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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. Key features of the model are that bank capital increases incentives for banks to monitor borrowers, thereby reducing the probability of default, 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 supply and demand shocks show that, depending on the elasticity that relates the repayment probability to the capital-loan ratio, a Basel II-type regime may be less procyclical than a Basel I-type regime.

This paper—a product of the Operations & Strategy, Development Economics Vice Presidency—is part of a larger effort in the department to investigate regulatory reforms in the financial sector after the crisis. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at pierre-richard.agenor@manchester.ac.uk and Lpereiradasilva@worldbank.org.

Capital Requirements and Business Cycles with Credit Market Imperfections

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Contents

1 Introduction

The role of the bank regulatory capital regime in the propagation of business cycles has been the subject of much scrutiny since the introduction of the Basel I regime 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 U.S. 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.

In a recent contribution, Agénor and Pereira da Silva (2009) argued that much of the analytical and empirical work devoted to the analysis of cyclicality of regulatory capital regimes focuses largely on industrialized countries and therefore does not account for the type of financial market imperfections that middle-income developing countries 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 absence of financial safety nets, and a high degree of exposure and vulnerability to domestic and external shocks. In such an environment, capital buffers may play an important role by helping banks convey a signal to depositors regarding their commitment to screening and monitoring their borrowers; they may therefore raise deposits at a lower cost. This analysis shares some similarities with Meh and Moran (2008), 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. As a result, higher bank capital increases the ability to raise loanable funds and facilitates bank lending. As shown by Agénor and Pereira da Silva (2009), 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 (2009) 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 (2009). An appealing feature of that framework is its explicit focus on the type of distortions (as described 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.[1] Because borrowers' ability to repay is uncertain, banks issue only collateralized loans to reduce incentives to default and mitigate moral hazard problems; they therefore incorporate a risk premium (which depends on the borrower's net worth and cyclical factors) in lending rates. At the prevailing lending 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. 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.

Banks are also subject to risk-based capital requirements; in order to compare Basel I-type 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.[2] We also assume that holding capital in excess of regulatory capital generates some benefits—it represents a signal that the bank's financial position is strong, and reduces the intensity of regulatory scrutiny.

We incorporate a bank capital channel, but we do so in a different (albeit complementary) manner than in Agénor and Pereira da Silva (2009).

[1] In turn, the models in Agénor and Alper (2009) and Agénor and Pereira da Silva (2009) build on the static framework with monopolistic banking and full price flexibility developed by Agénor and Montiel (2008).

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

We assume here that holding capital induces banks to screen and monitor borrowers more carefully.[3] As a result, the repayment probability tends to increase, which in turn leads to a lower cost of borrowing. Thus, bank capital may also play a significant cyclical role—the higher it is, the lower the lending rate, and the greater the expansionary effect on activity. Although we do not have (yet) strong evidence on this channel for middle-income countries, it 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.

The main result of our simulations is that, contrary to intuition, a Basel II-type regime may be *less* procyclical than a Basel I-type regime, once credit market imperfections and general equilibrium effects are accounted for. 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 tends to raise initially the collateral-loan ratio, which tends to increase the repayment probability. By contrast, the fall in cyclical output tends to lower the repayment probability. 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

[3] 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, the inability to fully diversify risk away is one of the key features of banking in developing countries.

capital requirements—which will in turn tend to mitigate the initial drop in the repayment probability. If this "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.

The paper continues as follows. Section II 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 (2009); 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 III and some key features of the log-linearized version of the model are highlighted in Section IV. After a brief discussion of the calibrated parameters, we present the results of our experiments: temporary, negative supply and demand shocks, to highlight the implications of the two regulatory regimes for the economy's response to a recession. 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, intermediate goods-producing (IGP) firms, a final-good-producing 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. Its supply of loans is perfectly elastic at the prevailing lending rate. To satisfy capital regulations, it issues shares at the beginning of time t. 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 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.[4]

[4]Goodhart, Sunirand, and Tsomocos (2005) also adopt the assumption of bank liquidation in a two-period framework. Thus, there is no intrinsic distinction between issuing

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 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 growth rate of output.

2.1 Household

The household consumes, holds financial assets (including securities issued by the bank), and supplies labor to IGP firms. It also owns the economy's stock of physical capital and rents it 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 working time, x_t a composite index of real monetary assets, $N_t = \int_0^1 N_t^j dj$, with N_t^j denoting the number of hours of labor provided to the intermediate-good producing firm j, and $\beta \in (0,1)$ the discount factor. E_t is the expectation operator conditional on the information available in period t, $\varsigma > 0$ is the constant intertemporal elasticity of substitution in consumption and $\eta_N, \eta_x > 0$.

The composite monetary asset is generated by combining real cash balances, m_t^H, and real bank deposits, d_t, respectively (both at the beginning of period t), through a Cobb-Douglas function:

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

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

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

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

equity or debt from the perspective of the bank; capital consists therefore, in the Basel terminology, solely of "Tier 2" capital. See Yilmaz (2009) for instance for a partial equilibrium model in which equity is accumulated over time.

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^D is the interest rate on deposits, principal and interest payments on maturing government bonds, $(1+i_{t-1}^B)B_{t-1}^H$, where i_{t-1}^B is the bond rate prevailing at $t-1$, as well as the value of redeemed shares and distributed dividends $(1+i_{t-1}^V)V_{t-1}$, where i_{t-1}^V is the nominal yield on equity shares.

At the beginning of the period, each household chooses the real levels of cash, deposits, equity capital, and bonds, and supplies labor and capital to intermediate goods-producing firms, for which it receives total real factor payment $r_t^K K_t + \omega_t N_t$, where r_t^K is the real rental price of 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 intermediate good-producing firms, $J_t^I = \int_0^1 \Pi_{jt}^I dj$.[5] 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. The household then 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}.

Under certainty, the household's end-of-period budget constraint is thus

$$M_t^H + D_t + B_t^H + P_t^V V_t \tag{4}$$

$$= P_t(r_t^K K_t + \omega_t N_t - T_t) + (1+i_{t-1}^D)D_{t-1} + (1+i_{t-1}^B)B_{t-1}^H + (1+i_{t-1}^V)P_{t-1}^V V_{t-1}$$

$$+J_t^I + J_t^B - P_t(C_t + I_t) + M_{t-1}^H - \Theta_V P_t \frac{V_t^2}{2},$$

where the last term represents transactions costs (measured in terms of the price of the good) associated with changes in the stock of equity, with $\Theta_V > 0$ denoting the adjustment cost parameter.

[5] As noted below, the final good-producing firm makes zero profits.

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

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

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 the 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, 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:

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

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

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

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

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

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

where λ_t is the Lagrange multiplier associated with the budget constraint and $z_t = P_t^V/P_t$ is the real equity price, together with the transversality condition

$$\lim_{s \to \infty} E_{t+s} \lambda_{t+s} \beta^s (\frac{x_{t+s}}{P_{t+s}}) = 0, \quad \text{for } x = m^H, K. \tag{12}$$

Equation (6) is the standard Euler equation. Equation (7) relates labor supply positively to the real wage and negatively to consumption. Equation (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, equation (9) relates the real demand for deposits positively with consumption and the deposit rate, and negatively with the bond rate. Equation (10) can be rewritten as

$$E_t(\frac{1+i_t^B}{1+\pi_{t+1}}) = E_t\left\{\left[\Theta_K(\frac{K_{ht+1}}{K_{ht}}-1)+1\right]^{-1}\left[1-\delta+r_{t+1}^K-\frac{\Theta_K}{2}(\frac{\Delta K_{ht+2}^2}{K_{ht+1}^2})\right]\right\}, \tag{13}$$

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 (adjusted for adjustment costs, incurred both in t and $t+1$). With $\Theta_K = 0$, this expression takes the simpler form $E_t[(1+i_t^B)/(1+\pi_{t+1})] + \delta = 1 + E_t r_{t+1}^K$; put differently, in the absence of adjustment costs, the household simply accumulates capital to equate the (expected) rental rate with the (expected) risk-free real interest rate on bonds, plus depreciation.

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

$$z_t V_t^d = \frac{1}{\Theta_V}(\frac{i_t^V - i_t^B}{1+i_t^B}), \tag{14}$$

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 is 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 $j \in (0,1)$:

$$Y_t = \left\{\int_0^1 [Y_{jt}]^{(\theta-1)/\theta} dj\right\}^{\theta/(\theta-1)}, \tag{15}$$

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

The final good-producing (FGP) firm sells its output to households 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

$$Y_{jt} = (\frac{P_{jt}}{P_t})^{-\theta} Y_t, \quad \forall j \in (0,1). \tag{16}$$

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

$$P_t = \left\{ \int_0^1 (P_{jt})^{1-\theta} dj \right\}^{1/(1-\theta)}. \tag{17}$$

2.3 Intermediate Good-Producing Firms

There is a continuum of IGP firms, indexed by $j \in (0,1)$. Each firm 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:

$$Y_{jt} = A_t N_{jt}^{1-\alpha} K_{jt}^{\alpha}, \tag{18}$$

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

$$\ln A_t = \rho_A \ln A_{t-1} + \xi_t^A, \tag{19}$$

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 such that

$$L_{jt}^F = P_t \omega_t N_{jt}, \tag{20}$$

for all $t \geq 0$. Repayment of loans occurs at the end of the period, at the gross nominal rate $(1 + i_t^L)$, 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

$$PAC_t^j = \frac{\phi_F}{2} (\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}} - 1)^2 Y_t, \tag{21}$$

where $\phi_F \geq 0$ 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 (15).

