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The 2007-8 world financial crisis highlighted the deficiency of the regulatory framework in place at the time. Thenceforth many papers have been assessing the introduction of macroprudential policy in a DSGE model. However, they do not focus on the choice of the variable to which the macroprudential instrument must respond - the anchor variable. In order to fulfil this gap, we input different macroprudential rules into the DSGE with a banking sector proposed by Gerali et al. (2010), and estimate its key parameters using Bayesian techniques applied to Brazilian data. We then rank the results using the unconditional expectation of lifetime utility as of time zero as the measure of welfare: the larger the welfare, the better the anchor variable. We find that credit growth is the variable that performs best.

Keywords: Macroprudential Policy; Basel III; Capital Buffer; Anchor Variable.

JEL Codes: E3; E5.

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1 Introduction

The 2007-8 world financial crisis highlighted the deficiency of the regulatory framework in place back then. Several observers attribute this episode to the lack of a macroprudential approach to regulation. While a microprudential approach intends to avoid individual financial institution failure, a macroprudential approach aims to preserve the financial system as a whole (Hanson et al., 2011). In this (not so new[1]) approach, risk can no longer be seen as exogenous, independent of individual agents' behavior, and becomes endogenous, dependent on collective behavior (Borio, 2003). Thus some practices that seem prudent from a micro perspective should be inhibited when a macro perspective is taken.

According to the Basel Committee, one of the main reasons behind the deepening of the recent financial and economic crisis was the excessive leverage of the banking sector. This was accompanied by a destruction of capital that, together with insufficient liquidity buffers, hampered the absorption of losses by the banking sector. Furthermore, the crisis was amplified by a procyclical deleveraging process and by the interconnectedness of the financial system spreading to the real economy (Basel Comittee on Banking Supervision, 2010a).

With the purpose of addressing the market failures exposed during the crisis, the Basel Committee has been introducing some fundamental reforms. The name given to this broad set of reform measures is Basel III. They seek to strengthen the regulation, supervision and risk management of the banking sector (Basel Comittee on Banking Supervision, 2010). Regarding the time series dimension (the procyclicality of risk), the Basel Committee suggests the construction of a capital buffer in "good times" that can absorb unexpected losses in periods of economic stress when the buffer has to be released without delay. This countercyclical capital buffer still offers the additional benefit of moderating credit growth in "good times" , by raising its cost (Basel Comittee on Banking Supervision, 2010a).

Concomitantly, many papers have assessed the introduction of macroprudential policy in a DSGE model. Nevertheless, most of them focus on the interaction of macroprudential and monetary policies without delving into the macroprudential policy itself (e.g., Angelini et al. (2012), Agénor et al. (2011), Kannan et al. (2012), Quint and Rabanal (2014), Suh (2012), Cecchetti and Kohler (2014)).

On the other hand, Drehmann et al. (2011) use a Signal Extraction Method to investigate the performance of different variables as anchors for setting the level of the countercyclical regulatory capital buffer requirements for banks. In their view, these anchors

[1]Clement (2010) points out that the term "macroprudential" can be found in unpublished documents prepared in the late 1970s by the Cooke Committee. However, only in the 1980s public references to macroprudential policy came up to prominence (Galati and Moessner, 2011).

are best used as leading indicators for boom periods, when the capital requirement should be increased, and coincident indicators for credit crunches, when it should be released almost immediately.

Drehmann et al. (2011) conclude that the best leading indicator is credit-to-GDP gap, whereas the best coincident indicator is banking spread. Still, the Basel Committee suggests the use of credit-to-GDP gap as an anchor variable for both periods. However, Repullo and Saurina (2011) argue that the use of such variable may exacerbate procyclicality inherent in the financial system and recommend the use of output growth.

To our knowledge, there are no papers that utilize a DSGE model to inquire into the effects of different anchors in the countercyclical capital requirement rule (from now on just macroprudential rule) on some important macroeconomic variables. The available studies simply take a given rule for granted, and then proceed to the step where they evaluate its effects and relationship to monetary policy.

In order to fulfil this gap and to bring together the two literatures, we input different macroprudential rules into the DSGE proposed by Gerali et al. (2010), which has helpful features for our purpose. First, it incorporates an imperfectly competitive banking sector and its interaction with the real economy. Second, it is estimated, which allow us to recover the parameters driving the banking dynamics (Angelini et al., 2012).

With the aim of comparing alternative macroprudential rules, we analyse the welfare-maximizing optimal policy using the second order approximation of the equilibrium as in Schmitt-Grohe and Uribe (2007). We measure welfare as the unconditional expectation of lifetime utility as of time zero, and then we rank the results: the larger the welfare, the better the anchor variable.

Credit growth is the variable that performs best. This variable is the most effective in reducing the transmission of the higher costs banks face after a capital destruction to the interest rate and hence in slowing down the weakening in demand for credit.

Since DSGE models can be used to analyse and understand the mechanisms through which exogenous shocks (e.g., destruction of bank capital) are transmitted to the real economy, how macro variables react to aggregate shocks and the transmission channels of different economic policies, we believe that it is important to complement the analysis made by Drehmann et al. (2011) addressing the choice of the anchor variable in a DSGE (Basel Comittee on Banking Supervision, 2012).

