Latin American Journal of Central Banking 4 (2023) 100095

Contents lists available at ScienceDirect

Latin American Journal of Central Banking

journal homepage: www.elsevier.com/locate/latcb

Countercyclical prudential tools in an estimated DSGE model☆

Serafín Frache[a], Javier García-Cicco[b], Jorge Ponce[c,*]

[a] Universidad de Montevideo, Uruguay
[b] Universidad de San Andrés, Argentina
[c] Banco Central del Uruguay and dECON-FCS-UdelaR, Uruguay

ARTICLE INFO

JEL classification:
G21
G28

Keywords:
Banking regulation
Minimum capital requirement
Countercyclical capital buffer
Reserve requirement
(Countercyclical or dynamic) loan loss provision
Endogenous default
Basel III
DSGE
Uruguay

ABSTRACT

We developed a dynamic stochastic general equilibrium (DSGE) model for a small, open economy with a banking sector and endogenous default to assess two macroprudential tools: countercyclical capital buffers (CCB) and dynamic provisions (DP). The model is estimated with data for Uruguay, where dynamic provisioning has existed since the early 2000s. Both tools force banks to build buffers, but DP seem to outperform the CCB in smoothing the cycle. We also find that the source of the shock affecting the financial system matters in assessing the relative performance of both tools. Given a positive external shock, the credit-to-GDP ratio decreases, which should discourage its use as an indicator variable to activate countercyclical regulation.

1. Introduction

In the wake of the global financial crisis of 2008–2009, the importance of systemic risk and the need for a macroprudential perspective on financial regulation becomes clear. In this spirit, new prudential regulation has been established, Basel III being of particular importance. Among other things, Basel III increases minimum capital requirements, establishes more stringent liquidity regulations, and introduces a countercyclical capital buffer. The latter measure is intended to build capital buffers during booms that may be used to (at least partially) absorb losses during a downturn, thereby prudentially attending to the cyclical and endogenous rise in systemic risk during upturns. Implementing CCB has been debated in jurisdictions where other macroprudential instruments developed with a similar objective were already in place. For example, Spain and several Latin American countries have used dynamic loan loss provisions as a countercyclical regulatory rule for several years.[1] Under dynamic provisioning, a fund is accumulated in

☆ The views in this paper are those of the authors and not necessarily of the institutions with which they are affiliated. The authors would like to thank Eddie Gerba, Marcos Ribeiro de Castro, two anonymous referees, and participants at BCU-RIDGE Financial Stability Workshop, BDE-CEMFI First Conference on Financial Stability, BOCCONI-SUERF Challenges to Central Banking Conference, and Banco Central do Brasil XXII Seminar on Risk, Financial Stability, and Banking for their comments and suggestions.
* Corresponding author.
E-mail address: jponce@bcu.gub.uy (J. Ponce).
[1] Recently, Spain stopped using dynamic loan loss provisions to implement a countercyclical capital buffer.

https://doi.org/10.1016/j.latcb.2023.100095
Received 11 July 2022; Received in revised form 9 March 2023; Accepted 9 April 2023
2666-1438/

periods with lower expected losses than the long-run or through-the-cycle level. DP are not released in periods with low default rates, but they are used to cover losses in a downturn.[2]

This paper aims to objectively assess the countercyclical regulation promulgated in Basel III and compare its relative performance with other macroprudential policies already used in many countries, i.e., dynamic loan loss provisions. To do so, we developed a DSGE model for a small and open economy with a banking sector and the possibility of loan default. The model was estimated with data for Uruguay, a country that has been running a dynamic provisioning system since 2001. In this modeled economy with financial frictions, we performed simulations of the key macroeconomic and banking-sector variables under different regulations to compare the results. More precisely, we compared the dynamics of real and financial variables when the economy is affected by external and domestic shocks[3] under alternative macroprudential regulations: CCB 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 also compare them in terms of their ability to reduce the overall volatility of GDP and bank credit, as well as their impact on welfare.

The results contribute to informing policymakers. They suggest that CCB and DP are effective in generating buffers that may cover future losses. However, their impact on activity and other real variables is quite different. Countercyclical capital requirements do not have major real effects. DP may, however, have a countercyclical impact on activity and other real variables.

The intuition for this difference is as follows. Capital buffers force banks to increase the capital-to-assets ratio during booms. In principle, banks can achieve this by using excess capital that they may hold over the minimum required by regulation and by reducing assets by either lending less to entrepreneurs or reducing holdings of other assets (e.g., government bonds). In the estimated model, banks mainly absorb excess capital and reduce the holding of other assets but bank loans.[4] Therefore, different degrees of countercyclicality in the capital buffer rule have little impact on the real side of the economy. In contrast, loan loss provisions, by directly affecting banks' marginal lending decisions, can potentially have a greater impact on smoothing the business cycle.

The analysis also highlights the fact that the source of the shock driving the boom is relevant in analyzing these policy instruments. First, we find that, given an external shock, the dynamics of the nominal credit-to-GDP ratio are procyclical, making this variable unreliable as an indicator to determine how to change capital requirements in a prudential fashion. This result is related to the real exchange rate behavior and, therefore, should be particularly relevant for small and open economies, especially those with non-trivial degrees of financial dollarization. Second, the shock source is relevant to calibrating the dynamic provisioning size (the same calibration may be too countercyclical if the shock is domestic rather than external). Finally, the cycle-smoothing abilities of these policy tools also depend on the source of the shock. Overall, it seems a prudent policy decision to have both tools available in the set of regulatory instruments and to have an assessment method for distinguishing the consequences of different shocks hitting the economy.

In the proposed DSGE model, borrowers (called entrepreneurs) are specified as in Bernanke et al. (1999) and can default on their loans. Banks use deposits and own capital to lend to entrepreneurs and buy other assets. Additionally, the banking sector is subject to prudential regulation. More precisely, we extended Bouvatier and Lepetit, 2012's (Bouvatier and Lepetit, 2012) dynamic provisioning framework to a general equilibrium model, endogenized the default-related losses by using the Bernanke et al. (1999) specification, and introduced various capital requirement rules, including countercyclical ones, as well as liquidity requirements.

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 required by regulation (Allen and Rai, 1996; Barth et al., 2006; Berger et al., 2008; Peura and Jokivuolle, 2004). Rather than strictly complying with capital regulation, banks exhibit their own target capital levels. Depending on the extent of their capital buffer, banks adjust their capital and risk-taking to reach their target levels (Ayuso et al., 2004; Jokipii and Milne, 2008; 2011; Lindquist, 2004; Milne and Whalley, 2001; Stolz and Wedow, 2011; VanHoose, 2008). Our model allows bankers to maintain capital above the minimum requirements. Moreover, we modeled countercyclical (dynamic) loan loss provisions by introducing the possibility of accumulating a loan loss provision reserve fund when some selected variable grows more than the historical average, thus linking provisioning to the credit and business cycles. This allowed us to study the performance of different provisioning rules and assess the relative efficiency of countercyclical loan loss provisioning and CCB.[5]

Banks in our model, as in that of Gerali et al. (2010), accumulate capital out of retained earnings and aim to keep their capital-to-assets ratio as close as possible to an exogenous target level, for they face a cost from deviating from that target. Moreover, banks' capital position affects the amount and price of loans, introducing a feedback loop between the economy's real and financial side. While in that study the exogenous target level is just a parameter, we instead specify it as having both a regulatory component and

[2] For the case of Spain, Jiménez et al. (2017) found that dynamic provisioning smooths credit supply cycles and, in bad times, supports firm performance. In a formal model, Gómez and Ponce (2019) studied the effectiveness of CCB and dynamic provisioning to provide the correct incentives to bank managers and concluded that both of them are adequate policy tools.

[3] For simplicity, we focused on two positive shocks: a reduction in the country premium (an aggregate external shock) and a reduction in the risk of entrepreneurs (an idiosyncratic domestic shock). Together, these two shocks explain most of the variance of bank capital, credit growth, and entrepreneurs' default in the estimated model.

[4] Interestingly, in the case of Uruguay, the data shows significant excess capital in banks. More precisely, according to the banks' balance sheet information, between 2005 and 2015, banks held, on average, excess capital equivalent to 0.6 times the minimum capital requirement. The data also shows that banks' holding of government bonds is similar in magnitude to loans, around 35% of total assets each. Most of the bonds are held to maturity. This means that these bonds are subject to risk weights. Hence, although these risk weights are slightly smaller on average than those of loans, reducing bonds holding entails a reduction in risk-weighted assets and, thus, less stringent capital requirements.

[5] The banking sector model also includes regulation of liquidity or reserve requirements, although we do not analyze the role of this instrument as a potential macroprudential tool. See Glocker and Towbin (2012) for an analysis of this alternative.

a self-imposed part, as previously discussed. Also different from that study, as well as from other modeling approaches that include banks, capital in general equilibrium, such as Gertler and Karadi (2011) or Gertler et al. (2012), we also allow for the possibility of endogenous defaults on loans.

Our results are in line with those of Agénor and Zilberman (2015), who found that a dynamic provisioning regime can effectively mitigate the financial system's procyclicality. Furthermore, they claim that, when combined with a credit gap-augmented Taylor rule, it may be highly effective in mitigating real and financial volatility associated with financial shocks. Agénor and Pereira da Silva (2017) reached similar conclusions. However, our modeling choice allowed us to assess the relative efficiency of other prudential tools such as the countercyclical capital buffer. Moreover, our results are based on an estimated version of the model rather than on a generic parametrization, as in those papers. Finally, relative to these related studies, our model includes a micro-founded default problem (as in Bernanke et al. (1999)), whereas they imposed a reduced form relationship between default and the business cycle.

In a dynamic stochastic general equilibrium framework, Aliaga-Díaz et al. (2017) also concluded that the anticyclical rules on bank capital in Basel III may have only a minor impact depending critically on how they are implemented and on the size of the buffers held by banks. Consistently with our results, Cabello et al. (2017) found that tightening dynamic provisioning in Peru reduced the growth in commercial loans, contributing to the reduction of the procyclicality of credit and thus reducing potential adverse effects of an excessive credit expansion.

The rest of the paper is organized as follows. In Section 2 we present the model. Section 3 is devoted to the estimation strategy. 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 essentially is a small and open economy DSGE model for monetary policy analysis in the New-Keynesian tradition. We use a simplified version of their macroeconomic setup, which is characterized by a small, open, and dollarized economy, and extend it further by introducing the possibility of endogenous default of the entrepreneurs à la Bernanke et al. (1999), a banking system similar to that of Gerali et al. (2010) and Agénor and Pereira da Silva (2017), and financial regulations. As the nominal and real blocks of the model are fairly standard in the literature of quantitative DSGE models of small and open economies, here we describe the details related to the financial sector and leave to the Appendix the model's complete description (see Tables A.1 and A.2 for a description of the variables).

2.1. Households

A continuum of households derives utility from the consumption of final goods (c_t) and offer working hours (h_t). In addition, households derive utility from holdings of liquid financial assets. More precisely, households demand money (M_t^d, in Uruguayan 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.[6] The instantaneous utility function of households is

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

where $M_t^a = \left[\left(1 - o_M\right)^{\frac{1}{\eta_M}} \left(\frac{S_t D_t}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} + o_M^{\frac{1}{\eta_M}} \left(\frac{M_t^d}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} \right]^{\frac{\eta_M}{\eta_M - 1}}$ captures imperfect substitution between domestic and foreign liquid assets, with P_t being the domestic price index and S_t being the nominal exchange rate.

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

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

2.2. Entrepreneurs

There is a continuum of risk-neutral entrepreneurs that manage the stock of capital. In each period t, entrepreneurs start with K_{t-1} units of capital, which they invest in a linear and stochastic production technology, leading to ex post different productivity levels. After this idiosyncratic shock (denoted by ω_t) is realized, entrepreneurs use productive capital for the production of domestic goods. At the end of the period, entrepreneurs obtain income from the capital, sell the part that is not depreciated to capital goods producers, and acquire new capital financed with their net worth (N_t) and loans from banks (L_t). We assume that bank loans are denominated in US dollars and the income obtained by entrepreneurs is denominated in pesos; thus, entrepreneurs bear all currency mismatch risk.[7] The price of capital at the end of period t is Q_t, so that the balance sheet is $Q_t K_t = N_t + L_t S_t$.