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

$$\frac{K_{jt}}{N_{jt}} = (\frac{\alpha}{1-\alpha})[\frac{(1+i_{jt}^{L})\omega_t}{r_t^K}], \tag{22}$$

whereas the unit real marginal cost is

$$mc_{jt} = \frac{\left[(1+i_{jt}^{L})\omega_t\right]^{1-\alpha}(r_t^K)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}A_t}. \tag{23}$$

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 $\Pi_{jt}^{J} = P_{jt}Y_{jt} - P_t mc_t Y_{jt} - PAC_t^j$. Taking $\{mc_{t+s}, P_{t+s}, Y_{t+s}\}_{s=0}^{\infty}$ as given, the first-order condition for this maximization problem is:

$$\left\{1-\theta+\theta(\frac{P_t}{P_{jt}})mc_{jt}\right\}\lambda_t(\frac{P_{jt}}{P_t})^{-\theta}\frac{Y_t}{P_t} - \lambda_t\phi_F\left\{(\frac{P_{jt}}{\tilde{\pi}^G P_{jt-1}}-1)\frac{Y_t}{\tilde{\pi}^G P_{jt-1}}\right\} \tag{24}$$

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

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, lending, L_t^F, is equal to

$$L_t^F = \int_0^1 L_{jt}^F dj = P_t\omega_t N_t, \tag{25}$$

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

$$L_t^F + B_t^B + RR_t = D_t + P_t^V V_t + L_t^B, \tag{26}$$

where

$$V_t = V_t^R + V_t^E, \tag{27}$$

with V_t^R denoting capital requirements and V_t^E excess capital. We assume in what follows that, due to prohibitive penalty or reputational costs, $V_t \geq V_t^R$ at all times. In fact, we will focus on the case where capital requirements are not strictly binding, that is, $V_t^E > 0$.[6]

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

$$RR_t = \mu D_t, \tag{28}$$

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

Using (28), and given that L_t^F and D_t are determined by private agents' behavior, the balance sheet constraint (26) can be used to determine borrowing from the central bank:

$$L_t^B = L_t^F + B_t^B - (1 - \mu)D_t - P_t^V V_t. \tag{29}$$

The bank is also subject to risk-based capital requirements; it must hold an amount of equity that covers at least a given percentage of its loans, exogenously set by the central bank. 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:

$$P_t^V V_t^R = \rho \sigma_t^F L_t^F, \tag{30}$$

where $\rho \in (0, 1)$ is the capital adequacy ratio. Under Basel I, σ_t^F is fixed at $\sigma_0^F \leq 1$; under Basel II, in a manner similar to Agénor and Pereira da Silva (2009), we relate the risk weight to the repayment probability estimated by the bank, because it reflects its perception of default risk:[7]

$$\sigma_t^F = (\frac{q_t^F}{\tilde{q}^F})^{-\phi_q}, \tag{31}$$

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

[7] 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.

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.[8]

The bank sets both the deposit and lending rates to firms and the household, 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 real profits,

$$\{i_{t+s}^D, i_{t+s}^L, b_{t+s}^B, V_{t+s}^E\}_{s=0}^{\infty} = \arg\max E_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} (\frac{\Pi_{t+s}^B}{P_{t+s}}), \tag{32}$$

where Π_t^B denotes current profits at the end of period t.[9] In the present setting (and given in particular the assumption that the bank is liquidated and equity is redeemed at the end of each period), this maximization problem boils down to a period-by-period problem.

Real expected gross profits can be defined as

$$E_t(\frac{\Pi_t^B}{P_t}) = (1+i_t^B)b_t^B + q_t^F(1+i_t^L)(\frac{L_t^F}{P_t}) + (1-q_t^F)\kappa K_t \tag{33}$$

$$+\mu d_t - (1+i_t^D)d_t - (1+i_t^R)(\frac{L_t^B}{P_t}) - (1+i_t^V)z_t V_t - \gamma_B \frac{(b_t^B)^2}{2}$$

$$-\gamma_V z_t V_t + 2\gamma_{VV} z_t (V_t^E)^{1/2},$$

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, $q_t^F(1+i_t^L)P_t^{-1}L_t^F$, represents expected repayment if there is no default. The third term represents what the bank expects to earn in case of default. Under limited liability, earnings if the loan is not paid back are given by the "effective" value of collateral pledged by the

[8] In practice, the capital requirements prescribed by the Internal Ratings Based (IRB) approach of Basel II are an increasing function of banks' estimates of not only the probability of default, but also loss given default (LGD) of each loan—that is, the fraction of exposure that will not be recovered following default. Here, given the presence of collateral, the value of LGD for each individual IGP firm is in fact $L_{jt}^F - \kappa P_t K_{jt}$; as discussed below, this is already accounted for in the repayment probability through the collateral-loan ratio. Thus, movements in LGD are also implicitly captured through the dependence of σ_t^F on q_t^F.

[9] 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.

borrower, κK_t.[10] "Raw" collateral consists therefore of the physical assets of the firm and κ measures the degree of credit market imperfections.[11]

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 $(1 + i_t^D)d_t$ represents repayment of deposits (principal and interest) by the bank. The term $(1 + i_t^V)z_t V_t$ represents the value of shares redeemed to households and dividend payments. The term $\gamma_B (b_t^B)^2/2$ captures the cost associated with transacting in government bonds (dealer commissions, etc.); 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, $2\gamma_{VV} z_t (V_t^E)^{1/2}$, 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, which in turn reduces the pecuniary cost associated with the preparation of data and documents required by the supervision authority.[12] We assume that this effect on expected profits is concave, which implies that the benefits of capital buffers diminish fairly rapidly over time.[13]

The maximization problem is subject, from (20) and (22), to the loan

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[10] Because firms are *ex ante* homogenous, the bank has no screening problems; *ex post* monitoring costs are captured implicitly by defining κ as the "effective" value of collateral (that is, net of monitoring and contract enforcement costs) that can be seized in case of default.

[11] 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 occuring during period t and beyond and on firms defaulting or not. Note also that in case of default the bank can seize only collateral, $P_t K_t$ (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. See Agénor, Bratsiotis, and Pfajfar (2009) for the alternative (and more complex) case.

[12] Because required capital depends on risk-weighted assets, this term accounts for a scale effect as well. A related argument—in a stochastic environment—is provided in Ayuso, Pérez, and Saurina (2004), in which capital buffers reduce the probability of not complying with capital requirements.

[13] Because costs asssociated 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.

demand function for IGP firms

$$\frac{L_t^F}{P_t} = \int_0^1 (\frac{L_{jt}^F}{P_t})dj = \Phi[\frac{(1+i_t^L)\omega_t}{r_t^K}; A_t], \tag{34}$$

the balance sheet constraint (26), used to substitute out L_t^B, the equation defining V_t (27), and the capital requirement constraint (30).

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 (34), and that changes in the level of loans affects capital requirements, as implied by (30). It also takes the repayment probability of firms, the value of collateral, the contract enforcement cost, prices and the refinance rate as given.

The first-order conditions for maximization yield:

$$-d_t - [(1+i_t^D) - \mu - (1-\mu)(1+i_t^R)](\frac{\partial d_t}{\partial i_t^D}) = 0, \tag{35}$$

$$\frac{q_t^F L_t^F}{P_t} + \left\{q_t^F(1+i_t^L) - (1-\rho\sigma_t)(1+i_t^R) - \rho\sigma_t\left[(1+i_t^V)+\gamma_V\right]\right\}\frac{\partial \Phi}{\partial i_t^L} = 0, \tag{36}$$

$$(1+i_t^B) - (1+i_t^R) - \gamma_B b_t^B = 0, \tag{37}$$

$$(1+i_t^R) - \left\{(1+i_t^V) + \gamma_V - \frac{\gamma_{VV}}{\sqrt{V_t^E}}\right\} = 0. \tag{38}$$

Let $\eta_D = (\partial d_t/\partial i_t^D)i_t^D/d_t$ denote the constant interest elasticity of the supply of deposits by the household. Condition (35), which can be rewritten as $d_t + \left[i_t^D - (1-\mu)i_t^R\right](\partial d_t/\partial i_t^D) = 0$, yields

$$i_t^D = (1+\frac{1}{\eta_D})^{-1}(1-\mu)i_t^R, \tag{39}$$

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 $\eta_F = [\partial\Phi/\partial i_t^L](i_t^L/L_t^F)$ denote the interest elasticity of the demand for loans. Using this definition, condition (36) yields

$$1+i_t^L = \frac{1}{(1+\eta_F^{-1})q_t^F}\left\{(1-\rho\sigma_t)(1+i_t^R) + \rho\sigma_t\left[(1+i_t^V)+\gamma_V\right]\right\}, \tag{40}$$

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 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.

Now, we assume that the repayment probability q_t^F depends positively on three sets of factors. First, it depends on 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.[14] As argued by Boot, Thakor, and Udell (1991), Bester (1994), and Hainz (2003), by increasing borrowers' effort and reducing their incentives to take on excessive risk, collateral reduces moral hazard and raises the repayment probability. Second, we assume that 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 aggregate 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). Third, we assume that 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 its 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. As noted earlier, 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 also consistent with the evidence in Barth, Caprio, and Levine (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 (which could reflect better screening and monitoring of loan applicants).[15]

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[14] 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 and moral hazard effects on the riskiness of the pool of borrowers.

[15] Another rationale for a negative link between the bank capital-credit 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

To capture these effects, we specify the repayment probability as

$$q_t^F = \varphi_0 (\frac{\kappa P_t K_t}{L_t^F})^{\varphi_1} (\frac{P_t^V V_t}{L^F})^{\varphi_2} (\frac{Y_t}{\tilde{Y}})^{\varphi_3}, \tag{41}$$

with $\varphi_i > 0 \;\; \forall i$.[16] Note that although we use a "quasi-reduced form" for the repayment probability, the impact of collateralizable net worth can be explicitly derived as in Agénor and Aizenman (1998), under the assumption that the distribution of the supply shock A_t is uniform.

Combining (40) and (41) yields the following partial equilibrium result:

Result 1. *An increase in bank capital (in proportion of outstanding loans), by increasing incentives to monitor borrowers, reduces borrowers' default probability and lowers the lending rate.*

From (37), the demand for bonds is

$$\frac{B_t^B}{P_t} = \gamma_B^{-1}(i_t^B - i_t^R), \tag{42}$$

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

Using equation (27), (38) yields

$$V_t^E = \left\{ \frac{\gamma_{VV}}{i_t^V + \gamma_V - i_t^R} \right\}^2, \tag{43}$$

which shows that an increase in the direct or indirect cost of issuing equity (i_t^V or γ_V) reduces excess capital, whereas an increase in 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 (43), (30), and (31), it can be seen that, a drop in aggregate output, due to a common negative productivity shock, affects the repayment

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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, as emphasized in the text.