The model is estimated for the Brazilian economy. Brazil is an important emerging market and it is an interesting case study for the issues raised in this paper. Brazil has been an early adopter of macroprudential tools and has been widely recognized by its prompt reaction to the 2007-8 financial turmoil (International Monetary Fund, 2013). Moreover, there are few papers that measure the impact of macroprudential policy on the Brazilian economy using DSGE models: Kanczuk (2013), Carvalho et al. (2013) and Carvalho and

Castro (2015).

The rest of the paper is organized as follows. Section 2 describes the model. In Section 3 we describe the data and we present the results of the estimation. Section 4 presents the application and the welfare analysis. Section 5 concludes.

2 Model

We take the DSGE model developed in Gerali et al. (2010) as the reference for our analysis. Angelini et al. (2012) have already introduced a macroprudential rule in this model, but they do not focus on the choice of the anchor variable.

Gerali et al. (2010) add monopolistically competitive banks to a model with credit frictions and borrowing constraints as in Iacoviello (2005) and a set of real and nominal frictions as in Christiano et al. (2005) and Smets and Wouters (2003). It fits well to Brazil because there is evidence that Brazilian banks are positioned somewhere between perfect competition and cartel arrangement showing some market power (Nakane, 2002).

The economy is populated by patient and impatient households, and by entrepreneurs. Patient households deposit their savings in banks. Impatient households and entrepreneurs borrow, subject to a binding collateral constraint. All households consume, work and accumulate housing, while entrepreneurs produce consumer and investment goods using capital and labor as inputs.

Banks set interest rates on deposits and on loans in order to maximize profits. Their assets include loans to firms and to households, and their liabilities are deposits and capital. Banks also face a balance-sheet constraint: there is a target for capital-to-assets ratio they have to observe. This target (set at a fixed level in Gerali et al. (2010)) is precisely our macroprudential instrument.

We reproduce here only the key equations for the complete understanding of the way macroprudential policy operates. For a detailed description of the model see Gerali et al. (2010).

2.1 Agents

Households consume, work and accumulate housing. The heterogeneity in agents' discount factors generates positive financial flows in equilibrium. Patient households have larger discount factors and will be net savers in equilibrium whereas impatient households will be net borrowers in equilibrium. Households provide differentiated labor types, sold by unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogeneous labor to entrepreneurs. Nominal wages are set by unions to which workers belong.

The representative patient household i maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\varepsilon_t^z log(c_t^P(i) - a^P c_{t-1}^P) + \varepsilon_t^h log h_t^P(i) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right] \tag{1}$$

which depends on individual current consumption $c_t^P(i)$, lagged aggregate consumption c_t^P, housing $h_t^P(i)$ and hours worked $l_t^P(i)$. The parameters a^P and ϕ measure, respectively, the degree of external habit formation and the inverse Frisch elasticity of labor supply. The budget constraint (in real terms) must be met:

$$c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) \leq w_t^P l_t^P(i) + (1+r_{t-1}^d)\frac{d_{t-1}^P}{\pi_t} + t_t^P(i) \tag{2}$$

where q_t^h is the real house price, d_t^P are the deposits, r_t^d is the interest rate on last period deposits, w_t^P is the real wage, π_t is the gross inflation and t_t^P are the lump-sum transfers that include a labor union membership net fee and dividends from firms and banks (of which patient households are the only owners).

The optimal choice between consumption and savings is given by the following equation:

$$\frac{(1-a^P)\varepsilon_t^z}{c_t^P - a^P c_{t-1}^P} = \beta_P E_t \left[\frac{(1-a^p)\varepsilon_{t+1}^z}{c_{t+1}^P - a^P c_t^P} \frac{1+r_t^d}{\pi_{t+1}} \right] \tag{3}$$

which depends on the return on deposits.

The representative impatient household i maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[(1-a^I)\varepsilon_t^z log(c_t^I(i) - a^I c_{t-1}^I) + \varepsilon_t^h log h_t^I(i) - \frac{l_t^I(i)^{1+\phi}}{1+\phi} \right] \tag{4}$$

with no change beyond the superscript that indexes the type of agent. The following budget constraint must be met:

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + (1+r_{t-1}^{bH})\frac{b_{t-1}^I(i)}{\pi_t} \leq w_t^P l_t^I(i) + b_t^I(i) + t_t^P(i) \tag{5}$$

in which resources spent on consumption, housing, and gross repayment of borrowing b_{t-1}^I (with a net interest rate of r_{t-1}^{bH}) have to be funded with labor income (w_t^I is the wage of impatient households) and new loans b_t^I (t_t^I only includes net union fees).

Impatient households face an additional borrowing constraint:

$$(1+r_t^{bH})b_t^I(i) \leq m_t^I E_t[q_{t+1}^h h_t^I(i)\pi_{t+1}] \tag{6}$$

where m_t^I is the loan-to-value ratio. This borrowing constraint implies that the expected value of their housing stock must ensure payment of debt and interests. Actually, housing can represent the consumption of non-durable goods. That is why collateral constraints appear to be a good approximation of credit markets in Brazil. Almost half of the loans to households in Brazil are collateralized (Banco Central do Brasil, 2013a) [2].

