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Capital requirements and business cycles with credit market imperfections

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ABSTRACT

The business cycle effects of bank capital regulatory regimes are examined in a New Keynesian model with credit market imperfections and a cost channel of monetary policy. Bank capital increases incentives for banks to monitor borrowers, thereby raising the repayment probability, and excess capital generates benefits in terms of reduced regulatory scrutiny. Basel I- and Basel II-type regulatory regimes are defined, and the model is calibrated for a middle-income country. Simulations of a supply shock show that, depending on the elasticity that relates the repayment probability to the bank capital–loan ratio, the Basel II regime may be *less* procyclical than a Basel I regime.

1. Introduction

The role of bank regulatory capital regimes in the propagation of business cycles has been the subject of much scrutiny since the introduction of the Basel I accord in 1988. The adoption of the Basel II accord in 2004—which involves using mark-to-market pricing rules and setting capital requirements on the basis of asset quality rather than only on asset type—and more recently the global financial crisis triggered by the collapse of the US subprime mortgage market have led to renewed focus by economists and policymakers alike on the procyclical effects of capital adequacy requirements. Indeed, it has been argued that because of the backward-looking nature of its risk estimates (based on past loss experience) Basel II induces banks to hold too little capital in economic upswings and too much during downturns. Thus, it does not restrain lending sufficiently in boom times, while it restrains it too much during recessions.

Much of the analytical and empirical work devoted to the analysis of cyclicality of regulatory capital regimes focuses on industrialized countries and therefore does not account for the type of financial market imperfections that middle-income developing countries typically face. These include the predominance of banks in the financial structure, severe asymmetric information problems and a weak judiciary (which combine to encourage highly collateralized lending), the inability to diversify risk, the absence of financial safety nets, and a high degree of exposure and vulnerability to domestic and external shocks. In such an environment, as argued by Agénor and Pereira da Silva (2012b), capital buffers may play an important role by helping banks convey a signal to depositors regarding their commitment to screening and

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monitoring their borrowers; they may therefore raise deposits at a lower cost, which in turn facilitates bank lending.[1] As shown by the authors, if capital requirements are binding, the introduction of this channel implies that in general, it cannot be concluded *a priori* whether Basel II is more procyclical than Basel I—in contrast to what a partial equilibrium analysis would imply.

Despite its intuitive appeal, the model presented in Agénor and Pereira da Silva (2012b) is a static, nonoptimizing model. In this paper, we further examine the cyclical effects of capital adequacy requirements in the New Keynesian model with credit market imperfections developed by Agénor and Alper (forthcoming). A key feature of that framework is its explicit focus on the type of distortions (as mentioned earlier) that characterize the financial structure in middle-income countries. It combines the cost and balance sheet channels of monetary policy with an explicit analysis of the link between collateralizable wealth and bank pricing behavior.[2] Because borrowers' ability to repay is uncertain, banks issue only collateralized loans to mitigate moral hazard problems and reduce incentives to default; they therefore incorporate a risk premium in lending rates. At the prevailing loan rate, the supply of funds by financial intermediaries is perfectly elastic. Moreover, the central bank fixes a policy interest rate (the refinance rate, which therefore represents the marginal cost of funds), using a Taylor-type rule and its supply of liquidity to banks is perfectly elastic at the target interest rate. As a result, banks are unconstrained in their lending operations and, in contrast to models in the Kiyotaki–Moore tradition, net worth does not impose a continuously-binding constraint on borrowing. Because changes in central bank liquidity affect the bond rate, changes in money supply play a significant role in determining the dynamics of real variables. Thus, money is not a side show—even under the assumption of separability between consumption and monetary assets in household utility.

In an important departure, however, banks in the present setting are also subject to risk-based capital requirements. In order to compare Basel I- and Basel II-type regimes, we assume that the risk weight on loans to firms (the only risky asset for banks) is either constant or a function of the repayment probability. This specification is based on the assumption that this probability is positively related to the (perceived) quality of a loan. We determine the banks' demand for capital, based on the assumption that issuing liabilities is costly. This, together with the capital regulation, causes deviations from the Modigliani–Miller framework.[3] We also assume that holding capital in excess of regulatory capital generates some benefits—by providing a signal that the bank's financial position is strong and thereby reducing the intensity of regulatory scrutiny.

We incorporate a bank capital channel as well, but we do so in a different manner than in Agénor and Pereira da Silva (2012b). We assume here that holding capital induces banks to screen and monitor borrowers more carefully.[4] As a result, the repayment probability tends to increase, which in turn leads to a lower cost of borrowing for the public. Thus, bank capital may also play a significant cyclical role—the higher it is, the lower the loan rate, and the greater the expansionary effect on activity. This effect is consistent with the evidence for the United States reported in Hubbard et al. (2002), which suggests that—controlling for information costs, loan contract terms, and borrower risk—the capital position of individual banks affects negatively the interest rate at which their clients borrow, and in Coleman et al. (2002), who found that capital-constrained banks charge higher spreads on their loans. It is also consistent with the results provided by Fonseca et al. (2010) for both developed and developing countries. Thus, although we calibrate our model for a middle-income country, the "monitoring incentive" effect identified here is potentially of equal relevance for industrial countries.

A key point of our analysis, which is in contrast with existing contributions in the tradition of Carlstrom and Fuerst (1997) and Bernanke et al. (2000), is that we provide a richer modeling of bank regulatory capital regimes. We model explicitly the issuance of capital and account for both the quantity and the price of bank capital. As in Liu and Seeiso (2011), the equilibrium loan rate depends not only on the marginal cost of funds (the central bank refinance rate here, rather than the deposit rate) but also on the rate of return on bank capital. This differs from models such as Gerali et al. (2010) or Angelini et al. (2011), where bank capital is accumulated through retained earnings and neither excess capital nor the direct cost of issuing capital are considered. In addition, and unlike Liu and Seeiso (2011) for instance, we also account for the monitoring incentive effect associated with bank capital, as described earlier, and explicitly model banks' excess holdings of capital.

The main result of our simulations is that, contrary to what is commonly believed, a Basel II-type regulatory regime may be *less* procyclical than a Basel I-type regime, once credit market imperfections and general equilibrium effects are accounted for. This stands in contrast to other studies where these imperfections have been introduced, such as Darracq Pariès et al. (2010) and Liu and Seeiso (2011). In our model, the repayment probability depends not only on the regulatory regime (through the bank capital–loan ratio), but also on the cyclical position of the economy (which affects cash flows and profitability) and the collateral–loan ratio (which mitigates moral hazard). Following, say, a negative shock to output, a fall in the demand for production-related loans raises initially the collateral–loan ratio, which tends to increase the repayment probability. By contrast, the fall in cyclical output (which signals lower cash flows) tends to lower the repayment probability.

[1] This analysis shares some similarities with Chen (2001) and Meh and Moran (2010), where banks lack the incentive to monitor borrowers adequately, because monitoring is privately costly and any resulting increase in the risk of loan portfolios is mostly borne by investors (households). This moral hazard problem is mitigated when banks are well-capitalized and have a lot to lose from loan default.

[2] In turn, the models in Agénor and Alper (forthcoming) and Agénor and Pereira da Silva (2012b) build on the static framework with monopolistic banking and full price flexibility developed by Agénor and Montiel (2008). The cost and balance sheet channels of monetary policy are particularly relevant for middle-income countries; see Agénor and Pereira da Silva (2010). See also Ravenna and Walsh (2006), Atta-Mensah and Dib (2008), and Tillmann (2008), for a discussion of the cost channel in New Keynesian models.

[3] Without these assumptions, whether bank loans are financed with deposits or debt would be irrelevant. See Miller (1988) for instance.

[4] Standard results suggest that a bank's incentive to monitor does not depend on its capital if it can completely diversify the risk in its loan portfolio. However, as noted earlier, the inability to fully diversify risk away is precisely one of the key features of banking in developing countries.

Both of these conflicting effects operate in the same manner under either regulatory regime. If the cyclical output effect dominates the collateral–loan effect on the repayment probability, and if the fall in that probability is sufficiently large, the Basel I-type regime mitigates the procyclicality inherent to the behavior of the repayment probability—because the cost of issuing equity falls as required capital falls; this in turn lowers the lending rate.In addition, while the bank capital–loan ratio does not change under a Basel I-type regime (given that risk weights are fixed), it may either increase or fall under a Basel II-type regime, because the risk weight is now directly related to the repayment probability. If again the cyclical output effect dominates the collateral–loan effect, so that the repayment probability falls, this will also lead to a higher risk weight and larger capital requirements—which will in turn tend to mitigate the initial drop in the repayment probability. If this particular "bank capital channel" is sufficiently strong, the Basel II-type regime may be less procyclical than the Basel I-type regime. Our numerical results suggest that this counterintuitive response can be obtained with relatively small and plausible changes in the sensitivity of the repayment probability to the bank capital–loan ratio.[5]

The paper continues as follows. Section 2 presents the model. We keep the presentation as brief as possible, given that many of its ingredients are described at length in Agénor and Alper (forthcoming); instead, we focus on how the model presented here departs from that paper, especially with respect to bank behavior and the regulatory capital regime. The equilibrium is characterized in Section 3 and some key features of the log-linearized version of the model are highlighted in Section 4. Calibration, which we view as illustrative but fairly representative for middle-income countries, is discussed in Section 5. Section 6 presents the results of our experiment—a temporary, negative supply shock, to highlight the implications of the two regulatory regimes for the economy's response to a recession.[6] The last section provides a summary of the main results and considers some possible extensions of the analysis.

2. The model

We consider a closed economy populated by five types of agents: a representative, infinitely-lived household, a continuum of intermediate goods-producing (IGP) firms of mass one and indexed by $j \in (0,1)$, a final-good-producing (FGP) firm—or, equivalently, a retailer—a commercial bank, the government, and the central bank, which also regulates the bank. The bank supplies credit to IGP firms to finance their short-term working capital needs. Loans are partly secured by physical capital, which is owned by the household but made available to IGP firms for use as collateral. The supply of loans is perfectly elastic at the prevailing lending rate. The maturity period of bank loans to IGP firms and the maturity period of bank deposits by households is the same. In each period, loans are extended prior to production and paid off at the end of the period, after the sale of output. The household deposits funds in the bank prior to production and collects them at the end of the period, after the goods market closes. The bank issues shares to satisfy capital regulations. It pays interest on household deposits and the liquidity that it borrows from the central bank, and dividends on the shares that it issues.