[16] We assume that φ_0 is such that the condition $q_t^F \in (0, 1)$ holds continuously.

probability through several channels. First, because the demand for labor (and thus 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 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-regime, because the risk weight is now directly related to the repayment probability—the initial response of which is 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. At the same time, the lower level of loans (which implies lower capital requirements) tends to lower the rate of return on equity to induce households to reduce their demand for these assets. In turn, the lower equity rate reduces the loan rate. As long as the risk effect 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. 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 (43))—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) as well; 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 (2009), who focus on the risk premium), we can summarize this result as follows:[17]

Result 2. *If the cyclical output effect dominates the collateral-loan effect*

[17] 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.

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 Basel II-type regime, relative to the Basel I-type regime, can be summarized as follows:

Result 3. *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; the profits that are distributed to shareholders are therefore given by

$$\frac{J_t^B}{P_t} = \max(0, \frac{\Pi_t^B}{P_t}), \tag{44}$$

where

$$\frac{\Pi_t^B}{P_t} = (1 + i_t^B)b_t^B + \min\left\{(1 + i_t^L)(\frac{L_t^F}{P_t}),\ \kappa K_t\right\}$$

$$+\mu d_t - (1 + i_t^D)d_t - (1 + i_t^R)(\frac{L_t^B}{P_t}) - (1 + i_t^V)z_t V_t - \gamma_B \frac{(b_t^B)^2}{2}$$

$$-\gamma_V z_t V_t - \gamma_{VV} z_t \frac{(V_t - V_t^R)^2}{2}.$$

2.5 Central Bank

The central bank's assets consists of holdings of government bonds, B_t^C, 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

$$B_t^C + L_t^B = M_t^s + RR_t. \tag{45}$$

Using (28), (45) yields

$$M_t^s = B_t^C + L_t^B - \mu D_t. \tag{46}$$

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.[18] The refinance rate itself determined by a Taylor-type policy rule:

$$i_t^R = \chi i_{t-1}^R + (1-\chi)[\tilde{r} + \pi_t + \varepsilon_1(\pi_t - \pi^T) + \varepsilon_2 \ln(\frac{Y_t}{\bar{Y}_t})] + \epsilon_t, \tag{47}$$

where $\tilde{r}$ is the steady-state value of the real interest rate on bonds, $\pi^T \geq 0$ the central bank's inflation target, and $Y_t/\bar{Y}_t$ is the output gap, with $\bar{Y}_t$ 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 output growth, respectively, and $\ln \epsilon_t$ is a serially correlated random shock with zero mean.

2.6 Government

The government purchases the final good and issues nominal riskless one-period bonds, which are held by the central bank and households. Its budget constraint is given by

$$B_t = (1 + i_{t-1}^B)B_{t-1} + P_t(G_t - T_t) - i_{t-1}^R L_{t-1}^B - i_{t-1}^B B_{t-1}^C, \tag{48}$$

[18] 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)).

where $B_t = B_t^B + B_t^C + B_t^H$ 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 term, $i_t^R L_t^B$ and $i_{t-1}^B B_{t-1}^C$, comes 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:

$$G_t = \psi_t Y_t, \tag{49}$$

where ψ_t is bounded between zero and one and is assumed to follow a first-order autoregressive process of the form

$$\ln \psi_t = \rho_\psi \ln \psi_{t-1} + \xi_t^\psi, \tag{50}$$

where $\rho_\psi \in (0,1)$ and $\xi_t^\psi \sim N(0, \sigma_{\xi^\psi})$. The innovations ξ_t^ψ and ξ_t^ψ are also assumed to be independent of each other.

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 $B_t^H = \bar{B} - \bar{B}^C - B_t^B$.

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, all households supply the same hours of labour, 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.[19] 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 always clear. For equilibrium in the goods markets we require that production be equal to aggregate

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

demand, that is, using (21),[20]

$$Y_t = C_t + G_t + I_t + \frac{\phi_F}{2}(\frac{1+\pi_t}{1+\tilde{\pi}} - 1)^2 Y_t. \tag{51}$$

Equation (5) can be rewritten as

$$I_t = K_{t+1} - (1-\delta)K_t + \Gamma(K_{t+1}, K_t). \tag{52}$$

Combining (49), (51), and (52), the aggregate resource constraint then takes the form

$$\left\{1 - \psi - \frac{\phi_F}{2}(\frac{1+\pi_t}{1+\tilde{\pi}} - 1)^2\right\} Y_t = C_t + K_{t+1} - (1-\delta)K_t + \Gamma(K_{t+1}, K_t). \tag{53}$$

The equilibrium condition of the market for cash is given by

$$M_t^s = M_t^H + M_t^F,$$

where M_t^s is defined in (46) and $M_t^F = \int_0^1 M_{jt}^F dj$ denotes firms' total holdings of cash. Suppose that bank loans to firms are made only in the form of cash; we therefore have $L_t^F = M_t^F$.[21] The equilibrium condition of the market for currency is thus given by $M_t^s = M_t^H + L_t^F$, that is, using (46)

$$L_t^B + B_t^C - \mu D_t = M_t^H + L_t^F.$$

Using (26) to eliminate L_t^B in the above expression yields

$$M_t^H + D_t = \bar{B}^C + B_t^B - P_t^V V_t. \tag{54}$$

Using (8) and (9) and aggregating, condition (54) becomes

$$\frac{\bar{B}^C + B_t^B}{P_t} - z_t V_t = \eta_x (C_t)^{1/\varsigma}(1 + i_t^B)\left\{\frac{\nu}{i_t^B} + \frac{(1-\nu)}{i_t^B - i_t^D}\right\}, \tag{55}$$

which can be solved for i_t^B.

As noted earlier, households take portfolio allocation decisions for period $t+1$ at the end of period t. Bank equity is thus priced so that its net return

[20]Implicit in (51) is the assumption that *ex post* bank monitoring (that is, in case of default) does not entail real costs.

[21]As discussed by Agénor and Alper (2009), condition (54) below does not change if instead the counterpart to loans consists of deposits.

at $t+1$ equals its expected return at t for $t+1$, which consists—given that there are no capital gains, the bank lasting only on period—of expected bank profits (which are distributed as cash dividends at the end of the period) per share:

$$i_t^V = \frac{E_t \Pi_{t+1}^B}{P_t^V V_t}. \tag{56}$$

Finally, the equilibrium condition of the bank equity market is obtained by equating (14) and (43):

$$V_t^d = V_t^R + V_t^E. \tag{57}$$

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

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

whereas steady-state interest rates are given by

$$\tilde{\imath}^B = \tilde{\imath}^R = \tilde{r}^K = \frac{1}{\beta} - 1, \quad \tilde{\imath}^D = (1 + \frac{1}{\eta_D})^{-1}(1-\mu)\tilde{\imath}^R,$$

$$\tilde{\imath}^V = \frac{\Theta_V \tilde{V}}{\beta} + \beta^{-1} - 1 > \tilde{\imath}^B,$$

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 $\tilde{\imath}^V > \tilde{\imath}^B = \tilde{r}^K$ 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 $\Theta_V = 0$, then $\tilde{\imath}^V = \tilde{\imath}^B = \tilde{r}^K$.[22] In addition, from (42),

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

the steady-state stock of bonds held by the bank is zero, given that $\tilde{\imath}^B = \tilde{\imath}^R$. Equation (43) determines $\tilde{V}^E$. Because $\tilde{\imath}^V > \tilde{\imath}^R$, $\tilde{V}^E > 0$, given that $\gamma_{VV} > 0$. By implication of (31), $\tilde{\sigma}^F = 1$ under both Basel I (by assumption) and Basel II.

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 (24) yields the familiar form of the New Keynesian Phillips curve (see, for instance, Galí (2008)):

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

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

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

where $\hat{\imath}_t^L$ and $\hat{r}_t^K$ denote percentage point deviations of the lending rate and the rental rate of 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 Calibration

To calibrate the model we dwell as much as possible on Agénor and Alper (2009); we therefore refer to that study for a detailed discussion of some of our choices. In addition, for some of the parameters that are "new" or specific to this study, we consider alternative values. This is the case, in particular, for the elasticity of the repayment probability with respect to bank capital, and the elasticity of the risk weight with respect to the repayment probability, given their importance for the issue at stake.

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 percent. 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 1.5. 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 adjustment cost parameter for equity holdings, Θ_V, is set at 0.3, whereas the adjustment cost for investment, Θ_K, is set at 8.6. 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—implying a steady-state value of the markup rate, $\theta/(\theta-1)$, equal to 11.1 percent. The adjustment cost parameter for prices, ϕ_F, is set at 74.5. The rate of depreciation of capital is set at 6.0 percent. The reserve requirement rate μ is set at 0.1, whereas the coefficient of the lagged value is set at $\chi = 0$ (which therefore implies that we abstract from persistence stemming from the central bank's policy response). We also set $\varepsilon_1 = 1.5$ and $\varepsilon_2 = 0.2$, 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 for Latin America by Moura and Carvalho (2009). For the degree of persistence of supply and demand shocks, we assume that $\rho_A = \rho_\psi = 0.6$, with standard deviations $\sigma_{\xi^A} = 0.02$ and $\sigma_{\xi^\psi} = 0.03$, respectively.

For the parameters characterizing bank behavior, we assume that the effective collateral-loan ratio, κ, is 0.2. The elasticity of the repayment probability with respect to collateral is set at $\varphi_1 = 0.05$, with respect to the bank capital-loan ratio at $\varphi_2 = 0.01$, and with respect to cyclical output at $\varphi_3 = 0.2$. In the case of φ_2, we also consider an alternative value of $\varphi_2 = 0.2$. Although somewhat arbitrary (as far as we know, there is not much empirical evidence about this parameter for middle-income 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, $\varphi_q = 0.05$. The cost parameters γ_B, γ_V, and γ_{VV} are also set at low values, 0.05, 0.1, and 0.001, 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. Finally, the steady-state value of the risk weight σ_t^F is calibrated so 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.