The optimal choice for the impatient household is given by the following equation:

$$\frac{(1-a^I)\varepsilon_t^z}{c_t^I - a^I c_{t-1}^I} = \beta_I E_t \left[\frac{(1-a^I)\varepsilon_{t+1}^z}{c_{t+1}^I - a^P c_t^I} \frac{1+r_t^{bH}}{\pi_{t+1}} \right] + \lambda_t^H (1+r_t^{bH}) \tag{7}$$

Such choice depends on the expected real cost of new loans and on the Lagrange multiplier associated with the collateral constraint (λ_t^H). λ_t^H is the increase in lifetime utility resulting from borrowing extra loans and reducing consumption next period. Combining the patient's steady-state Euler equation with the impatient's steady-state Euler equation returns:

$$\lambda^H = \frac{\frac{\beta_P}{M} - \beta_I}{\pi c^I} \tag{8}$$

where M is the markup over gross interest rate on deposits.

As the economy features imperfectly competitive banking sector and financial frictions, the usual assumption $\beta_P > \beta_I$ is no longer sufficient to guarantee that impatient households are constrained around the steady state. The larger M, the larger the difference in agents' discount factors must be for the constraint to be binding around the steady state . The same reasoning applies to the Lagrange multiplier associated with the entrepreneur's borrowing constraint.

The expected utility of entrepreneurs depends only on consumption c_t^E:

$$E_0 \sum_{t=0}^{\infty} \beta_E^t log\left(c_t^E(i) - a^E c_{t-1}^E\right) \tag{9}$$

This expected utility is maximized subject to the budget constraint:

$$c_t^E(i) + w_t^P l_t^{E,P}(i) + w_t^I l_t^{E,I}(i) + \left(1+r_{t-1}^{bE}\right)\frac{b_{t-1}^E(i)}{\pi_t} + q_t^k k_t^E(i) + \psi(u_t(i))k_{t-1}^E(i) =$$

$$\frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) \tag{10}$$

in which δ is the depreciation rate of capital k^E, q_t^k is the price of capital in terms of consumption, $\psi(u_t(i))k_{t-1}^E(i)$ is the real cost of setting a level u_t of utilization rate , $\frac{1}{x}$ is the relative competitive price of the wholesale good y^E produced from technology, capital

[2]Vehicle financing, Leasing and Real estate financing. Despite the fact that part of the latter are directed loans that affect the transmission channels, we decided to keep the model simple and focus only on non-regulated loans.

and a combination of labor supplied by patient and impatient households, and r_t^{BE} is the interest rate on loans to entrepreneurs b_t^E.

Entrepreneurs are also subject to a borrowing constraint:

$$(1+r_t^{bE})b_t^E(i) \leq m_t^E E_t[q_{t+1}^k \pi_{t+1}(1-\delta)k_t^E(i)] \tag{11}$$

i.e., the expected value of the capital stock must guarantee payment of debt and interests.

The optimal choice for the entrepreneur is given by the following Euler equation:

$$\frac{(1-a^E)}{c_t^E - a^E c_{t-1}^E} = \beta_P E_t \left[\frac{(1-a^E)}{c_{t+1}^E - a^E c_t^E} \frac{1+r_t^{bE}}{\pi_{t+1}} \right] + \lambda_t^E (1+r_t^{bE}) \tag{12}$$

Such choice depends on the expected real cost of new loans and on the Lagrange multiplier associated with the collateral constraint (λ_t^E).

2.2 Banks

Each bank in the model is composed of two "retail" branches and one "wholesale" unit. One retail unit provides differentiated loans to entrepreneurs and households and the other unit raises differentiated deposits. The wholesale unit is responsible for managing the bank's capital position. Banks accumulate capital out of earnings of the three branches, as follows:

$$\pi_t K_t^b = (1-\delta^b)K_{t-1}^b + j_{t-1}^b \tag{13}$$

in which K_t^b is the bank capital, π_t is the gross inflation, j_t^b are overall real profits and δ^b is the depreciation rate. Bank capital establishes a link, crucial to the model, between the credit supply and the economic cycle. In "good" times, retained earnings increase bank capital stock allowing the soaring of loans, while in "bad" times, when profits are smaller, bank capital shrinks leading to a contraction of loan supply further fuelling the crisis.

The maximization problem for the wholesale unit is to choose loans and deposits. The resulting wholesale interest rate on loans to credit-constrained households and entrepreneurs is as follows:

$$R_t^b = R_t^d - \kappa \left(\frac{K_t^b}{B_t} - v_t \right) \left(\frac{K_t^b}{B_t} \right)^2 \tag{14}$$

where R_t^b is the net wholesale loan rate, R_t^d is the net wholesale deposit rate, v_t the target for their capital-to-assets ratio, κ parameterizes the quadratic cost paid by the banks when they deviate from the target v_t and B_t is the sum of risk-weighted loans to entrepreneurs and to households. According to Angelini et al. (2012), B_t has the following specification:

$$B_t = w_t^E B_t^E + w_t^H B_t^H \tag{15}$$

where w_t is the cyclical risk which is modelled as:

$$w_t^i = (1-\rho_i)\bar{w}^i + (1-\rho_i)\chi_i(y_t - y_{t-4}) + \rho_i w_{t-1}^i \qquad i = I, E \tag{16}$$

where y is output and ρ_i is the inertia in risk and χ_i is the response to annual output growth. The steady state of w_t^i is 1.

When loans increase, the capital-to-assets ratio falls below v_t, leading banks to raise R_t^b, which contributes to reduction of the demand for credit.

