Countercyclical prudential tools in an estimated DSGE model*

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Abstract

We develop a DSGE model for a small, open economy with a banking sector and endogenous default in order to perform a realistic assessment of macroprudential tools: countercyclical capital buffer (CCB) and dynamic provisions (DP). The model is estimated with data for Uruguay, where dynamic provisioning is in place since early 2000s. We find that (i) the source of the shock affecting the financial system matters, to select the appropriate indicator variable under the CCB rule, and to calibrate the size of the DP. Given a positive external shock, CCB (ii) generates buffers without major real effects; (iii) GDP as an indicator variable has quicker and stronger effects over bank capital; and (iv) the ratio of credit to GDP decreases, which discourages its use as an indicator variable. DP (v) generates buffers with real effects, and (vi) seems to outperform the CCB in terms of smoothing the cycle.

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1 Introduction

In the wake of the global financial crisis of 2008-2009 it has become clear the importance of systemic risk and the need for a macroprudential perspective to financial regulation. In this spirit, new prudential regulation has been established, being of particular importance Basel III, which strengthens bank capital and liquidity requirements. Among other things, Basel III increases minimum capital requirements, introduce more stringent liquidity regulation and introduces a counter-cyclical capital buffer. This measure is intended to build capital buffers in booms, which may be used to (partially) absorb loses during a downturn, hence prudentially attending the cyclical and endogenous raise in systemic risk during upturns. The implementation and efficiency of these regulations has been a topic of vivid debate among policymakers and academics.

Regarding the implementation of countercyclical captial buffers, the debate is particularly relevant in jurisdictions where other macroprudential instruments developed to mitigate the prociclicallity of the financial system are currently in place. For example, Spain and several Latin American countries have been using dynamic loan loss provisions as a countercyclical regulatory rule for several years. Under dynamic provisioning a fund is accumulated in periods where the expected losses are lower than the long-run, or through-the-cycle, level. Dynamic provisions are not released in periods with low default rates, but they are used to cover losses in a downturn.[1]

The aim of this paper is to perform a realistic assessment of the countercylical regulation promulgated in Basel III, and to compare its relative performance with other macroprudential policies already used in many countries, i.e. dynamic loan loss provisions. To do it, we develop a DSGE model for a small, open economy. In the model, entrepreneurs' default is endogenous as in Bernanke et al. (1999). We put particular attention to the modeling of the banking sector and its prudential regulation. The model is estimated with data for Uruguay, a country that has been running a dynamic provisioning system since 2001. Finally, we perform simulations of the key macroe-

[1]For the case of Spain, Jiménez et al. (Forth.) find that dynamic provisioning smooths credit supply cycles and, in bad times, supports firm performance. In a formal model, Gómez and Ponce (2015) study the effectiveness of countercyclical capital buffers and dynamic provisioning to provide the correct incentives to bank managers and conclude that both of them are adequate policy tools.

conomic variables and of the banking sector under different regulations in order to compare the results. More precisely, we compare the dynamics of this modeled economy with financial frictions when it is affected by external and domestic shocks under alternative macroprudential regulations: countercyclical capital buffers with alternative indicators of the financial cycle (i.e. GDP and credit) and different rules for loan loss provisioning (i.e. static and dynamic).

We model the banking sector to account for different regulatory policies and commonly observed facts in banking. In particular, banks usually maintain more capital than the minimum that is required by regulation (see Allen and Rai, 1996; Peura and Jokivuolle, 2004; Barth et al., 2006; Berger et al., 2008).[2] Rather than strictly complying with capital regulation, banks exhibit their own target levels of capital. Depending on the extent of their capital buffer, banks will adjust their capital and risk taking to reach their target levels (Milne and Whalley, 2001; Ayuso et al., 2004; Lindquist, 2004; VanHoose, 2008; Jokipii and Milne, 2008, 2011; Stolz and Wedow, 2011). We explicitly model this desire of bankers to maintain capital above the minimum requirements. This allows us to account for the reaction of bankers to regulatory changes and hence to perform a more realistic assessment of policies such as increasing minimum capital requirements and imposing extra capital buffers, in particular the countercyclical one. Moreover, we model countercyclical (dynamic) loan loss provisions by introducing the possibility of accumulating a loan loss provision reserve fund when some selected variable grow more than the historical average, thus linking provisioning to the credit and business cycles. This allows us to study the performance of different provisioning rules and assessing the relative efficiency of countercyclical loan loss provisioning and countercyclical capital buffers.[3]

We estimate the model using data for Uruguay in the period 2005-2015. Uruguay has been using dynamic loan loss provisions since 2001. Hence, this data provides a nice counterfactual for a realistic estimation of the proposed DSGE model.

We perform a series of simulations for different regulatory policies in order to assess their performance. In particular, we focus on countercyclical capital

[2] For example, in the particular case of Uruguay banks hold on average between 2005 and 2015 a capital buffer equivalent to 0.6 times the minimum capital requirement.

[3] The banking sector model also includes liquidity or reserve requirements regulation.

requirements and on dynamic provisions. We analyze the dynamic of real and banking variables under different specifications of the countercyclical rules, and for different calibration of their governing parameters. For simplicity, we analyze two positive shocks: a reduction in the country premium (an aggregate, external shock) and a reduction on the risk of entrepreneurs (an idiosyncratic shock). Together these two shocks explain most of the variance of bank capital, credit growth and entrepreneurs' default. Overall, the focus is put on the buffering capacity of the tools and their effects on real and financial variables.

The results suggest that both countercyclical capital buffers and dynamic provisions are effective in generating buffers than may cover future losses. However, their impact on activity and other real variables is different. Countercyclical capital requirements do not have major real effects. Dynamic provisions may, however, have a countercyclical impact on activity and other real variables, which may be statistically significant for parametrizations of the provision rule where the weight of the dynamic component is relatively high.

When the economy faces a positive, external shock, a countercyclical capital rule based on real GDP growth has a quicker and stronger effect in buffering bank capital than a rule based on real credit growth. In this case, the ratio of credit to GDP decreases. Hence, the use of this variable to buffering bank capital will be procyclical instead of countercyclical. In terms of smoothing the cycles, dynamic provisions seems to outperform countercyclical capital requirements under external financial shocks.

Finally, we find that the source of the shock matters in three dimensions. Firstly, to select the indicator variable for the countercyclical capital requirement (credit to GDP does not seem adequate under external shocks). Secondly, to calibrate the size of the dynamic provisioning (the same calibration may be too countercyclical if the shock is domestic than if it is external). Thirdly, to select the policy tool (dynamic provisions seems to outperform countercyclical capital requirements under external financial shocks). Hence, it seems prudent to have both policy tools available on the set of regulatory instruments.

The rest of the paper is organized as follows. In Section 2 we present the model. Section 3 is devoted to the estimation results. In Section 4 we present the results of the counterfactual simulation of regulatory policies.

Finally, in Section 5 we offer some concluding remarks.

2 The model

Our model builds extensively on the one proposed by Basal et al. (2016) for the case of Uruguay, which essentialy is a small open economy DSGE model for monetary policy analysis. We use a simplified version of their macroeconomic setup, which is characterized by an small, open, and dollarized economy, and further extend it by introducing the possibility of endogenous default of the entrepreneurs à la Bernanke et al. (1999), a banking system and banking regulations.

2.1 Households

There is a continuous of mass 1 of households. Households derive utility from the consumption of final goods (c_t) and offer working hours (h_t). As it is customary in this kind of models, there are nominal rigidities on wages which are modeled as in Basal et al. (2016). In addition to that, households derive utility from the financial assets they own. More precisely, households demand money (M_t^d, in pesos) and deposits (D_t, in dollars). In order to account for the high level of dollarization of the Uruguayan financial system we assume that deposits are denominated in US Dollars. In practice, around 80% of bank deposits are denominated in foreign currency. The instantaneous utility function of households is

$$v_t \left[u(c_t, h_t) + \nu_t \frac{(M_t^a)^{1-\sigma_M} - 1}{1 - \sigma_M} \right], \tag{1}$$

where, $M_t^a = \left[(1 - o_M)^{\frac{1}{\eta_M}} \left(\frac{S_t D_t}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} + o_M^{\frac{1}{\eta_M}} \left(\frac{M_t^d}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} \right]^{\frac{\eta_M}{\eta_M - 1}}$.

Households also access to local bonds in pesos, B_t, and international bonds in dollars, B_t^*. The households' budget constraint related to financial assets is

$$B_t + S_t B_t^* + M_t + S_t D_t + ... = R_{t-1} B_{t-1} + S_t R_{t-1}^* B_{t-1}^* + M_{t-1} + S_t R_{t-1}^D D_{t-1} + ..., \tag{2}$$

where P_t is domestic prices and S_t is the nominal exchange rate.

2.2 Entrepreneurs

There is a continuous of risk neutral entrepreneurs that manage the stock of capital. In each period t, entrepreneurs start with K_{t-1} units of capital which invest on a linear and stochastic production technology, i.e. ex post each entrepreneur may have a different productivity level. After the productivity shock occurs, entrepreneurs rent productive capital to firms. At the end of the period, entrepreneurs obtain income from the rented capital, sell the part of capital that is not depreciated to capital good producers and acquire new capital which is financed with their net worth (N_t) and loans from banks (L_t). We assume that bank loans are nominated in US dollars so that entrepreneurs bear all currency mismatch risk. The price of capital at the end of period t is Q_t, so that $Q_tK_t = N_t + L_tS_t$.

