ISSN 1518-3548

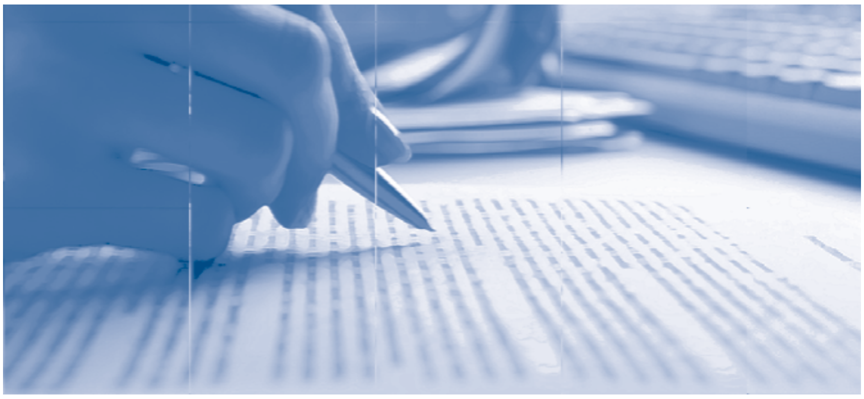
BANCO CENTRAL DO BRASIL

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 and Silvio M. A. Costa

November, 2013

Working Papers



336

ISSN 1518-3548
CNPJ 00.038.166/0001-05

Working Paper Series	Brasília	n. 336	November	2013	p. 1-88

Working Paper Series

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

Editor: Benjamin Miranda Tabak – E-mail: benjamin.tabak@bcb.gov.br
Editorial Assistant: Jane Sofia Moita – E-mail: jane.sofia@bcb.gov.br
Head of Research Department: Eduardo José Araújo Lima – E-mail: eduardo.lima@bcb.gov.br

The Banco Central do Brasil Working Papers are all evaluated in double blind referee process.

Authorized by Carlos Hamilton Vasconcelos Araújo, Deputy Governor for Economic Policy.

General Control of Publications

Banco Central do Brasil

Comun/Dipiv/Coivi

SBS – Quadra 3 – Bloco B – Edifício-Sede – 14º andar

Caixa Postal 8.670

70074-900 Brasília – DF – Brazil

Phones: +55 (61) 3414-3710 and 3414-3565

Fax: +55 (61) 3414-1898

E-mail: editor@bcb.gov.br

Citizen Service Division

Banco Central do Brasil

Deati/Diate

SBS – Quadra 3 – Bloco B – Edifício-Sede – 2º subsolo

70074-900 Brasília – DF

Toll Free: 0800 9792345

Fax: +55 (61) 3414-2553

Internet: <http//www.bcb.gov.br/?CONTACTUS>

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 ‡

Abstract

This paper investigates the transmission channel of macroprudential instruments in a closed-economy DSGE model with a rich set of financial frictions. Banks' decisions on risky retail loan concessions are based on borrowers' capacity to settle their debt with labor income. We also introduce frictions in banks' optimal choices of balance sheet composition to better reproduce banks' strategic reactions to changes in funding costs, in risk perception and in the regulatory environment. The model is able to reproduce not only price effects from macroprudential policies, but also quantity effects. The model is estimated with Brazilian data using Bayesian techniques. Unanticipated changes in reserve requirements have important quantitative effects, especially on banks' optimal asset allocation and on the choice of funding. This result holds true even for required reserves deposited at the central bank that are remunerated at the base rate. Changes in required core capital substantially impact the real economy and banks' balance sheet. When there is a lag between announcements and actual implementation of increased capital requirement ratios, agents immediately engage in anticipatory behavior. Banks immediately start to retain dividends so as to smooth the impact of higher required capital on their assets, more particularly on loans. The impact on the real economy also shifts to nearer horizons. Announcements that allow the new regulation on required capital to be anticipated also improve banks' risk positions, since banks achieve higher capital adequacy ratios right after the announcement and throughout the impact period. The effects of regulatory changes to risk weights on bank assets are not constrained to impact the segment whose risk was reassessed. We compare the model responses with those generated by models with collateral constraints traditionally used in the literature. The choice of collateral constraint is found to have important implications for the transmission mechanisms.

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

*Research Department, Central Bank of Brazil, fabia.carvalho@bcb.gov.br

†Research Department, Central Bank of Brazil, marcos.castro@bcb.gov.br

‡Research Department, Central Bank of Brazil, silvio.costa@bcb.gov.br

Acknowledgements

We are grateful to Werner Röger, Enrique Mendoza, Matteo Iacoviello, the participants in the BIS CCA Research Network Conference, in the XV Annual Inflation Targeting Seminar of the Banco Central do Brasil, at Ecomod 2013, at LuBraMacro 2013, at the IFABS 2013, the members of Central Bank of Brazil Working Group on Countercyclical Buffers and an anonymous referee for insightful comments and suggestions. Errors and omissions in the paper are of course the authors' sole responsibility. 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.

1 Introduction

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

Highly collateralized bank loans might have been a fair representation of banks' behavior in advanced economies, but other types of bank loans that are dissociated from physical collateral have been gaining ground[1]. At the beginning of 2013, for instance, the rating agency Moody's downgraded Canadian banks mostly because of an important exposure of the financial system to unsecured consumer loans, whose performance is tightly related to households' disposable income.

In countries with impediments to the execution of collateral warranties, creditors find alternative loan contract clauses that help minimize the risk of default. In Brazil, for instance, banks have adopted the practice of making retail loan decisions based on borrowers' payment affordability to settle their debt with labor income. Therefore, debt-to-income ratios are more relevant than loan-to-value to determine lending rates and authorize limits to automatic credit lines. As a matter of fact, about half the total volume of bank retail loans in Brazil are not collateralized by physical assets, and are advanced with no constraints on the final destination of borrowed funds. Credit lines advanced for purchases of vehicles represent another third part of retail loans, and although there are constraints on the destination of funds, a share of them do not take the underlying goods as collateral.

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

Financial frictions have important implications for the transmission of shocks to the economy. Notwithstanding, important conclusions in the DSGE literature are model-dependent[2]. In BGG-type financial accelerators, fluctuations in the price of physical collateral determine the occurrence of default, generating a strong connection between the external finance premium and borrowers' leverage. In this environment, financial frictions operate mainly through their impact on investment decisions. On the other hand, loan concessions based on the expected stream of labor income bring about other sources of banks' vulnerability. These types of financial frictions might also generate stronger procyclicality in the economy given their feedback effect from labor conditions to credit risk and credit conditions, and then from consumption decisions funded by loans to the demand for goods, and back to labor conditions. In Brazil, for instance, loan performance is tightly associated with labor market conditions and there seems to be a disconnect between historical arrears and households' leverage.

The purpose of this paper is to assess the transmission channels of macroprudential policies in Brazil through an appropriate DSGE model of financial frictions. Most of the financial frictions that we incorporate in the model are not singular to Brazil. They can also be found in countries where the collateral repossession process is cumbersome, where the perception of significant risk in lending operations makes public bonds an attractive investment choice for banks and compete with bank loans, where banks' funding faces competition from other investment opportunities easily available to banks' clients, and where banks are required to comply with a number of regulatory constraints that distort their optimal balance sheet allocation.

With respect to financial frictions, first we introduce retail loans in which the possibility of default is tightly associated with borrowers' labor income[3] so that the external finance premium co-moves with developments in the labor market. Debt-to-income ratios are allowed to vary with time to help reproduce the recent financial deepening of the Brazilian financial system. Second, we let Loan-to-Value ratios apply to housing loan concessions, but we introduce a number of regulatory constraints that conform with Brazilian practice and which affect the dynamics of the housing loans market. This credit segment interferes with retail loans through their impact on debt-commitment. Third, we introduce frictions to banks' optimal decisions on balance sheet allocations to better capture the competition between low-risk-low-return and high-risk-high-return bank assets. These strategic considerations have an important impact on the transmission channel of macroprudential policies to credit conditions, and, consequently, to the real economy. Fourth, we introduce frictions in (costly) stable banks' funding sources to account for the fact that time deposits issued by banks face fierce competition from other investment opportunities issued by non-bank institutions at similar liquidity risks. Finally, we introduce a rich set-up of macroprudential instruments and regulatory constraints, some of which are common

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

[3]Mendoza (2002) and Durdu, Mendoza & Terrones (2009) also incorporate income-driven credit constraints in models applied to emerging economies. However, in Mendoza (2002), the constraint takes the form of a collateral constraint, with a cap on debt-to-income ratios that is not endogenously determined after default risks are assessed.

to a number of countries, and others that seem to be more specific to Brazil.

The set of macroprudential instruments analyzed in this paper is composed of: simplified Basle-1 and Basle-2 core capital requirements, in which changes can be anticipated or not; reserve requirements on demand deposits, time deposits, savings deposits and a variant of the three, each one of them with a particular remuneration rule set by the monetary authority; and risk-weights on banks' assets to assess capital adequacy. The model can also be readily used to assess the impact of LTV caps on loan concessions, and changes in the required allocation of savings deposits to housing loans.

The model is estimated with Bayesian techniques using time series from the beginning of the inflation targeting regime (1999Q3 to 2012Q4). Bayesian IRFs are computed, and counterfactual exercises are reported to help understand the transmission channels of macroprudential instruments and refine the assessment of their economic effects.

Impulse responses show that the most important impact of changes in reserve requirement ratios lies on the composition of banks' balance sheet. Banks' liquidity positions have an important role in smoothing the impact on the real economy. Increased required reserve ratios put pressure on banks' opportunity costs, which are passed through to final lending rates. The strength of the passthrough is governed by expected loan performance, given the expected impact on collateral and on labor market conditions. The increase in lending rates depresses the demand for loans, reducing the total volume of credit in the economy. Both labor and goods markets are mildly affected, resulting in some output loss.

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

Few studies analyze the aggregate impact of reserve requirements in Brazil. Souza-Rodrigues & Takeda (2004) find empirical evidence that higher unremunerated reserve requirements in Brazil increase the mean of lending rates. Areosa & Coelho (2013) modify the original setup of Gertler & Karadi (2011) in which banks face agency problems to raise funds and find that reserve requirements have qualitatively equivalent (yet weaker) impact on the economy compared to the monetary policy instrument. Our model differs from Areosa & Coelho (2013) and Gertler & Karadi (2011) in several important ways. Apart from a more comprehensive description of the financial sector, our model features default in loans to the real sector, whereas they introduce default in bank deposits. An immediate consequence of their assumption is that there will be a wedge between banks' cost of funding from deposits and the base rate, driven by solvency concerns. We purposely choose not to adhere to this assumption since the spread between 90-day bank certificates of deposits (CDB) and the effective base rate (Selic) has been negligible after the implementation of the inflation targeting regime (0.2 p.p. from a nominal quarterly base rate of 3.6% on average), despite strong movements in volumes. This evidence also discards the assumption extensively used in the literature[4] that banks have monopolistic power in setting deposit rates. In this respect, there are a number of investment opportunities that compete with time deposits in Brazil. Treasury bonds, for instance, can be negotiated directly at Treasury's retail facility "Tesouro Direto"[5]. Another important difference from Areosa & Coelho (2013) is that in their model reserve requirements can only affect the economy through price effects, since their are dominated in return by public bonds. Instead, if reserve requirements were fully remunerated in their model, as is the case with time deposits in Brazil, reserve requirements would be neutral to the economy. Our model, on the other hand, is suited to address quantitative effects of macroprudential instruments.

Montoro & Moreno (2011) 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. In our model, the estimated impulse responses of changes in remunerated reserve requirements on time deposits can have non-negligible effects on the real economy notwithstanding the fact that there is no mismatch between the interest rate paid to depositors and that accrued on required reserves. The estimated frictions on banks' optimal balance sheet allocation imply that an exogenously imposed asset allocation is costly to the bank, and thus increased funding costs translate into higher lending rates. This has important policy implications.

In Brazil, reserve requirements on time deposits have been the instrument of choice when the central bank needs to drain liquidity from the economy. There is an implicit perception that this would be the least distortionary instrument for this purpose. The model responses to a shock on reserve requirements on time deposits are substantially stronger than those on other forms of reserve requirements. We show that this result is mostly driven by a base-effect, since the balance of time deposits in Brazil is almost eight times as large as demand deposits. After scaling the shocks to generate 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 marginal impact on the economy mostly through the direct impact on banks' profits and less so on banks' balance sheet allocations.

To understand the role of the liquidity preference channel in the transmission of the shock to reserve requirements, we muted this channel. We find that this channel is in fact important for remunerated reserve requirements to have an impact on the economy.

The literature interprets the modest degree of the real impact of reserve requirements as a consequence of a responsive monetary policy. Glocker & Towbin (2012),

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

[5]https://www.tesouro.fazenda.gov.br/tesouro-direto

for instance, argue that if interest rate setting is dissociated from decisions on reserve requirements, the former may neutralize the impact of the latter. We conduct a counterfactual exercise in which monetary policy remains nonresponsive to economic conditions while we stress the model with a shock to reserve requirements. Our results concur with the consensus. When monetary policy does not relieve the contractionist impact of shocks to reserve requirements, the economy faces a more significant downturn.

Shocks to core capital requirement have stronger effects on banks' funding costs. When the shock hits, banks permanently reshuffle their assets to improve capital adequacy ratio. Retail loans are more significantly curtailed since their risk weight is the highest amongst bank assets. Overall credit-to-GDP drops, with spillover effects on the demand for investment and consumption goods. GDP falls and remains dampened over a long horizon. Banks also accumulate dividends to improve their net worth position. The increase in bank capital is channeled towards bank liquidity. If monetary policy is kept unchanged throughout the impact period of the shock, the responses of funding costs, bank capital and liquidity buffer are the same as in the benchmark case. However, since monetary policy cannot accommodate the burden of tighter credit conditions on the real economy, and in particular in the labor market, lending rates rise substantially in response to a deterioration in borrowers' capacity to take loans. The overall effect on GDP is reinforced as the impact of the shock builds up.

Changes in capital requirements are usually announced with a substantial lag until the implementation. We simulate the model under the assumption that the announcement is made one year before implementation. Announcements trigger an anticipatory behavior in banks' decisions. Banks immediately start to retain dividends and improve their capital adequacy ratios over the impact period. Previous announcements are more effective in reducing the risk exposure of the economy even after the shock hits. Since economic agents anticipate the impact of the shock, the demand for loans becomes more sensitive to lending rates. Real variables, such as GDP and inflation are affected from start, but post smoother trajectories.

Our paper relates to the literature that analyzes the impact of macroprudential policies in a DSGE framework (Glocker & Towbin (2012), Pariès, Sørensen & Rodriguez-Palenzuela (2011), Roger & Vlcek (2011), Montoro & Tovar (2010), Areosa & Coelho (2013)). However, in most of these references housing or capital have a leading role in credit concessions. To better understand the consequences of our modeling choice for households' collateral constraints, we performed some counterfactual exercises to compare the responses of the baseline model with alternatives commonly found in the literature: the housing collateral constraint and the strict debt-to-income constraint. The model with housing collateral has very different predictions from both the baseline and the strict debt-to-income constraint model. Since housing prices strongly hit borrowers' capacity to take loans, households engage in an important swap in the housing market which affects the aggregate variables of the model. The responses of the models where labor income is included in the borrowing constraint are similar in some respects to the baseline model, but the possibility of default in the baseline model renders very distinct responses in the credit market, with some spillover to the real sector.

Our paper also relates to the literature on endogenous bank lending (Andrés, Arce & Thomas (2010), Gerali *et al.* (2010)). Our model goes beyond introducing monopolistic competition in bank lending. The embedded frictions are particularly suited to endogenously map the main determinants of lending spreads in Brazil: markup, risk of default, administrative costs, direct and indirect taxes, and regulatory costs.

The paper is presented as follows. Section 2 describes the theoretical model. Section 3 discusses the stationarization of the model and the computation of the steady state. Section 4 discusses the estimation conducted 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 countercyclical capital requirement rules. The final section concludes. A detailed description of the theoretical model is presented in the technical appendix.

2 The theoretical model

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

The financial sector is composed of a bank conglomerate and a retail money fund. The retail money fund represents an investment opportunity that dominates in return all other financial options[6]. The fund's portfolio is composed of government bonds and time deposits issued by the bank conglomerate. The bank conglomerate has a treasury department that channels the conglomerate's funding resources to loan concessions and dividend distribution, adhering to regulatory requirements on mandatory reserves, capital adequacy ratio, and housing loan concession, in addition to regulation on the remuneration of savings accounts which is more specific to Brazil. External funding to the conglomerate is available from time, savings and demand deposits. The conglomerate can also augment its net worth by retaining profits. Loan concessions are risky since entrepreneurs' projects and households' labor income are subject to idiosyncratic shocks that might adversely impact their capacity to settle their debt obligations. The conglomerate targets balance sheet components associated with its liquidity position and its more stable external funding source, i.e., time deposits. There is additional rigidity in time deposit balances and lending rates, and conglomerate activities generate administrative costs and are subject to

[6]Notwithstanding, households have preferences over other financial investment opportunities that are less rewarding in terms of nominal return. This allows the model to find a non-negligible role for assets that are dominated in return.

tax incidence.

In this session, we describe the main features of the theoretical model, emphasizing our contributions to existing models and adjustments to Brazilian particularities. The complete description of the theoretical model is in appendix A.

2.1 Households

The economy is inhabited by two groups of households: net creditors and net debtors of the financial system. Net creditors, henceforth "savers", have a range of available financial investment opportunities, namely demand and savings deposits issued by the bank conglomerate and retail money fund quotas[7]. In addition, savers have right to profits made after tax by all business activities. Savers derive utility from consumption goods, housing, and liquid financial balances[8].

Net debtors, henceforth "borrowers", also derive utility from consumption goods, housing, and demand deposits. They complement their labor income with loans to finance their purchases of goods and housing. Loans are granted by the bank conglomerate based on the assessment of borrowers' capacity to settle debt obligations with labor income. Consumption loans are risky since labor income is subject to idiosyncratic shocks that realize only after loan contracts are established.

In this instance, the model differs from the mainstream macroeconomic literature that introduces financial frictions in retail loan concessions. Although housing collateral is the preferred choice in this literature, weakly collateralized or uncollateralized bank loans are gaining ground, bringing along concerns over the building up of vulnerabilities in the financial systems[9].

Non-corporate loans in Brazil amount to 43% of total bank loans. About half the stock of retail loans are not collateralized with physical capital and are not associated with the purchase of any particular good. Credit lines financing purchases of vehicles represent another third of retail loans, but the underlying goods are not necessarily collateral. Moreover, regardless of collateral requirements, banks decisions on retail credit concessions heavily rely on borrowers' capacity to settle their debt obligations with labor income.

[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.

[8]Since savings accounts are return-dominated by investment fund quotas during most of the analyzed period in Brazil, we let depositors yield some utility from savings. Previous versions of the model attempted to introduce a third type of constrained 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.

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

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

In this environment, events that affect the labor market potentially spillover to banks' risk taking.

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 quotas of the retail money fund, to maximize

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

subject to the budget constraint

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

where

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

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

Labor is competitively supplied to labor unions at a nominal wage W_t^N. Labor unions distribute their net-of-tax profits $\Pi^{LU}_{S,t}$ obtained from monopolistic competition back to households as lump-sum transfers. Savers also receive lump sum transfers $TT_{S,t}$ from the government, in addition to net-of-tax profits $\Pi_{S,t}$ from firms, entrepreneurs, and the bank conglomerate. $TT_{\Gamma,S,t}$ are costs from capital utilization, which we assume are distributed as lump-sum transfers to savers and $T^{GN}_{S,t}$ are transfers from entrepreneurs that quit their projects at each period.

One-period returns on savings accounts and on retail money fund quotas are $R_{S,t}$ and $R_{F,t}$, respectively.

2.1.2 The Borrower's program

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

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

where W_t is wage negotiated between firms and unions[10].

At period t, household i gets two types of credit: a retail loan, with nominal value $B_{B,i,t}^{C}$, and a housing loan, $B_{B,i,t}^{H}$. Both loans redeem in the subsequent period and are negotiated at fixed interest rates, $R_{B,i,t}^{L,C}$ and $R_{B,t}^{L,H}$, respectively. The interest rate on housing loans is exogenously set by the government and does not depend on borrowers' leverage. This assumption accords with the tightly regulated market of Brazilian housing loans to low-priced real estate, which represents the bulk of the housing loans market[11]. These loans are subject to an interest rate cap of 12% p.a.. However, the market of loans to low-priced real estate is by far dominated by Caixa Econômica Federal (CEF), a state-owned bank specialized in housing loans and savings deposits, and the rates charged on these loans are not intimately associated with leverage or LTVs, although minimum LTV applies to the decision of whether or not to extend the loan to each particular proponent. Banks are required to channel a certain share of their savings deposits to low-priced real estate loans. In order to attract enough demand for their housing loans, they closely track CEF's lending rates. Several other regulatory requirements apply to the market of housing loans and savings deposits in Brazil. Our model addresses only the main aspects of such regulation.

In case of an adverse shock to the borrower's labor income that leads to default on bank loans, the bank seizes a fraction $\gamma_t^{B,C}$ of household's net-of-tax labor income, after incurring proportional monitoring costs $\mu_{B,C}$, in case default is on retail loans, and $\mu_{B,H}$, in case default is on housing loans[12].

---

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

[11]The upper bound for the price of houses that qualify for these cheaper credit lines is currently BRL 500 thousand (˜USD 250 thousand). As of June 2013, housing loans to low-priced real estate amounted to 76% of total housing loans financed through savings deposits in Brazil. Apart from the loans funded from savings deposits, an important segment of housing loans is funded with resources from the Severance Indemnity Fund (FGTS), managed by Caixa Econômica Federal, a state-owned bank. These housing loans represent 36% of total housing loans in Brazil and are granted at low rates, which bear no correspondence to the borrower's leverage or collateral.

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

Housing loans have precedence over retail loans with respect to income commitment[13]. Next period, after the idiosyncratic shock $\varpi_{B,i,t+1}$ realizes, the borrower chooses to default if the amount of labor income committed to the loan is less than the total debt redeeming[14]. This threshold $\overline{\varpi}_{B,i,t+1}$ is such that the borrower is indifferent between settling debt obligations or letting the bank seize the committed share of her labor income:

$$\gamma_t^{B,C}\overline{\varpi}_{B,i,t+1}\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}=R_{B,i,t}^{L,C}B_{B,i,t}^{C}+R_{B,t}^{L,H}B_{B,i,t}^{H} \tag{4}$$

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

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

Since lending branches are risk neutral and operate under perfect competition, for each borrower the expected return from loan concessions (left side of the following equation) must equal the funding costs from such operations (right side):

$$\begin{aligned}&E_t\left(1-\mu_{B,C}\right)\int_{\overline{\varpi}_{B,i,t+1}^{H}}^{\overline{\varpi}_{B,i,t+1}}\left[\gamma_t^{B,C}\varpi_{B,i,t}\left(1-\tau_{w,t+1}\right)N_{B,i,t+1}W_{t+1}-R_{B,t}^{L,H}B_{B,i,t}^{H}\right]dF\left(\varpi_{B,i,t}\right)\\&+E_t\int_{\overline{\varpi}_{B,i,t+1}}^{\infty}R_{B,i,t}^{L,C}B_{B,t}^{C}dF\left(\varpi_{B,i,t}\right)=R_{B,t}^{C}B_{B,i,t}^{C}\end{aligned} \tag{6}$$

or

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

where

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

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

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

where

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

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

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

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

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

and the expected settlement of bank loans is

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

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

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

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

The representative borrower[15] chooses the stream $\left\{C_{B,t}, N_{B,t}, H_{B,t}, \mathcal{X}_{B,t}, D_{B,t}^D, \overline{\varpi}_{B,t}, \overline{\varpi}_{B,t}^H, B_{B,t}^C, B_{B,t}^H\right\}$ to maximize the utility function

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

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

subject to the budget constraint

$$\left.\begin{array}{r}\left(1+\tau_{C,t}\right)P_{C,t}C_{B,t}+D^D_{B,t}\\+P_{H,t}\left(H_{B,t}-\left(1-\delta_H\right)H_{B,t-1}\right)\\+\gamma_t^{B,C}\left(1-\tau_{w,t}\right)N_{B,t}W_t^N H\left(\varpi_{B,t},0\right)\end{array}\right\}\leq\left\{\begin{array}{l}\left(1-\tau_{w,t}\right)\left(W_t^N N_{B,t}\right)\\+B^C_{B,t}+B^H_{B,t}+D^D_{B,t-1}\\+TT_{B,t}+\Pi^{LU}_{B,t}\end{array}\right. \tag{12}$$

and the constraints from the optimal contract

$$\gamma_t^{B,C}E_t\left(1-\tau_{w,t+1}\right)N_{B,t+1}W^N_{t+1}G_{B,C}\left(\varpi_{B,t+1},\varpi^H_{B,t+1}\right)=R^C_{B,t}B^C_{B,t} \tag{13}$$

$$\gamma_t^{B,C}\varpi^H_{B,t}\left(1-\tau_{w,t}\right)N_{B,t}W_t^N=R^{L,H}_{B,t-1}B^H_{B,t-1} \tag{14}$$

$$B^H_{B,t}\leq\gamma_t^{B,H}P_{C,t}Q_{H,t}H_t^B \tag{15}$$

$$\omega_B B^H_{B,t}\leq\tau_{H,S,t}\omega_{CS}D^S_{CS,t} \tag{16}$$

where

$$\mathcal{X}_{B,t}=\left[\left(1-\varepsilon_t^H\omega_{H,B}\right)^{\frac{1}{\eta_H}}\left(C_{B,t}-\bar{h}_B C_{B,t-1}\right)^{\frac{\eta_H-1}{\eta_H}}+\left(\varepsilon_t^H\omega_{H,B}\right)^{\frac{1}{\eta_H}}\left(H_{B,t}\right)^{\frac{\eta_H-1}{\eta_H}}\right]^{\frac{\eta_H}{\eta_H-1}}, \tag{17}$$

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

$$\gamma_t^{B,C}\left(\varpi_{B,t}-\varpi^H_{B,t}\right)\left(1-\tau_{w,t}\right)N_{B,t}W_t=R^{L,C}_{B,t-1}B^C_{B,t-1} \tag{18}$$

2.2 Entrepreneurs

Commercial loans are modeled as in Christiano, Rostagno & Motto (2010), except that we introduce time varying LTV ratios to account for the fact that capital stock in Brazil is hardly financed through bank loans. Changes in LTV ratios will also accommodate changes in leverage that are dissociated from innovations in the value of collateral. The recent financial deepening of the Brazilian economy can be captured through this variable.

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

$$P_{K,t}K_{E,i,t+1}=N^E_{i,t}+B_{E,i,t} \tag{19}$$

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

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

$$\begin{aligned} R^{TK}_{t+1} &\equiv \int_0^\infty \omega \left[R^K_{t+1} + P_{K,t+1}\left(1-\delta_K\right)\right] dF\left(\omega, \sigma_{E,t+1}\right) \\ &= R^K_{t+1} + P_{K,t+1}\left(1-\delta_K\right) \end{aligned} \tag{20}$$

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

$$R^L_{E,i,t} B_{E,i,t} = \varpi_{i,t+1} \gamma^E_t R^{TK}_{t+1} K_{E,i,t} \tag{21}$$

Whenever $\omega_{i,t+1} < \varpi_{i,t+1}$, the entrepreneur goes bankrupt and the bank seizes the collateral by incurring in monitoring costs that correspond to a fraction μ_E 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 commercial loans is such that the expected profit of the financial intermediary is zero:

$$R_{E,t} B_{E,i,t} = \gamma^E_t E_t R^{TK}_{t+1} K_{E,i,t} G\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right) \tag{22}$$

where

$$G\left(\varpi_{t+1}, \sigma_{E,t+1}\right) = \left(1-\mu_E\right) \int_0^{\varpi_{t+1}} \omega dF\left(\omega, \sigma_{E,t+1}\right) + \left(1 - F\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right) \varpi_{t+1} \tag{23}$$

The entrepreneur's expected cash flow is:

$$E_t R^{TK}_{t+1} K_{E,i,t} \left[1 - \gamma^E_t H\left(\varpi_{i,t+1}, \sigma_{E,t+1}\right)\right] \tag{24}$$

where

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

The entrepreneur's problem amounts to choosing a sequence of $\{\varpi_{i,t+1}, B_{E,i,t}, K_{E,i,t}\}$ to maximize (24) constrained by (22), (19), (21) and $B_{E,i,t} \geq 0$. We constrain the latter to be non-binding.

