Basel II and Business Cycles

By

Fabian Valencia
The Johns Hopkins University
fvalencia@jhu.edu

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Abstract[a]

This paper compares the behavior of a rational, infinite-horizon bank in a world where capital requirements are risk-sensitive (a proxy for Basel II) to a benchmark case in which they are not (a proxy for the current regime). In the model, borrowers' risk varies with the state of the economy and hence risk-sensitive capital requirements are procyclical. A key feature of the model, is that the bank hedges against the volatility of capital requirements by maintaining a buffer stock of bank capital. A negative productivity shock (an economic downturn in this framework) causes a deviation of solvency from the bank's long-run target, triggering a credit crunch which lasts until the bank restores its solvency level. Due to the tightening of capital requirements during the economic downturn, the resulting credit crunch under Basel II is worse than the one arising under Basel I. Nevertheless, the difference is relatively small. Consequently, the view that the procyclicality problem of Basel II can be solved by adjusting banks' capital buffers is confirmed in this model even when the volatility of capital requirements is very high and the negative productivity shock is large.

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1 Introduction

A substantial revision of commercial bank capital adequacy regulations is now being developed and is expected to be implemented in the Group of 10 countries in the next couple of years.[1] This new framework, Basel II, is far more complex than the 1988 Accord, Basel I.[2] It consists of three "pillars:" a new capital adequacy requirement,[3] supervisory review, and market discipline.

The primary focus of the reform is enhancement of the way in which the 1988 Basel Accord handles credit risk. Under the current regime, assets making immensely different contributions to portfolio credit risk often receive similar regulatory capital treatment. The result is a wedge between the market assessment of asset risks[4] and its regulatory counterpart, creating strong incentives for banks to restructure their activities and balance sheets.[5] The new accord has raised concerns about a number of issues, including its impact on macroeconomic stability.

The macroeconomic implications of risk-sensitive capital requirements have been widely debated during the consultation process for Basel II. Critics argue that new requirements may exacerbate cyclical deviations from potential output. During an economic downturn, lending risks typically increase, which under Basel II, would tighten capital requirements; this could force banks to limit their lending, thus intensifying the downturn.[6] The direct consequence of more precise risk assessment

[1] See Basel Committee on Banking Supervision (2005) for the latest version of the report describing the new framework.

[2] The Basel Accord, released in July 1988 by the Basel Committee on Banking Supervision required internationally active banks from the G10 countries to hold a minimum total capital equal to 8% of risk-weighted assets. The Accord was later amended to cover market risks.

[3] Basel II offers an array of options for assessing the capital adequacy of banks, including technically sophisticated alternatives, based on banks' internal ratings systems, but also comprising simpler approaches, based mainly on external ratings of borrowers

[4] In the banking jargon this is usually referred to as "economic capital requirements, "defined as the capital needed for a portfolio such that credit losses exceed capital with only a specified small probability. See Jokivuolle and Peura (2004).

[5] such activity is often called "capital arbitrage" or "regulatory arbitrage."

[6] See Danielsson, Embrechts, Goodhart, Keating, Muennich, Renault, and Shin (2001), Saiden-

is then a procyclical feature in capital requirements, implying a trade-off between greater efficiency in bank capital allocation and financial stability.

The business-cycle implications of Basel II are likely to depend on the extent to which measured risk changes over the business cycle and individual banks respond to the resulting changes in capital requirements.[7] By now, there are a great number of studies that focus on determining cyclical patterns in internal or external borrowers' ratings. The conclusions are mixed. Kashyap and Stein (2004), for instance, find that Basel II could indeed introduce additional cyclicality with significant economic effects. Carpenter, Whitesell, and Zakrajsek (2001), on the other hand, find no evidence of substantial additional cyclicality in capital requirements under the new regime. Gordy and Howells (2006) simulate an actively-managed portfolio using an exogenous lending rule and analyze several alternatives to dampen the procyclicality of Basel II. They find less procyclicality under the actively-managed portfolio than in the case of a passive portfolio as in Kashyap and Stein (2004).[8]

Several authors have suggested that the problem of procyclicality could be mitigated by hedging against the increased volatility of the minimum capital requirement. In such case, banks would simply adjust their capital buffers as a response to the additional volatility of capital requirements. The idea is that during normal times banks should hold capital above the minimum requirements to mitigate tightening capital requirements during economic downturns. However, even in the case of a bank who rationally self-insures against fluctuations in capital requirements, there could be a shock large enough that could trigger a severe credit crunch in the economy. The question is then, to what extend such event is exacerbated by

berg and Schuermann (2003), and others.

[7]Measured risk will also be sensitive to the loan-rating scheme chosen by the individual bank. See Catarineu-Rabell, Jackson, and Tsomocos (2005) and Jordan, Peek, and Rosengren (2002).

[8]Kashyap and Stein (2004) cite a number of empirical studies whose goal is to estimate the change in capital requirements derived from the cyclical variation of borrowers' default risk. Results vary significantly across papers.

risk-sensitive capital requirements. A proper answer to this question requires formal modeling of a bank's optimal decisions, which is what this paper pursues here. This paper provides a framework to analyze explicitly the buffer stock behavior of a bank in a micro-founded environment. The model presented here constitutes an adaptation of the framework developed in Valencia (2005). However, the idea of a precautionary behavior in banking has been directly or indirectly addressed in previous studies and some examples worth mentioning include Van Den Heuvel (2002), Estrella (2004), Furfine (2001), Jokivuolle and Peura (2004), Keppo and Peura (2005), and Valencia (2005).

