Business Cycle and Bank Capital Requirements: Monetary Policy Transmission under the Basel Accords

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Abstract

This paper improves the analysis of the role of bank capital requirements in the transmission of monetary policy and in business cycle fluctuations, by detailing a dynamic general equilibrium model, in which households require a (countercyclical) liquidity premium to hold bank capital and banks subject to the Basel regulatory standards.

We find that, together with the financial accelerator, the introduction of bank capital requirements significantly amplifies monetary policy shocks through a liquidity premium effect on the external finance premium faced by firms. This amplification effect is stronger under Basel II than under Basel I regulatory rules, thus supporting the current concerns on Basel II procyclicality.

Keywords: Bank capital channel; Basel capital requirements; Procyclicality; Liquidity premium; Monetary transmission mechanism

JEL Classification Codes: E44, E32, E52, G28

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1 Introduction

The reasons underlying the procyclicality of the banking sector and, in particular, those associated with the Basel regulatory standards, have been subject to academic and institutional debate. According to these standards, each bank must maintain a total risk-weighted capital ratio - defined as the ratio of bank capital to the bank's risk-weighted assets - of at least 8%.

Under the Basel Accord of 1988 (Basel I hereafter) the risk weights depend on the institutional nature of the borrower and the same risk weight thus applies to all loans of a particular category ('one-size-fits-all').[1] Basel I was already potentially procyclical: as mentioned by Rochet (2008), banks' maximum lending capacities decrease during recessions, as they incur more credit losses during recessions than during booms, which negatively impacts the numerator of the capital ratio. Empirically, a considerable number of papers have tested the hypothesis of a "credit crunch" that may have occurred in the U.S. during the early 90s, simultaneously with the implementation of Basel I.[2]

The introduction of the new rules under the Basel Accord of 2004 (Basel II hereafter) may further amplify these procyclical effects. One of the core changes introduced by the new Accord is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank must hold is determined, not only by the institutional nature of its borrowers, but also by the riskiness of each particular borrower at each moment in time. Specifically, an increase in the credit risk of a given asset should lead to an increase in the amount of capital that a bank must hold against it. Therefore, during a recession, the bank's capital ratio may decrease not only due to credit losses (as in Basel I), but also because non-defaulted loans are considered riskier (which leads to an increase in the denominator of the ratio), thus leading to a further decrease in the bank's lending capacity. Moreover, as pointed out by Benink *et al.* (2008), Basel II will tend to harmonize banks' behavior - by requiring financial institutions to use similar risk models and directly control the type of models used -, which by itself may exacerbate procyclicality: in times of uncertainty, all the risk models in the industry indicate higher risk, create a decrease in capital ratios and, consequently, motivate the whole industry of banks to sell risky assets and buy safe assets.

The recent events and continuing instability in financial markets all over the world, raised further concerns on Basel II potential procyclical effects, and this issue has moved to the agendas of international fora, such as the G7, the G20 and the Financial Stability Forum (FSF). In par-

[1] For example, a zero weight is assigned to a government security issued in the OECD, meaning that the bank can finance such an asset through deposits without adding any capital. Basel I allows for three other weights, in ascending order of risk: 0.2 (*e.g.*, for interbank loans in OECD countries), 0.5 (*e.g.*, for loans fully secured by mortgages on residential property) and 1 (*e.g.*, for industrial and commercial loans). For further details see Basel Committee on Banking Supervision (1988).

[2] On this credit crunch literature, see, for instance, Bernanke and Lown (1991), Peek and Rosengren (1995, 2000), and Sharpe (1995) for a review.

ticular, according to the Action Plan agreed in the G20 Washington Meeting, in November 2008, the International Monetary Fund, the FSF, and other regulators and bodies should develop recommendations to mitigate procyclicality, including the review of how bank capital, among others, may exacerbate cyclical trends. Additionally, a European working group on procyclicality was set up to assess the range of policy responses that could help to mitigate undue potential procyclical effects of financial regulation, including bank capital requirements under Basel II.

This paper contributes to the evaluation of the potential procyclical effects of regulatory capital requirements, by developing a dynamic general equilibrium model, which takes Bernanke *et al.* (1999) as a starting point, and properly defines the financial intermediaries as banks and specifies their behavior: although it excludes some bank activities, for simplicity, our model explicitly assumes the role of banks in financing two entities in financial deficit (the public sector and nonfinancial firms) using the households funds (the entity in financial surplus). We further assume that banks are constrained by a risk-based capital ratio requirement and are thus limited in their lending to nonfinancial firms by the amount of bank capital that households are willing to hold.

In line with Poterba and Rotemberg (1987) and, more recently, Gorton and Winton (2000) and Van den Heuvel (2008), deposits have an advantage in terms of liquidity when compared to bank capital. Consequently, households, in order to hold bank capital in their portfolios, require a liquidity premium. Bank capital is, thus, more expensive to raise than deposits, and this difference tends to widen (narrow) during a recession (expansion): after a negative monetary policy shock, for instance, households require an increase in the liquidity premium, which is passed on to firms by the bank through an increase in the external finance premium faced by those firms, which borrow from the bank to buy capital. The increase in the firms' financing cost is thus further exacerbated, leading to an amplified response of real activity. Our model thus brings together the borrowers' balance sheet channel developed by Bernanke *et al.*, with the bank capital channel, which, through the liquidity premium effect, also amplifies the real effects of exogenous nominal and real shocks.

The model is then extended in order to evaluate the impact of the bank capital channel under Basel II (*versus* Basel I). In this new context, we find that the increase in the liquidity premium, after the negative monetary policy shock, is more accentuated under Basel II due to the increase in firms' credit risk after the shock. Consequently, the liquidity premium effect underlying the bank capital channel is stronger under Basel II, leading to more amplified responses of both economic and financial variables after the monetary shock, thus supporting the Basel II procyclicality hypothesis.

Our paper relates to other theoretical work, namely by Van den Heuvel (2002, 2008), Berka and Zimmermann (2005), Bolton and Freixas (2006) and Repullo and Suarez (2008). According to Van den Heuvel (2002)'s model, an increase in funds rate after a contractionary monetary policy and, consequently, an increase in bank's cost of funding, leads to a decrease in bank profits, given the maturity mismatch on the bank's balance sheet. This, in turn, weakens the bank's future capital position, increasing the likelihood that its lending will be constrained in the presence of regulatory capital requirements. Therefore, new lending overreacts to the monetary policy shock, when compared to a situation of unconstrained banks. Van den Heuvel refers to this channel by which monetary policy influences the supply of bank loans through its impact on bank capital as the bank capital channel.

Berka and Zimmermann (2005) and Bolton and Freixas (2006) also assume regulatory capital requirements, but, in contrast with Van den Heuvel (2002), consider the possibility of bank capital issuance. However, capital issuance may involve costs, as in Bolton and Freixas, who consider a cost of outside capital for banks by assuming information dilution costs in issuing bank capital. In this context, the presence of regulatory and binding capital requirements may magnify the effects of a contractionary monetary policy, since this policy may trigger a decrease (or prevent an increase) in bank capital: a contractionary monetary policy may render bank loans insufficiently lucrative when information dilution costs in issuing bank capital are taken into account.

Concerning, in particular, Basel II capital requirements, the work by Repullo and Suarez (2008) considers the possibility that banks optimally choose to keep capital buffers, thus, counteracting the potential procyclicality of the new Basel Accord. The partial equilibrium model developed by these authors predicts, however, that these capital buffers are insufficient to neutralize this procyclicality: during a recession banks will significantly decrease the supply of credit causing a credit crunch that would not occur under Basel I.[3]

Our model relates to this literature by accounting for the interactions between bank capital and macroeconomic conditions. We assume that banks may issue capital to satisfy regulatory capital requirements (as Berka and Zimmermann, 2005, and Bolton and Freixas, 2006), but face an issuing cost due to households' preferences for liquidity. The mechanism through which bank capital affects the transmission of monetary policy to the real economy rests on the liquidity premium, thus differing from Van den Heuvel (2002)'s, in which households and liquidity preferences and, thus, the liquidity premium effect, are absent.

The rest of the paper is organized as follows. After this introduction, Section 2 develops and calibrates a dynamic general equilibrium model, paying particular attention to the banking relationships with entrepreneurs and households and assuming Basel I capital requirements. In order to identify the bank capital channel, section 3 simulates a monetary policy shock, comparing the results with Bernanke *et al.* (1999)'s model (without capital requirements). The model is then adapted to introduce Basel II capital requirements and compare the effects of the monetary policy shock under Basel I and Basel II. Section 4 offers current conclusions of this ongoing research.