We also assume that, at the end of each period, the bank is liquidated and a new bank opens at the beginning of the next. Thus, bank shares are redeemed at the end of each period, all its profits (including income from the redemption of one-period government bonds) are distributed, and new equity is issued at the beginning of the next period.[7] The central bank supplies liquidity elastically to the bank and sets its refinance rate in response to deviations of inflation from its target value and the output gap.

2.1. Household

The household consumes, holds financial assets (including shares issued by the bank), and supplies labor to IGP firms. It also owns the economy's stock of physical capital, which it provides to IGP firms. The objective of the household is to maximize

$$U_t = E_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{[C_{t+s}]^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - N_{t+s}) + \eta_x \ln x_{t+s} \right\}, \tag{1}$$

where C_t is the consumption bundle, $N_t = \int_0^1 N_t^j dj$, the share of total time endowment (normalized to unity) spent working, with N_t^j denoting the proportion of labor hours provided to the IGP firm j, x_t a composite index of real monetary assets, and $\beta \in (0,1)$ the discount factor. E_t is the expectation operator conditional on the information available at period t, $\varsigma > 0$ is the intertemporal elasticity of substitution in consumption and η_N, $\eta_x > 0$.

The composite monetary asset is generated by combining real cash balances, m_t^H, and real bank deposits, d_t, through a Cobb–Douglas function:

$$x_t = (m_t^H)^{\nu} d_t^{1-\nu}, \tag{2}$$

[5] Note also that because the risk-weighting scheme of the new Basel III accord adopted in November 2010 has remained pretty much identical to Basel II, determining if a risk-sensitive regime is more or less procylical than a regime with constant risk weights is equally relevant for Basel III.

[6] The working paper version of this article (available upon request) considers also a negative government spending shock. Our results regarding the procyclicality of alternative regulatory capital regimes also obtain with this shock.

[7] Goodhart et al. (2005) also adopt the assumption of bank liquidation in a two-period framework. Thus, there is no intrinsic distinction between issuing equity or debt from the perspective of the bank. See Yilmaz (2009) for instance for a partial equilibrium model in which equity is accumulated over time.

where $\nu \in (0,1)$.

Nominal wealth of the household at the end of period t, A_t, is given by

$$A_t = M_t^H + D_t + B_t^H + P_t K_t + P_t^V V_t, \tag{3}$$

where P_t is the price of the final good, $M_t^H = P_t m_t^H$ nominal cash holdings, $D_t = P_t d_t$ nominal bank deposits, B_t^H holdings of one-period nominal government bonds, K_t the real stock of physical capital held by the household at the beginning of period t, V_t the number of ownership shares issued by the bank, and P_t^V the nominal share price. As noted earlier, equity shares are redeemed at the end of each period; this is quite convenient analytically, because it allows us to avoid distinguishing between equity stocks and flows.

The household enters period t with K_t real units of physical capital and M_{t-1}^H holdings of cash. It also collects principal plus interest on bank deposits at the rate contracted in $t-1$, $(1+i_{t-1}^D)D_{t-1}$, where i_{t-1}^D is the interest rate on deposits, principal and interest payments on maturing government bonds, $\left(1+i_{t-1}^B\right)B_{t-1}^H$, where i_{t-1}^B is the bond rate at $t-1$, as well as the value of redeemed shares and distributed dividends $\left(1+i_{t-1}^V\right)P_{t-1}^V V_{t-1}$, where i_{t-1}^V is the nominal yield on equity shares.

At the beginning of the period, the household chooses the real levels of cash, deposits, equity capital, and bonds, and supplies labor and physical capital to IGP firms, for which it receives total real factor payment $r_t^K K_t + \omega_t N_t$, where r_t^K is the rate of return on physical capital and $\omega_t = W_t/P_t$ the economy-wide real wage, with W_t denoting the nominal wage.

The household receives all the profits made by the IGP firms, $J_t^I = \int_0^1 \Pi_{jt}^I \, dj$.[8] In addition, it receives all the profits of the bank, J_t^B, which is liquidated at the end of the period. It also pays a lump-sum tax, whose real value is T_t, and purchases the final good for consumption and investment, in quantities C_t and I_t, respectively. Investment turns into capital available at the beginning of the next period, K_{t+1}.

The household's end-of-period budget constraint is thus

$$\begin{aligned} M_t^H + D_t + B_t^H + P_t^V V_t = {} & P_t\left(r_t^K K_t + \omega_t N_t - T_t\right) + \left(1+i_{t-1}^D\right)D_{t-1} + \left(1+i_{t-1}^B\right)B_{t-1}^H + \left(1+i_{t-1}^V\right)P_{t-1}^V V_{t-1} + J_t^I + J_t^B \\ & - P_t(C_t + I_t) + M_{t-1}^H - \Theta_V P_t \frac{\left(z_t V_t^2\right)}{2}, \end{aligned} \tag{4}$$

where $z_t = P_t^V/P_t$ is the real price of equity and the last term represents costs (measured in terms of the price of the final good) associated with equity transactions, with $\Theta_V > 0$ denoting an adjustment cost parameter.

The stock of capital at the beginning of period $t+1$ is given by

$$K_{t+1} = (1-\delta)K_t + I_t - \frac{\Theta_K}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 K_t, \tag{5}$$

where $\delta \in (0,1)$ is a constant rate of depreciation and the last term is a capital adjustment cost function specified in standard fashion, with $\Theta_K > 0$ denoting an adjustment cost parameter.

Each household maximizes lifetime utility with respect to C_t, N_t, m_t^H, d_t, $b_t^H = B_t^H/P_t$, V_t, and K_{t+1}, taking as given period-$t-1$ variables as well as P_t, P_t^V, K_t, and T_t. Let $\pi_{t+1} = (P_{t+1} - P_t)/P_t$ denote the inflation rate; maximizing (1) subject to (2)–(5) yields the following solutions:

$$C_t^{-1/\varsigma} = \beta E_t\left[(C_{t+1})^{-1/\varsigma}\left(\frac{1+i_t^B}{1+\pi_{t+1}}\right)\right], \tag{6}$$

$$N_t = 1 - \frac{\eta_N (C_t)^{1/\varsigma}}{\omega_t}, \tag{7}$$

$$m_t^H = \frac{\eta_x \nu (C_t)^{1/\varsigma}\left(1+i_t^B\right)}{i_t^B}, \tag{8}$$

$$d_t = \frac{\eta_x (1-\nu)(C_t)^{1/\varsigma}\left(1+i_t^B\right)}{i_t^B - i_t^D}, \tag{9}$$

$$-\lambda_t\left[1 + \Theta_K\left(\frac{K_{t+1}}{K_t} - 1\right)\right] + \beta E_t\left\{\lambda_{t+1}\left[r_{t+1}^K + 1 - \delta - \frac{\Theta_K}{2}\left(\frac{K_{t+2}^2 - K_{t+1}^2}{K_{t+1}^2}\right)\right]\right\} = 0, \tag{10}$$

$$-\lambda_t + \beta E_t\left\{\lambda_{t+1}\left(\frac{1+i_t^V}{1+\pi_{t+1}}\right)\right\} - \Theta_V \lambda_t z_t V_t = 0, \tag{11}$$

[8] As noted below, the FGP firm makes zero profits.

where λ_t is the Lagrange multiplier associated with the budget constraint.

Eq. (6) is the standard Euler equation. Eq. (7) relates labor supply positively to the real wage and negatively to consumption. Eq. (8) relates the real demand for cash positively with consumption and negatively with the opportunity cost of holding money, measured by the interest rate on government bonds. Similarly, Eq. (9) relates the real demand for deposits positively with consumption and the deposit rate, and negatively with the bond rate. Eq. (10) can be rewritten as

$$E_t\left(\frac{1+i_t^B}{1+\pi_{t+1}}\right)=E_t\left\{\left[\Theta_K\left(\frac{K_{ht+1}}{K_{ht}}-1\right)+1\right]^{-1}\left[1-\delta+r_{t+1}^K-\frac{\Theta_K}{2}\left(\frac{\Delta K_{ht+2}^2}{K_{ht+1}^2}\right)\right]\right\}, \tag{12}$$

where the left-hand side is the expected real return on bonds (that is, the opportunity cost of one unit of capital), and the right-hand side is the expected return on the last unit of physical capital invested (corrected for adjustment costs, incurred both in t and $t+1$).

Because $\beta E_t(\lambda_{t+1}/\lambda_t)=E_t[(1+\pi_{t+1})/(1+i_t^B)]$, Eq. (11) yields

$$z_tV_t^d=\Theta_V^{-1}\left(\frac{i_t^V-i_t^B}{1+i_t^B}\right), \tag{13}$$

which shows that the demand for equity depends positively on its rate of return and negatively on the bond rate. In the particular case where $\Theta_V\to 0$, the household becomes indifferent between holding bank equity or government bonds, and $i_t^V=i_t^B$.

2.2. Final good producer

The final good, Y_t, is divided between private consumption, government consumption, and investment. It is produced by assembling a continuum of imperfectly substitutable intermediate goods Y_{jt}, with $j\in(0,1)$:

$$Y_t=\left\{\int_0^1[Y_{jt}]^{(\theta-1)/\theta}dj\right\}^{\theta/(\theta-1)}, \tag{14}$$

where $\theta>1$ is the elasticity of demand for each intermediate good.

The FGP firm sells its output at a perfectly competitive price. Given the intermediate-goods prices P_{jt} and the final-good price P_t, it chooses the quantities of intermediate goods, Y_{jt}, that maximize its profits. The maximization problem of the FGP firm is thus

$$Y_{jt}=\arg\max P_t\left\{\int_0^1[Y_{jt}]^{(\theta-1)/\theta}dj\right\}^{\theta/(\theta-1)}-\int_0^1 P_{jt}Y_{jt}\,dj.$$

The first-order conditions yield

$$Y_{jt}=\left(\frac{P_{jt}}{P_t}\right)^{-\theta}Y_t,\quad \forall j\in(0,1). \tag{15}$$

Imposing a zero-profit condition leads to the following final good price:

$$P_t=\left\{\int_0^1(P_{jt})^{1-\theta}dj\right\}^{1/(1-\theta)}. \tag{16}$$

2.3. Intermediate good-producing firms

Each IGP firm j produces (using both labor and capital) a distinct, perishable good that is sold on a monopolistically competitive market. Each firm must also borrow to pay wages in advance, that is, before production and sales have taken place. Price adjustment is subject to quadratic costs, as in Rotemberg (1982).

