Incentive-based Regulation of Banks: An Interpretation of Basel II

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ABSTRACT

This paper models the incentives of banks to undertake "Regulatory Capital Arbitrage," under the current capital requirements. I show that in equilibrium banks making risky investments pool with the banks investing safely so that they can be subject to a lower amount of regulatory capital because the risk exposures of banks cannot be precisely measured. The paper examines whether the proposed "Basel II" regulatory system would be more or less efficient and effective than the current system. I show that the Internal Ratings-based (IRB) Approach of Basel II can be interpreted as a way of forcing a separating equilibrium, in which good banks that do not pursue unduly risky strategies identify themselves to the regulators and are rewarded with a lower capital requirement. Such a separating equilibrium can only be sustained under an effective supervision system or by giving some incentives to the excessively risk-taking banks to stay in the current system rather than opting into the new IRB approach.

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1 Introduction

This paper models banks' incentives for "regulatory capital arbitrage" under the current capital adequacy rules. Because the risk exposures of different types of banks cannot be precisely measured, banks making risky investments pool with the banks investing safely so that they can be subject to a lower amount of regulatory capital. The new Basel II rules are an attempt to solve these problems with the current system. I show that Basel II's Internal Ratings-based (IRB) Approach can be interpreted as a way of forcing a separating equilibrium, in which good banks that do not pursue unduly risky strategies identify themselves to the regulators and are rewarded with a lower capital requirement.

Current capital adequacy regulations define risk categories for bank assets based on their observable characteristics. Assets in the riskier categories receive higher risk weights. The categories are broad, however, and banks can substitute high-risk assets for low-risk assets within each category, with no requirement to increase their risk-based capital. This risk-shifting is known as "regulatory capital arbitrage" (RCA), and is driven by the difference between a bank's actual economic risk exposures and the exposures as assessed by the regulators. As pointed out by Jones (2000), these divergences enable banks to repackage their portfolio risks in order to hold much less capital than implied by the economic risks incurred. RCA is implemented by unbundling and repackaging risks of assets, for example, through securitization of the banks' highest quality assets ("cherry-picking"), so that a portion of the credit risk of the bank loans is treated as if these loans belonged to an asset category with lower risk weights, consequently lowering effective capital requirements for these risky assets.

In response to criticisms of the current capital requirements that, as crude rules, they introduce divergences between economic risks and their regulatory counterparts, the Basel Committee on Banking Supervision released a proposal of amendment, known as "Basel II." The Committee completed the new Accord in June 2004 and implementation is intended to take effect in member countries by year-end 2006.[1]

Under the new Accord, there are primarily two approaches to defining the capital requirements. First is the "Standardized Approach," which slightly modifies the current risk-based system by adding, based on the estimates of some private credit agencies, new risk categories to evaluate the risk-weighted asset portfolios of banks.

[1]See Basel Committee on Banking and Supervision (2003) for an overview of the new Basel Capital Accord.

However, the change is a very superficial one since the new risk weights continue to allow only a very limited number of categories.

Second is the "Internal Ratings-based (IRB) Approach," which will be an alternative option for banks that satisfy infrastructure requirements. Under the IRB approach, if a bank's risk estimate models meet the criteria of the supervisors, the bank will be allowed to use its internal risk measurement models in order to assess the riskiness of its loan portfolios and estimate its required amount of capital. The IRB approach will be a more supervision-oriented system, in which supervisors check whether banks that decide to opt in have adequate levels of risk measurement infrastructure, and based on the risk estimates of the approved banks, interactively set the relevant capital requirements for them. The main criticism of this approach is the possibility that banks will mislead the regulator about risk estimates. (See, for instance, Danielsson et al. (2001) and Ward (2002), whose arguments will be described in section 4.)

This paper offers a different perspective on Basel II. Contrary to what might be expected, Basel II does not create incentives for all types of banks to use their own internal risk measurement models and to truthfully report their correct credit and market risk values. Indeed, the changes coming with Basel II could be interpreted as an attempt to reach a more efficient separating equilibrium, in which banks investing safely choose to adopt their own internal risk measurement systems, while banks making highly risky investments choose to stay with the old standardized system.

The argument is simple. Banks invest in an optimal portfolio of positive NPV good loans and zero NPV risky loans. Given the existence of the deposit insurance guarantee by the regulator, the tradeoff between the risk-shifting incentives and the continuation value can make banks choose corner solutions. Some banks choose to invest only in good loans in order to preserve their continuation value by minimizing their bankruptcy probability. On the other hand, some banks invest heavily in risky loans in order to exploit the deposit insurance provided by the regulator. If these good and risky loans are subcategories of the same asset-risk category, the regulator cannot see the details within the risk category and, consequently, does not know which type of bank he or she is dealing with. The current capital requirements lead to an inefficient pooling equilibrium, in which banks making highly risky investments pretend to be investing safely in order to have the same capital requirement as banks making safer investments. This equilibrium is socially costly for two main reasons. First, holding equity size constant, the increase in the capital requirements for safe banks puts an upper bound on bank assets and, consequently, on good loans to entrepreneurs. Second, the decline in the capital requirements for risky banks increases their probability of bankruptcy, which is already much higher than that for safe banks, and hence probability that deadweights costs of bankruptcy in addition to some other costs due to loss of fixed capital are incurred in the economy.

Under Basel II, the regulator will offer banks an option to switch to their own internal risk models as long as they satisfy some infrastructure criteria. Safe banks, by exercising this option, can identify themselves to the regulator. The banks that choose to use their internal risk models will be under close supervision. However, the information asymmetry problem of the current system will not be totally eliminated because of the difficulty of implementing an efficient back-testing. Therefore, risky banks can try to opt into the IRB approach and misreport the risk estimates. However, given that supervisors will visit banks more often and work closely with them on setting capital ratios, there will be some probability that a bank pretending to be investing safely, but in fact making highly risky investments, would be caught by the supervisors. Additionally, banks will incur high set-up costs in order to meet the infrastructure criteria for risk estimation and also will incur continuous supervision costs. Given these costs, if all the safe banks switch to the IRB approach, risky banks will be better off trying to opt into the IRB approach, instead of staying in the standardized approach and thereby identifying themselves as risky banks to the regulator. To avoid this inefficient pooling, the regulator can create incentives for the risky banks *not* to switch to using their internal risk measurement models by setting the capital requirements for the risky banks lower than their first-best. Thus, a separating equilibrium, in which safe banks identify themselves by adopting the IRB approach, can be sustained.[2]

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on risk taking, banking regulation, and capital requirements. Section 3 describes the main players of the model and shows the inefficient pooling equilibrium under the current capital requirements. Section 4 analyzes Basel II and derives the separating equilibrium and the conditions to sustain this equilibrium, and also briefly summarizes the planned implementation of the Basel II rules in the U.S. Section 5 concludes the paper.

[2]The implementation of the Basel II rules in the U.S. will be slightly different from the proposed Accord since about the ten largest banking firms in the U.S. will be obliged to adopt the IRB approach. That is because the regulators want these largest banks to invest in their internal risk assessment systems since they constitute the core of the U.S. financial system. Other banks will be given the option to switch to the IRB approach as long as they meet the infrastructure criteria.