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

$$N_t^E = \gamma_t^N R_t^{TK} K_{t-1} \left[1 - \gamma_t^E H\left(\overline{\varpi}_{E,t}, \sigma_{E,t}\right)\right] \tag{26}$$

where the survival rate γ_t^N is given by

$$\begin{aligned} \gamma_t^N &= \frac{1}{1+e^{-\gamma^N - \widetilde{\gamma}_t^N}} \\ \widetilde{\gamma}_t^N &= \rho_\gamma^N \widetilde{\gamma}_{t-1}^N + \sigma_\gamma^N \varepsilon_{\gamma,t}^N \end{aligned} \tag{27}$$

and

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

2.3 Goods producers

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

$$Z_{j,t}^d = A.\varepsilon_t^A \left[u_t K_{j,t-1}\right]^\alpha \left(\epsilon_t L_{j,t}\right)^{1-\alpha} \tag{29}$$

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

$$g_{\epsilon,t} = \rho_\epsilon . g_{\epsilon,t-1} + \left(1 - \rho_\epsilon\right) . g_\epsilon + \varepsilon_t^Z \tag{30}$$

Cost minimization is subject to capital utilization adjustment costs $\Gamma_u(u_t) \equiv \phi_{u,1}\left(u_t - 1\right) + \frac{\phi_{u,2}}{2}\left(u_t - 1\right)^2$. Intermediate goods producers sell their output to retailers, who operate under monopolistic competition setting prices on a staggered basis *à la* Calvo. Retailers who are not chosen to optimize set their prices according to the indexation rule:

$$P_t^d(k) = \pi_{t-1}^{d,\gamma_d} \overline{\pi}^{1-\gamma_d} P_{t-1}^d(k) \tag{31}$$

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

$$Y_t^d = \left[\int_0^1 Z_t^d(k)^{\frac{1}{\mu_d}} dk\right]^{\mu_d} \tag{32}$$

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

$$Y_t^{d,J} = \{G, C, I_{K,} I_H\} \tag{33}$$
$$P_t^J = P_t^d \tag{34}$$

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

2.4 Investment Fund

A recent strand of the literature has been inclined to introduce imperfect competition in the bank deposits market[16]. This has implications for the dynamic responses of changes in reserve requirements. Under this assumption, the impact of reserve requirements shocks on credit concessions is partially buffered by adjustments in the cost of funding to banks.

In Brazil, banks' time deposits face fierce competition from retail money funds and from domestic federal bonds. About half the outstanding balance of domestic federal bonds are held by bank's non-financial clients, either through direct ownership of securities or through quotas in mutual funds. Money market funds hold about 30% of domestic federal bonds. Private individuals can also hold claims to federal bonds negotiated at National Treasury's facility "Tesouro Direto"[17],

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

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

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

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

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

2.5 Banking sector

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

The bank conglomerate is composed of a continuum $[0,1]$ of competitive banks that get funding from deposit branches and extend credit to households and entrepreneurs through their lending branches. Banks are the financial vessel of the conglomerate: they channel money market funds to the lending branches while making all important decisions with respect to the composition of the conglomerate's balance sheet. The conglomerate is subject to regulatory requirements and can only accumulate capital through profit retention. Our adopted segmentation of the bank conglomerate allows the model to endogenously reproduce the most relevant determinants of lending spreads and the effects of regulatory requirements on bank rates and volumes.

2.5.1 Deposit branches

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

$$\omega_S D^D_{S,t} + \omega_B D^D_{B,t} = D^D_t = \int_0^1 \omega_{b,j} D^D_{j,t} dj \tag{35}$$

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

$$R^S_t = 1 + \varphi^S_{R,t} (R_t - 1)$$

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

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

2.5.2 Lending branches

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

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

$$B_{E,t}^{LB,E} = \left[\int_0^1 \omega_{b,j} \left(B_{E,j,t}^b \right)^{1/\mu_E^R} dj \right]^{\mu_E^R} \tag{36}$$

where

$$B_{E,t}^{LB,E} = \omega_E B_{E,t} \tag{37}$$

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

$$R_{E,t}^L B_{E,t}^{LB,E} - \int_0^1 \omega_{b,j} R_{E,j,t} B_{E,j,t}^b dj \tag{38}$$

subject to equation (36).

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

$$B_{E,j,t}^b = \left(\frac{R_{E,j,t}}{R_{E,t}} \right)^{\mu_E^R/(1-\mu_E^R)} B_{E,t}^{LB,E} \tag{39}$$

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

Aggregate funding to the lending branch bears the following correspondence with the total amount of loans extended to entrepreneurs:

$$\begin{aligned} B_{E,t}^b &\equiv \int_0^1 \omega_{b,j} B_{E,j,t}^b dj \\ &= B_{E,t}^{LB,E} \Delta_{E,t}^R \end{aligned} \tag{40}$$

where

$$\Delta_{E,t}^R = \int_0^1 \omega_{b,j} \left(\frac{R_{E,j,t}}{R_{E,T}} \right)^{\mu_E^R/(1-\mu_E^R)} dj \tag{41}$$

From Jensen's inequality, $\Delta_{E,t}^R > 1$.

The net cash flow $\Pi_t^{E,LB}$ from lending branch's operations in the commercial loans market is

$$\begin{aligned} \Pi_t^{E,LB} &= \int_0^1 \omega_{b,j} B_{E,j,t} dj - B_{E,t}^{LB,E} \\ &= B_{E,t}^{LB,E} \left(\Delta_{E,t}^R - 1 \right) > 0 \end{aligned} \tag{42}$$

which is distributed to banks as lump-sum transfers:

$$\Pi_t^{E,LB} = \int_0^1 \omega_{b,j} \Pi_{j,t}^{E,LB} dj \tag{43}$$

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

$$B_{B,j,t}^{C,b} = \left(\frac{R_{B,j,t}^{C}}{R_{B,t}^{C}} \right)^{-\frac{\mu_{B,C}^{R}}{\mu_{B,C}^{R}-1}} B_{B,t}^{C} \tag{44}$$

2.5.3 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[18]. We therefore assume that the final lending rate $R_{B,t}^{L,H}$ is set by the government as a markdown on the base rate:

$$\frac{R_{B,H,t}^{L}}{R_t} = \left(\frac{R_{B,H,t-1}^{L}}{R_{t-1}} \right)^{\rho_{R^H}} \left(\frac{R_{B,H}^{L}}{R} \right)^{1-\rho_{R^H}} e^{\varepsilon_{R^H,t}} \tag{45}$$

Consequently, the only role played by 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

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

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

$$\Pi_t^H = \omega_B \gamma_t^{B,C} \left(1 - \tau_{w,t}\right) N_{B,t} W_t G_{B,H} \left(\overline{\varpi}_{B,t}^{H}, 0\right) - R_{B,t-1}^{H,wb} B_{B,t-1}^{H,wb} \tag{46}$$

where

$$G_{B,H}\left(\overline{\varpi}_1, \overline{\varpi}_2\right) = \left\{ \begin{array}{l} \left(1 - \mu_{B,H}\right) \left[\int_{\overline{\varpi}_1}^{\overline{\varpi}_2} \varpi dF\left(\varpi\right) - \overline{\varpi}_1 \left[F\left(\overline{\varpi}_2\right) - F\left(\overline{\varpi}_1\right)\right] \right] \\ + \left(\overline{\varpi}_2 - \overline{\varpi}_1\right)\left(1 - F\left(\overline{\varpi}_2\right)\right) \end{array} \right. \tag{47}$$

The bank conglomerate absorbs the cost of default on mortgage loans as loss since it cannot be passed through to volumes or rates in this market.

[18]In loan concessions for expensive real estate, there is room for strategic decisions by banks. However, the bulk of loan concessions in Brazil finance low-priced real estate, which is subject to such regulation.

2.5.4 Banks

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

Banks have to comply with a number of regulatory requirements. Although the choice of regulation introduced in the model was made to reflect the regulatory framework faced by banks operating in Brazil, most of them are common place in the world. First, funding in the money market is subject to reserve requirements. In addition to unremunerated reserve requirements, which are commonly addressed in the literature and have been employed at various frequencies worldwide, we introduce remunerated requirements on savings and time deposits, and an "additional" reserve requirement detailed below [19]. Second, the benchmark model introduces a simplified version of Basle 1 and Basle 2-type capital requirement, which is based on the computation of capital adequacy ratios after weighting bank assets according to their risk factors. Third, we introduce an idiosyncrasy of the Brazilian regulatory framework that relates to the markets of savings deposits and housing loans. Finally, we introduce tax collection on specific credit operations in addition to an expense-deductible income tax on conglomerate's activities.

Banks have preferences over some balance sheet components, particularly liquidity and time deposits. These preferences are introduced as targets to be attained in the balanced growth path. We let the data determine the power of each of these assumptions by estimating cost-elasticity parameters. These frictions are necessary for the model to pin down the balances of public bonds and time deposits at the retail money fund's portfolio $R_t = R^T_t$.

Bank $j's$ balance sheet is:

$$\left.\begin{array}{r} B^b_{E,j,t} + B^{C,b}_{B,j,t} + B^{H,b}_{B,j,t} + B_{OM,j,t} \\ +RR^T_{j,t} + RR^S_{j,t} + RR^D_{j,t} + RR^{add}_{j,t} - RR^{S,H}_{j,t} \end{array}\right\} = \left\{\begin{array}{l} D^T_{j,t} + D^S_{j,t} + D^D_{j,t} \\ +Bankcap_{j,t} \end{array}\right. \tag{48}$$

where $Bankcap_{j,t}$ is net worth, $B_{OM,j,t}$ is liquidity in the form of public bonds, $RR^T_{j,t}$, $RR^S_{j,t}$, and $RR^D_{j,t}$ are required reserves on time, savings and demand deposits, respectively, and $RR^{add}_{j,t}$ are additional required reserves[20].

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

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

Reserve requirements are determined as:

$$RR_{j,t}^{(\cdot)} = \tau_{RR,(\cdot),t} D_{j,t}^{(\cdot)} \tag{49}$$
$$RR_{j,t}^{add} = \tau_{RR,add,t} \left(D_{j,t}^{D} + D_{j,t}^{T} + D_{j,t}^{S} \right) \tag{50}$$

where $\tau_{RR,(\cdot),t}$ are required ratios set by the government and follow AR(1) processes around the steady state. Reserve requirements deposited at the monetary authority accrue the same rate as their incidence base.

Banks that take savings deposits in Brazil are constrained by a requirement to extend a fraction of their savings deposits as loans to low-priced housing. However, about one third of the outstanding balance of housing loans in Brazil are extended by the publicly-owned bank Caixa Econômica Federal (CEF) with funds from the Severance Indemnity Fund (FGTS). For this reason, we let $RR_{j,t}^{S,H}$ represent funding for housing loans obtained from the FGTS. For simplicity, we assume that FGTS funds fill the gap between required and actual destination of savings deposits to housing loans.

$$RR_{j,t}^{S,H} = \tau_{H,S,t} D_{j,t}^{S} - B_{B,j,t}^{H} \tag{51}$$

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

$$\Gamma_T \left(\frac{D_{j,t}^{T}}{D_{j,t-1}^{T}} \right) \equiv \frac{\phi_T}{2} \left(\frac{D_{j,t}^{T}}{D_{j,t-1}^{T}} \varepsilon_t^{DT} - g_{\epsilon,t} \pi_{C,t} \right)^2 \tag{52}$$

Bank capital accumulates with the net flow of resources from bank operations, $FC_{j,t}^{b}$, reduces with dividend distribution, $P_{C,t} C_{B,j,t}$, and is subject to shocks $\varepsilon_t^{bankcap}$ that potentially capture changes in market's perception of bank capital quality or any other shocks that change the marked-to-market value of banks' net worth[21]. The capital accumulation rule is:

$$Bankcap_{j,t} = Bankcap_{j,t-1} + FC_{j,t}^{b} - P_{C,t} C_{B,j,t} + Bankcap_{j,t} \varepsilon_t^{bankcap} \tag{53}$$

For regulatory purposes, banks are constrained by a minimum capital requirement γ_t^{BankK} modeled as an AR(1) process with a very high persistence. Compliance with the minimum requirement is assessed through the computation of capital adequacy ratio $CAR_{j,t}^{b}$, which measures how much of risk-weighted assets can be backed up by bank's net worth:

$$BI_{j,t} = \frac{Bankcap_{j,t}}{CAR_{j,t}^{b}} \tag{54}$$

Brazil, such as requirements on marginal changes in deposits, among others.

[21]Our modeling choice dispenses with the need to artificially introduce depreciation to bank capital, which is essentially a financial variable.

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

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

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

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

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

$$\Gamma_{bankK}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right) = \frac{\chi_{bankK,2}}{2}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right)^2 + \chi_{bankK,1}\left(\frac{BI_{j,t}}{\gamma^{BankK}_t}\right) + \chi_{bankK,0} \tag{55}$$

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

$$FC^b_{j,t} = \left\{ \begin{array}{l} \left(R_{E,j,t-1} - \tau_{B,E,t-1} - s^{adm,E}_{t-1}\right) B^b_{E,j,t-1} - B^b_{E,j,t} \\ + \left(R^C_{B,j,t-1} - \tau_{B,B,t-1} - s^{adm,B}_{t-1}\right) B^{C,b}_{B,j,t-1} \\ - B^{C,b}_{B,j,t} + R^H_{B,t-1} B^{H,b}_{B,j,t-1} - B^{H,b}_{B,j,t} \\ + R_{t-1} B_{OM,j,t-1} - B_{OM,j,t} - R^T_{t-1} D^T_{j,t-1} + D^T_{j,t} - \Gamma_T\left(\frac{D^T_{j,t}}{D^T_{j,t-1}}\right) D^T_{j,t} \\ - R^S_{t-1} D^S_{j,t-1} + D^S_{j,t} - D^D_{j,t-1} + D^D_{j,t} \\ + R^T_{RR,t-1} RR^T_{j,t-1} + R^S_{RR,t-1} RR^S_{j,t-1} + R^D_{RR,t-1} RR^D_{j,t-1} \\ + R^{add}_{RR,t-1} RR^{add}_{j,t-1} - R^{S,H}_{RR,t-1} RR^{S,H}_{j,t-1} \\ - RR^T_{j,t} - RR^S_{j,t} - RR^D_{j,t} - RR^{add}_{j,t} + RR^{S,H}_{j,t} \\ - \Gamma_{bankK}\left(\dfrac{Bankcap_{j,t}}{\gamma^{BankK}_t CAR^b_{j,t}}\right) Bankcap_{j,t} \\ - \dfrac{\chi_{OM}}{2}\left(\dfrac{B_{OM,j,t}}{Lb^b_{j,t}} - \nu^{OM}_t\right)^2 L^b_t - \dfrac{\chi_{d\_T}}{2}\left(\dfrac{D^T_{j,t}}{Lb^b_{j,t}} - \nu^{d\_T}_t\right)^2 L^b_t \\ + \Pi^L_{j,t} + \Xi^b_{j,t} \end{array} \right. \tag{56}$$

where $s_t^{adm,(\cdot)}$ are administrative costs, which we assume to be proportional to the respective loan portfolio, $\tau_{B,(\cdot),t}$ are tax rates on credit operations, $R_{RR,t}^{(\cdot)}$ are the remuneration on bank reserves deposited at the monetary authority, χ_{OM} and χ_{d_T} are cost parameters that respectively translate into financial terms the gap between banks' liquidity and time deposit positions from their targeted path. $\Xi_{j,t}^{b}$ is a lump-sum transfer to insure against cash flow variations from interest rate rigidity, which allows for a representative bank

$$\Xi_{j,t}^{b} = \left(R_{E,t-1} - R_{E,j,t-1}\right) B_{E,j,t-1}^{b} + \left(R_{B,t-1}^{C} - R_{B,j,t-1}^{C}\right) B_{B,j,t-1}^{C,b} \tag{57}$$

and $\Pi_{j,t}^{L}$ are lump sum transfers from conglomerate branches to bank j, introduced in the model to facilitate aggregation:

$$\Pi_{j,t}^{L} = \Pi_{j,t}^{E,LB} + \Pi_{j,t}^{C,LB} + \Pi_{j,t}^{L,B,C} + \Pi_{j,t}^{L,B,H} + \Pi_{j,t}^{L,E} \tag{58}$$

$$\Pi_{j,t}^{E,LB} = B_{E,j,t} - \omega_E B_{E,t} \tag{59}$$

$$\Pi_{j,t}^{C,LB} = B_{B,j,t}^{C} - \omega_B B_{B,t}^{C} \tag{60}$$

$$\Pi_{j,t}^{L,B,C} = \gamma_t^{B,C}\left(1 - \tau_{\omega,t}\right)\omega_B N_{B,t} W_t^N G_{B,C}\left(\overline{\varpi}_{B,t}, \overline{\varpi}_{B,t}^{H}\right) - R_{B,t-1}^{C} B_{j,B,t-1}^{C} \tag{61}$$

$$\Pi_{j,t}^{L,B,H} = \gamma_t^{B,C}\left(1 - \tau_{\omega,t}\right)\omega_B N_{B,t} W_t^N G_{B,H}\left(\overline{\varpi}_{B,t}^{H}, 0\right) - R_{B,t-1}^{H} B_{j,B,t-1}^{H} \tag{62}$$

$$\Pi_{j,t}^{L,E} = \left[\gamma_t^{E}\left(R_t^K + P_{K,t}\left(1 - \delta_K\right)\right) K_{t-1} G\left(\varpi_{Et}, \sigma_{E,t}\right) - R_{E,t-1} B_{j,E,t-1}\right] \tag{63}$$

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

$$E_0 \left\{ \sum_{t \geq 0} \beta_{Bank}^{t} \left[\frac{1}{1 - \sigma_B} \left(\frac{C_{B,j,t}}{\epsilon_t} \right)^{1 - \sigma_B} \right] \varepsilon_t^{\beta,B} \right\} \tag{64}$$

subject to (39), (44), and (48) to (57), where $C_{B,j,t} = div_{j,t}^{b}/P_{C,t}$, and $div_{j,t}^{b}$ are banks' nominal dividends. We assume that banks' intertemporal discount factor β_{Bank} is lower than banks' stockholders'. This is a shortcut to a practical assessment on risk in the savers' investment choices, since bank shareholders demand a return on their risky investment in bank operations that is higher than their risk-free opportunity cost R_t.

Let Λ_{jt}^{Bank} be the Lagrange multiplier associated with the capital accumulation constraint (53), $\nu_{j,t}^{Bank}$ be the Lagrange multiplier of the balance sheet constraint, and $\eta_{j,t}^{Bank,(\cdot)}$ be the Lagrange multiplier of the lending branches' demand from loans. First order conditions to bank j's optimization problem are:

$$\frac{1}{\epsilon_t}\left(\frac{C_{B,j,t}}{\epsilon_t}\right)^{-\sigma_B}\varepsilon_t^{\beta,B} = \Lambda_{j,t}^{B} \tag{65}$$

$$\Lambda_{j,t}^{Bank}\left(1-\varepsilon_t^{bankcap}\right) = \left\{\begin{array}{l} \beta_{Bank}E_t\dfrac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}+\nu_{j,t}^{Bank} \\ -\Lambda_{j,t}^{Bank}\Gamma_{bankK}\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^{b}}\right) \\ -\Lambda_{j,t}^{Bank}\Gamma'_{bankK}\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^{b}}\right)\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^{b}} \\ +\Lambda_{j,t}^{Bank}\frac{\chi_{OM}}{2}\left(\dfrac{B_{OM,j,t}}{Lb_{j,t}^{b}}-\nu_t^{OM}\right)\left(\dfrac{B_{OM,j,t}}{Lb_{j,t}^{b}}+\nu_t^{OM}\right) \\ +\Lambda_{j,t}^{Bank}\dfrac{\chi_{d\_T}}{2}\left(\dfrac{D_{j,t}^{T}}{Lb_{j,t}^{b}}-\nu_t^{d\_T}\right)\left(\nu_t^{d\_T}+\dfrac{D_{j,t}^{T}}{Lb_{j,t}^{b}}\right) \end{array}\right. \tag{66}$$

$$\left.\begin{array}{r} \beta_{Bank}E_t\frac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}\Big(R_t^{T} \\ -R_{RR,t}^{T}\tau_{RR,T,t} \\ -R_{RR,t}^{add}\tau_{RR,add,t}\Big) \end{array}\right\} = \left\{\begin{array}{l} \beta_{Bank}E_t\dfrac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}\Gamma'_{T}\left(\dfrac{D_{j,t+1}^{T}}{D_{j,t}^{T}}\right)\left(\frac{D_{j,t+1}^{T}}{D_{j,t}^{T}}\right)^{2} \\ +\nu_{j,t}^{Bank}\left(1-\tau_{RR,T,t}-\tau_{RR,add,t}\right) \\ +\Lambda_{j,t}^{Bank}\left[\begin{array}{l} \left(1-\tau_{RR,T,t}-\tau_{RR,add,t}\right) \\ -\Gamma_{T}\left(\dfrac{D_{j,t}^{T}}{D_{j,t-1}^{T}}\right)-\Gamma'_{T}\left(\dfrac{D_{j,t}^{T}}{D_{j,t-1}^{T}}\right)\dfrac{D_{j,t}^{T}}{D_{j,t-1}^{T}} \\ +\dfrac{\chi_{OM}}{2}\left(\dfrac{B_{OM,j,t}}{Lb_{j.t}^{b}}-\nu_t^{OM}\right)\left(\dfrac{B_{OM,j,t}}{Lb_{j,t}^{b}}+\nu_t^{OM}\right) \\ +\dfrac{\chi_{d\_T}}{2}\left(\dfrac{D_{j,t}^{T}}{Lb_{j,t}^{b}}-\nu_t^{d\_T}\right)\left(\dfrac{D_{j,t}^{T}}{Lb_{j,t}^{b}}+\nu_t^{d\_T}-2\right) \end{array}\right] \end{array}\right. \tag{67}$$

$$\Lambda_{j,t}^{Bank} = \left\{\begin{array}{l} \beta_{Bank}E_t\dfrac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}R_t-\nu_{j,t}^{Bank} \\ +\gamma_t^{BankK}\tau_{\chi 4}\Lambda_{j,t}^{Bank}\Gamma'_{bankK}\left(\frac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_t^{b}}\right)\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_t^{b}}\right)^{2} \\ -\Lambda_{j,t}^{Bank}\chi_{OM}\left(\dfrac{B_{OM,j,t}}{L_t^{b}}-\nu_t^{OM}\right) \end{array}\right. \tag{68}$$

$$\Lambda_{j,t}^{Bank} = \left\{\begin{array}{l} \beta_{B}E_t\dfrac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}\left(R_{E,j,t}-\tau_{B,E,t}-s_t^{adm,E}\right) \\ -\nu_{j,t}^{Bank}-\eta_{j,t}^{Bank,E} \\ +\Lambda_{j,t}^{Bank}\tau_{\chi 2}\gamma_t^{BankK}\Gamma'_{bankK}\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_t^{b}}\right)\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_t^{b}}\right)^{2} \end{array}\right. \tag{69}$$

$$\Lambda_{j,t}^{Bank} = \left\{\begin{array}{l} \beta_{Bank}E_t\dfrac{\Lambda_{j,t+1}^{Bank}}{\pi_{C,t+1}}\left(R_{B,j,t}^{C}-\tau_{B,B,t}-s_t^{adm,B}\right) \\ -\nu_{j,t}^{Bank}-\eta_{j,t}^{Bank,BC} \\ +\Lambda_{j,t}^{Bank}\gamma_t^{BankK}\tau_{\chi 1}\Gamma'_{bankK}\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^{b}}\right)\left(\dfrac{Bankcap_{j,t}}{\gamma_t^{BankK}\ CAR_{j,t}^{b}}\right)^{2} \end{array}\right. \tag{70}$$

$$R^{O}_{E,j,t}\beta_B E_t\sum_{i\geq 0}\xi_E^i\beta_{Bank}^i\frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}}\frac{B^b_{E,j,t+i}}{P_{C,t+i}} = \frac{\mu^R_E}{\mu^R_E-1}E_t\sum_{i\geq 0}\xi_E^i\beta_{Bank}^i\eta^{Bank,E}_{j,t+i}\frac{B^b_{E,j,t+i}}{P_{C,t+i}} \tag{71}$$

$$R^{C,O}_{B,j,t}\beta_{Bank} E_t\sum_{i\geq 0}\xi_{B,C}^i\beta_{Bank}^i\frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}} = \frac{\mu^R_{B,C}}{\mu^R_{B,C}-1}E_t\sum_{i\geq 0}\xi_{B,C}^i\beta_{Bank}^i\eta^{Bank,BC}_{j,t+i}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}} \tag{72}$$

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

$$R^{C,O}_{B,j,t}\beta_{Bank}\aleph^{R,BC,2}_{j,t} = \frac{\mu^R_{B,C}}{\mu^R_{B,C}-1}\aleph^{R,BC,1}_{j,t} \tag{73}$$

$$\begin{aligned}\aleph^{R,BC,1}_{j,t} &= E_t\sum_{i\geq 0}\xi_{B,C}^i\beta_{Bank}^i\eta^{Bank,BC}_{j,t+i}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}}\\ &= \eta^{Bank,BC}_{j,t}\frac{B^{C,b}_{B,j,t}}{P_{C,t}} + \xi_{B,C}\beta_{Bank}E_t\aleph^{R,BC,1}_{j,t+1}\end{aligned} \tag{74}$$

$$\begin{aligned}\aleph^{R,BC,2}_{j,t} &= E_t\sum_{i\geq 0}\xi_{B,C}^i\beta_{Bank}^i\frac{\Lambda^{Bank}_{j,t+i+1}}{\pi_{C,t+i+1}}\frac{B^{C,b}_{B,j,t+i}}{P_{C,t+i}}\\ &= \frac{B^{C,b}_{B,j,t}}{P_{C,t}}E_t\frac{\Lambda^{Bank}_{j,t+1}}{\pi_{C,t+1}} + \xi_{B,C}\beta_{Bank}\aleph^{R,BC,2}_{j,t+1}\end{aligned} \tag{75}$$

Commercial lending rates have analogous representations.

These FOC show that the relevant opportunity cost for the bank is not just the base rate. By keeping the impact on the following periods fixed, it is easy to see that higher capital buffers and deviations from the optimal ratio of time deposit can increase banks' opportunity cost. Moreover, considering small deviations from the optimal liquidity buffer, a greater liquidity decreases the opportunity cost so as loans interest rates became more appealing to credit borrowers. On the other hand, on liquidity shortage the opportunity cost increases and loans became more expensive, which launch assets reshuffle. Since $\beta_{Bank} < \beta_S$, the shadow price of the marginal amount of bank capital is higher than one of external funds.

2.6 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. The fiscal authority purchases goods, issues public bonds, levies taxes, and makes lump sum transfers to households.

2.6.1 The monetary authority

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

$$R_t^4 = \left(R_{t-1}^4\right)^{\rho_R} \left[\left(E_t \frac{P_{C,t+4}}{P_{C,t}} \frac{1}{\overline{\pi}_t^4}\right)^{\gamma_\pi} \left(\frac{gdp_t}{gdp}\right)^{\gamma_Y} R^4\right]^{1-\rho} \left(\frac{\pi_{C,t}}{\pi_{C,t-1}}\right)^{\gamma_{\Delta\pi}} \varepsilon_t^R \tag{76}$$

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

$$GDP_t = Y_t - T_{bank,t} \tag{77}$$

$$T_{bank,t} = \begin{cases} s_{t-1}^{adm,E}\omega_E B_{E,t-1} + s_{t-1}^{adm,B}\omega_B B_{B,t-1}^C \\ +\frac{\chi_{OM,t-1}}{2}\left(\frac{B_{OM,t-1}}{Lb_{t-1}} - \nu_{t-1}^{OM}\right)^2 \times L_{t-1}^b \\ +\Gamma_T\left(D_{t-1}^T\right) D_{t-1}^{T,wb} \\ +\frac{\chi_{d\_T}}{2}\left(\frac{D_{t-1}^T}{L_{t-1}^b} - \nu_{t-1}^{d\_T}\right)^2 L_{t-1}^b \\ +\gamma_t^E\ \mu_E\ \left(R_t^K + P_{K,t}\left(1-\delta_K\right)\right)\omega_E K_{E,t-1} J\left(\overline{\omega}_{E,t}\right) \\ +\gamma_t^{B,C}\left(1-\tau_{w,t}\right)\omega_B N_{B,t} W_t\ \mu_{B,C} \begin{bmatrix} J\left(\overline{\omega}_{B,t}\right) - J\left(\overline{\omega}_{B,t}^H\right) \\ -\overline{\omega}_{B,t}^H\left(F\left(\overline{\omega}_{B,t}\right) - F\left(\overline{\omega}_{B,t}^H\right)\right) \end{bmatrix} \\ +\gamma_t^{B,C}\left(1-\tau_{w,t}\right)\omega_B N_{B,t} W_t\ \mu_{B,H}\ J\left(\overline{\omega}_{B,t}^H\right) \end{cases} \tag{78}$$

where

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

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

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

The time varying inflation target follows

$$\overline{\pi}_t^4 = \left(\overline{\pi}_{t-1}^4\right)^{\rho_{\overline{\pi}^4}} \left(\overline{\pi}^4\right)^{1-\rho_{\overline{\pi}^4}} \varepsilon_t^{\overline{\pi}^4} \tag{79}$$

2.6.2 The fiscal authority

The fiscal authority consumes final goods according to the rule:

$$\frac{G_t}{\epsilon_t} = \rho_g\left(\frac{G_{t-1}}{\epsilon_{t-1}}\right) + \left(1-\rho_g\right)\left(g - \mu_{B,G}\mathfrak{B}_{t-1}\right) + \varepsilon_t^G \tag{80}$$

$$\mathfrak{B}_{t-1} = \left[\frac{B_{t-1} + RR_{t-1}^D + RR_{t-1}^T + RR_{t-1}^S + RR_{t-1}^{add}}{P_{C,t-1}\epsilon_{t-1}} - \left(b + rr^D + rr^T + rr^S + rr^{add}\right)\right]$$

where lower-case variables denote stationary variables, g is the steady state value of stationarized government consumption, and the auxiliary $\mathfrak{B}$ stands for the government debt relevant for fiscal consolidation. Government consumption has a role in stabilizing gross public sector debt, which incorporates central bank's liabilities.

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

$$B_t = B_{OM,t} + B_{F,t} \tag{81}$$

Tax rates $\tau_{C,t}$, $\tau_{w,t}$, $\tau_{\Pi,t}$,and $\tau_{B,B,t}$ follow AR(1) processes around their steady states[22].