Production technology involves constant returns in labor and capital:

$$Y_{jt}=A_tN_{jt}^{1-\alpha}K_{jt}^{\alpha}, \tag{17}$$

where N_{jt} is labor hours, $\alpha\in(0,1)$, and A_t a common technology shock, which follows the process

$$\ln A_t=\rho_A\ln A_{t-1}+\xi_t^A, \tag{18}$$

where $\rho_A\in(0,1)$ and $\xi_t^A\sim N(0,\sigma_{\xi^A})$.

Each firm j borrows the amount L_{jt}^F from the bank at the beginning of the period to pay wages in advance. The amount borrowed is therefore

$$L_{jt}^F=P_t\omega_tN_{jt}. \tag{19}$$

Repayment of loans occurs at the end of the period, at the gross nominal rate $(1+i_{jt}^{L})$, where i_{jt}^{L} is the lending rate charged to firm j.

As in Rotemberg (1982), IGP firms incur a cost in adjusting prices, of the form

$$PAC_t^j = \frac{\phi_F}{2}\left(\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}} - 1\right)^2 Y_t, \tag{20}$$

where $\phi_F \geqslant 0$ is the adjustment cost parameter (or, equivalently, the degree of price stickiness), $\tilde{\pi}^G = 1 + \tilde{\pi}$ is the gross steady-state inflation rate, and Y_t aggregate output, defined in (14).

IGP firms are competitive in factor markets. Unit cost minimization yields the optimal capital–labor ratio as

$$\frac{K_{jt}}{N_{jt}} = \left(\frac{\alpha}{1-\alpha}\right)\left[\frac{\left(1+i_{jt}^{L}\right)\omega_t}{r_t^K}\right], \tag{21}$$

whereas the unit real marginal cost is

$$mc_{jt} = \frac{\left[\left(1+i_{jt}^{L}\right)\omega_t\right]^{1-\alpha}\left(r_t^K\right)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}A_t}. \tag{22}$$

Each firm chooses a sequence of prices P_{jt} so as to maximize the discounted real value of all its current and future real profits, where nominal profits at t, Π_{jt}^{J}, are defined as $\Pi_{jt}^{J} = P_{jt}Y_{jt} - P_t mc_t Y_{jt} - PAC_t^j$.[9] Taking $\{mc_{t+s}, P_{t+s}, Y_{t+s}\}_{s=0}^{\infty}$ as given, the first-order condition for this maximization problem is:

$$\left\{1-\theta+\theta\left(\frac{P_t}{P_{jt}}\right)mc_{jt}\right\}\lambda_t\left(\frac{P_{jt}}{P_t}\right)^{-\theta}\frac{Y_t}{P_t} - \lambda_t\phi_F\left\{\left(\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}} - 1\right)\frac{Y_t}{\tilde{\pi}^G P_{jt-1}}\right\} + \beta\phi_F E_t\left\{\lambda_{t+1}\left(\frac{P_{jt+1}}{\tilde{\pi}^G P_{jt}} - 1\right)Y_{t+1}\left(\frac{P_{jt+1}}{\tilde{\pi}^G P_{jt}^2}\right)\right\} = 0, \tag{23}$$

which gives the adjustment process of the nominal price P_{jt}.

2.4. Commercial bank

At the beginning of each period t, the bank collects deposits D_t from the household. Funds are used for loans to IGP firms, which use them to pay labor in advance. Thus, from (19), total lending is

$$L_t^F = \int_0^1 L_{jt}^F dj = P_t\omega_t N_t, \tag{24}$$

where again $N_t = \int_0^1 N_{jt}\,dj$.

Upon receiving household deposits, and given its equity $P_t^V V_t$ and loans L_t^F, the bank borrows from the central bank, L_t^B, to fund any shortfall in deposits. At the end of the period, it repays the central bank, at the interest rate i_t^R, which we refer to as the refinance rate. It also holds required reserves at the central bank, RR_t, and government bonds, B_t^B.

The bank's balance sheet is thus

$$L_t^F + B_t^B + RR_t = D_t + P_t^V V_t + L_t^B, \tag{25}$$

where

$$V_t = V_t^R + V_t^E, \tag{26}$$

with V_t^R denoting required capital and V_t^E excess capital. We assume in what follows that, due to prohibitive penalty or reputational costs, $V_t \geqslant V_t^R$ at all times. In fact, we will focus on the case where capital requirements are not strictly binding, that is, $V_t^E > 0$.[10]

Reserves held at the central bank do not pay interest. They are determined by:

$$RR_t = \mu D_t, \tag{27}$$

where $\mu \in (0,1)$ is the reserve requirement ratio.

Using (27), and given that L_t^F and D_t are determined by private agents' behavior, the balance sheet constraint (25) can be used to determine borrowing from the central bank:

$$L_t^B = L_t^F + B_t^B - (1-\mu)D_t - P_t^V V_t. \tag{28}$$

[9] For tractability, and in line with most of the DSGE literature, we do not explicitly account for the possibility that the risk of default may affect optimal price behavior.

[10] As documented in Pereira da Silva (2009), this is the more relevant case in practice.

The bank is also subject to risk-based capital requirements; by law, it must hold an amount of equity that covers at least a given percentage of its loans, exogenously set by the central bank (which also acts as the financial regulator, as noted earlier). Government bonds bear no risk and are subject to a zero weight in calculating capital requirements. The risk weight on loans to firms is σ_t^F :

$$P_t^V V_t^R = \rho \sigma_t^F L_t^F, \tag{29}$$

where $\rho \in (0,1)$ is the capital adequacy ratio. Under Basel I, σ_t^F is fixed at $\sigma_0^F \leqslant 1$; under Basel II, in a manner similar to Agénor and Pereira da Silva (2012b), we relate the risk weight to the repayment probability estimated by the bank, because it reflects its perception of default risk[11]:

$$\sigma_t^F = \left(\frac{q_t^F}{\tilde{q}^F}\right)^{-\phi_q}, \tag{30}$$

where $\phi_q > 0$ and $\tilde{q}^F$ is the steady-state value of q_t^F. In the steady state, the risk weight is therefore equal to unity.[12]

The bank sets both the deposit and lending rates, excess equity capital, and real holdings of government bonds, $b_t^B = B_t^B/P_t$, so as to maximize the present discounted value of its profits. Because the bank is liquidated and debt is redeemed at the end of each period, this maximization problem boils down to a static problem[13]:

$$i_t^D, i_t^L, b_t^B, \frac{V_t^E}{P_t} = \arg\max E_t\left(\frac{\Pi_{t+1}^B}{P_t}\right), \tag{31}$$

where expected profits at the end of period t (or beginning of $t+1$) are defined as

$$E_t\left(\frac{\Pi_{t+1}^B}{P_t}\right) = \left(1+i_t^B\right)b_t^B + q_t^F\left(1+i_t^L\right)\left(\frac{L_t^F}{P_t}\right) + (1-q_t^F)\kappa K_t + \mu d_t - \left(1+i_t^D\right)d_t - \left(1+i_t^R\right)\left(\frac{L_t^B}{P_t}\right) - \left(1+i_t^V\right)z_t V_t$$
$$- \gamma_B \frac{\left(b_t^B\right)^2}{2} - \gamma_V z_t V_t + 2\gamma_{VV} z_t \left(V_t^E\right)^{1/2}, \tag{32}$$

where $\kappa \in (0,1)$, γ_B, γ_V, $\gamma_{VV} > 0$, and $q_t^F \in (0,1)$ is the repayment probability of IGP firms, assumed identical across them. The second term in this expression on the right-hand side, $q_t^F\left(1+i_t^L\right)P_t^{-1}L_t^F$, represents repayment on loans if there is no default, which occurs with probability q_t^F. The third term represents what the bank earns in case of default (which occurs with probability $1-q_t^F$), that is, under limited liability, the "effective" value of collateral pledged by the borrower, κK_t. "Raw" collateral consists therefore of the physical assets of the firm and κ measures the degree of credit market imperfections.[14]

The fourth term, μd_t, represents the reserve requirements held at the central bank and returned to the bank at the end of the period (prior to its closure). The term $\left(1+i_t^D\right)d_t$ represents repayment of deposits (principal and interest) by the bank. The term $\left(1+i_t^V\right)z_t V_t$ represents the value of shares redeemed to the household and dividend payments. The term $\gamma_B\left(b_t^B\right)^2/2$ captures the cost associated with transacting in government bonds; for tractability, this cost is assumed to be quadratic.

The linear term $\gamma_V z_t V_t$ captures the cost associated with issuing shares (cost of underwriting, issuing brochures, etc.). By contrast, the last term, $2\gamma_{VV} z_t \left(V_t^E\right)^{1/2}$, captures the view that maintaining a positive capital buffer generates some benefits—it represents a signal that the bank's financial position is strong and reduces the intensity of regulatory scrutiny. This, in turn, reduces the pecuniary cost associated with the preparation of data and documents required by the supervision authority.[15] We assume that this effect on expected profits is concave, which implies that the benefits of capital buffers diminish over time.[16]

The maximization problem is subject, from (19) and (21), to the loan demand function for IGP firms

$$\frac{L_t^F}{P_t} = \int_0^1 \left(\frac{L_{jt}^F}{P_t}\right) dj = \Phi\left[\frac{\left(1+i_t^L\right)\omega_t}{r_t^K}; A_t\right], \tag{33}$$

---

[11] Appendix C provides a justification for this reduced-form, constant elasticity specification, based on actual Basel II formulas. See also Covas and Fujita (2010) and Darracq Pariès et al. (2010).

[12] The Standardized Approach in Basel II can be modeled by making the risk weight a function of the output gap, under the assumption that ratings are procyclical.

[13] In equilibrium, the lending rate is also the same across borrowers; we therefore economize on notation by using a lending that is independent of j.

[14] Note that although revenues depend on whether the borrower repays or not, payments of principal and interest to households and the central bank are *not* contingent on shocks occurring during period t and beyond and on firms defaulting or not. Note also that in case of default the bank can seize only collateral, P_tK_t (valued at the economy-wide price of the final good, P_t) not realized output (valued at the firm-specific intermediate price, P_{jt}). This is important because it implies that firm j, which takes P_t as given when setting its price, does not internalize the possibility of default.