[3] For a review on the bank capital channel theoretical literature see Drumond (2008).

2 A Model with Bank Capital

Our model economy comprises five types of agents:

- Entrepreneurs, who need external finance to buy capital, which is used in combination with hired labor to produce wholesale output;
- Households, who work, consume and allocate their savings to bank deposits and bank capital;
- Banks, which, using the funds of households, finance and monitor (*ex post*) the entrepreneurs;
- Retailers, added in order to incorporate inertia in price setting;
- Government, conducting both monetary and fiscal policy and regulating banks.

2.1 Entrepreneurs

The analysis of entrepreneurs' behavior closely follows the model of Bernanke, Gertler and Gilchrist (1999), BGG hereafter.

In each period t each entrepreneur j buys the entire capital stock, K_{t+1}^{j}, for his firm in order to, in combination with labor, produce output at time $t+1$. The return to capital is sensitive to both aggregate and idiosyncratic risk: the *ex post* gross return on capital for firm j is given by $\omega_{t+1}^{j}R_{t+1}^{K}$, where ω_{t+1}^{j} is an idiosyncratic disturbance to firms j's return and R_{t+1}^{K} is the *ex post* aggregate return to capital. The random variable ω^{j} is independently and identically distributed (i.i.d.) across time and across firms, with a continuous and once-differentiable cumulative distribution function (c.d.f.), $F(\omega)$, over a non-negative support, and $E\left(\omega^{j}\right)=1$.

At the end of period t, entrepreneur j has available net worth N_{t+1}^{j} which he uses to finance the acquisition of K_{t+1}^{j}. To finance the difference between his capital expenditures $Q_tK_{t+1}^{j}$, where Q_t represents the price paid per unit of capital at time t, and his net worth, he borrows an amount $L_{t+1}^{j}=Q_tK_{t+1}^{j}-N_{t+1}^{j}$ from a financial intermediary (bank), which imposes a required return on lending between t and $t+1$, R_{t+1}^{F}, resulting from bank's profit maximization (see 2.3, below - the level of R_{t+1}^{F} guarantees zero profits for a competitive bank). This relationship embodies an asymmetric information problem between each entrepreneur and the bank: only the entrepreneur observes costlessly the return of his project. Following BGG, we assume a costly state verification (CSV) problem, according to which the idiosyncratic disturbance ω_{t+1}^{j} is unknown to both the entrepreneur and the bank prior to the investment decision - that is, $Q_tK_{t+1}^{j}$and L_{t+1}^{j} are chosen prior to the realization of the idiosyncratic shock -, and after the investment decision is made, the bank can only observe ω_{t+1}^{j} by paying a monitoring cost equal to a proportion μ of the realized gross payoff of the firm's capital: $\mu\omega_{t+1}^{j}R_{t+1}^{K}Q_tK_{t+1}^{j}$, where $0<\mu<1$.

Given $Q_t K_{t+1}^j$, L_{t+1}^j and R_{t+1}^K, the optimal contract established between the entrepreneur and the bank is characterized by a gross non-default loan rate, Z_{t+1}^j, and a cutoff value $\overline{\omega}_{t+1}^j$, such that, if $\omega_{t+1}^j \geqslant \overline{\omega}_{t+1}^j$, the borrower pays the lender the amount $\overline{\omega}_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j$ and keeps the remaining $\left(\omega_{t+1}^j - \overline{\omega}_{t+1}^j\right) R_{t+1}^K Q_t K_{t+1}^j$. If $\omega_{t+1}^j < \overline{\omega}_{t+1}^j$, the borrower receives nothing, while the bank monitors the borrower and receives $(1-\mu)\omega_{t+1}^j R_{t+1}^K Q_t K_{t+1}^j$.

The optimal contract conditions result from the maximization of borrower's payoff, with respect to K_{t+1}^j and $\overline{\omega}_{t+1}^j$, subject to a set of state-contingent constraints that guarantee the lender an expected gross return on the loan equal to the required return R_{t+1}^F (taken as given in the contracting problem). In particular, the first order conditions of the contracting problem yield a positive relationship between $\frac{Q_t K_{t+1}^j}{N_{t+1}^j}$ and the expected discounted return to capital, $\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F}$ (see BGG for details):

$$\frac{Q_t K_{t+1}^j}{N_{t+1}^j} = \varphi\left(\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F}\right),$$

given $\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F} > 1$ and where $\varphi'(.) > 0$, $\varphi(1) = 1$, and E_t denotes the expectation operator conditional on the information available at time t. Aggregating the preceding equation over firms we obtain[4]

$$\frac{Q_t K_{t+1}}{N_{t+1}} = \varphi\left(\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F}\right) \Longrightarrow \frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F} = l\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right), \tag{1}$$

where K_{t+1} denotes the aggregate amount of capital purchased by all entrepreneurs at time t, N_{t+1} the aggregate net worth of those agents and $l(.)$ is increasing in $\frac{Q_t K_{t+1}}{N_{t+1}}$ for $N_{t+1} < Q_t K_{t+1}$. Thus, in equilibrium, the expected discounted return to capital, $\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F}$, depends negatively on the share of the firms' capital expenditures that is financed by the entrepreneurs' net worth. As argued by Walentin (2005), $l\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right) R_{t+1}^F$ should be interpreted as the return on capital required by banks, in order to grant loans to the firms. Therefore, in an environment where entrepreneurs must borrow, under imperfect information, to buy capital, the expected discounted return to capital, $\frac{E_t\left(R_{t+1}^K\right)}{R_{t+1}^F}$, may be interpreted as an opportunity cost of being an entrepreneur, or, as in BGG's acceptation, as the *external finance premium* faced by entrepreneurs.

Entrepreneurial Net Worth The net worth of entrepreneurs combines profits accumulated from previous capital investment with income from supplying labor. Let V_t be the entrepreneurs' total equity (*i.e.*, the wealth accumulated by entrepreneurs from operating firms, which depends

[4] As mentioned by BGG, the assumption of constant returns to scale generates a proportional relationship between net worth and the capital demand at the firm level, with a factor of proportionality independent of firm's specific factors. This facilitates aggregation.

on firms' earnings net of interest payments to financial intermediaries):

$$V_t = R_t^K Q_{t-1} K_t - R_t^F (Q_{t-1} K_t - N_t) - \mu\Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t,$$

where $\mu\Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t$ are the aggregate default monitoring costs with $\Theta(\overline{\omega}_t) \equiv \int_0^{\overline{\omega}_t} \omega_t^j f(\omega) d\omega$. Then, normalizing the total entrepreneurial labor to one, $N_{t+1} = \gamma V_t + W_t^e$, where W_t^e is the entrepreneurial wage and γ is the probability that a entrepreneur survives to the next period.[5]

Entrepreneurs who "die" in t are not allowed to buy capital and simply consume their residual equity $(1-\gamma)V_t$. That is, $C_t^e = (1-\gamma)V_t$, where C_t^e represents the total consumption of entrepreneurs who leave the market.

2.2 Households

The economy comprises a continuum of infinitely lived identical risk averse households of length unity. Each household works, consumes, and invests its savings in assets which include deposits, that pay a real riskless rate of return between t and $t+1$ of R_{t+1}^D, and (risky) shares of ownership of banks in the economy, that pay R_{t+1}^S.

The representative household chooses consumption, leisure and the asset portfolio to maximize the expected lifetime utility (appropriately discounted) subject to an intertemporal budget constraint that reflects intertemporal allocation possibilities. Specifically, the household's problem is given by

$$\max_{C_t, H_t^h, D_{t+1}, S_{t+1}} E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{(D_{t+k+1})^{1-\beta_0}}{1-\beta_0} + \alpha_1 \frac{(1-H_{t+k}^h)^{1-\beta_1}}{1-\beta_1} \right] \tag{2}$$
$$\text{s.t. } C_t = W_t^h H_t^h - T_t + \Pi_t + R_t^D D_t - D_{t+1} + R_t^S S_t - S_{t+1},$$

where C_t denotes household real consumption, D_{t+1} the deposits (in real terms) held by the household from t to $t+1$, H_t^h the household hours worked (as a fraction of total time endowment), $0 < \beta < 1$ the subjective discount factor, W_t^h the real wage, T_t the lump sum taxes, Π_t the dividends received from ownership of imperfect competitive retail firms, and S_t the real bank capital held by the household from $t-1$ to t.