The point of departure of this paper will be the assumption that risk-sensitive capital requirements are procyclical with default risk, which serves as a proxy for Basel II. The salient implication of this model is the existence of a target level of solvency. Negative deviations from this target level may trigger a credit crunch that persists until the bank restores the level of capital. The model is also solved also under a benchmark scenario that is a proxy for Basel I. In that case, capital requirements are equal to the average across the states of the economy of those under the Basel II scenario, thus invariant to changes in the state of the economy. The optimal responses of the bank are used to simulate the behavior of lending after a negative macroeconomic shock under both scenarios. As expected, the negative shock causes a credit crunch until the bank returns to equilibrium. Although the credit crunch under the Basel II scenario is more severe than the one arising under Basel I, the difference is relatively small due to the precautionary behavior of the bank. The buffer stock of capital is used then to mitigate the procyclical problem of Basel II. This result holds even in the case of a large and negative productivity shock and a considerably large amount of volatility in capital requirements. Therefore, the idea that the procyclicality problem of Basel II can be solved by adjusting the capital buffers seems to be corroborated by the model even in the case of very high volatility of capital requirements and large swings in the economy.

This paper is organized as follows: the next section provides the model details. Sections 3 and 4 provide the values for the parameters and the numerical solutions respectively. Section 5 implements quantitative experiments using the optimal decision rules, and section 6 concludes.

2 The Environment

The recession of the early nineties coincided with a decline in credit in many countries around the world. Many refer to that episode as the "*credit crunch*"period. A number of studies were undertaken in order to determine the causes of the credit crunch and how it affected the real economy,[9] with the purpose of understanding if the credit crunch had any impact on the magnitude of the recession. One of the hypotheses examined by many researchers was that the introduction of risk-based capital requirements, Basel I, around the world was the cause of or at least one of the causes of the credit crunch. However, empirical tests in the U.S. and other countries provided mixed results, and the hypothesis that Basel I caused the credit crunch lacked clear-cut support.[10]

Although it has been more than a decade since the implementation of the original capital accord, the aggregate implications of capital requirements are not yet completely understood.[11] A new accord is about to be implemented and its potential effects have been discussed from almost every perspective. The objective of this paper, is to analyze the macroeconomic consequences of the change in bank

[9]See Berger and Udell (1994), Bernanke and Lown (1991), Hancock and Wilcox (1994), Peek and Rosengren (1995) for an analysis of the U.S. and Vihriala (1996) for the Finnish experience.

[10]See Jackson (1999) for a literature review.

[11]See Cecchetti and Li (2005) and Morrison and White (2005) for two recent deliveries regarding the aggregate implications of bank capital regulation.

capital regulation with special attention to its possible impact on business cycles. The paper is not concerned with the complete analysis of benefits and costs of risk-sensitive capital requirements, therefore, the regulatory framework is assumed to be exogenous.

The regulatory framework in this model then imposes a cost on the bank whenever leverage increases. The bank then holds capital to mitigate regulatory costs. While in practice is it not clear whether economic capital requirements dominate regulatory capital requirements or the other way around,[12] this paper assumes the latter. In that case, one would expect that a change in regulatory restrictions will certainly induce a change in the behavior of the bank. Such an assumption may seem extreme at first, but its justification comes from the goal of determining what type of effects can be expected in the extreme case in which regulatory restrictions are the sole determinant of bank capital holdings.

The bank is modeled as a monopoly that makes "*take-it-or-leave-it*"offers to entrepreneurs that include an interest rate and a loan amount. The bank raises deposits to fund new lending, but equity finance is assumed to be prohibitively expensive. There exist a continuum of ex-ante identical entrepreneurs who borrow from the bank to invest in a two-period investment project. Entrepreneurs live for only two periods and consume when the outcome of the project is realized.

The intuition behind the model is as follows: because a low capital level induces high regulatory costs, the bank has the incentive to increase solvency when it is low, but when solvency is too high–and regulatory costs are virtually zero–the bank distributes dividends because stockholders' discount rate exceeds the risk-free rate–

[12] Alternatively, one could introduce both mechanisms, one in which financial markets impose a penalty as leverage increases, proxying for increases in expected default costs (see Valencia (2005)), and one proxying for regulatory restrictions. It is clear that the maximum of the two will dominate the other.

the interest rate paid on deposits.[13] The bank, then has a target level of solvency. Default risk of individual borrowers depends on the aggregate state of the economy, captured by aggregate productivity. Therefore, whenever a decline in productivity takes effect, defaults increase and the bank's capital position weakens. The goal is then to analyze the adjustment towards equilibrium under two scenarios, one in which the regulatory restrictions are sensitive to borrowers risk, which in turn is linked to aggregate productivity–a proxy for Basel II–, and a second one in which such restrictions do not respond to changes in productivity over the business cycle.

2.1 Entrepreneurs

The borrower-bank relationship follows the same structure as Valencia (2005).[14] Borrowers are ex-ante identical, and to avoid the complication of keeping track of their entire credit history, it is assumed that they live for only two periods. They all have access to a common production technology which uses only capital, k, as an input. Ex-post production, y, at time $t+2$, is given by

$$y_{t+2} = \alpha_{t+2}\Phi_{t+2}k_{t+2} \tag{1}$$

where α and Φ are productivity shocks of idiosyncratic and aggregate nature respectively, both assumed to be lognormal and i.i.d. During the lifetime of the investment project, there will be only one realization of productivity that will affect the outcome of the project. Entrepreneurs are all endowed with a common amount of resources at birth, which for simplicity is normalized to 1. However, there is a minimum scale for investment projects that exceeds the value of endowment. Entrepreneurs use their endowment and loans from the bank, l, to acquire capital at a unit price,

[13] There is an implicit assumption that all deposits are insured.