The joint public sector budget constraint is

$$\left.\begin{array}{r} P_{G,t}G_t + TT_t \\ -R_{t-1}^{S,H} RR_{t-1}^{S,H} \\ +R_{t-1}^{RR,T} RR_{t-1}^{T} + R_{t-1}^{RR,S} RR_{t-1}^{S} \\ +R_{t-1}^{RR,add} RR_{t-1}^{add} + RR_{t-1}^{D} \\ +R_{t-1}B_{t-1} \end{array}\right\} = \left\{\begin{array}{l} \tau_{w,t} W_t^N N_t + \tau_{C,t} P_{C,t} C_t \\ +\omega_E \tau_{B,E,t-1} B_{E,t-1} + \omega_B \tau_{B,B,t-1} B_{B,t-1}^C \\ +\tau_{w,t} \Pi_t^{LU} + \tau_{\Pi,t}\Pi_t + \tau_{\Pi,t}\nu^b \Pi_t^b \\ -RR_t^{S,H} \\ +RR_t^T + RR_t^S \\ +RR_t^{add} + RR_t^D \\ +B_t \end{array}\right. \tag{82}$$

2.7 Market clearing

Market clearing requires:

$$\begin{aligned} Y_t^d &= Y_t^{C,d} + Y_t^{G,d} + Y_t^{I_K,d} + Y_t^{IH,d} \\ Y_t^{G,d} &= G_t,\ Y_t^{IH,d} = I_{H,t},\ Y_t^{IK,d} = I_{K,t},\ Y_t^C = C_t \end{aligned} \tag{83}$$

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

Regardless of the model, 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

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

give the wrong idea of where economic variables are 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 their average in the inflation targeting period (Table 1)[23]. The base rate and GDP growth were also fixed according to the average in this period.

Bank series show serious trend and transition issues (Figure 1). Over the past decade, credit-to-GDP ratios have accelerated. This brings important challenges to calibrate the steady state of the model. The observed acceleration has not been accompanied by an increased perception of risk. Absolute levels of credit as a share of GDP are still low compared to international evidence. The ratio between non-mandatory loans and time deposits has declined during most part of the credit acceleration period, indicating that more stable funds are stepping in to finance the increased demand for loans. We expect the financial deepening of the economy to proceed with further rounds of sustainable credit expansion. However, since we cannot take a stand on what the equilibrium credit level will be given structural changes which the Brazilian financial sector has undergone, we 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 2.9% for investment loans and 7% for retail loans, in line with recent available data on actual default. We fixed steady state lending rates and balances as shares of GDP, in addition to banking spread components. We set the variance of the idiosyncratic shock to entrepreneur's collateral value (σ_E) to 0.58 to calibrate capital depreciation at 1.5% per quarter[24]. The variance of the idiosyncratic shock to borrower's committed income (σ_B) was fixed at 0.2[25]. From these assumptions, all the remaining variables related to financial accelerators, including threshold levels of idiosyncratic shocks, LTV ratios, and monitoring costs are obtained after evaluating the model at the steady state. The stock of capital is then determined from the entrepreneur's financial accelerator.

The capital adequacy ratio was fixed at the actual average of the Brazilian Financial System[26] since the beginning of the series on December 2000. Required capital was set at 11%, the regulatory rate for tier-1 capital since the implementation of Basle 1. Risk weights on bank assets were set at the actual values reported by Brazilian banks on portfolios that bear correspondence with the model (1.5 for retail loans, 1 for investment loans, 0.9 for housing loans, and 0 for government bonds). Given the capital adequacy ratio and banks' intertemporal discount factor, we calibrated the intercept and the slope parameter of the cost function associated with deviations

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

[24]At the initial stage of the estimation process, attempts to estimate σ_E resulted in unrealistically high capital depreciation rate and low capital stock.

[25]This parameter has an important effect on the model's impulse responses. Higher values drive the responses of retail loans to monetary policy rate shocks to a very unlikely region.

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

from the capital requirement. Then, the curvature parameter could be estimated.

We assumed a log-linear utility function at banks' optimization problem, and set bank's intertemporal discount factor at 0.98 which would represent a 17.5% nominal return on banks' dividends[27].

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, when this requirement was last reintroduced. Average additional reserves were calculated from the series starting on December 2002, when they were introduced. Requirements on savings accounts and demand deposits were averages of the entire inflation targeting period.The minimum required allocation of savings deposits in housing loans was set according to the actual compliance[28].

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[29].

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 collateral put up in housing loans and the model's implied value of real estate in the economy[30]. We also assumed that the government does not make transfers to borrowers[31].

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

4 Estimation

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

- Consumer inflation $\left(\pi_{C,t}^{obs}\right)$: inflation index used to assess compliance with the

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

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

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

[30] 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.

[31] By the time we finished this version of the paper, we had not had access to data on debt commitment by indebted households. We thus fixed borrowers' participation in the labor market under the arbitrary assumption that indebted households in Brazil have a debt commitment of 50% of their annual labor income.

inflation target (IPCA - Índice de Preços ao Consumidor Amplo – IBGE).

- Inflation target $\left(\bar{\pi}_{C,t}^{obs}\right)$: 4-quarter-ahead actual inflation target.

- Nominal interest rate $\left(R_t^{obs}\right)$: quarterly effective nominal base rate (Selic).

- Aggregate private consumption $\left(c_t^{obs}\right)$: share of seasonally adjusted private consumption in nominal values to the seasonally adjusted proxy for a closed economy nominal GDP. The proxy for a closed economy GDP was calculated as the sum of the nominal values of private and public consumption and fixed capital formation.

- Government consumption $\left(g_t^{obs}\right)$: share of seasonally adjusted government consumption in nominal values to the seasonally adjusted proxy for a closed economy nominal GDP.

- Unemployment $\left(U_t^{obs}\right)$: Brazilian National Statistics Institute (IBGE)'s new unemployment series with missing values filled up by an interpolation of a series econometrically built from IBGE's discontinued series of unemployment. The resulting series was detrended by its mean from 1999Q1 to 2012Q1.

- Real wage change $\left(\Delta w_t^{obs}\right)$: quarterly change in IBGE's seasonally adjusted real wage series with missing values filled up by an interpolation of a series econometrically built from IBGE's discontinued series of real wages.

- GDP $\left(\widehat{gdp}_t^{obs}\right)$: HP cycle of the log of the proxy for the real GDP of the closed economy. This proxy was constructed by deflating the proxy for the closed economy nominal GDP by a composite of consumer and producer price inflation, to proxy for the quarterly GDP deflator.

- Installed capacity utilization $\left(u_t^{obs}\right)$: quarterly capacity utilization published by Fundação Getúlio Vargas, demeaned by the average from 1999Q1 to 2012Q2.

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

- Lending spread for commercial loans $\left(\check{R}_{E,t}^{L,obs}\right)$: Ratio between the quarterly effective nominal interest rate on investment loans granted with freely allocated funds and the base rate. The lending rates on each type of loan are weighted by their respective stock outstanding. Missing observations at the beginning of the series were filled up by an interpolation of the series of lending rates on 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 only available from September 2000 onwards.

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

- Default rate on 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:Q4). Missing variables were filled up with standard Dynare routines. Employment in the model was mapped into the unemployment series according to:

$$\begin{aligned}\left(1+\beta^S\right)\mathrm{E}_t &= \beta^S\mathrm{E}_{t+1}+\mathrm{E}_{t-1}+\left(1-\beta^S\xi_{\mathrm{E}}\right)\frac{(1-\xi_{\mathrm{E}})}{\xi_{\mathrm{E}}}\left(N_t-\mathrm{E}_t\right)\\ \Delta w_t^{obs} &= \frac{W_t/P_t^C\epsilon_t}{W_{t-1}/P_{t-1}^C\epsilon_{t-1}}/\Delta n \qquad (84)\end{aligned}$$

where Δn is the steady state growth of the employed population. This bridge equation traces to Smets & Wouters (2007).

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. Table 2 shows the results of the estimation, including prior and posterior moments[32].

Table 3 reports the variance decomposition of selected variables[33]. Shocks to technology, preferences and capital investment are the main drivers of output volatility. Unemployment and inflation are mostly driven by markup, preference and temporary technology shocks. Shocks to LTVs or debt-to-income ratios explain most of the variance in the volume of loans, suggesting that the trend in these series is captured by these shocks. Capital investment is also importantly influenced by the shock to entrepreneurs' LTV ratios. On the other hand, housing investment is not significantly affected by financial shocks. Capital adequacy ratios are mostly driven by shocks to bank capital and also importantly by shocks to LTV ratios.

[32] We used Dynare to conduct the log-linear approximation of the model to the calibrated steady state and to perform all estimation routines. We ran 2 chains of 180,000 draws of the Metropolis Hastings to estimate the posterior.

[33] The shocks included in the table correspond to those whose standard deviation was estimated.

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 9)[34]. Notwithstanding, the financial frictions of the model entail more elaborate transmission channels. A 100 bp shock to the nominal base rate reduces consumption, labor and output through the traditional channels. Financial frictions reinforce the responses. The reduction in labor income puts pressure on the level of borrowers' non-performing loans, increasing the external finance premium, and, consequently, final lending rates. Given higher lending rates, the demand for retail loans falls, and borrower's consumption further adjusts to accommodate tighter funding conditions.

Worsened demand conditions reduce prices. In particular, the fall in the price of capital reduces the value of collateral put up for commercial loans, putting pressure on default rates and, consequently, on the external finance premium, as predicted by the financial accelerator mechanisms. Increased external finance premia translate into higher lending rates, leading to a reduction in the demand for investment loans, further depressing investment.

The increase in the base rate puts pressure on banks' external and internal funding costs. The reduction in the demand for bank loans is accommodated through an expansion in banks' liquidity buffer and a retrenchment of profit distribution. The recomposition of banks' balance sheet towards safer assets and larger capital accumulation improves the capital adequacy ratio.

The price of housing falls with depressed demand conditions, therefore lower collateral values reduce the volume of mortgage loan concessions.

Reserve requirement ratios were shocked at 10 p.p., a magnitude that is not unusual in practice. This implies that reserve requirements on demand deposits rise on impact to 59.6%, from the steady state level of 49.6%, reserve requirements on time deposits rise to 21% from 11%, reserve requirements on savings accounts rise to 28% from 18%, and the additional requirement rises to 17.6% from 7.6%.

The 10 p.p. shock to unremunerated reserve requirements on demand deposits $\left(\tau^D_{RR,t}\right)$ (Figure 13) has very limited contractionist impact on the real economy. Although this might seem at odds with the literature, we argue below that the base-effect has an important contribution to this result. The most important effects are restricted to banks' balance sheets, with some spillover to decisions on capital investment. Increased reserve requirements could be fulfilled with an unleash of bank liquidity or an increase in funding sources. On impact, banks immediately cut down

[34]We present the IRFs of temporary technology and price markup shocks in the appendix (Figures 10 and 11). The focus of the paper is on macroprudential shocks, so we drop the discussion of those shocks.

on their liquidity buffer. Rigidities in time deposits allow banks to only gradually adjust this funding. Therefore, banks find it optimal to retain earnings to alleviate some of the burden of liquidity shortage. The liquidity shortage triggers an important increase in banks' funding cost, which is only partially passed through to final lending rates, since leverage is not under pressure from the real economy. Higher lending rates for commercial loans reduce the demand for investment goods, which drives the price of capital down, further constraining credit conditions for entrepreneurs.

A shock to (remunerated) reserve requirements on time deposits (Figure 14) has a similar transmission, yet the responses are substantially stronger. The main distinction in the transmission of this shock rests on bank's profits and dividend distribution. Since this reserve is remunerated at the base rate, the pressure on asset remuneration is not as strong as that produced by increased unremunerated reserves. As a result, banks choose not to retain dividends.

A shock to (remunerated) reserve requirements on savings accounts (Figure 15) is qualitatively analogous to that on reserve requirements on time deposits. The amplitude of the responses is lower since the incidence base of reserve requirements on savings accounts is about half of that on time deposits.

An unanticipated 1 p.p. increase in required capital, from 11% to 12% (Figure 16), has striking effects on banks' funding costs. When the shock hits, bank assets are permanently reshuffled to improve the capital adequacy ratio. On impact, interest rates on retail and investment loans increase by roughly the same amount. However, as entrepreneurs start to reduce leverage and their financing costs, interest rates and total volume of commercial loans decrease faster than retail loans. As a result of higher interest rates, investment decreases and drags GDP down. Borrower consumption falls to a lower plateau, but is partially compensated by increased saver's consumption. GDP falls and remains dampened over a long horizon.

Banks accumulate dividends to improve their net worth position. The increase in bank capital is channeled towards bank liquidity. Monetary policy immediately reacts to worsened economic conditions, which dampens the pass through of worsened credit conditions to the rest of the real economy. That is generated through the impact of low base rates on savers' consumption. Faced with lower rates of return on their assets, the saver anticipates consumption and, consequently, increases savings deposits, since the latter have a strong elasticity in savers' utility function.

If monetary policy is kept unchanged after a shock to capital requirement ratios, funding costs, the accumulation of bank capital and the liquidity buffer are not substantially changed. However, since monetary policy cannot alleviate the burden of tighter credit conditions on the real economy, and in particular in the labor market, lending rates rise more in response to a deteriorated condition for loan concessions to borrowers. The final drop in GDP is therefore much more severe as the impact of the shock builds up.

Figures 17 and 18 show the impact of a 10 p.p. to the risk weights on retail loans and investment loans. Although they immediately affect their specific sectoral interest rate, their impact also spills over to the other credit segment. To improve their capital adequacy ratios, banks increase their liquidity buffer and raise lending rates on both retail and investment loans to cut down on the stock of credit. Dividend distribution is reduced so as to accelerate bank capital accumulation. Tighter credit conditions impact households' consumption causing a contractionist impact on output and the labor market. Figure 19 shows the impact of a shock to the risk weight on housing loans. As the bank has no control on regulated housing loans interest rates, it may only increase the interest rates of investment and retail loans, in order to reduce risk weighted assets and accumulate dividends. Housing loan rates decrease because, by regulation, they are linked to the base interest rate.

The analysis of the model responses over a 12 quarter horizon indicate that macroprudential instruments are not as effective as monetary policy to affect the real economy[35] (Table 4). A 1 p.p. increase in the yearly base rate has a stronger impact on GDP and inflation than any of the scaled shocks to macroprudential instruments. In particular, the impact of the scaled monetary policy shock on inflation is 3.5 times stronger than a 1 p.p. shock to capital requirement.

A 1 p.p. increase in capital requirement represents an output loss of 1.1% over 12 quarters, and very limited impact on inflation (0.8%). The impact of this instrument on bank loans is stronger. In particular, the retrenchment in commercial loans after a capital requirement shock is the strongest amongst bank loans, mostly due to the type of collateral (physical capital) put up in the operation, which takes longer to recover after initial impacts.

Housing loans do not respond as much to capital requirements as they do to monetary policy shocks because they closely track the housing colateral value, which is more sensitive to the base rate shock. The impact of monetary policy shocks on retail and commercial loans over a 12 quarter horizon is substantially less important than scaled shocks to capital requirements or reserve requirements.

Increases of the same magnitude in sectoral risk weights do not spread uniformly to the credit market whose risk was reassessed. In particular, a 10 p.p. increase in the risk weight of commercial loans reduces the outstanding balance of these loans by 12.5%, whereas the same increase in the risk weight of retail loans reduces these loans by 2.5%. There is some spillover to the other credit sectors, but to a much lesser extent. Changes in risk weights of housing loans are practically neutral since banks cannot directly influence the demand over and above what the base rate already does.

Finally, the impact of shocks to reserve requirements is likely over-estimated since their autoregressive response was assumed to be much higher (0.99) than the smoothing coefficient of the Taylor rule (0.81)[36].

[35] These exercises were carried out under the assumption that monetary policy followed the estimated Taylor rule.

[36] We set the $\rho_{\tau,(\cdot)} = 0.99$ to emulate the belief that once reserve requirements are changed, the new ratio is the best prediction for any future ratios.

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 improve our understanding of the transmission channels operating in the modeled economy.

6.1 Removing the base-effect of reserve requirements

A fair comparison of the potential impact of reserve requirements needs to take into account the size of their incidence base. In order to set aside the size effect of the incidence base, we shocked each reserve requirement ratio so that the increase in the incidence base would be equal for all types of instruments. In particular, we applied a 50 p.p. shock to reserve requirements on demand deposits, a 7 p.p. shock to reserve requirements on time deposits, and a 15 p.p. shock to reserve requirements on savings deposits. Figure 24 shows the comparative impulse responses. In all cases, monetary policy was kept unresponsive.

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. The impact of reserve requirements on savings accounts is stronger than that of reserve requirements on time deposits, since interest rates on savings accounts are regulated by the government, and are usually lower than the base rate.

6.2 Nonresponsive monetary policy

We 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 are auxiliary instruments to monetary policy.

Figure 20 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 follows the estimated Taylor rule, and the other where the base rate is kept unchanged throughout the perturbed period[37]. When monetary policy is unresponsive, the impact of changes in reserve requirements on GDP is stronger and more prolonged. When banks increase lending rates to accommodate the increase in funding costs, savers' consumption is no longer stimulated through lower base rates, since monetary policy is kept unresponsive. As such, the impact on the demand for goods is not alleviated, and consequently the drop in the demand for labor curtails borrowers' capacity to take loans. As a result, borrowers' consumption is more severely affected. Further reinforcement to the shock comes from the higher cost of funding (since the baseline scenario implies an expansionist monetary policy). As a result of a stronger divestment of riskier bank assets, the capital adequacy ratio rises more

[37]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.

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 above (Figures 21 and 22).

6.3 Anticipated vs. unanticipated announcements of changes in capital requirements

The baseline model assumes that innovations in required capital are not anticipated by economic agents. However, changes in capital requirements are usually announced with a substantial lag to the implementation. To investigate whether announcements made prior to the actual implementation of this instrument trigger any anticipatory behavior, we compare the impulse responses of the model under two alternative scenarios: one in which the macroprudential authority announces a 1 p.p. increase in required capital to be implemented only 4 quarters after the announcement, and the other in which the announcement is synchronized with implementation. Figure 27 shows the results.

Previous announcements trigger an anticipatory behavior in banks' decisions. Banks immediately start to retain dividends and show a better performance in improving their capital adequacy ratios over the entire period. In this respect, announcements are more effective in reducing the risk exposure of the economy even after the shock hits. Economic agents also anticipate the impact of the shock and the demand for loans becomes more sensitive to lending rates. As a result, lending rates do not need to rise as much to curtail credit as what would occur if the shock was unanticipated. Real variables, such as GDP and inflation are impacted from start, but show smoother trajectories.

6.4 Alternative borrowing constraints on retail loans

In order to incorporate debt-to-income borrowing constraints and credit default to retail loans we introduced a variant of the Bernanke, Gertler & Gilchrist (1999) model in which wage income replaces physical assets – capital or housing – as loan collateral. To better understand the consequences of assuming this representation, we performed some counterfactual exercises to compare this modeling choice to a couple of alternatives commonly found in the literature: housing stock as collateral, and strict debt-to-income borrowing constraints[38].

In the version with housing collateral, we introduced the following constraint on borrowers' optimization problem, along the lines of Iacoviello (2005) and Gerali *et al.*

[38]To perform this exercise, we set the model parameters at the mean of the posterior estimated on the benchmark model. The modifications in the model were restricted to the equations that we present in this subsection and the changes that these equations imply in borrower's optimization program first order conditions.

(2010):

$$R_{B,t}^{L,C} B_{B,t}^{C} + R_{B,t}^{L,H} B_{B,t}^{H} \leq \gamma_t^{B,C} E_t P_{H,t+1} \left(1 - \delta_H\right) H_{B,t}$$

The second alternative model states that households' debt constraints are strictly tied to the current wage income[39]:

$$R_{B,t}^{L,C} B_{B,t}^{C} + R_{B,t}^{L,H} B_{B,t}^{H} \leq \gamma_t^{B,C} \left(1 - \tau_{w,t}\right) N_{B,t} W_t^N$$

None of these alternative models features default on household loans, so there are no bank losses coming from default in retail credit.

Figure 28 shows the impulse responses of the three models to a monetary policy shock. The responses from the model with strict debt-to-income constraint strongly resemble those generated by the baseline model, a much expected result since in both cases borrowing constraints depend on labor income. However, in the alternative model, retail loans track labor income more tightly, while the baseline model produces a more pronounced immediate negative response of retail credit as a result of credit default, and allows for more consumption smoothing afterwards. Credit losses in the baseline model also have effects on dividend distribution and bank capital, but this mechanism is absent in the alternative specifications.

The impulse responses of the model with collateral constraint in housing show more pronounced short term reactions to retail credit. This sort of behavior comes up as borrowers and savers swap housing stock and labor supply among themselves in order to smooth the unexpected impact of the monetary policy shock on borrowers' collateral. This response does not seem very plausible, and may happen because there is no adjustment cost in the model to prevent households from trading their housing stock to smooth consumption, even in the short term[40]. Nonetheless, this exercise shows how housing collateral may render retail credit and consumption much more responsive to shocks that affect housing prices.

The impulse responses to a capital requirement shock are presented in figure 29. Monetary policy reaction was muted in order to highlight the effects of increased capital requirement. Again, the responses of the baseline model are similar to the strict debt-to-income model, but now credit default plays a different role. In the baseline model, as banks reduce retail credit supply to cope with the higher capital requirement, borrowers' leverage decreases and there is less credit default. In addition, as bank credit losses are born by borrowers in the form of negative transfers, these reduced transfers imply lower household income and consumption as compared to the alternative model, thus the contractionary effect of the shock is stronger in the baseline model.

[39]This formulation is similar, but slightly different from Mendoza (2002), in which current wage income is tied only to debt stock, whereas our restriction associates wage income to debt plus accrued interest rates, in order to make it closer to baseline model formulation.

[40]Note for instance that Iacoviello (2005) introduces housing adjustment costs that attenuate this behavior. We decided not to introduce this feature in the alternative model to keep it as close as possible to the baseline model.

Furthermore, the impulse responses of the model with housing collateral are quite different from the baseline model, and retail loans decrease considerably more than in the other models. This could be explained by the greater sensitivity of housing collateral value to higher interest rates on loans but, again, the housing stock swapping between borrowers and savers might have an important role in this result.

6.5 Reserve requirements and the role of bank liquidity preferences

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

Some categories of reserve requirements in Brazil are remunerated at the short term policy rate – commonly taken as a good proxy of banks' opportunity costs. By introducing liquidity preferences in the bank's problem, the model is able to produce relevant responses to policy changes in reserve requirements, even in those fully remunerated by the base rate. To illustrate the point, we carried out a couple of counterfactual exercises in which the economy undergoes a shock that increases reserve requirements, and compared the baseline model to an alternative model with no role for bank's liquidity preference (i.e., by imposing $\chi_{OM} = 0$).

The first exercise compares impulse response functions to a permanent 1 p.p. increase in reserve requirements on time deposits. Inasmuch as reserve requirements on time deposits are fully remunerated, the standard transmission channel does not operate, as shown in figure 25. According to this alternative specification, the only visible effect of the shock is an immediate reduction in bank's liquidity buffer, which is used to cope with the new requirements without creating any further costs to the bank. The baseline model, however, presents relevant responses (albeit small in absolute magnitude) on banking costs, on lending rates, and also on real economy variables,as banks attempt to recompose their liquidity buffer through a combination of actions to increase time deposits and reduce loan supply.

A second exercise compares the impulse responses of both models to a permanent 1 p.p. increase in reserve requirements on demand deposits. Here, we kept the base interest rate constant to focus on the first-round effects of changes in reserve requirements. As reserve requirements on demand deposits yield no interest, both transmission channels are active in the baseline model, but only the first one is so in the alternative model. Therefore, the exercise allows us to disentangle the transmission channels from each other. Figure 26 shows the impulse responses. Most of the impact on lending rates and on the real economy comes from the liquidity preference channel, since the responses of the alternative model are considerably smaller than those of the baseline model.

7 Conclusion

This paper presents a DSGE model with matter-of-fact financial frictions to assess the transmission channel of a set of selected macroprudential policy instruments. Banks' decisions on risky retail loan concessions are grounded on the assessment of borrowers' labor income. Therefore, debt-to-income ratios replace loan-to-value in one of the financial accelerators.

The model also features frictions in the optimal composition of banks' balance sheet. Banks are assumed to have liquidity targets, and the optimal responses imply that liquidity buffers are used to relieve the impact of macroprudential instruments on credit markets. Banks can also optimally choose between sources of funding: external, via deposits; or internal, via dividend retaining.

The main macroprudential instruments introduced in this version of the model are the traditional (Basle 1 and 2) core capital requirements, allowed for anticipated or unanticipated implementation; reserve requirements on demand deposits, savings deposits, time deposits, and "additional" deposits; and risk-weights on bank assets for the computation of capital adequacy ratios. Other policy instruments featuring some Brazilian singularities were also included to replicate the dynamics of mortgage loans.

The model is estimated through Bayesian techniques using Brazilian data from the inflation targeting regime. We find that macroprudential instruments have strong effects on banks' balance sheet composition. The transmission to the rest of the economy differs according to the type of instrument. For instance, shocks to reserve requirements have a weak impact on the real economy. However, most relevant effects are restrained to banks' balance sheet. When the shock hits, banks unleash liquidity to fulfill increased required reserves. Since this represents deviation from the optimal balance sheet allocation, banks are faced with an increase in the perception of their opportunity cost, which is partially passed through to lending rates. Even when required reserves are remunerated at the central bank, they have a non-neutral effect on bank aggregates and on the economy. In particular, the size of deposits in the economy is a key variable to determine the magnitude of the impact of the shock to the financial sector and to the real economy.

Capital requirements have the most important impact on banks' funding costs. Since risk considerations become prominent as banks decide on the composition of their balance sheet to better fulfill the new requirement, the riskier loans, i.e., retail loans, are more severely impacted in the short run. The economic impact of policy changes is substantial, with singular dynamics. When the implementation of new capital requirements is preceded by an announcement, banks can anticipate to the impact of the new regulation by improving their capital adequacy from start. As a result, the economic effects of the shock can be seen long before the shock hits.

Monetary policy is more effective to affect the real economy, and especially inflation, than macroprudential instruments. It is in the credit market that macroprudential instruments have their strongest impact.

We compared the baseline model responses with those produced by household credit constraints traditionally used in the literature: the housing collateral constraint and the strict debt-to-income constraint. The model with housing collateral has very different predictions from both the baseline and the strict debt-to-income constraint model. Since housing prices strongly hit borrowers' capacity to take loans, households engage in an important swap in the housing market which affects the aggregate variables of the model. The responses of the models where labor income is included in the borrowing constraint are similar in some respects to the baseline model, but the presence of loan losses in the baseline model renders very distinct responses in the credit market, with some spillover to the real sector.

We also compare the baseline model responses to those in which the liquidity preference channel is muted. We find this channel to be important for remunerated reserve requirements to have an impact on the economy.

Despite the improvements to depict matter-of-fact frictions, and already revealing a substantial complexity, this version cannot account for all relevant transmission channels of macroprudential policy in Brazil. Opening the economy is one necessary improvement to the theoretical setup, so that the model can address the recent spillover of international liquidity to domestic credit conditions, the build-up of international reserves, and vulnerabilities to the financial system stemming from foreign operations. In addition, other particularities of the Brazilian financial system, mainly those related to the outstanding importance of public banks and their leading role in mortgage markets, also need to be addressed in the theoretical setup if one believes that these banks face different funding costs and have different objective functions as compared to private banks.

Furthermore, there are important issues regarding calibration and estimation of models with financial considerations in Brazil. Trends show up all over the data, especially in financial variables, even when they are taken as ratios of GDP. This can reflect some structural changes such as the financial deepening that the country has recently experienced. Traditional detrending techniques might not be suitable under such circumstances, since trends convey relevant information on leverage and debt service coverage ratio. Moreover, data missing for key variables, such as housing prices and stocks, and investment disaggregated between housing and capital, can also shade the complete understanding of financial channels.

LATEX

References

ANDRÉS, Javier; ARCE Óscar; THOMAS, Carlos. *Banking Competition, Collateral Constraints and Optimal Monetary Policy.* [S.l.], 2010. (Banco de España Working Papers, 1001). Disponível em: <http://ideas.repec.org/p/bde/wpaper/1001.html>.

AREOSA, Waldyr Dutra; COELHO, Christiano Arrigoni. *Using a DSGE Model to Assess the Macroeconomic Effects of Reserve Requirements in Brazil.* [S.l.], 2013. Disponível em: <http://ideas.repec.org/p/bcb/wpaper/303.html>.

BERNANKE, Ben S.; GERTLER, Mark; GILCHRIST, Simon. The financial accelerator in a quantitative business cycle framework. In: TAYLOR, J. B.; WOODFORD, M. (Ed.). *Handbook of Macroeconomics.* Elsevier, 1999, (Handbook of Macroeconomics, v. 1). cap. 21, p. 1341–1393. Disponível em: <http://ideas.repec.org/h/eee/macchp/1-21.html>.

BRZOZA-BRZEZINA, Michal; KOLASA, Marcin; MAKARSKI, Krzysztof. The anatomy of standard dsge models with financial frictions. *Journal of Economic Dynamics and Control*, v. 37, n. 1, p. 32–51, 2013. Disponível em: <http://ideas.repec.org/a/eee/dyncon/v37y2013i1p32-51.html>.