6 Procyclical Effects of Regulatory Regimes

We now consider the procyclical effects—as measured by the behavior of the repayment probability—of two types of shocks: a negative productivity (or supply) shock, and a negative (or demand) shock to the share of government spending in output.[23] In each case, we report the result for the two different values of the elasticity of the repayment probability with respect to the capital-loan ratio ($\varphi_2 = 0.01$ and $\varphi_2 = 0.2$). As is made clear below, this parameter change allows us to illustrate the ambiguity in the procyclical effects of the two regulatory regimes.

6.1 Negative Productivity Shock

Figures 1 and 2 shows 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 (43); as a result, total capital under the two regimes is more closely related.[24]

The direct effect of the shock is to lower temporarily the rental rate of capital, which reduces investment and tends to reduce marginal production costs. However, because the increase in borrowing costs (as discussed below) dominates, real marginal costs go up, thereby raising inflation.[25] The policy

[23]Note that we do not compare the results under either regulatory regime with the case where there is no bank capital channel (that is, $V_t = 0 \; \forall t$). As is made clear below, the main factor that makes the Basel II-type regime differ from the Basel I-type regime is the endogeneity of the risk weight in the former. This channel disappears if there is no bank capital. Hence, in that case, we would expect the convergence path to be similiar to what happens under the Basel I-type regime. However, because the steady-state level of the repayment probability would be lower in the absence of bank capital, the lending rate and real wages would be higher and aggregate output would be lower compared to what we obtain under that regime.

[24]However, by changing the parameters by more, we could magnify these differences.

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

rate, which is determined by a Taylor rule, rises in response to the increase in prices. By and large, other interest rates in the economy tend to follow the rise in the policy rate.[26] The rise in the expected real bond rate induces intertemporal substitution in consumption toward the future, which translates into a drop in current spending by households. 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 also lowers the repayment probability directly, whereas the collateral-loan ratio tends to increase at first—thereby raising the repayment probability. The net effect of these two channels is therefore ambiguous in general; given our calibration, the first effect dominates and the repayment probability falls, thereby raising the lending rate and marginal costs. In addition, however, there is a third channel in the model, 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 Figure 1, which corresponds to $\varphi_2 = 0.01$, the shock lead to the conventional case where Basel II is more procyclical than Basel I, whereas in Figure 2, which corresponds to $\varphi_2 = 0.2$, the opposite occurs. Thus, Basel II can be *less* procyclical than Basel 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.

[26] 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.

6.2 Negative Government Spending Shock

Figures 3 and 4 show the impulse response functions associated with a temporary, one percentage point reduction in the share of government spending in output. In both cases the reduction in the government spending share raises the proportion of output going to household consumption. This lowers immediately the marginal utility of consumption and reduces on impact the supply of labor. As a result, real wages increase initially and output falls. The policy rate falls as well, thereby lowering the deposit rate and thus the bond rate—which in turn stimulates private current consumption, by inducing households to shift consumption toward the present. However, due to the relatively low intertemporal elasticity of substitution in our calibration, this offsetting effect is only partial; aggregate demand falls on impact, albeit by less than public spending.

The fall in aggregate supply results from an increase in the real effective cost of labor, due not only to an increase in wages (alluded to earlier), but also from a higher lending rate—which itself stems from the fact that, despite the fall in the policy rate, the repayment probability falls in both regimes. Indeed, although the drop in bank borrowing raises the collateral-debt ratio (thereby exerting upward pressure on the repayment probability), the downward effect due to the fall in output dominates. The increase in effective labor costs leads to higher marginal costs (despite a reduction in the cost of capital), and this exerts upward pressure on inflation, which increases in both regimes when Basel II is more procyclical (Figure 3), and in Basel I, when Basel II is less procyclical (Figure 4). In the latter case, in the Basel II regime, inflation actually falls because the repayment probability falls by less, and the increase in the lending rate is smaller; as a result, the "cost channel" is not as strong, in contrast to the other cases. The increase in the marginal product of labor dominates the increase in the cost of working capital, which leads to a fall in inflation.

A comparison of Figures 3 and 4 also shows that, depending on the elasticity of the repayment probability with respect to the capital-loan ratio, φ_2, the repayment probability may drop by less under Basel II. The reason is the same as before—under Basel II, the initial fall in the repayment probability leads to a higher risk weight, which increases the bank capital-loan ratio and thereby mitigates the initial downward pressure on that probability associated with changes in the collateral-loan ratio and output. In Figure 3, which corresponds to $\varphi_2 = 0.01$, the shock generates the "conventional" result, whereas in Figure 4, which corresponds to $\varphi_2 = 0.2$, Basel II is less procyclical than Basel I–whether this is measured in terms of the behavior of the repayment probability, the lending rate, or aggregate output.

In addition, the increase in the lending rate may, or may not, be larger under Basel II. This is because the (downward) response of the policy rate is weaker under Basel I (given that inflation drops less under that regime), but the drop in the repayment probability may or may not dominate. If movements in the policy rate and the repayment probability tend to offset each other, the lending rate mat not change by much under Basel II. This pattern also explain differences in the behavior of the rate of return on equity under the two regimes. The larger increase in the lending rate (and thus the marginal cost of the labor) under Basel I explains why aggregate output may contract more under that regime, despite higher consumption under Basel II. Marginal costs may also fall by more under Basel II, which in turn accounts for the larger drop in inflation under that regime.

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 (2009) and Agénor and Pereira da Silva (2009), 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. The model is calibrated for a middle-income country. Numerical simulations 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, a Basel II-type regime may be *less* procyclical than a Basel I-type regime, in response to contractionary supply and demand shocks. The key reason is that, following a negative supply shock for instance, the bank capital channel mitigates the drop in the repayment probability, due to an increased 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, as for instance in Meh and Moran (2008) and Valencia (2008). This would enrich the dynamics of the model, because changes in banks' net worth would affect price-setting behavior and the real economy. Second, it could be assumed that the central bank might choose a monetary policy that mitigates economic fluctuations arising from capital requirements. The reason is that the objective of prudential supervision might be in conflict with the goal of maintaining high and stable growth. For instance, Cecchetti and Li (2008) have shown (in their specific framework) that it is possible to derive an optimal monetary policy that reinforces prudential capital requirements and at the same time stabilizes aggregate economic activity. Further research, however, is needed to determine the optimal monetary policy in the Basel II framework.

Third, 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 got 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. A more recent proposal has been put forward by Goodhart and Persaud (2008) and involves essentially adjusting the Basel II capital requirements to take into account the relevant point in the economic cycle. In particular, in the Goodhart-Persaud proposal, the capital adequacy requirement on mortgage lending would be linked to the rise in both mortgage lending and house prices.[27] 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 in our view is to evaluate carefully their welfare implications. 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 some serious 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 enhance welfare. A key issue therefore is to determine the net benefits of countercyclical bank capital rules. Our belief is that this issue can be fruitfully addressed by extending the existing model to account explicitly for systemic financial stability.

[27] Goodhart and Persaud argue that their proposal could be introduced under the so-called "Second Pillar" of Basel 2. Unlike Pillar I, which consists of rules for requiring minimum capital against credit, operational and market risks, Pillar II is supposed to take into account all the additional risks to which a bank is exposed to arrive at its actual capital needs.

Appendix A
Steady-State Solution

Given the parameter values, the steady-state values of all endogenous variables (denoted by tildes) are calculated by dropping all time subscripts from the relevant equations. Endogenous variables would converge to these values if the system is not disturbed by shocks.

From (47), with $\Delta \ln \tilde{Y} = 0$,

$$\tilde{\imath}^R = \tilde{r} + \tilde{\pi} + \varepsilon_1(\tilde{\pi} - \pi^T). \tag{A1}$$

We require inflation to be equal to its target value in the steady state:

$$\tilde{\pi} = \pi^T. \tag{A2}$$

Substituting this result in (A1) yields therefore the steady-state value of the refinance rate:

$$\tilde{\imath}^R = \tilde{r} + \tilde{\pi}. \tag{A3}$$

We will focus in what follows on the case where $\pi^T = 0$, so that $\tilde{\pi} = 0$.

The steady-state value of the bond rate is determined by setting $C_t = C_{t+1}$ and $\tilde{\pi} = 0$ in (6),

$$\tilde{\imath}^B = \tilde{r} = \tilde{\imath}^R = \beta^{-1} - 1. \tag{A4}$$

In the steady state, with $K_{t+1} = K_t$, capital adjustment costs are zero:

$$\frac{\Theta}{2}(\frac{\tilde{K}}{\tilde{K}} - 1)^2 \tilde{K} = 0. \tag{A5}$$

Substituting this result in (5) yields

$$\tilde{I} = \delta \tilde{K}. \tag{A6}$$

Substituting (A5) in (10) gives

$$-1 + \beta(\tilde{r}^K + 1 - \delta) = 0,$$

which implies that the steady-state value of the rate of return to physical capital is

$$\tilde{r}^K = \frac{1}{\beta} - (1 - \delta), \tag{A7}$$

which is also equal to $\tilde{\imath}^R$ if $\tilde{\pi} = 0$, as implied by (A3).

From (39), the steady-state value of the desired (and actual) deposit rate is

$$\tilde{\imath}^D = (1 + \frac{1}{\eta_D})^{-1}(1-\mu)(1+\tilde{\imath}^R) - 1. \tag{A8}$$

Setting $Y_{t-1} = \tilde{Y}$ in (41), the steady-state value of the repayment probability is

$$\tilde{q}^F = \varphi_0(\frac{\kappa\tilde{P}\tilde{K}}{\tilde{L}^F})^{\varphi_1}(\frac{\tilde{P}\tilde{V}}{\tilde{L}^F})^{\varphi_2}. \tag{A9}$$

Using (40) and (A4), the steady-state lending rate is given by

$$1 + \tilde{\imath}^L = \frac{1}{(1+\eta_F^{-1})\tilde{q}^F}\left\{(1-\rho)\beta^{-1} + \rho\left[(1+\tilde{\imath}^V) + \gamma_V\right]\right\}, \tag{A10}$$

which is the same for Basel I and Basel II, given the assumption that $\tilde{\sigma}^F$ is also equal to unity under Basel I.