[14] The contracting framework is based on Gale and Hellwig (1985).

which implies

$$k_{t+2} = (1 + l_t) \tag{2}$$

The normalization of endowment equal to 1 implies that the amount borrowed can be interpreted as leverage. The bank makes "*take-it-or-leave-it*"offers to entrepreneurs that include an interest rate, R_t, and loan amount, l_t. For an entrepreneur who accepts the bank's offer, ex-post profits will be determined by the outcome of production minus payments to the bank; that is[15]

$$\pi(\alpha_{t+2}, \Phi_{t+2}, l_t, R_t) = \alpha_{t+2}\Phi_{t+2}(1 + l_t) - l_t R_t \tag{3}$$

Capital depreciates fully by the end of production. Since an entrepreneur's decision is limited to accepting or rejecting the bank's offer and α is assumed to be continuously distributed over a non-negative support, there exists a cutoff value $\underline{\alpha} \; \epsilon \; [0, \infty)$ such that the return to an entrepreneur is equal to zero. For realizations of α above this cutoff value, an entrepreneur's surplus is given by (3). Otherwise, he declares bankruptcy, earns a zero return, and the bank seizes output. The cut-off value of productivity $\underline{\alpha}$ is defined by

$$\underline{\alpha}_{t+2}\Phi_{t+2}(1 + l_t) - l_t R_t = 0 \tag{4}$$

$$\underline{\alpha}(R_t, l_t, \Phi_{t+2}) = \frac{R_t l_t}{(l_t+1)\Phi_{t+2}} \tag{5}$$

Imposing limited liability to guarantee a non-negative consumption level in the second period, the return to the borrower can be summarized as follows

$$\pi(\alpha_{t+2}, \Phi_{t+2}, l_t, R_t) = \begin{cases} \alpha_{t+2}\Phi_{t+2}(1 + l_t) - l_t R_t & \text{if } \alpha_{t+2} \geq \underline{\alpha}(R_t, l_t, \Phi_{t+2}) \\ 0 & \text{if } \alpha_{t+2} < \underline{\alpha}(R_t, l_t, \Phi_{t+2}) \end{cases} \tag{6}$$

[15]For notation clarity, the superscripts on idiosyncratic productivity have been omitted, but keep in mind that the ex-ante identical borrowers are ex-post different.

An entrepreneur accepts the bank's offer if the expected return from the project is at least as good as his opportunity cost. An entrepreneur's problem then can the be written as

$$\underset{\{accept,reject\}}{Max}\Big[E_t\big(\pi(\alpha_{t+2},\Phi_{t+2},l_t,R_t)\big),(1+\rho)^2\Big] \tag{7}$$

where ρ denotes the one-period risk-free rate, assumed to be constant over time.[16] Should an entrepreneur accept the bank's offer, it is assumed that he is required to invest the entire endowment on the project. Participation of any entrepreneur is subject to a rationality constraint that requires the rate of return from the project to be at least as good as an entrepreneur's opportunity cost. Hence the bank's offer of R_t and l_t must satisfy

$$E_t\big(\pi(\alpha_{t+2},\Phi_{t+2},l_t,R_t)\big)\geq(1+\rho)^2 \tag{8}$$

With the "*take-it-or-leave-it*" assumption and assuming an interior solution, equation (8) will hold with equality. Otherwise, the bank can always increase the interest rate and would still have a borrower accepting the offer. Equation (8) determines implicitly the lending interest rate as a function of the amount lent, $R(l_t)$.[17]

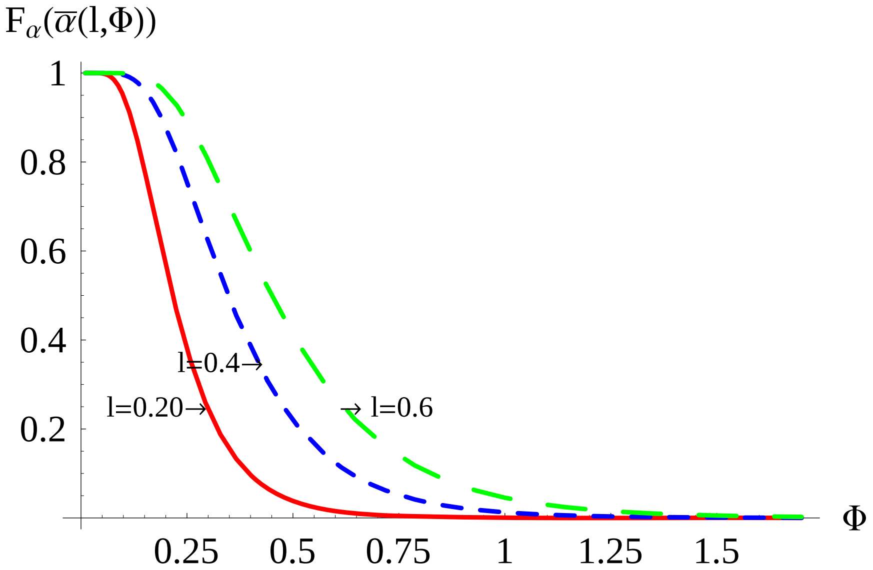
Notice that the probability of default of an individual borrower can be written as $F_\alpha(\underline{\alpha}(R(l),l,\Phi)$, where $F_\alpha(\cdot)$ denotes the cumulative distribution function of α. The probability of default of an individual borrower is then affected by the level of aggregate productivity in the economy and therefore, borrowers' creditworthiness is going to fluctuate over time. The contracting framework adopted here makes it straightforward to introduce aggregate risk in the model; however, it comes with a cost: optimality of the contract may not be preserved. The way that aggregate risk

[16] $(1+\rho)^2$ denotes the two-period compounded return for the entrepreneur.

[17] It is assumed that $E[\alpha]>(1+\rho)^2$, to guarantee a positive lending rate.

is introduced in the model generates a departure from the Gale and Hellwig (1985) framework, but yields the benefit of analyzing in a very simple way the effects of aggregate uncertainty.[18] Figure 1 depicts the default probability of borrowers as a function of loan amount and aggregate productivity. Default risk decreases with aggregate productivity.