2 Relationship to Existing Literature

Bhattacharya and Thakor (1993), Freixas and Rochet (1997), Santos (2000), and Palia and Porter (2003) provide reviews of the banking literature and contemporary issues in bank capital regulation. Moral hazard under the fixed-rate deposit insurance system was first formalized by Merton (1977), which shows that deposit insurance can be viewed as a put option on the value of banks' assets, with a strike price equal to the promised maturity value of its debt. Under the Federal Deposit Insurance Corporation's fixed-rate deposit insurance system, banks are tempted to borrow at or below the risk-free rate through insured deposits, and invest in risky assets in order to maximize the value of this put option, and consequently their equity, by increasing the risk of their asset portfolios. (See Kane (1985), Keeley (1990), Flannery (1991), and Cole et al. (1995) for the incentives to take on excessive risk ("gambling for resurrection") that the deposit insurance system with insurance premiums independent of risk creates.)[3]

The Basel Accord imposes capital adequacy requirements on banks in an effort to control these moral hazard problems.[4] In order to be compatible with the current regulatory system, this paper takes the existence of the fixed-rate deposit insurance as given and assumes that the guarantor of the deposit insurance aims to adjust capital requirements, instead of the deposit insurance premiums, in order to set the expected loss of providing deposit guarantee equal to zero.[5]

There are many papers showing that, contrary to what is intended, capital adequacy requirements fail to control risk taking. (See, for example, Koehn and Santomero (1980), Kim and Santomero (1988), Genotte and Pyle (1991), Rochet (1992),

[3]See also Chan, Greenbaum and Thakor (1992) arguing that in the presence of moral hazard and adverse selection of banks, fairly priced deposit insurance may be impossible. However, Giammarino, Lewis, and Sappington (1993) shows an optimal design of risk-adjusted deposit insurance in the presence of adverse selection and moral hazard.

[4]The 1988 Basel Capital Accord (the "Accord"), elaborated by the Basel Committee on Banking Supervision (BCBS), created by the Bank of International Settlements (BIS), required banks of the G10 countries to hold capital equal to at least 8% of their risk-adjusted assets. These prudential regulations were adopted in the U.S. through the FDIC Improvement Act in 1991. With the 1997 Market Risk Amendment, capital adequacy rules were amended to cover market risk. See Basel Committee on Banking Supervision (1988, 1997).

[5]Allen and Gale (2003) argue that one bad policy (deposit insurance) should not justify others and in the absence of welfare-relevant pecuniary externality, banks would choose their socially optimal capital structure themselves, without government intervention. Their argument is based on assumptions of complete markets and the absence of financial crises. This paper does not question the validity of the deposit insurance. See the seminal paper of Diamond and Dybvig (1983) for an explicit model of the rationale for its existence. And see also Dewatripont and Tirole (1994) for a representation theory of banking regulation, in which the prudential regulation aims to protect the interests of the depositors while avoiding bank-runs.

Berger, Herring and Szego (1995), Besanko and Kanatas (1996), and Blum (1999).) While one side of the banks' trade-off, which affects their investment choices, is this risk-shifting incentive, the other side of the trade-off is the loss of charter value in case of bankruptcy. The discounted stream of current and future rents on real loans is called charter (franchise) value in the banking literature, and since this charter value is lost when the bank goes bankrupt, it creates incentives for the banks to choose more conservative levels of risk and leverage. (See, for instance, Furlong and Keeley (1989), Keeley (1990), Hellmann, Murdock, and Stiglitz (2000), Pelizzon (2001), Gan (2003), and Repullo (2004).) This paper does not question the validity of capital requirements as a regulatory mechanism, but analyzes the regulatory capital arbitrage incentives that the current system creates.

Since this paper has a dynamic setting, which is relatively uncommon in the literature, the model endogenizes the charter (franchise) value of the bank. The dynamic nature of the model set-up is similar to Hellman, Murdock, and Stiglitz (2000), which shows that capital requirement regulation without a deposit rate ceiling yields inefficient outcomes. However, the essence of my study, which is about the regulatory capital arbitrage incentives of the banks, is the asymmetric information within a risk category. Therefore, the model should incorporate at least two different assets with both random returns and positive variances. In Hellman, Murdock, and Stiglitz (2000), the prudent asset has a constant return, and the gambling asset has binomial payoffs. Such a set-up would help the regulator infer, after just a few periods, which asset the bank is investing in, and therefore would not be applicable to this paper. Moreover, in my model, the probability of bankruptcy depends on the random returns as well, while it is fixed in their model. Pelizzon (2001) also uses a similar dynamic model and comes up with a similar value function to this paper's in order to show how different sources of rents ("underpriced deposit insurance, supernormal returns on banks, and imperfect competition for deposits") affect banks' risk-taking behavior. In her model, although there is one risky asset that has a random return, the second asset is a risk-free bond, which again would not be compatible with this paper's premise of asymmetric information between the banks and the regulator. To my knowledge, this paper is the first paper that both formally models regulatory capital arbitrage within a risk category in a dynamic setting, and also analytically shows the separating equilibrium interpretation of the Basel II rules.

There is an extensive literature analyzing both the movement towards using one's own internal risk models instead of the "one-size-fits-all" approach and also the newly proposed accord, Basel II. There are two main criticisms of using internal risk models. The first concerns the drawbacks of all possible risk estimation models (see Kupiec and O'Brien (1995a), Rochet (1999), Danielsson (2000), Embrechts, McNeil and Straumann (2000), and Danielsson et al. (2001)). The second concerns the cyclical implications of Basel II standards: the argument is that the new capital standards will exacerbate business cycles (see Danielsson et al. (2001), Danielsson, Shin, and Zigrand (2002), Ward (2002b), Danielsson and Zigrand (2003), Stein and Kashyap (2004), and Gordy and Howells (2004)). This paper does not argue that Basel II regulations will be the most efficient system of regulation. It shows that under Basel II rules, it is possible to have a more efficient separating equilibrium than the inefficient pooling equilibrium of the current system if high supervision criteria are met. By suggesting such a different interpretation of Basel II, this paper also exempts itself from the above criticisms.

An alternative to internal risk models approach was suggested by Kupiec and O'Brien (1995b, 1997), and is called "Pre-commitment Approach (PCA)."[6] The PCA would require each bank to state the maximum loss exposure for its trading portfolio over a fixed subsequent period. The capital charge for market risk would be equal to this pre-committed maximum loss. If the bank incurs trading losses exceeding the pre-committed level, penalties would be imposed that are proportional to the amount of excess loss. PCA was criticized as being applicable to only well-capitalized banks (See, for instance, Daripa and Varotto (1997)).

3 The Model

3.1 Model Set-up and Assumptions

There are two main players in this model: "banks" and "the regulator." Although banks are highly regulated and their assets are partly verifiable, there still exists information asymmetry between banks and the regulator. The current Basel Accord defines risk categories based on observable characteristics of bank assets and assigns a higher risk weight to higher risk categories. The final capital requirement for each bank is set based on the risk-weighted assets in the bank's portfolio. However, these risk categories are very crude and they are very limited in number. Since the regulator can only see the aggregate values of the risk categories, but not the details, banks know the risk details within each risk category better than the regulator does.

[6]See Prescott (1997) for a description and Marshall and Venkataraman (1999) for a welfare analysis of the Pre-commitment approach.

For instance, all of the commercial loans in the bank's portfolio are assigned a risk weight of 1, independently of their riskiness. "Regulatory capital arbitrage" (RCA) is the substitution of riskier assets within a risk category for safer assets, with no requirement to increase the risk-based capital.

Bank deposits are fully insured by the regulator. Throughout banks pay a fixed-rate premium (p) on deposits at the end of each period in return for this insurance.[7]

- **Risky Assets:**

Let banks, on the liability side of the balance sheet, have deposits (D_t) and equity (E_t) and, on the asset side, have the risky assets (A_t) at a given time t.[8] At time $t = 0$, the balance sheet of a bank looks like:

Assets	*Liabilities*
A_0	D_0
	E_0

where $A_0 = E_0 + D_0$. For simplicity, the risk-free rate of return is normalize to 0 in the model.