CARVALHO, Fabia Aparecida de; AZEVEDO, Cyntia F. The incidence of reserve requirements in brazil: Do bank stockholders share the burden? *Journal of Applied Economics*, v. 0, p. 61–90, May 2008. Disponível em: <http://ideas.repec.org/a/cem/jaecon/v11y2008n1p61-90.html>.

CHRISTIANO, Lawrence; ROSTAGNO, Massimo; MOTTO, Roberto. *Financial Factors in Economic Fluctuations.* [S.l.], 2010. (Working Paper Series, 1192). Disponível em: <http://ideas.repec.org/p/ecb/ecbwps/20101192.html>.

DIB, Ali. *Capital Requirement and Financial Frictions in Banking: Macroeconomic Implications.* [S.l.], 2010. (Bank of Canada Working Papers, 2010-26). Disponível em: <http://EconPapers.repec.org/RePEc:bca:bocawp:10-26>.

DURDU, Ceyhun Bora; MENDOZA, Enrique G.; TERRONES, Marco E. Precautionary demand for foreign assets in sudden stop economies: An assessment of the new mercantilism. *Journal of Development Economics*, v. 89, n. 2, p. 194–209, July 2009. Disponível em: <http://ideas.repec.org/a/eee/deveco/v89y2009i2p194-209.html>.

FIORE, Fiorella de; TRISTANI, Oreste. Optimal monetary policy in a model of the credit channel. *The Economic Journal*, Blackwell Publishing Ltd, v. 123, n. 571, p. 906–931, 2013. ISSN 1468-0297. Disponível em: <http://dx.doi.org/10.1111/j.1468-0297.2012.02558.x>.

GERALI, Andrea; NERI, Stefano; SESSA, Luca; SIGNORETTI, Federico M. Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking*, v. 42, n. s1, p. 107–141, 09 2010. Disponível em: <http://ideas.repec.org/a/mcb/jmoncb/v42y2010is1p107-141.html>.

GERTLER, Mark; KARADI, Peter. A model of unconventional monetary policy. *Journal of Monetary Economics*, v. 58, n. 1, p. 17–34, January 2011. Disponível em: <http://ideas.repec.org/a/eee/moneco/v58y2011i1p17-34.html>.

GLOCKER, Christian; TOWBIN, Pascal. Reserve requirements for price and financial stability: When are they effective? *International Journal of Central Banking*, v. 8, n. 1, p. 65–114, March 2012. Disponível em: <http://ideas.repec.org/a/ijc/ijcjou/y2012q1a4.html>.

IACOVIELLO, Matteo. House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, v. 95, n. 3, p. 739–764, June 2005. Disponível em: <http://ideas.repec.org/a/aea/aecrev/v95y2005i3p739-764.html>.

JIMÉNEZ, Gabriel; ONGENA, Steven; PEYDRÓ, José-Luis; SAURINA, Jesús. *Macroprudential policy, countercyclical bank capital buffers and credit supply: Evidence from the Spanish dynamic provisioning experiments*. [S.l.], 2012. Disponível em: <http://ideas.repec.org/p/nbb/reswpp/201210-231.html>.

MENDOZA, Enrique G. Credit, prices, and crashes: Business cycles with a sudden stop. In: *Preventing Currency Crises in Emerging Markets*. National Bureau of Economic Research, Inc, 2002, (NBER Chapters). p. 335–392. Disponível em: <http://ideas.repec.org/h/nbr/nberch/10639.html>.

MESQUITA, Mário; TORÓS, Mário. Brazil and the 2008 panic. In: BANK FOR INTERNATIONAL SETTLEMENTS. *The Global Crisis and Financial Intermediation in Emerging Market Economies*. 2011, (BIS Papers, 54). p. 113–120. Disponível em: <http://EconPapers.repec.org/RePEc:bis:bisbpc:54-06>.

MONTORO, Carlos; MORENO, Ramon. The use of reserve requirements as a policy instrument in latin america. *BIS Quarterly Review*, v. 1, March 2011. Disponível em: <http://ideas.repec.org/a/bis/bisqtr/1103g.html>.

MONTORO, Carlos; TOVAR, Camilo. Macroprudential tools: Assessing the implications of reserve requirements in a DSGE model. Incomplete Draft. 2010.

PARIÈS, Matthieu Darracq; SØRENSEN, Christoffer Kok; RODRIGUEZ-PALENZUELA, Diego. Macroeconomic propagation under different regulatory regimes: Evidence from an estimated dsge model for the euro area. *International Journal of Central Banking*, v. 7, n. 4, p. 49–113, December 2011. Disponível em: <http://ideas.repec.org/a/ijc/ijcjou/y2011q4a3.html>.

QUEIROZ, Mardilson Fernandes. Comportamento diário do mercado brasileiro de reservas bancárias – nível e volatilidade – implicações na política monetária. In: ANPEC [BRAZILIAN ASSOCIATION OF GRADUATE PROGRAMS IN ECONOMICS]. *Proceedings of the 32th Brazilian Economics Meeting*. 2004. Disponível em: <http://ideas.repec.org/p/anp/en2004/096.html>.

ROGER, Scott; VLCEK, Jan. *Macroeconomic Costs of Higher Bank Capital and Liquidity Requirements*. [S.l.], 2011. (IMF Working Papers, 11/103). Disponível em: <http://ideas.repec.org/p/imf/imfwpa/11-103.html>.

SMETS, Frank; WOUTERS, Rafael. Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review*, v. 97, n. 3, p. 586–606, June 2007. Disponível em: <http://ideas.repec.org/a/aea/aecrev/v97y2007i3p586-606.html>.

SOUZA-RODRIGUES, Eduardo; TAKEDA, Tony. Reserve requirements and bank interest rate distribution in Brazil. In: ANPEC [BRAZILIAN ASSOCIATION OF GRADUATE PROGRAMS IN ECONOMICS]. *Proceedings of the 32th Brazilian Economics Meeting*. 2004. Disponível em: <http://ideas.repec.org/p/anp/en2004/096.html>.

TOVAR, Camilo; GARCIA-ESCRIBANO, M.; MARTIN, M. *Credit Growth and the Effectiveness of Reserve Requirements and Other Macroprudential Instruments in Latin America*. [S.l.], 2012. (IMF Working Papers, 12/142). Disponível em: <http://ideas.repec.org/p/imf/imfwpa/12-142.html>.

A Technical Appendix

Please contact the authors for a copy of the technical appendix.

B Tables

Table 1: Steady state calibrations

Symbol	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)	3.0
i_K	Investment in capital (% of GDP)	14.4
g	Government spending (% of GDP)	20.4
D^D	Demand deposits (% of GDP)	3.4
D^T	Time deposits (% of GDP)	20.9
D^S	Savings deposits (% of GDP)	10.73
$B^{B,C}$	Retail loans (% of GDP)	12.53
$B^{B,H}$	Housing loans (% of GDP)	5.52
B^E	Commercial loans (% of GDP)	13.78
$R_{L,B,c}$	Nominal retail lending rate (% per annum)	34.3
$R_{L,B,H}$	Nominal housing lending rate (% per annum)	7.4
$R_{L,E}$	Nominal commercial lending rate (% per annum)	21.1
τ_C	Consumption Tax (%)	16.2
τ_W	Wage Tax (%)	15
τ_π	Tax on profits (%)	15
τ_B	Tax on retail loans (%)	0.3
bankcap	Bank capital (% of GDP)	13.0
γ^{bankK}	Capital requirement (%)	11.0
$\tau_{RR,T}$	Reserve requirement ratio on time deposits (%)	11.0
$\tau_{RR,S}$	Reserve requirement ratio on saving deposits (%)	18.1
$\tau_{RR,D}$	Reserve requirement ratio on demand deposits (%)	49.6
τ_H	Min required allocation of savings deposits in housing loans (%)	34.0
$\tau_{RR,\text{adic}}$	Additional reserve requirement (%)	7.7
	Parameters	
φ_R^S	Markdown on savings deposits rate	0.76
$\omega_S, \omega_B, \omega_E$	Relative size of agents	1
μ_w	Wage markup	1.1
δ_H	Housing depreciation (% per annum)	4
σ_{bank}	Bank's inverse elasticity of intertemporal substitution	1
β_{bank}	Bank's utility discount factor	0.98
$\tau_{\chi 1}$	Risk weight on consumption credit	1.5
$\tau_{\chi 2}$	Risk weight on investment credit	1
$\tau_{\chi 3}$	Risk weight on housing credit	0.9
$\tau_{\chi 4}$	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	0.626	0.561	0.694
σ_L	Inverse Frisch elasticity of labor	Gamma	1.50	0.10	1.445	1.278	1.608
σ_S	EoS of savings deposits	Gamma	4.00	3.00	23.509	16.254	30.331
σ_D	EoS of demand deposits	Gamma	4.00	3.00	8.968	4.780	12.928
η_H	EoS of housing	Gamma	1.00	0.25	2.113	1.371	2.903
$\phi_{u,2}$	Capital utilization cost	Gamma	0.20	0.15	0.099	0.040	0.154
ξ_E	Adjustment cost of employment to hours	Beta	0.75	0.10	0.621	0.569	0.675
ϕ_K	Adjustment cost of capital investment	Gamma	3.00	0.50	3.870	2.981	4.730
ϕ_H	Adjustment cost of housing investment	Gamma	3.00	0.50	3.941	3.065	4.820
Nominal Rigidities							
ξ_D	Calvo - prices	Beta	0.75	0.05	0.818	0.756	0.881
α_W	Calvo - wages	Beta	0.75	0.05	0.837	0.789	0.886
γ_D	Price indexation	Beta	0.50	0.20	0.238	0.051	0.405
γ_W	Wage indexation	Beta	0.50	0.20	0.265	0.055	0.466
ξ^{R_E}	Calvo - commercial lending rate	Beta	0.50	0.20	0.276	0.065	0.470
$\xi^{R_{B,c}}$	Calvo - retail lending rate	Beta	0.50	0.20	0.361	0.124	0.588
Policy rules							
ρ_R	Interest rate smoothing	Beta	0.70	0.03	0.807	0.779	0.837
γ_π	Inflation coefficient	Gamma	2.00	0.05	1.963	1.881	2.044
γ_Y	Output gap coefficient	Gamma	0.20	0.10	0.089	0.022	0.152
ρ_g	Government spending smoothing	Beta	0.70	0.20	0.709	0.571	0.843
Financial Frictions							
$\chi_{bankK,2}$	Capital buffer deviation cost	Gamma	0.06	0.01	0.064	0.048	0.080
$\chi_{b_{OM}}$	Liquidity buffer deviation cost	Gamma	0.10	0.05	0.054	0.030	0.076
$\chi_{d,T}$	Time deposits to loans deviation cost	Gamma	0.10	0.05	0.087	0.032	0.138
ϕ_T	Adjustment cost of time deposits	Gamma	0.20	0.10	0.292	0.135	0.448
Autoregressive shocks							
$\rho_{\varepsilon^{I_K}}$	Adjustment cost of capital investment	Beta	0.50	0.10	0.482	0.326	0.634
$\rho_{\varepsilon^{I_H}}$	Adjustment cost of housing investment	Beta	0.50	0.10	0.443	0.300	0.595
$\rho_{\varepsilon^{B,S}}$	Savers' preference	Beta	0.50	0.10	0.757	0.639	0.868

Continued on next page

Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
$\rho_{\varepsilon^{B,B}}$	Borrowers' preference	Beta	0.50	0.10	0.530	0.343	0.712
$\rho_{\varepsilon^{A}}$	Temporary technology	Beta	0.50	0.10	0.779	0.703	0.852
$\rho_{\varepsilon^{u}}$	Capital utilization	Beta	0.50	0.10	0.733	0.635	0.828
ρ_{μ_D}	Price markup	Beta	0.50	0.10	0.473	0.316	0.630
ρ_{μ_W}	Wage markup	Beta	0.50	0.10	0.383	0.264	0.500
ρ_{ϵ}	Permanent technology	Beta	0.95	0.03	0.968	0.941	0.995
Autoregressive financial shocks							
$\rho_{\varepsilon^{S,S}}$	Preference for savings deposits	Beta	0.50	0.20	0.958	0.930	0.988
ρ_{R_H}	Housing lending rate smoothing	Beta	0.50	0.20	0.878	0.807	0.960
$\rho_{\mu^R_E}$	Markup on commercial loans	Beta	0.50	0.10	0.609	0.502	0.720
$\rho_{\mu^R_{B,C}}$	Markup on retail loans	Beta	0.50	0.10	0.891	0.846	0.944
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.20	0.679	0.497	0.864
ρ_{σ_B}	Risk distribution st.dev. in retail loans	Beta	0.50	0.20	0.536	0.257	0.807
ρ_{σ_E}	Risk distribution st.dev. in commercial loans	Beta	0.50	0.20	0.660	0.578	0.744
$\rho_{d,D}$	Preference for demand deposits	Beta	0.70	0.20	0.914	0.850	0.983
$\rho_{d,T}$	Adjustment cost in time deposits	Beta	0.70	0.20	0.799	0.693	0.904
$\rho_{\gamma_{B,H}}$	Debt-to-Income in housing loans	Beta	0.90	0.05	0.974	0.959	0.992
ρ_{γ_E}	LTV in commercial loans	Beta	0.90	0.05	0.988	0.980	0.997
$\rho_{\gamma_{B,C}}$	Debt-to-income in retail loans	Beta	0.90	0.05	0.973	0.959	0.986
$\rho_{IB^{rem}}$	Exogenous component in CAR	Beta	0.50	0.20	0.957	0.929	0.989
$\rho_{\phi^{R_S}}$	Markdown on savings deposits rates	Beta	0.50	0.20	0.961	0.935	0.990
$\rho_{\varepsilon^{bank\ cap}}$	Dividend distribution	Beta	0.50	0.20	0.679	0.497	0.864
Traditional shocks							
ϵ^R	Monetary policy shock	Inverse Gamma	0.01	Inf	0.016	0.013	0.019
ϵ^G	Government spending shock	Inverse Gamma	0.01	Inf	0.007	0.006	0.008
ϵ^{I_K}	Capital investment adjustment cost	Inverse Gamma	0.05	Inf	0.081	0.063	0.098
ϵ^{I_H}	Housing investment adjustment cost	Inverse Gamma	0.05	Inf	0.035	0.027	0.042
ϵ^{β_S}	Savers' preference shock	Inverse Gamma	0.05	Inf	0.063	0.040	0.085
ϵ^{β_B}	Borrowers' preference shock	Inverse Gamma	0.05	Inf	0.089	0.046	0.134
ϵ^A	Temporary technology shock	Inverse Gamma	0.02	Inf	0.017	0.014	0.020
ϵ^u	Capital utilisation shock	Inverse Gamma	0.02	Inf	0.018	0.014	0.022

Continued on next page

Table 2 – (cont.)

Description		Prior Distribution			Posterior Distribution		
		Distribution	Mean	Std Dev	Mean	Credible set	
ϵ^{μ_D}	Price markup shock	Inverse Gamma	0.03	Inf	0.046	0.029	0.062
ϵ^{μ_W}	Wage markup shock	Inverse Gamma	0.03	Inf	0.102	0.068	0.135
ϵ^{Z}	Permanent technology shock	Inverse Gamma	0.00	Inf	0.001	0.001	0.002
$\epsilon^{\overline{\pi}}$	Inflation target	Inverse Gamma	0.01	Inf	0.005	0.004	0.006
Financial shocks							
$\epsilon^{S,S}$	Preference for savings deposits	Inverse Gamma	0.10	Inf	0.672	0.472	0.875
ϵ^{R_H}	Markup on housing loans	Inverse Gamma	0.01	Inf	0.005	0.004	0.006
$\epsilon^{\mu^{R_E}}$	Markup on commercial loans	Inverse Gamma	0.02	Inf	0.005	0.004	0.006
$\epsilon^{\mu^{R_{B,C}}}$	Markup on retail loans	Inverse Gamma	0.02	Inf	0.008	0.006	0.009
ϵ^{bankK}	Dividend distribution	Inverse Gamma	0.02	Inf	0.036	0.030	0.042
ϵ^{σ_B}	Risk shock to retail loans	Inverse Gamma	0.10	Inf	0.071	0.053	0.090
ϵ^{σ_E}	Risk shock to commercial loans	Inverse Gamma	0.10	Inf	0.160	0.128	0.189
$\epsilon^{D,S}$	Preference for demand deposits	Inverse Gamma	0.10	Inf	0.328	0.177	0.466
$\epsilon^{d,T}$	Time deposit adjustment cost	Inverse Gamma	0.05	Inf	0.043	0.026	0.060
$\epsilon^{\gamma_{B,H}}$	Housing debt-to-income	Inverse Gamma	0.05	Inf	0.043	0.033	0.052
ϵ^{γ_E}	Collateral in commercial loans	Inverse Gamma	0.05	Inf	0.212	0.168	0.254
$\epsilon^{\gamma_{B,C}}$	Retail debt-to-income	Inverse Gamma	0.05	Inf	0.041	0.033	0.050
$\epsilon^{IB,rem}$	Exogenous component in CAR	Inverse Gamma	0.10	Inf	0.099	0.082	0.115
$\epsilon^{\phi^{R_S}}$	Markdown on savings rates	Inverse Gamma	0.01	Inf	0.066	0.055	0.077
$\epsilon^{\tau_{RR,T}}$	Time deposits reserve requirements	Inverse Gamma	0.02	Inf	0.029	0.024	0.033
$\epsilon^{\tau_{RR,add}}$	Time deposits reserve requirements	Inverse Gamma	0.02	Inf	0.012	0.010	0.014
$\epsilon^{\tau_{RR,S}}$	Savings deposits reserve requirements	Inverse Gamma	0.02	Inf	0.007	0.006	0.008
$\epsilon^{\tau_{RR,D}}$	Demand deposits reserve requirements	Inverse Gamma	0.02	Inf	0.040	0.034	0.046

Table 3: Variance Decomposition

	Shocks	GDP	Consump. /GDP	Unempl.	Inflation	Base Rate	Capacity Utiliz.	Marginal Cost
$\epsilon^{S,S}$	Preference for savings deposits	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ϵ^{A}	Temporary technology shock	1.9	3.1	12.8	13.3	10.9	4.3	37.0
ϵ^{u}	Capital utilisation shock	0.1	0.2	2.8	0.8	0.9	17.5	1.5
ϵ^{R}	Monetary policy shock	2.9	2.2	5.0	4.4	9.4	1.6	3.3
ϵ^{G}	Government spending shock	2.2	0.2	2.3	0.6	0.7	1.1	1.3
ϵ^{σ_E}	Risk shock to commercial loans	0.1	0.0	0.0	0.0	0.1	0.0	0.0
ϵ^{μ_W}	Wage markup shock	1.3	2.0	12.1	8.0	7.0	1.7	16.8
ϵ^{μ_D}	Price markup shock	1.2	2.0	1.0	41.4	4.2	3.9	16.3
ϵ^{I_K}	Capital invest. adjustment cost	13.1	2.8	14.6	2.9	3.1	6.2	5.6
$\epsilon^{\overline{\pi}}$	Inflation target	0.7	0.4	1.3	1.3	0.2	0.4	0.8
ϵ^{Z}	Permanent technology shock	49.1	53.3	1.1	9.2	33.1	48.4	0.2
$\epsilon^{\mu^{R_E}}$	Markup on commercial loans	0.1	0.0	0.1	0.0	0.0	0.0	0.0
$\epsilon^{\mu^{R_{B,C}}}$	Markup on retail loans	0.3	0.9	0.8	0.3	0.6	0.2	0.2
$\epsilon^{\tau_{RR,T}}$	Time deposits reserve req.	0.1	0.1	0.1	0.0	0.0	0.1	0.0
$\epsilon^{\tau_{RR,add}}$	Time deposits reserve req.	0.1	0.0	0.1	0.0	0.0	0.0	0.0
$\epsilon^{\tau_{RR,D}}$	Demand deposits reserve req.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ϵ^{σ_B}	Risk shock to retail loans	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{\gamma_{B,C}}$	Retail debt-to-income	1.4	0.7	7.9	0.2	0.4	0.3	0.2
ϵ^{γ_E}	Collateral in commercial loans	8.9	2.4	7.1	2.4	4.3	5.0	1.7
ϵ^{β_S}	Savers' preference	10.5	21.2	17.1	14.5	24.4	6.8	12.5
ϵ^{β_B}	Borrowers' preference	5.3	8.1	12.0	0.6	0.5	2.3	2.6
$\epsilon^{d,T}$	Time deposit adjustment cost	0.0	0.0	0.1	0.0	0.0	0.0	0.0
$\epsilon^{D,S}$	Preference for demand deposits	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{\gamma_{B,H}}$	Housing debt-to-income	0.1	0.0	0.4	0.0	0.0	0.0	0.0
ϵ^{R_H}	Markup on housing loans	0.1	0.0	0.3	0.0	0.0	0.0	0.0
ϵ^{I_H}	Housing invest. adjustment cost	0.1	0.1	0.2	0.1	0.1	0.0	0.0
$\epsilon^{IB,rem}$	Exogenous component in CAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{\phi^{R_S}}$	Markdown on savings rates	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ϵ^{bankK}	Dividend distribution	0.7	0.1	0.9	0.1	0.1	0.2	0.0

Table 3: Variance Decomposition (cont.)

Shocks		Capital Stock	Housing Stock	Invest. in Capital	Invest. in Housing	Credit /GDP	Retail loans /GDP
$\epsilon^{S,S}$	Preference for savings deposits	0.0	0.0	0.0	0.0	0.0	0.0
ϵ^{A}	Temporary technology shock	0.1	0.8	0.2	7.3	0.1	1.0
ϵ^{u}	Capital utilisation shock	0.1	0.1	0.2	0.8	0.0	0.1
ϵ^{R}	Monetary policy shock	0.2	0.2	1.2	1.6	0.0	0.2
ϵ^{G}	Government spending shock	0.0	0.1	0.2	0.4	0.0	0.1
ϵ^{σ_E}	Risk shock to commercial loans	0.1	0.0	0.4	0.1	0.1	0.0
ϵ^{μ_W}	Wage markup shock	0.0	0.5	0.1	4.5	0.1	0.6
ϵ^{μ_D}	Price markup shock	0.1	0.1	0.9	0.5	0.1	0.7
ϵ^{I_K}	Capital invest. adjustment cost	6.1	0.5	49.1	2.0	0.1	0.5
$\epsilon^{\overline{\pi}}$	Inflation target	0.1	0.0	0.3	0.2	0.0	0.0
ϵ^{Z}	Permanent technology shock	82.2	92.1	0.2	42.2	1.0	1.5
$\epsilon^{\mu^{R_E}}$	Markup on commercial loans	0.0	0.0	0.3	0.0	0.0	0.0
$\epsilon^{\mu^{R_{B,C}}}$	Markup on retail loans	0.1	0.1	0.1	0.8	0.1	0.8
$\epsilon^{\tau_{RR,T}}$	Time deposits reserve req.	0.1	0.0	0.2	0.1	0.1	0.0
$\epsilon^{\tau_{RR,add}}$	Time deposits reserve req.	0.1	0.0	0.1	0.0	0.0	0.0
$\epsilon^{\tau_{RR,D}}$	Demand deposits reserve req.	0.0	0.0	0.0	0.0	0.0	0.0
ϵ^{σ_B}	Risk shock to retail loans	0.0	0.0	0.0	0.0	0.0	0.2
$\epsilon^{\gamma_{B,C}}$	Retail debt-to-income	0.3	0.1	0.4	0.3	3.3	74.1
ϵ^{γ_E}	Collateral in commercial loans	9.1	1.0	42.9	5.4	94.0	0.2
ϵ^{β_S}	Savers' preference	0.4	3.3	1.1	25.2	0.4	2.3
ϵ^{β_B}	Borrowers' preference	0.2	0.0	0.8	0.3	0.0	5.1
$\epsilon^{d,T}$	Time deposit adjustment cost	0.0	0.0	0.1	0.0	0.0	0.0
$\epsilon^{D,S}$	Preference for demand deposits	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{\gamma_{B,H}}$	Housing debt-to-income	0.0	0.2	0.0	0.5	0.0	12.0
ϵ^{R_H}	Markup on housing loans	0.0	0.0	0.0	0.0	0.0	0.2
ϵ^{I_H}	Housing invest. adjustment cost	0.0	0.7	0.0	7.1	0.0	0.0
$\epsilon^{IB,rem}$	Exogenous component in CAR	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{\phi^{R_S}}$	Markdown on savings rates	0.0	0.0	0.0	0.2	0.0	0.0
ϵ^{bankK}	Dividend distribution	0.6	0.1	1.1	0.4	0.4	0.4

Table 3: Variance Decomposition (cont.)

Shocks		Commercial loans /GDP	Delinquency on Retail Loans	Delinquency on Comm. Loans	Bank Liquidity /GDP	Basel Ratio	Bank Capital
$\epsilon^{S,S}$	Preference for savings deposits	0.0	0.0	0.0	0.9	0.0	0.0
ϵ^{A}	Temporary technology shock	0.1	9.2	0.7	0.8	0.4	0.1
ϵ^{u}	Capital utilisation shock	0.0	1.8	0.1	0.1	0.1	0.0
ϵ^{R}	Monetary policy shock	0.0	1.0	0.1	0.4	0.4	0.2
ϵ^{G}	Government spending shock	0.0	1.7	0.1	0.1	0.0	0.0
ϵ^{σ_E}	Risk shock to commercial loans	0.2	0.1	26.9	0.3	0.3	0.3
ϵ^{μ_W}	Wage markup shock	0.1	2.3	0.4	0.5	0.3	0.1
ϵ^{μ_D}	Price markup shock	0.0	0.1	0.1	0.3	0.0	0.0
ϵ^{I_K}	Capital invest. adjustment cost	0.2	2.7	0.8	0.6	0.4	0.4
$\epsilon^{\overline{\pi}}$	Inflation target	0.0	0.2	0.0	0.1	0.0	0.0
ϵ^{Z}	Permanent technology shock	1.6	0.2	0.1	1.1	2.0	3.5
$\epsilon^{\mu^{R_E}}$	Markup on commercial loans	0.0	0.0	0.1	0.5	0.5	0.3
$\epsilon^{\mu^{R_{B,C}}}$	Markup on retail loans	0.1	6.1	0.4	3.8	7.0	4.5
$\epsilon^{\tau_{RR,T}}$	Time deposits reserve req.	0.1	0.1	0.2	5.8	2.1	1.0
$\epsilon^{\tau_{RR,add}}$	Time deposits reserve req.	0.0	0.0	0.1	2.8	1.0	0.5
$\epsilon^{\tau_{RR,D}}$	Demand deposits reserve req.	0.0	0.0	0.0	0.4	0.0	0.0
ϵ^{σ_B}	Risk shock to retail loans	0.0	18.2	0.0	0.1	0.1	0.1
$\epsilon^{\gamma_{B,C}}$	Retail debt-to-income	0.1	34.2	0.2	3.0	2.6	3.7
ϵ^{γ_E}	Collateral in commercial loans	96.7	2.9	67.1	47.4	31.7	57.2
ϵ^{β_S}	Savers' preference	0.2	12.2	1.0	3.0	1.6	0.7
ϵ^{β_B}	Borrowers' preference	0.0	4.7	0.2	0.3	0.2	0.2
$\epsilon^{d,T}$	Time deposit adjustment cost	0.0	0.0	0.0	7.0	0.2	0.1
$\epsilon^{D,S}$	Preference for demand deposits	0.0	0.0	0.0	0.1	0.0	0.0
$\epsilon^{\gamma_{B,H}}$	Housing debt-to-income	0.0	1.6	0.0	0.6	0.5	0.5
ϵ^{R_H}	Markup on housing loans	0.0	0.1	0.0	0.1	0.2	0.2
ϵ^{I_H}	Housing invest. adjustment cost	0.0	0.0	0.0	0.0	0.0	0.0
$\epsilon^{IB,rem}$	Exogenous component in CAR	0.0	0.0	0.0	0.0	8.5	0.1
$\epsilon^{\phi^{R_S}}$	Markdown on savings rates	0.0	0.0	0.0	0.2	0.8	0.5
ϵ^{bankK}	Dividend distribution	0.4	0.8	1.1	19.9	39.0	25.8

Table 4: Accumulated impact of shocks over 12 quarters

Shock	Capital requirement (% of CAR)	Base Rate (% p.y.)	RR ratio on demand deposits (% of dep.)	RR ratio on savings deposits (% of dep.)
Size of the shock	1 p.p.	1 p.p.	10 p.p.	10 p.p.
% change in GDP	-1.1%	-2.5%	-0.2%	-0.6%
% change in yearly inflation	-0.8%	-2.8%	-0.2%	-0.5%
% change in retail loans	-3.8%	0.0%	-0.6%	-1.6%
% change in commercial loans	-12.2%	-2.3%	-2.5%	-8.0%
% change in housing loans	-2.7%	-9.5%	-0.6%	-1.5%

Shock	RR ratio on time deposits (% of dep.)	Risk weight on retail loans	Risk weight on commercial loans	Risk weight on housing loans
Size of the shock	10 p.p.	10 p.p.	10 p.p.	10 p.p.
% change in GDP	-1.2%	-0.2%	-0.7%	0.0%
% change in yearly inflation	-0.8%	-0.2%	-0.4%	0.0%
% change in retail loans	-3.1%	-2.5%	-0.5%	-0.1%
% change in commercial loans	-15.7%	-0.4%	-12.5%	-0.5%
% change in housing loans	-2.9%	-0.2%	-1.1%	-0.1%