Figure 1: Probability of default



Following Townsend (1979), Gale and Hellwig (1985), and Williamson (1987), with costly state verification, once idiosyncratic productivity α is realized, it is assumed to remain the private information of entrepreneurs. The bank may observe the productivity realization of an entrepreneur only after paying monitoring costs $1 > u > 0$, expressed as a fraction of a borrower's project value. The revenues obtained by the bank from an individual borrower can be summarized by

$$g(\alpha_{t+2}, \Phi_{t+2}, l_t) = \begin{cases} R(l_t)l_t & \text{if } \alpha_{t+2} \geq \underline{\alpha}(R(l_t), l_t, \Phi_{t+2}) \\ (1-u)\alpha_{t+2}\Phi_{t+2}(1+l_t) - l_t R(l_t) & \text{if } \alpha_{t+2} < \underline{\alpha}(R(l_t), l_t, \Phi_{t+2}) \end{cases} \quad (9)$$

Because of the law of large numbers, ex-post aggregate revenues for the bank are obtained by averaging across the realizations of idiosyncratic productivity of entre-

[18] To be sure that the optimality of the contract is preserved, as in Gale and Hellwig (1985), it would be sufficient to have the lending rate contingent on aggregate productivity.

preneurs. Denoting with $M[\cdot]$ the mean of a variable across borrowers, aggregate revenues for the bank are given by

$$G(l_t, \Phi_{t+2}) = \underset{\alpha}{M}\left[g(l_t, \alpha_{t+2}, \Phi_{t+2})\right] \tag{10}$$

2.2 The Bank

The bank is assumed to be owned by risk-neutral stockholders who maximize the present discounted value of future dividends by simultaneously choosing dividends (d_t), lending (l_t) and deposits (c_t)

$$\underset{\{d_t, c_t, l_t\}}{Max} \sum_{s=t}^{\infty} \beta^{s-t} d_s \tag{11}$$

The bank makes decisions in the middle of each period, and uncertainty is revealed between periods. It is assumed that the bank faces regulatory restrictions in the form of risk-based capital adequacy requirements. For simplicity and analytical convenience, those requirements are embedded in the model in the form of a continuous penalty function that decreases with the capital adequacy ratio of the bank, to be defined momentarily.[19]

The transition between periods can be described as follows: at the end of period $t-1$, the bank has already made its decisions and has state variables $c_{t-1}, l_{t-1}, andl_{t-2}$, where l_{t-2} denotes the loans granted in period $t-2$ that will mature in period t. Uncertainty is realized between periods $t-1$ and t, and the values of Φ_t and idiosyncratic productivity of entrepreneurs become known. It is assumed that right after the realization of aggregate productivity, but before loans

[19]The continuity of the penalty function implies that even if the bank holds capital above the minimum it will still face a small cost. One can argue that as the bank gets close to violating regulatory constraints, authorities will take preemptive measures to guarantee that the bank will not become undercapitalized

mature, the capital adequacy ratio of the bank is monitored by regulators. Regulators then charge a fine to the bank, denoted with f_t, which from now on will be called *regulatory costs*. The bank then collects revenues $G(l_{t-2}, \Phi_t)$ and it pays to depositors principal and interest $(1+\rho)c_{t-1}$. Deposits are assumed to be implicitly insured and therefore the deposit rate equals the constant and exogenous risk-free rate. The result is a new level of book value of bank capital given by the difference between assets and liabilities: $n_t = G(l_{t-2}, \Phi_t) + l_{t-1} - (1+\rho)c_{t-1} - f_t$.[20] The bank then arrives at the middle of period t with state variables n_t and l_{t-1}. Decisions on c_t, l_t, and d_t are made and the bank ends the period with state variables c_t, l_t, and l_{t-1}. Table 1 summarizes the steps just described.

Table 1: **B**ank's Sequence of Events

t-1
State variables after decisions are made: $c_{t-1}, l_{t-1}, l_{t-2}$
t
Uncertainty is realized: Φ_t
Bank capital after profits $n_t = G(l_{t-2}, \Phi_t) + l_{t-1} - (1+\rho)c_{t-1} - f_t$
Bank's state variables: n_t, l_{t-1}
Bank chooses: c_t, l_t, d_t
State variables after decisions are made: c_t, l_t, l_{t-1}

[20] An alternative way to write equation (15) is to define profits as $\wp = \underbrace{G(l_{t-1}, \Phi_{t+1}) - l_{t-1} - (\rho)c_t}_{\text{Interest Margin}} - f_{t+1}$, and the transition equation for bank capital as $n_{t+1} = n_t - d_t + \wp$

2.2.1 The Dynamic Optimization Problem

The dynamic problem of the bank, written in Bellman's equation form, is shown below

$$V(n_t, l_{t-1}) = \underset{\{c_t, l_t, d_t\}}{Max} \Big[d_t + \beta E_t V(n_{t+1}, l_t) \Big] \tag{12}$$

s.t.

$$l_t + l_{t-1} \leq c_t + n_t - d_t \tag{13}$$

$$d_t \geq 0 \tag{14}$$

$$n_{t+1} = G(l_{t-1}, \Phi_{t+1}) + l_t - (1+\rho)c_t - f_{t+1} \tag{15}$$

Equation (13) tells us that the amount of liabilities is at least as large as the amount of loans or assets. The liability side includes deposits and bank capital net of dividends. Since it is assumed that it is infinitely costly for the bank to issue equity, constraint (14) restricts dividends to be non-negative. Finally, equation (15) denotes the transition equation for the book value of bank capital.