Each bank has one category of assets, which can be invested in two different investment opportunities (subcategories): positive NPV "good loans" and zero NPV "risky loans." Risky loans can be interpreted in many ways: they may be zero NPV, high variance loans, or some securitization of assets, or other derivative instruments that are highly risky. Good loans have higher expected returns than the risky loans, however, risky loans have a strong upside potential, but are likely to cause bankruptcy otherwise. Since the deposit insurance pays for the losses in case of bankruptcy, the risky loans may have higher *effective* private returns to the banks. The opportunity cost of this put option, created by deposit insurance, is the possible loss of the continuation value of the bank.

Good loans have a random gross return, $r_{L,t}$, with a mean of $\overline{r}_L$ and a small variance of σ_L^2, while risky loans have a random gross return, $r_{M,t}$, with a mean of $\overline{r}_M$ and a relatively higher variance of σ_M^2. Note that $\overline{r}_L$ is larger than the gross risk-free

[7] As stated by Calem and Rob (1999), after 1993, in addition to the fixed insurance premium, undercapitalized banks are asked to pay an extra premium based on capital ratios and risk-weighted assets. However, banks in this model are assumed to be at least adequately capitalized, since incorporating the possiblility of undercapitalization does not add to the scope of the paper.

[8] The asset side of the balance sheet could include mandatory reserves (C_t), which include cash or liquid assets that have risk-free returns. This would only add a constant to our equations, and would not change any of the results. Therefore, for simplicity, I assume that this term is zero.

rate and $\overline{r}_M$ is equal to the gross risk-free rate. Hence, good loans are not risk-free, but their variance is much less than the variance of the risky loans.

Banks invest β_t of the total value in good loans and $1-\beta_t$ in risky loans. Let r_t be the period t gross return on the total investment. Thus,

$$r_t = \beta_t r_{L,t} + (1-\beta_t) r_{M,t}. \tag{1}$$

Let the sequences of returns, $r_{L,1}, r_{L,2}, \ldots, r_{L,T}$ and $r_{M,1}, r_{M,2}, \ldots, r_{M,T}$ be *iid*, normally distributed and independent.[9] Short selling of bank assets is not possible, i.e., $0 \leq \beta_t \leq 1$, since the regulator can observe negative β_t. Moreover, in the presence of the deposit insurance guarantee, short selling can increase the risky asset size without limit, allowing the banks to take an infinite amount of risk. (See Gan (2004) for an analysis of banks' risk taking behavior if there is no limit on their size.)

Given that $r_{L,t} \sim N(\overline{r}_L, \sigma_L^2)$ and $r_{M,t} \sim N(\overline{r}_M, \sigma_M^2)$ are independent, r_t is also normally distributed with mean $\mu_{r,t}$ and variance $\sigma_{r,t}^2$, where

$$\mu_{r,t} = \beta_t \overline{r}_L + (1-\beta_t)\overline{r}_M \tag{2}$$

and

$$\sigma_{r,t}^2 = \beta_t^2 \sigma_L^2 + (1-\beta_t)^2 \sigma_M^2. \tag{3}$$

- **Capital Requirement:**

The risk weight of the asset category is assumed to be 1. Note that the risk weight on the commercial loan category is also 1 in the current system. The capital requirement function, $f(A_0)$, under the current fixed-rate (k) capital requirements is

$$f(A_0) = kA_0. \tag{4}$$

Thus,

$$E_0 \geq kA_0 \tag{5}$$

is required for a bank to be adequately capitalized.[10]

[9] Although empirical tests show that returns have fatter tails than implied by normal distribution, the normality assumption is best suited to the additive nature of the problem. Besides, r_L can be viewed as a convex combination of N independent safe investment returns for some large N. Then even if each $r_{L,i}$ can be lognormal, the Central Limit Theorem implies that the distribution of $r_L = \sum_{i=1}^{N} r_{L,i}\alpha_i$ converges to a normal distribution.

[10] $k = 8\%$ under the current capital regulations.

- **Asset Size:**

Bank size is assumed to be fixed across time. The bank holds the amount invested in risky assets (A_0) constant over time by distributing the profits to shareholders as dividends. In case of a loss without bankruptcy, the initial shareholders are assumed to subsidize the bank with new capital equal to the loss, and therefore equity is always equal to the initial amount E_0 while the asset size is equal to A_0. The model assumes the threshold closing rule. Hence, in case of a bankruptcy (if $A_0 r_t < D_0$), the deposit insurer takes over the firm without giving shareholders the option to recapitalize. As discussed in Pelizzon (2001), if shareholders have an option to recapitalize in case of bankruptcy, the probability of bankruptcy will increase because the shareholders will invest in a riskier way, with the supposition that they would put more money in if something unexpectedly bad were to happen.[11]

Holding equity fixed at E_0 also creates an upper bound for the amount of deposits, D_0. Therefore D_0 is also constant over time at an amount equal to the maximum allowed by the capital requirements.[12] Since deposits are riskless assets, their gross return is 1. Then, the amount of dividend distributed at the end of each period is

$$Div_t = \begin{cases} 0, & A_0 r_t < D_0 \\ (r_t - 1)A_0 - pD_0, & \text{otherwise} \end{cases}, \tag{6}$$

where r_t is the gross return on risky assets, as defined in Eq. (1) and p is the fixed-rate premium per deposits for the deposit insurance.

3.2 Banks

- **Value Function of Banks:**

Risk-neutral shareholders will have managers maximize the total dividend received by the shareholders. At a given period t,

$$\max_{\beta} E\left\{\sum_{\tau=1}^{\infty} d^{\tau} Div_{t+\tau}\right\}$$

[11] In the model, I assume that the threshold for the bankruptcy is zero amount of equity. This threshold could be changed to any other positive or negative value without altering the results and the conclusions. Moreover, endogeneizing the optimal threshold choice for the equity holders would not change my results either as long as this choice is kept constant over all t, for the model to be technically solvable.

[12] See Stein (1998) for an adverse selection model, in which banks prefer to raise funds through insured deposits rather than equity due to information problems.

where d is the probability that the next period will not be the last period of the bank. Note that this probability is constant since A_t is fixed for all t and r_t is an iid process.[13]

Since the investment size is assumed to be fixed across time, the bank faces the same static problem each period; therefore, the value of the bank and the amount of investment in the good loans, β, as well as the mean and variance of the gross return on assets (μ_r and σ_r^2), should be constant over time. Thus, with the optimum choice of β, the value of the bank equity at any given period is

$$\begin{aligned} V(\beta) &= E\left\{\sum_{\tau=1}^{\infty} d^{\tau}(Div_{t+\tau})\right\} \qquad (7) \\ &= d\Pr(A_0 r_{t+1} > D_0)\left[E((r_{t+1}-1)A_0 - pD_0 | A_0 r_{t+1} > D_0) + V(\beta)\right]. \end{aligned}$$

From the Appendix A, the solution for the above problem is given by:

$$V(\beta) = (1 - df(\beta))^{-1} d\left[g(\beta) + f(\beta)\left((\mu_r - 1)A_0 - pD_0\right)\right] \qquad (8)$$

where

$$f(\beta) = \Phi\left[\frac{\mu_r A_0 - D_0}{A_0 \sigma_r}\right] \qquad (9)$$

and

$$g(\beta) = A_0 \frac{\sigma r}{\sqrt{2\pi}} \exp\left[\frac{-(D_0 - \mu_r A_0)^2}{2A_0^2 \sigma_r^2}\right]. \qquad (10)$$

Note that $1 - f(\beta)$ is the probability of bankruptcy. Without loss of generality I assume that the capital requirement is binding for the bank.[14] Hence,

$$E_0 = kA_0 \Leftrightarrow D_0 = (1-k)A_0$$

This allows us to rewrite (8) as

$$V(\beta) = (1 - df(\beta))^{-1} d\left[g(\beta) + f(\beta)(\mu_r - 1 - p(1-k))A_0\right] \qquad (11)$$

[13]The probability of continuation, d, should not be viewed as an interest-rate discount factor. Indeed, we normalized the gross risk-free return to be 1. By incorporating the probability of having the end-period, we implicitly assumed that the bank has a random lifetime ($< \infty$ w.p. 1.) instead of an infinite one. This assumption is realistic since we cannot expect a bank to survive for an infinite period.