C Figures

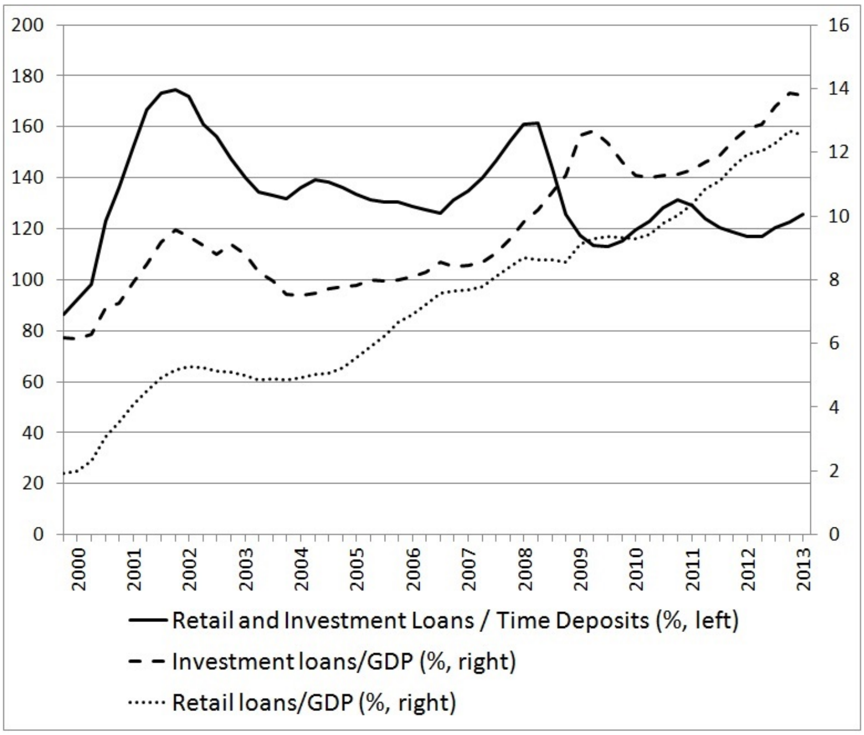


Figure 1: Retail and Investment Loans Growth over GDP and Deposits

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

D Observable Variables

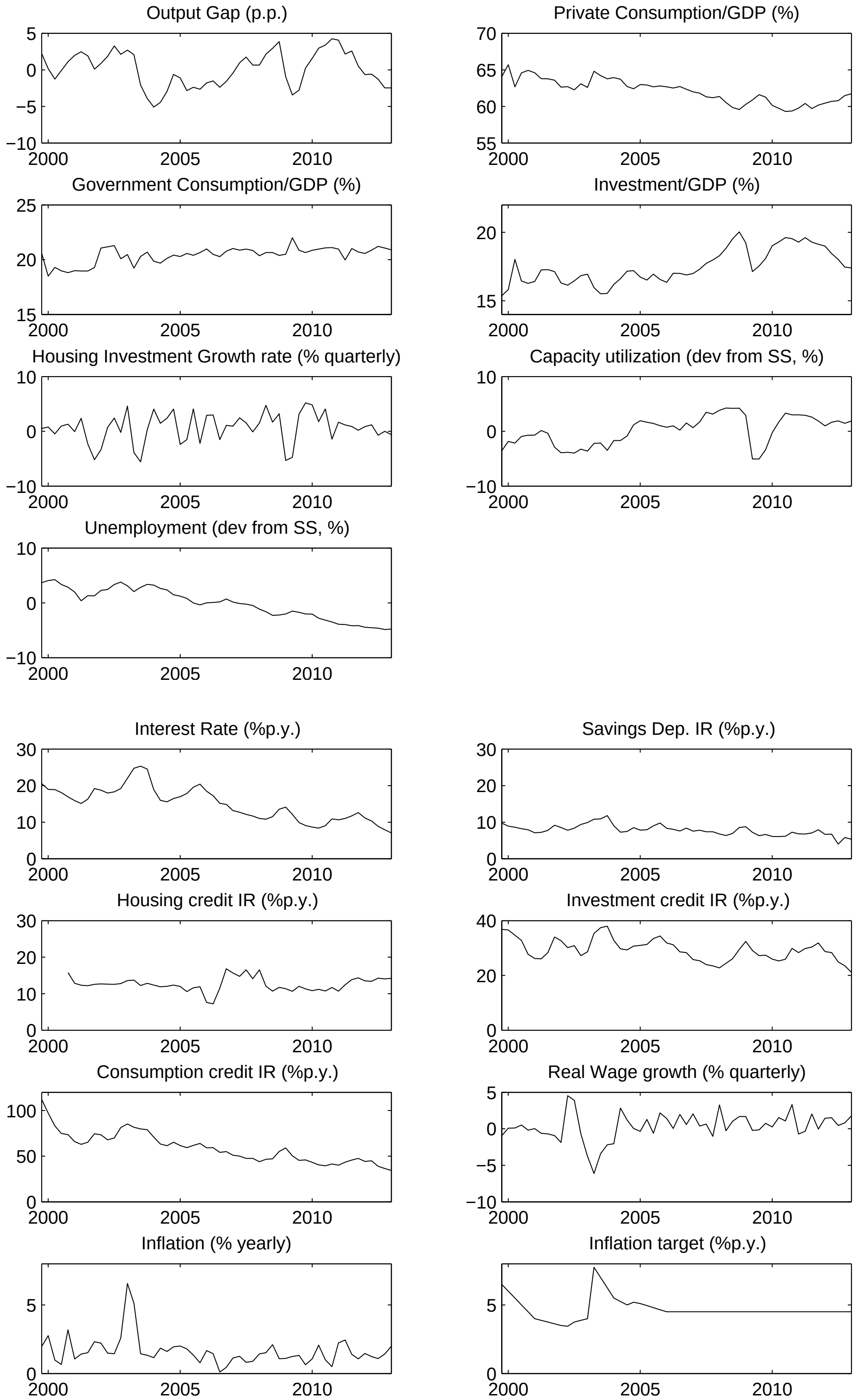


Figure 2: Observable Variables

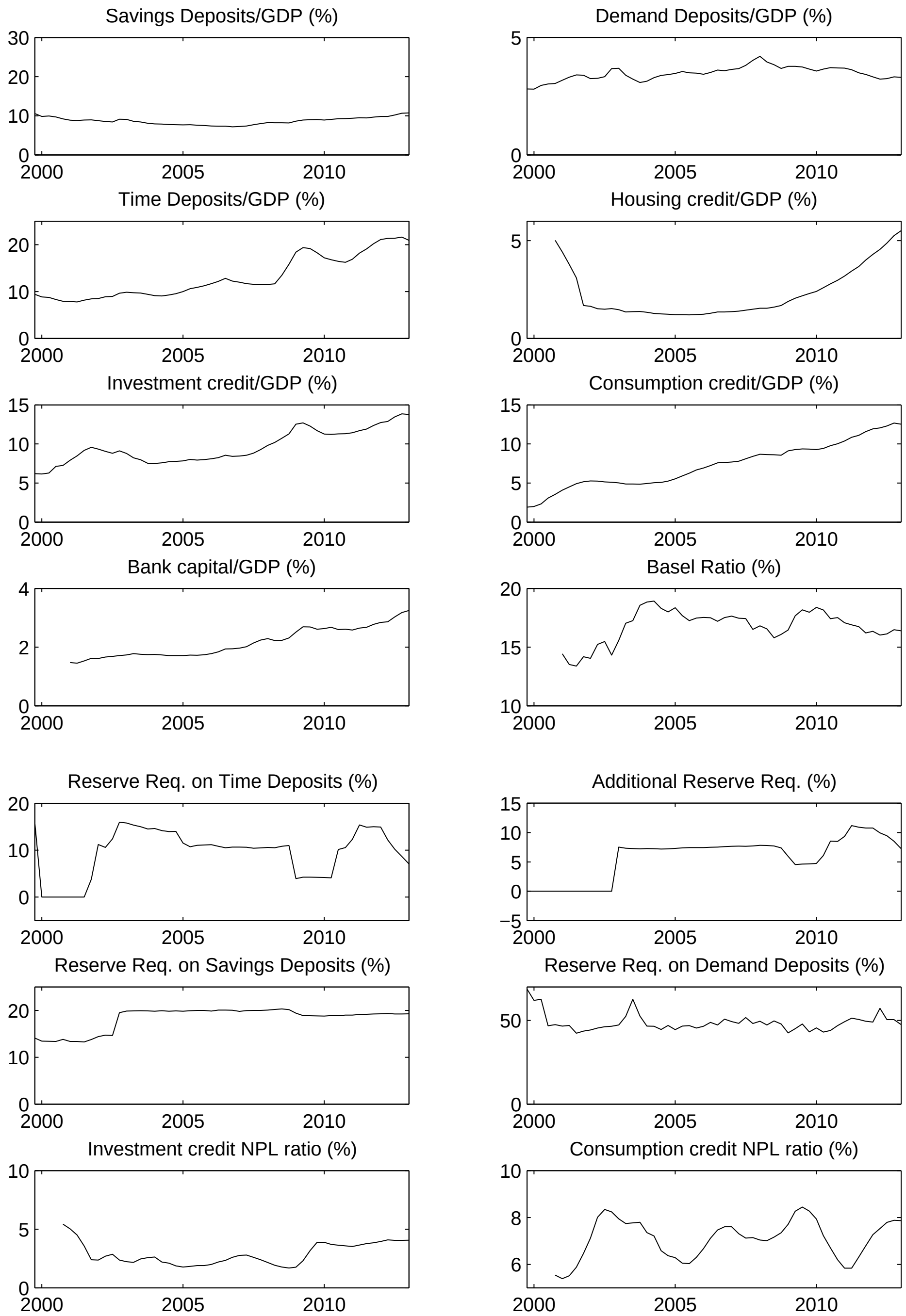


Figure 3: Observable Variables

E Priors and Posteriors

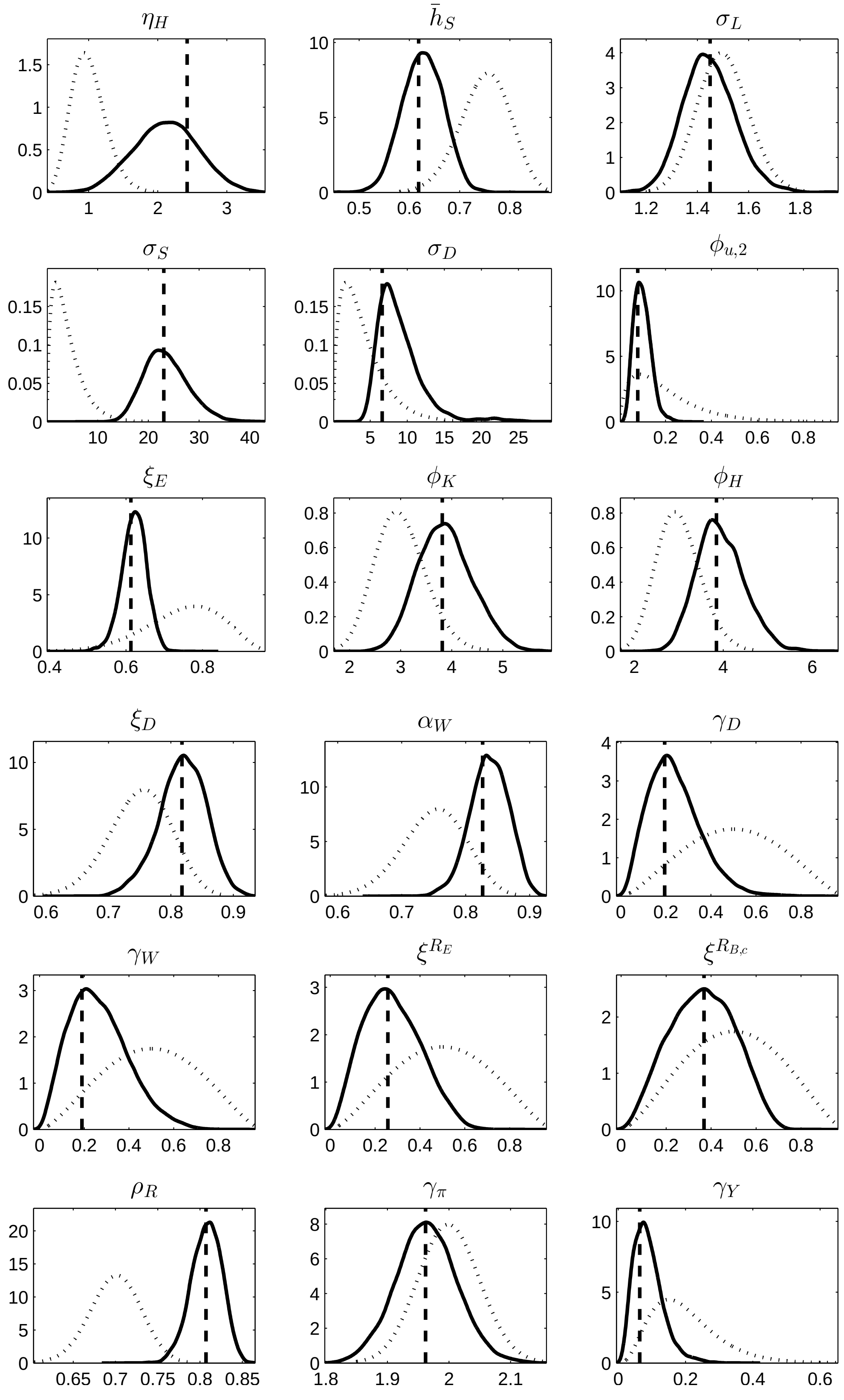


Figure 4: Priors and Posteriors

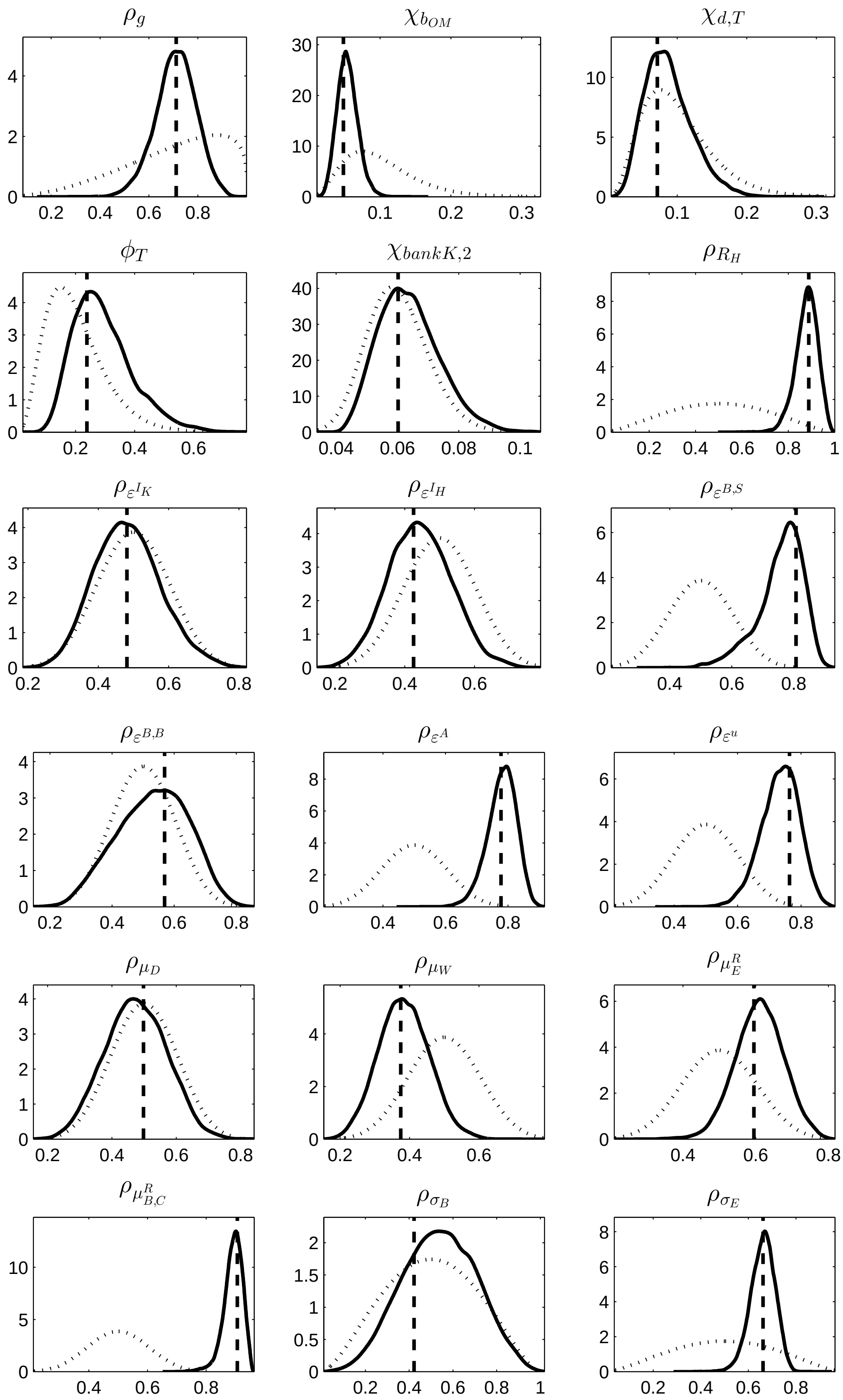


Figure 5: Priors and Posteriors

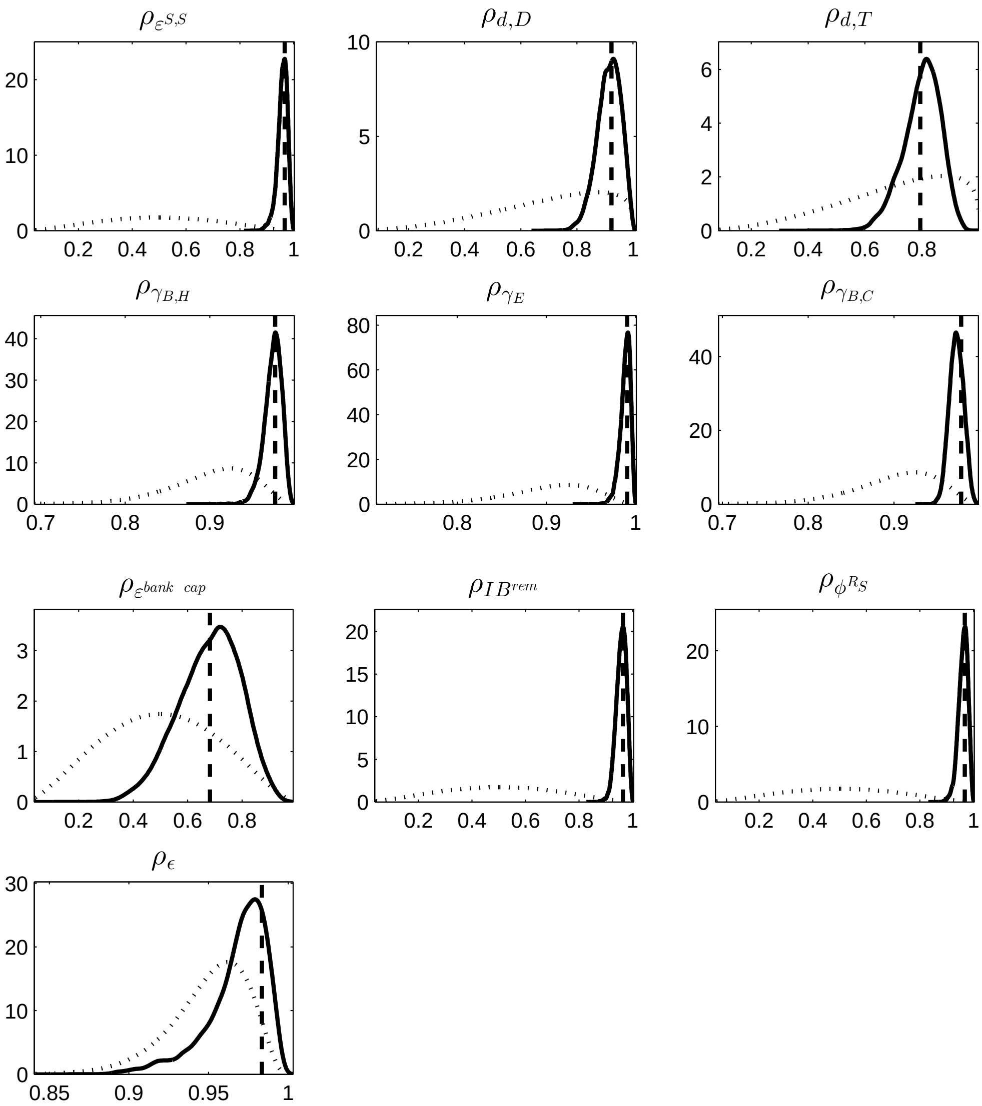


Figure 6: Priors and Posteriors

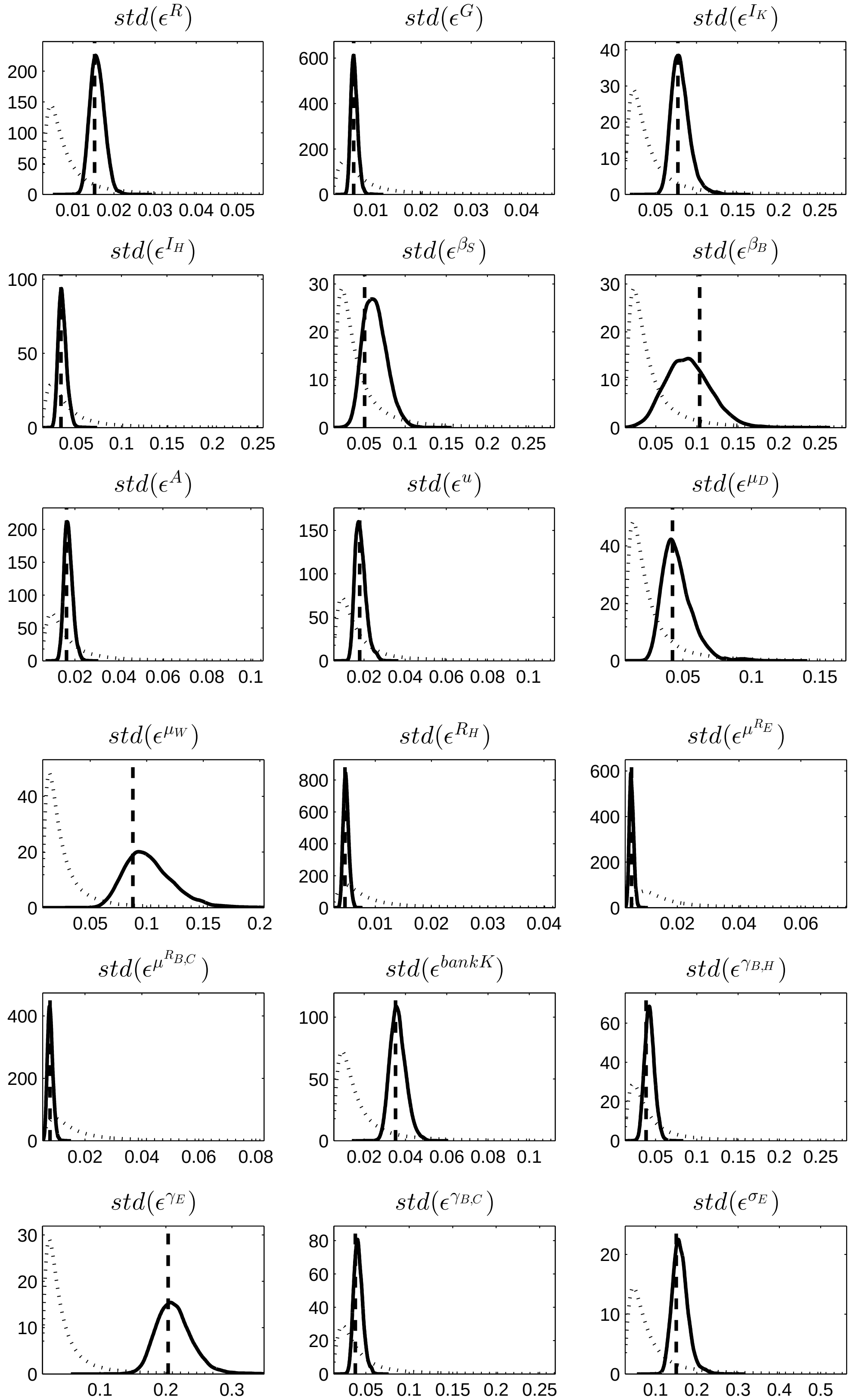


Figure 7: Priors and Posteriors

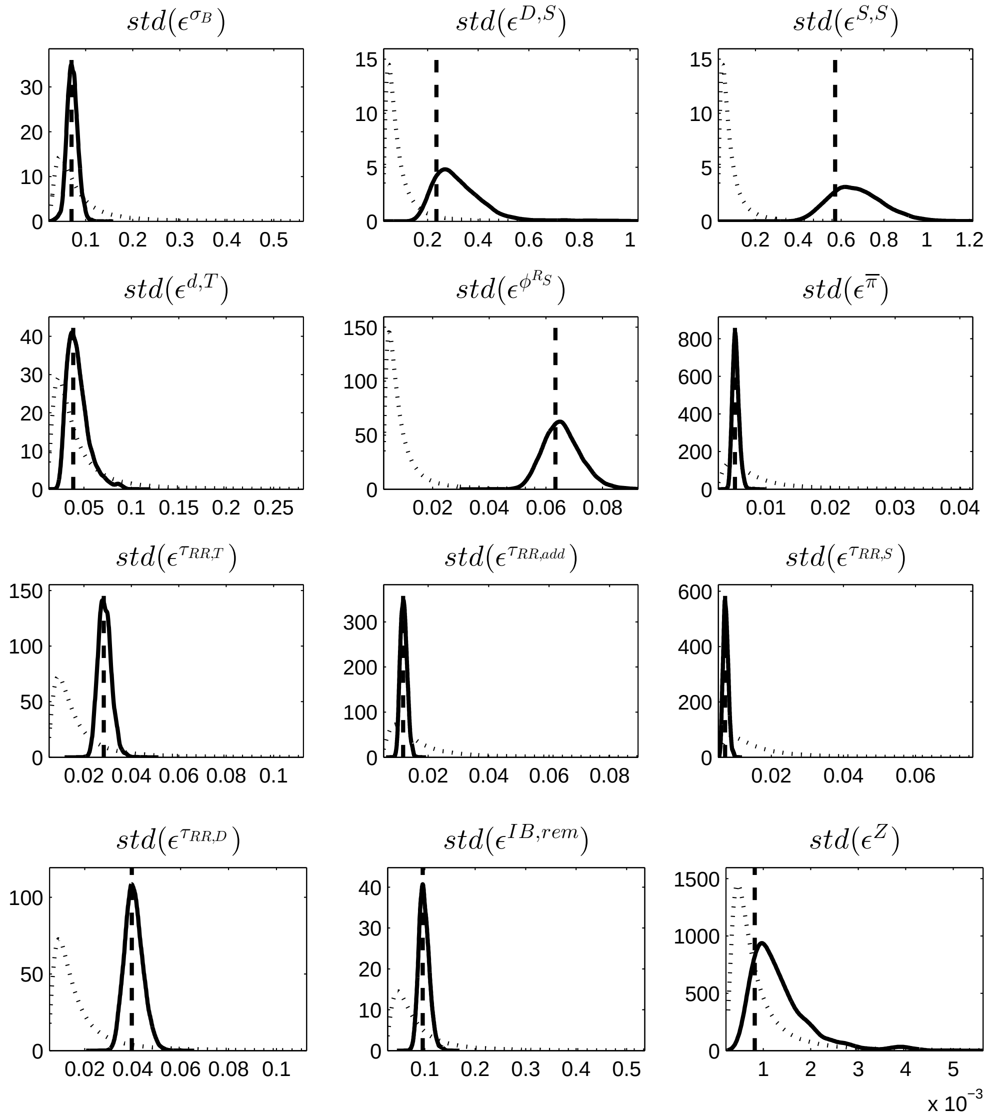


Figure 8: Priors and Posteriors

F Impulse Response Functions

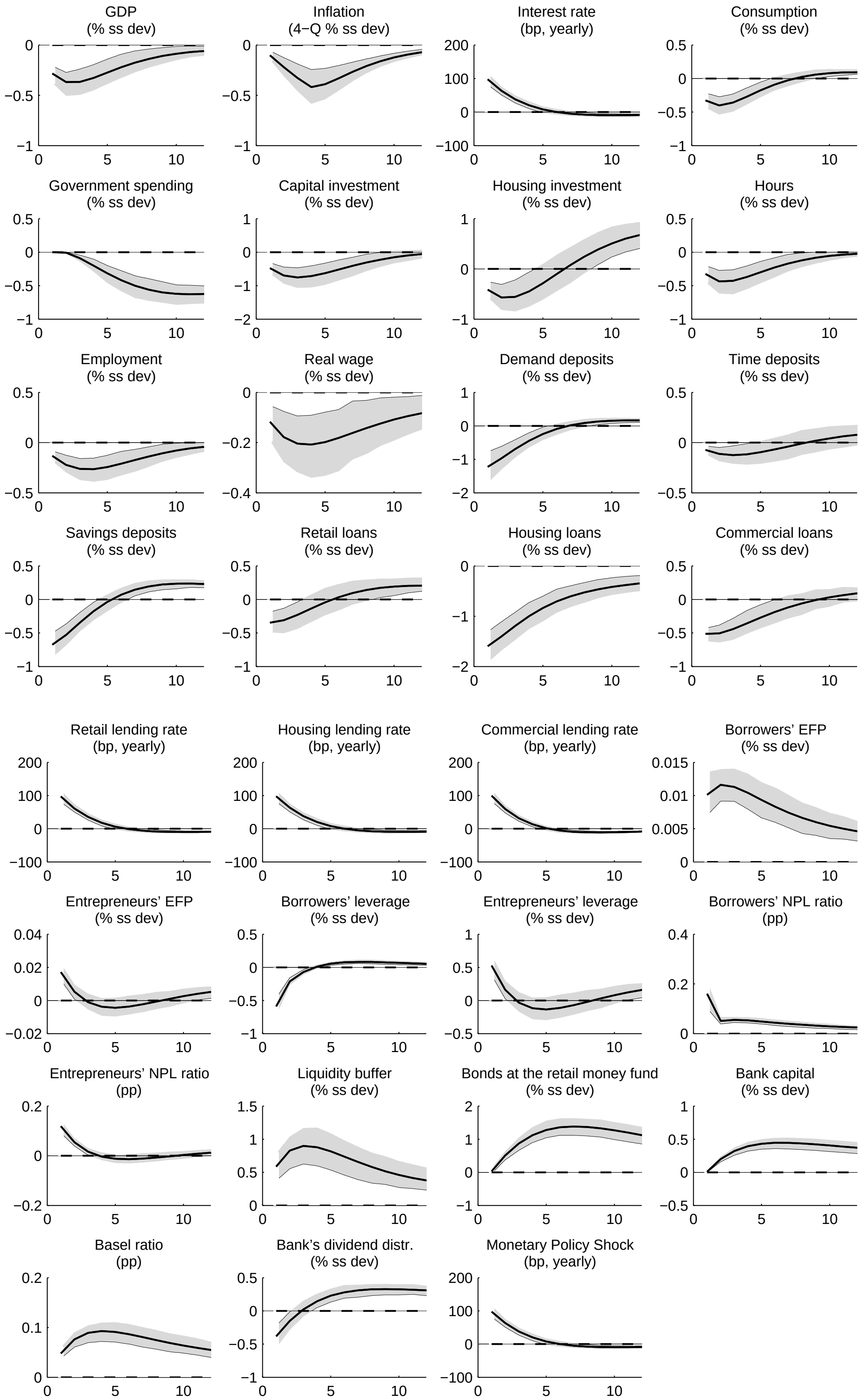