From (8), (9), and (14), the household's demand for real cash balances, bank deposits, and equity are

$$\tilde{m}^H = \frac{\eta_x \nu \tilde{C}^{1/\varsigma}(1+\tilde{\imath}^B)}{\tilde{\imath}^B}, \tag{A11}$$

$$\tilde{d} = \frac{\eta_x(1-\nu)\tilde{C}^{1/\varsigma}(1+\tilde{\imath}^B)}{\tilde{\imath}^B - \tilde{\imath}^D}, \tag{A12}$$

$$\tilde{V} = \frac{1}{\Theta_V}(\frac{\tilde{\imath}^V - \tilde{\imath}^B}{1+\tilde{\imath}^B}), \tag{A13}$$

or equivalently, using (A3), (A4), (A7), and (A8) with $\tilde{\pi} = 0$,

$$\tilde{m}^H = \frac{\eta_x \nu \tilde{C}^{1/\varsigma}}{1-\beta}, \tag{A14}$$

$$\tilde{d} = \frac{\eta_x(1-\nu)\tilde{C}^{1/\varsigma}}{(1-\beta)\mu}, \tag{A15}$$

$$\tilde{V} = \frac{1}{\Theta_V}(\frac{1+\tilde{\imath}^V}{1+\tilde{\imath}^B} - 1) = \frac{\beta}{\Theta_V}(\tilde{\imath}^V - \beta^{-1} + 1). \tag{A16}$$

The last equation can be solved for $\tilde{\imath}^V$, with $\tilde{V}$ given. The solution is

$$\tilde{\imath}^V = \frac{\Theta_V\tilde{V}}{\beta} + \beta^{-1} - 1, \tag{A17}$$

which implies, given that $\tilde{V} > 0$, that $\tilde{\imath}^V > \tilde{\imath}^B$, as discussed in the text.

From (7), the steady-state value of labor supply is

$$\tilde{N} = 1 - \frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega}}. \tag{A18}$$

From (18), steady-state output of intermediate goods is given by

$$\tilde{Y} = A\tilde{N}^{1-\alpha}\tilde{K}^{\alpha}. \tag{A19}$$

The marginal productivity conditions yield

$$\tilde{r}^K = \alpha(\frac{\tilde{K}}{\tilde{Y}})^{-1}(\frac{\theta - 1}{\theta}), \qquad \tilde{\omega} = (\frac{1-\alpha}{\alpha})\frac{\tilde{r}^K\tilde{K}}{(1+\tilde{\imath}^L)\tilde{N}}.$$

These equations can be combined to give the capital-labor ratio, whose steady-state value is

$$\frac{\tilde{K}}{\tilde{N}} = (\frac{\alpha}{1-\alpha})[\frac{(1+\tilde{\imath}^L)\tilde{\omega}}{\tilde{r}^K}].$$

Substituting (A4) and (A7) in this expression, and solving for $\tilde{\omega}$ with $\tilde{\pi} = 0$ yields the steady-state real wage as

$$\tilde{\omega} = \left(\frac{1-\alpha}{\alpha}\right)\frac{\tilde{K}(\beta^{-1} - 1 + \delta)}{\tilde{N}(1+\tilde{\imath}^L)}. \tag{A20}$$

The steady-state level of borrowing from the bank is thus

$$\tilde{L}^F = \tilde{N}\tilde{\omega}\tilde{P}. \tag{A21}$$

From (21), and with $\tilde{\pi} = 0$ (so that $\tilde{\pi}^G = 1$), price adjustment costs are zero in the steady state ($PAC = 0$). From the price adjustment equation (24),

$$(1-\theta) + \theta\widetilde{mc} - \phi_F(\frac{\tilde{\pi}}{\tilde{\pi}} - 1)(\frac{\tilde{\pi}}{\tilde{\pi}}) + \beta\phi_F\frac{\tilde{\lambda}}{\tilde{\lambda}}(\frac{\tilde{\pi}}{\tilde{\pi}} - 1)(\frac{\tilde{\pi}}{\tilde{\pi}})(\frac{\tilde{Y}}{\tilde{Y}}) = 0,$$

which can be solved for the steady-state value of the marginal cost:

$$\widetilde{mc} = \frac{\theta - 1}{\theta}. \tag{A22}$$

From (42) and (43), and using (A4), the steady-state values of the bank's demand for bonds and supply of equity are

$$\tilde{B}^B = \gamma_B^{-1}\tilde{P}(\tilde{\imath}^B - \tilde{\imath}^R) = 0, \tag{A23}$$

$$\tilde{V}^E = \left\{ \frac{\gamma_{VV}}{\beta^{-1} - 1 - (\tilde{\imath}^V + \gamma_V)} \right\}^2, \tag{A24}$$

where, from (30) and (31), assuming that under Basel I the constant risk weight is also equal to unity,

$$\tilde{V}^R = \rho\tilde{\sigma}^F(\frac{\tilde{L}^F}{\tilde{P}}), \qquad \tilde{\sigma}^F = 1. \tag{A25}$$

From (A24) and(A25), total capital can be calculated as

$$\tilde{V} = \tilde{V}^R + \tilde{V}^E. \tag{A26}$$

From (29) and (A23), the steady-state level of the bank's borrowing from the Central bank is

$$\tilde{L}^B = \tilde{L}^F - (1-\mu)\tilde{d}\tilde{P} - \tilde{P}\tilde{V}. \tag{A27}$$

The equilibrium condition of the goods market, equation (51) yields the steady-state condition $\tilde{Y} = \tilde{C} + \tilde{G} + \tilde{I}$, which can be rearranged, using (A6) and (49), to give

$$(1-\psi)\tilde{Y} = \tilde{C} + \delta\tilde{K}. \tag{A28}$$

From (55) and (A23), the equilibrium condition of the market for cash yields

$$\frac{\bar{B}^C}{\tilde{P}} = \eta_X \tilde{C}^{1/\varsigma}(1+\tilde{\imath}^B)(\frac{\nu}{\tilde{\imath}^B} + \frac{1-\nu}{\tilde{\imath}^B - \tilde{\imath}^D}),$$

which can rearranged as, using (A3), (A4), (A7), and (A8), and with $\tilde{\pi} = 0$,

$$\frac{\bar{B}^C}{\tilde{P}} = \frac{\eta_X \tilde{C}^{1/\varsigma}}{1-\beta}(\nu + \frac{1-\nu}{\mu}). \tag{A29}$$

This equation can be solved for $\tilde{P}$. Given that the overall stock of bonds $\bar{B}$ is also constant, and that $\tilde{B}^B = 0$, household holdings of government bonds are given by

$$\bar{B}^H = \bar{B} - \bar{B}^C. \tag{A30}$$

From (48) and (49), the steady-state value of lump-sum tax to households is thus

$$\tilde{T} = \psi\tilde{Y} + \tilde{\imath}^B\bar{B}^H - \tilde{\imath}^R\tilde{L}^B. \tag{A31}$$

Appendix B
Log-Linearized System

Based on the results of Appendix A, the log-linearized equations of the model are presented below. Variables with a hat denote percentage point deviations of the related variables for interest rates and inflation, and log-deviations for the others, from steady-state levels.[28]

From the first-order conditions from household optimization, equations (6) and (8), private consumption is driven by

$$E_t\hat{C}_{t+1} = \hat{C}_t + \varsigma(\hat{\imath}_t^B - E_t\pi_{t+1}), \tag{B1}$$

where π_{t+1} is defined as, given that $\tilde{\pi} = 0$,

$$E_t\pi_{t+1} = E_t\hat{P}_{t+1} - \hat{P}_t. \tag{B2}$$

From (8) the demand for cash is

$$\hat{m}_t^H \tilde{m}^H = \frac{\eta_x \nu(\tilde{C})^{1/\varsigma}}{1-\beta}[\frac{\hat{C}_t}{\varsigma} - (\frac{\beta}{1-\beta})\hat{\imath}_t^B]. \tag{B3}$$

By using the steady-state value of cash balances from (A14), equation (B3) can be written as

$$\hat{m}_t^H = \frac{\hat{C}_t}{\varsigma} - (\frac{\beta}{1-\beta})\hat{\imath}_t^B. \tag{B4}$$

From (9) and (A15), the demand for deposits is

$$\hat{d}_t = \frac{\hat{C}_t}{\varsigma} + \left[\beta^{-1} - (\beta^{-1} - 1)\mu\right]\hat{\imath}_t^D - \left(\beta^{-1} - 1\right)\hat{\imath}_t^B. \tag{B5}$$

From (14) and (A16), the demand for equity is

$$\hat{V}_t = (1 - \frac{\Theta_V}{\tilde{\imath}^V\beta})^{-1}\left(\hat{\imath}_t^V - \hat{\imath}_t^B\right), \tag{B6}$$

which can be used to determine the behavior of $\hat{\imath}_t^V$.

[28] Net interest rates are thus used as approximations of the log gross interest rates.

The Fisher equation, defined in (10), yields

$$(1+\beta\delta)E_t\hat{r}^K_{t+1} + \beta\Theta(E_t\hat{K}_{t+2} - E_t\hat{K}_{t+1}) - \Theta(E_t\hat{K}_{t+1} - \hat{K}_t) - \hat{\imath}^B_t + E_t\pi_{t+1} = 0, \tag{B7}$$

which can be used to determine the behavior of $\hat{r}^K_t$.