---

6 Although this is a simplification, around 80 percent of bank deposits in Uruguay are denominated in foreign currency.

7 Chui et al. (2016) argue that the recent increase in borrowing from global markets by non-financial companies operating in emerging market economies has not been closely matched with the currency of their earnings. Their measures show that, as a consequence, currency mismatches of

The ex post return per unit of capital includes the marginal product of capital, R^K_{t+1}, and the resale value of non-depreciated capital, $(1-\delta)Q_{t+1}$. Thus, the ex post income received by entrepreneurs is

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

where $R^e_{t+1} = [R^K_{t+1} + (1-\delta)Q_{t+1}]/Q_t$. The entrepreneurs' idiosyncratic shock, $\omega_{t+1} > 0$, is assumed to have the cumulative distribution function $F_t(\omega_{t+1})$, the density function $f_t(\omega_{t+1})$, the standard deviation $\sigma_{\omega,t}$ and an expected value equal to one, $E(\omega_t) = 1$. As in Christiano et al. (2014), the volatility $\sigma_{\omega,t}$ is interpreted as a risk shock,[8] which in turn has a direct impact on loans' default rate, as discussed below.

Following Bernanke et al. (1999), 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., pay back the nominal interest rate stipulated in the loan contract, or default. In the latter case, the entrepreneur gets nothing, and the bank receives a fraction $(1-\mu)$ of the firm's value. As in Bernanke et al. (1999), the optimal debt contract specifies an interest rate on the loan R^L_t and a threshold value $\overline{\omega}_{t+1}$ such that:

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

$$R^L_t L_t = \frac{\overline{\omega}_{t+1}R^e_{t+1}Q_tK_t}{S_{t+1}}. \tag{4}$$

In equilibrium, the ex post interest rate ($\widetilde{R}^L_{t+1}$) received by banks satisfies

$$\widetilde{R}^L_{t+1}L_t = [1 - F_t(\overline{\omega}_{t+1})]R^L_t L_t + (1-\mu)\left(\int_0^{\overline{\omega}_{t+1}} \omega f_t(\omega)d\omega\right)\frac{R^e_{t+1}Q_tK_t}{S_{t+1}}, \tag{5}$$

where the first term on the right-hand side is the income received from repaid loans, and the second is the income obtained from defaulted loans, net of monitoring costs. Using the expression for R^L_t in (4), the previous expression can be written as

$$\widetilde{R}^L_{t+1}L_t = g_t(\overline{\omega}_{t+1})\frac{R^e_{t+1}Q_tK_t}{S_{t+1}}, \tag{6}$$

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

$$\widetilde{R}^L_{t+1}(lev_t - 1) = g_t(\overline{\omega}_{t+1})\frac{R^e_{t+1}}{\pi^S_{t+1}}lev_t, \tag{7}$$

where $\pi^S_t = S_t/S_{t-1}$ is the nominal depreciation rate.

The expected income for the entrepreneur is given by

$$E_t\left\{R^e_{t+1}Q_tK_th_t(\overline{\omega}_{t+1})\right\}, \tag{8}$$

where[9]

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

Eq. (8) can be divided by N_t (which is predetermined), and it can then be expressed in terms of leverage. Thus, the entrepreneur's problem is to choose a state-contingent $\overline{\omega}_{t+1}$ 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: This is an external finance premium $E_t\{R^e_{t+1}\}/E_t\{\widetilde{R}^L_{t+1}\}$ which, as in Bernanke et al. (1999), is an increasing function of entrepreneurs' leverage.

the non-financial sector are larger and show a greater rise than the aggregate in emerging market economies. Using data for non-financial firms in Uruguay for 2008–2011, we computed an indicator of their absolute currency mismatch using the same methodology as Tobal (2018) and obtained a figure almost three times larger (14.4 percent) than the indicator for banks. Tobal (2018) found that the banking sector of Uruguay was second among the seventeen Latin American and Caribbean countries in the sample when ranked by the absolute value of its currency mismatch; its FX assets minus FX liabilities in absolute terms average 5.24 percent of foreign currency liabilities. Moreover, most countries (11) have below-average indicators of currency mismatch: The median is 11.07 percent, while the average is 16.3 percent. Nevertheless, the Uruguayan banking sector is highly dollarized: Approximately 80 percent of its assets and liabilities are denominated in US dollars. We assume that the banking sector is fully dollarized to account for these features and keep the model simple (see Section 2.3).

[8] Christiano et al. (2014) identify this as a relevant business and financial cycle driver in the US.

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

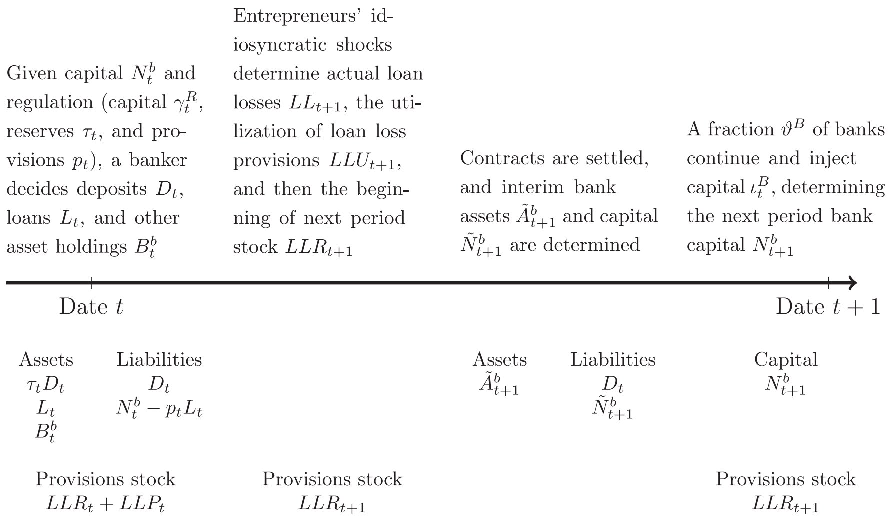

Fig. 1. Timeline, balance sheet, and stock of provisions for loan losses.

At the end of the period, a fraction ϑ of entrepreneurs continue operating while the rest exit the market, transferring the accumulated net worth to households. At the same time, there are an equal number of entrants to the market, with new capital given by ι_t^e.[10] Thus, the evolution of an entrepreneur's net worth is given by

$$N_t = \vartheta\left\{R_t^e Q_{t-1} K_{t-1} h_{t-1}(\overline{\omega}_t)\right\} + \iota_t^e P_t. \tag{10}$$

At equilibrium, the default rate is the fraction of loans that are not repaid, given by

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

The functional form for $F_{t-1}(\omega_t)$ is, as in Bernanke et al. (1999), log normal: We assume that $ln(\omega_t) \sim N(-.5\sigma^2_{\omega,t-1}, \sigma^2_{\omega,t-1})$ (so that $E(\omega_t^e) = 1$). Letting $\Phi(\cdot)$ be the standard normal cumulative distribution function, we have

$$\text{def}_t = \Phi\left(\frac{ln(\overline{\omega}_t) + .5\sigma^2_{\omega,t-1}}{\sigma_{\omega,t-1}}\right). \tag{12}$$

As mentioned before, the time-varying dispersion $\sigma_{\omega,t}$ directly affects the default rate.

2.3. Banks

There is a competitive banking sector that lends to entrepreneurs and is financed by deposits and bank capital. Fig. 1 shows the sequence of decisions and shocks. At date t, banks have capital (N_t^b), which is predetermined with respect to the decisions to be made on that date. Given bank capital, bankers decide how much to leverage, i.e., how much deposits (D_t) to raise and how to allocate their portfolio, i.e., how much to lend to entrepreneurs (L_t) and how much of other assets (B_t^b) to hold (for simplicity, we assume that these are government bonds). On top of minimum capital regulation, there is a reserve (liquidity) requirement with rate τ_t. For each new loan, banks need to build provisions for loan losses at a rate p_t.[11] The balance sheet when decisions are made at t is shown in Fig. 1, and the following constraint holds at date t:

$$(1 + p_t)L_t + B_t^b = (1 - \tau_t)D_t + N_t^b. \tag{13}$$

At date t, banks hold a predetermined stock or reserve of provisions for loan losses (LLR_t) to which the new loan loss provisions, $LLP_t \equiv p_t L_t$, are added. This fund is part of the dynamic or countercyclical provisioning scheme and is kept out of the balance sheet in contingent accounts. Under countercyclical provisioning, a fund is accumulated in periods where the expected losses are lower than the long-run, or through-the-cycle, level (the alternative accumulation rules, i.e., the rules governing the parameter p_t and hence LLP_t, are described in Section 2.4). The fund is not released in periods with low default rates, but it is used to cover losses in a downturn. Hence, the fund LLR_t and the new flow of provisions (LLP_t) are used to cover (maybe only partially) losses due to loan

[10] The time variation ι_t^e is due to the stochastic trend in the model so that new capital injections are constant in real terms along the balanced growth path.

[11] For simplicity, we assume that there is no strategic behavior of depositors that could materialize in bank runs. Hence, introducing a deposit insurance scheme into the model is unnecessary.

default. Since actual banks' loan losses at $t+1$ (LL_{t+1}) are equal to $LL_{t+1} \equiv \text{def}_t L_t - (1-\mu)\left(\int_0^{\overline{\omega}_{t+1}} \omega f_t(\omega) d\omega\right) \frac{R^e_{t+1} Q_t K_t}{S_{t+1}}$, i.e., the face value of the loans in default net of the amount that is recovered by the bank, then the utilization of the loan -loss provision (LLU_{t+1}) is such that

$$LLU_{t+1} = \min\left\{LL_{t+1}; LLR_t + LLP_t\right\}. \tag{14}$$

The existing reserve of provisions ($LLR_t + LLP_t$) is completely used if actual loan losses (LL_{t+1}) are larger than the provisions reserve. Otherwise, the reserve of provisions covers the actual losses, and a positive stock of provisions accumulates to the next period. Hence, the stock of provisions for loan losses evolves according to the equation

$$LLR_{t+1} = LLR_t + LLP_t - LLU_{t+1}. \tag{15}$$

The banks' objective is to choose L_t, B^b_t, and D_t to maximize

$$E_t\left\{r^*_{t,t+1}\left[\tilde{N}^b_{t+1} - PEN_{t+1}\right]\right\} - COST_t, \tag{16}$$

where $r^*_{t,t+1}$ is the stochastic discount factor,

$$\tilde{N}^b_{t+1} = \widetilde{R}^L_{t+1} L_t + B^b_t R^*_t \xi_t + LLU_{t+1} - (R^D_t - \tau_t) D_t \tag{17}$$

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

$$COST_t = \frac{s_t}{A_{t-1}}(S^L L_t^2 + B_t^{b2}), \tag{18}$$

where s_t is an exogenous process that captures imperfect substitutability between alternative investment opportunities for banks, A_{t-1} is the stochastic trend for real variables, and S^L is a parameter that governs the composition of the bank's steady-state portfolio. Maximization is subject to the balance-sheet constraint (13), taking N^b_t, LLR_t, and the discount factor as given.

