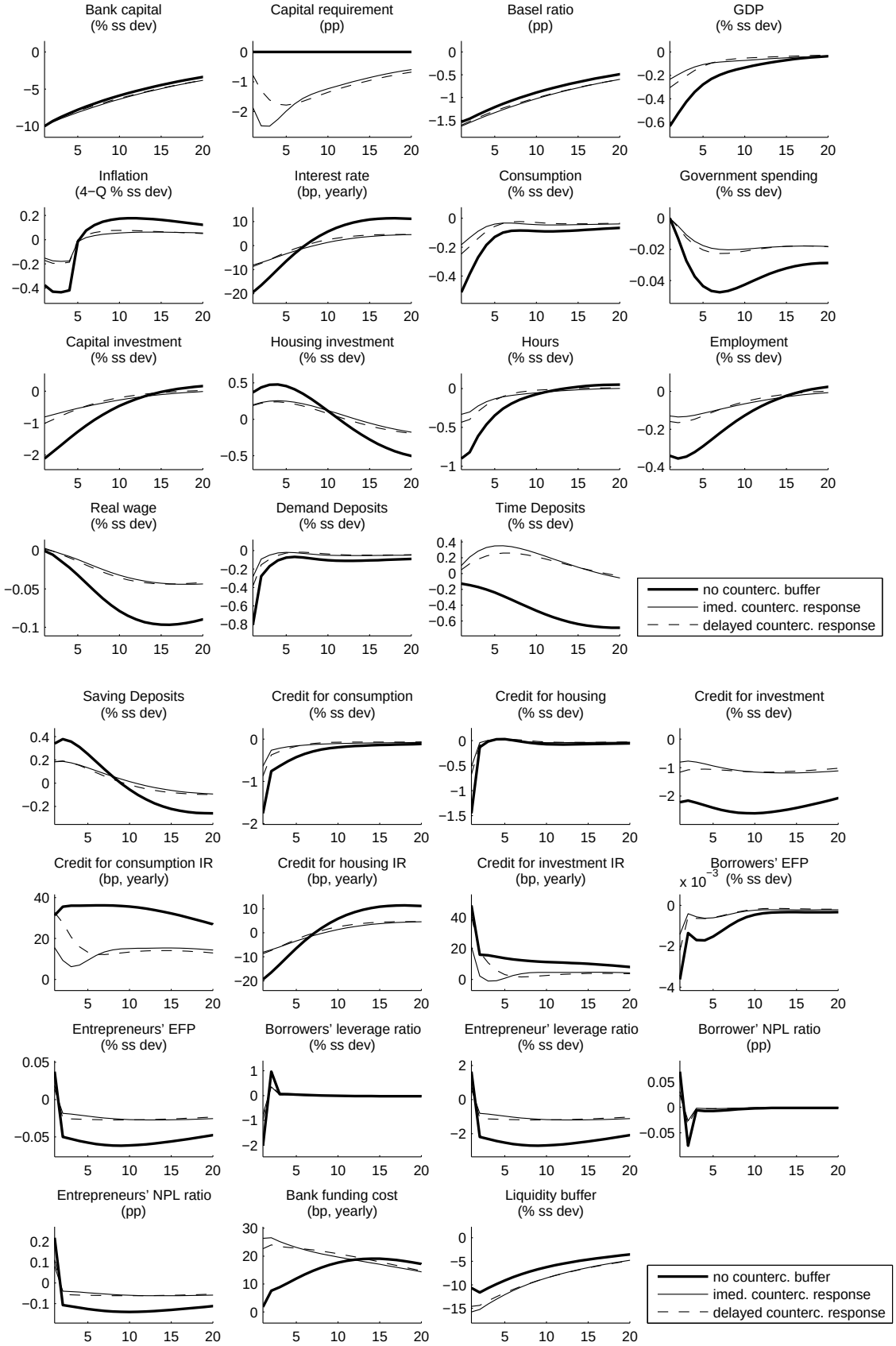

Figure 18: Countercyclical capital buffers