It is assumed that banks have access to unlimited finance at policy rate r_t. Thus, by arbitrage, $R_t^d = r_t$ and then we have:

$$S_t^w \equiv R_t^b - r_t = -\kappa \left(\frac{K_t^b}{B_t} - v_t \right) \left(\frac{K_t^b}{B_t} \right)^2 \tag{17}$$

where S_t^w is the spread at the wholesale level. The left-hand side of the equation represents the marginal benefit of an increase in loans while the right-hand side represents the marginal cost of its increase, because the bank would be farther from the target v_t. Thus, banks choose to operate at the point that equalizes the benefits and the costs of reducing the capital-to-assets ratio.

The retail loan branch applies a markup over the wholesale rate. The retail interest rate on loans to credit-constrained households and entrepreneurs is as follows:

$$r_t^{bs} = \frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs} - 1} R_t^b + Adj_t^{bs} \Longrightarrow r_t^{bs} = \frac{\varepsilon_t^{bs}}{\varepsilon_t^{bs} - 1} \left[r_t - \kappa \left(\frac{K_t^b}{B_t} - v_t \right) \left(\frac{K_t^b}{B_t} \right)^2 \right] + Adj_t^{bs} \tag{18}$$

where $\varepsilon_t^{bs} > 1$ is the elasticity of loan demand and s indexes the agent, and Adj_t^{bs} captures the cost of adjusting loan rates.

It is assumed, as in Carvalho et al. (2013), that there is no markdown over the policy rate:

$$r_t^d = r_t \tag{19}$$

Loan demand elasticities are decisive in determining the spreads between the policy rate and the retail ones. To sum up, the deposit branch raises deposits, the wholesale branch determines its lending rate, which depends on the capital-to-assets ratio, and upon which the loan branch applies a markup to determine the interest rate on loans to impatient households and entrepreneurs.

The bank's trade-off can also be seen in the equation that shows overall bank profits (in real terms). It is easy to see that the greater the distance between $\frac{K_t^b}{B_t}$ and v_t, the lower the bank profits. However, the larger b_t^H and b_t^E, the higher the profits:

$$j_t^b = r_t^{bH} b_t^H + r_t^{bE} b_t^E - r_t^d d_t - \kappa \left(\frac{K_t^b}{B_t} - v_t \right)^2 K_t^b - Adj_t^B \tag{20}$$

where r_t^{bH} is the interest rate on loans to households, r_t^{bE} is the interest rate on loans to entrepreneurs, r_t^d is the interest rate on deposits and Adj_t^B captures the costs of adjusting interest rates.

As the business cycle affects bank profits and, therefore, capital (accumulated out of retained earnings), there is room for active policies aiming to mitigate its effects on the real economy.

2.3 Macroprudential and Monetary Policies

The central bank is assumed to follow a standard Taylor rule:

$$r_t = (1-\rho_R)\bar{r} + (1-\rho_R)[\chi_\pi(\pi_t - \bar{\pi}) + \chi_y(y_t - y_{t-1})] + \rho_R r_{t-1} + \varepsilon_t^R \tag{21}$$

where $\bar{r}$ is the steady-state policy rate, ρ_R is the inertia in the adjustment of the policy rate, χ_π measures the response to deviations of inflation π to the target($\bar{\pi}$), χ_y measures the response to output growth (y_t) and ε_t^R is the monetary policy shock.

Our macroprudential instrument is the countercyclical capital buffer. We follow Angelini et al. (2012):

$$v_t = (1-\rho_v)\bar{v} + (1-\rho_v)\chi_v X_t + \rho_v v_t \tag{22}$$

where $\bar{v}$ is the steady-state level of v_t, ρ_v is the inertia in the adjustment of the countercyclical capital buffer and X_t is a macroeconomic variable with sensibility χ_v. X_t is what we call anchor variable. Anchor variables can be seen as proxies for the cyclicality that the instrument is designed to mitigate.

Angelini et al. (2012) point out that the capital requirement is a good macroprudential instrument for two reasons. Primarily, based on recent experience, systemic crises affect bank capital and credit supply directly or indirectly. Additionally, bank capital is at the hub of the current debate on regulatory reform.

Equations (18) and (19) show that monetary and macroprudential policies have potentially different roles. Policy rate affects the deposit rate and the loan rate; macroprudential policy only affects the loan rate giving greater freedom to the policymaker. If there is a need to affect differently savers and borrowers, the authority in question can change only v_t.

3 Estimation

We apply standard Bayesian Methods to estimate model parameters without macroprudential policy [3]. Bayesian estimation is a bridge between calibration and maximum likelihood: priors can be seen as weights on the likelihood function in order to give more importance to certain areas of the parameter subspace (Griffoli, 2007).

There are many advantages of using Bayesian methods to estimate a model. First, Bayesian estimation fits the DSGE model. Second, Bayesian techniques prevent the posterior distribution from peaking at strange points where the likelihood peaks. Third, the inclusion of priors helps identifying parameters (Griffoli, 2007).

Since there is not much literature regarding the parameters driving the banking dynamics in Brazil, we decided to focus our estimation on these parameters, while we calibrate the others. In this section, we present the data, the calibrated parameters, the prior and the posterior distributions.