Bank assets at $t+1$ are

$$\tilde{A}^b_{t+1} = \widetilde{R}^L_{t+1} L_t + B^b_t R^*_t \xi_t + LLU_{t+1} + \tau_t D_t. \tag{19}$$

The introduction of a penalty for a capital-to-assets ratio that is different from the target level, PEN_{t+1}, follows Gerali et al. (2010) and Darracq-Pariès et al. (2011). In particular, part of the penalty is associated with the minimum capital adequacy ratios, denoted by γ^R_t. 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; Barth et al., 2006; Berger et al., 2008; Peura and Jokivuolle, 2004). Rather than strictly complying with capital regulations, banks exhibit their target capital levels. Depending on the extent of their capital buffers, banks will adjust their capital and risk-taking to reach their target levels (e.g. Ayuso et al., 2004; Jokipii and Milne, 2008; 2011; Lindquist, 2004; Milne and Whalley, 2001; Stolz and Wedow, 2011; VanHoose, 2008). Hence, we assume that banks target a ratio of capital to assets $\gamma_t > \gamma^R_t$ and pay a penalty when the actual ratio differs from the target level. As in Gerali et al. (2010) and Darracq-Pariès et al. (2011), the penalty for deviating from the target capital-to-assets ratio takes a quadratic form,

$$PEN_{t+1} = \frac{\phi_D}{2}\left(\frac{\tilde{N}^b_{t+1}}{\tilde{A}^b_{t+1}} - \gamma_t\right)^2 \tilde{N}^b_{t+1}. \tag{20}$$

Several papers provide evidence on the determinants of capital buffers and the target level of bank capital. Fonseca and Gonzalez (2010) 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) supports the hypothesis that capital buffers serve as insurance against failure to meet the capital requirements. In addition, bank capital is costly, so 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^R_t) and target other buffers. In particular, we assume that banks are willing to maintain a capital-to-asset ratio above the minimum requirement for precautionary reasons and to avoid frequent supervisory intervention. We model this kind of buffer as a constant factor γ_0. In addition, forecasting higher-than-normal default rates in the next period may provide incentives to increase capital. Together, these buffers may be associated with Lindquist's insurance against failure to meet the capital requirements hypothesis. Moreover, to account for the effect of competition on capital buffers (as found by Fonseca and Gonzalez, 2010), 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 to compete better tomorrow.

Overall, we simply capture these features by modeling the target ratio of bank capital to assets as

$$\gamma_t = \gamma^R_t + \gamma_0 + \alpha_d(E\{def_{t+1}\} - def_{ss}) + \alpha_l(E\{\Delta L_{t+1}\} - \Delta L_{ss}) + \gamma^{exo}_t, \tag{21}$$

where γ^{exo}_t is a shock to the desired capital ratio.

Finally, as in the description of entrepreneurs, we assume that only a fraction ϑ^B of banks continue from one period to the other. 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

$$N_{t+1}^b = \vartheta^B \left[\tilde{N}_{t+1}^b - PEN_{t+1} - COST_t\right] + \iota_t^B. \tag{22}$$

2.4. Bank regulation

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 ($\gamma_t^R = \gamma_0^R$), we consider four versions of countercyclical capital requirements depending on the trigger variable. Two of them are related to credit: In one, the feedback is to credit growth (ΔL_t), while in the other it is the credit level relative to a stochastic trend (l_t), a measure of credit gap. Under these alternatives, the countercyclical capital requirement takes one of the following forms:

$$\gamma_t^R = \gamma_0^R + \alpha_{\Delta L}^R(\Delta L_t - \Delta L_{ss}) \text{ or } \gamma_t^R = \gamma_0^R + \alpha_l^R(l_t - l_{ss}), \tag{23}$$

where the subscript ss refers to steady-state levels (along the balanced-growth path). The other two alternatives we explore are related to GDP: In one, the trigger variable is GDP growth (ΔY_t), and in the other it is the GDP level relative to a stochastic trend (l_t), a measure of the output gap. With these variants, then the requirement is either

$$\gamma_t^R = \gamma_0^R + \alpha_{\Delta Y}^R(\Delta Y_t - \Delta Y_{ss}) \text{ or } \gamma_t^R = \gamma_0^R + \alpha_y^R(y_t - y_{ss}). \tag{24}$$

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

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

where l_0 is the coverage ratio, that is, the proportion of default loans that loan loss provisions would cover. We consider different rules according to $j \in \{t, t+1\}$, i.e., by considering the current or the next period expected default, respectively.[12] 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 Eq. 15). We consider the following dynamic provisioning rule:

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

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 of domestic goods is achieved by using capital and labor. There is also a commodity sector whose production is an endowment, completely exported at an internationally given price. Consumption and investment are composed of domestic and imported goods. There exist an endowment of commodities, habits in consumption, investment adjustment costs, sticky prices and wages, and delayed exchange rate pass-through. The monetary policy follows a standard interest rate rule, and there is a Ricardian fiscal policy.

There exist the following macroeconomic shocks. Domestic shocks: trend in productivity, stationary productivity, consumption, investment, government expenditures, production of commodities, and demand for liquidity. External shocks: interest rate, country premium, deviations from uncovered interest parity, foreign output and inflation, and commodity prices.

3. Data and estimation

The model is estimated using quarterly data for Uruguay from 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 operating in Uruguay since the early 2000s, and no CCB are in place.

The same data for 2008–2015 is used to calibrate the target levels of financial parameters. The first years of the sample were not considered because of the instability of 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)

[12] In Bouvatier and Lepetit, 2012's (Bouvatier and Lepetit, 2012) framework, the default rate is endogenous, but the loss given default is fixed. Hence, expected loan losses are proportional to the default rate. In our model, however, default rate and loss given default are closely intertwined, so expected loan losses are less than proportional to the default rate. In the model, for simplicity, we maintained the proportionality between LLP_t and def, acknowledging that this may generate more provisions than expected losses and ameliorating this effect through calibration of the parameter l_0 to actual data where provisions are reduced by guaranties and recoveries.

Table 1
Goodness of fit (standard deviation in percent).

Variable	Data	Base
GDP growth	1.41	1.85
Cons. growth	1.49	2.15
Inv. growth	4.66	2.23
Country premium	0.28	0.79
Monetary Policy Rate	0.83	1.00
Default rate	0.31	2.54
Bank's capital growth	5.36	6.66
Credit growth	7.28	6.75
Deposits growth	3.15	7.37
Required buffer capital growth	17.61	11.22
Bank's buffer capital growth	7.66	19.01

Table 2
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

- 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 combination of calibration and Bayesian estimation to assign parameter values. As observables, we use the following macroeconomic variables: growth rate of real output, consumption and investment, inflation, monetary policy rate, nominal depreciation, foreign interest rate, country premium, and commercial partners' inflation and output. We also include the following financial variables: real growth of credit, deposits and banks' capital, default rate, interest rate spread, and regulatory and total capital buffer. Finally, the reserve requirement τ_t is constant throughout, and for estimation, we assume γ_t^R is an exogenous process and llp_t features no dynamic component. Alternatively, in the exercises shown in the following sections, they can be determined by the policy rules previously described. The calibrated and estimated parameter values are reported in Tables C.1 and C.2, respectively, in the Appendix. We set the estimated parameters for the exercises conducted below at their posterior mode.

The goodness of fit of the estimated model may be evaluated by comparing the standard deviation of variables on the data versus that implied by the model, as reported in Table 1. Overall, the model's goodness of fit is adequate, although the model implies larger unconditional volatility than the data.

As a by-product of the estimated model, it is possible to determine the main shocks behind the movements of financial variables. Table 2 shows the variance decomposition of three selected financial variables. The country premium and other international financial factors (e.g., deviations from uncovered interest rate parity and world inflation) are important for explaining the volatility of bank capital, credit growth, and default. On the other hand, real domestic factors matter for explaining credit growth, while shocks to the productivity of entrepreneurs are the most important domestic factor for explaining the rate of default. Given these results, we focus on how alternative rules for γ_t^R and llp_t affect the propagation of country premium and entrepreneurs' productivity shocks.

4. Results

In this section, we present the results of a series of simulation exercises. Our objective is to assess the relative efficiency of different countercyclical bank regulations. First, we analyze the macroeconomic and financial effects of the two most important shocks identified in the previous section under acyclical capital buffers and static provisioning assumptions. Second, we evaluate how the propagation is affected by the alternative specifications for γ^R presented in Section 2.4. Third, we explore the role of dynamic provisioning in smoothing the effects of these shocks. Finally, we show how alternative parametrizations of these rules can affect the volatility of relevant macro and financial variables, and we also discuss welfare-based analysis.

4.1. The effect of shocks under acyclical regulation

Fig. 2 shows the impulse-response functions after a surprise reduction in the country premium. In the following figures, the solid blue lines are the responses computed at the posterior mode (which we call the baseline case). At the same time, the light blue

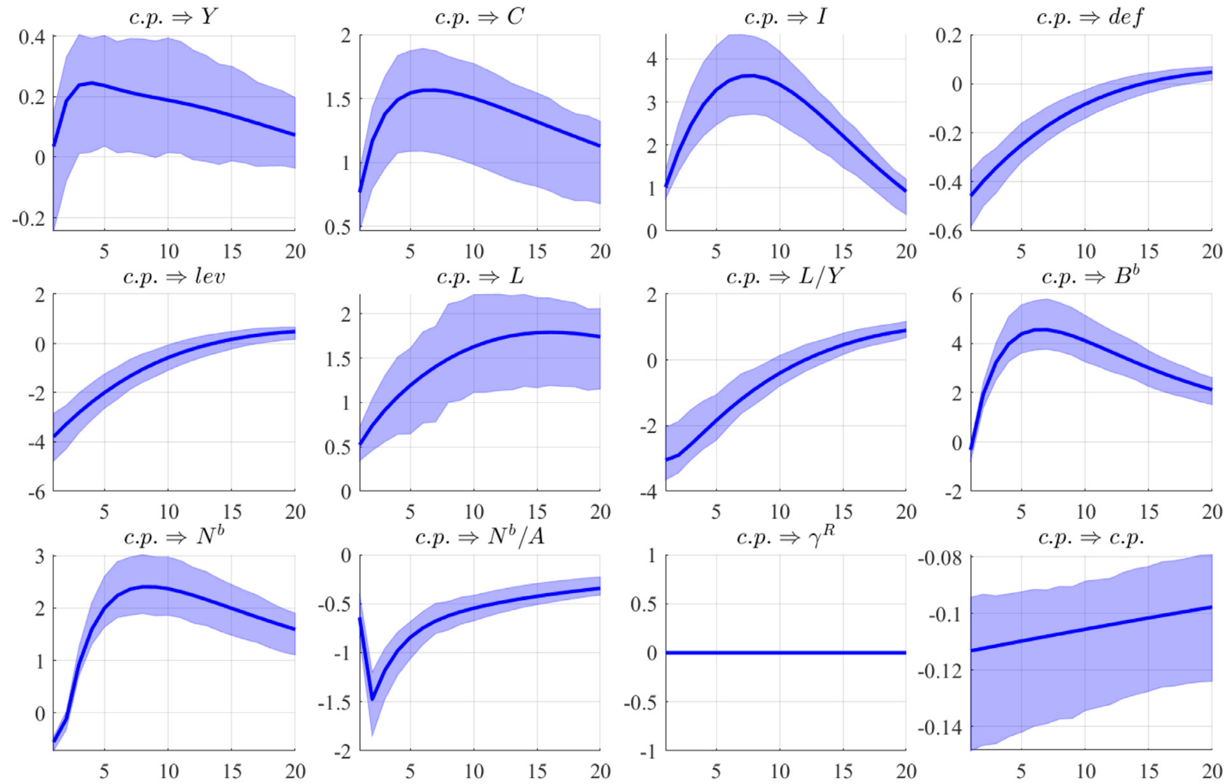

Fig. 2. Country premium shock: Baseline. Notes: The variables depicted are output (Y), consumption (C), investment (I), default rate (def), entrepreneurs' leverage (lev), credit (L), the ratio of nominal credit to GDP L/Y, banks' bond holdings (B^b), banks' capital (N^b), the ratio of banks' capital to assets (N^b/A), regulatory capital ratio (γ_{REG}), and the variable being shocked (country premium, $c.p.$ in this case). Solid blue: baseline no rule (evaluated at posterior mode), light-blue areas: 90% credible sets (obtained from 100k draws from the posterior distribution). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

areas represent 90% credible sets (obtained from 100,000 draws from the posterior distribution). The shock is expansionary: Output (Y), consumption (C), and investment (I) rise persistently after the shock. The reduction in country risk lowers the entrepreneurs' funding cost, reducing their leverage (lev^e), which in turn translates into a lower default rate (def) and an expansion in bank credit (L).