[14]Holding the asset size fixed, the value of the bank is a decreasing function of its capital requirement k. (See the proofs of Propositions 1 and 3 below.) Thus, in equilibrium, the capital requirements bind, and banks do not hold cushion capital.

where

$$f(\beta) = \Phi\left[\frac{(k+\mu_r)-1}{\sigma_r}\right] \tag{12}$$

and

$$g(\beta) = A_0 \frac{\sigma r}{\sqrt{2\pi}} \exp\left[\frac{-(1-(k+\mu_r))^2}{2\sigma_r^2}\right]. \tag{13}$$

This can be solved numerically for $\beta^* = \arg\max V(\beta)$. (See Appendix C.) Figure 1 shows how $V(\beta)$ changes as β and σ_M^2 change. Note that, when the variance of the risky loan (σ_M^2) is equal to the variance of the safe loan, the bank optimally sets $\beta^* = 1$. That is because the expected return on the safe loan is higher than the expected return on the risky loan while their variances are the same. However, holding other parameters constant, as the variance of the risky loan increase, β^* changes from 1 to 0 since the put option value due to the deposit insurance exceeds the continuation (franchise) value of the bank.

- **Types of Banks:**

There are two types of banks in this model. "G" banks always invest all their assets in good loans (set $\beta = 1$) in order to reduce the probability of bankruptcy and preserve their franchise value. "B" banks do not have the opportunity to invest in good loans, or are better off exploiting the deposit insurance as much as possible, and they always invest all their assets in highly risky loans (set $\beta = 0$). Notice that if both safe and risky investment opportunities are available to all the banks, "G" and "B" types of banks are endogenously determined in the model. Because of the convexity of their value function, banks optimally choose corner solutions: a "G" bank, for which continuation value of the bank is more important than the put option value created by the deposit insurance optimally sets $\beta = 1$ while a "B" bank sets $\beta = 0$ valuing the put option value, and, therefore, asset return variance more than the continuation value of the bank. Note that these banks could also differ in their quality of lending as well as their potential lending opportunities. Some banks earn relatively more on their portfolios due to better monitoring and risk management techniques, better client relationships, better ability to use soft/hard information, or any other expertise unique to them.

Figure 2 illustrates numerical simulations for G and B banks. Holding other parameters fixed, for instance, a 2% difference in expected return on safe loans (3.75% vs. 1.75%) makes the same bank shift from safe investment ($\beta = 1$) to risky investment ($\beta = 0$) .

The value of the B bank is

$$V(\beta = 0, k) = \left[1 - d\Phi\left(\frac{k}{\sigma_M}\right)\right]^{-1} d\left[A_0 \frac{\sigma_M}{\sqrt{2\pi}} \exp(\frac{-(k)^2}{2\sigma_M^2}) - \Phi\left(\frac{k}{\sigma_M}\right)(1-k)pA_0\right], \tag{14}$$

and the value of the G bank is

$$V(\beta = 1, k) = \frac{d\left[A_0 \frac{\sigma_L}{\sqrt{2\pi}} \exp\left[\frac{-(1-(k+\overline{r}_L))^2}{2\sigma_L^2}\right] + \Phi\left(\frac{(k+\overline{r}_L)-1}{\sigma_L}\right)(\overline{r}_L - 1 - p(1-k))A_0\right]}{\left[1 - d\Phi\left(\frac{(k+\overline{r}_L)-1}{\sigma_L}\right)\right]}. \tag{15}$$

Suppose G banks constitute a fraction, s^G, while B banks constitute a fraction, s^B, of the population. The regulator knows these fractions in the economy and if bankrupt banks are continuously replaced by other banks of the same type, these fractions are, on average, constant across time. Banks are assumed to be symmetric within types with fixed investment in loans, A_0, each period. For the given capital requirement ratio, the probabilities of bankruptcy for the G banks and the B banks are, respectively,

$$p_G = (1 - f^G(\beta)) = \Phi\left(\frac{1-(k+\overline{r}_L)}{\sigma_L}\right) \tag{16}$$

and

$$p_B = (1 - f^B(\beta)) = \Phi\left(\frac{-k}{\sigma_M}\right). \tag{17}$$

Thus, $p_G \ll p_B$.

3.3 The Regulator

In addition to providing deposit insurance to protect small depositors and prevent bank runs, the regulator's main objectives are as follows[15]:

- Maximize the productive capacity of the economy, by making sure that entrepreneurs with good projects will be able to find funding through G banks.
- Enforce a policy function determining capital requirements for the banks in order to prevent bankruptcies and their consequent deadweight losses. This leads to a goal of setting capital requirements at a level which would, given the

[15] Although in the U.S. there exist multiple regulators, such as the Federal Reserve Board, the Federal Deposit Insurance Corporation (FDIC), and the Office of the Comptroller of the Currency (OCC), this paper assumes that all the banking regulation and supervision is done by a single regulator. Separating the functions of the regulator in the model would not add any insight, but only complication.

fixed-rate deposit insurance premiums, covers the expected loss to the regulator in case of default.

The regulator could ensure the solvency of the banks by making them invest only in risk-free securities, but this is socially undesirable since the primary function of a bank, as an intermediary between the lenders and the borrowers, is to provide funding to entrepreneurs with good projects. The flow of entrepreneurial positive NPV project ideas in the economy requires loans from the banks in order to start these projects. Let γ_t represent the net return for entrepreneurs on borrowing from G banks. The first objective of the regulator is to maximize the expected value of the following social welfare function at each time period t:

$$SW_t = s^G(\gamma_t + r_{L,t} - 1)\frac{E_0}{k^G} \tag{18}$$

where SW_t constitutes the NPV of the investment in good loans during the time period t from both the banks' and entrepreneurs' perspectives. The second objective of the regulator is to set the capital requirement such that, given the fixed-rate deposit insurance premiums, the expected value of providing deposit insurance is at least equal to zero:

$$E(InsurancePremium_t^i - Loss_t^i) \geq 0,\ i \in G, B. \tag{19}$$

Note that if the regulator has lexicographic preference for maximizing the social welfare function, SW_t, it might be optimal to set the capital requirement for the G banks such that the expected loss to the deposit insurance fund is in fact less than zero. That is because SW_t is a decreasing function of k^G. But, remember that, although not large, the probability of bankruptcy for the G banks (p_G as in (16)) is positive. Therefore, if we consider the deadweight losses in case of bankruptcy of G banks as well as decreasing returns to the investment in good loans for the entrepreneurs ($\gamma_t = c \ln \frac{E_0}{k^G}$, where c is a constant), the amount of optimal expected loss to the regulator of providing the deposit insurance to the G banks will be endogenously determined.[16] For simplicity, I assume that the regulator sets the capital requirement for the G banks such that its expected loss of providing deposit insurance is equal to zero. This might be interpreted as a long-run equilibrium assumption, where marginal return on good loans is expected to be zero.

[16]If the good loans in the economy is in limited supply, then net return to the G bank, $r_{L,t} - 1$, would also be decreasing in total size of the assets, $\frac{E_0}{k^G}$.