Figure 9: Monetary Policy Shock

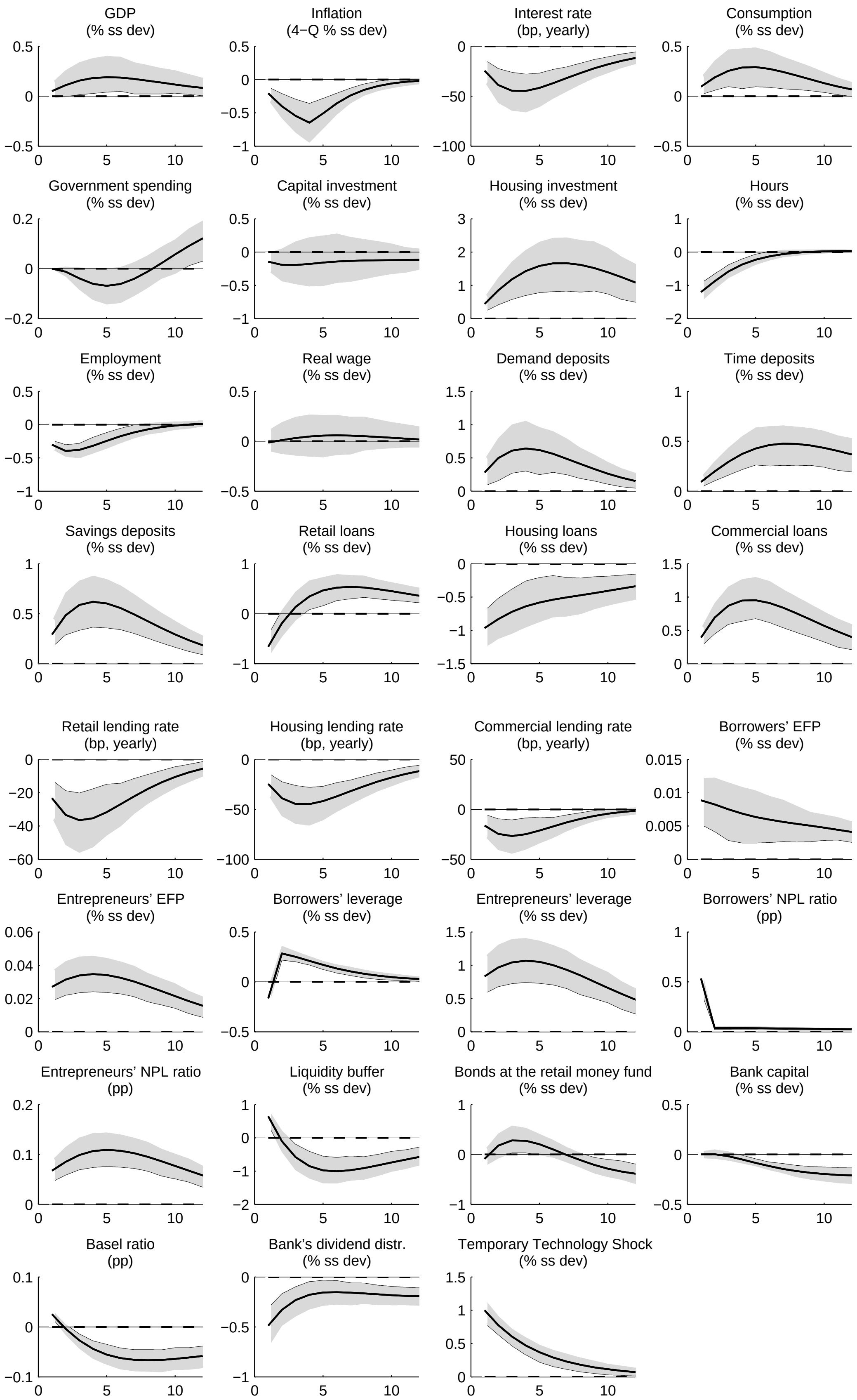


Figure 10: Temporary Technology Shock

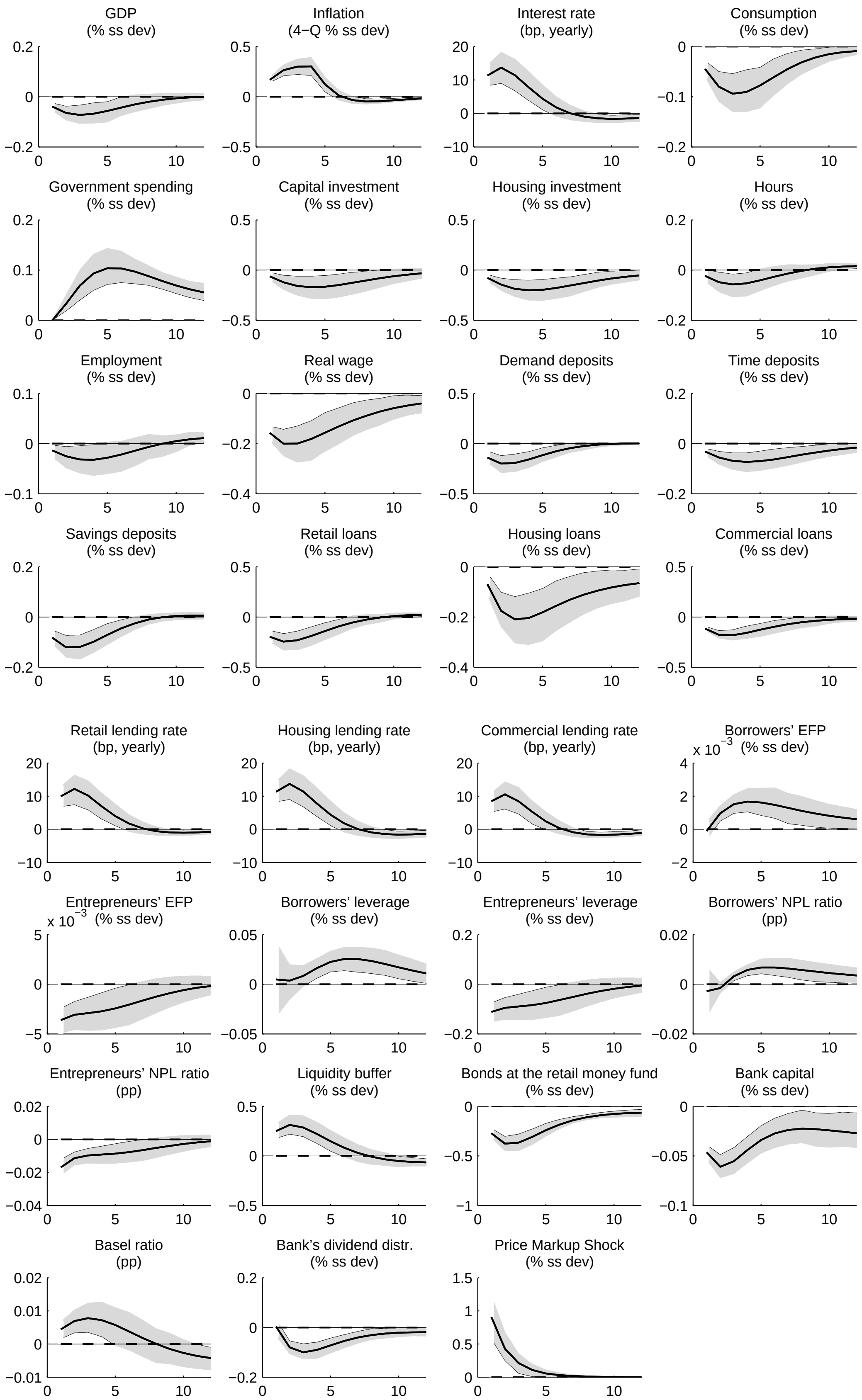


Figure 11: Price Markup Shock

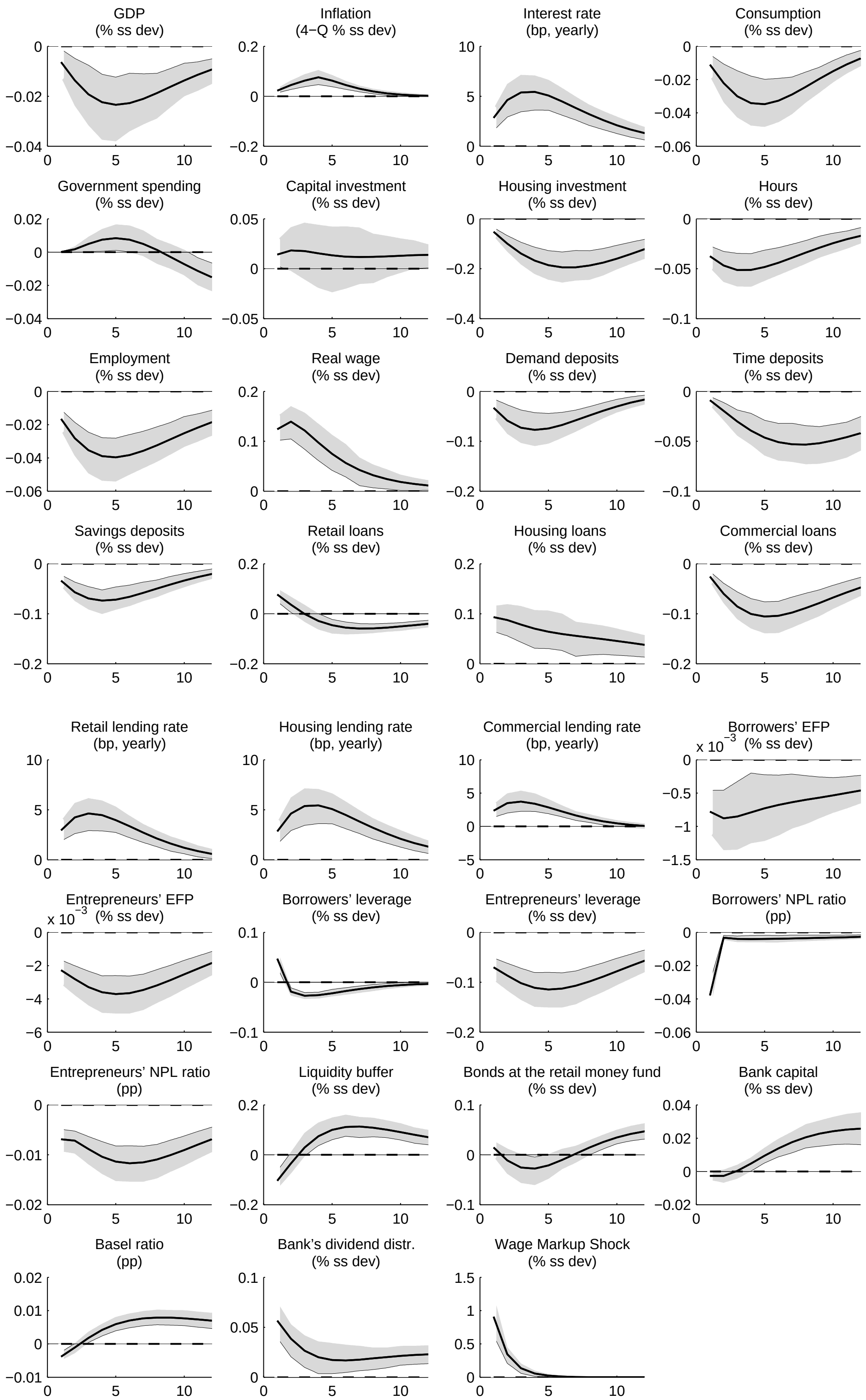


Figure 12: Wage Markup Shock

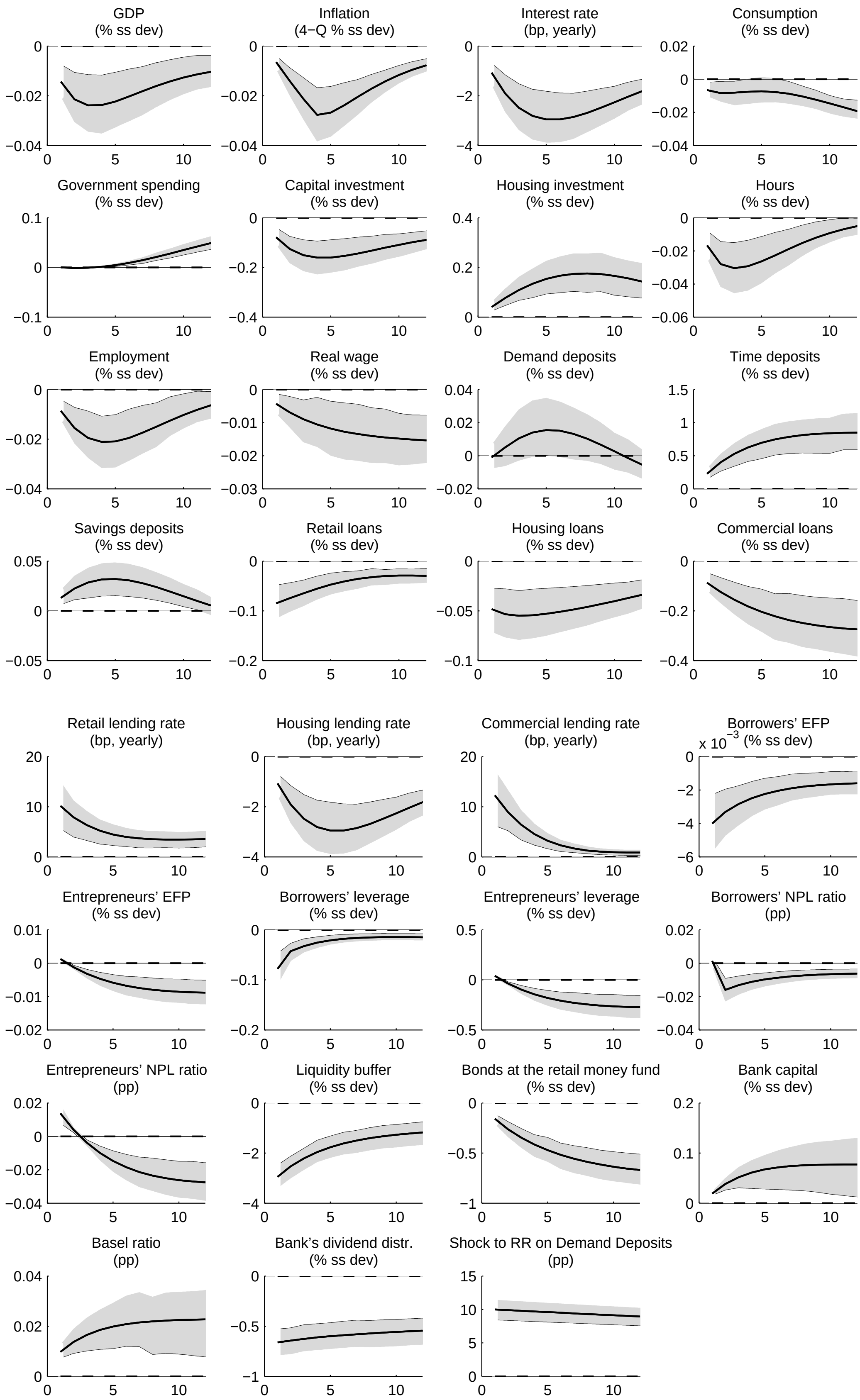


Figure 13: Shock to Reserve Requirement Ratio on Demand Deposits

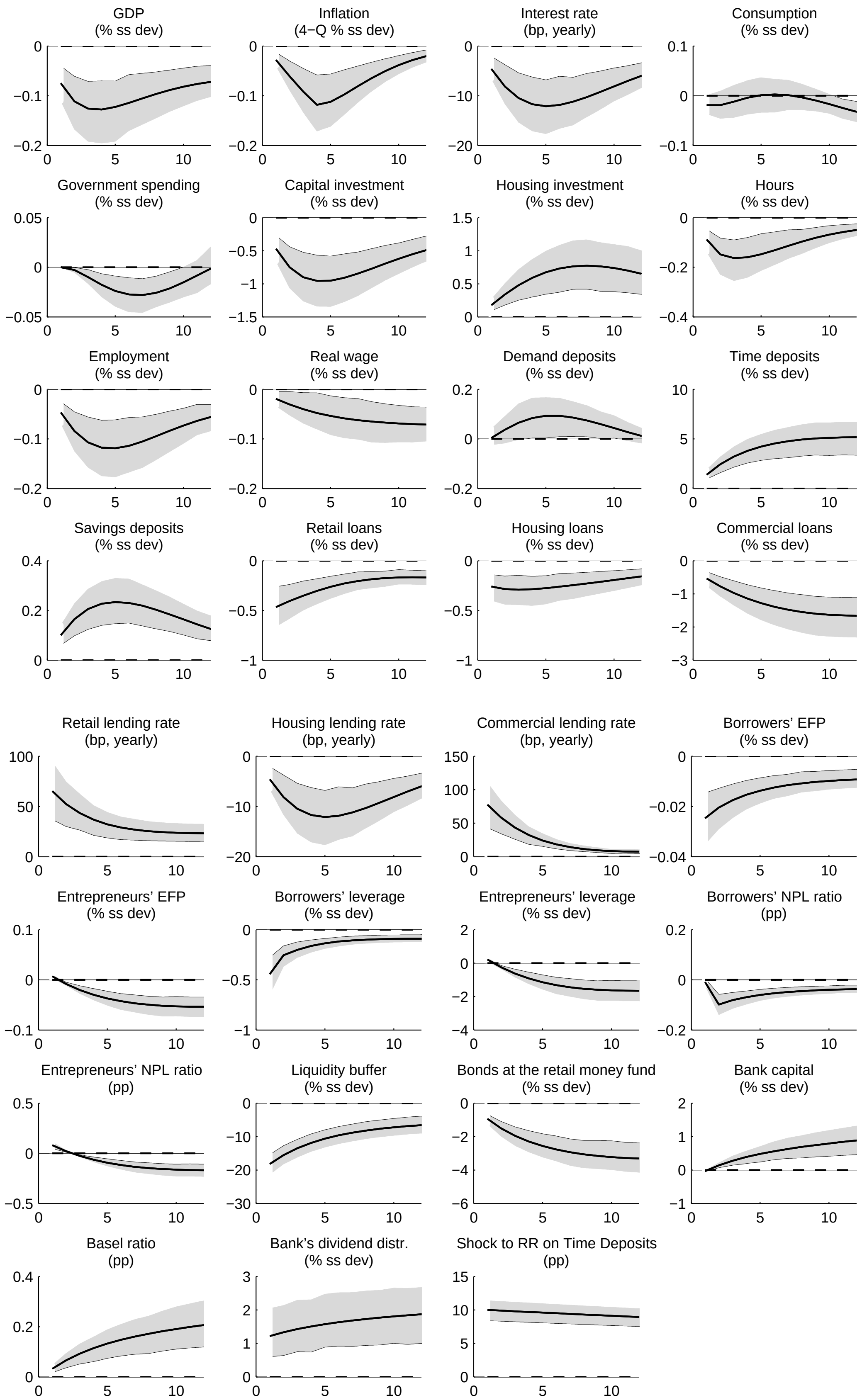


Figure 14: Shock to Reserve Requirement Ratio on Time Deposits

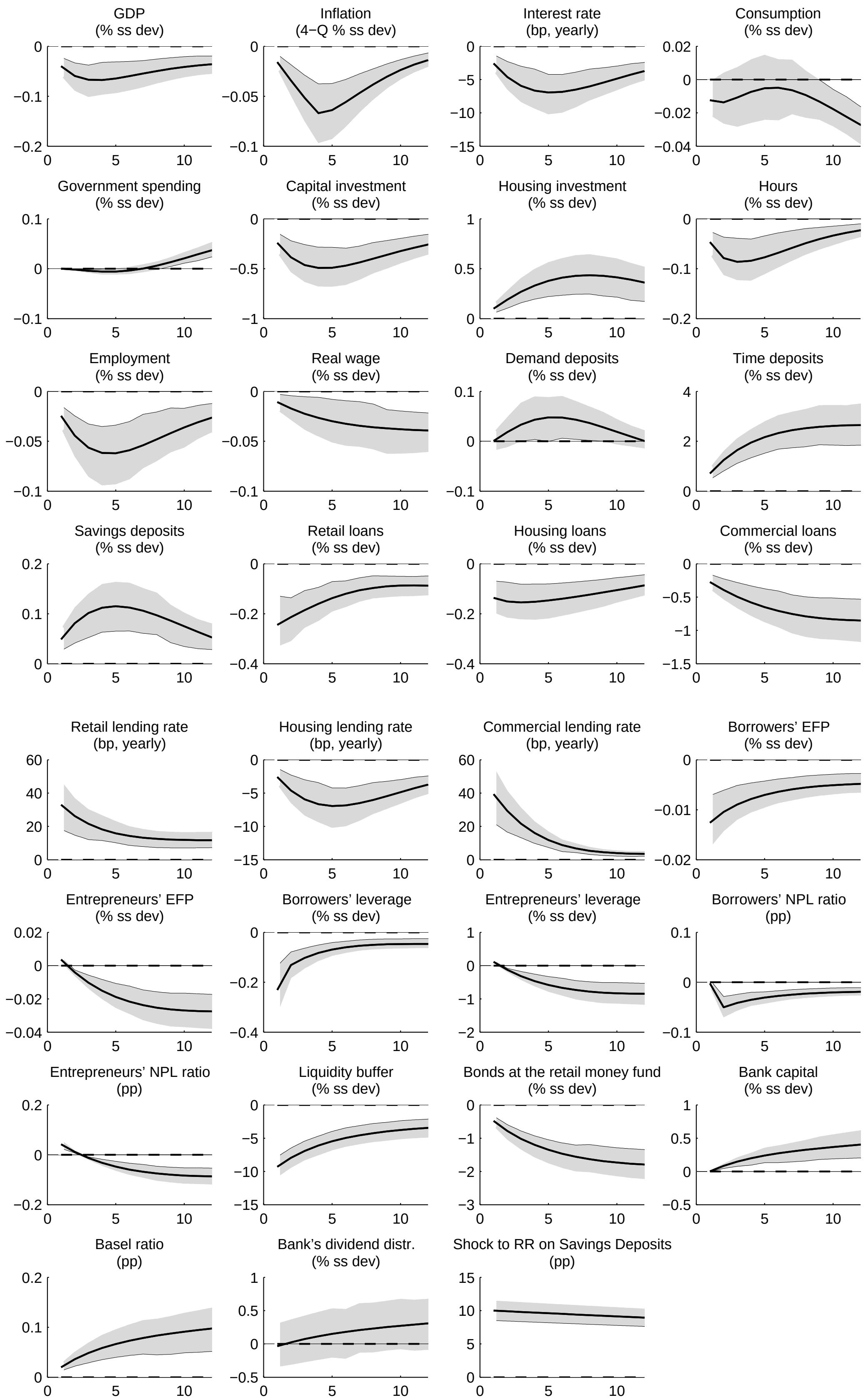


Figure 15: Shock to Reserve Requirement Ratio on Saving Deposits

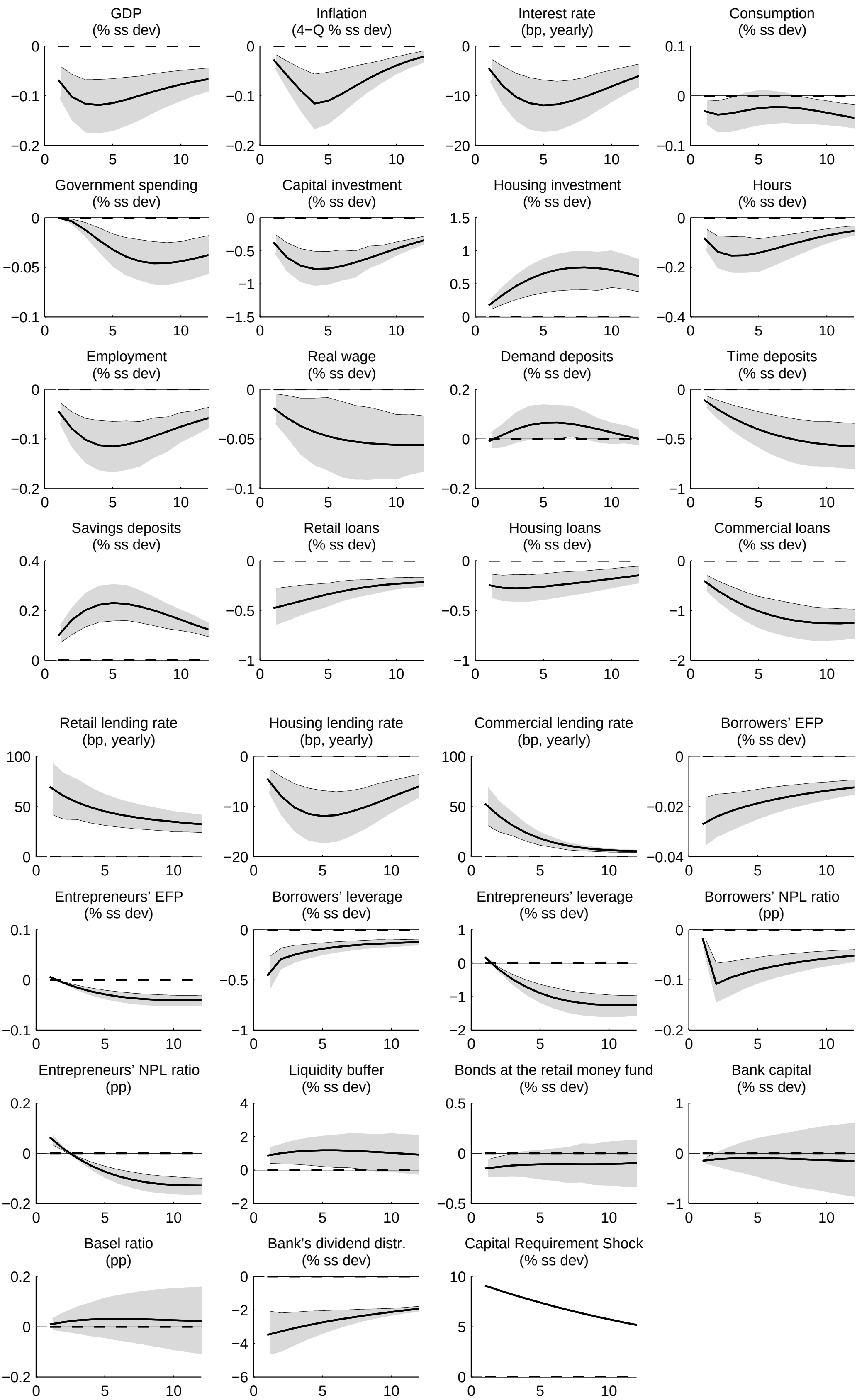


Figure 16: Capital Requirement Shock

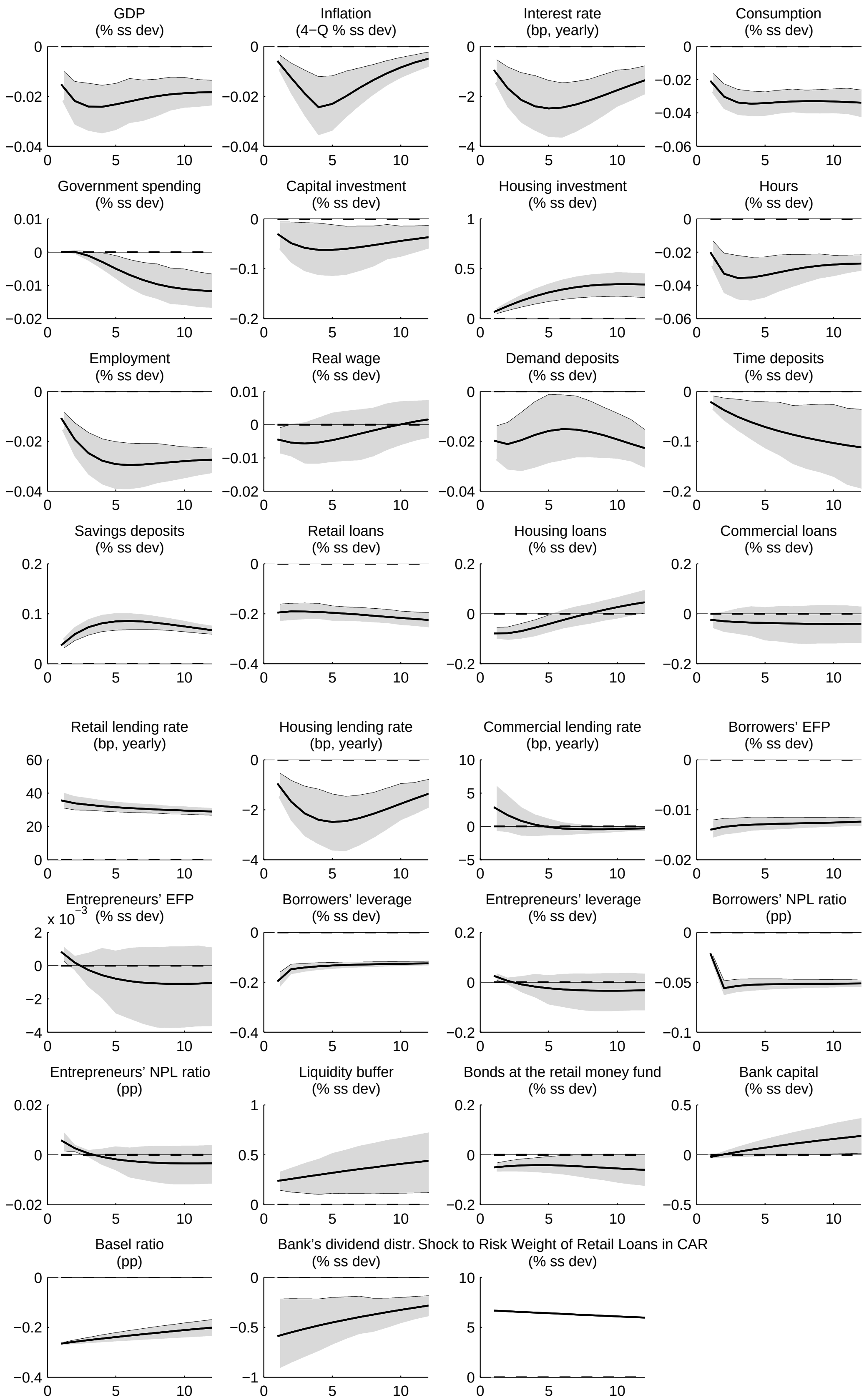


Figure 17: Sectoral Risk Weight Shock of Retail Loans in Capital Adequacy Ratio

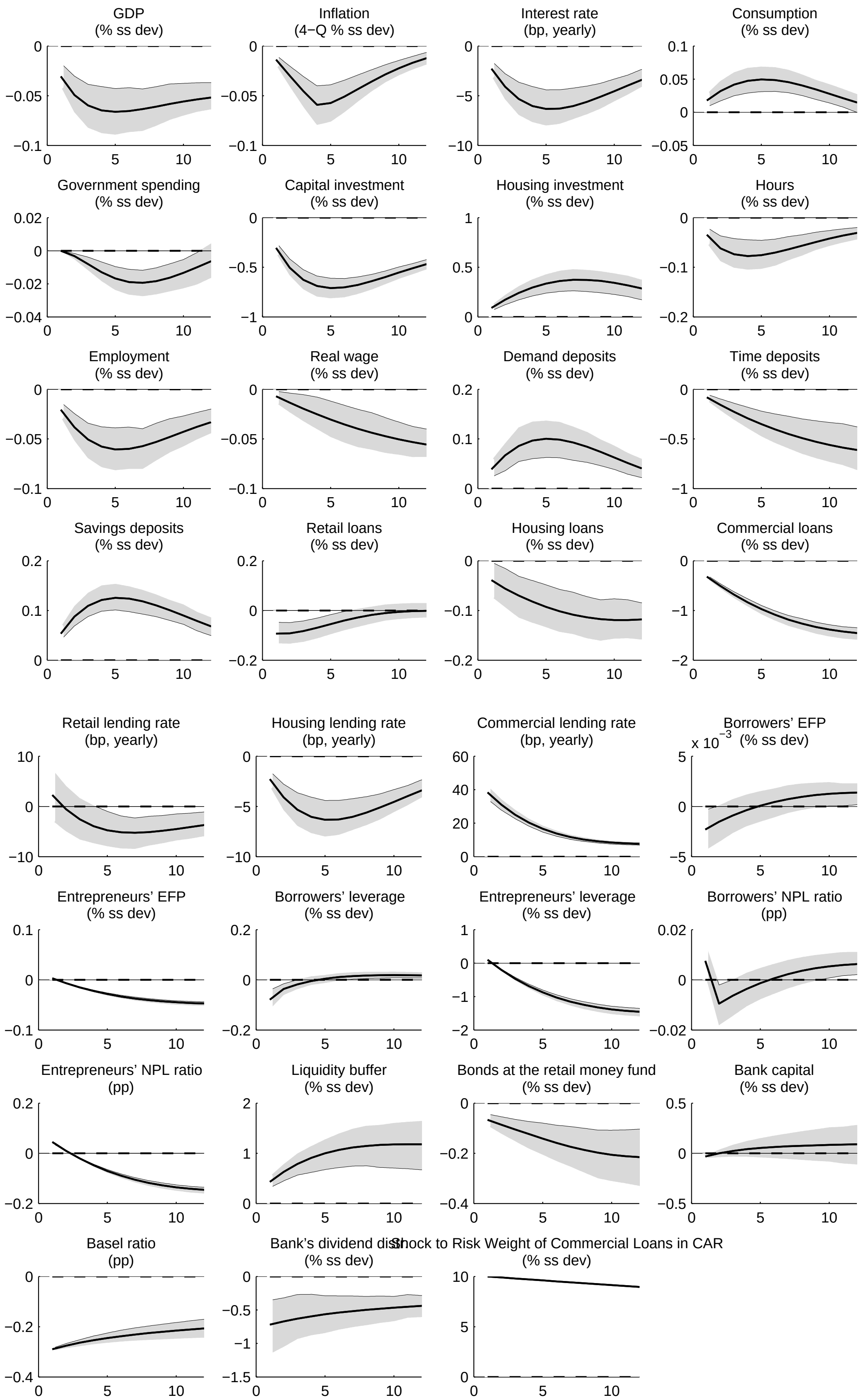