Real deposits are included in the instantaneous utility function to indicate the existence of liquidity services from wealth held in the form of that asset. That is, despite yielding a gross return of R^D, deposits also serve transaction needs since currency is absent from our model: we assume

[5] To avoid the possibility that entrepreneurs accumulate enough net worth to be fully self financed, it is assumed that those agents have finite horizons. The fraction of agents who are entrepreneurs is held constant by the birth of a new entrepreneur for each dying one.

that deposits can be used in an almost money like fashion to simplify a variety of transactions. In short, we are assuming that, when compared to bank capital, deposits have an advantage in terms of liquidity, similarly to Poterba and Rotemberg (1987) and, more recently, Gorton and Winton (2000) and Van den Heuvel (2008).

The first order conditions of the household's maximization problem (2) yield the following conditions:

$$(C_t)^{-\sigma} = \beta R^D_{t+1} E_t \left[(C_{t+1})^{-\sigma} \right] + \alpha_0 {D_{t+1}}^{-\beta_0}, \tag{3}$$

which takes into account that the gross real rate of return on deposits, R^D_{t+1}, is certain at time t;

$$(C_t)^{-\sigma} = \beta \left\{ E_t \left(R^S_{t+1} \right) E_t \left[(C_{t+1})^{-\sigma} \right] + cov_t \left(R^S_{t+1}, (C_{t+1})^{-\sigma} \right) \right\}; \tag{4}$$

and the labor supply condition

$$\alpha_1 (1 - H^h_t)^{-\beta_1} = (C_t)^{-\sigma} W^h_t. \tag{5}$$

In this representation, the expected excess return on the risky asset (bank capital) is linked both to a risk and a liquidity premium, since it depends both on the covariance between the aggregate consumption and bank capital's return and on deposits liquidity. A spread between the expected real return on bank capital and the real return on deposits is, then, justified by the liquidity services provided by deposits and by the riskless return on this asset, *i.e.*, $E_t(R^S_{t+1}) > R^D_{t+1}$.

2.3 Banks

Financial intermediation, consisting of collecting funds from households and granting loans to entrepreneurs, is assured by banks, which are legally subject to a risk-based regulatory capital requirement: based on the rules established by the Basel Accords - see Basel Committee on Banking Supervision (1988, 2004), bank capital must cover at least 8% of banks' risk weighted assets. Following Basel I capital requirements, a 100% risk weight applies to the loans granted to firms. Banks' assets also comprise government bonds, with zero weight in the risk-based capital requirement since they bear no risk.

We assume that only banks issue equity (as in Bolton and Freixas, 2006, for instance), on terms that depend on demand, *i.e.*, on households' willingness to hold capital in addition to deposits. In line with the contract established between the representative bank and each entrepreneur, we assume that all bank's assets and liabilities have the same, one period, maturity.[6]

[6] It should be noted that we maintain BGG's hypothesis, in which lenders, by avoiding both idiosyncratic and aggregate risks, do not default. By holding a diversified portfolio of loans, banks guarantee idiosyncratic risk diversification. The aggregate risk that could be associated to deposits, is passed on to the entrepreneurs. As for

The representative bank maximizes its expected profits, acting as a price (interest rate) taker in a competitive market. Its choice variables are loans, riskless government bonds, deposits and capital. The bank's objective is then given by:

$$\max_{L_{t+1},B_{t+1},D_{t+1},S_{t+1}} \left(R^F_{t+1}L_{t+1} + R_{t+1}B_{t+1} - R^D_{t+1}D_{t+1} - E_t\left(R^S_{t+1}\right)S_{t+1}\right)$$

$$\text{s.t. } L_{t+1} + B_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \tag{6}$$

$$\frac{S_{t+1}}{L_{t+1}} \geq \alpha_e = 0.08 \text{ (capital requirements constraint)} \tag{7}$$

where L_{t+1} represents the real loans granted to all firms from t to $t+1$, B_{t+1} the real government bonds held by the bank from t to $t+1$, D_{t+1} the real households' deposits, S_{t+1} the real bank's capital, R^F_{t+1} the required gross real return on loans between t and $t+1$, R_{t+1} the gross real return on government bonds, R^D_{t+1} the gross real return on deposits and $E_t\left(R^S_{t+1}\right)$ the expected real return on bank capital. As bank capital is more expensive to raise than deposits, due to the equity premium and to the households' preference for liquidity, the capital requirements constraint is always binding.

The first order conditions of the interior solution of this problem yield

$$R_{t+1} = R^D_{t+1}, \tag{8}$$

$$R^F_{t+1} = (1-\alpha_e)R_{t+1} + \alpha_e E_t\left(R^S_{t+1}\right), \tag{9}$$

which satisfy the bank's zero profit condition. Due to the introduction of binding capital requirements, the required return on lending by the bank, R^F_{t+1}, becomes a weighted average of the gross return on deposits and the expected gross return on bank capital.[7]

2.4 General Equilibrium

Now, following the modeling strategy of BGG, we embed the solution of the partial equilibrium contracting problem within a dynamic new Keynesian general equilibrium model, also taking into account the results obtained in the household and the bank optimization problems.

Each entrepreneur's investment decision is specified, under adjustment costs, assuming that each entrepreneur j purchases the capital goods from some other competitive firms, producers of

bank capital, its risk is borne by the representative household which owns stocks on the bank. Bolton and Freixas (2006), in a similar context of regulatory capital requirements, also consider perfectly diversified banks that do not go bankrupt.

[7] Whereas in BGG $R^F_{t+1} = R^D_{t+1} = R_{t+1}$.

capital. In this context, the aggregate capital stock follows an intertemporal accumulation equation with external adjustment costs,

$$K_{t+1} = \Xi\left(\frac{I_t}{K_t}\right) K_t + (1-\delta)K_t,$$

where δ denotes the depreciation rate and $\Xi\left(.\right)$ is an increasing and concave function, with $\Xi\left(0\right) = 0$. The introduction of adjustment costs permits variation in the price of a unit of capital in terms of the numeraire good, Q_t, derived from the profit maximization of the capital producer firms and increasing in the quantity invested.

Aggregate Production Function Physical capital acquired at period t is then combined with labor to produce output in period $t+1$, by means of a constant returns to scale technology:

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha}$$

with $0 < \alpha < 1$ and where Y_t represents the aggregate output of wholesale goods, H_t the labor input (comprising both households and entrepreneurial labor - see BGG for details) and A_t an exogenous technology term. The final output may then be either transformed into a single type of consumption good, invested, consumed by the government (G_t) or used in monitoring costs:

$$Y_t = C_t + C_t^e + I_t + G_t + \mu\Theta(\overline{\omega}_t)R_t^K Q_{t-1}K_t.$$

Entrepreneurs sell the output to retailers at a relative price of $\frac{1}{X_t}$, where X_t is the gross markup of retail goods over wholesale goods. Therefore, the expected gross return to holding a unit of capital from t to $t+1$ can be written as:

$$E_t\left(R_{t+1}^K\right) = E_t\left[\frac{\frac{1}{X_{t+1}}\alpha\frac{Y_{t+1}}{K_{t+1}} + Q_{t+1}(1-\delta)}{Q_t}\right],$$

where $\frac{1}{X_{t+1}}\alpha\frac{Y_{t+1}}{K_{t+1}}$ represents the rent paid to a unit of capital in $t+1$. In turn, the supply of investment capital is described by the return on physical capital the bank requires in order to grant loans to the firms (see equation 1).

The Retail Sector and Price Setting We introduce sticky prices in the model using standard devices used in new-Keynesian research. Namely, we incorporate monopolistic competition and costs of adjusting nominal prices by distinguishing between entrepreneurs and retailers: entrepreneurs produce wholesale goods in competitive markets, and then sell their output to retailers who are monopolistic competitors. Retailers are included only in order to introduce price inertia in a tractable manner: following Calvo (1983), it is assumed that the retailer is free to change its price in a given period only with probability $1-\theta$ (with $0 < \theta < 1$). The profits from retail activity are rebated lump-sum to households (Π_t in the household's intertemporal budget constraint).[8]

Government Government comprises the monetary, fiscal and regulatory authorities. We assume that conflicts between policies are internalized within the agent government, since we do not aim at exploring those differences in this paper.

Public expenditures, G_t, are financed by lump-sum taxes, T_t, and by issuing securities (government bonds, B_{t+1}). The government adjusts the mix of financing between bonds issuance and lump-sum taxes to support an interest rate monetary policy rule, to be defined below.

2.5 The Linearized Model

According to the model just described, and in the absence of exogenous shocks, the economy converges to a steady state growth path, along which all variables are constant over time (including prices, which implies a zero inflation rate in steady state).