The ex-post income of entrepreneurs is given by

$$[R^K_{t+1} + (1-\delta)Q_{t+1}]\omega_{t+1}K_t = \omega_{t+1}R^e_{t+1}Q_tK_t, \tag{3}$$

where $R^e_{t+1} = \dfrac{[R^K_{t+1} + (1-\delta)Q_{t+1}]}{Q_t}$ and ω_t is an exogenous shock to the entrepreneurs risk with cumulative distribution function $F_t(\omega_{t+1})$, density function $f_t(\omega_{t+1})$, standard deviation $\sigma_{\omega,t}$ and such that $E(\omega_t) = 1$.

We assume that state verification is costly: ω_t is private information of the entrepreneur and may be observed by third parties at a monitoring cost μ. Hence, for each possible state of the world in period $t+1$ entrepreneurs may fulfill their financial obligations, i.e. paying back the nominal interest rate stipulated in the loan contract, or default. In the latter case the entrepreneur gets nothing and the bank gets a fraction $(1-\mu)$ of the value of the firm.

Following Bernanke et al. (1999), the optimal debt contract specifies an interest rate on the loan F^L_t and a threshold value $\bar{\omega}_{t+1}$ such that:

- If $\omega_{t+1} \geq \bar{\omega}_{t+1}$ the entrepreneurs pays $R^L_tL_tS_{t+1}$ to the bank (R^L_t is the *ex-ante* interest rate stipulated in the loan contract) and gets $(\omega_{t+1} - \bar{\omega}_{t+1})R^e_{t+1}Q_tK_t$.

- If $\omega_{t+1} < \bar{\omega}_{t+1}$ the entrepreneur defaults and gets nothing, while the bank recovers $(1-\mu)\omega_{t+1}R^e_{t+1}Q_tK_t$.

Hence, the non-contingent interest rate on the bank loan satisfies

$$R_t^L L_t = \frac{\bar{\omega}_{t+1} R_{t+1}^e Q_t K_t}{S_{t+1}}. \quad (4)$$

In equilibrium, the ex-post interest rate ($\tilde{R}_{t+1}^L$) received by banks satisfies

$$\tilde{R}_{t+1}^L L_t = [1 - F_t(\bar{\omega}_{t+1})] R_t^L L_t + (1-\mu) \left(\int_0^{\bar{\omega}_{t+1}} \omega f_t(\omega) d\omega \right) \frac{R_{t+1}^e Q_t K_t}{S_{t+1}}, \quad (5)$$

and determines the participation of banks. Using the expresion for R_t^L, the previous expression can be written as follows

$$\tilde{R}_{t+1}^L L_t = g_t(\bar{\omega}_{t+1}) \frac{R_{t+1}^e Q_t K_t}{S_{t+1}}, \quad (6)$$

where $g_t(\bar{\omega}_{t+1}) \equiv \bar{\omega}_{t+1}[1 - F_t(\bar{\omega}_{t+1})] + (1-\mu) \int_0^{\bar{\omega}_{t+1}} \omega f_t(\omega) d\omega$. Finally, defining the leverage of the entrepreneur as $lev_t \equiv \frac{Q_t K_t}{N_t}$ and using $S_t L_t = Q_t K_t - N_t$,[4] the participation constraint of banks becomes

$$\tilde{R}_{t+1}^L (lev_t - 1) = g_t(\bar{\omega}_{t+1}) \frac{R_{t+1}^e}{\pi_{t+1}^S} lev_t. \quad (7)$$

The expected income for the entrepreneur is given by

$$E_t \left\{ R_{t+1}^e Q_t K_t h_t(\bar{\omega}_{t+1}) \right\}, \quad (8)$$

where[5]

$$h_t(\bar{\omega}_{t+1}) \equiv \int_{\bar{\omega}_{t+1}}^{\infty} \omega f_t(\omega) d\omega - \bar{\omega}_{t+1}[1 - F_t(\bar{\omega}_{t+1})]. \quad (9)$$

Equation (8) can be rewritten in terms of leverage, so that the problem of the entrepreneur is to chose a state contingent $\bar{\omega}_{t+1}$ and a value of lev_t to maximize (8) subject to (7) holding state by state. The solution implies a difference between the expected return on capital and the expected return obtained by banks: a external finance premium $E_t\{R_{t+1}^e\}/E_t\{\tilde{R}_{t+1}^L\}$, which is an increasing function of entrepreneurs' leverage.

[4]Notice that loans are in dollars while the income obtained by entrepreneurs is denominated in pesos. We are implicitly assuming that entrepreneurs bear all aggregate risk, including that associated with the exchange rate.

[5]Notice that $g(\bar{\omega}_{t+1}) + h(\bar{\omega}_{t+1}) = 1 - \upsilon_{t+1}$, where $\upsilon_{t+1} \equiv \mu \int_0^{\bar{\omega}_{t+1}} \omega f(\omega) d\omega$.

The evolution of entrepreneur's net worth is given by

$$N_t = \vartheta \left\{ R_t^e Q_{t-1} K_{t-1} h_{t-1}(\bar{\omega}_t) \right\} + \iota^e P_t A_{t-1}, \tag{10}$$

where ϑ is the fraction of entrepreneurs that continue the next period and $\iota^e P_t A_{t-1}$ is the injection of net worth of new entrants.

At equilibrium, the default rate is given by

$$\text{def}_t = F_{t-1}(\bar{\omega}_t). \tag{11}$$

Finally, we need a functional form for $F_{t-1}(\omega_t)$. We follow Bernanke et al. (1999) and assume that $\ln(\omega_t) \sim N(-.5\sigma^2_{\omega,t-1}, \sigma^2_{\omega,t-1})$ (so that $E(\omega_t^e) = 1$). Under this assumption, we can define

$$aux_t^1 \equiv \frac{ln(\bar{\omega}_t) + .5\sigma^2_{\omega,t-1}}{\sigma_{\omega,t-1}}. \tag{12}$$

Letting $\Phi(\cdot)$ be the standard normal c.d.f. and $\phi(\cdot)$ its p.d.f., we can write,[6]

$$\text{def}_t = \Phi(aux_t^1). \tag{13}$$

2.3 Banks

There is a competitive banking sector that lends to entrepreneurs financed by deposits and bank capital. At the end of period t banks have capital (N_t^b). The balance sheet of a bank imposes the following constraint (in flows)

$$L_t + B_t^b + LLP_t = (1 - \tau_t) D_t + N_t^b, \tag{14}$$

[6]See, for instance, the appendix of Devereux *et al.* (2006), from were it is possible to write

$$\begin{aligned}
g_{t-1}(\bar{\omega}_t) &= \bar{\omega}_t[1 - \Phi(aux_t^1)] + (1-\mu)\Phi(aux_t^1 - \sigma_{\omega,t-1}), \\
g'_{t-1}(\bar{\omega}_t) &= [1 - \Phi(aux_t^1)] - \bar{\omega}_t \phi(aux_t^1) \frac{1}{\sigma_{\omega,t-1}} \frac{1}{\bar{\omega}_t} + (1-\mu)\phi(aux_t^1 - \sigma_{\omega,t-1}) \frac{1}{\sigma_{\omega,t-1}} \frac{1}{\bar{\omega}_t} \\
&= [1 - \Phi(aux_t^1)] - \mu\phi(aux_t^1), \\
h_{t-1}(\bar{\omega}_t) &= 1 - \Phi(aux_t^1 - \sigma_{\omega,t-1}) - \bar{\omega}_t[1 - \Phi(aux_t^1)], \\
h'_{t-1}(\bar{\omega}_t^e) &= -\phi(aux_t^1 - \sigma_{\omega,t-1}) \frac{1}{\sigma_{\omega,t-1}} \frac{1}{\bar{\omega}_t} - [1 - \Phi(aux_t^1)] + \bar{\omega}_t \phi(aux_t^1) \frac{1}{\sigma_{\omega,t-1}} \frac{1}{\bar{\omega}_t} \\
&= -[1 - \Phi(aux_t^1)], \\
\text{def}_t &= \Phi(aux_t^1).
\end{aligned}$$

where L_t are new loans, B_t^b are other bank assets, LLP_t is the flow of new provisions for loan losses, τ_t is reserve requirement and D_t are deposits.

At the end of period t, banks hold a stock of provisions for loan losses (LLR_t). This fund is part of the dynamic or countercyclical provisioning scheme. Under countercyclical provisioning a fund is accumulated in periods where the expected losses are lower than the long-run, or through-the-cycle, level (see the accumulation rules in Section 2.4). The fund is not released in periods with low default rates, but they are used to cover losses in a downturn. Hence, the fund LLR_t and the new flow of provisions (LLP_t) is used to cover (maybe only partially) losses due to loan default. Since banks' losses in $t+1$ are equal to $(R_t^L - \tilde{R}_{t+1}^L)L_t$, then the utilization of the loan-loss provision is such that

$$LLU_{t+1} = \min\left\{(R_t^L - \tilde{R}_{t+1}^L)L_t, LLR_t + LLP_t\right\}, \tag{15}$$

and the stock of provisions for loan losses evolves according to

$$LLR_{t+1} = LLR_t + LLP_t - LLU_{t+1}. \tag{16}$$

The banks objective is to choose L_t, B_t^b and D_t to maximize

$$E_t\left\{r_{t,t+1}^*\left[\tilde{N}_{t+1}^b - PEN_{t+1}\right]\right\} - COST_t, \tag{17}$$

where $r_{t,t+1}^*$ is a discount factor,

$$\tilde{N}_{t+1}^b = \tilde{R}_{t+1}^L L_t + B_t^b R_t^* \xi_t + LLU_{t+1} - (R_t^D - \tau_t)D_t \tag{18}$$

is the income left after all contracts are settled in $t+1$, PEN_{t+1} is a penalty for holding a ratio of capital different from the target level and $COST_t$ are operational costs. For simplicity, we assume that the cost function is

$$COST_t = \frac{s_t}{A_{t-1}}(S^L L_t^2 + B_t^{b^2}), \tag{19}$$

where s_t is an exogenous process, which capture imperfect substitutability between alternative investment opportunities for banks, and A_{t-1} is bank assests. Maximization is subject to the balance-sheet constraint (14), taking