It is assumed that the fine the bank pays to regulators takes the following form: $vc_t \frac{c_t}{\omega(\Phi_t)l_{t-1} + \omega(\Phi_{t+1})l_t}$, with $v > 0$, where $\omega(\Phi_t)l_{t-1} + \omega(\Phi_{t+1})l_t$ denotes the risk-weighted value of the loans portfolio, where $\omega(\Phi)$ denotes the risk weights for each component of the loans portfolio, as a function of aggregate productivity. This last assumption captures the cyclical nature of risk-sensitive capital requirements. The assumed fine implies that regulatory costs increase with the leverage level of the bank, expressed as the ratio of deposits to risk-weighted assets. This fine can be interpreted as the monetary consequences of intense regulatory scrutiny as solvency declines. This assumption also implies that equation (13) holds with equality. Otherwise, the bank can always increase profits by reducing the amount of deposits, and therefore decreasing regulatory costs.[21]

The capital adequacy ratio of the bank can be computed using $\frac{n_t - d_t}{\omega(\Phi_t)l_{t-1}+\omega(\Phi_{t+1})l_t}$. Hence, the assumed fine decreases as the capital adequacy ratio increases. [22] In this model, the bank holds a positive amount of bank capital because of the existence of regulatory constraints. Since this is the sole friction in this model, one would expect that changes in bank capital regulation will have a strong effect on the bank's optimal behavior. In reality, regulation is not the only friction banks face. Their decisions may also be determined by economic capital requirements, deposit insurance premia, and other mechanisms. Therefore, whether a change in regulation will have a strong, mild, or weak effect will depend on which is the dominant mechanism. As mentioned earlier, by imposing only capital requirements, this model incorporates bank capital regulation as the dominant factor.

Recall that Figure 1 showed how the probability of default of any borrower declines with the value of aggregate productivity, Φ, which is the source of aggregate fluctuations in this framework. The simplistic assumption of having regulatory costs linked to aggregate productivity captures the idea of capital requirements changing over the business cycle due to fluctuations in default risk in the loans portfolio. Thus, the $\omega(\Phi)$ function is assumed to be non-increasing in aggregate productivity. The penalty function imposed here can be interpreted as the requirements for the overall portfolio after aggregation. Furthermore, the Basel I benchmark is constructed assuming constant weights that are equal to the average of the risk-sensitive weights, and for simplicity it has been normalized to 1. That is, $1 = \overline{\omega} = \int_0^\infty \omega(\Phi) dF_\Phi$.

[21]Notice that equation (13) can be simply referred as the balance sheet identity of the bank.

[22]Substituting out deposits, the fine can be written as $(l_{t-1}+l_t-(n_t-d_t))\left(\frac{l_{t-1}+l_t-(n_t-d_t)}{\omega(\Phi_t)l_{t-1}+\omega(\Phi_{t+1})l_t}\right)v$, then $f^n = -2\left(\frac{l_{t-1}+l_t-(n_t-d_t)}{\omega(\Phi_t)l_{t-1}+\omega(\Phi_{t+1})l_t}\right)v < 0$ for $l_{t-1}+l_t-(n_t-d_t) > 0$.

2.2.2 First Order Conditions

After substituting out deposits, the problem can be written with respect to only two control variables, and the solution obeys the following first order conditions.

$$1 = \beta E_t\big[1 + \rho + f^d_{t+1}\big]V^n(n_{t+1}, l_t) \tag{16}$$

$$0 = E_t\Big[V^l(n_{t+1}, l_t) + (1 - \rho - f^l_{t+1})V^n(n_{t+1}, l_t)\Big] \tag{17}$$

Equations (16) and (17) are the first order conditions with respect to dividends and lending, respectively. The left-hand side of equation (16) denotes the marginal value of dividends, while the right-hand side denotes the marginal value of internal funds. The amount of dividends distributed is such that the marginal value of dividends equals the marginal value of internal funds. When bank capital is low, its marginal value is high because of high regulatory costs (because $f^n < 0$). The bank then reduces the distribution of dividends until equation (16) is satisfied. When bank capital is high, then impatience[23] induces the bank to distribute dividends until the marginal value of dividends equals the marginal value of internal funds.

As far as lending decisions are concerned, the first term in the right-hand side of equation (17) denotes the expected marginal benefits from lending, while the second term corresponds to the cost that the bank incurs in raising funds to make new loans. The optimal amount of lending is such that the marginal benefit equals the marginal cost. Notice that the cost is determined by the interest payments on new deposits and the additional regulatory costs because of the increase in leverage. Also notice that these costs are also affected by the change in the future value of the bank, because today's lending decisions affect the bank's future capital position.

Now consider equation (16). In the case of Basel I, uncertainty affects the mar-

[23] $\frac{1}{\beta} - 1 > \rho$.

ginal value of internal funds only through revenues. However, in the case of the proxy for Basel II, uncertainty has an additional impact through the risk weights that are used in the regulatory penalty function. The uncertainty about regulatory costs generates a precautionary motive which induces the bank to hold more capital as a buffer against the additional volatility in capital requirements. This effect can be better appreciated in Figure 2.