To linearize the preceding equations, we use a first order Taylor series expansion around the steady state. The complete log-linearized model is provided in Aguiar and Drumond (2007), the working paper version. Here we focus on the main equations necessary to clarify the results and discussion in the following section. Let the lower case letters denote the percentage deviation of each variable from its steady state level: $x_t = \ln\left(\frac{X_t}{X}\right)$, where X, without the time subscript, is the value of X_t in nonstochastic steady state. In the aggregate demand side, the household's Euler equations (3) and (4) can be written in log-linear form as (assuming that $\sigma = \beta_0$):[9]

$$-\sigma c_t = -\sigma\beta R^D E_t\left(c_{t+1}\right) + \beta R^D r^D_{t+1} - \alpha_0\sigma\left(\frac{C}{D}\right)^{\sigma} d_{t+1}, \tag{10}$$

$$-\sigma c_t = -\sigma\beta R^S E_t\left(c_{t+1}\right) + \beta R^S E_t\left(r^S_{t+1}\right). \tag{11}$$

In what concerns the relationship between the external finance premium and the ratio of capital expenditures to net worth, equation (1) becomes, in the log-linearized version of the model,

$$E_t(r^K_{t+1}) - r^F_{t+1} = v(k_{t+1} + q_t - n_{t+1}), \tag{12}$$

where v is the steady state elasticity of $\frac{E_t(R^K_{t+1})}{R^F_{t+1}}$ with respect to $\frac{Q_t K_{t+1}}{N_{t+1}}$.

[8] Detailed derivation, not presented here since it is standard in new Keynesian framework, is available from the authors.

[9] We take a first-order Taylor approximation around the steady state ignoring the second order terms (or assuming that they are constant over time: $cov_t(.) = cov(.), \forall t$). Thus, the difference between $E_t\left(r^S_{t+1}\right)$ and r^D_{t+1} rests solely on liquidity.

Concerning the representative bank, equations (8) and (9) can be written in log-linear form as:

$$r_{t+1} = r_{t+1}^{D} \tag{13}$$

$$r_{t+1}^{F} = \alpha_e \frac{R^S}{R^F} E_t\left(r_{t+1}^{S}\right) + (1-\alpha_e)\frac{R}{R^F} r_{t+1} \tag{14}$$

The capital requirement constraint $S_{t+1} = \alpha_e(Q_t K_{t+1} - N_{t+1})$, turns into:

$$s_{t+1} = \frac{K}{L}\left(q_t + k_{t+1}\right) - \frac{N}{L} n_{t+1}. \tag{15}$$

The model comprises the following asset holding constraints that prevent arbitrage: the household does not hold physical capital and the entrepreneur cannot invest in bank capital. Nevertheless, we impose the same path for the deviations of the expected real return on bank capital and the expected real return on physical capital from their steady state values, over the business cycle - that is, $E_t(r_{t+1}^{S}) = E_t(r_{t+1}^{K})$. We are thus considering that, even if the levels of the returns are different, due to the aforementioned asset holding constraints, the effects of an exogenous shock on that difference are negligible, as both returns are subject to the same aggregate risk and neither bank capital nor physical capital provide liquidity services.

The interest rate monetary policy rule is given by

$$r_{t+1}^{n} = \rho r_t^{n} + \varsigma \pi_{t-1} + \varepsilon_t^{r^n} \tag{16}$$

where $r_{t+1}^{n} \equiv r_{t+1} + E_t \pi_{t+1}$ is the nominal interest rate from t to $t+1$ (with $\pi_{t+1} \equiv p_{t+1} - p_t$), r_{t+1} the real return on government bonds and $\varepsilon_t^{r^n}$ an i.i.d. disturbance at time t. As in BGG, we standardly assume that the current nominal interest rate responds to the lagged inflation rate and the lagged interest rate.

After log-linearizing and calibrating the model (see the appendix for some details on calibration) we applied the computational procedure used for solving linear rational expectations models developed by McCallum (1999).

3 The Bank Capital Channel at Work

To analyze the role of regulatory bank capital requirements in the transmission of monetary policy and, thus, in business cycle fluctuations, we present now some quantitative experiments focusing on the economy response to an unanticipated temporary negative monetary policy shock. In particular, we compare the effects of a negative innovation in the nominal interest rate (which corresponds to an annual increase of 25 basis points) under two distinct variants:

- Basel I, which corresponds to the model derived above;

- BGG, which corresponds to the BGG hypothesis applied to our model, thus excluding bank capital (leading to $R = R^D = R^F$).

Figures 1 and 2 illustrate the impulse response functions of the relevant variables (Basel I: solid line; BGG: dashed-dotted line), using the calibrated model economy with each period equivalent to a quarter and the variables expressed as percentage deviations from steady state values.

The increase in the nominal interest rate triggers an immediate decline in output, investment and consumption below their steady state values, after which the economy returns gradually to its steady state. As predicted by the Phillips curve in a sticky prices context, inflation also decreases in response to the output decline, and then gradually reverts to its stationary value. Inflation behavior, in turn, influences the nominal interest rate through the monetary policy rule.

Figure 2 depicts the responses of the financial sector variables. In both variants of the model, the external finance premium and the required return on lending by the bank (R^F) evolve countercyclically, increasing in response to the deterioration of entrepreneurs' financial position following the decline in assets prices, as in BGG. In fact, the financial accelerator effect of monetary policy (the borrowers' balance sheet channel), arising from the loan demand side and embedded within equation (12), is present in both variants. In line with the analysis in 2.1, this demand effect is based on the prediction that the external finance premium facing a borrower depends on the borrower's financial position - the smaller the borrower's self-financing ratio is, the higher the external finance premium should be. Intuitively, a deteriorated financial position increases the expected monitoring costs that arise from the informational asymmetry between each entrepreneur and the bank, leading to a higher external finance premium.

However, it is notable that the impact of the monetary policy shock is stronger in the presence of capital requirements (that is, stronger in Basel I than in BGG). This amplification effect can be explained through the analysis of bank and household behavior, as follows.

Combining the log-linearized equations (13) and (14), which have been derived from the representative bank's profit maximization problem, and assuming that the return on bank and physical capital follow the same path over the business cycle, it is straightforward to derive the following condition:

$$E_t(r^K_{t+1}) - r^F_{t+1} = \left(1 - \alpha_e \frac{R^S}{R^F}\right) E_t(r^S_{t+1}) - (1-\alpha_e)\frac{R^D}{R^F} r^D_{t+1}. \tag{17}$$

Furthermore, since $\left(1 - \alpha_e \frac{R^K}{R^F}\right) = (1-\alpha_e)\frac{R^D}{R^F}$ (see equations 8 and 9), equation (17) may be rewritten as

$$E_t(r^K_{t+1}) - r^F_{t+1} = \left(1 - \alpha_e \frac{R^S}{R^F}\right) \left[E_t(r^S_{t+1}) - r^D_{t+1}\right]. \tag{18}$$

According to this expression, the external finance premium, $E_t(r^K_{t+1}) - r^F_{t+1}$, depends positively on $E_t(r^S_{t+1}) - r^D_{t+1}$, which we will refer to as the liquidity premium.[10]

As illustrated in Figure 2, a contractionary monetary policy shock leads to an increase in the level of capital issued by the bank (s_{t+1}) in Basel I. This happens for two reasons: (i) the level of commercial and industrial (both uncollateralized) loans also increases - although entrepreneurs invest less, the sharp decrease in their net worth leads to an increase of $L_{t+1}(= Q_t K_{t+1} - N_{t+1})$ above its steady state level;[11] and (ii) as bank capital requirements are binding in Basel I, the bank, to grant more credit, must issue more capital. To hold more bank capital during the recession, households, in turn, require an increase in the liquidity premium, $E_t(r^S_{t+1}) - r^D_{t+1}$, since they must reduce the amount of deposits to attenuate the decline in consumption (in line with Gorton and Winton, 2000's model, for instance).[12] Note that, as illustrated in Figure 2, the liquidity premium under Basel I increases with a simultaneous decrease in deposits' level. It is clear from equation (18) that the larger the increase in the liquidity premium the larger will be the increase in the external finance premium and, consequently, the decrease in physical capital expenditures and output.[13]

We call this relationship between deposits and the external finance premium (through the liquidity premium), the *liquidity premium effect*. This effect is strictly related to the financial accelerator effect. That is, in variant Basel I, the external finance premium increases not only because the entrepreneurs' financial position deteriorates following the decline in assets prices, as in variant BGG, but also because the liquidity premium required by the households increases (a cost that is passed on to firms by the bank):

$$\begin{array}{llcccc} \text{(A)} & \text{Liquidity Premium Effect:} & \Delta^- D & \Longrightarrow & \Delta^+ \frac{E_t R^S_{t+1}}{R^D_{t+1}} & \Longrightarrow \\ \text{(B)} & \text{Financial Accelerator Effect:} & \Delta^- Q & \Longrightarrow & \Delta^- \frac{N_{t+1}}{Q_t K_{t+1}} & \Longrightarrow \end{array} \quad \Delta^+ \frac{E_t R^K_{t+1}}{R^F_{t+1}}.$$

Variant Basel I includes both the financial accelerator and the liquidity premium effects, whereas BGG only comprises the financial accelerator effect. In other words, Basel I comprises the

[10] Note that, since we use a first-order Taylor approximation around the steady state (ignoring the second order terms) to linearize the model, $E_t(r^S_{t+1}) - r^D_{t+1}$ does not correspond to the equity premium, defined as the extra return required by risk averse households to compensate for the covariance between equity returns and the stochastic discount factor. Instead, it reflects the liquidity advantage of deposits over bank capital, properly called liquidity premium.