N_t^b, LLR_t and the discount factor as given. Bank assets in $t+1$ are

$$\tilde{A}_{t+1}^b = \tilde{R}_{t+1}^L L_t + B_t^b R_t^* \xi_t + LLU_{t+1} + \tau_t D_t. \quad (20)$$

The introduction of a penalty for ending with a ratio of bank capital which is different from the target level, PEN_{t+1}, deserves further explanation. First, banks are limited by minimum capital adequacy ratios, which are modeled by the parameter γ_t^R. A series of papers, however, have shown that banks hold buffers of capital indicating that capital standards are in general not binding (see Allen and Rai, 1996; Peura and Jokivuolle, 2004; Barth et al., 2006; Berger et al., 2008).[7] Rather than strictly complying with capital regulation, banks exhibit their own target levels of capital. Depending on the extent of their capital buffer, banks will adjust their capital and risk taking to reach their target levels (Milne and Whalley, 2001; Ayuso et al., 2004; Lindquist, 2004; VanHoose, 2008; Jokipii and Milne, 2008, 2011; Stolz and Wedow, 2011). Hence, we assume that banks target a ratio of capital to assets γ_t and pay a penalty when the actual ratio is different from the target level. The penalty for deviating from the target capital-to-assets ratio is

$$PEN_{t+1} = \frac{\phi_D}{2} \left(\frac{\tilde{N}_{t+1}^b}{\tilde{A}_{t+1}^b} - \gamma_t \right)^2 \tilde{N}_{t+1}^b. \quad (21)$$

Second, several papers provide evidence on the determinants of capital buffers and the target level of bank capital. Fonseca and Gonzalez (2009) show that capital buffers are related to the cost of deposits and the level of competition, although the relations vary across countries depending on regulation, supervision, and institutions. Lindquist (2004) finds support for the hypothesis that capital buffers serve as an insurance against failure to meet the capital requirements. In addition to that, bank capital is costly, so that too large buffers are not profitable. Hence, in determining the target γ_t we assume that banks consider the minimum capital-to-assets requirement (γ_t^R) and target other buffers. In particular we assume that banks are willing to maintain a capital-to-asset ratio above the minimum requirement because of precautionary reasons and in order to avoid frequent supervisory intervention. We model this kind of buffers has a constant factor γ_0. In addition to

[7]For example, in the particular case of Uruguay banks hold on average between 2005 and 2015 a capital buffer equivalent to 0.6 times the minimum capital requirement.

that, the forecast of higher than normal default rates in the next period may provide incentives to keep more capital today. Together, these buffers may be associated to Lindquist's insurance against failure to meet the capital requirements hypothesis. In order to account for the effect of competition on capital buffers (as found by Fonseca and Gonzalez, 2009) we assume that the expectation of a rapid increase in credit may provide incentives to keep more capital today in order not to fall short and better compete tomorrow. We capture these features in a simple way by modeling the target ratio of bank capital to assets as

$$\gamma_t = \gamma_t^R + \gamma_0 + \alpha_d(E\{def_{t+1}\} - def_{ss}) + \alpha_l(E\{\Delta L_{t+1}\} - \Delta L_{ss}). \tag{22}$$

Finally, we assume that only a fraction ϑ^B of banks continue from one period to the other. Moreover, new banks enter each period with a capital injection ι_t^B. Hence, at the end of period $t+1$ the level of bank capital is

$$N_{t+1}^b = \vartheta^B \left[\tilde{N}_{t+1}^b - PEN_{t+1} - COST_t\right] + \iota_t^B. \tag{23}$$

2.4 Bank regulation

Bank regulation affects the behavior of banks through minimum capital requirements (γ_t^R), reserve requirements (τ_t) and loan loss provisions (LLP_t).

In addition to a plain minimum capital requirement ($\gamma_t^R = \gamma_{0,t}^R$), we consider two versions of counter-cyclical capital requirements depending on the trigger variable. When the feedback is to credit growth (Δl_t), then the counter-cyclical capital requirement is

$$\gamma_t^R = \gamma_0^R + \alpha_l^R(\Delta l_t - \Delta l_{ss}),$$

where the subscript ss refers to steady state levels. When the trigger variable is GDP growth (Δy_t), then the requirement is

$$\gamma_t^R = \gamma_0^R + \alpha_y^R(\Delta y_t - \Delta y_{ss}).$$

Regarding loan loss provisioning, we consider two specifications following Bouvatier and Lepetit (2012). First, we model the traditional provision system for expected losses as

$$LLP_t = l_0 \mathrm{def}_j L_t,$$

where l_0 is the coverage ratio: the proportion of default loans that would be covered by loan loss provisions. We consider different rules according to $j \in \{t, t+1\}$, i.e. by considering the current or the next period expected default respectively. Second, we consider a forward-looking (commonly called statistical, countercyclical or dynamic) provision system. Under this system more provisioning is required when the actual level of default is lower than the normal (or steady-state) level so that the stock of provisions for loan losses (LLR_t) increases (see Equation 16). We consider the following dynamic provisioning rule

$$LLP_t = [\mathrm{def}_j + l_1(\mathrm{def}^{ss} - \mathrm{def}_j)] l_0 L_t,$$

where l_1 weights the relative importance of the dynamic provisioning component.

2.5 Other features and shocks

Other features of the model may be summarized as follows. Production is achieved by using capital and labor. There is an endowment of commodities, habits in consumption, investment adjustment costs, sticky prices and wages and delayed pass-trough. Monetary policy follows a standard interest rate rule and there is Ricardian fiscal policy.

There are the following macroeconomic shocks. Domestic shocks: productivity, consumption, investment, goverment expenditures, production of commodities and demand for liquidity. External shocks: interest rate, country premium, deviations from uncovered interest parity, foreign output and inflation, and price of commodities.

2.6 Equilibrium

In this model, real variables quantities contain a unit root due to the presences of a stochastic productivity trend A_t, and nominal variables contain and additional trend due to long-run inflation. We need to transform the variables to have a stationary version of the model. All prices are then expressed in relative terms, and real quantities are de-trended by the productivity trend. To do this, with one exception, lowercase variables denote the uppercase variable divided by A_{t-1} (e.g. $c_t \equiv \frac{C_t}{A_{t-1}}$). The only exception is the Lagrange multiplier Λ_t that is multiplied by A_{t-1} (i.e. $\lambda_t \equiv \Lambda_t A_{t-1}$); it decreases along the balanced growth path.

The rational expectations equilibrium of the stationary version of the model model is the set of sequences

$$\{\lambda_t, c_t, h_t, h_t^d, w_t, \tilde{w}_t, mc_t^W, f_t^W, \Delta_t^W, i_t, k_t, r_t^K, q_t, y_t, y_t^C, y_t^F, y_t^H, x_t^F, x_t^H, x_t^{H*}, R_t, \xi_t, \pi_t, rer_t, p_t^H, \tilde{p}_t^H, p_t^F, \tilde{p}_t^F, p_t^Y, \pi_t^S, mc_t^H, f_t^H, \Delta_t^H, mc_t^F, f_t^F, \Delta_t^F, b_t^*, m_t, tb_t, m_t^d, m_t^a, d_t, R_t^e, R_t^D, R_t^L, \tilde{R}_t^L, n_t, l_t, lev_t, rp_t, \bar{\omega}_t, def_t, mon_t, \tilde{R}_t^D, n_t^B, \tilde{n}_t^B, \tilde{a}_t^b, spr_t, pen_t, llr_t, llu_t, cost_t\}_{t=0}^{\infty},$$

which total 63 variables. The definition of vatiables and the conditions that need to be satisfied at equilibrium are detailed in the Appendix.

The exogenous processes are

$$\log(x_t/x_{ss}) = \rho_x \log(x_{t-1}/x_{ss}) + \varepsilon_t^x, \qquad \rho_x \in [0,1), \qquad x_{ss} > 0,$$

for $x = \{v, u, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g, \pi^T, \sigma_\omega, s, \gamma, \tau, llp\}$, where the ε_t^x are assumed to be normal and identically distributed shocks.

Finally, notice that here we are assuming that γ_t, τ_t and llp_t are exogenous processes. Alternatively, they can be determined by some policy rule.

3 Data and estimation

The model is estimated using quarterly data for Uruguay in the period 2005Q1 to 2015Q4. Uruguay is a small, open economy, with a highly dollarized financial sector. In terms of regulation, a dynamic loan loss provision system has been working in Uruguay since early 2000s.

The same data but for the period 2008-2015 is used to calibrate the target levels of financial parameters. The first years of the sample were not considered because of the inestability on the ratios after the banking crisis of 2002. Financial targets, in US dollars, correspond to the following values:

- Quarterly Default rate: 1.3% (default/loans)

- Quarterly active rate: 2.4% (loans interest/ loans)
- Quarterly passive rate: 0.3% (deposit interest/ deposits)
- Loans share: 48% (loans/(loans+bonds))
- Capital adequacy ratio: 8.49% (capital / assets)
- Minimum capital requirement: 4.88% (minimum capital / assets)
- Provisions coverage ratio: 6.73% (provisions / loans)

We use a Bayesian approach to estimate the model parameters. As observables we use the following macroeconomic variables: growth of output, consumption, investment, inflation, monetary policy rate, nominal depreciation, foreign interest rate, country premium, inflation and ouput of commercial partners; and of the following financial variables: real growth of credit, deposits, bank's capital, default rate, interest rate spread, regulatory and total capital buffer.

The estimated values of selected parameters of the model are presented in Table 1.