The shock also reduces the bank capital-to-asset ratio (N^b/A), as banks are willing to maintain a lower buffer above the minimum capital requirement. This implies that, even if bank capital (N^b) increases, it does so by less than banks assets. In turn, the better scenario banks face also leads to an increase in their holdings of other assets (B^b).

Interestingly, the ratio of nominal credit to nominal GDP (L/Y) falls, even though real credit grows faster than output after the shock. This is mainly due to the change in relative prices (this shock induces a real appreciation), which affects this ratio of nominal variables.[13] This is a relevant observation, for this ratio features prominently in many countercyclical buffer discussions. Our analysis shows that the behavior of this ratio depends on which shock is hitting the economy, and thus it might be unreliable as an indicator of the credit cycle. Moreover, these issues should be particularly relevant for small and open economies, as external shocks are relevant drivers of relative prices.

We now turn to the case of an idiosyncratic shock reducing the riskiness of entrepreneurs (i.e., a drop in $\sigma_{\omega,t}$). Fig. 3 includes the baseline responses. The decrease in entrepreneurs' riskiness directly impacts the rate of default, which in turn raises bank credit with a positive impact on activity and other real variables. Unlike in the case of a shock to country risk, in this case, the ratio of credit to GDP increases (while this shock also induces a real appreciation, it is quantitatively milder and thus its influence in this ratio is not as relevant). As bank capital does not significantly move initially, the capital-to-asset ratio falls, meaning that banks use part of their capital buffer to fund new loans.

[13] Under our maintained assumption that credit is fully dollarized, the real appreciation has a direct effect on the relative price between credit (denominated in dollars) and GDP (which is influenced by both domestic prices and the nominal exchange rate), inducing a decrease in the ratio. But it is relevant to mention that, even if we assumed instead that credit is denominated in local currency, we would still have a relative price effect (although smaller). The real appreciation would still induce a relative price change that reduces the nominal credit-to-output ratio.

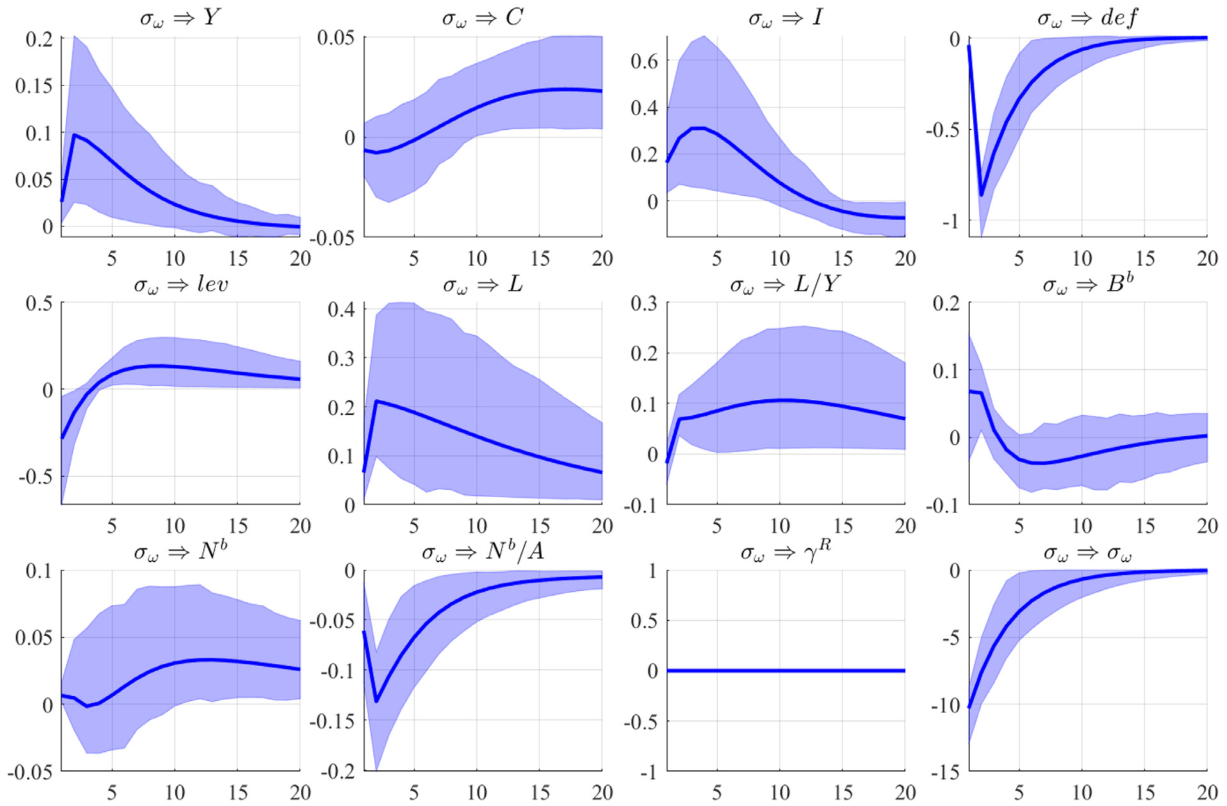

Fig. 3. Entrepreneurs' risk premium shock: Baseline. Notes: See Fig. 2 for the definitions of variables.

4.2. Countercyclical capital buffers

We begin by analyzing how alternative rules for γ_t^R affect the propagation of country premium shocks. Fig. 4 displays the baseline responses from Fig. 2 and also includes the dynamics under two alternatives presented in Eq. (23): The solid red lines display the case where the regulatory ratio is a function of credit growth, while the dashed red lines correspond to a rule where buffers are built based on the credit gap, both cases with a coefficient equal to 0.5. A first observation is that introducing this rule effectively raises the bank capital requirement (γ^R) during the period in which bank credit is expanding due to the positive external shock. Second, this impacts bank capital positively, so the ratio of bank capital to bank assets falls by less during the boom than without a cyclically-adjusted capital requirement. Thus, the higher minimum capital requirements imply an overall higher level of bank capital.

We can also see that, using the same value for the parameters $\alpha_{\Delta L}^R = \alpha_l^R = 0.5$, the effect on banks' capital is greater in the case of a rule related to the credit gap, which persistently deviates from the pre-shock level, than in the alternative responding to credit growth, which exhibits positive but decreasing values for at least 15 quarters. From that perspective, a gap-based rule seems to have more potential to increase capital buffers.

Despite these effects on bank capital, the alternative rules have a limited impact on real variables such as output, consumption, and investment, without having any major impact on the dynamics of credit (the blue lines are almost indistinguishable from the red ones). In turn, banks reduce their holdings of other assets (B^b), particularly under the credit-gap rule, which requires a more persistent rise in the regulatory ratio.

Fig. 5 shows how dynamics after an entrepreneurs' risk shock are affected by these two alternative credit-based rules for minimum capital requirements. Similar to the analysis after a country premium shock, these rules effectively increase the bank's capital, particularly under a credit-gap rule. However, it has only a small impact on credit and the real economy. Banks' assets are indeed reduced with a higher required capital ratio, but this is materialized by a reduction in holdings of other assets instead of a contraction in credit.

The Appendix includes Figures D.1 and D.2, which are analogous to Figs. 4 and 5, comparing the baselines' responses to the output-growth rules as in Eq. (24). Again, the conclusions are similar to those obtained with credit-related rules: relative to the baseline, banks' capital increases (particularly under an output-gap rule), but the effect on credit and, thus, the real economy is very limited. In addition, although the regulation reduces banks' assets, this materializes through a reduction in non-credit assets. Overall, the analysis suggests that this policy efficiently generates buffers during boom periods, but they provide almost no smoothing effect on the real or financial cycle.

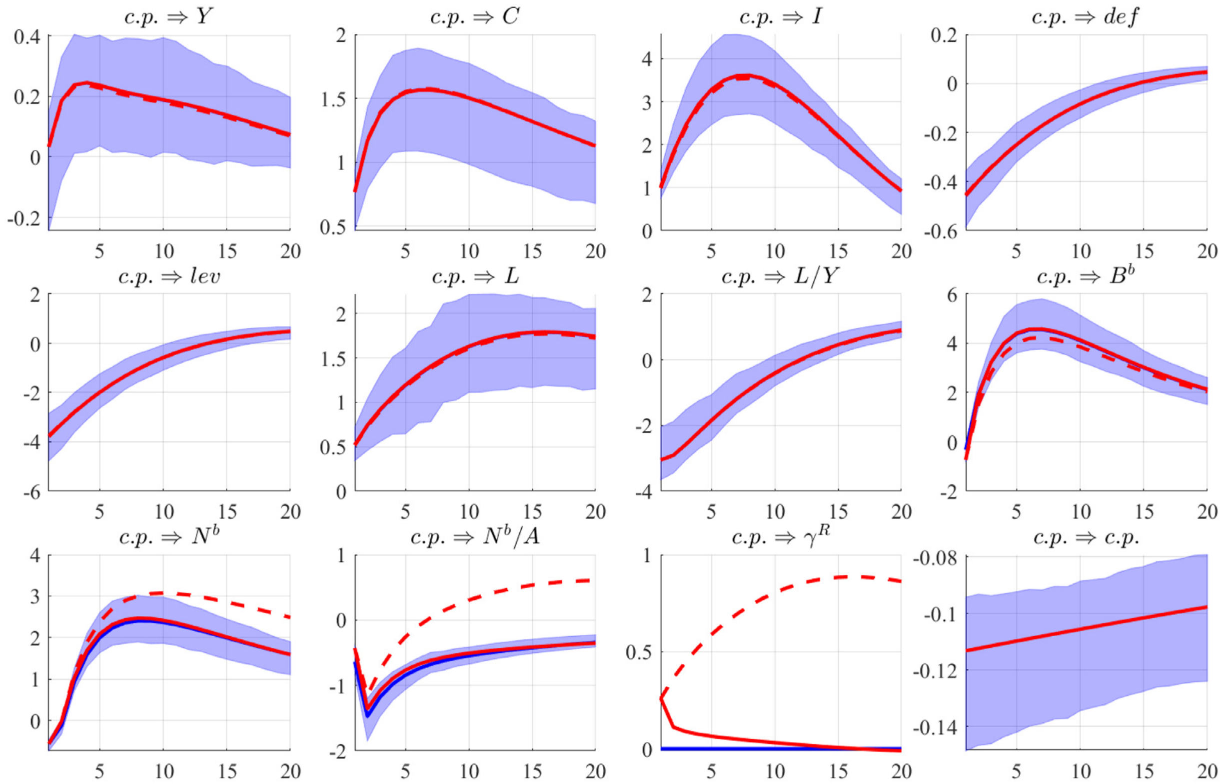

Fig. 4. Country premium shock: Baseline and CCB credit-related rules. Notes: Solid blue: Baseline. Solid red: Credit growth rule, $\alpha^R_{\Delta L} = 0.5$. Dashed red: Credit level rule, $\alpha^R_l = 0.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.3. Dynamic provisions

In this section, we analyze how the dynamics after the same shocks are affected by the presence of a dynamic provision rule for loan losses (i.e. $LLP_t = [\text{def}_t + l_1(\text{def}^{ss} - \text{def}_t)]l_0 L_t$), relative to the baseline that assumes an acyclical capital requirement and static provisions ($l_1 = 0$). In the following figures, we use three illustrative values for the parameter l_1, which governs the dynamic part of the provisioning rule: 0.5, 1, and 1.5.

Fig. 6 shows the benchmark case, where loan loss provisions are static, in solid blue lines. The unexpected reduction in the country's risk premium translates into lower entrepreneurs' leverage and default rates. Given the static nature of the provisioning rule, current period loan loss provisions (LLP_t) fall, adding procyclicality to financial variables like bank credit. The introduction of a dynamic component provision rule is effective in mitigating this procyclicality. Moreover, loan loss provisions become countercyclical if the weight of the dynamic component of 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.