[11] See Gertler and Gilchrist (1993) and Den Haan *et al.* (2007) for some evidence on the increase of commercial and industrial loans right after a contractionary monetary policy.

[12] To better understand this last effect recall the log-linearized Euler equations (10) and (11) derived in Section 2. Combining these two equations, with the calibrated $\sigma = 1$, yields

$$\beta R^S E_t\left(r^S_{t+1}\right) - \beta R^D r^D_{t+1} = \left(R^S - R^D\right) \beta E_t\left(c_{t+1}\right) - \alpha_0 \frac{C}{D} d_{t+1}$$

where $\alpha_0 \frac{C}{D} > 0$, which confirms that the liquidity premium required by the households depends negatively on deposits (d_{t+1}).

[13] The bank's balance sheet equilibrium is guaranteed by a reduction in bonds held by the bank.

effects arising from the loan demand side (due to the informational asymmetry between each entrepreneur and the bank, which gives rise to the financial accelerator effect) and the effects arising from the loan supply side (due to the presence of bank capital requirements in the model, which gives rise to the liquidity premium effect); BGG, in turn, only comprises loan demand effects. This justifies the much stronger real effects of the monetary policy shock in Basel I than in BGG (see Figure 1): in Basel I the external finance premium set by the bank must not only compensate the bank for the costs of mitigating incentive problems due to informational asymmetries (as in BGG), but also the return required by the households to hold bank capital; since the liquidity premium required by the households is countercyclical (see Figure 2), due to deposits' response, the countercyclical movement in the external finance premium is exacerbated leading to a more amplified response of the real activity.

Our result of a much more powerful propagation than in BGG's model, is in line with Kocherlakota (2000)'s argument that credit constraints can help to explain the properties of output fluctuations in the U.S., including the large movements in aggregate output. According to this author, these large movements cannot be explained by large shocks (those "are hard to find in the data," p. 3), but by mechanisms which transform "small, barely detectable, shocks to some or all parts of the economy into large, persistent, asymmetric movements in aggregate output." Our model contributes to clarify the nature of those mechanisms by introducing, in addition to the borrowers' balance sheet channel of monetary policy transmission, the bank capital channel, which, through the liquidity premium effect, further amplifies the monetary policy shock effects.[14]

The Procyclicality of Capital Requirements: Basel I *vs* Basel II

We now modify the model developed in Section 2, in order to introduce Basel II capital requirements. Under Basel II rules, the risk weight assigned to each bank exposure depends on its nature (*e.g.*, loans granted to firms *vs* government bonds) and its estimated credit risk. In our model economy, firms default on loans if the idiosyncratic disturbance, ω_{t+1}^{j}, turns out to be smaller than the cutoff value $\overline{\omega}_{t+1}^{j}$ (see 2.1 above). It is straightforward to show that the optimal financial contract established between the bank and each entrepreneur yields a common cutoff value, $\overline{\omega}_{t+1}$, for all entrepreneurs. The intuition is that, facing a common external finance premium, producers choose the same leverage ratio, leading to a common cutoff value; larger firms, rather than benefiting from lower interest rates, have, instead, access to larger amounts of credit.[15]

Yet, the common cutoff value and, consequently, the credit risk, vary with the business cycle. This allows straightaway the analysis of the business cycle properties of Basel II, insulated from

[14] We have also performed some sensitivity and robustness checks - *e.g.*, by simulating a technology shock and a shock to government expenditures, or by removing the adjustment costs in the production of capital (which leads to a constant price of capital) - and the bank capital channel remained at work in all experiments.

[15] The formal proof is available in the working paper version of the paper (Aguiar and Drumond, 2007).

the effects of credit risk heterogeneity across firms.

According to the Internal Ratings Based (IRB) approach of Basel II, the estimated credit risk and, consequently, the risk weights used to compute capital requirements, are assumed to be a function of four parameters associated with each loan: the probability of default (PD), the loss given default (LGD), the exposure at default (EAD) and the loan's maturity (M). Banks adopting the foundation variant of the IRB approach are only responsible for calculating the PD parameter, while the other three parameters are to be set by the regulatory authorities. As in Basel I, the ratio of bank capital to the risk-weighted assets must be at least 8%. The risk-weighted assets are, in turn, computed as follows.

1. The capital requirement for corporate exposures, under the assumption of one-year maturity, is given by[16]

$$CR = LGD \times \Phi\left[(1-\tau)^{-0.5} \times \ \Phi^{-1}(PD) + \left(\frac{\tau}{1-\tau}\right)^{0.5} \Phi^{-1}(0.999)\right] - PD \times LGD,$$

where $\Phi(.)$ denotes the cumulative distribution function for a standard normal random variable and τ represents the asset-value correlation which parameterizes dependence across borrowers and is assumed to be a decreasing function of the PD;

2. Under the foundation variant of the IRB approach, the LGD is set to 0.45 to all corporate exposures. The expected losses, $PD \times LGD$, should be covered with loss general provision. However, from the perspective of our work, provisions are treated as bank capital (as in Repullo and Suarez, 2008);

3. The risk-weighted assets are then given by $CR \times 12.5 \times EAD$.

Since all firms in our model have the same leverage ratio and, thus, the same probability of default (the same cutoff value $\overline{\omega}$), they are all assigned the same CR . The bank capital requirement constraint can thus be defined as

$$\frac{S_{t+1}}{CR_{t+1} \times 12.5 \times L_{t+1}} \geq 0.08 \Longleftrightarrow \frac{S_{t+1}}{CR^*_{t+1} \times L_{t+1}} \geq 0.08,$$

where $CR^*_{t+1} = CR_{t+1} \times 12.5$. By keeping track of how CR^* evolves over the business cycle, our model is able to give some insight into procyclicality of Basel II.

Under the foundation variant of the IRB approach of Basel II, CR^*_{t+1} varies only with PD_{t+1}. As mentioned, the probability of default on each loan in our model, $prob(\omega^j_{t+1} < \overline{\omega}_{t+1})$, depends

[16] See Basel Committee on Banking Supervision (2004), paragraph 272, for details.

positively on the cutoff value $\overline{\omega}_{t+1}$. The latter, in turn, depends positively on the ratio of capital expenditures to net worth, $\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right)$, which, for simplicity, we refer to as the leverage ratio.[17] The optimal financial contract established between the bank and each entrepreneur can thus be used to derive a positive relationship between CR^*_{t+1} and $\frac{Q_t K_{t+1}}{N_{t+1}}$ as reported in Figure 5. According to our simulations, this relationship can be approximated by the linear function

$$CR^*_{t+1} = -1.65 + 1.23 \frac{Q_t K_{t+1}}{N_{t+1}}.$$

Taking into account that the leverage ratio depends, in turn, on the loans granted to firms, since $L_{t+1} = Q_t K_{t+1} - N_{t+1}$, and that bank capital is more costly to raise than deposits, the bank's objective is now given by:

$$\begin{gathered} \max_{L_{t+1}, B_{t+1}, D_{t+1}, S_{t+1}} \left(R^F_{t+1} L_{t+1} + R_{t+1} B_{t+1} - R^D_{t+1} D_{t+1} - E_t\left(R^S_{t+1}\right) S_{t+1}\right) \\ \text{s.t. } L_{t+1} + B_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \\ \frac{S_{t+1}}{L_{t+1}} = 0.08 \left[-1.65 + 1.23 \left(\frac{L_{t+1}}{N_{t+1}} + 1\right)\right] \text{ (capital requirements constraint)} \end{gathered} \tag{19}$$

and the first order conditions of the interior solution yield

$$R_{t+1} = R^D_{t+1}, \tag{20}$$

$$R^F_{t+1} = \left[1 - 0.08 \left(a - b + 2b \frac{Q_t K_{t+1}}{N_{t+1}}\right)\right] R_{t+1} + 0.08 \left(a - b + 2b \frac{Q_t K_{t+1}}{N_{t+1}}\right) E_t\left(R^S_{t+1}\right) \tag{21}$$

As in Basel I, the required return on lending, R^F_{t+1}, depends on a weighted average of the deposits' return and the bank capital's expected return. However, the weights depend now on firms' leverage. In particular, and taking into account the log-linearized version of equation (21) - see equation (23) in the appendix -, the higher the firms' leverage, that is, the higher the credit risk, the higher the required return on lending by banks.