Table 1: Estimation of selected parameters

Param.	Description	Estimation
μ	Monitoring costs	0.04
υ	Survival rate of entrepreneurs	0.91
ϕ_B	Elasticity of bank penalty function	319
γ_{DEF}	Banks capital default component	0.08
γ_L	Banks capital credit component	0.10
$\rho_{\sigma\omega}$	Persistence entrepreneurs' shock	0.69
$\epsilon_{\sigma\omega}$	Std. dev. entrepreneurs' shock	0.11
ρ_{γ_0}	Exogenous capital rule persistence	0.97
$\rho_{\gamma_{reg}}$	Banks capital buffer persistence	0.96
ϵ_{γ_0}	Exogenous capital rule std. dev.	0.36
$\epsilon_{\gamma_{reg}}$	Banks capital buffer std. dev.	0.29

The goodness of fit of the estimated parameters may be evaluated by comparing the standard deviation of variables on the data versus that implied by the model. This comparison is in Table 2. Overall, the goodness of fit of the model is adequate.

Table 2: Goodness of fit (standard deviation in percent)

Variable	Data	Base
GDP growth	1.47	1.85
Cons. growth	1.51	2.15
Inv. growth	6.94	6.75
Country premium	0.28	0.91
R	0.82	1.00
Default	1.39	2.54
Bank's capital growth	5.36	6.66
Credit growth	4.67	2.23
Deposits growth	3.16	7.37
Required buffer capital growth	17.61	15.35
Bank's buffer capital growth	7.66	17.56

As a by product of the estimated model it is possible to determine what explain the movements of financial variables. Table 3 shows the variance decomposition of three selected financial variables. The country premium and other international financial factors, e.g. the interest rate parity and the rate of international inflation, are important to explain the movement of bank capital, credit growth and default. Instead, domestic real factors matter to explain credit growth while shocks to the productivity of entrepreneurs is the most important domestic factor to explain the rate of default.

Table 3: Variance decomposition (percent)

Source of shocks	Bank capital growth	Credit growth	Default
International financial factors	46	68	62
Domestic real factors	1	28	3
Entrepreneurs productivity shock	0	1	24
Bank costs	37	1	0
Others	16	2	11

4 Countercyclical capital buffer and dynamic provisions

In this section we present the results of a series of simulation exercises. Our objective is to provide an assessment of the relative efficiency of different countercyclical bank regulations. We focus on countercyclical capital requirements and on dynamic provisions. We analyze the dynamic of real and banking variables under different specifications of the countercyclical rules, and for different calibration of their governing parameters. For simplicity, we analyze two positive shocks: a reduction in the country premium (an aggregate, external shock) and a reduction on the risk of entrepreneurs (an idiosyncratic shock). Overall, the focus is on the tools' buffering capacity and their effects on real and financial variables.

4.1 Countercyclical capital buffer

Before introducing a countercyclical capital requirement (or buffer), Figure 1 shows the impulse-response functions for a positive shock (a reduction) of the country premium in the case where capital requirements are not cyclically adjusted (notice that γ_{REG} does not change with the shock). The shock is expansionary. Gross Domestic Product (GDP), consumption (C) and investment (I) raise after the shock, which shows to have persistent effects. The reduction in country risk affects the entrepreneurs relative cost of funding, reducing their leverage (lev^e) which determines a lower default rate (def). Bank credit (l) also expands but more slowly than GDP, which determines that during the 10 first quarters after the shock the ratio of credit to GDP falls. Interestingly, if based on this ratio, a cyclically-adjusted bank capital requirement would be procyclical rather than countercyclical! Indeed, the shock reduces the bank capital to asset ratio (N^b/A) because banks are willing to maintain a lower buffer above the minimum capital requirement (γ_{BUFFER}). This implies that, although bank capital (n^b) increases, it does less than bank assets.

In Figure 2 we show the impulse-response functions for the same unexpected, positive shock to country premium when capital requirements follow a countercyclical rule based on the dynamic of real credit growth: $\gamma_t^R = \gamma_0^R + \alpha_l^R(\Delta L_t - \Delta L_{ss})$, for three values of the parameter α_l^R. A first observation is that the introduction of this rule effectively raises the bank

Figure 1: Impulse-response functions: country risk premium shock

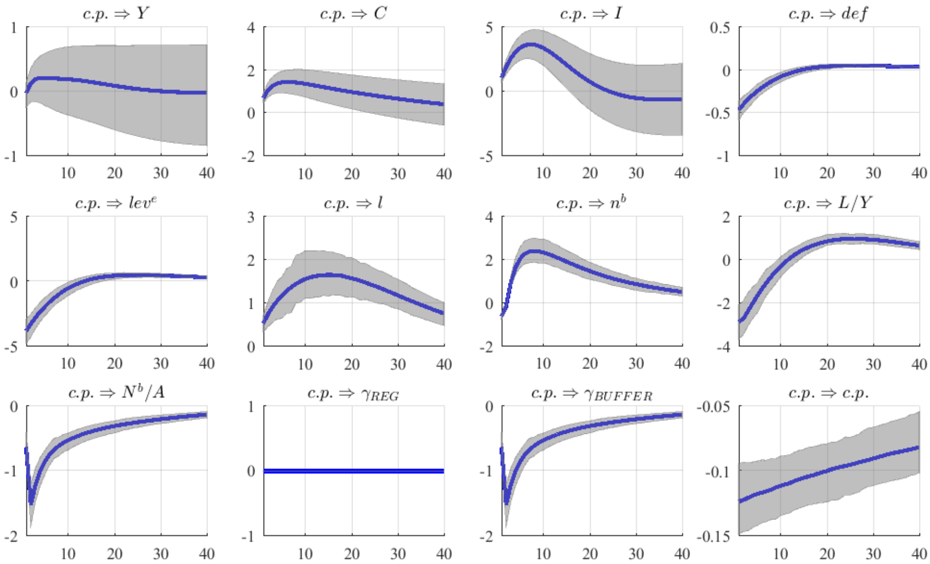
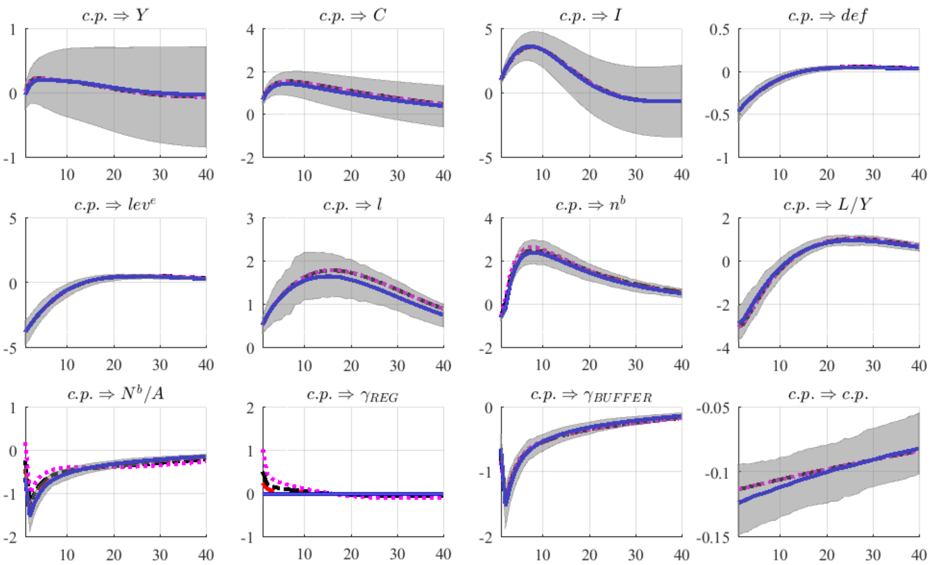


Figure 2: Country risk premium shock: CCB - real credit growth rule



Solid blue: baseline no rule. Dashed red: $\alpha_l^R = 0.5$. Dashed black: $\alpha_l^R = 1.0$. Dotted magenta: $\alpha_l^R = 2.0$.

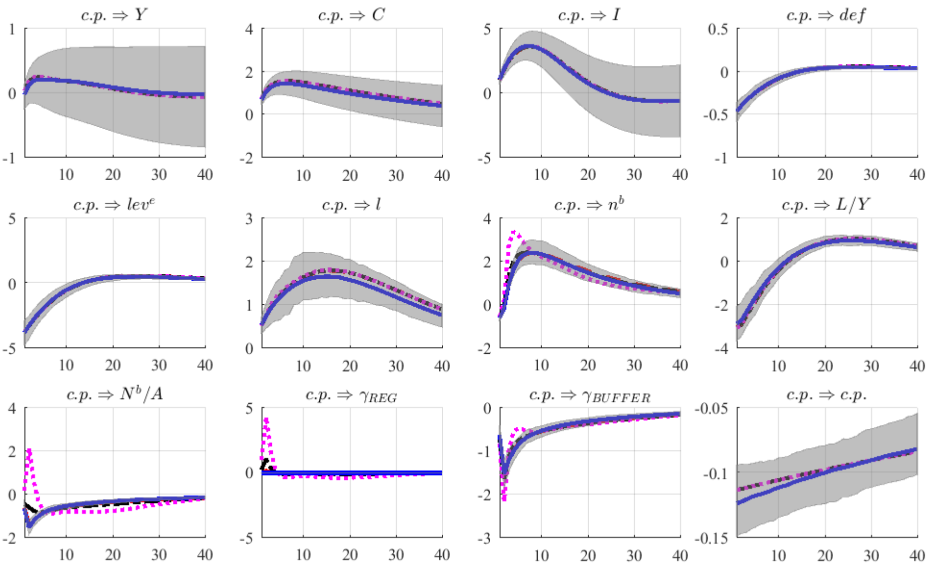
capital requirement (γ_{REG}) during the period in which bank credit is expanding due to the positive external shock (15 quarters approximately). Second, this impacts positively on bank capital, so that the ratio of bank capital to bank assets fall less during the boom than without a cyclically-adjusted capital requirement. Although there is no major effects on the capital buffer (γ_{BUFFER}) that banks are willing to maintain, the higher minimum capital requirements implies an overall higher level of bank capital. Third, the higher capital requirements due to the countercyclical capital rule do not have major effects on real variables such as activity, consumption or investment. Fourth, it does not have major effects on the dynamic of credit neither.