[15] A related argument—in a stochastic environment—is provided in Ayuso et al. (2004), in which capital buffers reduce the probability of not complying with capital requirements.

[16] Because costs associated with issuing capital are modeled linearly, assuming that the benefit associated with capital buffers is quadratic would imply a profit-maximizing value of V_t^E equal to infinity. A more general specification would be to assume that the benefits associated with capital buffers have a convex-concave shape, but this is much less tractable numerically.

together with the balance sheet constraint (25), used to substitute out L_t^B in (32), the equation defining V_t (26), and the capital requirement constraint (29).

The bank internalizes the fact that the demand for loans (supply of deposits) depends negatively (positively) on the lending (deposit) rate, as implied by (9) and (33), and that changes in the level of loans affects capital requirements, as implied by (29). It also takes the repayment probability, the value of collateral, the contract enforcement cost, prices, and the refinance rate as given.

The first-order conditions for maximization yield:

$$-d_t - \left[\left(1+i_t^D\right) - \mu - (1-\mu)\left(1+i_t^R\right)\right]\left(\frac{\partial d_t}{\partial i_t^D}\right) = 0, \tag{34}$$

$$\frac{q_t^F L_t^F}{P_t} + \left\{q_t^F\left(1+i_t^L\right) - (1-\rho\sigma_t^F)\left(1+i_t^R\right) - \rho\sigma_t^F\left[\left(1+i_t^V\right)+\gamma_V\right]\right\}\frac{\partial \Phi}{\partial i_t^L} = 0, \tag{35}$$

$$\left(1+i_t^B\right) - \left(1+i_t^R\right) - \gamma_B b_t^B = 0, \tag{36}$$

$$\left(1+i_t^R\right) - \left\{\left(1+i_t^V\right) + \gamma_V - \frac{\gamma_{VV}}{\sqrt{V_t^E}}\right\} = 0. \tag{37}$$

Let $\eta_D = \left(\partial d_t/\partial i_t^D\right) i_t^D/d_t$ denote the constant interest elasticity of the supply of deposits by the household. Condition (34) yields

$$i_t^D = \left(1+\frac{1}{\eta_D}\right)^{-1}(1-\mu)i_t^R, \tag{38}$$

which shows that the equilibrium deposit rate is set as a markup over the refinance rate, adjusted (downward) for the implicit cost of holding reserve requirements.

Similarly, let $\eta_F = \left(\partial \Phi/\partial i_t^L\right) i_t^L/L_t^F$ denote the interest elasticity of the demand for loans. Using this definition, condition (35) yields

$$1+i_t^L = \frac{1}{(1+\eta_F^{-1})q_t^F}\left\{(1-\rho\sigma_t^F)\left(1+i_t^R\right) + \rho\sigma_t^F\left[\left(1+i_t^V\right)+\gamma_V\right]\right\}, \tag{39}$$

which implies that the gross lending rate depends negatively on the repayment probability, and positively on a weighted average of the marginal cost of borrowing from the central bank (at the gross rate $1+i_t^R$) and the total cost of issuing equity, which accounts for both the gross rate of return to be paid to investors and issuing costs. Weights on each component of funding costs are measured in terms of the share of equity in proportion of loans.

We adopt a quasi-reduced form, as in Cúrdia and Woodford (2010) for instance, to relate the repayment probability to three sets of factors. First, we relate q_t^F to borrowers' net worth; it increases with the effective collateral provided by firms, $\kappa P_t K_t$, and falls with the amount borrowed, L_t^F.[17] As argued by Boot et al. (1991), Bester (1994), and Hainz (2003), among others, by increasing borrowers' effort and reducing their incentives to take on excessive risk, collateral reduces moral hazard and raises the repayment probability.

Second, q_t^F depends on the cyclical position of the economy, as measured by $Y_t/\tilde{Y}$, with $\tilde{Y}$ denoting the steady-state value of final output. This term captures the view that in periods of high (low) levels of activity, profits and cash flows tend to improve (deteriorate) and incentives to default diminish (increase).[18] If net worth values are also procyclical, both of these effects are consistent with the large body of evidence suggesting that price-cost margins in banking are consistently countercyclical (see for instance Aliaga-Díaz and Olivero (2010)).

Third, q_t^F increases with the bank's capital relative to the outstanding amount of loans, $P_t^V V_t/L_t^F$, because bank capital (irrespective of whether it is required by regulation or chosen discretionarily) increases incentives for the bank to screen and monitor borrowers. In turn, greater monitoring mitigates the risk of default and induces lenders (if marginal monitoring costs are not prohibitive) to reduce the cost of borrowing.[19] As noted in the Introduction, this is consistent with the evidence in Hubbard et al. (2002), according to which well-capitalized banks tend to charge lower loan rates than banks with low capital, and the results in Coleman et al. (2002), in which capital-constrained banks charge higher spreads on their loans. This effect is

[17] In standard Stiglitz–Weiss fashion, the repayment probability could be made a decreasing function of the lending rate itself, as a result of adverse selection problems. In the present setting, however, borrowers are homogeneous.

[18] Note that the ability to recover real assets pledged as collateral may also fall (improve) in a cyclical downturn (upturn); this would make κ endogenous as well. We abstract from this channel here, given that it is somewhat tangential to our main argument.

[19] In Agénor and Pereira da Silva (2012a), the repayment probability is endogenously determined as part of the bank's optimization process. Specifically, they assume, following Allen et al. (2011), that the bank can affect the repayment probability on its loans by expending effort to select (*ex ante*) and monitor (*ex post*) its borrowers; the higher the effort, the safer the loan. Assuming that the cost of monitoring depends (inversely) not only on the collateral–investment loan ratio but also on the cyclical position of the economy and the capital–loan ratio yields a specification similar to (40). Alternatively, Mehran and Thakor (forthcoming) construct a dynamic model in which bank capital increases the future survival probability of the bank, which in turn enhances the bank's monitoring incentives. The "quasi reduced form" approach used here can be viewed as a tractable shortcut in a macro framework.

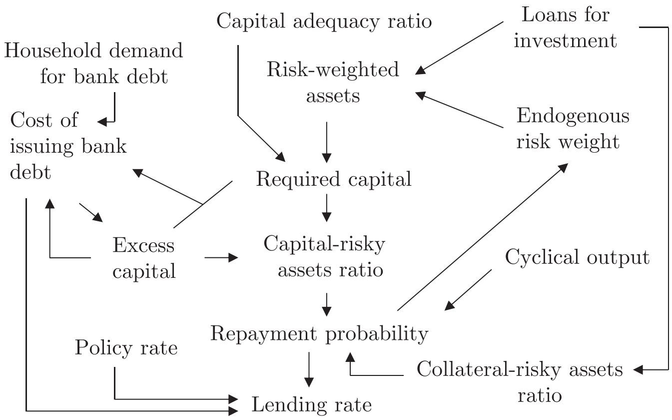


Fig. 1. Bank capital and lending rate determination.

also consistent with the evidence in Barth et al. (2004), based on cross-country regressions for 107 industrial and developing countries, which suggests that all else equal capital requirements are associated with a lower share of non-performing loans in total assets—a fact that could reflect better screening and monitoring of loan applicants.[20] Finally, the dependence of the repayment probability on the capital–loan ratio implies, through Eq. (39), that it is also negatively related with bank lending spreads; direct support for this link—while accounting for the possibility of reverse causality—is provided by Fonseca et al. (2010), in a study of pricing behavior by more than 2300 banks in 92 countries over the period 1990–2007. They also found a stronger relationship for developing countries; this is consistent with the view that, in these countries, a weak institutional environment (or the absence of a credible safety net) increases incentives for banks to screen and monitor borrowers when more of their capital is engaged.

The repayment probability is thus specified as

$$q_t^F = \varphi_0 \left(\frac{\kappa P_t K_t}{L_t^F} \right)^{\varphi_1} \left(\frac{P_t^V V_t}{L^F} \right)^{\varphi_2} \left(\frac{Y_t}{\tilde{Y}} \right)^{\varphi_3}, \tag{40}$$

with $\varphi_i > 0 \quad \forall i$.

The relationship between bank capital, the repayment probability, and the bank lending rate is summarized in Fig. 1. Combining (39) and (40) implies that an increase in bank capital (in proportion of outstanding loans), by improving incentives to monitor borrowers and reducing borrowers' default probability, lowers the lending rate.

From (36), the demand for bonds is

$$b_t^B = \gamma_B^{-1} \left(i_t^B - i_t^R \right), \tag{41}$$

which is increasing in the bond rate and decreasing in the marginal cost of funds.

Using Eqs. (26), (37) yields

$$V_t^E = \left\{ \frac{\gamma_{VV}}{i_t^V + \gamma_V - i_t^R} \right\}^2, \tag{42}$$

which shows that an increase in the cost of issuing equity (either through i_t^V or γ_V) reduces excess capital, whereas an increase in benefit (as measured by γ_{VV}) raises excess capital. Note that required capital, by affecting the cost of issuing equity, has an indirect effect on the capital buffer: an increase in V_t^R, by raising i_t^V will lower excess capital. In that sense, there is some degree of substitutability between required and excess capital.

From (42), (29), and (30), it can be seen that, a drop in aggregate output, due to a common negative productivity shock, affects the repayment probability and the lending rate through several channels. First, because the demand for labor (and thus the supply of bank loans) falls, the collateral–loan ratio rises initially; this tends to increase the repayment probability and to lower the lending rate. Second, the fall in cyclical output tends to lower the repayment probability and to raise the lending rate. These two (conflicting) effects operate in either regulatory regime. Third, although the bank capital–loan ratio does not change under a Basel I-type regime (given that the risk weight is fixed), it may either increase or fall under a Basel II-regime, because the risk weight is now directly related to the repayment probability—the initial response of which is

[20] Another rationale for a negative link between the capital–loan ratio and the repayment probability could result from the fact that investors, while increasing their holdings of bank debt, may exert pressure on the bank to increase profits. Given that the bank has a perfectly elastic supply of credit, the only way to do so is to stimulate the demand for loans by reducing the lending rate—and this can happen only if the repayment probability increases. However, in this interpretation, the negative link between these two variables would reflect *greater*risk taking and reckless lending, rather than improved monitoring.

ambiguous, due to the conflicting effects mentioned earlier. The net, general equilibrium effect on the repayment probability is thus also ambiguous in general—and so is the relationship between the degree of procyclicality of both regimes.