The calibrated model delivers, in steady state, a smaller ratio of bank capital to loans (S/L) than in Basel I (0.072 *vs* 0.08 under Basel I), which is in line with the results of Committee of European Banking Supervisors (2006). Besides, the ratio of bank capital to bank loans fluctuates over the business cycle, in contrast with Basel I. Specifically, the higher the leverage ratio, the higher the fraction of loans which must be financed by bank capital.

[17] Intuitively, everything else equal, higher leverage means higher exposure, implying a higher probability of default, which the bank translates into a higher cutoff value. The formal proof, similar to the one in BBG's Appendix A, is available from the authors.

Figures 3 and 4 show the real and financial effects of the same monetary policy shock analyzed before, under Basel I (solid line) and Basel II (dashed line). It is straightforward to conclude that the response of both economic and financial variables under Basel II is more pronounced than in Basel I.

Under Basel II, bank capital depends positively on both the level of loans (as in Basel I) and firms' leverage (see the bank's maximization problem, above). Since both variables increase after the contractionary shock, for the same reasons described before, the response of bank capital is amplified under Basel II when compared to Basel I, as illustrated in Figure 4. To hold more bank capital during the recession, households require an increase in the liquidity premium, since they must reduce the amount of deposits held in order to attenuate the decline in consumption. In fact, Figure 4 shows that the amplified increase in bank capital after the shock, under Basel II, leads to an amplified decrease in deposits and, consequently, to a marked increase in the liquidity premium required by households.

Combining the log-linearized versions of equations (20) and (21) - see the appendix - and assuming that the return on bank and physical capital follow the same path over the business cycle, yields

$$E_t\left(r_{t+1}^K\right) - r_{t+1}^F = \left(1 - 0.08 \times B\frac{R^S}{R^F}\right)\left[E_t(r_{t+1}^S) - r_{t+1}^D\right] - 0.08 \times 2b\frac{R^S - R^D}{R^F}\frac{QK}{N}lev_{t+1}$$

where $B = a - b + 2b\frac{QK}{N}$, and $lev_{t+1} = q_t + k_{t+1} - n_{t+1}$. According to this equation, the external finance premium, $E_t\left(r_{t+1}^K\right) - r_{t+1}^F$, depends positively on the liquidity premium, $E_t(r_{t+1}^S) - r_{t+1}^D$, as before, and negatively on firms' leverage, lev_{t+1}. However, the latter effect is relatively small when compared to the former.[18] Therefore, the more amplified increase in the liquidity premium under Basel II leads to a more amplified increase in the external finance premium faced by firms, when compared to Basel I, and, consequently, to a stronger decrease in physical capital expenditures and output.

In sum, our model predicts that after the contractionary shock banks must issue more capital under Basel II than under Basel I, since (i) the level of uncollateralized loans increases, (ii) firms' credit risk increases, and (iii) bank capital requirements are binding. In order to hold more bank capital, households require a higher increase in the liquidity premium, which, in turn, leads to

[18] For instance, immediately after the negative shock, the equation above can be rewritten as:

$$\begin{aligned} E_t\left(r_{t+1}^K\right) - r_{t+1}^F &= 0.8227\left[E_t(r_{t+1}^S) - r_{t+1}^D\right] - 0.0036 lev_{t+1} \Longleftrightarrow \\ 0.08908 &= 0.09548 - 0.0064 \end{aligned}$$

a higher increase in the external finance premium faced by firms. Consequently, the liquidity premium effect which underlies the bank capital channel, detailed before, is stronger under Basel II, leading to more amplified responses of both economic and financial variables after the monetary shock.

This outcome supports the procyclicality hypothesis of Basel II, mentioned in the introduction and according to which the application of the new bank capital requirements rules may further accentuate the procyclical tendencies of banking, working against the main objective of Basel II of promoting the stability of the international banking system.

4 Concluding Remarks

Focusing on how microeconomic structures - namely the bank funding structure and the relationship between banks, entrepreneurs and households - interact with macroeconomic business conditions, we have built a bank capital channel into a general equilibrium model, and found that it amplifies the real effects of monetary policy shocks and business cycle fluctuations, through a liquidity premium effect. This effect is strictly related to the financial accelerator effect underlying the borrowers' balance sheet channel: when the liquidity premium and the financial accelerator effects are both present, the external finance premium responds not only to borrowers' financial position (as in Bernanke *et al.*, 1999), but also to the liquidity premium required by households to hold bank capital. This significantly exacerbates the response of the external finance premium faced by firms to a monetary policy shock, since the liquidity premium also moves countercyclically and influences positively the external finance premium.

The amplification effect rests on the fact that bank capital, mandatory due to Basel risk-based capital requirements, is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion): after a contractionary monetary policy shock, households decrease the amount of deposits held to attenuate the decline in consumption and, as deposits are the only asset that provide liquidity services, require an increase in liquidity premium to hold bank capital.

As the amount of bank capital that banks must hold under the Basel II framework depends on the riskiness of the loans granted to firms in each moment of time, the changeover from Basel I capital requirements accentuates the aforementioned amplification effect due to the increase in firms' credit risk during a recession. Our model thus supports the Basel II procyclicality hypothesis and, consequently, the work that is currently underway in several international fora to develop tools to counteract this hypothesis, such as the building up of countercyclical capital buffers over the regulatory minimum held by the banking institutions and the use of a through-the-cycle approach to compute the default probability over the life of the loan.

Economic policy conclusions should be drawn carefully, however, since the model simplifies and abstracts from many important features of the economy. As a matter of fact, our analysis has not been concerned with questions such as whether bank regulation is itself optimal and what type of regulation is more appropriate. We ignore risk and incentives that support capital adequacy regulation, as the social cost of bank failure, and, therefore, our analysis does not attempt at any normative conclusion regarding the benefits of bank capital regulation.

So far, the value added by our work to the discussion of the role of financial imperfections in the monetary policy transmission mechanism and in business cycle fluctuations, and to the issue of procyclicality of Basel II, encourages to proceed this research. A promising direction is to introduce the aforementioned tools, which are being developed to attenuate the Basel II procyclicality, and test their effectiveness.

Appendix

A. Calibration

We calibrate the model assuming that a period is a quarter. To evaluate the parameters and steady state (SS) variables common to the BGG's model, we followed these authors, focusing on U.S. data. See Table 1 and BGG for details.

Entrepreneurial Consumption/Output in SS	$\frac{C^e}{Y}$	0.01
Government Expenditure/Output in SS	$\frac{G}{Y}$	0.2
Gross Markup of Retail Goods over the Wholesale Goods in SS	X	1.1
Price of Capital in SS	Q	1
Elasticity of the price of capital with respect to I/K	φ	0.25
Capital Share	α	0.35
Labor Supply Elasticity	η	3
Depreciation Rate	δ	0.025
Interest Rate Smoothing	ρ	0.9
Coefficient on inflation in the interest rate rule	ς	0.11
Prob. that an entrepreneur survives to the next quarter	γ	0.9728
Probability of a firm does not change its price within a given period	θ	0.75
Serial correlation parameter for technology shock	ρ_a	1
Serial correlation parameter for gov. expend. shock	ρ_g	0.95
Standard Deviation of $\ln(\omega)$	$\sigma_{\ln \omega}$	0.28
Monitoring Costs Parameter	μ	0.12
Loans/Deposits in SS	$\frac{L}{D}$	0.75
Bank Capital Requirement	α_e	0.08
Preference Parameter	σ	1
Preference Parameter	β_1	1
Preference Parameter	β_0	1

Table 1: Calibration

To compute the SS ratio of loans to deposits, $\frac{L}{D}$, we use data on commercial and industrial (C&I) loans made by all U.S. commercial banks - provided by the Survey of Terms of Business Lending that is published by the Federal Reserve - and data on the total loans and deposits at all U.S. commercial banks - available at the Federal Reserve Bank of St. Louis.

In calibrating the preference parameters, we assume, for simplicity, that $\sigma = \beta_0$. By that, we only need to compute the deposit to consumption ratio in steady state $\left(\frac{D}{C}\right)$ to solve the model, instead of defining both variables, C and D, separately. And, as in many business cycle models, including BGG, σ is set equal to 1 (log preferences).