3.1 Data

The model is estimated for the Brazilian economy. We use 9 observables: real consumption, real investment, inflation, deposits, loans to households and to firms, interest rates on loans to households and firms, and the overnight rate. For a detailed description of the data, see the Appendix. The sample period is 2000q3-2012q4. Data with a trend are made stationary using one-sided HP filter[4], while inflation rate is demeaned and interest rates are demeaned using the mean overnight growth rate (Pfeifer, 2014). Figure 1 reports the transformed data.

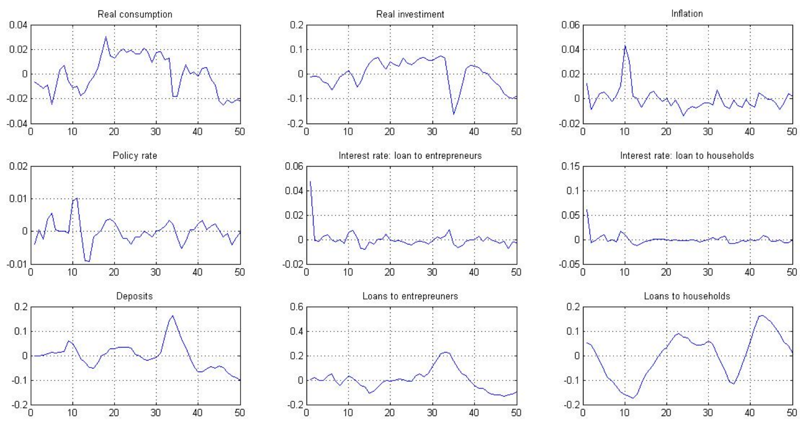

Figure 1: *Observed Variables Used in Estimation*

[3] We only add macroprudential policy to the model after the estimation is complete. In the sample period, there was no countercyclical capital buffer in Brazil. Thus it is possible to properly recover some unknown parameters from the banking sector.

[4] Smoothing parameter equal to 1,600.

3.2 Calibrated Parameters

Table 1 reports the values of the calibrated parameters. As in Castro et al. (2011) we set the discount factor of patient households at 0.989. We assume that the discount factors are the same for impatient households and entrepreneurs and we set them at 0.95 as in Iacoviello (2005). The target capital-to-loans ratio is set at (16%). The interest rate elasticities were calibrated so as to match the interest spread found in the Brazilian economy. Furthermore, LTV ratios were calibrated in order to generate the credit-to-GDP ratio found in the data. All other parameters follow studies for the Brazilian economy[5].

Table 1
Calibrated Parameters

Parameters	Description	Value	Reference
β_P	Patient households' discount factor	0.989	1
β_I	Impatient households' discount factor	0.95	5
β_E	Entrepreneurs discount factor	0.95	5
ϕ	Inverse of the Frisch elasticity	1	1
μ	Share of unconstrained households	0.8	4
ε^h	Weight of housing in households' utility function	0.2	4
α	Capital share in the production function	0.448	1
δ	Depreciation rate of physical capital	0.025	4
ε^y	Elasticity in the goods market	11	1
ε^l	Elasticity in the labor market	3	1
m^I	Households' LTV ratio	0.9	7
m^E	Entrepreneurs' LTV ratio	0.1	7
v^b	Target capital-to-loans ratio	0.16	2
ε^{bE}	Interest rate elasticity of loan demand E	2.3	7
ε^{bH}	Interest rate elasticity of loan demand HH	1.78	7
ρ_H	Risk response to lagged risk - impatient	0.94	8
ρ_E	Risk response to lagged risk - entrepreneur	0.92	8
χ_H	Risk response to output - impatient	-10	8
χ_E	Risk response to output - entrepreneur	-15	8
ρ_{ib}	Monetary policy response to lagged interest rate	0.79	1
ϕ_π	Monetary policy response to inflation	2.43	1
ϕ_y	Monetary policy response to output	0.16	1

* (1) Castro et al. (2011), (2) Banco Central do Brasil (2011), (3) Agénor et al. (2012), (4) Gerali et al. (2010), (5) Iacoviello (2005), (6) Banco Central do Brasil (2013b), (7) Data and (8) Angelini et al. (2010).

[5]Risk responses to output were set to zero in the estimation.