From (7), labor supply is

$$\tilde{N}\hat{N}_t = \frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega}}\hat{\omega}_t - \frac{\eta_N \tilde{C}^{1/\varsigma}\hat{C}_t}{\varsigma\tilde{\omega}},$$

that is, using (A18),

$$\hat{N}_t = (\frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega} - \eta_N \tilde{C}^{1/\varsigma}})(\hat{\omega}_t - \frac{\hat{C}_t}{\varsigma}). \tag{B8}$$

From (22), labor demand can be derived as

$$\hat{N}_t = \hat{K}_t - \hat{\imath}^L_t - \hat{\omega}_t + (\frac{1+\beta\delta}{1+\beta\delta-\beta})\hat{r}^K_t. \tag{B9}$$

A log-linear approximation around the steady state of the price adjustment equation (24) yields

$$\pi_t = (\frac{\theta-1}{\phi_F})\widehat{mc}_t + \beta E_t\pi_{t+1}, \tag{B10}$$

where, using (23),

$$\widehat{mc}_t = (1-\alpha)(\hat{\imath}^L_t + \hat{\omega}_t) + (\frac{\alpha+\alpha\beta\delta}{1+\beta\delta-\beta})\hat{r}^K_t - \hat{A}_t. \tag{B11}$$

From the production function (18), output of intermediate goods is

$$\hat{Y}_t = \hat{A}_t + (1-\alpha)\hat{N}_t + \alpha\hat{K}_t. \tag{B12}$$

From (39) and (A8), the deposit rate is given by

$$\hat{\imath}^D_t = \frac{(1-\mu)}{1-(1-\beta)\mu}\hat{\imath}^R_t. \tag{B13}$$

From (40), the linearized equation for the lending rate under Basel I is

$$\hat{\imath}^L_t = \frac{1}{(1+\tilde{\imath}^L)\tilde{q}^F}\left\{\frac{(1-\rho)}{\beta}\hat{\imath}^R_t + \rho(1+\tilde{\imath}^V)\hat{\imath}^V_t - [\frac{(1-\rho)}{\beta} + \rho(1+\tilde{\imath}^V) + \rho\gamma_V]\hat{q}^F_t\right\}, \tag{B14}$$

whereas under Basel II it is given by

$$\hat{\imath}_t^L = \frac{1}{(1+\tilde{\imath}^L)\tilde{q}^F} \left\{ \frac{(1-\rho)}{\beta}\hat{\imath}_t^R + \rho(1+\tilde{\imath}^V)\hat{\imath}_t^V - [\frac{(1-\rho)}{\beta} + \rho(1+\tilde{\imath}^V) + \rho\gamma_V]\hat{q}_t^F \right. \tag{B15}$$

$$\left. + \rho[(1+\tilde{\imath}^V) + \gamma_V - \frac{1}{\beta}]\hat{\sigma}_t^F \right\}.$$

Thus, (B14) corresponds to (B15) with $\hat{\sigma}_t^F = 0$.

From (41), the linearized equation for the probability of repayment is

$$\hat{q}_t^F = \varphi_1(\hat{K}_t + \hat{P}_t - \tilde{L}_t^F) + \varphi_2\hat{\sigma}_t^F + \varphi_3\hat{Y}_t, \tag{B16}$$

where the term $\varphi_2\hat{\sigma}_t^F$ on the right-hand side of this expression drops out for Basel I.

From (47), the central bank policy rate is determined by

$$\hat{\imath}_t^R = \chi\hat{\imath}_{t-1}^R + \varepsilon_1\hat{\pi}_t + \varepsilon_2\hat{Y}_t. \tag{B17}$$

Firms' demand for credit is, from (20),

$$\hat{L}_t^F = \hat{N}_t + \hat{\omega}_t + \hat{P}_t. \tag{B18}$$

From (42) and (43), the bank's demand for bonds and supply of capital are given by

$$\hat{B}_t^B = \hat{P}_t + \frac{(1+\tilde{\imath}^B)\hat{\imath}_t^B - (1+\tilde{\imath}^R)\hat{\imath}_t^R}{\tilde{\imath}^B - \tilde{\imath}^R}, \tag{B19}$$

$$\hat{V}_t^E = 2\frac{\beta^{-1}\hat{\imath}_t^R - (1+\tilde{\imath}^V)\hat{\imath}_t^V}{1+\tilde{\imath}^V + \gamma_V - \beta^{-1}}, \tag{B20}$$

whereas, from (30)

$$\hat{V}_t^R = \hat{L}_t^F - \hat{P}_t, \quad \text{(Basel I)} \tag{B21}$$

$$\hat{V}_t^R = \hat{L}_t^F - \hat{P}_t + \hat{\sigma}_t^F, \quad \text{(Basel II)} \tag{B22}$$

For the risk weight under Basel II, linearization of (31) yields

$$\hat{\sigma}_t^F = -\phi_q\hat{q}_t^F. \tag{B23}$$

Equation (B20), and either (B21) or (B22), can be used to calculate $\hat{V}_t$ as

$$\hat{V}_t = (\frac{\tilde{V}^R}{\tilde{V}})\hat{V}_t^R + (\frac{\tilde{V}^E}{\tilde{V}})\hat{V}_t^E,$$

which can then be substituted in (B6) to determine $\hat{i}_t^V$.

From (29), the bank's borrowing from the central bank is

$$\hat{L}_t^B = \frac{1}{\tilde{L}^B}\left[\tilde{L}^F\hat{L}_t^F + \frac{\tilde{P}(i_t^B - i_t^R)}{\gamma_b\beta} - (1-\mu)\tilde{P}\tilde{d}(\hat{d}_t + \hat{P}_t) - \tilde{P}\tilde{V}^R(V_t^R + \hat{P}_t)\right]. \tag{B24}$$

The equilibrium condition of the market for cash, equation (55), yields

$$\nu\left\{\hat{P}_t + \frac{\hat{C}_t}{\varsigma} - (\frac{\beta}{1-\beta})\hat{i}_t^B\right\} + \frac{(1-\nu)}{\mu}\left\{\hat{P}_t + \frac{\hat{C}_t}{\varsigma}\right. \tag{B25}$$

$$\left. + \left[\frac{1}{\beta} - (\frac{1}{\beta} - 1)\mu\right]\hat{i}_t^D - (\frac{1}{\beta} - 1)\hat{i}_t^B\right\} = 0.$$

Equation (B25) can be solved for $\hat{i}_t^B$.

The equilibrium condition of the goods market, equation (51), is, using (49):

$$(1-\psi)(\frac{\tilde{Y}}{\tilde{C}})\hat{Y}_t = \hat{C}_t + \frac{\tilde{K}}{\tilde{C}}(E_t\hat{K}_{t+1} - \hat{K}_t) + \delta\frac{\tilde{K}}{\tilde{C}}\hat{K}_t. \tag{B26}$$

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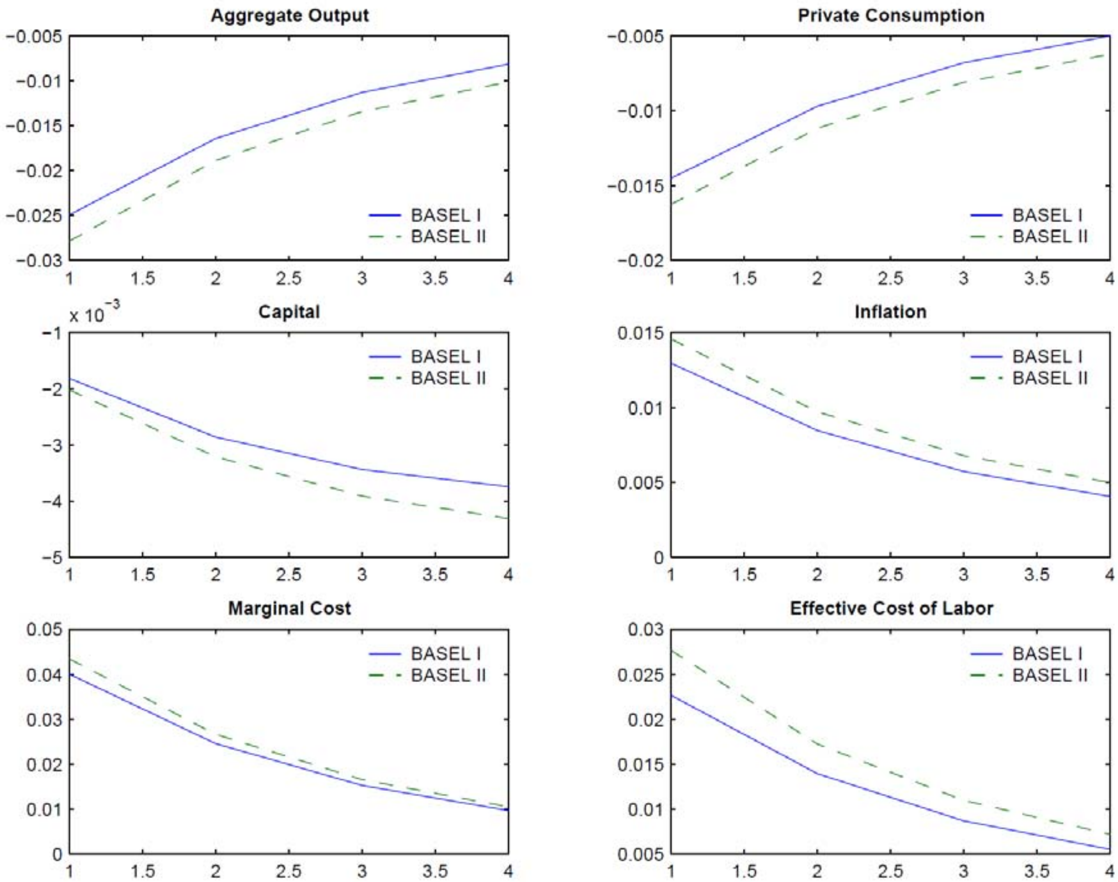
Table 1
Calibrated Parameter Values

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 capital
Bank		
κ	0.5	Effective collateral-loan ratio
φ_1	0.05	Elasticity of repayment prob wrt collateral
φ_2	0.01,0.2	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
Shocks		
ρ^A, σ_A	$0.6, 0.02$	Persistence/standard dev, productivity shock
ρ^ψ, σ_ψ	$0.6, 0.03$	Persistence/standard dev, public spending shock

Figure 1
Negative Productivity Shock
Basel II more Procyclical than Basel I
(Deviations from Steady State)



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.