Figure 3 shows the results when the countercyclical capital rule is linked to the dynamics of real GDP growth: $\gamma_t^R = \gamma_0^R + \alpha_y^R(\Delta Y_t - \Delta Y_{ss})$. This case shares the qualitative conclusions from the real credit growth rule: capital requirements raises in response to the shock implying higher bank capitalization than in the benchmark case without major real effects. However, the raise in capital requirements takes place in a shorter period of time because the growth rate of GDP is higher than that of credit over the first four quarters after the shock. Moreover, on the more stringent calibrations of the countercyclical rule ($\alpha_y^R = 2.0$) the ratio of bank capital to bank assets raises instead of falling as in the benchmark case. This implies a higher capitalization of the banking system. However, it is important to notice that higher capital requirement (γ_{REG}) over a shorther period of time implies a more volatile desired capital buffer (γ_{BUFFER}).

We now turn the analysis to the case of an idiosyncratic, positive shock to the riskiness of entrepreneurs (i.e. a reduction on the standard deviation σ_ω of their distribution of risk). Figure 4 shows impulse and response functions to this shock for the benchmark case with plain capital requirements, as well as for the countercyclical capital requirement linked to real credit growth. The decrease on entrepreneurs' riskiness has direct impact on the rate of default, which in turn raises bank credit with a positive impact on activity and other real variables. Differently than in the case of a shock to country risk, in this case the ratio of credit to GDP increases. Overall, banks use their capital buffers to fund new loans, and just raises new capital after 5-10 quarters, so that the ratio of bank capital to bank assets decreases.

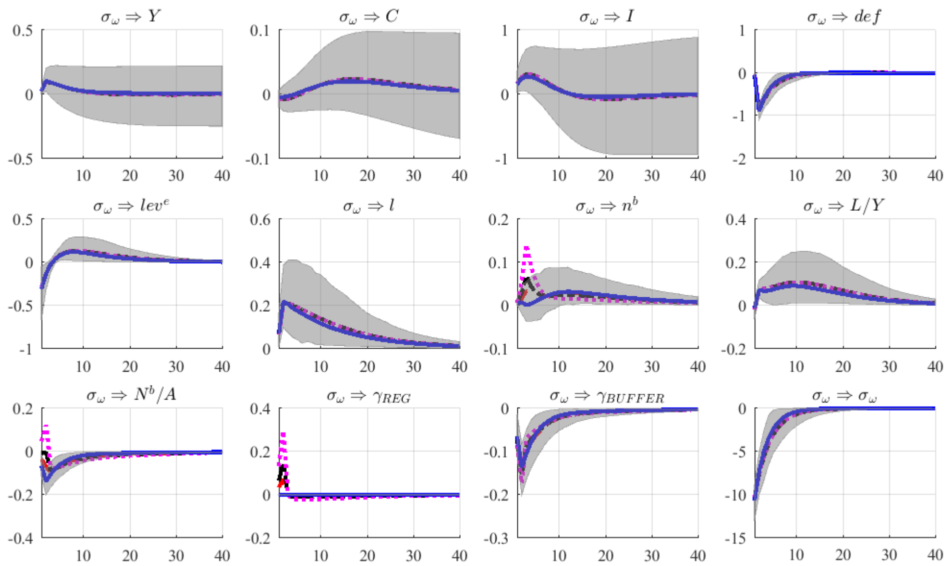
The countercyclical capital requirement linked to real credit growth ($\gamma_t^R =$

Figure 3: Country risk premium shock: CCB - real GDP growth rule



Solid blue: baseline no rule. Dashed red: $\alpha_y^R = 0.5$. Dashed black: $\alpha_y^R = 1.0$. Dotted magenta: $\alpha_y^R = 2.0$.

Figure 4: Entrepreneurs risk premium shock: CCB - real credit growth rule

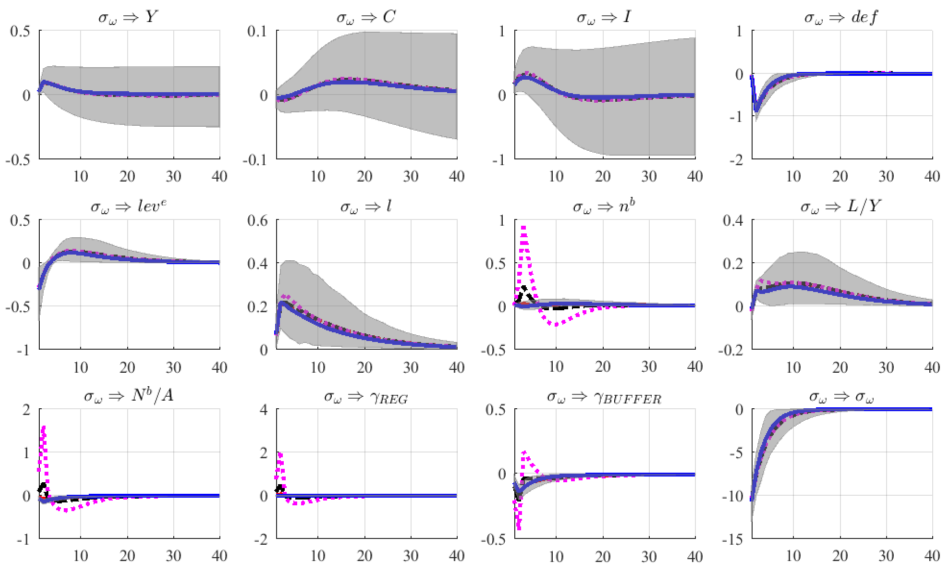


Solid blue: baseline no rule. Dashed red: $\alpha_l^R = 0.5$. Dashed black: $\alpha_l^R = 1.0$. Dotted magenta: $\alpha_l^R = 2.0$.

$\gamma_0^R + \alpha_l^R(\Delta L_t - \Delta L_{ss})$) is effective to buffer bank capital during the period in which the idiosyncratic shock persists. Indeed, in all calibrations of the rule the level of bank capital (n^b) increases instead of staying constant over the first quarters after the shock. However, there are not major effects on real variables nor on bank credit.

Similar conclusions are reached when the countercyclical capital requirement is linked to real GDP growth (see Figure 5). However, this rule is more sensitive than the former one to the calibration of the governing parameter. Indeed, by setting $\alpha_l^R = 2.0$ bank capital rises to a point that allows an increase of credit over the benchmark case, then adding more procyclicality to the ratio of credit to GDP. Moreover, in this case the regulatory capital requirement (γ_{REG}) and the in-excess desired level of capital by banks (γ_{BUFFER}) increase volatility with respect to the benchmark case.

Figure 5: Entrepreneurs risk premium shock: CCB - real GDP growth rule



Solid blue: baseline no rule. Dashed red: $\alpha_y^R = 0.5$. Dashed black: $\alpha_y^R = 1.0$. Dotted magenta: $\alpha_y^R = 2.0$.

4.2 Dynamic provisions

In this section we analyze the dynamics impulsed by the same shocks that were analyzed in the previous section but considering now a dynamic provision rule for loan losses (i.e. $LLP_t = l_0 \text{def}_t L_t + l_1(\text{def}^{ss} - \text{def}_t) l_0 L_t$) instead of a countercyclical capital requirement. As in the previous section, we consider expansionary shocks and focus the assessment on the buffering capacity of the regulatory tools.

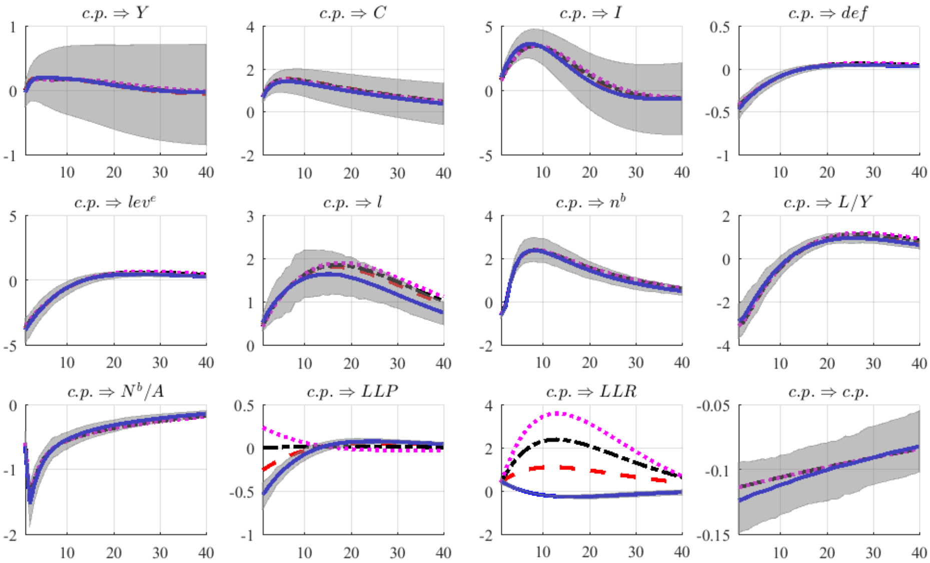
Figure 6 shows in solid blue lines the benchmark case were loan loss provisions are static (i.e. $LLP_t = l_0 \text{def}_t L_t$). The unexpected reduction in the country risk premium translate into lower entrepreneurs' leverage and default rates. In turn, given the static nature of the provision rule, current period loan loss provisions (LLP_t) fall, which adds procyclicality to financial variables like, for example, bank credit. The introduction of a dynamic component to the loan loss provision rule is effective to mitigate this procyclicality. Moreover, loan loss provisions become countercyclical if the weight of the dynamic component on the rule is high enough. In this case, bank capital (N^b) and the ratio of bank capital to total assets (N^b/A) are similar to those in the benchmark case. Nevertheless, the provision fund (LLR_t) accumulates a buffer that may be used when the cycle reverts.