3.3 Prior and Posterior Distributions

Table 2

Estimated Parameters

			Prior			Posterior	
		Dist.	Mean	Std. Dev.	Mean	Median	Std. Dev.
Structural Parameters							
κ_p	Adj. cost for *p*	Gamma	50	20	14.33	13.16	4.85
κ_w	Adj. cost for *w*	Gamma	50	20	41.67	39.21	14.93
ι_p	Degree of indexation of *p*	Gamma	0.5	0.15	0.32	0.30	0.15
ι_w	Degree of indexation of *w*	Gamma	0.5	0.15	0.47	0.46	0.10
κ_{be}	Firms' rate adj. cost	Gamma	3	2.5	0.30	0.28	0.11
κ_{bh}	HH's rate adj. cost	Gamma	6	2.5	0.17	0.16	0.05
κ_{kb}	Leverage dev. cost	Gamma	20	5	23.15	22.96	2.63
a_i	Habit coefficient	Beta	0.5	0.1	0.68	0.69	0.08
κ_i	Investment adj. cost	Gamma	2.5	1	3.40	3.31	0.74
Exogenous process: AR Coefficients							
ρ_z	Consumpt. pref.	Beta	0.8	0.1	0.44	0.44	0.08
ρ_a	Technology	Beta	0.8	0.1	0.81	0.82	0.05
ρ_{mE}	Firms' LTV	Beta	0.8	0.1	0.90	0.91	0.04
ρ_{mH}	HH's LTV	Beta	0.8	0.1	0.93	0.94	0.03
ρ_{bH}	HH's loans markup	Beta	0.8	0.1	0.73	0.74	0.08
ρ_{bE}	Firms' loans markup	Beta	0.8	0.1	0.86	0.86	0.05
ρ_{qk}	Invest. efficiency	Beta	0.8	0.1	0.56	0.55	0.08
ρ_y	p markup	Beta	0.8	0.1	0.80	0.81	0.10
ρ_{Kb}	Balance Sheet	Beta	0.8	0.1	0.80	0.81	0.10
Exogenous process: Standard deviations							
σ_z	Consumpt. pref.	Inv. G.	0.01	0.05	0.06	0.06	0.01
σ_a	Technology	Inv. G.	0.01	0.05	0.01	0.01	0.01
σ_{mE}	Firms' LTV	Inv. G.	0.01	0.05	0.01	0.01	0.00
σ_{mH}	HH's LTV	Inv. G.	0.01	0.05	0.02	0.02	0.00
σ_{bH}	HH's loans markup	Inv. G.	0.01	0.05	0.51	0.50	0.06
σ_{bE}	Firms' loans markup	Inv. G.	0.01	0.05	0.27	0.27	0.03
σ_{qk}	Invest. Efficiency	Inv. G.	0.01	0.05	0.05	0.05	0.01
σ_R	Monetary policy	Inv. G.	0.01	0.05	0.01	0.01	0.00
σ_y	p markup	Inv. G.	0.01	0.05	0.01	0.01	0.01
σ_{Kb}	Balance Sheet	Inv. G.	0.01	0.05	0.12	0.13	0.01

Table 2 presents the prior distributions. They follow mainly Gerali et al. (2010). Table 2 also reports the posterior mean and median, and the standard deviations of the estimated parameters. The posterior distribution was obtained using the Metropolis-Hastings algorithm. We ran 5 chains, each of 500,000 draws.

The habit coefficient and the investment adjustment cost values are close to the values found in Castro et al. (2011). The shocks are rather persistent. In the following section, parameter values are set at the posterior median.

4 Applications

This section discusses optimal macroprudential policy after an unexpected destruction of 5% of bank capital. Such shock is introduced in the bank capital accumulation equation:

$$\pi_t K_t^b = (1-\delta^b)\frac{K_{t-1}^b}{\varepsilon_t^k} + j_{t-1}^b \tag{23}$$

in which ε_t^k is the financial shock[6].

First, the anchor variables are ordered using a measure of welfare. Then the impulse response functions of the model that displays the best results will be presented. Thus, it is possible to better understand the propagation mechanism of bank capital destruction, and the best way to mitigate its effects.

4.1 Welfare

Welfare analyses have recently been increasingly used to measure the benefits of macroprudential policy (e.g., Rubio and Carrasco-Gallego (2014), Rubio and Carrasco-Gallego (2015), Laseen et al. (2015)). The optimal combination of monetary and macroprudential policies is here obtained by a second order approximation of the equilibrium.

The welfare measure is the unconditional expectation of average household utility given initial values. Aggregated welfare is given by:

$$E_0 V = E_0\left\{V_P + V_I + V_E\right\} \tag{24}$$

in which V_P is the expectation of patient households' lifetime utility, V_I is the expectation of impatient households' lifetime utility and V_E is the expectation of entrepreneurs' lifetime utility.

As in Schmitt-Grohe and Uribe (2007) and Suh (2012), policy rules are easily implementable because they are functions of observable macroeconomic indicators. As

[6] For this exercise, we set $\bar{v}$ at 13%, the required level when the countercyclical capital buffer is on.

pointed out, the Taylor rule is standard:

$$r_t = (1-\rho_R)\bar{r} + (1-\rho_R)[\chi_\pi(\pi_t - \bar{\pi}) + \chi_y(y_t - y_{t-1})] + \rho_R r_{t-1} \tag{25}$$

Macroprudential rule has a very similar format, being a function of the anchor variable:

$$v_t = (1-\rho_v)\bar{v} + (1-\rho_v)\chi_v X_t + \rho_v v_{t-1} \tag{26}$$

Since there is more information in the literature about monetary policy parameters (χ_y and χ_π), they are restricted to a small range: χ_y between 0 and 3 and χ_π between 1 and 3. The macroprudential policy parameter, about which there is greater uncertainty, is restricted to a broader range: (χ_v) between 0 and 10.

The range for χ_v is partinioned with grids of size 2 and the ranges for all the other parameters are partitioned with grids of size 0.2. Macroprudential policies are assumed to have inertia ($\rho_v = 0.9$) (Suh, 2012). For each combination of parameters, the welfare $E_0 V$ is calculated. The optimal policy is the one that presents the greatest welfare subject to the ranges mentioned.

The anchor variables used in the exercise are some of the variables classified as macroeconomic by the Basel Guide: GDP growth, credit growth, credit-to-GDP growth, risk-weighted credit growth, GDP gap, credit gap, credit-to-GDP gap and risk-weighted credit gap. Then we have nine possible cases: “the monetary policy” (benchmark) and eight models with different anchor variables. The coefficients presented are those associated with the optimal policy for each case.