Figure 2: Target level of Solvency

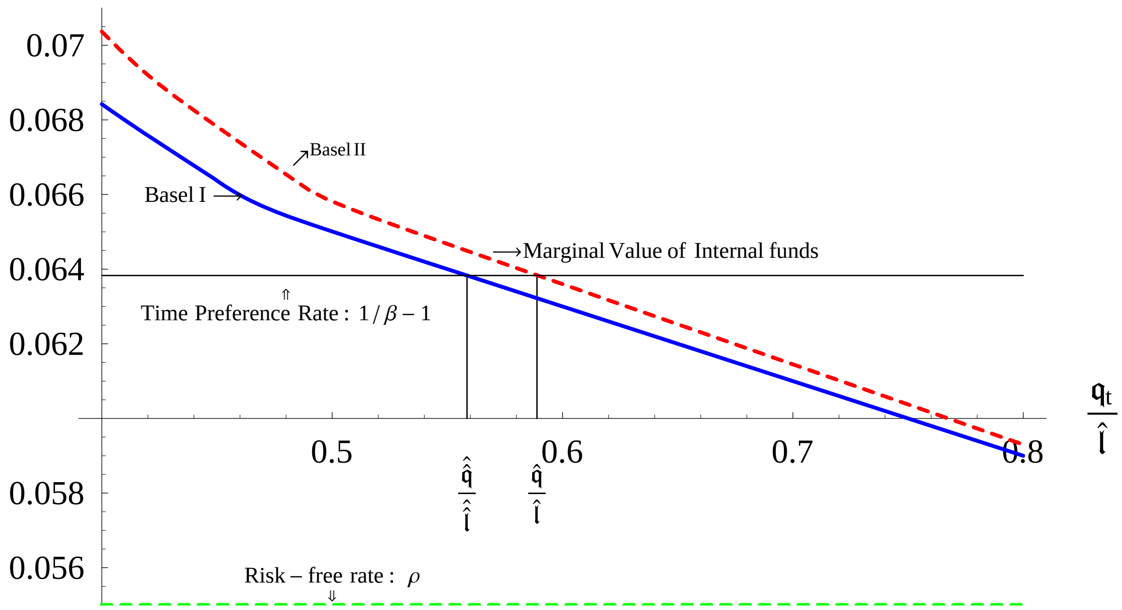


Figure 2 plots equation (16) after some algebra.[24] The figure plots the marginal value of internal funds[25] as a function of end-of-period solvency, denoted by the ratio of bank capital after dividends, denoted with $\mathfrak{q}$, to the size of the loans portfolio at the end of the period, $\mathfrak{l}$. The graph shows two scenarios: the solid line depicts the Basel I benchmark, and the dashed line depicts the Basel II case. As mentioned earlier, the marginal value of internal funds is high when solvency is high. The

[24]The figure shows the right-hand side of $\frac{1}{\beta} - 1 = \rho + E_t[f^d_{t+1}]V^n(n_{t+1}, l_t)$.
[25]The parameter values used to construct the figure are shown in the next section.

interaction between decreasing marginal value of internal funds and the impatience condition (that is $\frac{1}{\beta} > 1 + \rho$) generate a target level of solvency, as depicted in the graph.[26] Notice however, that when the model is solved under the assumption of cyclical capital requirements, the target level of solvency is higher. This target is time-invariant due to the assumption of i.i.d. shocks.

3 Parameter Values

The baseline model is solved assuming the following parameter values:

Table 2: **P**arameter Values

σ_α	0.5
$E[\alpha]$	1.15
σ_Φ	0.3
$E[\Phi]$	1
β	0.94
ρ	5.5%
u	0.20
$\omega(\Phi)$	=0.01 If $\Phi \geq 2$ =1.99m1-0.99$*\Phi$ If $0.2 \leq \Phi < 2$ =1.79 If $\Phi \leq 0.2$
v	0.01

4 Solution

The model is solved numerically by applying backwards induction to the first order conditions until the policy functions converge. The converged rules $\lim_{i\to\infty} l_{t-i}(n,l) = l(n,l)$ and $\lim_{i\to\infty} d_{t-i}(n,l) = d(n,l)$ are interpreted as the infinite-horizon policy functions and are the main instruments to obtain all the results shown in this paper.

[26]Valencia (2005) provides a more detailed explanation of how the target is affected as impatience decreases or when the marginal value of internal funds is linear.

The solution algorithm is identical to the one used in Valencia (2005), the appendix of which contains a detailed description.[27]

Figure 3 shows the infinite-horizon policy functions for the two scenarios under analysis. The point at which the slope of the policy functions changes is where the constraint on dividends is binding. The general shape of the solutions suggest that lending and dividends increase with the level of solvency of the bank. The first noticeable difference between the two scenarios is that the bank lends a bit more in the case of Basel I than in the case of Basel II. The differences in the target values can be better appreciated in Table 3.

Table 3: **T**arget Values

	$\frac{q}{l}$[1]	l	q
Basel I	1.00	1.00	1.00
Basel II, baseline	1.06	0.99	1.05
Basel II, case 2[2]	1.07	0.99	1.06
Basel II, case 3[2]	1.12	0.99	1.10