Figure 1 (Continued)
Negative Productivity Shock
Basel II more Procyclical than Basel I
(Deviations from Steady State)

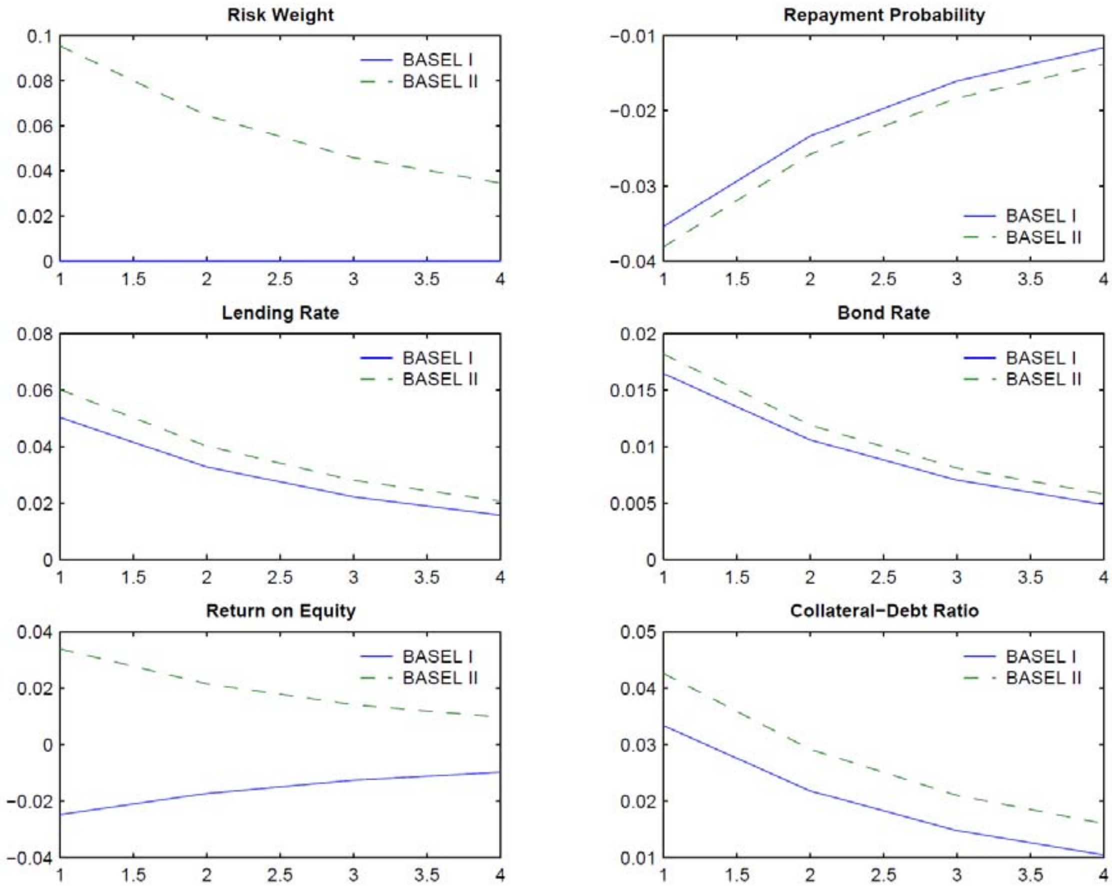
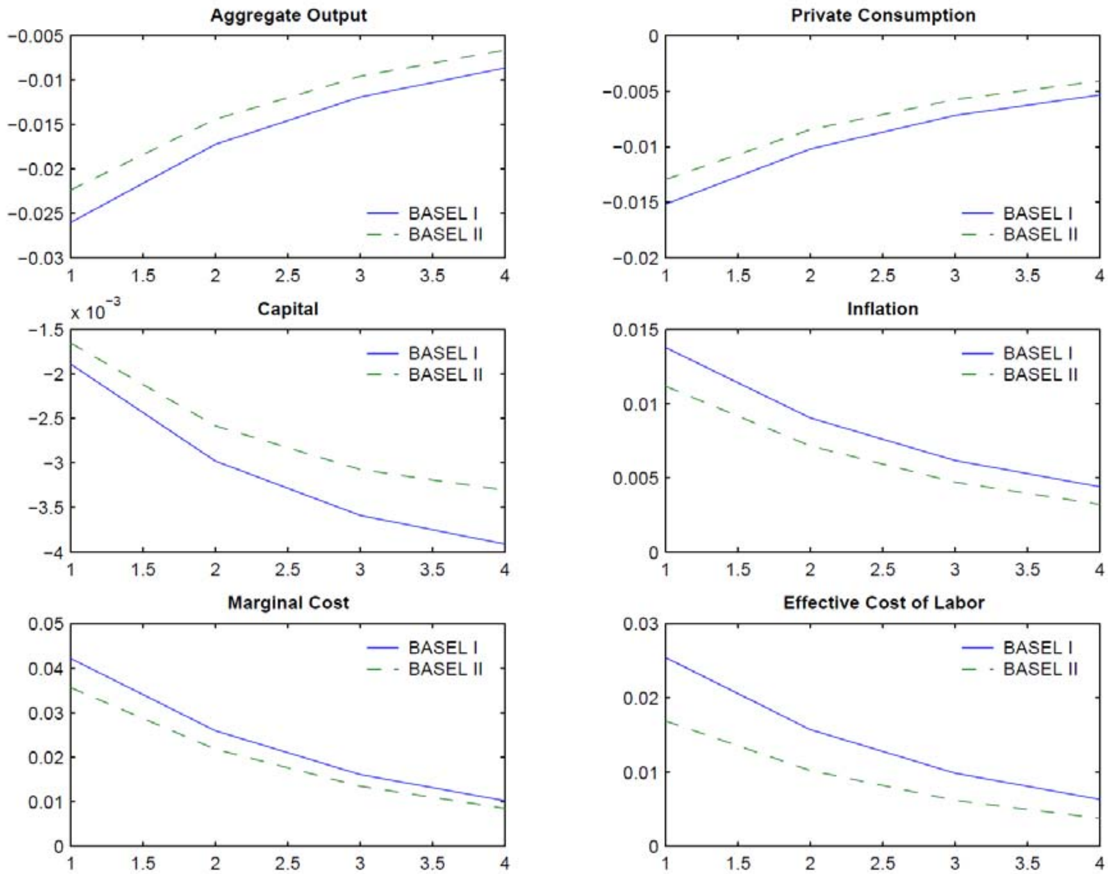


Figure 2
Negative Productivity Shock
Basel II less Procyclical than Basel I
(Deviations from Steady State)



Note: See note to Figure 1.

Figure 2 (Continued)
Negative Productivity Shock
Basel II less Procyclical than Basel I
(Deviations from Steady State)

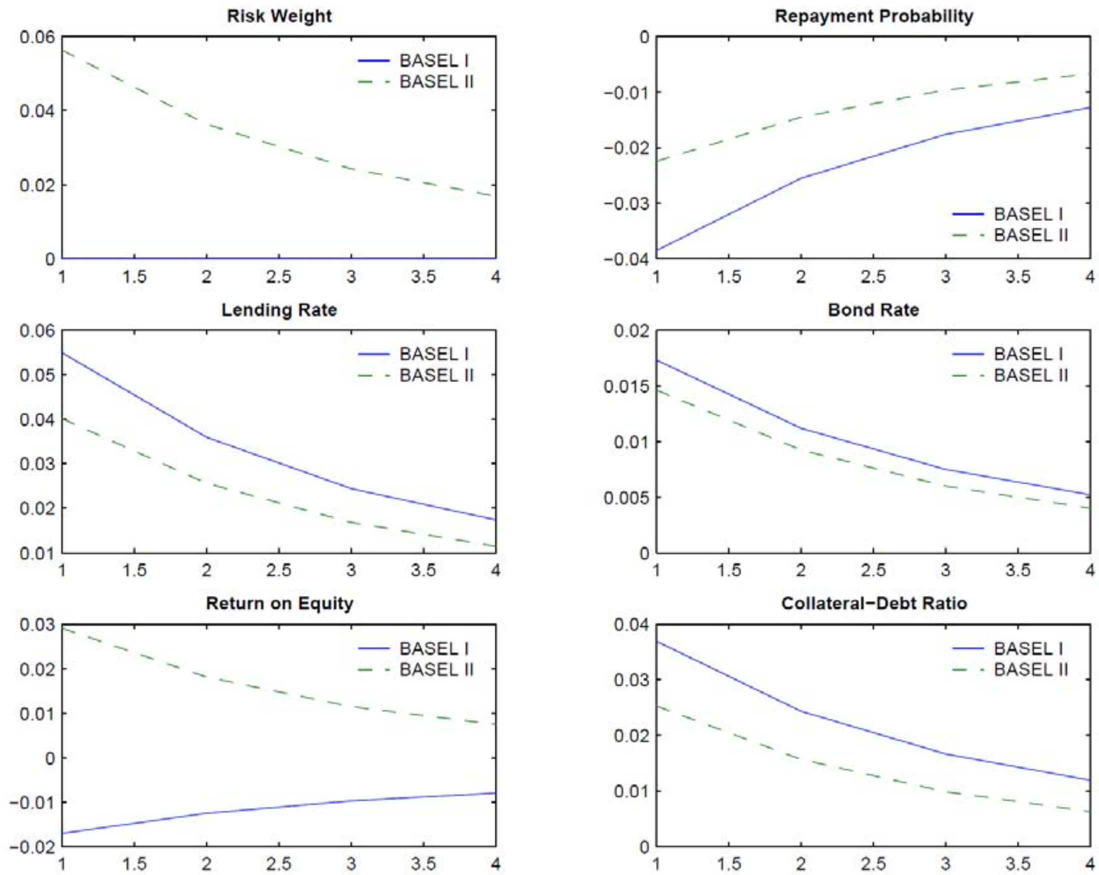
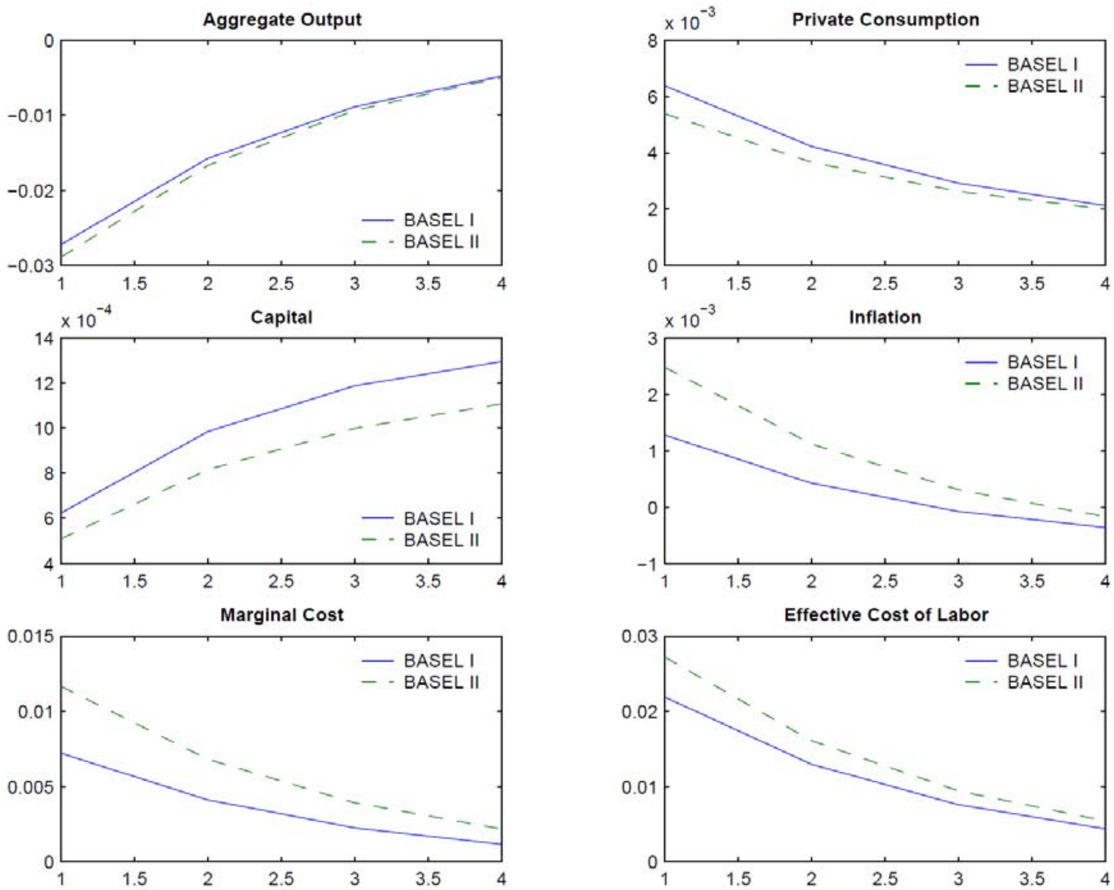