Table 3 suggests that the introduction of macroprudential policy generates welfare gains. The variables are ranked according to the welfare: (1) is the variable that produces the highest welfare and (5) the lowest. The “gap variables” have no benefit in terms of welfare compared to the case with only monetary policy[7].

On the other hand, the more effective macroprudential policy in terms of welfare is the one which uses credit growth as an anchor variable. It is as if target and objective coincide: in order to avoid a drop in credit that would be detrimental to the economy, the relevant authority must be attentive to the behaviour of credit itself.

[7] We also run a model in which we set monetary policy parameters at the calibrated values ($\chi_y = 0.16$ and $\chi_\pi = 2.43$), allowing only χ_v to vary. The optimal choice for χ_v in this scenario is zero, but, as expected, the agents are worse off (they could have chosen these values, but they have not).

Table 3

Taylor and Macroprudential Policy (MaP)

	Optimal Parameters				
	Taylor		MP		
	χ_π	χ_y	χ_v	Welfare	
Taylor only	1.1	0.5	-	-143.2689	(5)
Taylor + MP					
GDP growth	1.1	0	10	-143.2448	(4)
Taylor + MP					
Credit growth	1.1	0	10	-142.9508	(1)
Taylor + MP					
Risk-weighted Credit growth	1.1	0	10	-142.9527	(3)
Taylor + MP					
Credit-to-GDP growth	1.1	0	10	-142.9523	(2)
Taylor + MP					
GDP gap	1.1	0.5	0	-143.2688	(5)
Taylor + MP					
Credit gap	1.1	0.5	0	-143.2688	(5)
Taylor + MP					
Risk-weighted Credit gap	1.1	0.5	0	-143.2688	(5)
Taylor + MP					
Credit-to-GDP gap	1.1	0.5	0	-143.2689	(5)

Using an alternative approach (Bayesian Structural Time Series Models in 34 countries), Gonzalez et al. (2015) also find that the credit-to-GDP gap is dominated by the credit-to-GDP growth. According to them, the credit-to-GDP growth exhibits results as accurate as those of the BCBS indicator and lower noise-to-signal ratios.

The result is similar to the one proposed by Akerlof and Shiller (2009), who defended a credit target as a means of mitigating the effects of the recent international financial crisis on the economy. According to them, while the credit crunch lasts, multipliers are much smaller than in normal conditions. Thus, avoiding credit contractions (and consequently multipliers reduction), the need for too large fiscal and monetary stimulus is reduced.

However, the effects of the new policy differ among agents. If given a choice, patient consumers would prefer the regime in which only monetary policy operates, as it ensures greater welfare. On the other hand, entrepreneurs and impatient consumers would choose the regime that combines monetary and macroprudential policies. Thus, the ordering of welfare is sensitive to changes in the weights.

Figure 2 displays the welfare when the anchor variable is credit growth. The axis on the right side displays the range for χ_v and the axis on the left side displays the range for χ_y[8]. The larger χ_v and the lower χ_y, the larger the welfare, implying that when the response of the countercyclical capital buffer to the anchor variable is strong, there is no need for monetary policy to react.

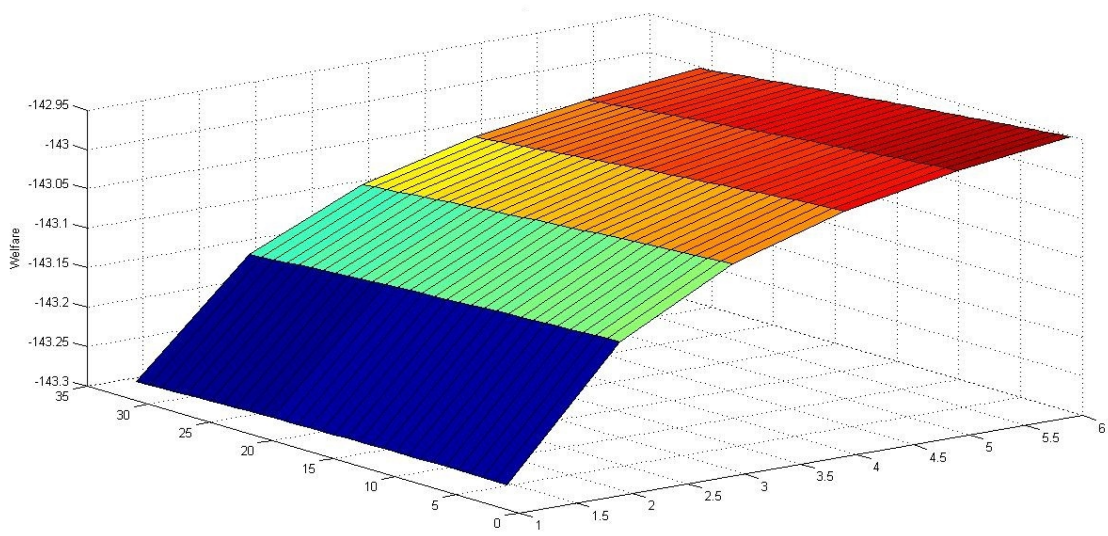

Figure 2: *Anchor: credit growth*

The following subsection presents the impulse response functions of the model with credit growth as an anchor variable. The parameters of monetary and macroprudential policies were set at the associated optimal policy values ($\chi_y = 0$, $\chi_\pi = 1.1$ and $\chi_v = 10$)[9]. It will be compared to the model with only monetary policy that has the parameter values set at $\chi_y = 1.1$ and $\chi_\pi = 0.5$.