Unlike the countercyclical capital requirement case, dynamic loan loss provisions have a countercyclical effect on real variables. However, the differences are not as large in the case of a country premium shock. This happens because the dynamic provision rule dampens the dynamics of bank credit. During a boom, the provision rate increases, which acts as a tax on the provision of new credit, giving banks incentives to moderate credit expansion. This effect on credit then channels to real variables: The procyclicality of activity, consumption, and investment falls slightly. After approximately twelve quarters, when the impact of the shock on entrepreneurs' default is over, the provision rate falls, impulsing bank credit.

Fig. 7 shows the effects of an unexpected shock on the entrepreneurs' risk premium. Overall, the qualitative results of the country risk premium shock case also hold for this case. However, the impact on credit and real variables is quantitatively more important. In particular, dynamic loan loss provisions effectively mitigate the procyclicality introduced by the shock and build a reserve fund that may be used to absorb future losses. Moreover, in this case, DP achieve the near 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.[14]

[14] The qualitative results from Figs. 6 and 7 hold if we consider that the dynamic provision rule is linked to expected default, i.e., $E(\text{def}_{t+1})$, instead of current default, i.e., def_t, as shown in Figures D.3 and D.4 the Appendix.

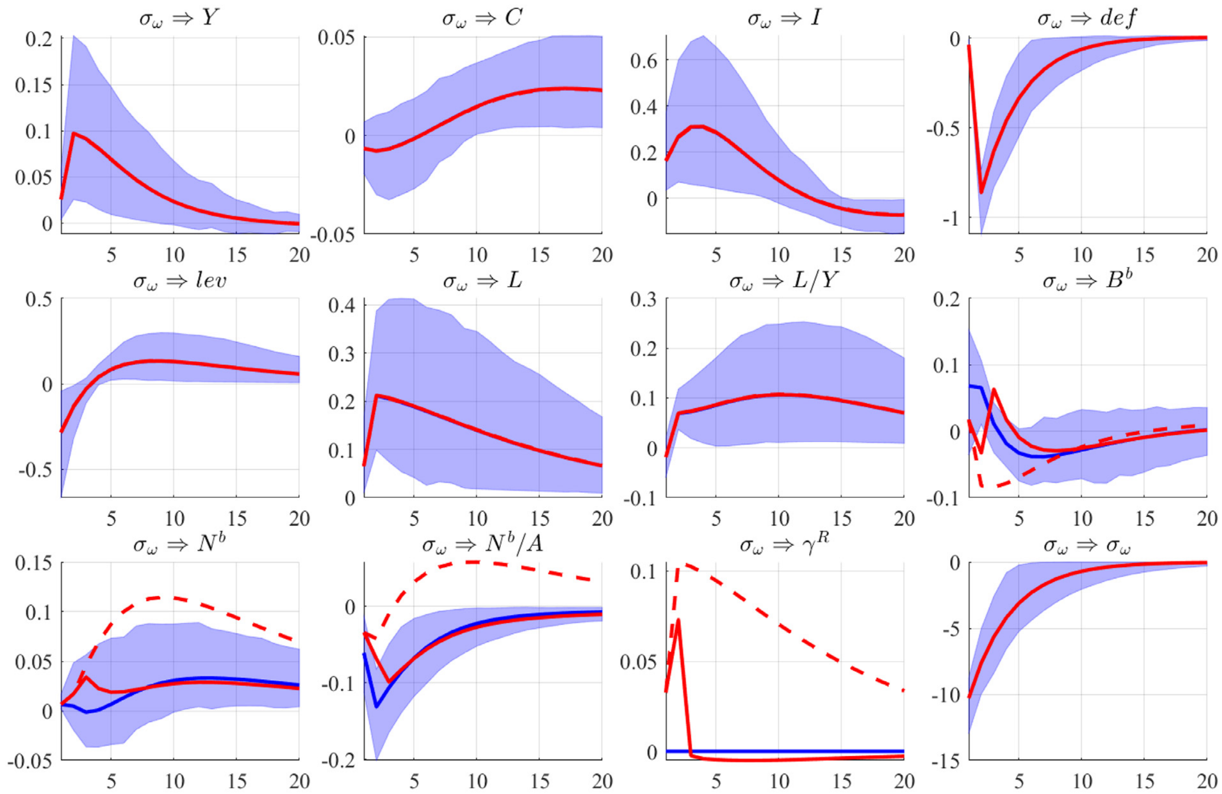

Fig. 5. Entrepreneurs' risk premium shock: Baseline and CCB credit-related. rules. Notes: Solid blue: Baseline, no rule. Solid red: Credit growth rule, $\alpha^R_{\Delta L} = 0.5$. Dashed red: Credit level rule, $\alpha^R_l = 0.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Like the CCB, dynamic loan loss provisions help build buffers during booms that can eventually be used in a downturn. However, dynamic provisioning seems more effective in smoothing both the financial and the real cycle. This happens because this policy tool directly affects the relevant margin for banks' lending decisions, while the CCB tool does so only indirectly. However, the quantitative importance of this effect seems to be shock-dependent. For example, under a country premium shock, the dampening effect is limited, while the dynamics after a reduction in entrepreneurs' risk are quantitatively greater.

4.4. Volatility and welfare

We finish the analysis by exploring how alternative policies under different parameter values affect output, credit growth volatility, and households' welfare. While the previous impulse-response analysis helps build intuition about the effect of alternative policies, according to the estimated model, dynamics are driven by various shocks. Therefore, studying how the volatility of relevant variables and welfare changes with different rules provides a complementary summary of the overall effect of alternative regulations.

Fig. 8 displays output and credit growth volatility under alternative policy configurations relative to the baseline case. The top panel compares the alternative CCB rules using a grid of values for the elasticity of the countercyclical component. According to these measures, rules specified in terms of gaps (either credit or output) tend to reduce real and financial volatility. However, this reduction seems to be monotonic with the parameter values for the output gap rule. In contrast, with the credit gap rule, this reduction begins to disappear for values larger than 5 for α_l. Instead, both growth-based rules tend to increase the overall volatility. Nonetheless, we should notice that the magnitudes are rather small. For instance, the maximum reduction in output-growth volatility would change the observed volatility of 1.41% (as reported in Table 1) to 1.38%. At the same time, the maximum reduction in credit-growth volatility will bring the observed 7.28% to 7.01%.

An analogous comparison is reported for the dynamic provisioning rule in the lower panel of Fig. 8. This tool also helps to reduce the volatility of both variables, reaching a maximum reduction for values of 2 and 1.7 in the rule's parameter, respectively, for output and credit volatility. However, as in the case of CCB, the obtained volatility decrease is not large.

Another metric to summarize the comparison of alternative policy tools is welfare, reported in Fig. 9. In particular, for each rule and alternative values for the relevant parameter, we compute the by-period consumption compensation (in percentage terms) that

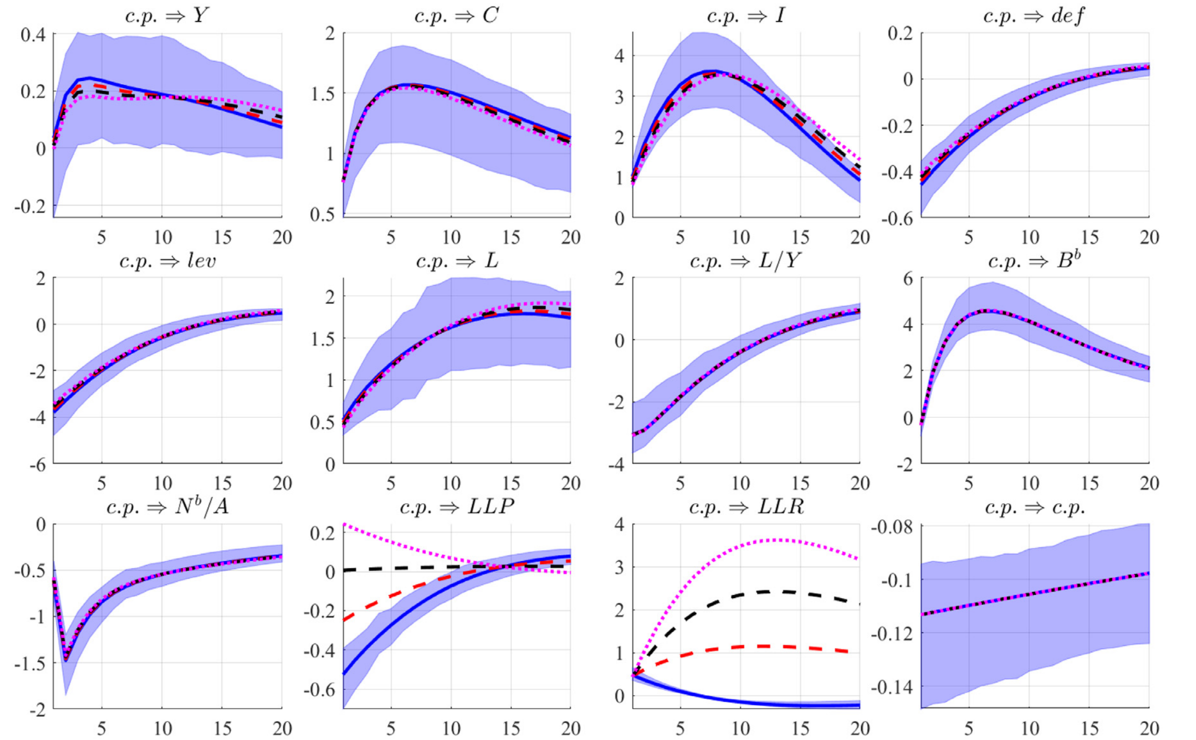

Fig. 6. Country risk premium shock: Static vs. dynamic provisions. Notes: Solid blue: Baseline, static provisions ($l_1 = 0$). Dashed red: $l_1 = 0.5$. Dashed black: $l_1 = 1.0$. Dotted magenta: $l_1 = 1.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

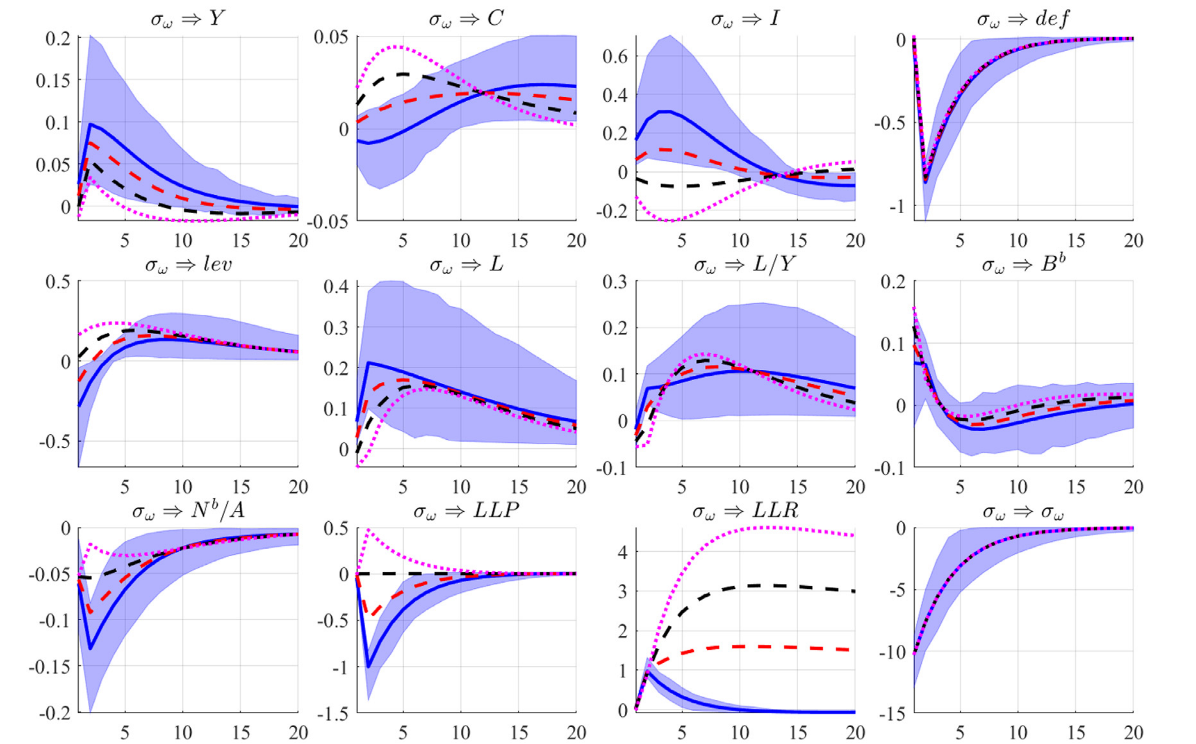

Fig. 7. Entrepreneurs' risk premium shock: Static vs. dynamic provisions. Notes: Solid blue: Static provisions ($l_1 = 0$). Dashed red: $l_1 = 0.5$. Dashed black: $l_1 = 1.0$. Dotted magenta: $l_1 = 1.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