$E(InsurancePremium_t^i - Loss_t^i) = 0$ would imply the following constraints on the capital requirements of the G and the B banks (see Appendix A.2 for their derivation).

$$p(1-k^G)+(k^G+\overline{r}_L-1)\Phi\left[\frac{1-(k^G+\overline{r}_L)}{\sigma_L}\right]-\frac{\sigma_L}{\sqrt{2\pi}}\exp\left[\frac{-(1-(k^G+\overline{r}_L))^2}{2\sigma_L^2}\right]=0 \quad (20)$$

$$p(1-k^B)+k^B\Phi\left[-\frac{k^B}{\sigma_M}\right]-\frac{\sigma_M}{\sqrt{2\pi}}\exp\left[\frac{-(k^B)^2}{2\sigma_M^2}\right]=0 \quad (21)$$

where k^G and k^B are the amounts of capital that make the deposit insurance system break even in case of default within that time period for the G and the B banks, respectively, and p is the fixed-rate deposit insurance premium paid by the banks on insured deposits. In other words, k^G and k^B are the first-best values of the capital requirement for the two types of banks in this model. Figure 3 plots equations (20) and (21). Note that k^B is significantly larger than k^G.

Capital requirements create an upper bound on the asset size of the banks. First-best values for the maximum allowable sizes of the G banks and B banks are

$$A_0^G = \frac{E_0}{k^G} \quad (22)$$

and

$$A_0^B = \frac{E_0}{k^B}, \quad (23)$$

where $A_0^G > A_0^B$. Note that, holding equity fixed, the sizes of the banks decrease as their capital requirements increase.

3.4 Pooling Equilibrium

Under asymmetric information, first-best values of the capital requirements are not feasible because B banks have an incentive to act as if they were G banks. Since the regulator cannot differentiate good banks from bad banks and only knows their fractions in the economy, as in the current fixed-rate capital requirement system, the regulator sets the required amount of capital for each bank (or asset category) equal to

$$k^* = w_G k^G + w_B k^B, \quad (24)$$

where $k^G < k^* < k^B$ and w_G and w_B are the weights. These weights are functions of s^G and s^B, and they also depend on the demand for the good loans in the economy and the relative probability and costs of bankruptcy for G and B banks.[17]

Proposition 1 *If the regulator cannot differentiate B banks from G banks, B banks always pool with G banks in order to have the fixed-rate (k^*) capital requirement.*

Proof. See Appendix B.1. ■

The current regulations make the B banks better off by reducing the required amount of capital for them and consequently increasing the upper bound on their sizes while making the G banks worse off by increasing their capital requirement and shrinking their sizes. Since the reduction in the upper bound on the sizes of the G banks reduces loans to good entrepreneurs, and the increase in the size of B banks means higher probable bankruptcy costs, the economy is worse off in the presence of the information asymmetry between the banks and the regulator.

Corollary 2 *The social welfare function is expected to decrease as the economy switches from the first-best capital requirements to the pooling equilibrium capital requirement, k^*.*

Proof. See Appendix B.2. ■

As the capital requirement for the G banks increases, holding equity constant, their sizes, and hence, good loans to entrepreneurs, decrease. Therefore, $E(SW_t)$ decreases under the pooling equilibrium.

Moreover, under the pooling equilibrium,

$$E(InsurancePremium_t^B - Loss_t^B) < 0,$$

which implies that the expected value of providing deposit insurance to the B banks is, on average, less than zero. In other words, if both types of banks are subject to the same capital requirement, k^*, the condition to satisfy a prime objective of the regulator-to set expected value of providing deposit insurance to B banks equal to

[17] While setting the capital requirement under asymmetric information, the regulator also considers the tradeoff between minimizing the deadweight costs in case of bankruptcy of the G or B banks and maximizing the expected social welfare function, $E(SW_t)$, by increasing the size of the good loans. If the only aim of the regulator were to make the deposit insurance fund on average break even, then the capital requirement, k^*, would be determined by the following equality.

$$p(1-k^*) + s^G\left[\alpha\Phi\left(\frac{-\alpha}{\sigma_L}\right) - \frac{\sigma_L}{\sqrt{2\pi}}\exp\left(\frac{-(\alpha)^2}{2\sigma_L^2}\right)\right] + s^B\left[k^B\Phi\left(-\frac{k^*}{\sigma_M}\right) - \frac{\sigma_M}{\sqrt{2\pi}}\exp\left(\frac{-(k^*)^2}{2\sigma_M^2}\right)\right] = 0$$

where $\alpha = k^* + \overline{r}_L - 1$.

at least zero-never holds. That is because, holding equity constant, A_0 is a declining function of k and

$$\frac{d}{dk}(p_B) = \frac{d}{dk}(1 - f^B(\beta)) = -\frac{1}{\sigma_M}\Phi\left(\frac{-k}{\sigma_M}\right) < 0,$$

where p_B is the probability of bankruptcy for the B banks.

In other words, due to the decrease in their capital requirement, both the sizes and the bankruptcy probabilities of the B banks increase under the pooling equilibrium. On the other hand, the increase in capital requirement from k^G to k^* for the G banks reduce their probability of bankruptcy, making the expected value of providing deposit insurance to the safe banks positive for the regulator. However, when compared to the increase in the probability of bankruptcy for B banks, this effect is minor since G banks already have a much lower probability of going bankrupt compared to the B banks (see equations (16) and (17) above). Therefore, expected losses due to bankruptcy increase in the pooling equilibrium.

To sum up, the current system creates an inefficient pooling equilibrium where G and B banks are exposed to the same capital requirement, decreasing the sizes of the safe banks while increasing both the sizes and the bankruptcy probabilities of the risky banks in the economy.

4 BASEL II:

The new Capital Accord, Basel II, is an attempt to be more effective in regulating banks' risky investments. A major change proposed by Basel II regulations is the introduction of an option for banks to choose between two approaches in calculating their asset risk.[18] These two options, the "Standardized Approach" and the "Internal Ratings-based (IRB) Approach," are already described in the introduction. If a bank chooses to use the IRB Approach and if this decision is approved by the supervisors after some examination, the regulatory capital that it has to hold against a credit exposure will be determined by a function of the credit risk of this exposure. Under this approach, a bank's internal risk measurement systems will assign probabilities

[18] There are three pillars of Basel II: capital adequacy requirements, supervisory review, and market discipline. This model does not incorporate the third pillar since it is not related to the regulatory arbitrage problem. See Decamps, Rochet, and Roger (2004) for a continuous-time model of market discipline and its effects on banks' behavior and capital requirements. Moreover, this paper concentrates on the Accord as prepared by the Basel Committee of the Bank of International Settlements (BIS). Different countries could be implementing it with their own modifications. In a later section, the U.S. case will be discussed in detail.

of default (PDs) for the risky assets. Moreover, the risk assessments by the bank will also include the loss given (LGD) and the exposure at default (EAD). Based on these estimates, the regulator enforces the capital requirement function that will set the regulatory capital for the bank.[19] Jackson (2002) gives a simplified version of the capital requirement functions as follows:

$$k^{IRB} = LGD \times \Phi\left[\frac{\Phi^{-1}(PD) + \rho^{1/2}\Phi^{-1}(C)}{\sqrt{1-\rho}}\right] \times EAD, \tag{25}$$

where Φ is the normal distribution cdf, C is the confidence interval, and ρ is the asset correlation that is set by the supervisory committee. (See Basel Committee on Banking Supervision (2003) for the capital requirement function, including maturity of the exposure and the formula defining ρ.)[20]