Suppose then that the cyclical output effect dominates the collateral–loan effect; the repayment probability falls and the lending rate tends to increase.[21] At the same time, the lower level of loans (which implies lower capital requirements) must be accompanied by a lower the rate of return on equity, to induce households to reduce their demand for that category of asset. In turn, the lower equity rate reduces the loan rate. As long as the risk effect (the drop in the repayment probability) is large enough compared to this cost effect, the Basel I-type regime mitigates the procyclicality inherent to the behavior of the repayment probability but does not reverse it.

However, under the Basel II-type regime, the initial fall in the repayment probability leads also to a higher risk weight and *larger* capital requirements—if actual capital can increase to reflect higher regulatory requirements (as implied by (42))—than under Basel I. As a result of the larger increase (or smaller reduction) in the supply of equity, the cost of issuing equity falls by less (or may even increase, if the effect of the higher risk weight dominates the drop in the amount of loans). This tends to *increase* the lending rate by more, thereby making the Basel II-type regime *more* procyclical. This is consistent with the view held by many observers. Thus, if we define procyclicality in terms of the behavior of the repayment probability—in a manner akin to Agénor and Pereira da Silva (2012b), who focus on the risk premium—we can summarize this result as follows[22]:

Result 1. *If the cyclical output effect dominates the collateral–loan effect on the repayment probability, and if the fall in that probability is sufficiently large, the Basel II-type regime magnifies the procyclicality inherent to the behavior of the credit market.*

However, in the model the higher capital–loan ratio also tends to *increase* the repayment probability; this will tend to mitigate the initial fall in that variable. If the sensitivity of the repayment probability to the capital–loan ratio (as measured by φ_2) is sufficiently high, this will tend to make the Basel II-type regime *less* procyclical than the Basel I-type regime. This fundamental ambiguity in the procyclical effects of the two regulatory regimes can be summarized as follows:

Result 2. *If there is no bank capital channel ($\varphi_2 = 0$), the Basel II-type regime is always more procyclical than the Basel I-type regime. If $\varphi_2 > 0$ and sufficiently large, the Basel II-type regime may be less procyclical than the Basel I-type regime.*

Finally, at the end of the period, as noted earlier, the bank pays interest on deposits, redeems equity shares, and repays with interest loans received from the central bank. There are no retained earnings; all profits are distributed to the household. in

2.5. Central bank

The central bank's assets consists of holdings of government bonds, B_t^C, and loans to the commercial bank, L_t^B, whereas its liabilities consists of currency supplied to households and firms, M_t^s, and required reserves RR_t; the latter two make up the monetary base. The balance sheet of the central bank is thus given by

$$B_t^C + L_t^B = M_t^s + RR_t. \tag{43}$$

Using (27), (43) yields

$$M_t^s = B_t^C + L_t^B - \mu D_t. \tag{44}$$

Any income made by the central bank from loans to the commercial bank is transferred to the government at the end of each period.

Monetary policy is operated by fixing the refinance rate, i_t^R, and providing liquidity (at the discretion of the bank) through a standing facility.[23] The refinance rate itself is determined by a Taylor-type policy rule:

$$i_t^R = \chi i_{t-1}^R + (1-\chi)\left[\tilde{r} + \pi_t + \varepsilon_1(\pi_t - \pi^T) + \varepsilon_2 \ln\left(\frac{Y_t}{\overline{Y}_t}\right)\right], \tag{45}$$

where $\tilde{r}$ is the steady-state value of the real interest rate on bonds, $\pi^T \geqslant 0$ the central bank's inflation target, and $Y_t/\overline{Y}_t$ is the output gap, with $\overline{Y}_t$ denoting the frictionless level of aggregate output (that is, corresponding to $\theta = 0$). Coefficient $\chi \in (0,1)$ measures the degree of interest rate smoothing, and $\varepsilon_1, \varepsilon_2 > 0$ the relative weights on inflation deviations from target and the output gap, respectively.

[21] The financial system is thus procyclical. This is consistent with what is typically observed in a recession.

[22] In the numerical simulations that we report next, procyclicality could be defined equivalently in terms of the behavior of the lending rate or aggregate output; relative rankings of the two regimes are the same in response to the shocks that we consider.

[23] In several middle-income countries, as in many industrial countries, the standard mechanism through which the central bank injects liquidity is through open-market operations of various kinds, aimed at providing sufficient cash *on average* to maintain the short-term policy interest rate at its target level. Above and beyond that, banks still short of cash can obtain additional funds at the upper band of a corridor, the discount window, or a standing facility (typically slightly above the policy rate). Conversely, banks with excess cash can deposit it at the central bank (at a rate typically below the policy rate). Our specification abstracts from open-market operations and corresponds to a "channel system" in which deposits held at the central bank earn a zero interest rate (see Berentsen and Monnet, 2007).

2.6. Government

The government purchases the final good and issues nominal riskless one-period bonds, which are held by all other agents in the economy. Its budget constraint is given by

$$B_t = \left(1 + i^B_{t-1}\right)B_{t-1} + P_t(G_t - T_t) - i^R_{t-1}L^B_{t-1} - i^B_{t-1}B^C_{t-1}, \tag{46}$$

where $B_t = B^B_t + B^C_t + B^H_t$ is the outstanding stock of government bonds, B_{t+1} bonds issued at the end of period $t + 1$, G_t real government spending, and T_t real lump-sum tax revenues. The final terms, $i^R_{t-1}L^B_{t-1}$ and $i^B_{t-1}B^C_{t-1}$, come from our assumption that all interest income that the central bank makes (from its lending to the commercial bank and its holdings of government bonds) is transferred to the government at the end of each period.

Government purchases are assumed to be a constant fraction of output of final goods:

$$G_t = \psi Y_t, \tag{47}$$

where $\psi_t \in (0,1)$.

3. Symmetric equilibrium

In what follows we will assume that the government equilibrates its budget by adjusting lump-sum taxes, while keeping the overall stock of bonds constant at $\bar{B}$, and that the central bank also keeps its stock of bonds constant at $\bar{B}^C$. Private holdings of government bonds are thus equal to $B^H_t = \bar{B} - \bar{B}^C - B^B_t$.

In a symmetric equilibrium, all firms producing intermediate goods are identical. Thus, $K_{jt} = K_t$, $N_{jt} = N_t$, $Y_{jt} = Y_t$, $P_{jt} = P_t$, for all $j \in (0,1)$. All firms also produce the same output, and prices are the same across firms. In the steady state, inflation is constant at $\tilde{\pi}$.

Equilibrium conditions must also be satisfied for the credit, deposit, goods, and cash markets.[24] Because the supply of loans by the bank, and the supply of deposits by households, are perfectly elastic at the prevailing interest rates, the markets for loans and deposits clear through quantity adjustment. For equilibrium in the goods markets we require production to be equal to aggregate demand, that is, using (20),[25]

$$Y_t = C_t + G_t + I_t + \frac{\phi_F}{2}\left(\frac{1+\pi_t}{1+\tilde{\pi}} - 1\right)^2 Y_t. \tag{48}$$

Eq. (5) can be rewritten as

$$I_t = K_{t+1} - (1-\delta)K_t + \Gamma(K_{t+1}, K_t). \tag{49}$$

Combining (47)–(49), the aggregate resource constraint then takes the form

$$\left\{1 - \psi - \frac{\phi_F}{2}\left(\frac{1+\pi_t}{1+\tilde{\pi}} - 1\right)^2\right\}Y_t = C_t + K_{t+1} - (1-\delta)K_t + \Gamma(K_{t+1}, K_t). \tag{50}$$

Suppose that bank loans to firms are made only in the form of cash.[26] The equilibrium condition of the market for cash is given by

$$M^s_t = M^H_t + L^F_t.$$

Given (44), this condition becomes

$$L^B_t + B^C_t - \mu D_t = M^H_t + L^F_t.$$

Using (25) to eliminate L^B_t in the above expression yields

$$M^H_t + D_t = \bar{B}^C + B^B_t - P^V_t V_t. \tag{51}$$

Using (8) and (9) and aggregating, condition (51) becomes

$$\frac{\bar{B}^C + B^B_t}{P_t} - z_t V_t = \eta_x (C_t)^{1/\varsigma}\left(1 + i^B_t\right)\left\{\frac{\nu}{i^B_t} + \frac{(1-\nu)}{i^B_t - i^D_t}\right\}, \tag{52}$$

which can be solved for i^B_t.

As noted earlier, the household's portfolio allocation decisions for period $t + 1$ are taken at the end of period t. Bank equity is thus priced so that its net return at $t + 1$ equals its expected return at t for $t + 1$, which consists—given that there are no

[24] By Walras' Law, the equilibrium condition of the market for government bonds can be eliminated.

[25] The transactions costs appearing in (4) and (32) are assumed to be purely financial in nature; and in equilibrium, there is no actual default. There are therefore no real costs associated with household portfolio decisions or banking activity.