Differently than in the case of a countercyclical capital requirement, dynamic loan loss provisions do have a countercyclical effect on real variables. This happens because the dynamic provision rule smooths the dynamics of bank credit. During the boom, the provision rate increases, then it taxes the provision of new credit, which in turn moderates credit expansion. After approximately twelve quarters, when the effect of the shock on entrepreneurs' default is over, the provision rate falls, then impulsing bank credit. In turn, this effects channels to real variables: the procyclicality of activity, consumption and investment falls. Interestingly, while the static provision rule makes activity to fall below the steady-state level after several periods, the dynamic provision rule reduces this risk.

Figure 7 shows the effects of an unexpected shock to the entrepreneurs' risk premium. Overall, the qualitative results of the country risk premium shock case hold for the case of the shock to entrepreneurs' risk premium. In particular, dynamic loan loss provisions are effective to mitigate the procyclicality introduced by the shock and to build a reserve fund that may be used to absorb future losses. Moreover, in this case dynamic provisions achieve almost the stabilization of banks' leverage (the inverse of the ratio N^b/A) by moderating bank credit and slightly raising bank capital over the benchmark with only static provisions.

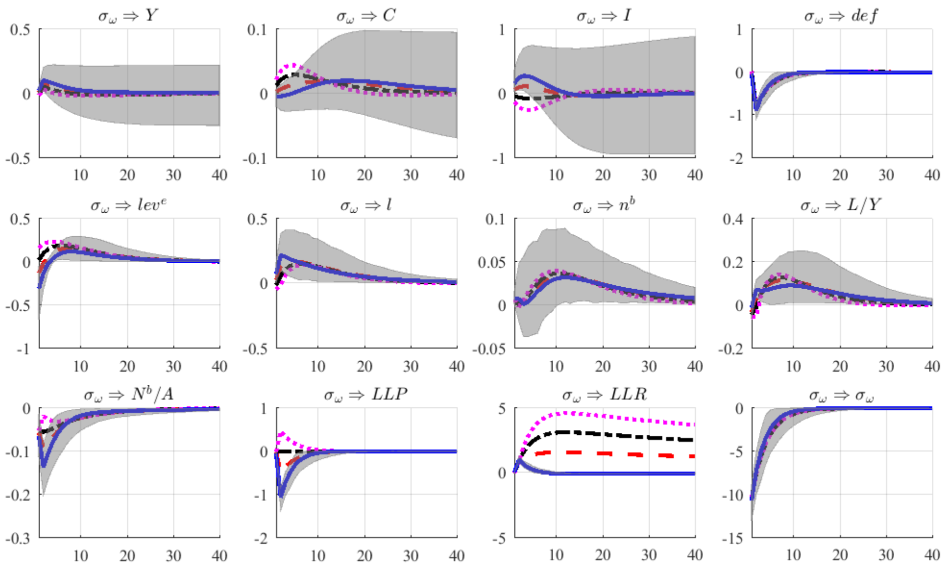
The qualitative results from Figures 6 and 7 hold if we consider that the

Figure 6: Country risk premium shock: static vs. dynamic provisions



Solid blue: static provisions ($l_1 = 0$). Dashed red: $_1 = 0.5$. Dashed black: $_1 = 1.0$. Dotted magenta: $_1 = 1.5$.

Figure 7: Entrepreneurs risk premium shock: static vs. dynamic provisions



Solid blue: static provisions ($l_1 = 0$). Dashed red: $_1 = 0.5$. Dashed black: $_1 = 1.0$. Dotted magenta: $_1 = 1.5$.

dynamic provision rule is linked to expected default, i.e. $E(\text{def}_{t+1})$, instead of current default, i.e. def_t (see the Appendix).

5 Final remarks

With the aim of performing a realistic assessment of the countercyclical regulation promulgated in Basel III, and to compare its relative performance with other macroprudential policies already used in many countries, i.e. dynamic loan loss provisions, we develop a DSGE model for a small, open economy. In the model, entrepreneurs' default is endogenous and we put particular attention to the modeling of the banking sector and its prudential regulation.

The model has been estimated using quarterly data for Uruguay in the period 2005Q1 to 2015Q4. Uruguay has been using dynamic loan loss provisions since 2001. Hence, this data provides a nice counterfactual for a realistic estimation of the proposed DSGE model.

The results suggest that both countercyclical capital buffers and dynamic provisions are effective in generating buffers than may cover future losses. However, countercyclical capital requirements do not have major real effects while dynamic provisions may have. When the economy faces a positive, external shock, a countercyclical capital rule based on real GDP growth has a quicker and stronger effect in buffering bank capital than a rule based on real credit growth. In this case, the ratio of credit to GDP decreases, which discourages the use of this variable to guide the buffering decision. In terms of smoothing the cycles, dynamic provisions seems to outperform countercyclical capital requirements under external financial shocks.

Finally, the source of the shock matters to select the indicator variable for the countercyclical capital requirement (credit to GDP does not seem adequate under external shocks), to calibrate the size of the dynamic provisioning (the same calibration may be too countercyclical if the shock is domestic than if it is external), and to select the policy tool (dynamic provisions seems to outperform countercyclical capital requirements under external financial shocks). Hence, it seems prudent to have both policy tools available on the set of regulatory instruments.

Appendix

A Definition of variables

Table A.1: Exogenous processes

v	Households' preference shock
u	Investment shock
z	Temporary TFP shock
a	Permanent TFP shock
ζ	Country premium shock
R^*	Foreign interest rate
π^*	Foreign inflation rate
p^{Co*}	Commodities price
y^{Co}	Commodities endowment
y^*	Foreign GDP
g	Fiscal expenditures
σ_ω	Std. dev. of entrepreneurs' risk shock
s	Costs of banks' assets substitution
γ	Banks' capital to assets ratio
τ	Banks' reserve requirement

Table A.2: Selected endogenous variables

c	Consumption	mc^H	Home goods marginal cost
h	Labor supply (hours)	mc^F	Foreign goods marginal cost
h^d	Labor demand (hours)	Δ^H	Hours dispersion
w	Wage	Δ^W	Wage dispersion
$\tilde{w}$	Adjusters' optimal wage	Δ^F	Foreign good dispersion
mc^W	Labor marginal costs	m	Imports
r^K	Rent capital rate	b^*	Banks bonds holdings
i	Investment	tb	Trade balance
k	Entrepreneurs' capital	m^d	Money demand
π^S	Currency depreciation	m^a	Households' financial assets
q	Price of entrepreneurs' capital	d	Bank deposits
y	GDP	R^e	Entrepreneurs' return
y^C	Domestic absorption	R^D	Deposits interest rate
y^F	Foreign good supply	R^L	Loans interest rate
x^F	Foreign good demand	y^H	Home composite goods supply
x^H	Domestic home good demand	l	Bank loans
x^{H*}	Home good exports	lev	Entrepreneurs' leverage
R	Monetary policy rate	rp	Entrepreneurs' risk premium
ξ	Country premium	$\bar{\omega}$	Optimal threshold
π	Inflation rate	def	Default rate
rer	Real exchange rate	p^H	Home good price
$\tilde{p}^H$	Adjusters' optimal home good price	n^B	Predetermined banks' capital
p^F	Foreign good price	$\tilde{n}^B$	Banks' capital
$\tilde{p}^F$	Adjusters' optimal foreign good price	$\tilde{a}^b$	Banks' assets
p^Y	GDP deflator	spr	Spread on banks' interest rates
pen	Banks' capital penalty	llr	Loan loss reserve fund
llu	Loan loss utilization	cost	Banks' costs
λ	Lagrange multiplier		

B Equilibrium conditions

Given initial values and exogenous sequences

$$\{v_t, u_t, z_t, a_t, \zeta_t, R_t^*, \pi_t^*, p_t^{Co*}, y_t^{Co}, y_t^*, g_t, \pi_t^T, \sigma_{\omega,t}, s_t, \gamma_t, \tau_t\}_{t=0}^{\infty},$$

the following conditions are satisfied at the equilibrium:

Households:

$$\lambda_t = \left(c_t - \varsigma \frac{c_{t-1}}{a_{t-1}}\right)^{-1} - \beta\varsigma E_t\left\{\frac{v_{t+1}}{v_t}\left(c_{t+1}a_t - \varsigma c_t\right)^{-1}\right\}, \tag{E.1}$$

$$w_t mc_t^W = \kappa \frac{h_t^\phi}{\lambda_t}, \tag{E.2}$$

$$\lambda_t = \frac{\beta}{a_t} R_t E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\pi_{t+1}}\right\}, \tag{E.3}$$

$$\lambda_t = \frac{\beta}{a_t} R_t^* \xi_t E_t\left\{\frac{v_{t+1}}{v_t}\frac{\pi_{t+1}^S \lambda_{t+1}}{\pi_{t+1}}\right\}, \tag{E.4}$$

$$f_t^W = mc_t^W \tilde{w}_t^{-\epsilon_W} h_t^d + \beta\theta_W E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_W}(\pi_{t+1}^T)^{1-\vartheta_W}}{\pi_{t+1}}\right)^{-\epsilon_W}\left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}}\right)^{-\epsilon_W}\left(\frac{w_t}{w_{t+1}}\right)^{-1-\epsilon_W} f_{t+1}^W\right\}. \tag{E.5}$$

$$f_t^W = \tilde{w}_t^{1-\epsilon_W} h_t^d\left(\frac{\epsilon_W - 1}{\epsilon_W}\right) + \beta\theta_W E_t\left\{\frac{v_{t+1}}{v_t}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t^{\vartheta_W}(\pi_{t+1}^T)^{1-\vartheta_W}}{\pi_{t+1}}\right)^{1-\epsilon_W}\left(\frac{\tilde{w}_t}{\tilde{w}_{t+1}}\right)^{1-\epsilon_W}\left(\frac{w_t}{w_{t+1}}\right)^{-\epsilon_W} f_t^W\right\}. \tag{E.6}$$

$$1 = (1-\theta_W)\tilde{w}_t^{1-\epsilon_W} + \theta_W\left(\frac{w_{t-1}}{w_t}\frac{\pi_{t-1}^{\vartheta_W}(\pi_t^T)^{1-\vartheta_W}}{\pi_t}\right)^{1-\epsilon_W}. \tag{E.7}$$

$$\Delta_t^W = (1-\theta_W)\tilde{w}_t^{-\epsilon_W} + \theta_W\left(\frac{w_{t-1}}{w_t}\frac{\pi_{t-1}^{\vartheta_W}(\pi_t^T)^{1-\vartheta_W}}{\pi_t}\right)^{-\epsilon_W}\Delta_{t-1}^W. \tag{E.8}$$

$$h_t = h_t^d \Delta_t^W. \tag{E.9}$$

$$m_t^a = \left[(1-o_M)^{\frac{1}{\eta_M}}(rer_t d_t)^{\frac{\eta_M-1}{\eta_M}} + o_M^{\frac{1}{\eta_M}}\left(m_t^d\right)^{\frac{\eta_M-1}{\eta_M}}\right]^{\frac{\eta_M}{\eta_M-1}} \tag{E.10}$$

$$\lambda_t(1-R_t^{-1}) = \nu_t\left(m_t^a\right)^{-1+\frac{1}{\eta_M}} o_M^{\frac{1}{\eta_M}}\left(m_t^d\right)^{\frac{-1}{\eta_M}} \tag{E.11}$$

$$\lambda_t\left(1 - \frac{R_t^D}{R_t^*\xi_t}\right) = \nu_t\left(m_t^a\right)^{-1+\frac{1}{\eta_M}}(1-o_M)^{\frac{1}{\eta_M}}(rer_t d_t)^{\frac{-1}{\eta_M}} \tag{E.12}$$

Aggregate Consumption:

$$y_t^C = \left[(1-o)^{\frac{1}{\eta}}\left(x_t^H\right)^{\frac{\eta-1}{\eta}} + o^{\frac{1}{\eta}}\left(x_t^F\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{E.13}$$

$$x_t^F = o\left(p_t^F\right)^{-\eta} y_t^C, \tag{E.14}$$

$$x_t^H = (1-o)\left(p_t^H\right)^{-\eta} y_t^C, \tag{E.15}$$

Home goods:

$$mc_t^H = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{(r_t^K)^\alpha w_t^{1-\alpha}}{p_t^H z_t a_t^{1-\alpha}}, \tag{E.16}$$

$$\frac{k_{t-1}}{h_t^d} = a_{t-1} \frac{\alpha}{1-\alpha} \frac{w_t}{r_t^K}, \tag{E.17}$$

$$y_t^H \Delta_t^H = z_t \left(\frac{k_{t-1}}{a_{t-1}}\right)^\alpha (a_t h_t^d)^{1-\alpha}, \tag{E.18}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{-\epsilon_H} y_t^H mc_t^H + \beta\theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} (\pi_{t+1}^T)^{1-\vartheta_H}}{\pi_{t+1}} \right)^{-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H}\right)^{-1-\epsilon_H} f_{t+1}^H \right\}, \tag{E.19}$$

$$f_t^H = \left(\tilde{p}_t^H\right)^{1-\epsilon_H} y_t^H \left(\frac{\epsilon_H - 1}{\epsilon_H}\right) + \beta\theta_H E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_H} (\pi_{t+1}^T)^{1-\vartheta_H}}{\pi_{t+1}} \right)^{1-\epsilon_H} \left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{1-\epsilon_H} \left(\frac{p_t^H}{p_{t+1}^H}\right)^{-\epsilon_H} f_{t+1}^H \right\}, \tag{E.20}$$

$$1 = \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} (\pi_t^T)^{1-\vartheta_H}}{\pi_t} \right)^{1-\epsilon_H} + (1-\theta_H) \left(\tilde{p}_t^H\right)^{1-\epsilon_H}, \tag{E.21}$$

$$\Delta_t^H = (1-\theta_H) \left(\tilde{p}_t^H\right)^{-\epsilon_H} + \theta_H \left(\frac{p_{t-1}^H}{p_t^H} \frac{\pi_{t-1}^{\vartheta_H} (\pi_t^T)^{1-\vartheta_H}}{\pi_t} \right)^{-\epsilon_H} \Delta_{t-1}^H, \tag{E.22}$$

Import Agents:

$$1 = \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} (\pi_t^T)^{1-\vartheta_F}}{\pi_t} \right)^{1-\epsilon_F} + (1-\theta_F) \left(\tilde{p}_t^F\right)^{1-\epsilon_F}. \tag{E.23}$$

$$\Delta_t^F = (1-\theta_F) \left(\tilde{p}_t^F\right)^{-\epsilon_F} + \theta_F \left(\frac{p_{t-1}^F}{p_t^F} \frac{\pi_{t-1}^{\vartheta_F} (\pi_t^T)^{1-\vartheta_F}}{\pi_t} \right)^{-\epsilon_F} \Delta_{t-1}^F. \tag{E.24}$$

$$mc_t^F = rer_t / p_t^F. \tag{E.25}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{-\epsilon_F} y_t^F mc_t^F + \beta\theta_F E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} \pi^{1-\vartheta_F}}{\pi_{t+1}} \right)^{-\epsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{-\epsilon_F} \left(\frac{p_t^F}{p_{t+1}^F}\right)^{-1-\epsilon_F} f_{t+1}^F \right\}. \tag{E.26}$$

$$f_t^F = \left(\tilde{p}_t^F\right)^{1-\epsilon_F} y_t^F \left(\frac{\epsilon_F - 1}{\epsilon_F}\right) + \beta\theta_F E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_t^{\vartheta_F} (\pi_{t+1}^T)^{1-\vartheta_F}}{\pi_{t+1}} \right)^{1-\epsilon_F} \left(\frac{\tilde{p}_t^F}{\tilde{p}_{t+1}^F}\right)^{1-\epsilon_F} \left(\frac{p_t^F}{p_{t+1}^F}\right)^{-\epsilon_F} f_{t+1}^F \right\}. \tag{E.27}$$

$$m_t = y_t^F \Delta_t^F. \tag{E.28}$$

Investment:

$$k_t = (1-\delta) \frac{k_{t-1}}{a_{t-1}} + \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 \right] u_t i_t, \tag{E.29}$$

$$\begin{aligned} \frac{1}{q_t} &= \left[1 - \frac{\gamma}{2} \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right)^2 - \gamma \left(\frac{i_t}{i_{t-1}} a_{t-1} - \bar{a} \right) \frac{i_t}{i_{t-1}} a_{t-1} \right] u_t \\ &\quad + \frac{\beta}{a_t} \gamma E_t \left\{ \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1}}{\lambda_t} \frac{q_{t+1}}{q_t} \left(\frac{i_{t+1}}{i_t} a_t - \bar{a} \right) \left(\frac{i_{t+1}}{i_t} a_t \right)^2 u_{t+1} \right\}. \end{aligned} \tag{E.30}$$

Entrepreneurs:

$$\frac{R^e_t}{\pi_t} = \frac{r^K_t + q_t(1-\delta)}{q_{t-1}}. \tag{E.31}$$

$$\tilde{R}^L_t l_{t-1} rer_{t-1} \pi^S_t = g_{t-1}(\bar{\omega}_t) R^e_t q_{t-1} k_{t-1}, \tag{E.32}$$

$$q_t k_t = n_t + l_t rer_t, \tag{E.33}$$

$$lev_t = \frac{q_t k_t}{n_t}, \tag{E.34}$$

$$E_t \left\{ R^e_{t+1} \left[h_t(\bar{\omega}_{t+1}) - \frac{h'_t(\bar{\omega}_{t+1}) g_t(\bar{\omega}_{t+1})}{g'_t(\bar{\omega}_{t+1})} \right] \right\} = E_t \left\{ \frac{h'_t(\bar{\omega}_{t+1})}{g'_t(\bar{\omega}_{t+1})} \tilde{R}^L_{t+1} \pi^S_{t+1} \right\}, \tag{E.35}$$

$$rp_t = E_t \left\{ R^e_{t+1} \right\} / E_t \{ \tilde{R}^L_t \pi^S_{t+1} \}, \tag{E.36}$$

$$n_t = \vartheta \left\{ R^e_t \frac{q_{t-1}}{\pi_t} \frac{k_{t-1}}{a_{t-1}} h_{t-1}(\bar{\omega}_t) \right\} + \iota^e, \tag{E.37}$$

$$R^L_{t-1} l_{t-1} rer_{t-1} \pi^S_t = \bar{\omega}_t R^e_t q_{t-1} k_{t-1}, \tag{E.38}$$

$$def_t = \Phi \left(\frac{ln(\bar{\omega}_t) + .5\sigma^2_{\omega,t-1}}{\sigma_{\omega,t-1}} \right), \tag{E.39}$$

$$mon_t = \left[1 - h_{t-1}(\bar{\omega}_t) - g_{t-1}(\bar{\omega}_t) \right] R^e_t q_{t-1} k_{t-1}. \tag{E.40}$$