The other parameters and variables in steady state are set in the following way:

1. v, $\frac{R^K}{R^F} = l$, $\frac{QK}{N}$, and Z follow from the computation of $\overline{\omega}$, which, according to the optimal financial contract established between the bank and each entrepreneur in steady state, must

satisfy the following condition

$$l(\overline{\omega}) - (1-\delta)\frac{1}{R^F} = \frac{\alpha}{(1-\alpha)(1-\Omega)}\left[\frac{1}{R^F}\frac{1}{LEV(\overline{\omega})} - \gamma l(\overline{\omega})(1-\Gamma(\overline{\omega}))\right],$$

where $LEV = \frac{QK}{N}$ and $\Gamma(\overline{\omega}) \equiv \int_0^{\overline{\omega}} \omega^j f(\omega)d\omega + \overline{\omega}\int_{\overline{\omega}}^{\infty} f(\omega)d\omega$. Details on $\overline{\omega}$ and v computation are available upon request. See also Gertler *et al.* (2007).

2. The variables and parameters must satisfy the steady state equations derived from the model's FOC and optimization constraints.

3. R represents the quarterly steady state real gross return on government bonds. Taking into account the first Euler equation (3) evaluated in steady state,

$$1 = \beta R^D + \alpha_0 \left(\frac{D}{C}\right)^{-\sigma}$$

and the relationship between R and R^D (see equation 8), we set the parameter α_0 to guarantee $R = 1.01$ in steady state (a value which is assumed by many other business cycle models, including BGG, for the riskless real rate of return, since it guarantees an average riskless interest rate of 4% per year).

B. The log-linearized equations of the Basel II extension

By log-linearizing equations (20) and (21), derived from the bank's objective first order conditions, we get:

$$r_{t+1} = r^D_{t+1} \tag{22}$$

$$\begin{aligned} r^F_{t+1} &= 0.08\left(a - b + 2b\frac{QK}{N}\right)\frac{R^S}{R^F}E_t\left(r^S_{t+1}\right) + \left[1 - 0.08\left(a - b + 2b\frac{QK}{N}\right)\right]\frac{R^D}{R^F}r^D_{t+1} + \\ &\quad + 0.08 \times 2b\frac{R^S - R^D}{R^F}\frac{QK}{N}(q_t + k_{t+1} - n_{t+1}). \end{aligned} \tag{23}$$

Additionally, the log-linearized version of the binding capital constraint is

$$s_{t+1} = \left(\frac{K}{L} + 0.08b\frac{L}{S}\frac{QK}{N}\right)(k_{t+1} + q_t) - \left(\frac{N}{L} + 0.08b\frac{L}{S}\frac{QK}{N}\right)n_{t+1}. \tag{24}$$

Figures

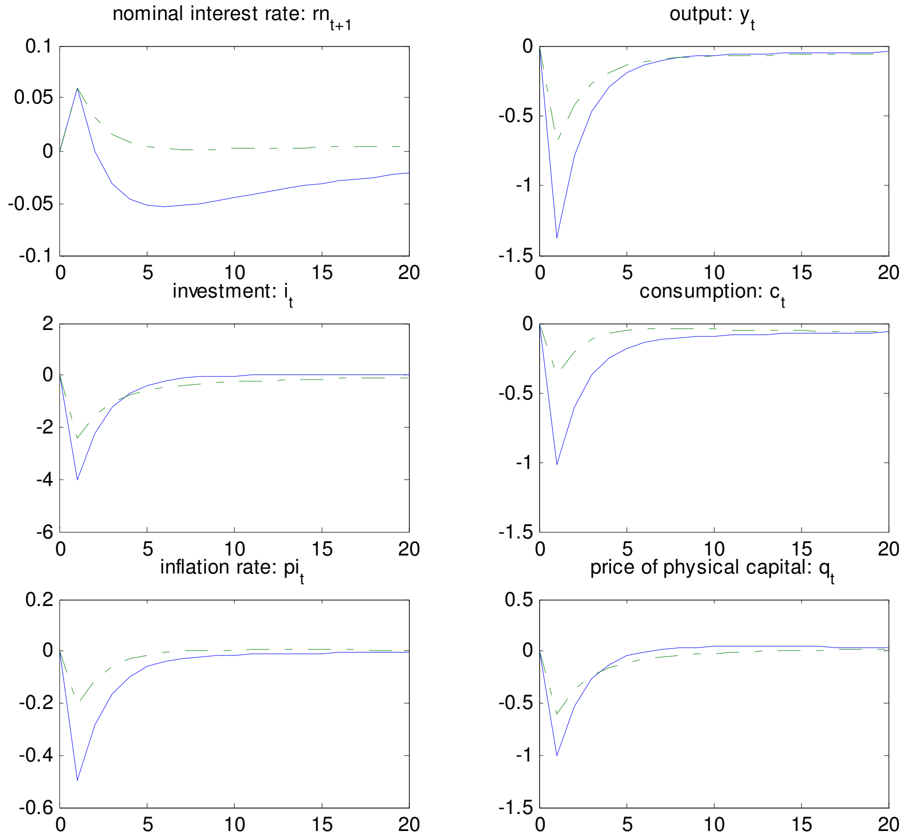

Figure 1: Response of economic activity to a negative monetary policy shock: Basel I (solid line) *vs* BGG (dashed-dotted line).

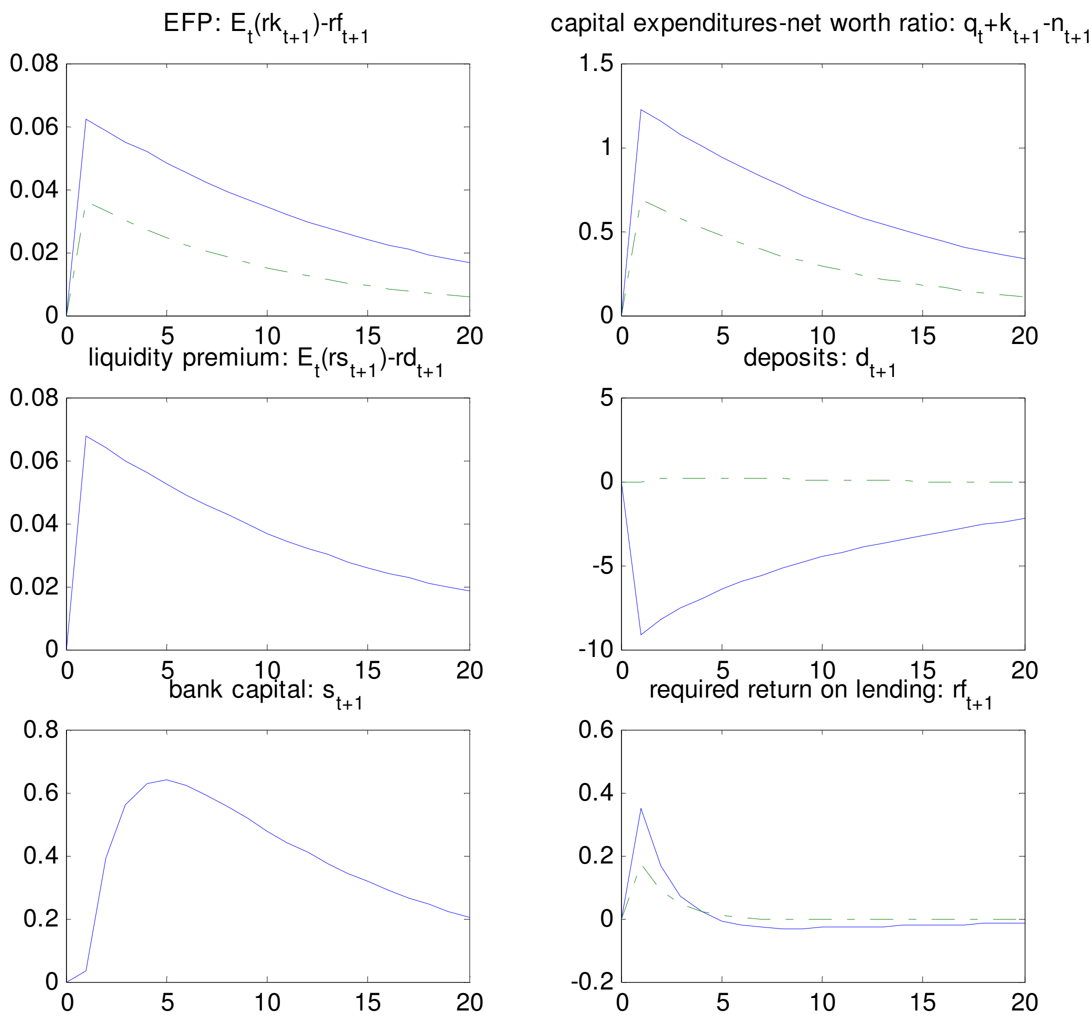

Figure 2: Response of financial variables to a negative monetary policy shock: Basel I (solid line) *vs* BGG (dashed-dotted line).