[26] Recall that firms hold cash only to pay wages at the beginning of the production process. As discussed by Agénor and Alper (forthcoming), condition (51) would not change if instead the counterpart to loans consists of deposits.

capital gains, the bank lasting only one period—of expected bank profits (which are distributed as cash dividends at the end of the period) per share:

$$i_t^V = \frac{E_t \Pi_{t+1}^B}{P_t^V V_t}. \tag{53}$$

Finally, the equilibrium condition of the bank equity market is obtained by equating (13) and (42):

$$V_t^d = V_t^R + V_t^E. \tag{54}$$

4. Steady state and log-linearization

The steady-state of the model is derived in Appendix A. With a zero inflation target $\pi^T = 0$, the steady-state inflation rate is also $\tilde{\pi} = 0$. In addition to standard results (the steady-state value of the marginal cost, for instance, is given by $(\theta - 1)/\theta$), the steady-state value of the repayment probability is

$$\tilde{q}^F = \varphi_0 \left(\frac{\kappa \widetilde{P} \widetilde{K}}{\widetilde{L}^F} \right)^{\varphi_1} \left(\frac{\widetilde{P} \widetilde{V}}{\widetilde{L}^F} \right)^{\varphi_2},$$

whereas steady-state interest rates are given by

$$\tilde{\imath}^B = \tilde{\imath}^R = \beta^{-1} - 1 = \tilde{r},$$
$$\tilde{\imath}^D = \left(1 + 1\eta_D^{-1}\right)^{-1} (1 - \mu) \tilde{\imath}^R < \tilde{\imath}^R,$$
$$\tilde{\imath}^V = \beta^{-1} \Theta_V \widetilde{V} + \beta^{-1} - 1 > \tilde{\imath}^B,$$
$$\tilde{r}^K = \beta^{-1} - 1 + \delta,$$

and

$$\tilde{\imath}^L = \frac{1}{(1 + \eta_F^{-1}) \tilde{q}^F} \left\{ (1 - \rho) \beta^{-1} + \rho \left[(1 + \tilde{\imath}^V) + \gamma_V \right] \right\} - 1.$$

From these equations it can be shown that $\tilde{\imath}^B > \tilde{\imath}^D$. The reason why $\tilde{\imath}^V > \tilde{\imath}^B$ is because holding equity is subject to a cost; from the perspective of the household, the rate of return on equity must therefore compensate for that and exceed the rate of return on government bonds or physical capital. Of course, when $\Theta_V = 0,\ \tilde{\imath}^V = \tilde{\imath}^B$.[27] In addition, from (41), the steady-state stock of bonds held by the bank is zero, given that $\tilde{\imath}^B = \tilde{\imath}^R$. Equation (42) determines $\widetilde{V}^E$. Because $\tilde{\imath}^V > \tilde{\imath}^R,\ \widetilde{V}^E > 0$, given that $\gamma_{VV} > 0$. By implication of (30), $\tilde{\sigma}^F = 1$ under both Basel I (by assumption) and Basel II. This is a convenient normalization to compare dynamic paths across regulatory regimes.

To analyze how the economy responds to shocks we proceed in standard fashion by log-linearizing it around a nonstochastic, zero-inflation steady state. The log-linearized equations are summarized in Appendix B. In particular, log-linearizing condition (23) yields the familiar form of the New Keynesian Phillips curve (see, for instance, Galí, 2008):

$$\pi_t = \left(\frac{\theta - 1}{\phi_F} \right) \widehat{mc}_t + \beta E_t \pi_{t+1},$$

where $\widehat{mc}_t$ is the log-deviation of mc_t from its steady-state level, given by

$$\widehat{mc}_t = (1 - \alpha)\left(\hat{\imath}_t^L + \hat{\omega}_t\right) + \left(\frac{\alpha + \alpha\beta\delta}{1 + \beta\delta - \beta} \right) \hat{r}_t^K,$$

where $\hat{\imath}_t^L$ and $\hat{r}_t^K$ denote percentage point deviations of the lending rate and the rate of return of physical capital from their steady-state levels, and $\hat{\omega}_t$ the log-deviation of the real wage from its steady-state value. Because changes in bank capital affect the repayment probability and the lending rate, they will also affect the behavior of real marginal costs.

5. Illustrative calibration

To illustrate the properties of the model, we provide an illustrative (but fairly representative) calibration for a middle-income country. To do so we dwell as much as possible on Agénor and Alper (forthcoming). We therefore refer to that study for a detailed discussion of some of our choices and focus here on the parameters that are new to this study or critical for the issue at stake, such as the elasticity of the repayment probability with respect to bank capital.

[27] Thus, the arbitrage condition in Aguiar and Drumond (2007) between the rates of return on equity and physical capital holds only when $\Theta_V = 0$.

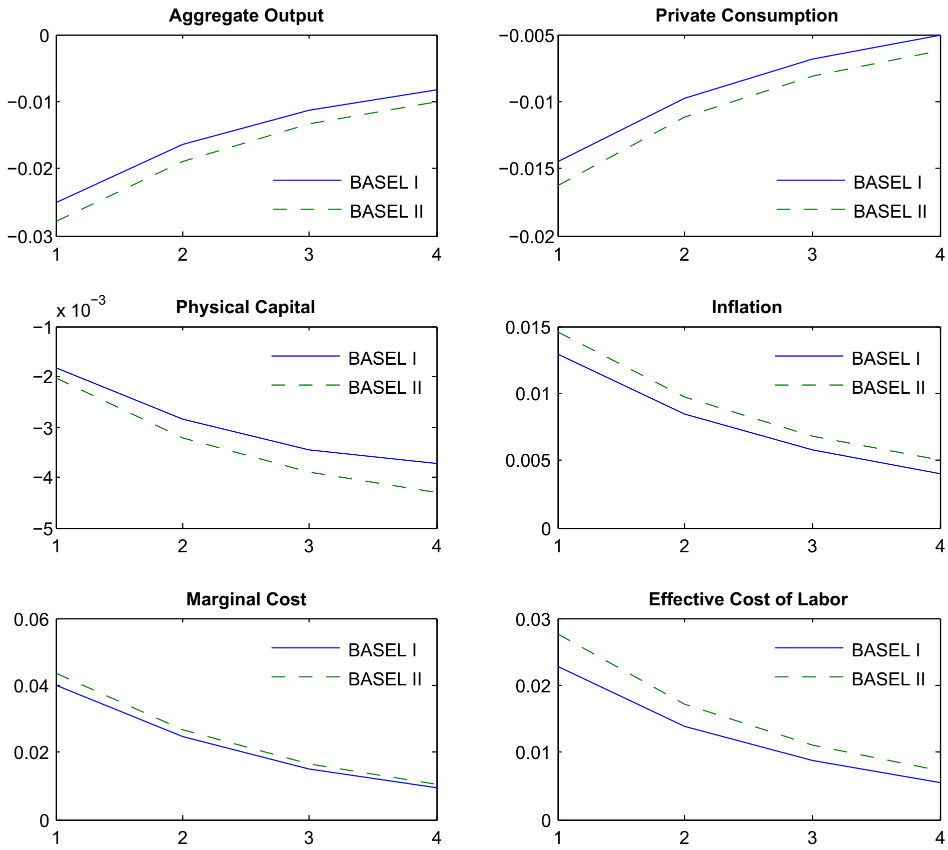
Parameter values are summarized in Table 1. The discount factor β is set at 0.95, which corresponds to an annual real interest rate of 5%. The intertemporal elasticity of substitution, ς, is 0.6, in line with estimates for middle-income countries (see Agénor and Montiel, 2008). The preference parameters for leisure, η_N, and for composite monetary assets, η_x, are both set at the first parameter is close to values used in many existing studies (see for instance Atta-Mensah and Dib, 2008). The share parameter in the index of money holdings, ν, which corresponds to the relative share of cash in narrow money, is set at 0.2. The combination of the values of η_x and ν gives a steady-state value of the ratio of cash and deposits to GDP ratio of the order of 70%, which is consistent with existing data for a large range of middle-income countries. The adjustment cost parameter for equity holdings, Θ_V, is set at 0.3, whereas the adjustment cost parameter for investment, Θ_K, is set at 8.6, as in Atta-Mensah and Dib (2008). The first parameter is chosen so as to deliver a ratio of bank capital to GDP that is relatively low, consistent with the evidence. The share of capital in output of intermediate goods, $1-\alpha$, is set at 0.35, whereas the elasticity of demand for intermediate goods, θ, is set at 10. Both values are close to the values used by Medina and Soto (2007) for Chile. The value of θ gives a steady-state estimate of the markup rate, $\theta/(\theta-1)$, equal to 11.1%. The adjustment cost parameter for prices, ϕ_F, is set at 74.5, which is the average of the values used by Ireland (2001). The rate of depreciation of capital is set at 0.033, a value slightly higher than those commonly used in the literature, to reflect poorer quality of infrastructure in middle-income countries. The share of government spending in output, ψ, is set at 20%, a value consistent with the evidence for a number of middle-income countries, such as South Africa (see Liu and Seeiso, 2011) and Mexico, where the ratio of general government expenditure as a share of GDP was about 24% in 2011.

The reserve requirement rate μ is set at 0.1, which is consistent with the data reported by Montoro and Moreno (2011) for some countries in Latin America. The coefficient of the lagged value of the policy rate in the Taylor rule, χ, is set to 0, which therefore implies that we abstract from persistence stemming directly from the central bank's policy response. We also set ε_1 = 1.5 and ε_2 = 0.2, which are conventional values for Taylor-type rules for middle-income countries. The relatively low value of ε_2 (compared to estimates for industrial countries, which are closer to 0.5) is consistent with the evidence reported by Medina and Soto (2007) for Chile, Cebi (2011) for Turkey, and by Moura and Carvalho (2010) for a group of Latin American countries. For the degree of persistence of the supply shock, we assume that ρ_A = 0.6, with standard deviation $\sigma_{\xi^A} = 0.02$. Thus, we consider a shock that is only mildly persistent.

For the parameters characterizing bank behavior, we assume that the effective collateral–loan ratio, κ, is 0.2. This is somewhat lower than the value of 0.31 used in Cavalcanti (2010) for instance, but consistent with the evidence suggesting that due to weak legal systems seizing collateral is difficult in most developing countries (see Agénor and Pereira da Silva, 2010). The elasticity of the repayment probability with respect to collateral is set at φ_1 = 0.05, with respect to the bank capital–loan ratio at φ_2 = 0.0, and with respect to cyclical output at φ_3 = 0.2. The value of the parameter φ_1 is close to the elasticity of the

Table 1
Calibrated parameter values.

Parameter	Value	Description
Household		
β	0.95	Discount factor
ς	0.6	Elasticity of intertemporal substitution
η_N	1.5	Relative preference for leisure
η_x	1.5	Relative preference for money holdings
ν	0.2	Share parameter in index of money holdings
Θ_V	0.3	Adjustment cost parameter, equity holdings
Θ_K	8.6	Adjustment cost parameter, investment
Production		
θ	10.0	Elasticity of demand, intermediate goods
α	0.65	Share of labor in output, intermediate good
ϕ_F	74.5	Adjustment cost parameter, prices
δ	0.06	Depreciation rate of physical capital
Bank		
κ	0.2	Effective collateral–loan ratio
φ_1	0.05	Elasticity of repayment prob wrt collateral–loan ratio
φ_2	0.0, 0.2	Elasticity of repayment prob wrt capital–loan ratio
φ_3	0.2	Elasticity of repayment prob wrt cyclical output
φ_q	0.05	Elasticity of the risk weight wrt repayment prob
γ_B	0.05	Cost of adjustment, bond holdings
γ_V	0.1	Cost of issuing bank capital
γ_{VV}	0.001	Benefit of holding excess bank capital
ρ	0.08	Capital adequacy ratio
Central bank		
μ	0.1	Reserve requirement rate
χ	0.0	Degree of persistence in interest rate rule
ε_1	1.5	Response of refinance rate to inflation deviations
ε_2	0.5	Response of refinance rate to output growth
Shock		
ρ^A,σ_A	0.6, 0.02	Persistence/standard dev., productivity shock



Note: Interest rates, inflation rate and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. All other variables are measured in percentage deviations.