[8]From 0 to 10 with grids of 2 results in 6 elements for the range of χ_v. The same reasoning applies for χ_y

[9]Taking into account the inertia parameter, this implies a response 4 times more reactive than the intended: according to (Basel Comittee on Banking Supervision, 2010b), when the gap is 10% or larger, the buffer add-on is at its maximum (2.5%).

4.2 The Effects of a Bank Capital Loss

Figure 3 displays the impact of a bank capital loss on some important macroeconomic variables.

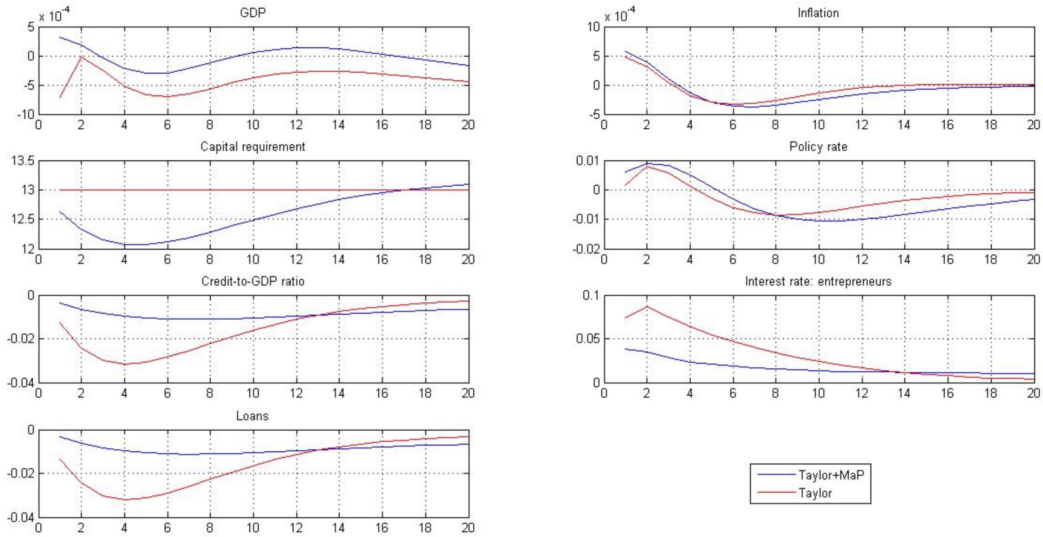

Figure 3: *Anchor: credit growth versus Taylor only*

After the shock, banks face higher costs linked to its capital position and pass it to the interest rates on loans, weakening the demand for credit. The contraction of loans leads to a reduction in the level of investments and product. However, the interest rate charged on loans to entrepreneurs increases less in the case with macroprudential policy because the capital requirement also decreases, reducing costs related to the bank's capital position. This, in turn, results in a lower decrease of loans when macroprudential policy operates.

Thus, the performance of monetary and macroprudential policies reduces the impact that the original destruction of bank capital has on the economy, mitigating the feedback process. As in Gerali et al. (2010), the magnitude of the change in the trajectory of variables is greatly reduced. This occurs for two reasons. First, because the shock was calibrated to generate a relatively small bank capital loss. Second, because the shock is unique and disregards other shocks potentially generated by it.

5 Conclusion

We have examined the process of choosing the best anchor variable in a DSGE model. Unlike studies that focus on the regulatory issue, our analysis was focused on the behavior of macroeconomic variables and welfare. We believe that both aspects should be complementary.

In order to fulfil this gap, we input different macroprudential rules into the DSGE proposed by Gerali et al. (2010). We estimate the model for the Brazilian economy, and then we sort the results using a measure of welfare given by the unconditional expectation of lifetime utility as of time zero: the larger the welfare, the better the anchor variable. Credit growth is the variable that performs best.

It should be noted, however, that the difference between the variables in terms of consumption appears to be very low. So it is hard to say that the results are general. More studies are needed to make that assessment and even ask how relevant the welfare should be when addressing financial regulatory issues.

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A Data

Real consumption: Consumption of households, constant prices, seasonally adjusted (IBGE).
Real investment: Gross fixed capital formation, constant prices, seasonally adjusted (IBGE).
Policy rate: Selic rate - % p.y (BCB).
Inflation rate: IPCA - % p.y (BCB).
Deposits: Analytical accounts - Deposit money banks - Time, savings and other deposits - c.m.u. (million)
Loans to entrepreneurs: Credit operations with nonearmarked funds - Consolidate balance (end of period) - Working capital - c.m.u. (thousand)
Loans to households: Credit operations with nonearmarked funds - Consolidate balance (end of period) - Acquisition of goods total-individuals - c.m.u. (thousand)
Interest rate on loans to firms: Average interest rate of nonearmarked new credit operations - Non-financial corporations - Working capital total - % p.y. (BCB)
Interest rate on loans to households: Credit operations with nonearmarked funds (preset rate) - Monthly average rate - Acquisition of goods-individuals - % p.y. (BCB)