Switching to the IRB approach will be costly for the banks because of the high costs of setting up a sound internal risk assessment infrastructure that can be approved by the regulator. The criteria for getting this approval are quite demanding. As explained in Gallati (2003), the bank must have a sufficient number of staff familiar with complex models not only in the area of trading, but also risk control, internal auditing, and back office functions. The bank must also possess an adequate electronic data processing infrastructure. The following quotation is from *Financial Times* of March 2, 2004, with the title "HSBC spells out cost of global regulation," representative of the banks' complaints about these high set-up costs:

> HSBC has become the first bank to spell out the mounting cost of regulation round the world, saying that compliance with different rules and regimes cost it about $400m last year. HSBC, which operates in 79 countries and is overseen by about 370 regulators, expects the burden to rise as new regulations, such as Basel II rules on bank capital, come

[19] In fact, there are two variants of IRB; one is the "Advanced IRB Approach" that was already introduced. Second one is the "Foundation IRB Approach", where the bank determines only the probablity of default (PD) for the risky assets, and the regulator determines other parameters (LGD, EAD) as well as the capital requirement function. For this paper's purpose, there is no need to differentiate between these two approaches, Therefore, I will use the word "IRB approach", refering to any of the two. LGD measures the proportion of exposure that will be lost if a default occurs; EAD for loan commitments measures the amount of the facility that is likely to be drawn if a default occurs.

[20] A similar formula to determine capital requirement due to market risk is the following: $k^{IRB}_{market} = 3VaR + constant$, where VaR is the statistical measure Value-at-Risk, which gives the maximum loss that can occur over a given time period, at a given confidence interval, due to exposure to market risk. The IRB Approach for market risk was introduced in the 1997 amendment to the current Accord, and the proposed Basel II rules extend this approach to credit and operational risks.

into force...The Basel II rules will require banks to invest heavily in new systems for assessing credit and operational risk before 2007...

Another essential feature of the IRB approach is the "back-testing" by the supervisors. Based on the past years' observations, supervisors check the accuracy of the estimates reported by the banks. However, Ward (2002a) argues that relying on banks' risk estimates is not incentive-compatible unless those risk estimates are backed up by other safety measures that penalize excessive risk taking since the back-tests by supervisors do not have the power to distinguish good risk estimating models from bad ones, banks have incentives to manipulate the models to have lower risk estimates, and securitization will again be rewarded. Moreover, as pointed out by Rochet (1999), the practical implementation of risk models raises concerns as well. For instance, all possible estimation methods (e.g., historical simulations, first-order Gaussian approximations, or Monte Carlo or bootstrap methods) have some drawbacks: the stationary assumption of historical simulations is empirically rejected; returns empirically have fatter tails than their Gaussian approximations; etc.[21] Danielsson et al. (2001), criticizing the Basel II Accord, also emphasizes that statistical models used for forecasting risk have been proven to give inconsistent and biased forecasts, and their performance is very sensitive to the specification of parameters such as estimation horizon. Therefore, when internal models are used to determine capital requirements, banks will have incentives to manipulate the internal risk assessment models to have lower risk estimates, and risk shifting will again be rewarded.

4.1 Basel II Model Set-up and Assumptions

We have the same setup as before; however, banks now have an option to choose from the old system of fixed-rate capital requirement (k^*) and their own internal risk assessment system (only after getting approval from the supervisor) in order to determine how much capital to hold. Main characteristics of the model are listed below.

- **Capital Requirements under the IRB Approach:**

Under the IRB approach, the regulator sets the capital requirement, k^{IRB}, based on the risk estimates produced by the banks' internal risk assessment models. For the

[21] See also Kupiec and O'Brien (1995a) for a review and critique of the internal models approach.

G banks, this capital requirement, k^{IRB}, would be equal to k^G, which is the amount of capital that makes expected loss to the regulator providing deposit insurance equal to zero (as defined in equation (20)). If k^G were higher than k^{IRB}, the regulator would like to enforce k^G; on the other hand, if it were lower, the bank would prefer to report k^G instead.[22] Thus, G banks will enjoy a lower capital requirement than the pooling equilibrium capital requirement, k^*, if they adopt the IRB approach.

For a B bank, the IRB approach would require a higher capital requirement (for instance k^B, as defined in equation (21)) than the one in the standardized approach. Note that since a similar information asymmetry between the banks and the regulator still exists under the IRB approach and back-tests do not work efficiently, any B bank can has incentives to switch to the IRB approach in order to pretend to be a G bank, with its lower capital requirements and higher size.

- **Supervision under the IRB Approach:**

Banks that choose to use their internal risk models will be under close supervision. We assume that there exists some probability θ that any B bank, switching to the IRB approach and pretending to be a G bank will be caught misreporting own risk estimates by the regulator . When such a bank is caught, it will be penalized to have k^B as the capital requirement for all periods afterwards.[23]

In addition, like a G bank, a B bank will have to pay a per unit asset size of c_s when it is subject to supervision.

- **Set-up Costs under the IRB Approach:**

A reasonable assumption for the set-up costs for the IRB approach is that they will be much higher for B banks than G banks. Since G banks might already have these risk measurement systems or similar ones set up in order to be able to choose more prudent investments, their set- up costs under the IRB approach are less than

[22] It is worth mentioning again that k^G is the upper bound on the capital requirement that the G banks will be obliged to hold. Given that, holding the size of the equity constant, the social welfare function is decreasing in k^G, it might not be optimal for the regulator to set the capital requirement such that deposit insurance system breaks even. The optimal capital ratio will be determined by the trade-off between the deadweight cost due to bankruptcy of G banks and the marginal increase in social welfare function due to increase in size of the G banks.

[23] As the ratio of capital to deposits increases, the incentives of the shareholders to gamble decrease. Therefore, the increase in the capital requirement to the first-best level can make some B banks switch to investing safely if they have alternative safer investment opportunities. Moreover, this model simply concentrates on only a single asset-risk category, and there might be some other safe investments of the banks that correspond to some other asset-risk categories. That is because the regulator is not better off closing the B banks as they are caught.

those for B banks. One can also argue that since the average life-time of a G bank is much longer than a B bank because of the difference in their respective bankruptcy probabilities, this set-up cost per year within the life-time is much smaller for the G banks than for the B banks. Formally, the fixed set-up cost is C_F^B for the B banks, is C_F^G for the G types and $C_F^G \ll C_F^B$. For simplicity, $C_F^G = 0$ in the analyses.

Proposition 3 *Every G bank will adopt the "IRB approach," and will hold their first-best capital amount, k^G.*

Proof. See Appendix B.3. ■

The G banks are always better off identifying themselves to the regulator by adopting the IRB approach, so that they can hold less capital.

Corollary 4 *Neither a pooling equilibrium, in which both types of banks choose to continue using the "Standardized approach," nor a separating equilibrium, in which G banks choose to continue using the "Standardized approach" and B banks adopt the "IRB approach," are possible.*

Proof. Following Proposition 3, since G banks will always switch to the IRB approach, the proof of the corollary is trivial. ■

The decision of B banks depends on the relative benefits and costs of switching to the IRB approach. Will B banks always have an incentive to switch to the new system? The next section will address this question.

4.2 Separating Equilibrium Under Basel II

Given that all the G banks will adopt the IRB approach, B banks have two alternatives: either stay in the old system and identify themselves to the regulator or try to adopt the IRB approach and pretend to be G banks. The capital requirement in the standardized approach, k^*, is higher now because all the banks that stay out of the IRB approach will be B banks. The regulator will increase k^* to k^B, which sets the expected loss to the regulator from providing deposit insurance to the B banks equal to zero.