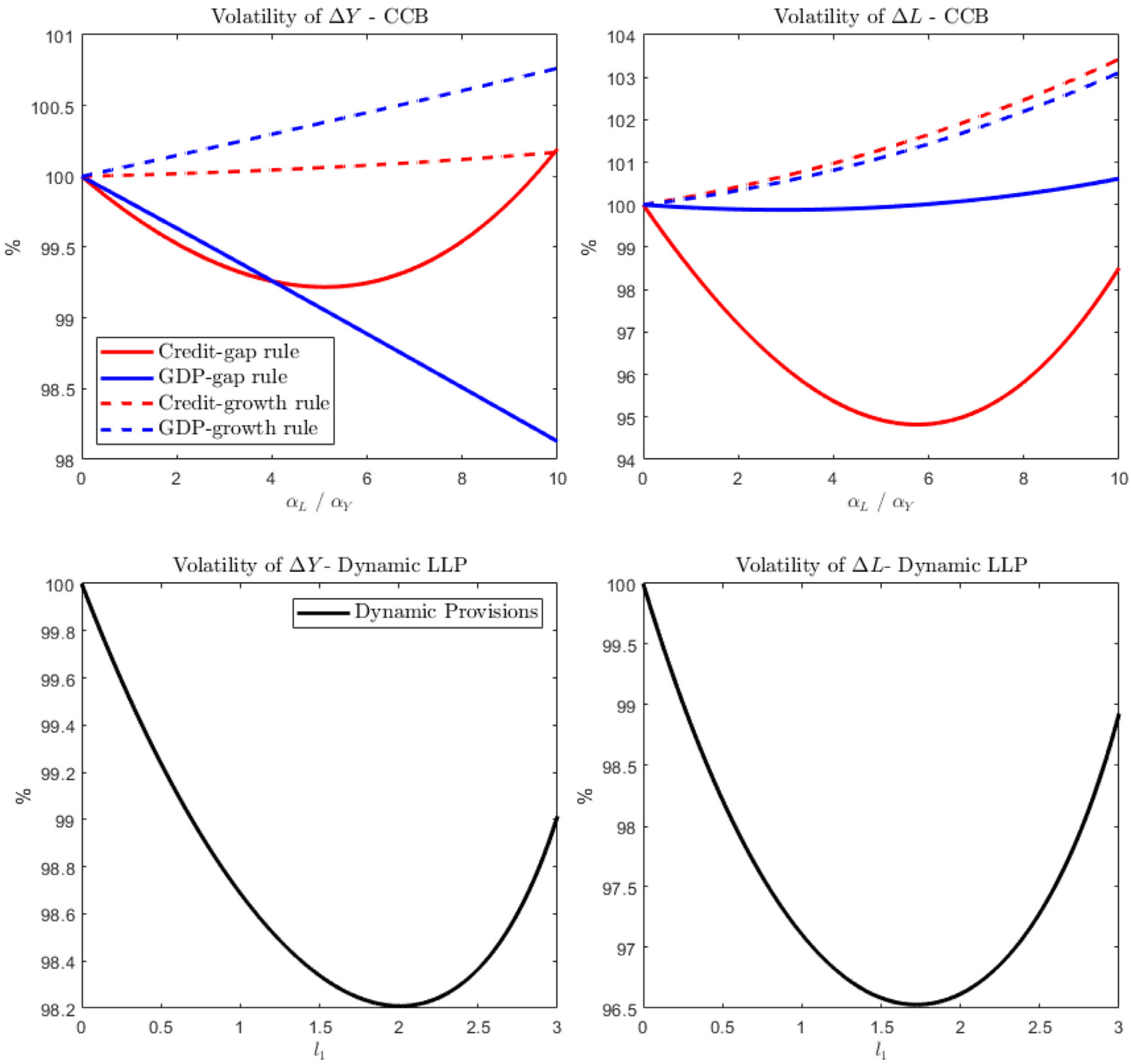

Fig. 8. Relative volatility. Notes: The value in the vertical axis is the ratio of the volatility of each variable obtained with a rule with the parameter value indicated in the horizontal axis relative to that obtained in the baseline (where the parameter equals zero), expressed in percentage terms.

would make the household indifferent (in terms of unconditional expected utility) to living in a world with that particular rule and parameter value relative to the baseline that features no CCB and static provisions. In that metric, a positive value indicates that the alternative is preferred to the baseline. This is computed by a second-order approximation to the equilibrium conditions, as in Schmitt-Grohe and Uribe (2007).

Regarding CCB rules, we can see that welfare is improved under the four evaluated alternatives, with the credit-gap rule increasing welfare the most. Qualitatively, this improvement is brought about by a reduction in the volatilities of consumption and hours worked, which are the main determinants of consumer welfare. However, in line with the previous results, quantitatively, these differences are quite small: The maximum reported improvement is equivalent to a compensation of a quarter of a percentage point in each period's consumption.

A dynamic provisioning scheme tends to reduce welfare, with larger losses with a more aggressive dynamic component. As previously analyzed, provisions act as a distortionary tax on lending. While this feature is precisely what allows this tool to provide a potentially larger effect in smoothing the credit cycle, as discussed in the previous subsection, this distortionary nature induces a welfare loss. Therefore the analysis points to a trade-off between, on the one hand, smoothing the credit cycle and building buffers and, on the other, welfare in normal times.

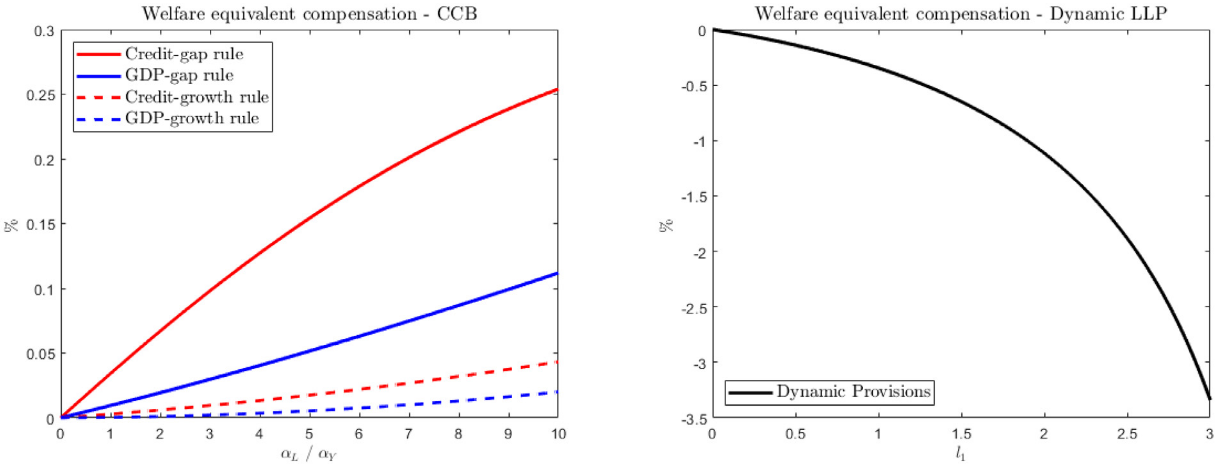

Fig. 9. Welfare equivalent consumption Notes: The value in the vertical axis is the percentage of each period's consumption that makes the household indifferent to whether it lives in the baseline world (where the parameter equals zero) or in a world with a rule with the parameter value indicated in the horizontal axis. A positive value indicates the alternative is preferred to the baseline.

However, it is important to remember that our model is not well suited to capturing large crisis events (which would be computationally costly, as it would require dealing with nonlinearities). Thus, the analysis is abstracting from the potential benefits of building buffers to confront these events that, although materialized with a low unconditional probability, can induce large welfare costs once they appear. This points to an interesting avenue for future research.

5. Final remarks

To perform 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 developed a DSGE model for a small and open economy. In particular, loan default is endogenous in the model, and specific attention is paid to modeling the banking sector and its prudential regulation.

The model is estimated using quarterly data for Uruguay from 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 CCB and DP are effective in generating buffers that may cover future losses. However, countercyclical capital requirements do not have major real effects, while DP may. When the economy faces a positive external shock, a countercyclical capital rule based on either credit or GDP gaps has a quicker and stronger effect in buffering bank capital than a rule based on output or real credit growth. From that perspective, DP also effectively increase buffers to cover potential losses.

A second relevant result is that CCB rules seem to have little effect on bank lending and, thus, the real side of the economy. Instead, DP can play a larger role in smoothing the real and financial cycles. However, its effectiveness also depends on the type of shock driving the economy.

Another important observation is that the nominal ratio of credit to GDP, which tends to be used as a relevant indicator to assess the phase credit cycle, might be unreliable. This is because this ratio tends to be affected not only by the behavior of credit in real terms but also by the evolution of relative prices (e.g., the real exchange rate). Thus, particularly for small and open economies, external shocks can generate a decrease in this ratio while the economy is booming (an effect that is larger the more dollarized the banking sector is). As this discussion is relevant for the CCB rule but not for dynamics provisions, this seems also to be a relevant factor in comparing both policy alternatives.

Finally, we highlight a potential trade-off in considering dynamic provisions. While in good times this tool is effective not only in building buffers to cover for potential losses but also in affecting the credit and real cycles, its use may induce a welfare cost. However, a complete evaluation of this trade-off is computationally challenging. It would require a model that can trigger crisis-like events to evaluate the potential gains of building buffers in good times. Nevertheless, we suggest this as an interesting line to explore in future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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' asset substitution
γ	Banks' capital-to-assets ratio
τ	Banks' reserve requirement

Table A.2
Selected endogenous variables.

c	Consumption	mc^H	Domestic 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 goods dispersion
mc^W	Labor marginal costs	m	Imports
r^K	Rent capital rate	b^*	Banks' bond 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	Deposit interest rate
y^F	Foreign goods supply	R^L	Loan interest rate
x^F	Foreign goods demand	y^H	Domestic composite goods supply
x^H	Domestic goods demand	l	Bank loans
x^{H*}	Domestic goods exports	lev	Entrepreneurs' leverage
R	Monetary policy rate	rp	Entrepreneurs' risk premium
ξ	Country premium	$\overline{\omega}$	Optimal threshold
π	Inflation rate	def	Default rate
rer	Real exchange rate	p^H	Domestic goods price
$\tilde{p}^H$	Adjusters' optimal domestic goods price	n^B	Predetermined banks' capital
p^F	Foreign goods price	$\tilde{n}^B$	Banks' capital
$\tilde{p}^F$	Adjusters' optimal foreign goods 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		

Appendix B. Equilibrium conditions

Real variable quantities contain a unit root due to a stochastic productivity trend A_t, and nominal variables contain an additional trend due to long-run inflation. Thus, variables are transformed 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. In particular, with one exception, lowercase variables denote either relative prices or 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, which 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 is the set of sequences

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

which totals 63 variables. The exogenous processes are

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

for $x = \{v, u, z, a, \zeta, R^*, \pi^*, p^{Co*}, y^{Co}, y^*, g, \pi^T, \sigma_\omega, s, \gamma, \tau, llp\}$, where ε_t^x is assumed to represent normal and identically distributed shocks. Given initial values and the processes for the exogenous variables, the following conditions are satisfied at the equilibrium:

Households:

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

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

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

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

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

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

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

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

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

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

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

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

Aggregate Consumption:

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

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

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

Domestic 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:

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

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

Entrepreneurs:

$$\frac{R^e_t}{\pi_t} = \frac{q_t(1-\delta)}{q_{t-1}} + \frac{p_t y^H_t - w_t h^d_t}{q_{t-1}k_{t-1}}, \tag{E.31}$$

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

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

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

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

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

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

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

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

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

Banks:

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

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

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

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

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

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

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

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

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

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

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

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

Rest of the world:

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

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

Policy:

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

Aggregation and market clearing:

$$y^H_t=x^H_t+x^{H*}_t, \tag{E.56}$$

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

$$\frac{rer_t}{rer_{t-1}}=\frac{\pi^S_t\pi^*_t}{\pi_t}, \tag{E.58}$$

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

$$tb_t=p^H_t x^{H*}_t+rer_t p^{Co*}_t y^{Co}_t-rer_t m_t, \tag{E.60}$$

$$rer_t b^*_t=rer_t\frac{b^*_{t-1}}{a_{t-1}\pi^*_t}R^*_{t-1}\xi_{t-1}+tb_t-(1-\chi)rer_t p^{Co*}_t y^{Co}_t, \tag{E.61}$$

$$p^Y_t y_t=c_t+i_t+g_t+tb_t, \tag{E.62}$$

$$y^F_t=x^F_t. \tag{E.63}$$

Appendix C. Parametrization

Table C.1
Calibrated parameters and targeted steady-state values.