Fig. 2. Negative productivity shock. Basel II more procyclical than Basel I (deviations from steady state).

external finance premium—the inverse of the repayment probability here—to leverage used by Liu and Seeiso (2011) for South Africa. In the case of φ_2, we also consider an alternative value of 0.2, which is within the two-standard error confidence interval for the elasticity of the bank loan spread with respect to the capital–risky assets ratio estimated by Fonseca et al. (2010) for developing countries. These two different values allow us to explore the extent to which procyclical effects differ across regulatory regimes. The elasticity of the risk weight under Basel II with respect to the repayment probability is set at a relatively low value, $\varphi_q = 0.05$, consistent with studies like Covas and Fujita (2010).[28] The cost parameters γ_B and γ_V are also set at relatively low values, 0.05 and 0.1, respectively. The capital adequacy ratio, ρ, is set at 0.08, which corresponds to the target value for Basel I and the floor value for Basel II. As noted earlier, the steady-state value of the risk weight σ_t^F is specified in such a way that it is equal to unity under both regimes. For Basel I, given that the risk weight is constant, this choice also implies that it remains continuously equal to unity. By implication, the steady-state required capital–loan ratio is 8% under both regimes. Finally, the "benefit" parameter γ_{VV} is set at 0.001, to ensure that the steady-state excess capital–loan ratio is about 4%, in line with the evidence reported by Pereira da Silva (2009) and Fonseca et al. (2010).

This calibration implies that the steady-state values of the refinance rate (which is equal to the bond rate here), the deposit rate, the loan rate, and the rate of return on bank capital, are 4.2%, 3.8%, 8.7%, and 5.9%, respectively. Thus, the steady-state inequalities highlighted in the previous section are all satisfied. In addition, the loan rate is higher than the bond rate, indicating that the bank has no incentive to hold only government paper as assets. The steady-state value of the repayment probability is 0.967; equivalently, the default probability is 3.3%. The steady-state ratio of consumption to output is about 61%, whereas the ratio of investment to output is 18.6%. These values are well within the range observed for middle-income countries. In Liu and Seeiso (2011) for instance, these two ratios are 58% and 16%, respectively, for South Africa. The steady-state value of the collateral–loan ratio is 1.15 (with $\kappa = 0.2$), whereas the ratio of loans to bank capital is 7.8. We therefore consider an economy where, to begin with, the degree of leverage of the financial system is relatively moderate.

[28] A high value of φ_q would actually strengthen the counterintuitive results that we report later.

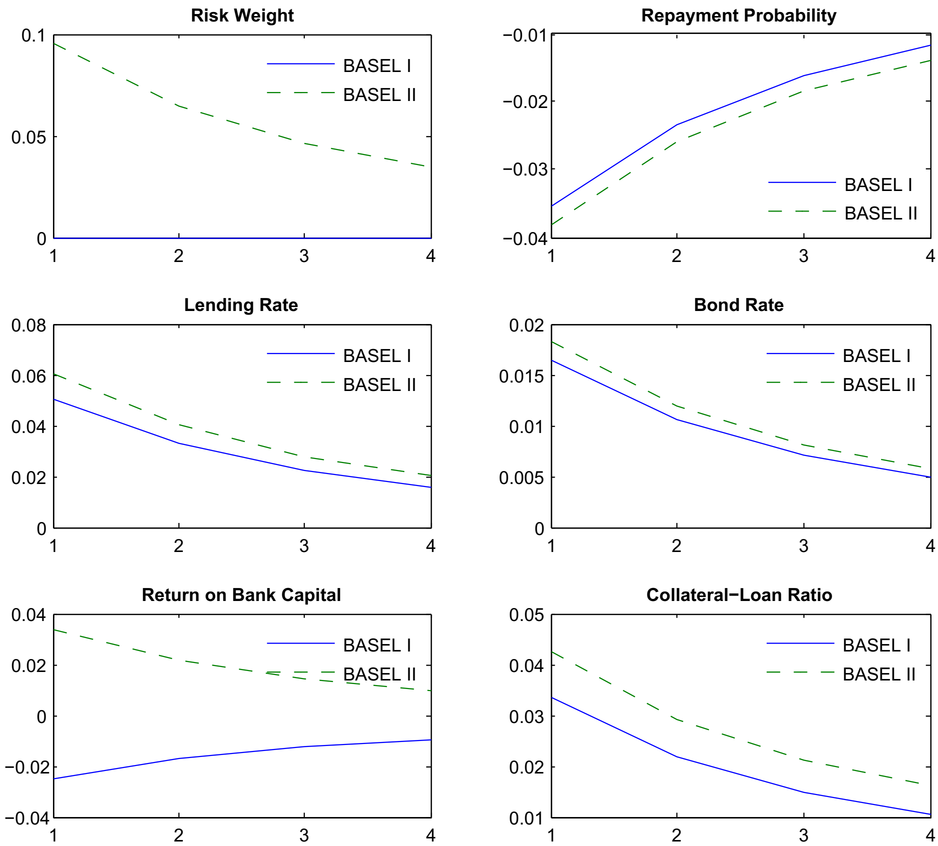


Fig. 2 (*continued*)

6. Procyclical effects of regulatory regimes

We now consider the procyclical effects—as measured by the behavior of the repayment probability—of a negative productivity (or supply) shock. We report results for two different values of the elasticity of the repayment probability with respect to the capital–loan ratio, $\varphi_2 = 0.0$ and $\varphi_2 = 0.2$. As is made clear below, this parameter change by itself is sufficient to allow us to illustrate the ambiguity in the procyclical effects of the two regulatory regimes.

Figs. 2 and 3 show the impulse response functions of some of the main variables of the model following a temporary, one percentage point negative shock to productivity. The results show indeed that two different outcomes may occur, depending on the elasticity of the repayment probability with respect to the capital–loan ratio, φ_2. In both figures, the behavior of most of the variables (except for marginal costs) does not differ much across regimes. This is because of the negative relation between the capital buffer and required capital, as implied by (42); as a result, total capital under the two regimes is more closely related.[29]

The direct effect of the shock is to lower temporarily the rate of return on physical capital, which reduces investment and tends to reduce marginal production costs. However, because the increase in borrowing costs (as discussed next) dominates, real marginal costs go up, thereby raising inflation.[30] The policy rate, which is determined by a Taylor rule, rises in response to the increase in inflation. By and large, other interest rates in the economy tend to follow the rise in the policy rate.[31] In particular, the bond rate increases because the rise in the deposit rate (which follows directly from the increase in the policy rate) raises household demand for these assets, reduces borrowing from the central bank and the supply of currency, which in turn requires a fall in the demand for cash—and thus an increase in the bond rate. The expected real bond rate rises as well and induces

[29] However, by changing the parameters by more, we could magnify differences across regimes.

[30] Note that, with our cost-of-price-adjustment assumption, IGP firms are actually free to reset nominal prices every period, in contrast to Calvo-style specification of price stickiness.

[31] By itself, the reduction in the demand for loans and capital requirements puts downward pressure on the rate of return on equity. However, given that the bond rate increases quite significantly, the rate of return on equity ends up increasing to mitigate the drop in the demand for equity. Note also that if the cost of issuing equity γ_V is procyclical rather than constant (as may be the case in practice), the increase in the rate of return on equity would be magnified.

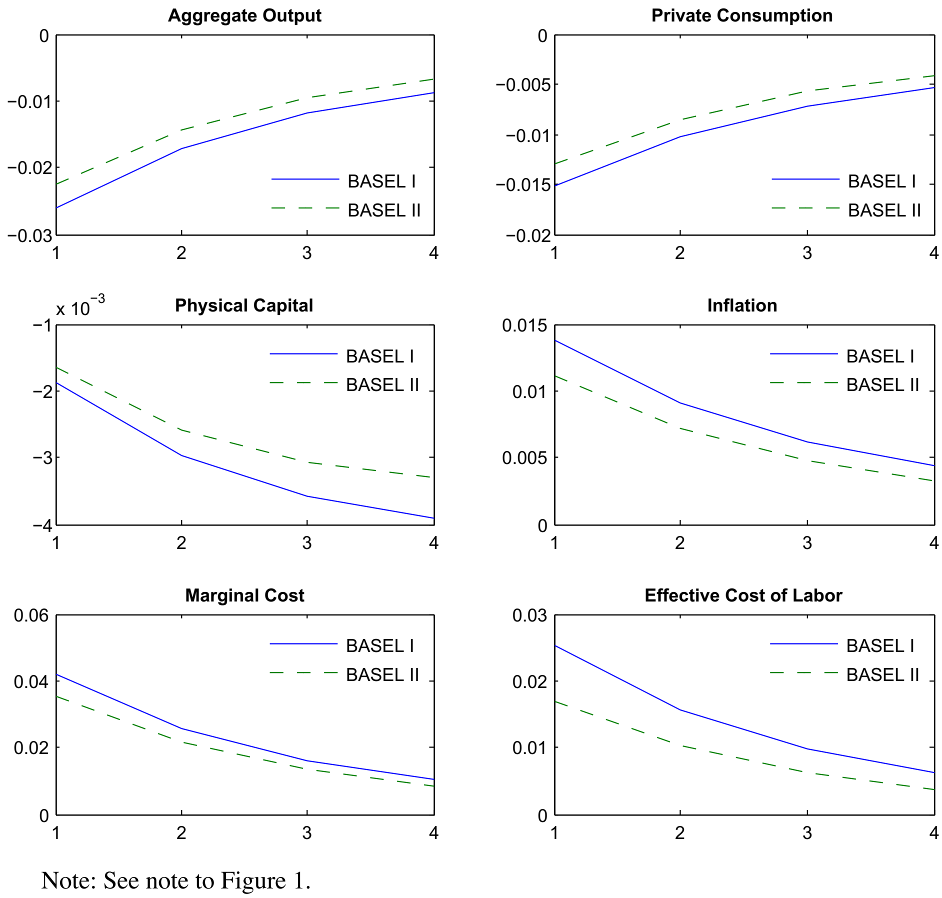


Fig. 3. Negative productivity shock. Basel II less procyclical than Basel I (deviations from steady state).

intertemporal substitution in consumption toward the future, which translates into a drop in current household expenditure.[32] Because government spending is a fixed proportion of output, it falls immediately in response to the adverse shock to aggregate supply. The net effect on aggregate demand is thus negative as well.