A separating equilibrium, in which B banks stay in the standardized approach and are required to hold k^B amount of capital while G banks switch to the IRB approach is possible only if the probability of being caught (θ) or the cost of switching to the IRB approach (C_F^B) is high enough:

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B < V(\beta = 0, k^B), \tag{26}$$

where $V^{IRB}(\beta = 0, k^G, C_S^B)$ is the value of the B bank, pretending to be a G bank under the IRB approach, with k=k^G and supervision cost, C_S^B; C_F^B are the fixed set-up costs; and $V(\beta = 0, k^B)$ is the value of the B bank, as given in equation (14) with $k = k^B$ in the old standardized system. It can be shown that $V^{IRB}(\beta = 0, k^G, C_S^B)$ is equal to

$$\frac{d\left[\frac{E_0}{k^G}\frac{\sigma_M}{\sqrt{2\pi}}\exp\left(\frac{-(k^G)^2}{2\sigma_M^2}\right) + \Phi\left(\frac{k^G}{\sigma_M}\right)\left[\theta V(\beta = 0, k^B) - (c_s + (1 - k^G)p)\frac{E_0}{k^G}\right]\right]}{\left[(1 - d(1 - \theta)\Phi\left(\frac{k^G}{\sigma_M}\right)\right]}. \tag{27}$$

(See Appendix A.3 for the derivation.)

However, inequality (26) is unlikely to hold because, given the criticisms of the efficiency of supervision and back-testing, θ is not expected to be very high. For $\theta < 1$, B banks will switch to the IRB regime with its lower capital requirements by pretending to be a G bank, as long as the set-up costs are not sufficiently high. This incentive is also driven by the fact that the required capital ratio in the old standardized approach (k^B) is the same as the penalty capital ratio that the B bank would be obliged to hold if caught. Hence, the following inequality holds if C_F^B or θ is sufficiently low:

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B > V(\beta = 0, k^B) \tag{28}$$

Therefore, it is not in the interest of the regulator to increase the capital requirement for the standardized approach up to k^B since the aim of the regulator is the separation of G banks from B banks so that G banks' sizes and consequently good loans going to the entrepreneurs are not rationed. On the other hand, the goal of the regulator is to set the capital requirement for the B banks as high as possible so as to both reduce the costs in case of bankruptcy and induce a switch to safe investment by them. Because the first-best values of capital requirements are not possible to enforce by making all types of banks switch to the IRB approach, the regulator would prefer giving some incentives to B banks in order to prevent the IRB approach from being an inefficient pooling equilibrium.

If there exists a k^*_{new} that is higher than the current capital requirement (k^*) but lower than the first-best for the B banks (k^B), such that for the given C_S^B and θ, a B bank is made indifferent between trying to adopt the IRB approach and staying in the old system, the regulator can sustain a separating equilibrium by setting the capital requirement for the standardized approach less than k^*_{new}. Proposition 5 below defines this separating equilibrium.

Proposition 5 *Given the supervision and set-up costs for the banks and the probability of being caught as a B bank pretending to a G bank under the IRB approach, there exists a* k^*_{new} *such that the following separating equilibrium exists:*

1. *G banks switch to the IRB approach, and their capital requirement is* k^G.
2. *B banks stay in the old system of the standardized approach and their capital requirement will be* $k^*_{new} - \varepsilon$, *where* $k^G < k^*_{new} < k^B$ *and the following equation is satisfied.*

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B = V(\beta = 0, k^*_{new}).$$

Proof. See Appendix B.4. ■

The following corollary shows that, compared to the current system, the regulator will be better off if the separating equilibrium, in which both G and B banks are identified by the regulator and G banks are rewarded with the decrease in their capital requirements, can be sustained.[24]

Corollary 6 *Compared to the pooling equilibrium under the standardized approach (as described in Proposition 1), the separating equilibrium, in which all the G banks adopt the IRB approach and all the B banks stay in the standardized approach (as described in Proposition 3), increases the social welfare function.*

Proof. See Appendix B.5. ■

The corollary states that social welfare is maximized because the sizes of the safe banks, and consequently the sizes of the good loans to the entrepreneurs, increase when the G banks adopt the IRB approach.

[24] A reasonable question to ask here is why the regulator does not wait for a few periods and identify the B banks, and then close them. There are a few answers to this question. First, among the B type banks, there might be some BG types, which *could* create safe investment opportunities for themselves and for which a high enough increase in capital requirements might cause their investment decision to shift to these safe assets. If $k^*_{new} > k^*$, these BG types might start investing safely because as the share of their own capital within the portfolio, which can be lost, increases, their incentives to gamble decrease. As stated in Furlong and Keeley (1989), low levels of capital increase banks' incentives to take risks and this is one of the main motives for the capital adequacy regulation. Second, there exists continuous replacement of bankrupt firms; in other words, each period there could be some new B banks entering the economy. Thus, such a penalty would destroy the separating equilibrium for the incoming B banks. Third, this is a very simplified model of regulatory capital arbitrage, concentrating only in a single asset-risk category. There could be some other investments of the same bank belonging to the risk-free category or other types of safe investments.

On the other hand, one of the main objectives of the regulator is to set the capital requirements such that the expected loss of providing the deposit insurance is at least equal to zero. In the pooling equilibrium under both the IRB approach and the standardized approach, this constraint is not satisfied for the B banks since they are required to hold less capital than the first-best value. In this way, the sizes and, more importantly, the probability of bankruptcy of the B banks become larger than they should be. Therefore, the increase in capital requirements for the B banks under the separating equilibrium of Basel II will better align the regulatory capital of the B banks with their true portfolio risks and reduce the probability of default as well as the loss given default.

This statement is true only under certain conditions, though. Since, with probability θ, B banks are caught misreporting the risk estimates under the IRB approach and thereafter penalized by being obliged to hold their first-best capital requirements, the regulator will be better off by giving incentives ($k^*_{new} - \epsilon$ instead of k^B) to the B banks to stay in the standardized approach only if θ is not high enough. Moreover, when compared to the pooling equilibrium under the standardized approach, the regulator will certainly be better off under the Basel II separating equilibrium if $k^*_{new} - \epsilon > k^*$. However, if $k^*_{new} - \epsilon < k^*$, in order to conclude that the regulator would still be better off, we need to show that the increase in the social welfare function due to increase in sizes of the G banks is larger than the decrease in value due to increase in the sizes and bankruptcy probabilities of the B banks when they have $k^*_{new} - \epsilon$ instead of k^* as the capital requirement.

Using the IRB approach would also be a better way for G banks to align regulatory measures of risk with the true economic risks of their portfolio. Securitization and credit derivatives could be used for diversification of portfolio risk and reducing the costs of debt financing. In other words, these instruments can be used to reduce underlying economic risk instead of exploiting deposit insurance, as long as they are within efficiency limits. Therefore, it is good to separate the banks that use risky instruments within efficiency limits from banks that use them in order to create discrepancies between economic risk and its regulatory measure.

The empirical question is whether the Basel II separating equilibrium described in Proposition 3 can be sustained for reasonable values of the probability of being caught (θ) and the sunk-cost of switching to IRB for B banks (C_F^B). In the numerical simulations, $k^*_{new} > k^*$ exists only for really high values of C_F^B or θ. Given the set-up cost differences between G and B banks should be sufficiently observable or the back-testing and supervision must sufficiently be efficient, this is the main regulatory challenge.