Parameters	Description	Value
σ	Risk aversion	1
ϕ	Frisch elasticity	1
α	Capital share	0.34
δ	Depreciation	0.015
ϵ^j	E.o.S. varieties of $j = \{H; F; W\}$	11
o	Share of F in final goods	0.32
χ	Share of y^{Co} owned by domestic agents	0.6
β	Discount factor	1.0071
$o*$	Scale factor for exports	0.3254
κ	Scale factor for labor utility	9.1223
ρ_{e^R}	Monetary policy shock persistence	0
$\rho_{y^{Co}}$	Commodity endowment persistence	0.846
ρ_{R^*}	World interest rate persistence	0.9775
ρ_{π^*}	World inflation persistence	0.2527
$\rho_{p^{Co*}}$	World commodity price persistence	0.7016
ρ_{y^*}	World GDP persistence	0.8669
ρ_g	Gov. expenditures persistence	0.5569
$\sigma_{y^{Co}}$	Commodity endowment volatility	0.1235
σ_{R^*}	World interest rate volatility	0.001
σ_{π^*}	World inflation volatility	0.0378
$\sigma_{p^{Co*}}$	World commodity price volatility	0.0808
σ_{y^*}	World GDP volatility	0.0094
σ_g	Gov. expenditures volatility	0.018
h	Hours worked	0.3
ξ	Country premium	1.0063
π	Inflation target	1.0189
TB/GDP	Trade balance to output	0
d^*	Net foreign liabilities	1.7775
y^{Co}/GDP	Commodity production to GDP	0.0311
G/GDP	Gov. expenditures to GDP	0.1055
a	Long-run growth	1.0079
R^*	World interest rate	1.0097
π^*	World inflation	1.0153
o^M	Share of money in total liquidity	0.3305
M/GDP	Money to GDP	0.0461
M/D	Money to deposits	0.4201
ν	Scale in liquidity preference	0.5058
τ	Reserve requirements	0.1864
s	Scale in banks' cost function	0.0013
ι^e	Capital injection for new entrepreneurs	0.0903
rp	Entrep. risk premium	1.002
lev^e	Entrep. Leverage	2.2
def	Default rate	0.0125
ι^b	Capital injection for new banks	0.0479
υ^b	Survival rate banks	0.97
γ^R	Required capital ratio	0.0488
γ^0	Extra capital ratio	0.0849
l_0	Loan provisions	0.1354
S^L	Banks cost function	1.6356
L/A	Loans to banks assets	0.4827

Table C.2
Estimated parameters.

Parameters	Description	Posterior		Prior		
		Mod	St.Dev.	Dist	Mean	St.Dev.
ς	Habits in cons.	0.5375	0.063	β	0.7	0.1
ψ	Country premium elast	0.0075	0.0014	Γ^{-1}	0.005	∞
η	E.o.S. x^H, x^F	2.8386	0.3741	$\mathcal{N}$	1.75	0.5
η_M	E.o.S. m^d, d	0.3822	0.0469	$\mathcal{N}$	0.7	0.1
η^*	Elast of exports	0.5222	0.1309	Γ^{-1}	0.65	0.25
γ	Inv. adj. cost	4.2997	0.9085	$\mathcal{N}$	4	1
θ_W	Calvo wages	0.9385	0.0232	β	0.75	0.15
ϑ_W	Indexation wages	0.6114	0.1033	β	0.6	0.1
θ_H	Calvo price H	0.6968	0.0453	β	0.75	0.1
ϑ_H	Indexation price H	0.0215	0.0446	β	0.2	0.15
θ_F	Calvo price F	0.8792	0.0282	β	0.9	0.1
ϑ_F	Indexation price F	0.5858	0.1096	β	0.5	0.1
ρ_R	Smoothing Taylor rule	0.9126	0.0159	β	0.75	0.1
α_π	Response to infl. Taylor rule	1.4739	0.1719	$\mathcal{N}$	1.5	0.2
α_y	Response to output Taylor rule	0.1614	0.0436	Γ^{-1}	0.2	0.1
α_{π^S}	Response to dep. Taylor rule	0.4791	0.1	Γ^{-1}	0.5	0.2
μ	Entrep. monitoring costs	0.0307	0.0177	β	0.08	0.04
υ	Entrep. survival rate	0.9066	0.0185	β	0.98	0.01
ϕ_B	Elasticity of bank penalty function	157.6655	77.0847	Γ^{-1}	50	∞
α_d	Banks' capital default component	0.0752	0.0399	$\mathcal{N}$	0.08	0.04
α_l	Banks' capital credit component	0.0945	0.0499	$\mathcal{N}$	0.1	0.05
ρ_{σ_ω}	Entrepreneurs' shock persistence	0.7414	0.1103	β	0.65	0.15
$\rho_{\gamma^{exo}}$	Exogenous capital rule persistence	0.9757	0.0134	β	0.8	0.1
ρ_{γ_R}	Banks' capital buffer persistence	0.9699	0.0174	β	0.8	0.1
ρ_s	Banks' cost shock persistence	0.4551	0.0952	β	0.75	0.1
ρ_v	Liquidity demand persistence	0.9245	0.0335	β	0.75	0.1
ρ_υ	Consumption shock persistence	0.9432	0.0263	β	0.8	0.1
ρ_u	Investment shock persistence	0.1294	0.055	β	0.3	0.1
ρ_z	Transitory productivity persistence	0.2737	0.0793	β	0.4	0.1
ρ_a	Permanent productivity persistence	0.0254	0.0357	β	0.75	0.25
$\rho_{\zeta^{obs}}$	Country premium persistence	0.9923	0.0034	β	0.75	0.1
$\rho_{\zeta^{UIP}}$	UIP shock persistence	0.8744	0.0602	β	0.75	0.1
ρ_{ξ^X}	Export shock persistence	0.9095	0.0408	β	0.75	0.1
σ_{σ_ω}	Entrepreneurs' shock volatility	0.1029	0.0123	Γ^{-1}	0.1	∞
$\sigma_{\gamma^{exo}}$	Exogenous capital rule volatility	0.3363	0.0463	Γ^{-1}	0.1	∞
σ_{γ_R}	Banks' capital buffer volatility	0.2732	0.0437	Γ^{-1}	0.1	∞
σ_s	Banks' cost shock persistence	0.2828	0.0349	Γ^{-1}	0.1	∞
σ_v	Liquidity demand volatility	0.0835	0.0132	Γ^{-1}	0.1	∞
σ_υ	Consumption shock volatility	0.0556	0.0119	Γ^{-1}	0.1	∞
σ_u	Investment shock volatility	0.2699	0.0601	Γ^{-1}	0.1	∞
σ_z	Transitory productivity volatility	0.034	0.0097	Γ^{-1}	0.1	∞
σ_a	Permanent productivity volatility	0.0098	0.0014	$\mathcal{N}$	0.05	0.05
$\sigma_{\zeta^{obs}}$	Country premium volatility	0.0113	0.0016	$\mathcal{N}$	0.05	0.05
$\sigma_{\zeta^{UIP}}$	UIP shock volatility	0.0176	0.0038	$\mathcal{N}$	0.1	0.05
σ_{e^R}	Monetary policy shock volatility	0.0117	0.0021	Γ^{-1}	0.04	∞
σ_{ξ^X}	Export shock volatility	0.0439	0.0055	Γ^{-1}	0.1	∞

Appendix D. Extra figures

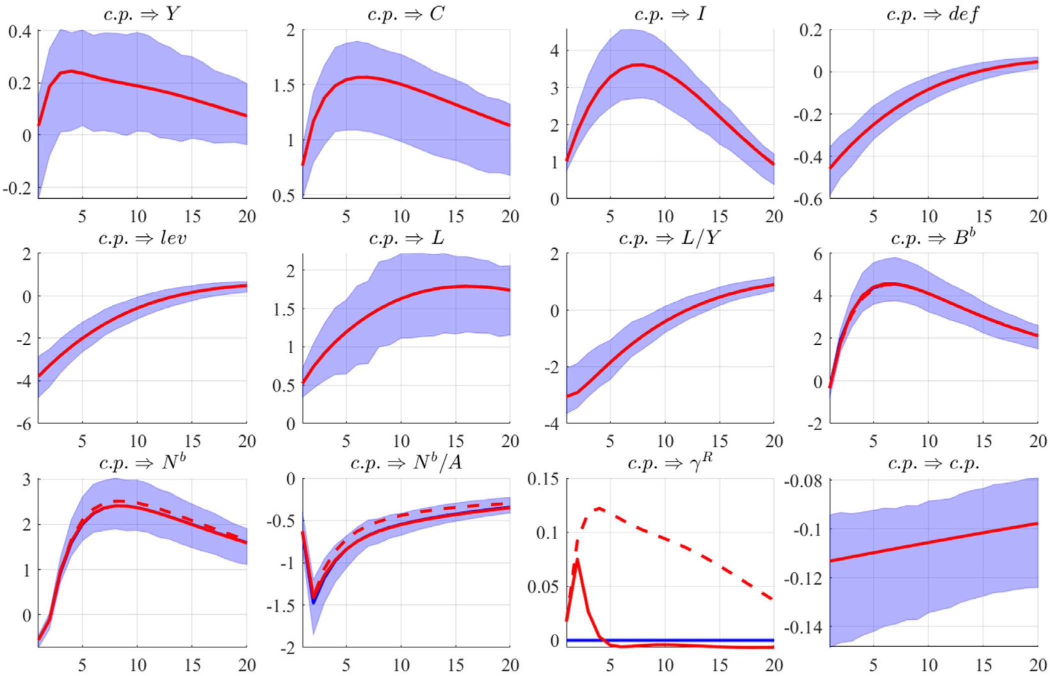

Fig. D.1. Country premium shock: Baseline and CCB growth-related rules. Solid blue: Baseline. Solid black: GDP growth rule, $\alpha^R_{\Delta Y} = 0.5$. Dashed black: GDP level rule, $\alpha^R_y = 0.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