[1] End-of-period solvency

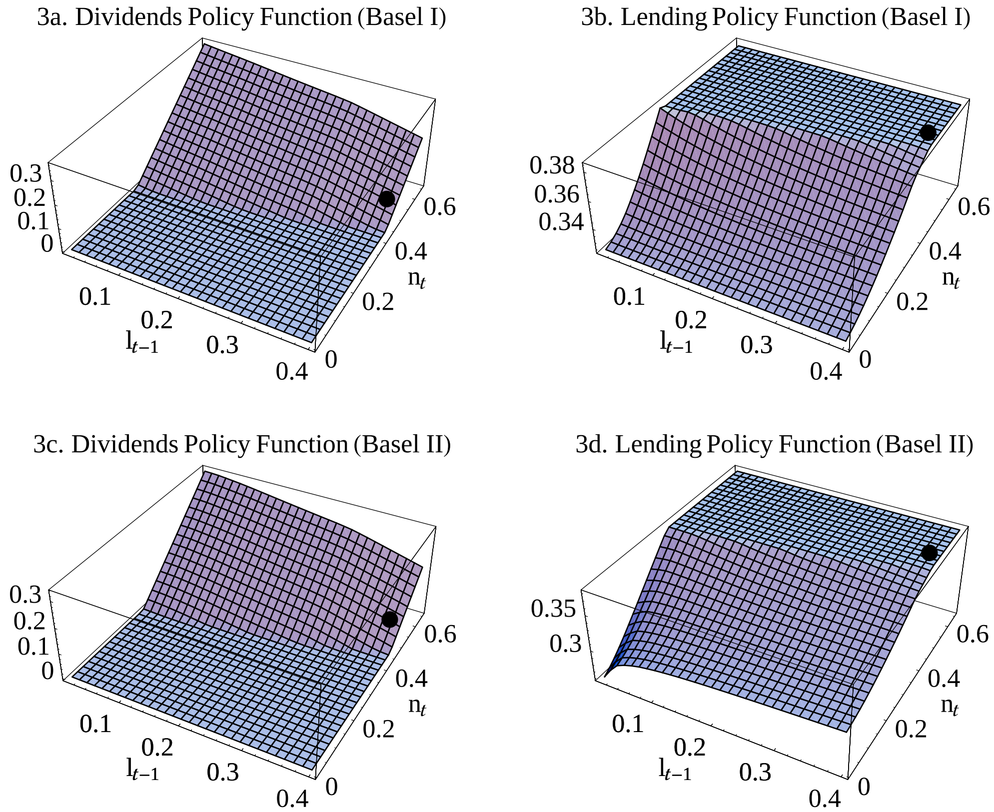
[2] See Table 4

Table 3 shows the target values for the state variables, normalized by the values that arise from the Basel I scenario, (i.e. the target for bank capital under the baseline scenario corresponding to Basel II is 1.05 times the one under Basel I). The forward-looking bank raises the target of bank capital and hence solvency as a response to the volatility in capital requirements.[28]

[27] Available at http://econ.jhu.edu/People/Valencia

[28] Because f^n is linear in bank capital, it is the non-linearity in the weighting functions $\omega(\Phi)$, which together with the constraint on dividends generate convexity of the marginal value of internal funds. Adding strict convexity in f^n would intensify the precautionary motive. Such an exercise would be similar to increasing the degree of risk aversion of a buffer stock consumer–See Carroll and Kimball (2001).

Figure 3: Optimal Decision Rules*



*Black dots indicate location of targets

5 Simulations

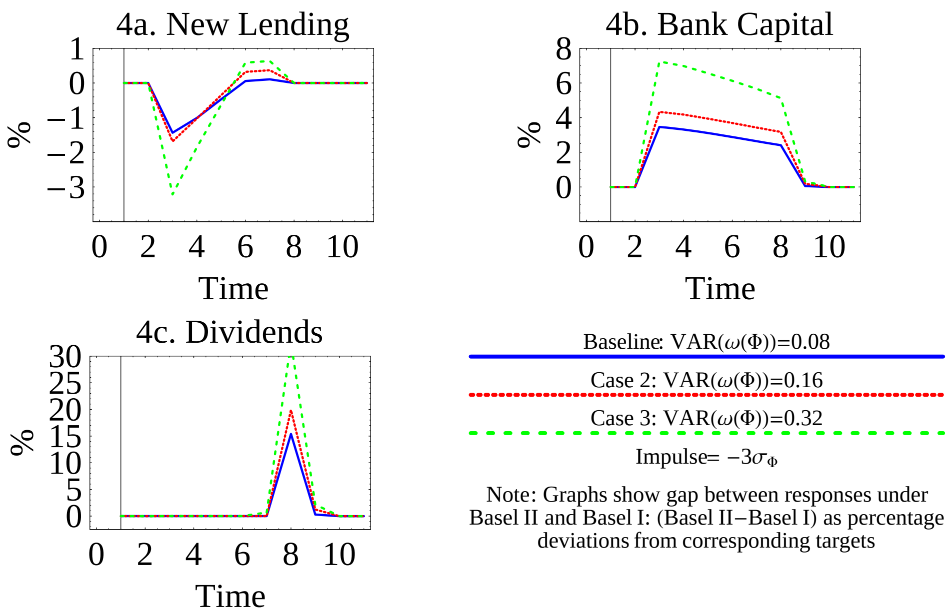
This section presents some quantitative exercises using the converged decision rules derived in the previous section. The experiment involves simulating a decline in productivity and comparing the adjustment towards equilibrium that arises under the benchmark case and the Basel II scenario.

The macroeconomic effects of Basel II will likely depend on the extent to which banks respond to changes in capital requirements and on the extent to which time-varying default risk induces significant changes in capital requirements. Using diverse datasets and statistical methods, several authors have found a wide range of effects regarding the change in capital requirements that could arise under Basel II; see Kashyap and Stein (2004) and their references. Thus, the precise amount of volatility that will be incorporated in capital requirements once Basel II is implemented has yet to be determined. However, even if Basel II introduces a very high volatility in capital requirements, without a formal model, it is difficult to determine how much of that volatility could be transmitted to the economy through volatility in lending. The goal of this section is to use the model presented in this paper to determine how different the bank reacts to negative shocks under the two scenarios analyzed in this paper.

The experiment involves computing the responses of the bank to a 3-standard-deviation productivity shock under four scenarios. The first scenario uses the optimal decision rules derived under the Basel I proxy. The other three correspond to the Basel II case, and include the baseline calibration and two additional sensitivity experiments in which the function $\omega(\Phi)$ has been modified to increase the volatility of regulatory costs. The responses are computed as percentage deviations from their corresponding target values and then they are compared to the Basel I benchmark. Figure 4 shows the results, where the different scenarios plotted correspond to the difference between the Basel II response and the Basel I response.

Following the shock, the bank's capital level deteriorates, which implies a negative deviation of the solvency level from the optimal long-run target. In all cases, the bank restores solvency by reducing dividends and cutting lending until the bank gradually returns to equilibrium. In the process, a credit crunch arises and lasts for several periods until the target values of lending and capital are reached. In the case of Basel I, the economic downturn causes a decline in revenues and a deterioration of bank capital, which in turn increases the size of the regulatory fine. However,

Figure 4: Responses to a Productivity Decline



in the Basel II scenarios, the productivity decline has an additional effect: capital requirements tighten as a response to the increase in risk. [29] The tightening of capital requirements takes the form of an increase in regulatory costs of much larger proportions than the increase under Basel I. This effect follows from the fact that the penalty function under Basel II is linked to aggregate productivity through the risk weights. Therefore, the credit crunch arising under Basel II is more severe than the one under Basel I, which is not a surprising finding. Notice that Figure 4a shows a negative difference between Basel II and Basel I.