Figure 3
Negative Government Spending Shock
Basel II more Procyclical than Basel I
(Deviations from Steady State)



Note: See note to Figure 1.

Figure 3 (Continued)
Negative Government Spending Shock
Basel II more Procyclical than Basel I
(Deviations from Steady State)

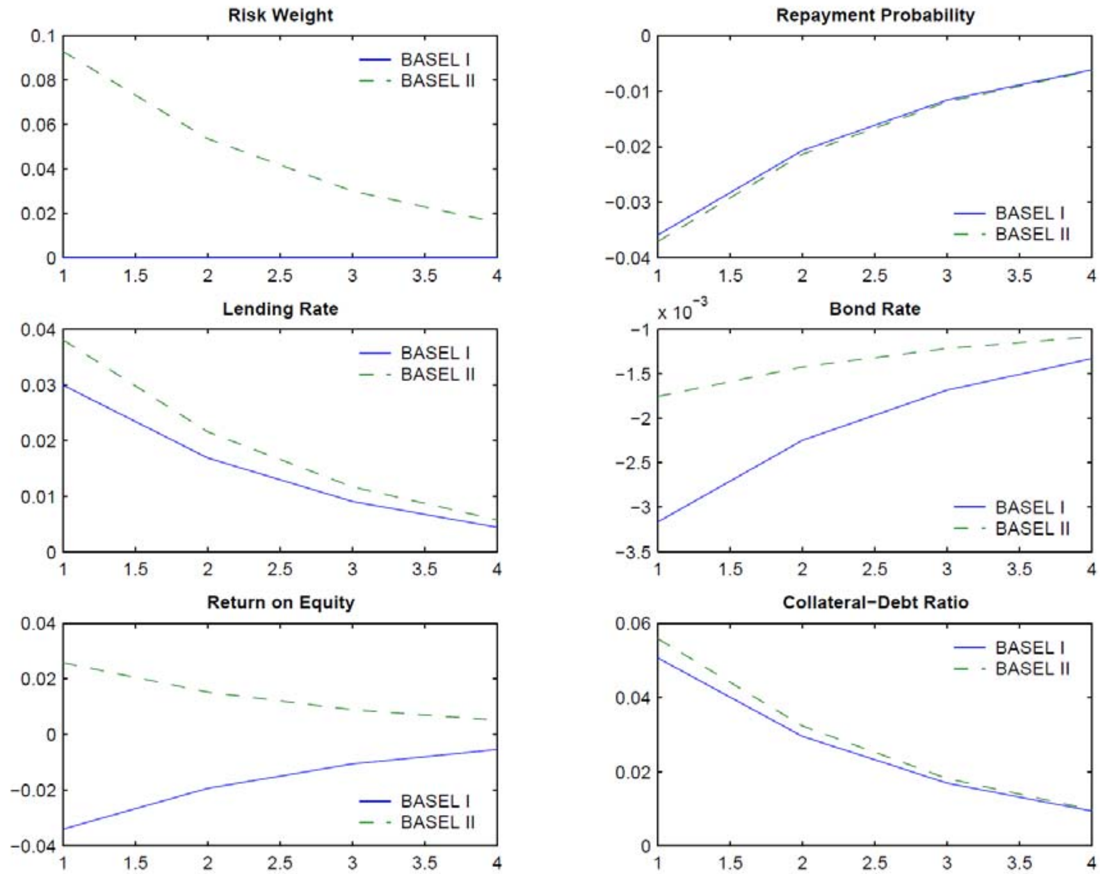
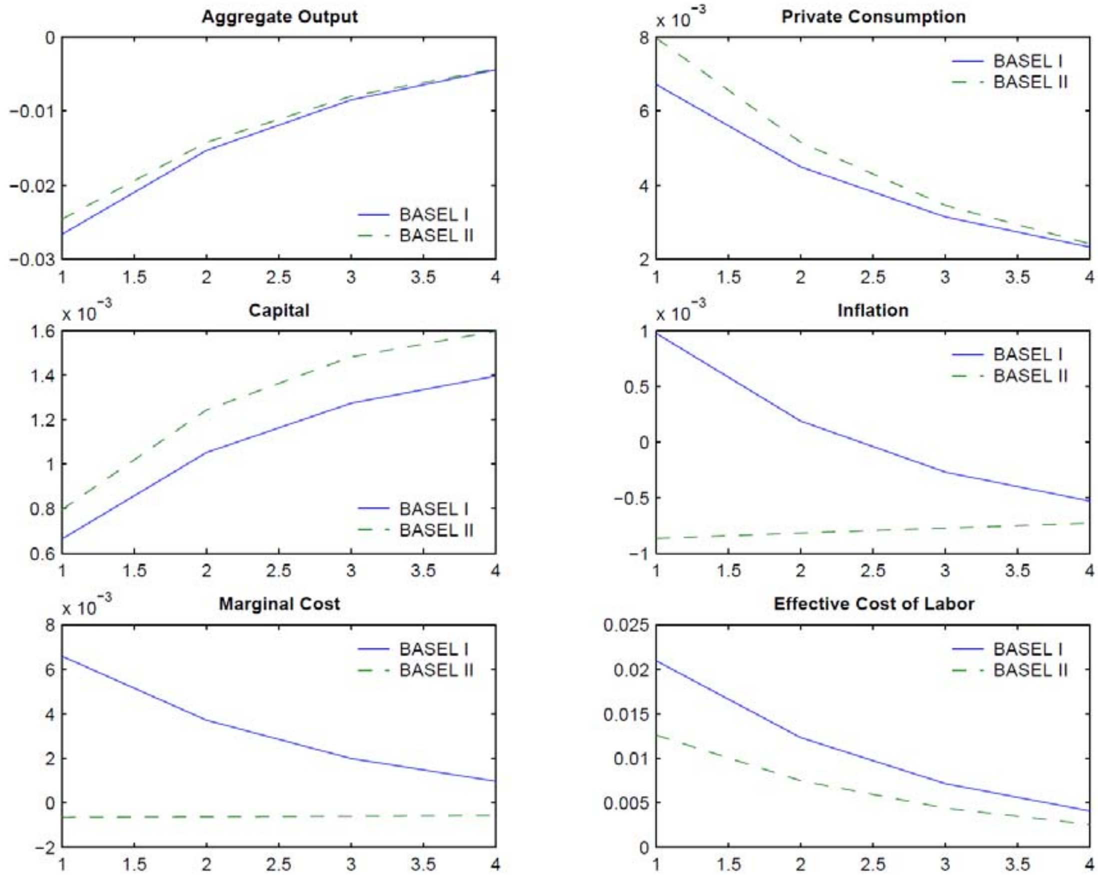


Figure 4
Negative Government Spending Shock
Basel II less Procyclical than Basel I
(Deviations from Steady State)



Note: See note to Figure 1.

Figure 4 (Continued)
Negative Government Spending Shock
Basel II less Procyclical than Basel I
(Deviations from Steady State)