Figure 18: Sectoral Risk Weight Shock of Commercial Loans in Capital Adequacy Ratio

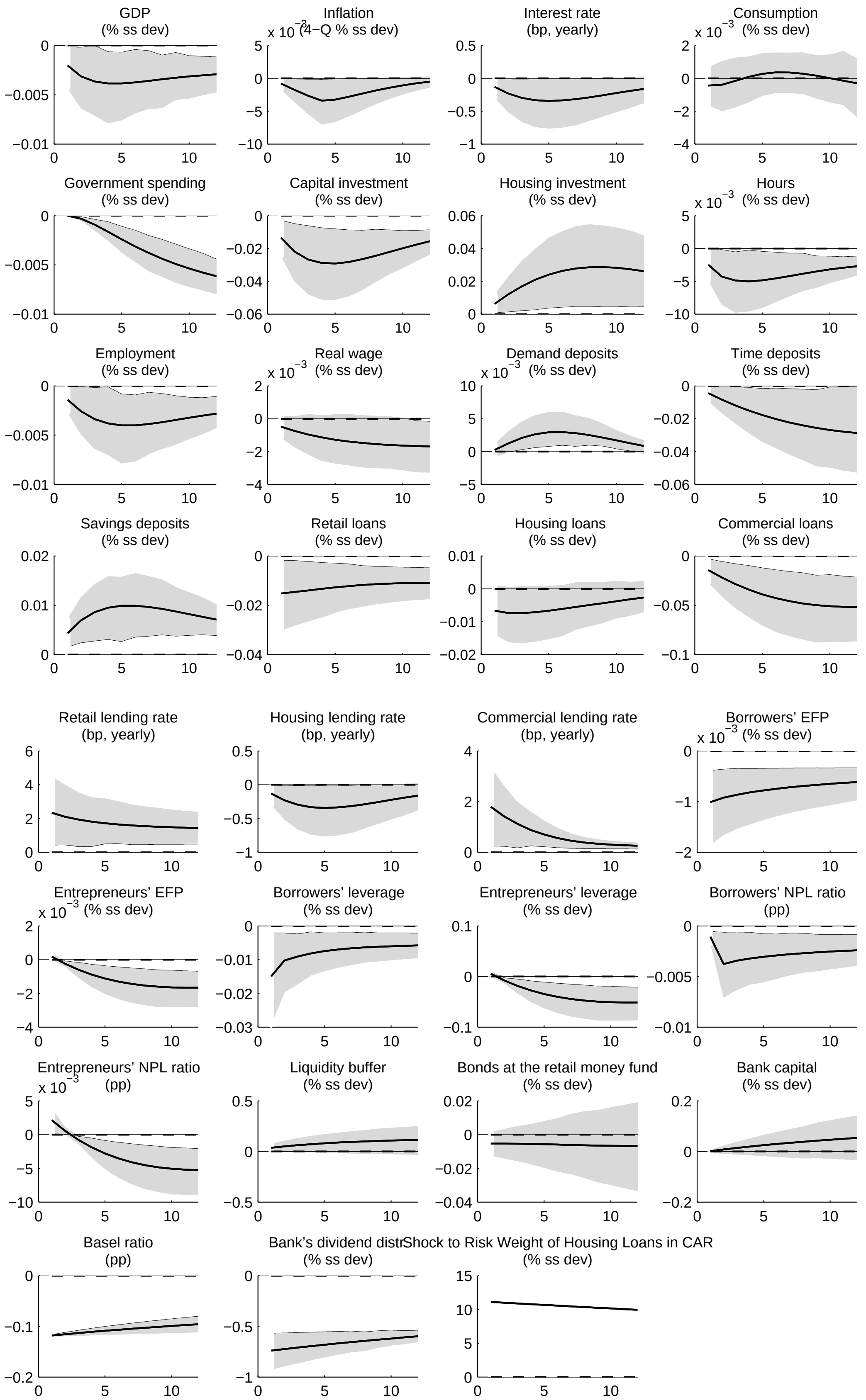


Figure 19: Sectoral Risk Weight Shock of Housing Loans in Capital Adequacy Ratio

G Reserve Requirement exercises

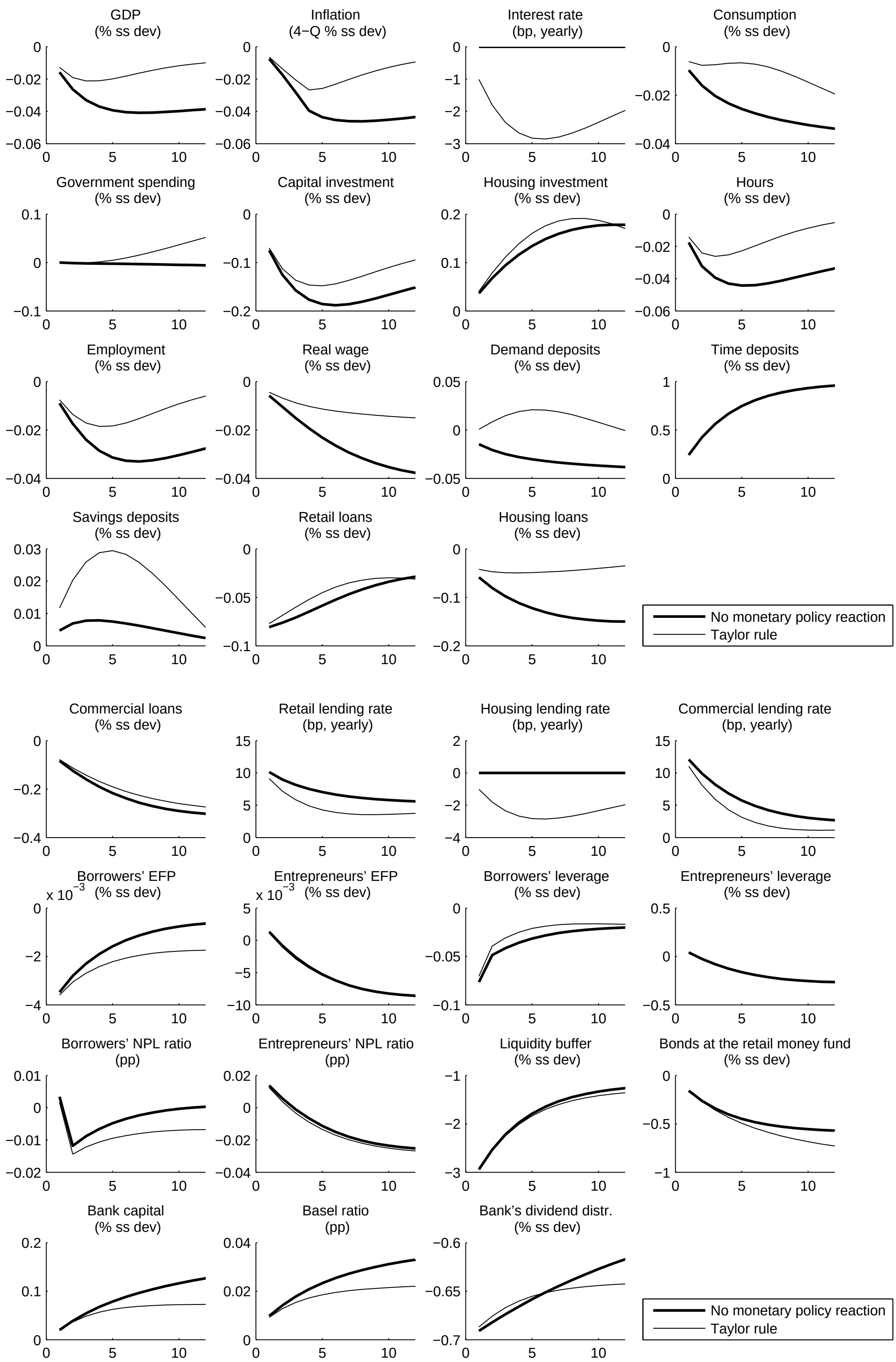


Figure 20: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Demand Deposits

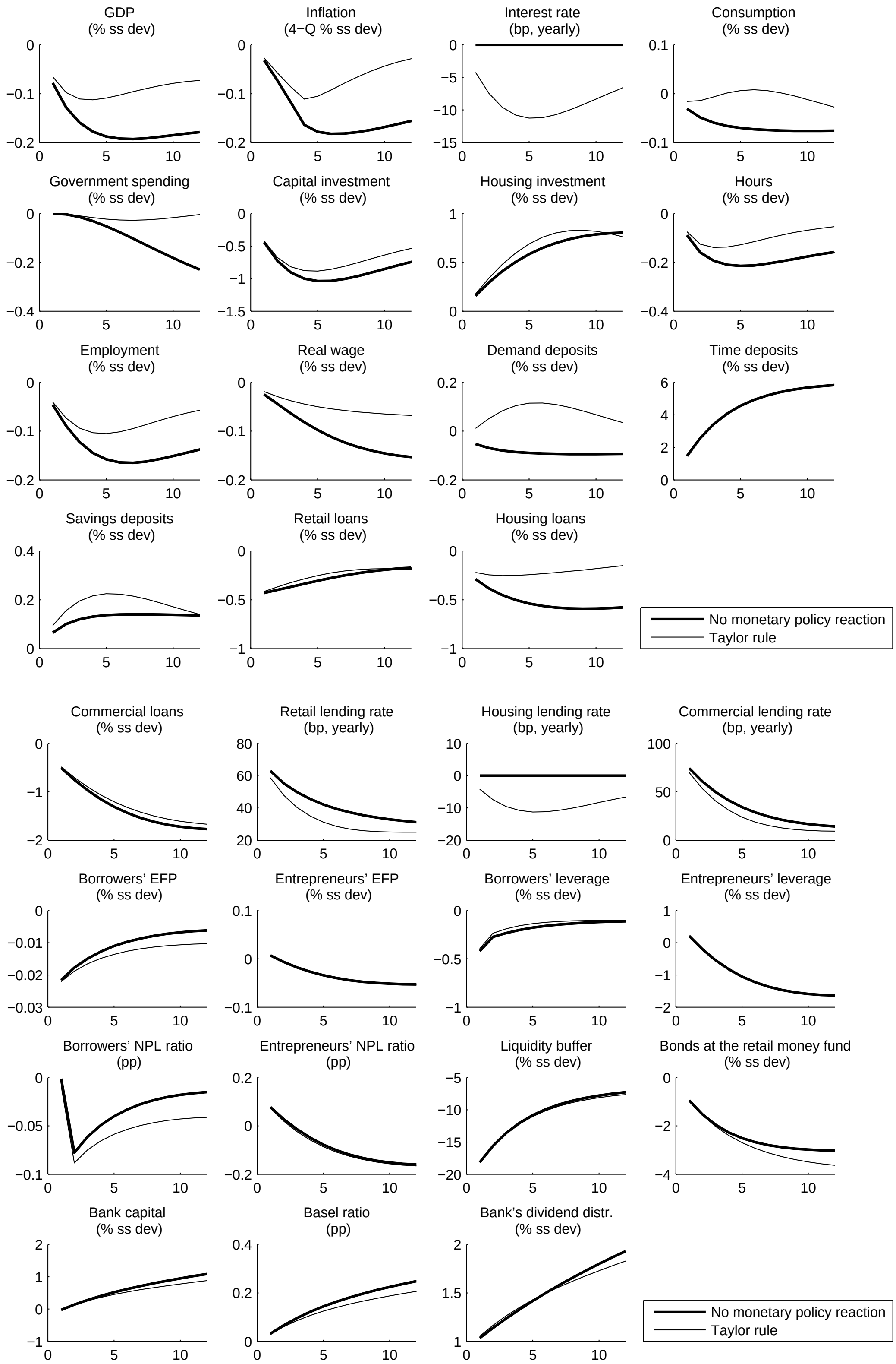


Figure 21: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Time Deposits

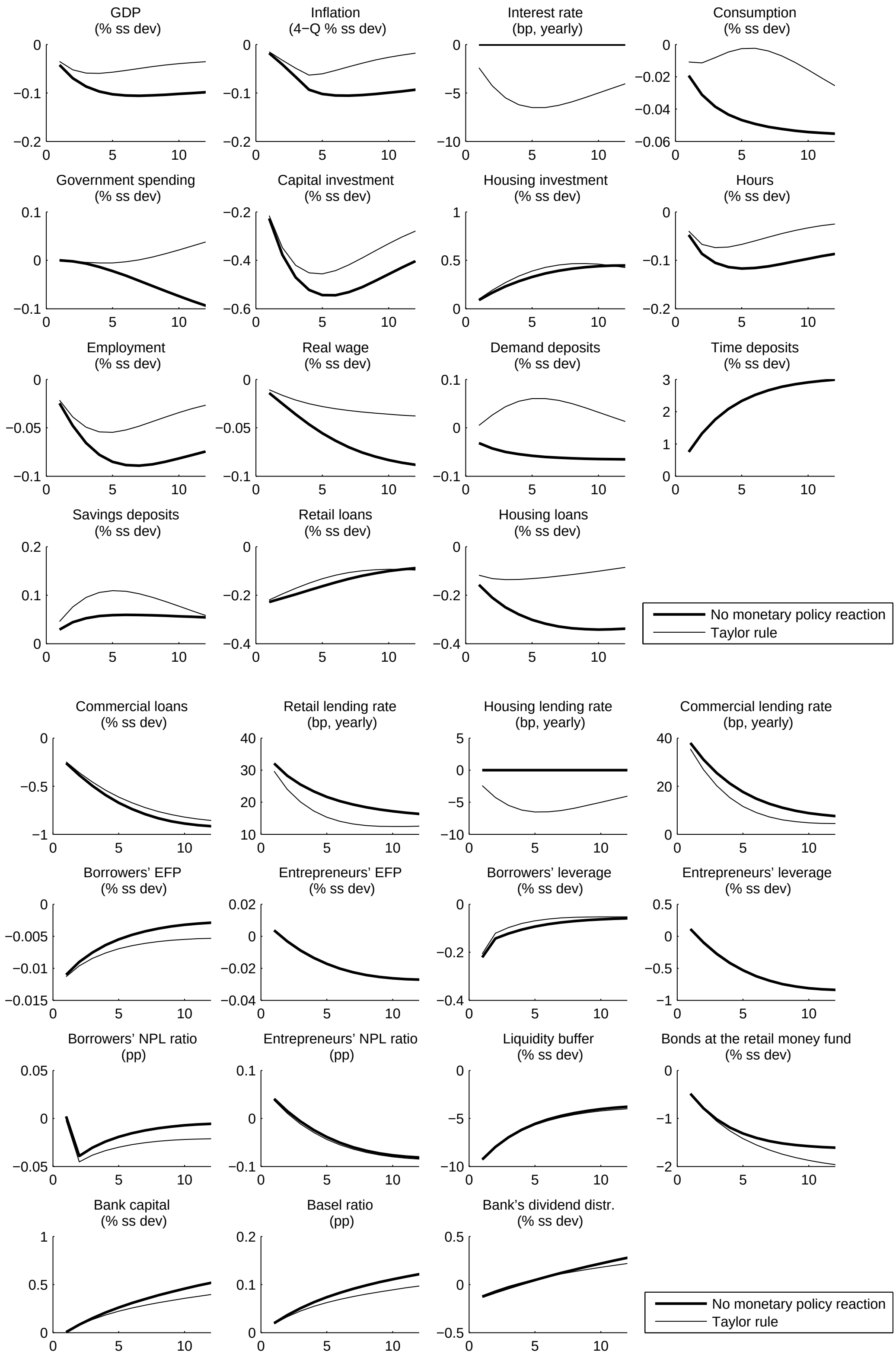


Figure 22: The role of Monetary Policy behavior on the transmission mechanisms of a shock to Reserve Requirement Ratio on Saving Deposits

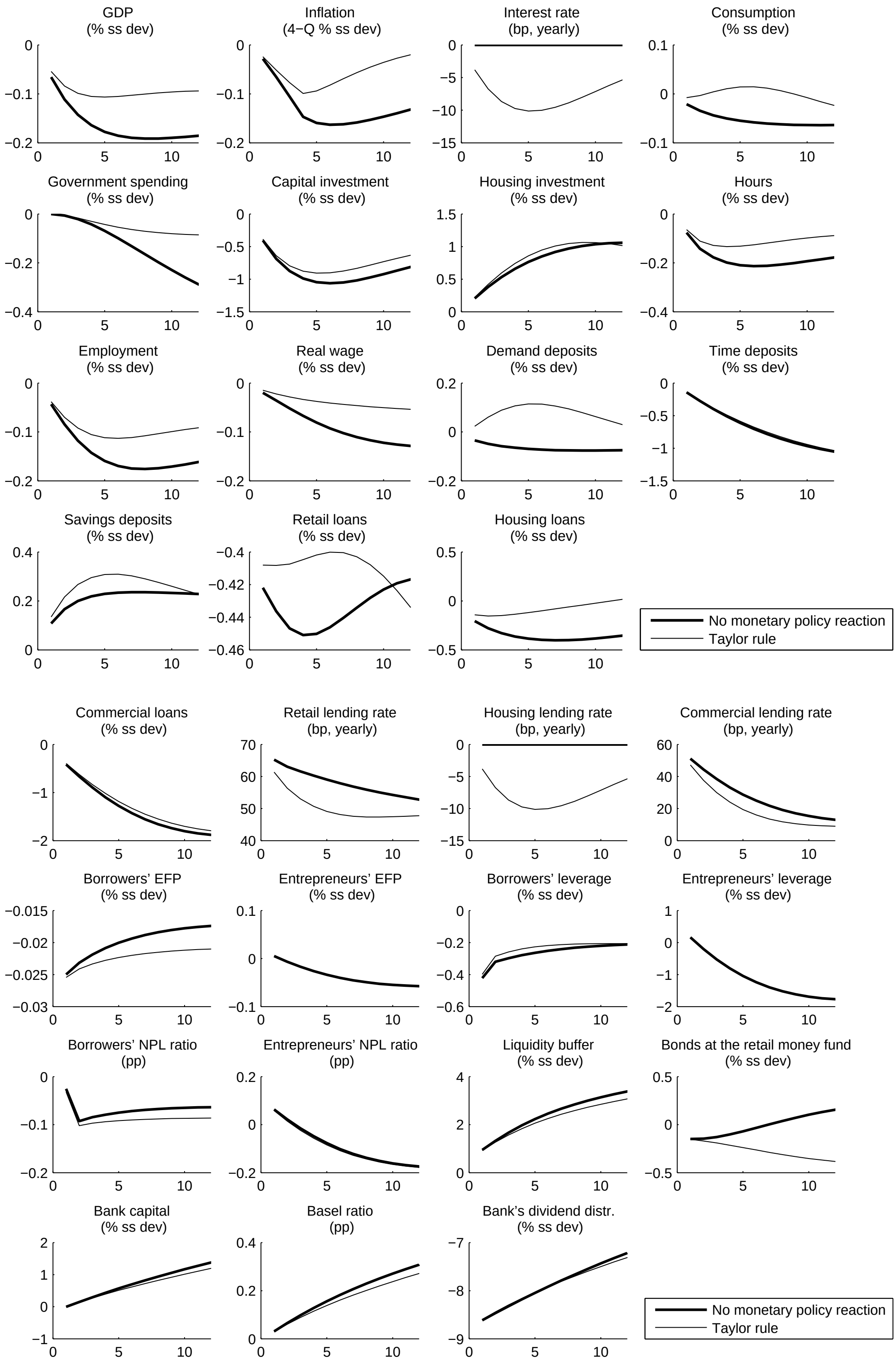


Figure 23: The role of Monetary Policy behavior on the transmission mechanisms of a Capital Requirement Shock