The initial drop in output (relative to its steady-state value) tends to lower the repayment probability, whereas the initial increase in the collateral–loan ratio (due to the reduction in the real demand for loans) tends to raise it. The net effect of these two channels is therefore ambiguous in general; given our calibration, the first effect dominates and the repayment probability falls (as one often observe in a recession), thereby raising the loan rate and marginal costs.[33] The rise in the loan rate, by increasing the effective cost of labor, tends to further depress production.

However, there is also a third effect, which operates through the bank capital–loan ratio and depends on the regulatory regime. Under Basel I, the bank capital–loan ratio does not change by much, because excess capital changes very little (given our calibration) and, by definition, the risk weight σ^F is constant. There is therefore a negligible indirect effect on the repayment probability under this regime. By contrast, under Basel II, the initial drop in the repayment probability raises the risk weight and therefore actual and required capital. Because credit falls, the bank capital–loan ratio rises unambiguously, which implies an *upward* effect on the repayment probability, thereby mitigating the initial downward effect under that regime. The net effect is thus ambiguous in general and depends on the value of φ_2. In Fig. 2, which corresponds to $\varphi_2 = 0.0$, the shock leads to the conventional case where Basel II is more procyclical than Basel I, whereas in Fig. 3, which corresponds to $\varphi_2 = 0.2$, the opposite occurs. Thus, Basel II can be *less* procyclical than Basel

[32] The fall in consumption, which lowers the demand for currency, helps to mitigate the initial increase in the bond rate.

[33] Note that if the price of capital was explicitly accounted for, and if the physical capital stock was valued at that price (instead of the price of the final good), then the collateral effect could actually amplify the initial effects of a negative productivity shock. In the present case, the effect of the collateral–loan ratio, as indicated earlier, is to raise the repayment probability, as a result of a drop in the real value of loans and a constant physical stock of capital on impact. If a negative productivity shock induces a larger drop in the price of capital than in the price of final goods, the fall in the value of collateral implies that the increase in the collateral–loan ratio would be less significant. This, in turn, would tend to mitigate the increase in the repayment probability. As a result, the negative effect on that probability associated with the drop in output (relative to its steady-state value) would indeed be magnified.

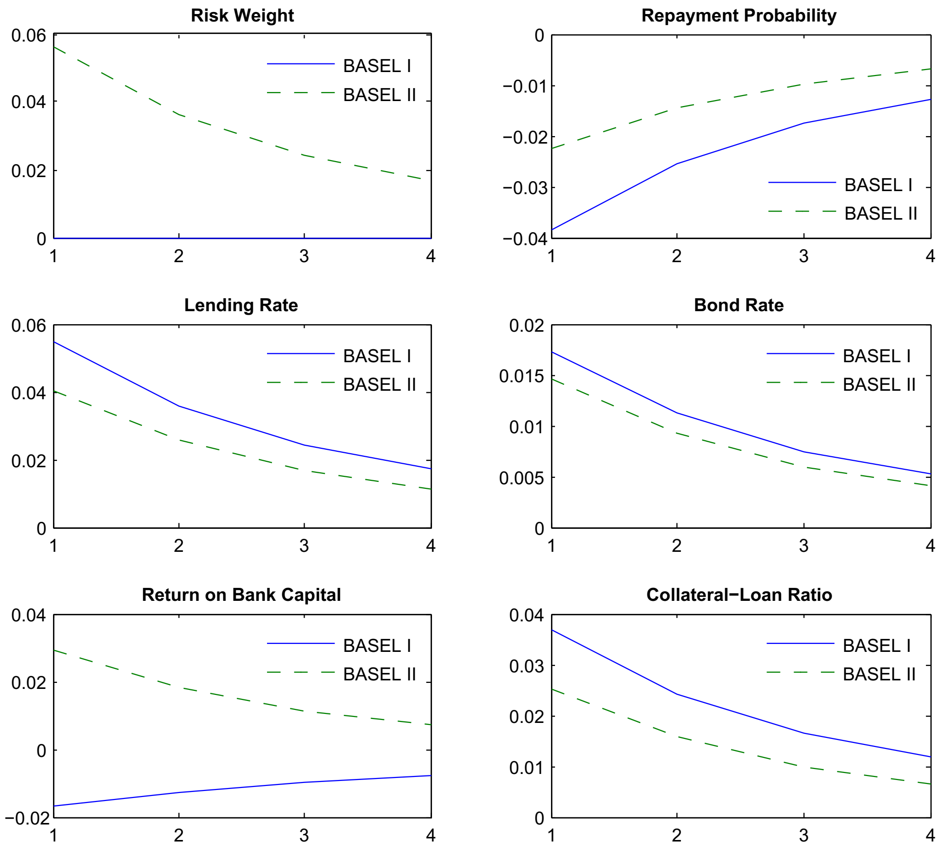


Fig. 3 (*continued*)

I—in the sense that the drop in the repayment probability, the increase in the lending rate, and the fall in output, are all of a smaller magnitude.

7. Summary and extensions

In this paper the business cycle effects of bank capital requirements were examined in a New Keynesian model with credit market imperfections, a cost channel of monetary policy, and a perfectly elastic supply of liquidity by the central bank at the prevailing policy rate. In the model, which combines elements developed in Agénor and Alper (forthcoming) and Agénor and Pereira da Silva (2012b), Basel I- and Basel II-type regulatory regimes are defined. In the latter case, the risk weight is related directly to the repayment probability that is embedded in the loan rate that the bank imposes on borrowers. A bank capital channel is introduced by assuming that higher levels of capital (relative to the amount of loans) induce banks to screen and monitor borrowers more carefully, thereby reducing the risk of default and increasing the repayment probability. An illustrative calibration for a middle-income country is provided. Numerical simulations of a negative productivity shock show that, in the absence of the bank capital channel, a Basel II-type regime is always more procyclical than a Basel I-type regime, as in the conventional, partial equilibrium view. By contrast, if the elasticity of the repayment probability to the bank capital–loan ratio is sufficiently high, the Basel II-type regime may be *less* procyclical. The key reason is that, following a negative supply shock, the bank capital channel mitigates the drop in the repayment probability, due to the monitoring incentive effect.

The analysis in this paper can be extended in a variety of directions. First, the assumption that the bank lasts only one period allowed us to avoid any distinction between stocks and flows in the dynamics of bank capital. A useful extension would be to consider an explicit link between (flow) dividends and banks' net worth. This would enrich the dynamics of the model, because changes in banks' net worth would affect price-setting behavior and the real economy.

Second, the analysis could be extended to consider a variety of additional financial shocks, as in Covas and Fujita (2010), Darracq Pariès et al. (2010), Gerali et al. (2010), and Liu and Seeiso (2011) for instance, such as a net worth shock, an increase in the minimum capital requirement, and bank capital losses. These experiments will help to assess the importance of financial shocks in macroeconomic fluctuations, and the role of bank regulatory capital regimes in the transmission process of these shocks.

Third, another useful extension would be to analyze the performance of regulatory capital regimes in an open economy. The experience of several middle-income countries during the past few years has shown that the ability of policymakers to respond to the risk of macroeconomic and financial instability created by severe external shocks through monetary policy is limited, because changes in domestic interest rates may have large effects on international capital flows. Although foreign exchange market intervention and capital controls have had some success, much recent thinking has focused on the role of macroprudential regulation (especially countercyclical capital requirements) in mitigating the impact of these shocks.

Fourth, by adding an objective of financial stability in the central bank's loss function (or by adding explicitly a regulator with the same objective), the model could be used to examine several recent policy proposals aimed at strengthening the financial system and at encouraging more prudent lending behavior in upturns. Indeed, several observers have argued that by raising capital requirements in a countercyclical way, regulators could help to choke off asset price bubbles—such as the one that developed in the US housing market—before the party really gets out of hand. Counter-cyclical bank provisions have already been used for some time in countries such as Spain and Portugal. The Spanish system, for instance, requires higher provisions when credit grows more than the historical average, thus linking provisioning to the credit and business cycle. This discourages (although it does not eliminate) excessive lending in booms while strengthening banks for bad times. On November 12, 2010, G20 leaders adopted BCBS's proposal to implement a countercyclical capital buffer ranging from 0% to 2.5% of risk-weighted assets, as part of the new Basel III framework. However, there are several potential problems with this type of rules. For instance, the introduction of counter-cyclical provisions in Spain was facilitated by the fact that the design of accounting rules falls under the authority of the Central Bank of Spain. But accounting rules in many other countries do not readily accept the concept of *expected* losses, on which the Spanish system is based, preferring instead to focus on *actual* losses—information that is more relevant for short-term investors. This raises therefore the question of redesigning accounting principles in ways that balance the short-term needs of investors with those of individual-bank and systemic banking-sector stability.

From the perspective of the appropriate design of countercyclical bank capital requirements rules, however, a pressing task may be to evaluate carefully their implications for economic stability and welfare. Zhu (2008) is one of the few contributions that focuses on this issue, but he does so in a setting that is more appropriate for industrial economies. In the context of middle-income countries, where credit (as is the case here) plays a critical role in financing short-term economic activity, an across-the-board rule could entail significant welfare costs. At the same time, of course, to the extent that they succeed in reducing financial volatility, and the risk of full-blown crises, they may also improve stability and enhance welfare. In another contribution (Agénor et al., 2011), we have extended the existing model to account explicitly for both macroeconomic and financial stability in an analysis of the net benefits of countercyclical bank capital rules, as proposed in the new Basel III framework. In that paper, the issue of combining countercyclical bank regulation and monetary policy, as well as possible trade-offs between these policies, are also explored.

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