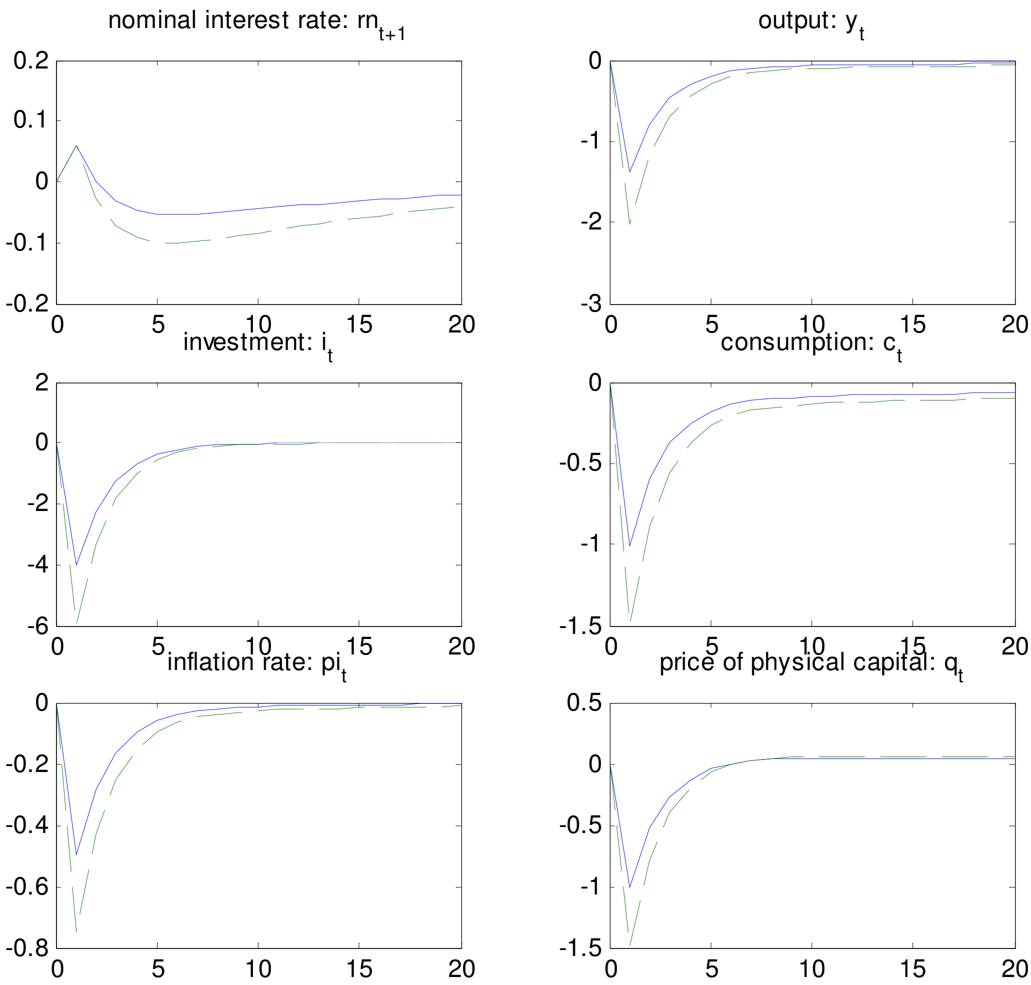

Figure 3: Response of economic activity to a negative monetary policy shock: Basel I (solid line) *vs* Basel II (dashed line).

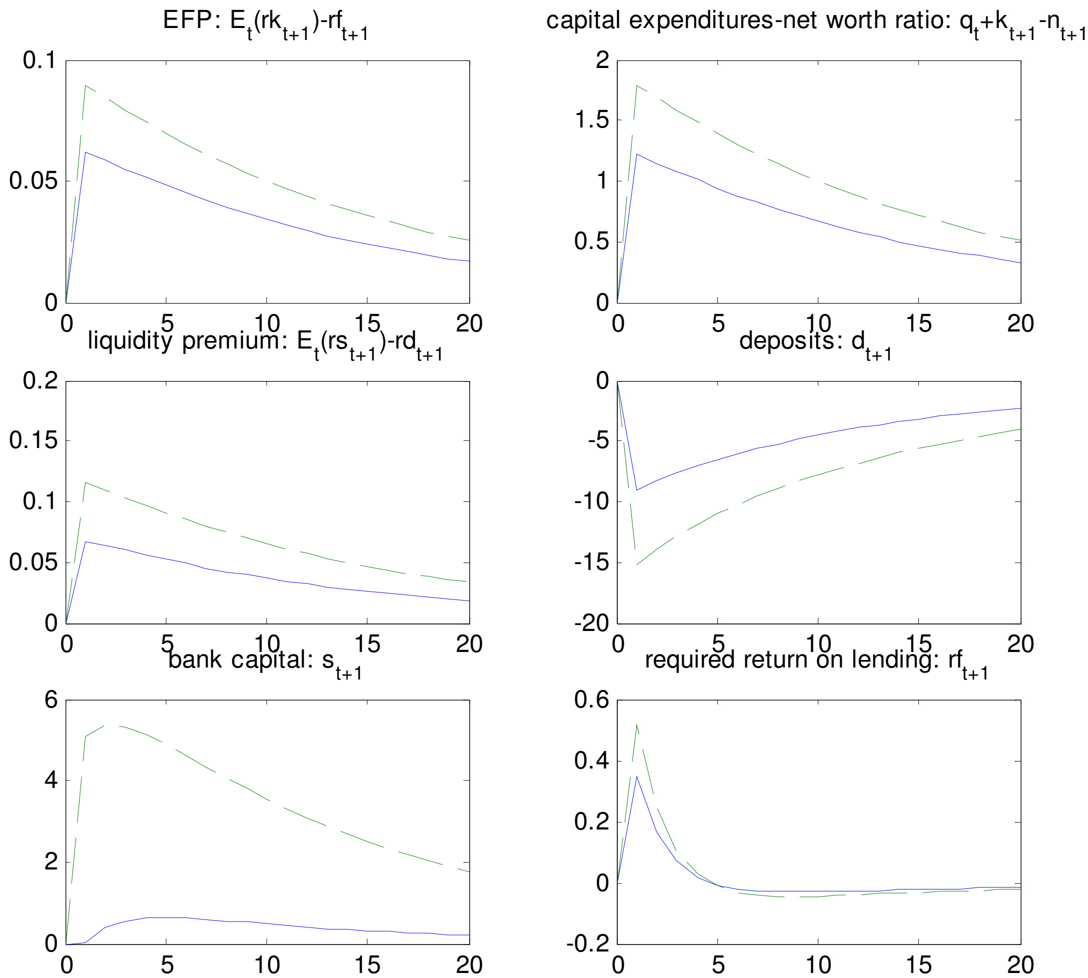

Figure 4: Response of financial variables to a negative monetary policy shock: Basel I (solid line) *vs* Basel II (dashed line).

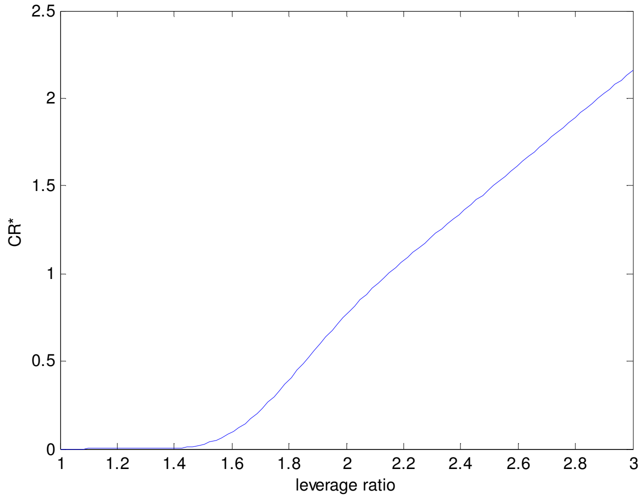

Figure 5: Relationship between the leverage ratio and the capital requirements weights, under Basel II, derived from the steady state optimal financial contract.

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