Banks:

$$l_t + b + llp_t = (1 - \tau_t) d_t + n^b_t, \tag{E.41}$$

$$a_{t-1} \tilde{n}^b_t = \tilde{R}^L_t l_{t-1} + b_{t-1} R^*_t \xi_t + llu_t - (R^D_{t-1} - \tau_{t-1}) d_{t-1}, \tag{E.42}$$

$$a_{t-1} llu_t = \min \left\{ (R^L_{t-1} - \tilde{R}^L_t) l_{t-1}, llr_{t-1} + llp_{t-1} \right\}, \tag{E.43}$$

$$a_{t-1} \tilde{a}^b_t = \tilde{R}^L_t l_{t-1} + b_{t-1} R^*_t \xi_t + a_{t-1} llu_t + \tau_{t-1} d_{t-1}, \tag{E.44}$$

$$llr_t = \frac{(llr_{t-1} + llp_{t-1})}{a_{t-1}} - llu_t, \tag{E.45}$$

$$E_t \left\{ \frac{\beta}{a_t} \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1} \pi^S_{t+1}}{\lambda_t \pi_{t+1}} \left[\frac{\partial \tilde{n}^b_{t+1}}{\partial L_t} - \frac{\partial pen_{t+1}}{\partial L_t} \right] \right\} = s_t S^L L_t, \tag{E.46}$$

$$E_t \left\{ \frac{\beta}{a_t} \frac{v_{t+1}}{v_t} \frac{\lambda_{t+1} \pi^S_{t+1}}{\lambda_t \pi_{t+1}} \left[\frac{\partial \tilde{n}^b_{t+1}}{\partial B_t} - \frac{\partial pen_{t+1}}{\partial B_t} \right] \right\} = s_t B_t. \tag{E.47}$$

$$\tilde{R}^D_t = \frac{R^D_t - \tau_t}{1 - \tau_t}, \tag{E.48}$$

$$pen_t = \frac{\phi_D}{2} \left(\frac{\tilde{n}^b_t}{\tilde{a}^b_t} - \gamma_{t-1} \right)^2 \tilde{n}^b_t, \tag{E.49}$$

$$n^b_t = \frac{\vartheta^B}{\pi_t} \left[\tilde{n}^b_t - pen_t - cost_{t-1} \right] + \iota^B n^b, \tag{E.50}$$

$$spr_t = R^L_t / R^D_t, \tag{E.51}$$

$$cost_t = s_t (S^L l^2_t + b^2_t). \tag{E.52}$$

Rest of the world:

$$x^{H*}_t = o^* \left(\frac{p^H_t}{rer_t} \right)^{-\eta^*} y^*_t, \tag{E.53}$$

$$\xi_t = \bar{\xi} \exp \left[-\psi \left(\frac{rer_t b_t^* - rer \times b^*}{rer \times b^*} \right) + \frac{\zeta_t - \zeta}{\zeta} \right], \tag{E.54}$$

Policy:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi_t^T} \right)^{\alpha_\pi} \left(\frac{y_t}{y} \right)^{\alpha_y} \left(\frac{\pi_t^S}{\bar{\pi}^S} \right)^{\alpha_{\pi^S}} \right]^{1-\rho_R} \exp(\varepsilon_t^R), \tag{E.55}$$

Aggregation and Market clearing:

$$y_t^H = x_t^H + x_t^{H*}, \tag{E.56}$$

$$y_t^C = c_t + i_t + g_t + mon_t, \tag{E.57}$$

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^S \pi_t^*}{\pi_t}. \tag{E.58}$$

$$y_t = c_t + i_t + g_t + x_t^{H*} + y_t^{Co} - m_t, \tag{E.59}$$

$$tb_t = p_t^H x_t^{H*} + rer_t p_t^{Co*} y_t^{Co} - rer_t m_t, \tag{E.60}$$

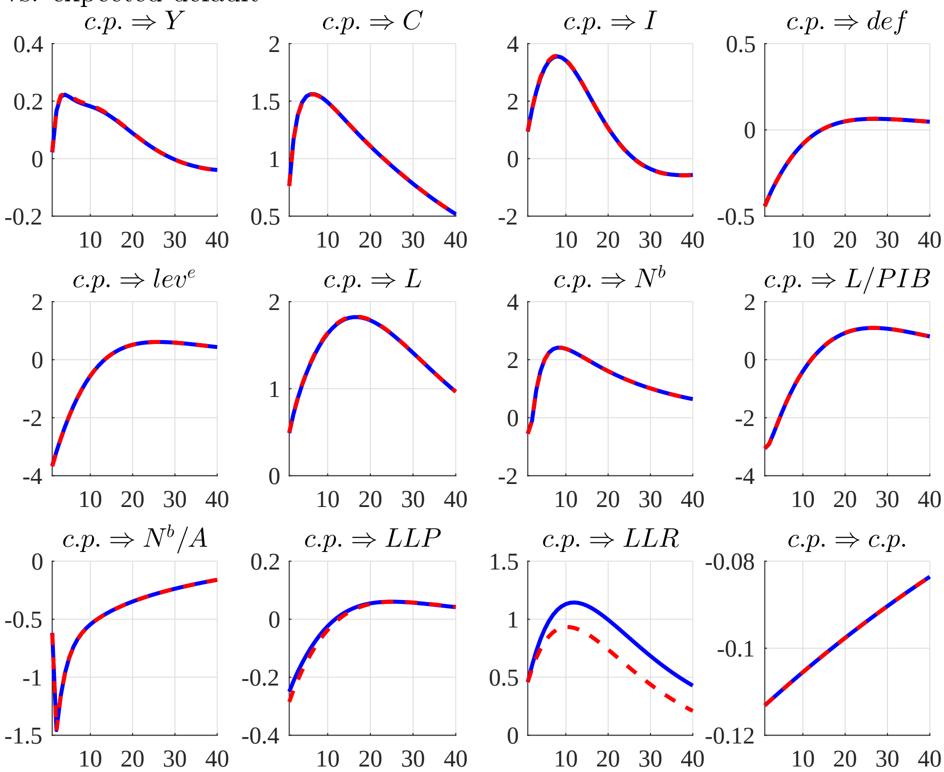
$$rer_t b_t^* = rer_t \frac{b_{t-1}^*}{a_{t-1} \pi_t^*} R_{t-1}^* \xi_{t-1} + tb_t - (1-\chi) rer_t p_t^{Co*} y_t^{Co}, \tag{E.61}$$

$$p_t^Y y_t = c_t + i_t + g_t + tb_t. \tag{E.62}$$

$$y_t^F = x_t^F. \tag{E.63}$$

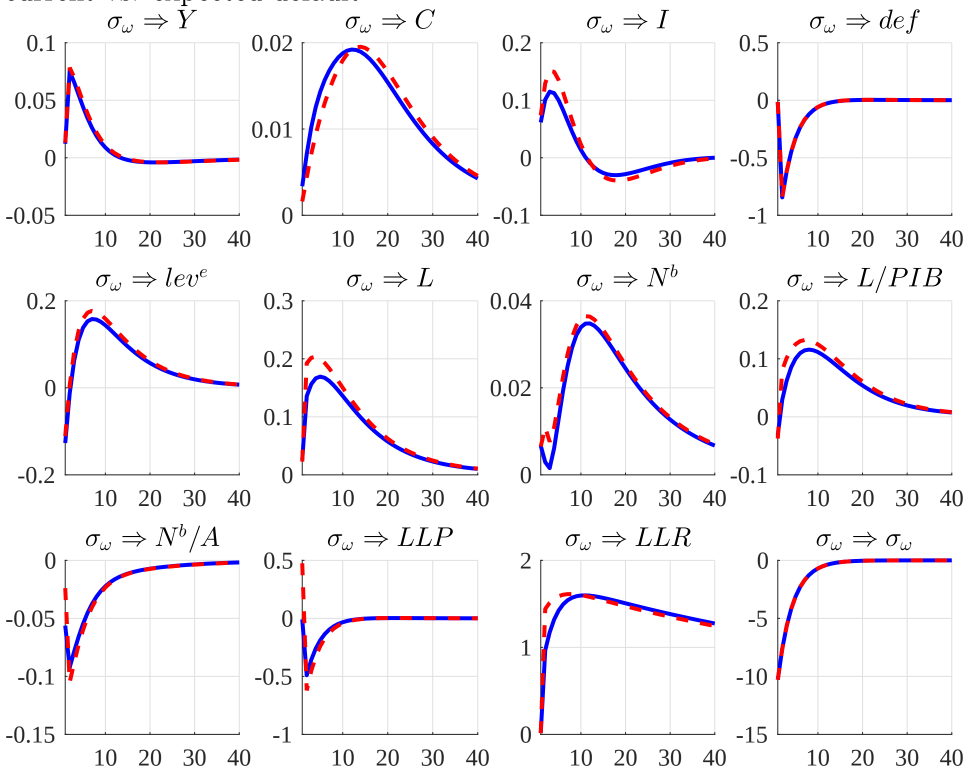
C Extra figures

Figure A.1: Dynamic provisions with country risk premium shock: current vs. expected default



Solid blue: current default ($j = t$). Dashed red: expected default ($j = t+1$). Both $l_1 = 0.5$.

Figure A.2: Dynamic provisions with entrepreneurs risk premium shock: current vs. expected default



Solid blue: current default ($j = t$). Dashed red: expected default ($j = t+1$). Both $l_1 = 0.5$.

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