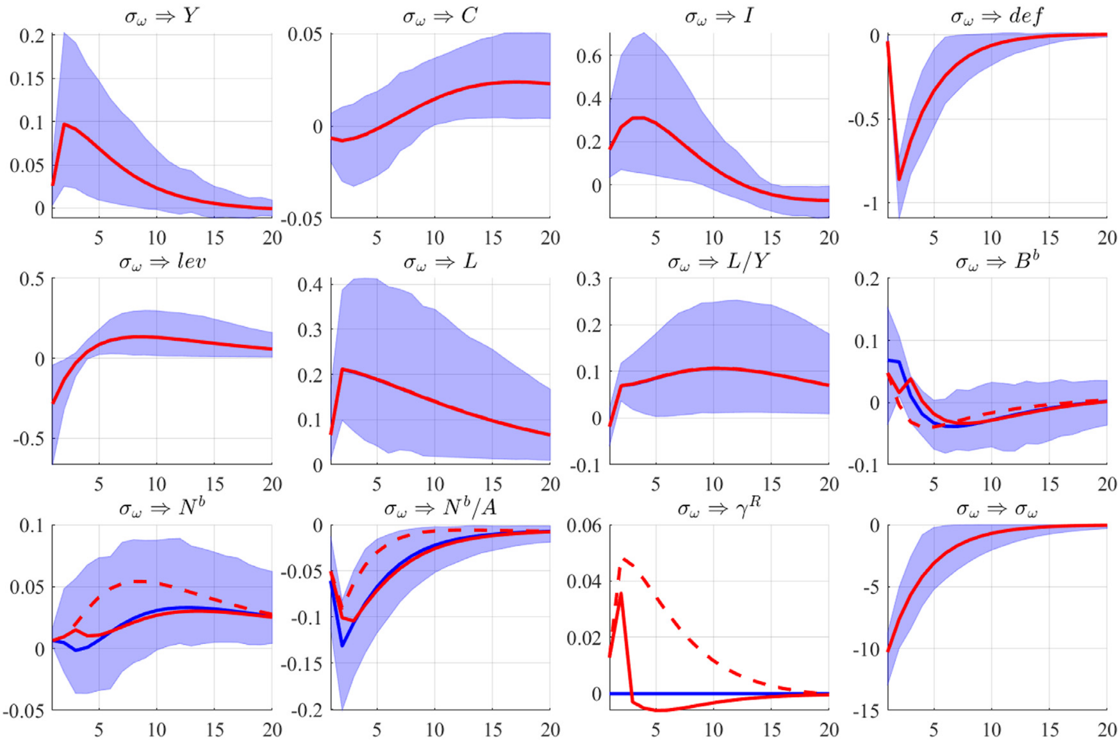

Fig. D.2. Entrepreneurs' risk premium shock: Baseline and CCB growth-related rules. Solid blue: Baseline. Solid black: GDP growth rule, $\alpha^R_{\Delta Y} = 0.5$. Dashed black: GDP level rule, $\alpha^R_y = 0.5$. See Fig. 2 for variable definitions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

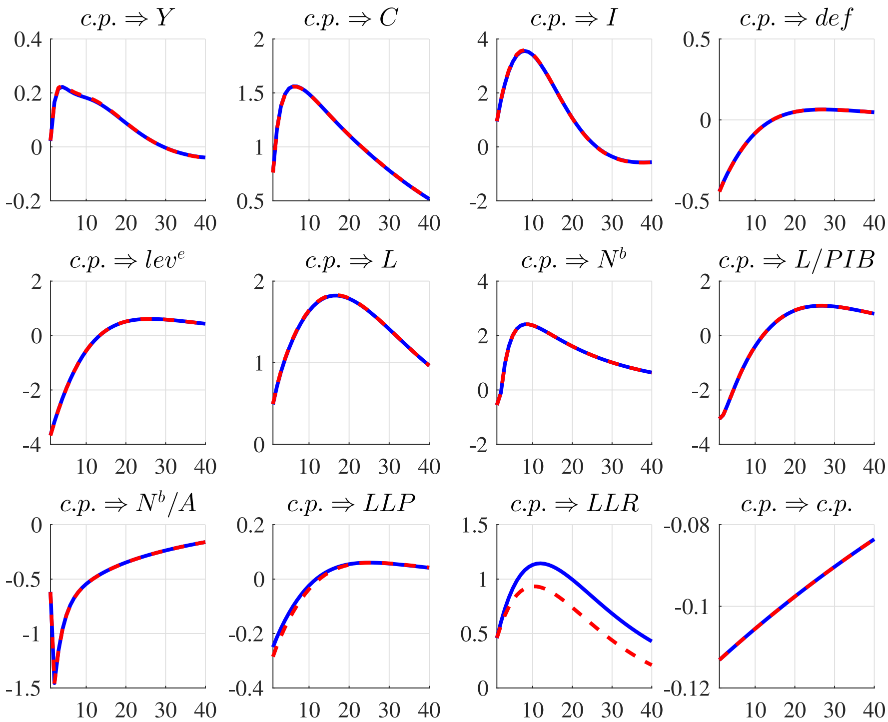

Fig. D.3. DP with country risk premium shock: Current vs. expected default. Solid blue: Current default ($j = t$). Dashed red: Expected default ($j = t + 1$). Both $l_1 = 0.5$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

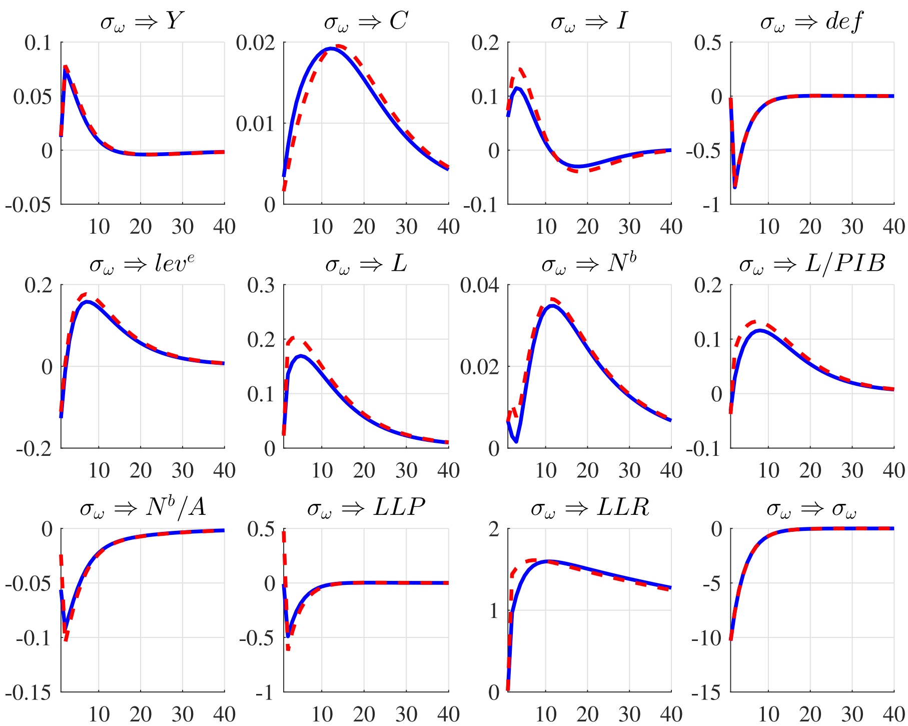

Fig. D.4. DP with entrepreneurs risk premium shock: Current vs. expected default Solid blue: Current default ($j = t$). Dashed red: Expected default ($j = t + 1$). Both $l_1 = 0.5$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

References

Agénor, P.-R., Pereira da Silva, L., 2017. Cyclically adjusted provisions and financial stability. J. Financ. Stab. 28, 143–162.
Agénor, P.-R., Zilberman, R., 2015. Loan loss provisioning rules, procyclicality, and financial volatility. J. Bank. Financ. 61, 301–315.
Aliaga-Díaz, R., Olivero, M., Powell, A., 2017. Monetary policy and anti-cyclical bank capital regulation. Econ. Inq.
Allen, L., Rai, A., 1996. Bank charter values and capital levels: an international comparison. J. Econ. Bus. 48 (3), 269–284.
Ayuso, J., Perez, D., Saurina, J., 2004. Are capital buffers pro-cyclical? Evidence from Spanish panel data. J. Financ. Intermediation 13 (2), 249–264.
Barth, J., Caprio, G., Levine, R., 2006. Rethinking Bank Regulation: Till Angels Govern. Cambridge University Press.
Basal, J., Carballo, P., Cuitiño, F., Frache, S., Licandro, G., Mourelle, J., Rodríguez, H., Rodriguez, V., Vicente, L., 2016. Un modelo estocástico de equilibrio general para la economía uruguaya. Documento de trabajo del BCU.
Berger, A., DeYoung, R., Flannery, M., Oztekin, O., 2008. How do large banking organizations manage their capital ratios? J. Financ. Serv. Res. 34 (2), 123–149.
Bernanke, B., Gertler, M., Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. In: Taylor, J., Woodford, M. (Eds.), Handbook of Macroeconomics. Elsevier, pp. 1341–1393.
Bouvatier, V., Lepetit, L., 2012. Provisioning rules and bank lending: a theoretical model. J. Financ. Stab. 8, 25–31.
Cabello, M., Lupú, J., Minaya, E., 2017. Macroprudential policies inPeru: the effects of dynamic provisioning and conditional reserve requirements. BIS Working Paper No. 675.
Christiano, L., Motto, R., Rostagno, M., 2014. Risk shocks. Am. Econ. Rev. 104 (1), 27–65.
Chui, M., Kuruc, E., Turner, P., 2016. A new dimension to currency mismatches in the emerging markets: non-financial companies. BIS Working paper 550.
Darracq-Pariés, M., Kok-Sørensen, C., Rodriguez-Palenzuela, D., 2011. Macroeconomic propagation under different regulatory regimes: evidence from an estimated DSGE model for the euro area. Int. J. Cent. Bank. 7 (4), 49–113.
Fonseca, A., Gonzalez, F., 2010. How bank capital buffers vary across countries: the influence of cost of deposits, market power and bank regulation. J. Bank. Financ. 34 (4), 892–902.
Gerali, A., Neri, S., Sessa, L., Signoretti, F., 2010. Credit and banking in a DSGE model of the euro area. J. Money Credit Bank. 42 (1), 107–141.
Gertler, M., Karadi, P., 2011. A model of unconventional monetary policy. J. Monet. Econ. 58 (1), 17–34.
Gertler, M., Kiyotaki, N., Queralto, A., 2012. Financial crises, bank risk exposure and government financial policy. J. Monet. Econ. 59 (S), 17–34.
Glocker, C., Towbin, P., 2012. Reserve requirements for price and financial stability: when are they effective? Int. J. Cent. Bank. 8 (1), 65–114.
Gómez, F., Ponce, J., 2019. Regulation and bankers' incentives. J. Financ. Serv. Res. 56, 209–227.
Jiménez, G., Ongena, S., Peydró, J.-L., Saurina, J., 2017. Macroprudential policy, countercyclical bank capital buffers, and credit supply: evidence from the spanish dynamic provisioning experiments. J. Polit. Econ. 125 (6).
Jokipii, T., Milne, A., 2008. The cyclical behaviour of european bank capital buffers. J. Bank. Financ. 32 (8), 1440–1451.
Jokipii, T., Milne, A., 2011. Bank capital buffer and risk adjustment decisions. J. Financ. Stab. 7 (3), 165–178.
Lindquist, K.-G., 2004. Banks buffer capital: how important is risk. J. Int. Money Financ. 23 (3), 493–513.
Milne, A., Whalley, E., 2001. Bank capital regulation and incentives for risk-taking. Cass business School Research Paper.
Peura, S., Jokivuolle, E., 2004. Simulation based stress tests of banks' regulatory capital adequacy. J. Bank. Financ. 28 (8), 1801–1824.
Schmitt-Grohe, S., Uribe, M., 2007. Optimal simple and implementable monetary and fiscal rules. J. Monet. Econ. 54 (6), 1702–1725.
Stolz, S., Wedow, M., 2011. Banks' regulatory capital buffer and the business cycle: evidence for german savings and cooperative banks. J. Financ. Stab. 7, 98–110.
Tobal, M., 2018. Currency mismatch: new database and indicators for latin america and the caribbean. Int. J. Cent. Bank. 14 (1).
VanHoose, D., 2008. Bank capital regulation, economic stability, and monetary policy: what does the academic literature tell us? Atl. Econ. J. 36 (1), 1–14.