The credit crunch is clearly worse under Basel II, but the difference is relatively small. Even in the highest volatility scenario, scenario 3, the additional contraction in lending due to the presence of risk-sensitive capital requirements peaks at around -3%. The existence of a buffer stock of capital shields lending against the tightening

[29] Recall that borrowers' default risk decreases with aggregate productivity

of regulatory requirements. Therefore, in this model, the procyclicality nature of Basel II seems to have only a mild impact on lending and consequently one could also infer that its impact on macroeconomic stability would be mild as well. The remaining panels in the figure show the adjustment for bank capital and dividends. In order to have an idea of the volatility involved in each scenario, Table 4 shows the weights used to compute risk-weighted assets for some realizations of aggregate productivity.

Table 4: **A**ssumed Scenarios for Risk Weights

Φ	Default Probability[1]	Basel I, ω	Basel II,$\omega(\Phi)$		
		Baseline	Baseline	Case 2[2]	Caseam 3[3]
E[Φ]-3σ_Φ	0.99	1.00	1.79	5.33	12.61
E[Φ]-2σ_Φ	0.36	1.00	1.59	2.58	3.74
E[Φ]-1σ_Φ	0.06	1.00	1.30	1.44	1.58
E[Φ]	0.01	1.00	1.00	0.89	0.81
E[Φ]+1σ_Φ	$2x10^{-3}$	1.00	0.70	0.58	0.47
E[Φ]+2σ_Φ	$4x10^{-4}$	1.00	0.41	0.40	0.29
E[Φ]+3σ_Φ	$1x10^{-4}$	1.00	0.11	0.29	0.20

[1]Probability of default of an individual borrower evaluated at target level of lending

[2]$\omega(\Phi) = \left((\Phi+1)^{-3}\right)/0.14098$, with $\int_0^\infty \omega(\Phi)dF_\Phi = 1$

[3]$\omega(\Phi) = \left((\Phi+0.5)^{-3}\right)/0.367103$, with $\int_0^\infty \omega(\Phi)dF_\Phi = 1$

Notice that in Table 4, the most extreme scenario, scenario 3, shows a capital requirement change relative to Basel I of about 270% when the economy is hit by a 2-standard-deviation shock. That number is slightly larger than the maximum capital requirement change found by Jordan, Peek, and Rosengren (2002), which is the largest change among all the studies quoted in Kashyap and Stein (2004). The precise degree of additional volatility that could be attributed to Basel II following its implementation is uncertain. Nevertheless, the experiment implemented in this paper shows that even in the case of a drastic increase in regulatory costs, the buffer stock behavior of the bank mitigates substantially the procyclicality problem of Basel II, even in the absence of any dampening rule.[30]

In this paper, capital requirements under Basel I are the average of those assumed under Basel II. This agnostic view has been adopted because the focus has been on volatility rather than on the change in the level of capital requirements. An additional concern that remains to be addressed is if the implementation of Basel II could induce a credit crunch, just as Basel I was thought to have had a role in the credit crunch of the early nineties. The answer will depend on whether the capital requirements of Basel II are on average higher or lower than those under Basel I. The precise answer will depend on the composition of banks' portfolios and the chosen rating methodology. However, on average, it seems that Basel II will reduce capital requirements for most types of secured loans. If that is the case for the entire loans portfolio, then one should expect a smooth transition between Basel I and Basel II.

6 Summary of Results

The current bank capital regulatory framework is about to be modified substantially in at least the G-10 countries. The regime, far more complex than the original one introduced in 1988, is praised for its potential benefit of inducing more efficiency in risk-management and capital allocation in banking firms. However, some critics have also raised concerns about its possible harmful effects on macroeconomic stability. The key source of concern is the linkage of capital requirements to borrowers' default probability, a feature that would induce cyclical changes in capital requirements if default risk is cyclical itself. If banks respond to changes in capital requirements, then the added volatility could exacerbate business cycles.

This paper has presented a dynamic, rational expectations banking model to

[30] See Gordy and Howells (2006) for a discussion of the use of dampening rules.

analyze the behavior of a bank under two different scenarios: one in which capital requirements are risk-sensitive and a second scenario in which they are not. These scenarios serve as proxies for the new and the current regime, respectively. Capital requirements were modeled as a regulatory fine that increases with the level of capital adequacy of the bank. Since in this model, borrowers' default risk decreases with aggregate productivity, the risk weights have been modeled as a function of productivity for the case of Basel II, in order to capture the procyclical nature of risk-sensitive capital requirements. The alternative scenario is modeled with constant weights.

In the model, the bank exhibits a precautionary motive. The optimal target level of solvency is higher under Basel II than Basel I. The bank then self-insures against the volatility of capital requirements by keeping a buffer stock level of bank capital. Then the optimal decision rules were used to simulate the response of the bank to a large and negative macroeconomic shock, which in the model takes the form of a decline in aggregate productivity. The decline in productivity causes a decline in revenues, which deteriorates the solvency of the bank. A credit crunch arises while the bank restores its financial condition back to the targeted level. In the case of Basel II, the decline in productivity has an additional impact through a tightening of capital requirements, or an increase in regulatory costs, and therefore the credit crunch is more severe under the Basel II scenario, as one would have expected. However, despite the large decline in productivity, and even when substantial volatility in risk weighs is added, the additional contraction in credit due to risk-sensitive capital requirements is quite mild.

In conclusion, the precautionary motive of the bank mitigates substantially the cyclical effects that arise under Basel II following an economic downturn. These results are important because they suggest that effective hedging by banking firms through an adequate adjustment of their capital buffers may suffice to mitigate the procyclicality problem of Basel II, and therefore the trade-off between a more efficient capital allocation and financial stability may not be as worrisome as some policymakers fear.

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