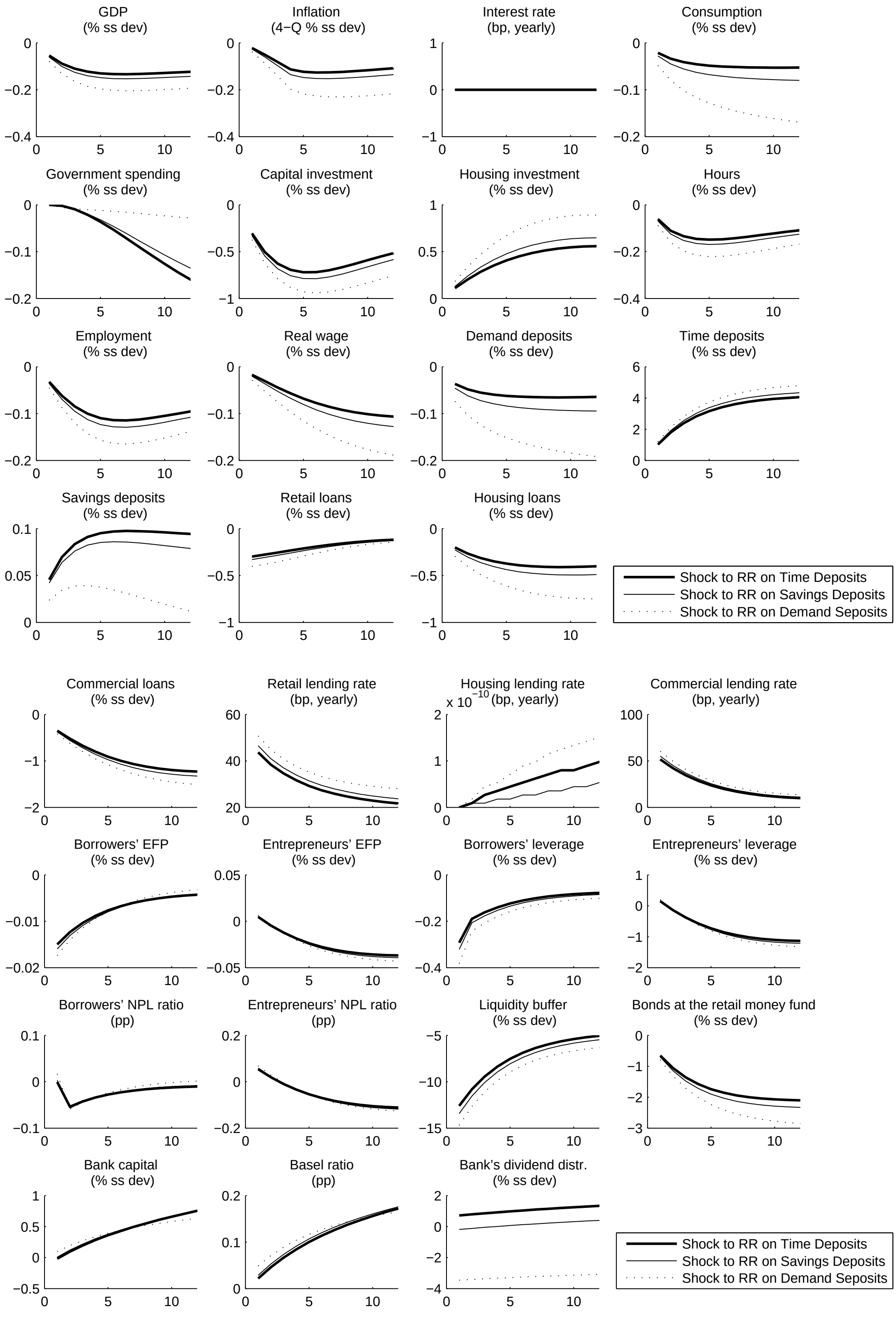


Figure 24: Comparing same scale shocks to Reserve Requirement Ratios

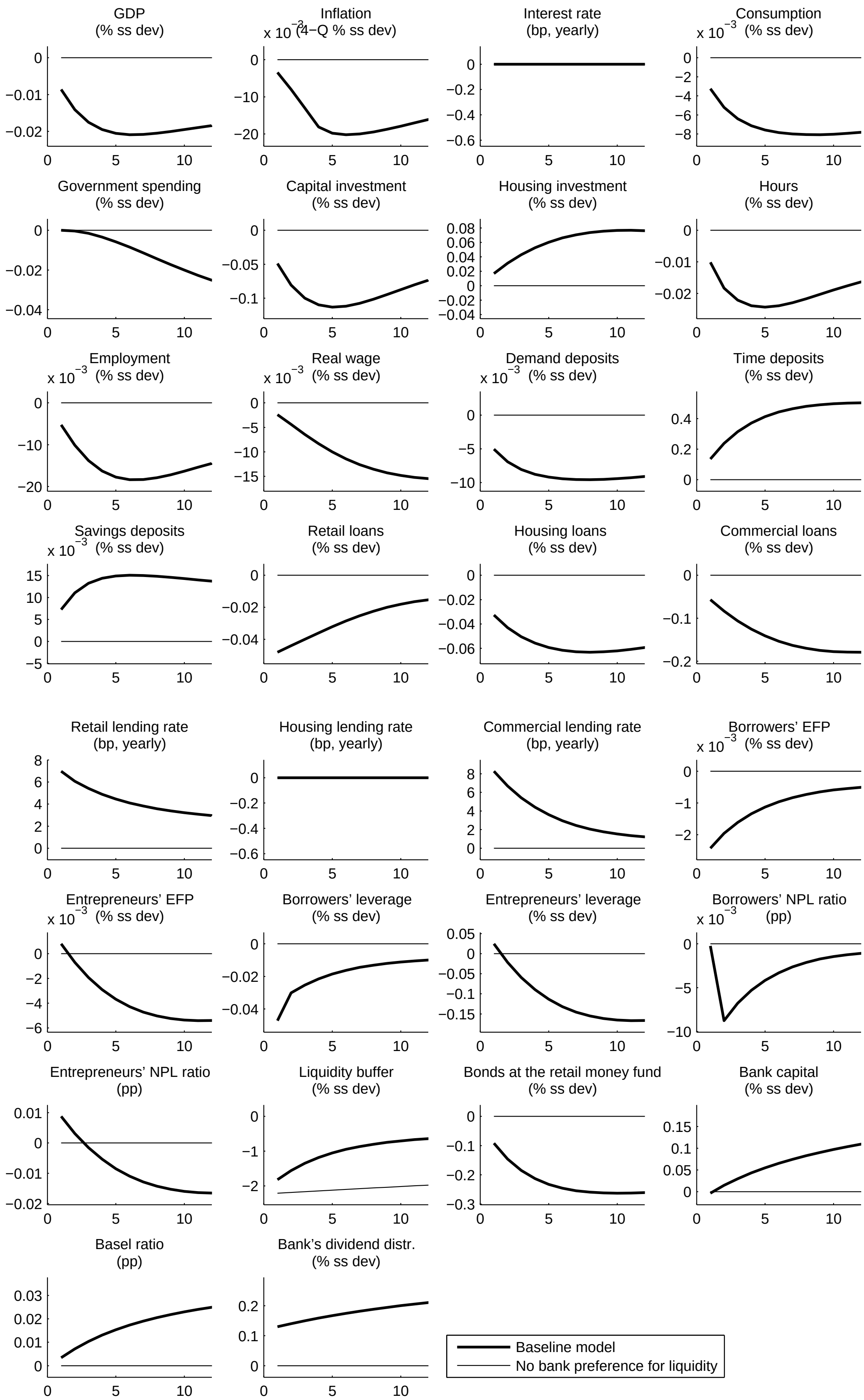


Figure 25: Reserve requirement shock on time deposits - the role of bank liquidity preference

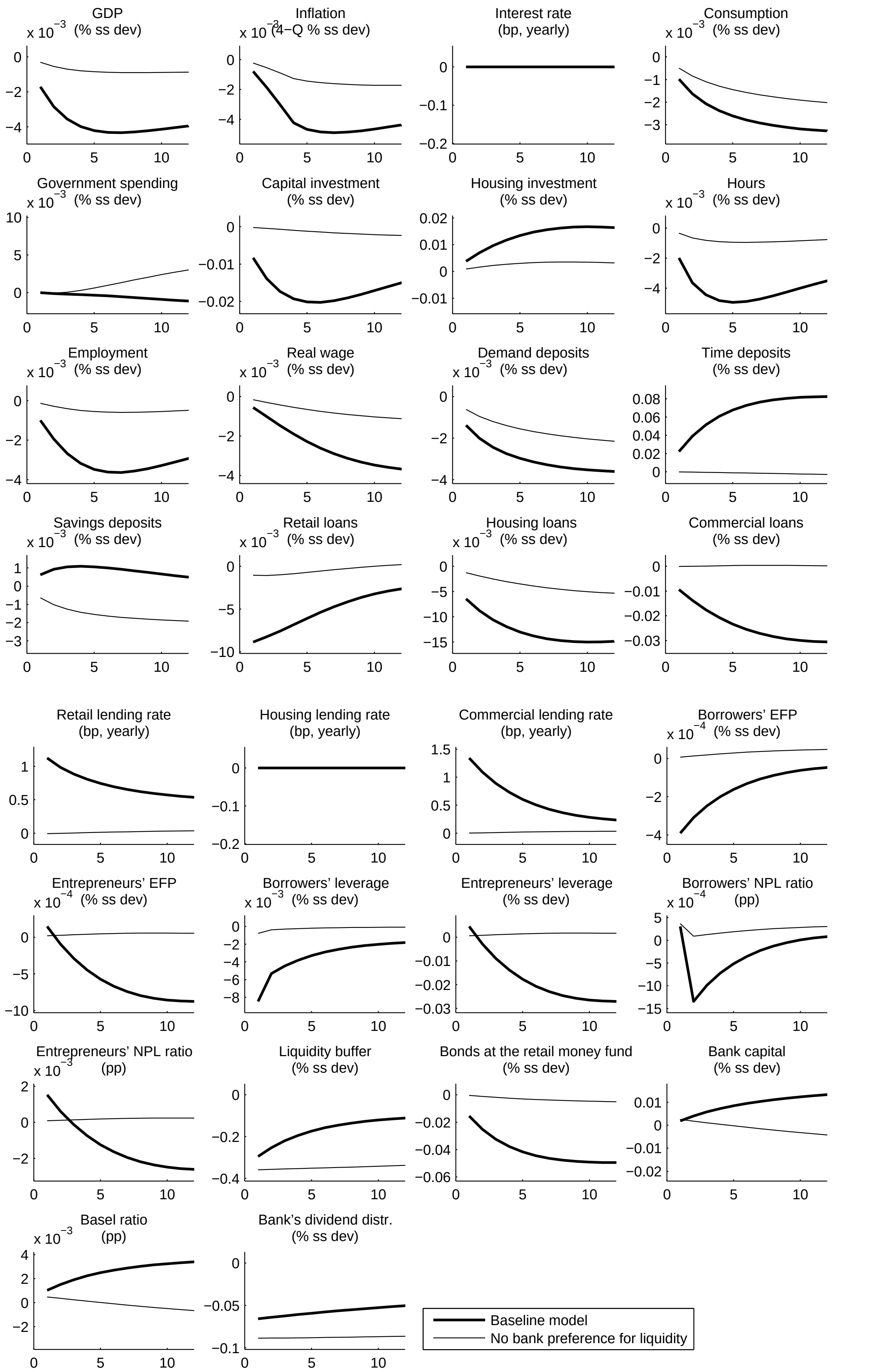


Figure 26: Reserve requirement shock on demand deposits - the role of bank liquidity preference

H Capital Requirement exercises

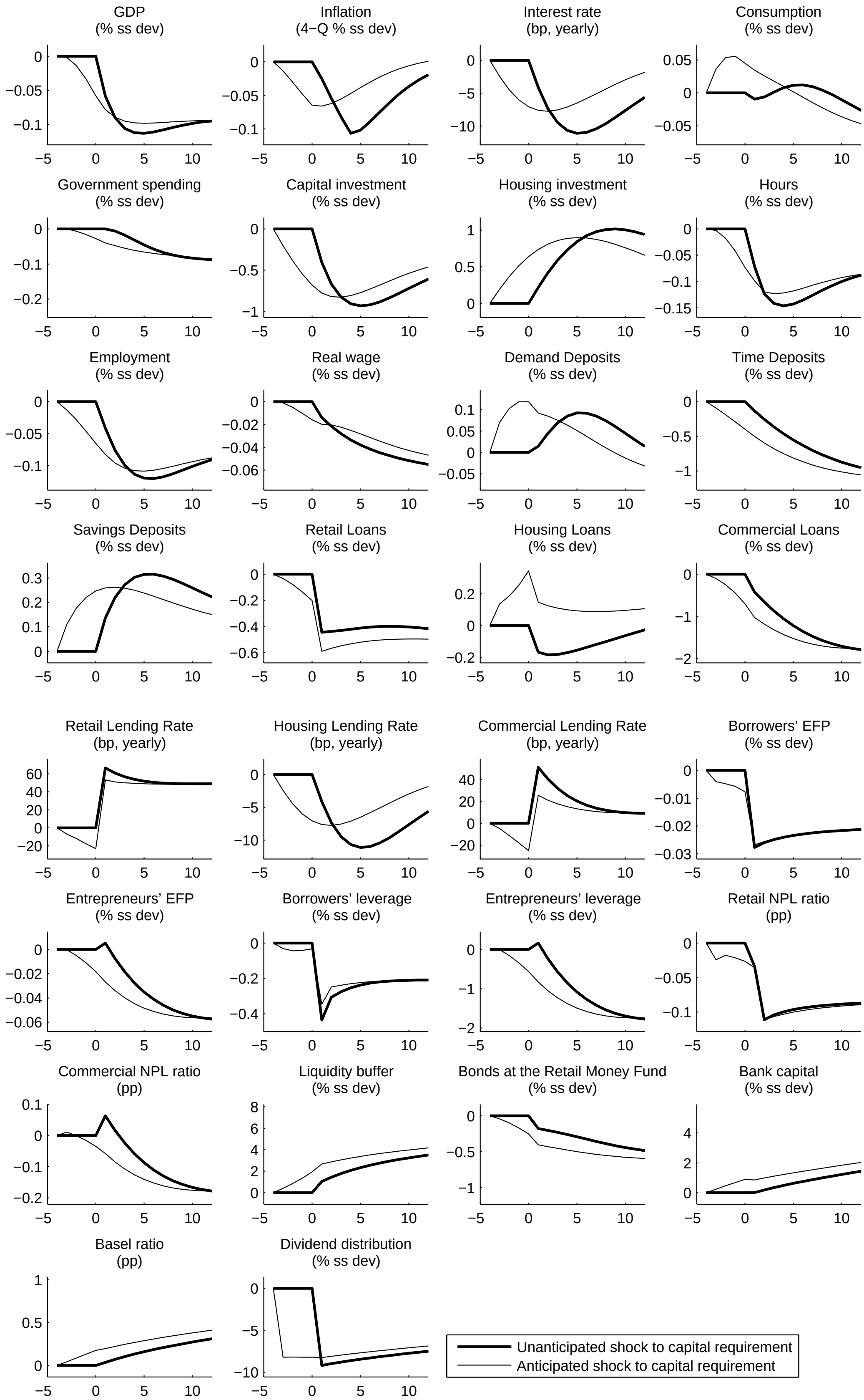


Figure 27: Anticipated x Non-anticipated capital requirement shocks

I Exercises with alternative retail loan constraints

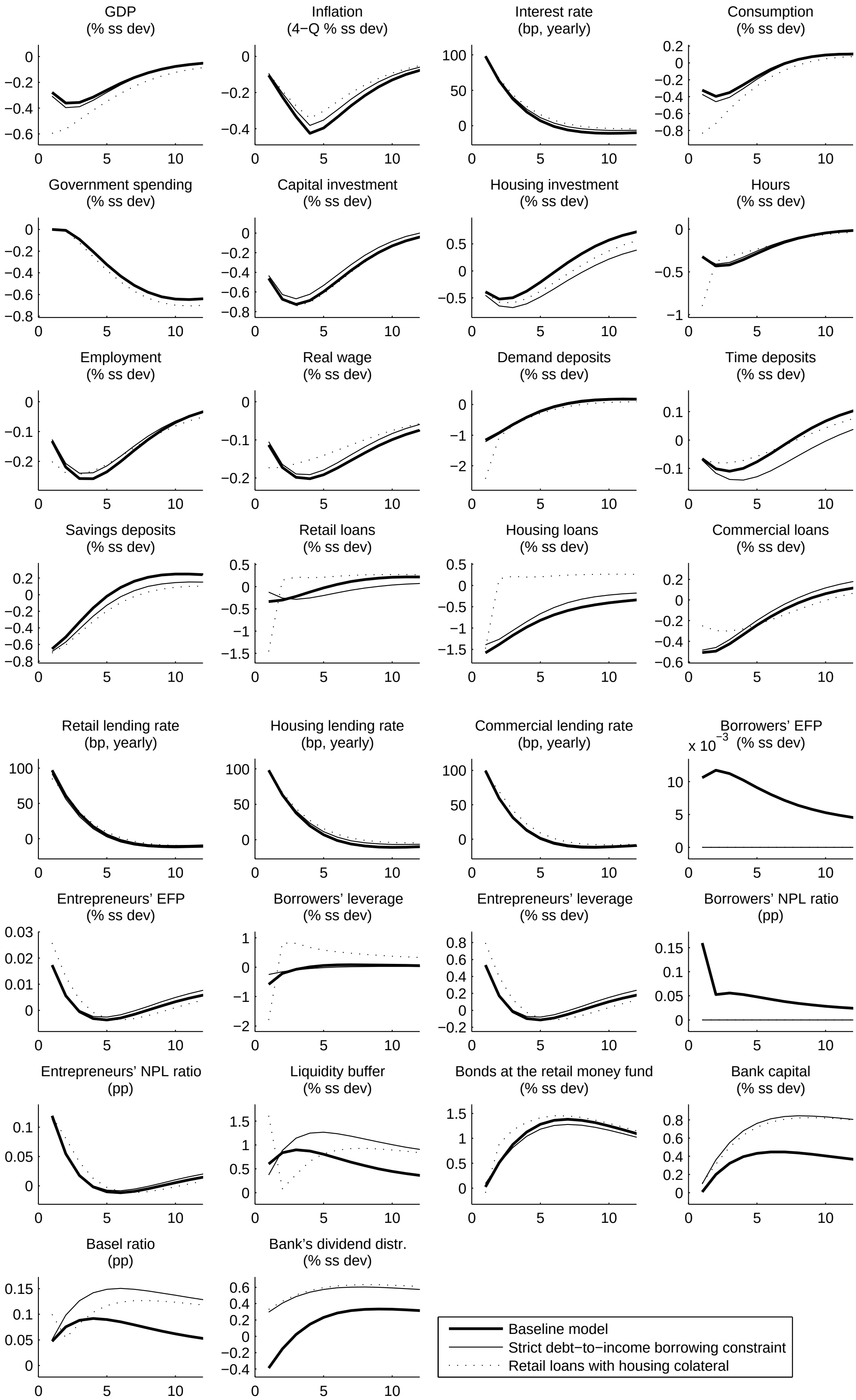


Figure 28: Monetary policy shock under alternative household borrowing constraints

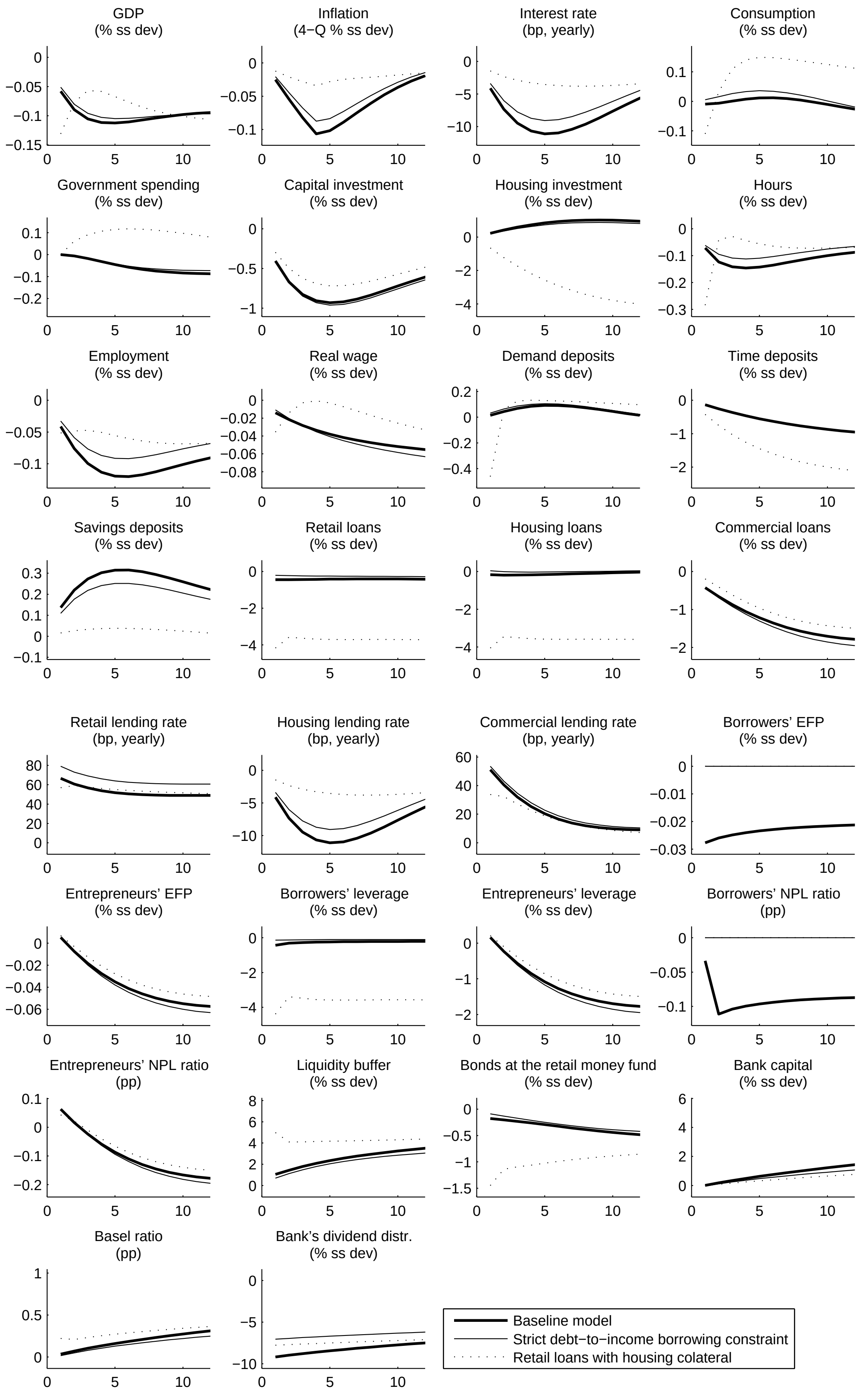


Figure 29: Unanticipated capital requirement shock under alternative household borrowing constraints

Banco Central do Brasil

Trabalhos para Discussão

Os Trabalhos para Discussão do Banco Central do Brasil estão disponíveis para download no website
http://www.bcb.gov.br/?TRABDISCLISTA

Working Paper Series

The Working Paper Series of the Central Bank of Brazil are available for download at
http://www.bcb.gov.br/?WORKINGPAPERS

297	**Avaliando a Volatilidade Diária dos Ativos: a hora da negociação importa?** *José Valentim Machado Vicente, Gustavo Silva Araújo, Paula Baião Fisher de Castro e Felipe Noronha Tavares*	Nov/2012
298	**Atuação de Bancos Estrangeiros no Brasil: mercado de crédito e de derivativos de 2005 a 2011** *Raquel de Freitas Oliveira, Rafael Felipe Schiozer e Sérgio Leão*	Nov/2012
299	**Local Market Structure and Bank Competition: evidence from the Brazilian auto loan market** *Bruno Martins*	Nov/2012
299	**Estrutura de Mercado Local e Competição Bancária: evidências no mercado de financiamento de veículos** *Bruno Martins*	Nov/2012
300	**Conectividade e Risco Sistêmico no Sistema de Pagamentos Brasileiro** *Benjamin Miranda Tabak, Rodrigo César de Castro Miranda e Sergio Rubens Stancato de Souza*	Nov/2012
300	**Connectivity and Systemic Risk in the Brazilian National Payments System** *Benjamin Miranda Tabak, Rodrigo César de Castro Miranda and Sergio Rubens Stancato de Souza*	Nov/2012
301	**Determinantes da Captação Líquida dos Depósitos de Poupança** *Clodoaldo Aparecido Annibal*	Dez/2012
302	**Stress Testing Liquidity Risk: the case of the Brazilian Banking System** *Benjamin M. Tabak, Solange M. Guerra, Rodrigo C. Miranda and Sergio Rubens S. de Souza*	Dec/2012
303	**Using a DSGE Model to Assess the Macroeconomic Effects of Reserve Requirements in Brazil** *Waldyr Dutra Areosa and Christiano Arrigoni Coelho*	Jan/2013
303	**Utilizando um Modelo DSGE para Avaliar os Efeitos Macroeconômicos dos Recolhimentos Compulsórios no Brasil** *Waldyr Dutra Areosa e Christiano Arrigoni Coelho*	Jan/2013
304	**Credit Default and Business Cycles: an investigation of this relationship in the Brazilian corporate credit market** *Jaqueline Terra Moura Marins and Myrian Beatriz Eiras das Neves*	Mar/2013

304	**Inadimplência de Crédito e Ciclo Econômico: um exame da relação no mercado brasileiro de crédito corporativo** *Jaqueline Terra Moura Marins e Myrian Beatriz Eiras das Neves*	Mar/2013
305	**Preços Administrados: projeção e repasse cambial** *Paulo Roberto de Sampaio Alves, Francisco Marcos Rodrigues Figueiredo, Antonio Negromonte Nascimento Junior e Leonardo Pio Perez*	Mar/2013
306	**Complex Networks and Banking Systems Supervision** *Theophilos Papadimitriou, Periklis Gogas and Benjamin M. Tabak*	May/2013
306	**Redes Complexas e Supervisão de Sistemas Bancários** *Theophilos Papadimitriou, Periklis Gogas e Benjamin M. Tabak*	Maio/2013
307	**Risco Sistêmico no Mercado Bancário Brasileiro – Uma abordagem pelo método *CoVaR*** *Gustavo Silva Araújo e Sérgio Leão*	Jul/2013
308	**Transmissão da Política Monetária pelos Canais de Tomada de Risco e de Crédito: uma análise considerando os seguros contratados pelos bancos e o *spread* de crédito no Brasil** *Debora Pereira Tavares, Gabriel Caldas Montes e Osmani Teixeira de Carvalho Guillén*	Jul/2013
309	**Converting the NPL Ratio into a Comparable Long Term Metric** *Rodrigo Lara Pinto Coelho and Gilneu Francisco Astolfi Vivan*	Jul/2013
310	**Banks, Asset Management or Consultancies' Inflation Forecasts: is there a better forecaster out there?** *Tito Nícias Teixeira da Silva Filho*	Jul/2013
311	**Estimação não-paramétrica do risco de cauda** *Caio Ibsen Rodrigues Almeida, José Valentim Machado Vicente e Osmani Teixeira de Carvalho Guillen*	Jul/2013
312	**A Influência da Assimetria de Informação no Retorno e na Volatilidade das Carteiras de Ações de Valor e de Crescimento** *Max Leandro Ferreira Tavares, Claudio Henrique da Silveira Barbedo e Gustavo Silva Araújo*	Jul/2013
313	**Quantitative Easing and Related Capital Flows into Brazil: measuring its effects and transmission channels through a rigorous counterfactual evaluation** *João Barata R. B. Barroso, Luiz A. Pereira da Silva and Adriana Soares Sales*	Jul/2013
314	**Long-Run Determinants of the Brazilian Real: a closer look at commodities** *Emanuel Kohlscheen*	Jul/2013
315	**Price Differentiation and Menu Costs in Credit Card Payments** *Marcos Valli Jorge and Wilfredo Leiva Maldonado*	Jul/2013
315	**Diferenciação de Preços e Custos de Menu nos Pagamentos com Cartão de Crédito** *Marcos Valli Jorge e Wilfredo Leiva Maldonado*	Jul/2013

316	**Política Monetária e Assimetria de Informação: um estudo a partir do mercado futuro de taxas de juros no Brasil** *Gustavo Araújo, Bruno Vieira Carvalho, Claudio Henrique Barbedo e Margarida Maria Gutierrez*	Jul/2013
317	**Official Interventions through Derivatives: affecting the demand for foreign exchange** *Emanuel Kohlscheen and Sandro C. Andrade*	Jul/2013
318	**Assessing Systemic Risk in the Brazilian Interbank Market** *Benjamin M. Tabak, Sergio R. S. Souza and Solange M. Guerra*	Jul/2013
319	**Contabilização da Cédula de Produto Rural à Luz da sua Essência** *Cássio Roberto Leite Netto*	Jul/2013
320	**Insolvency and Contagion in the Brazilian Interbank Market** *Sergio R. S. Souza, Benjamin M. Tabak and Solange M. Guerra*	Aug/2013
321	**Systemic Risk Measures** *Solange Maria Guerra, Benjamin Miranda Tabak, Rodrigo Andrés de Souza Penaloza and Rodrigo César de Castro Miranda*	Aug/2013
322	**Contagion Risk within Firm-Bank Bivariate Networks** *Rodrigo César de Castro Miranda and Benjamin Miranda Tabak*	Aug/2013
323	**Loan Pricing Following a Macro Prudential Within-Sector Capital Measure** *Bruno Martins and Ricardo Schechtman*	Aug/2013
324	**Inflation Targeting and Financial Stability: A Perspective from the Developing World** *Pierre-Richard Agénor and Luiz A. Pereira da Silva*	Sep/2013
325	**Teste da Hipótese de Mercados Adaptativos para o Brasil** *Glener de Almeida Dourado e Benjamin Miranda Tabak*	Set/2013
326	**Existência de equilíbrio num jogo com bancarrota e agentes heterogêneos** *Solange Maria Guerra, Rodrigo Andrés de Souza Peñaloza e Benjamin Miranda Tabak*	Out/2013
327	**Celeridade do Sistema Judiciário e Créditos Bancários para as Indústrias de Transformação** *Jacopo Ponticelli e Leonardo S. Alencar*	Out/2013
328	**Mercados Financeiros Globais – Uma Análise da Interconectividade** *Marcius Correia Lima Filho, Rodrigo Cesar de Castro Miranda e Benjamin Miranda Tabak*	Out/2013
329	**Is the Divine Coincidence Just a Coincidence? The Implications of Trend Inflation** *Sergio A. Lago Alves*	Oct/2013
330	**Forecasting Multivariate Time Series under Present-Value-Model Short- and Long-run Co-movement Restrictions** *Osmani Teixeira de Carvalho Guillén, Alain Hecq, João Victor Issler and Diogo Saraiva*	Oct/2013
331	**Measuring Inflation Persistence in Brazil Using a Multivariate Model** *Vicente da Gama Machado and Marcelo Savino Portugal*	Nov/2013

332	**Does trade shrink the measure of domestic firms?** *João Barata R. B. Barroso*	Nov/2013
333	**Do Capital Buffers Matter? A Study on the Profitability and Funding Costs Determinants of the Brazilian Banking System** *Benjamin Miranda Tabak, Denise Leyi Li, João V. L. de Vasconcelos and Daniel O. Cajueiro*	Nov/2013
334	**Análise do Comportamento dos Bancos Brasileiros Pré e Pós-Crise Subprime** *Osmani Teixeira de Carvalho Guillén, José Valentim Machado Vicente e Claudio Oliveira de Moraes*	Nov/2013
335	**Why Prudential Regulation Will Fail to Prevent Financial Crises. A Legal Approach** *Marcelo Madureira Prates*	Nov/2013