4.3 Implementation of Basel II Rules in the U.S.

Although the U.S. is the most influential member of the Basel Committee on Banking Supervision, the implementation of the Basel II rules in the U.S. will be slightly different from the proposed Accord. (See, for instance, Hannan and Pilloff (2004) for discussion and references, and, for an overview, the "U.S. Implementation of Basel II: An Overview (2003).") According to the current proposal, banks of at least $250 billion asset size or of at least $10 billion on-balance-sheet foreign exposure will be obliged to adopt the IRB approach (in fact, the Advanced IRB approach; see footnote 14 for the definition). These criteria include about the ten largest banking firms in the U.S. Other banks will be given the option to switch to the IRB approach as long as they have sound enough risk assessment infrastructures. The ten or so largest banks and also the ones that later become eligible to adopt the IRB approach will, most probably, be subject to lower capital requirements than under the standardized approach. Among the objectives of the revisions to the Basel Accord are listed the following: "develop a measure of capital that is more risk sensitive than the current approach and better suited to the complex activities of the international banks" and also "encourage improvements in risk management and enhance internal assessments of capital adequacy." (See the "U.S. Implementation of Basel II: An Overview (2003).") The banks that are obliged to adopt the IRB approach might have been chosen by using their sizes and foreign exposures as indicators of their prudence. However, a more important reason could be that, as expressed by the regulators, these banks form the core of the financial stability in the U.S., and making them invest in their risk measurement systems is therefore essential.

Within the U.S. implementation of the Basel II, my model is more applicable to all U.S. banks excluding the ten or so largest banks because in the model, all banks are assumed to have an option to stay in the standardized approach. However, the model can be easily modified such that the regulator might use some exogenous factors such as banks' asset sizes as indicators of the prudence of their investments. Such a modification will not alter the conclusions of this paper since, in the current model, these largest banks are expected to be investing safely and switching to the IRB approach due to their very high continuation value.

5 Conclusion

This paper contributes to the ongoing discussions about the Basel II Accord, and its model provides some empirical predictions which can be tested after the implementation of these new rules. In particular, this study provides an understanding of banks' risk-shifting incentives, derived from the divergences between true economic risks and their regulatory counterparts, under the current capital regulations. These incentives create an inefficient pooling equilibrium, in which banks investing in an unduly risky way pretend to be investing safely in order to have a lower capital requirement. The paper examines whether the proposed "Basel II" regulatory system would be more efficient and effective in dealing with these incentives. The IRB Approach of Basel II is an attempt to use banks' own internal risk estimates in setting regulatory capital requirements. I show that this approach can instead be interpreted as an attempt to create a separating equilibrium, in which safe banks adopt the IRB approach while the banks that do not invest prudently stay with the old standardized approach. This will be a signaling equilibrium, in which

- by choosing to use their own internal risk assessment systems, safe banks identify themselves to the regulator and are rewarded by a lower capital requirement than the one in the pooling equilibrium;
- banks that do not invest prudently will have some incentives to stay in the old system instead of using their own internal risk assessment models and pretending to be safe banks because adopting the IRB approach creates high set-up and supervision costs for them;
- and the regulator might be better off setting the capital requirement of the standardized approach to be less than the first-best capital ratios of risky banks in order to give them enough incentives to stay in the standardized approach.

In interpreting the changes coming with Basel II, the objective of the regulator while implementing the new rules is critical. If the regulator's only aim is to make all the banks invest in their risk assessment systems, then the regulator might aim to provide incentives to create a pooling equilibrium under the IRB approach for both safe and risky banks. If, additionally, Basel II attempts to solve the regulatory capital arbitrage problem of the current capital adequacy rules, the regulator must create incentives for the risky banks to stay in the standardized approach unless adopting the IRB approach will make them invest more prudently. This is possible only if the supervision system under the IRB approach is effective enough to considerably reduce the information asymmetry between the banks and the regulator. However, given that the supervision system is not expected to be effective enough, separating equilibrium can only be sustained by giving some incentives to the excessively risk-taking banks not to opt into the new IRB approach, by setting the capital requirements in the standardized approach lower than their first-best.

The planned U.S. implementation of Basel II uses the size or foreign exposure of the banks as the main indicator for their prudence, and obliges the ten or so largest U.S. banks to adopt the IRB approach. The main reason for this decision is stated as to make these banks improve their risk assessment systems since these banks constitute the core of the U.S. banking system, which can easily affect the financial stability of the economy. However, what about the rest of the banks? Will the implementation of Basel II in the U.S. be effective in preventing risk-shifting incentives of the banks other than the largest ten or so? Will the set-up costs for the required infrastructure to meet the criteria of the supervisors be low enough for the smaller-sized but prudent banks that they can adopt the IRB approach instead of staying in the inefficient pooling equilibrium of the standardized approach? We must wait for the implementation of Basel II to be able to empirically answer these questions.

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6 Appendix A

6.1 Appendix A.1: Derivation of $V(\beta)$, Value of the Bank

$$
\begin{aligned}
V(\beta) &= E\left\{\sum_{\tau=1}^{\infty} d^{\tau}(Div_{t+\tau})\right\} \\
&= E\left\{dDiv_{t+1} + \underbrace{\sum_{\tau=2}^{\infty} d^{\tau}(Div_{t+\tau})}_{V(\beta)}\right\} \\
&= d\Pr(A_0 r_{t+1} > D_0)\left[E\left[(r_{t+1}-1)A_0 - pD_0 | A_0 r_{t+1} > D_0\right] + V(\beta)\right],
\end{aligned}
$$

where

$$
\begin{aligned}
\Pr\left[A_0 r_{t+1} > D_0\right] &= \Pr\left[r_{t+1} - \mu_r > \frac{D_0 - A_0\mu_r}{A_0\sigma_r}\right] \\
&= \Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right]
\end{aligned}
$$

and

$$
E\left[A_0(r_{t+1}-1)|A_0 r_{t+1} > D_0\right] = E\left[A_0(r_{t+1}-\mu_r)|A_0(r_{t+1}-\mu_r) > D_0 - \mu_r A_0)\right] + (\mu_r - 1)A_0 - pD_0.
$$

Let $z = A_0(r_{t+1} - \mu_r)$. Since $r_{t+1} \sim N(\mu_r, \sigma_r^2)$ and $z \sim N(0, \sigma_z^2)$ where $\sigma_z^2 = A_0\sigma_r^2$,

$$
\begin{aligned}
E\left[A_0(r_{t+1}-1)|A_0 r_{t+1} > D_0\right] &= \frac{\int_a^{\infty} \frac{1}{\sigma_z\sqrt{2\pi}} z \exp\left[\frac{-z^2}{2\sigma_z^2}\right]}{\Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right]} + (\mu_r - 1)A_0 - pD_0 \\
&= \frac{\frac{\sigma_z}{\sqrt{2\pi}} \exp\left[\frac{-(D_0 - \mu_r A_0)^2}{2\sigma_z^2}\right]}{\Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right]} + (\mu_r - 1)A_0 - pD_0 \\
&= \frac{\frac{A_0\sigma_r}{\sqrt{2\pi}} \exp\left[\frac{-(D_0 - \mu_r A_0)^2}{2A_0^2\sigma_r^2}\right]}{\Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right]} + (\mu_r - 1)A_0 - pD_0
\end{aligned}
$$

Thus,

$$
V(\beta) = d\frac{A_0\sigma_r}{\sqrt{2\pi}} \exp\left[\frac{-(D_0 - \mu_r A_0)^2}{2A_0^2\sigma_r^2}\right] + d\Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right]\left[V(\beta) + (\mu_r - 1)A_0 - pD_0\right]
$$

If

$$f(\beta) = \Phi\left[\frac{\mu_r A_0 - D_0}{A_0\sigma_r}\right] \text{ and } g(\beta) = A_0\frac{\sigma r}{\sqrt{2\pi}}\left[\exp\frac{-(D_0-\mu_r A_0)^2}{2A_0^2\sigma_r^2}\right],$$

then the value of the bank will be

$$V(\beta) = (1 - df(\beta))^{-1}d\left[g(\beta) + f(\beta)(\mu_r - 1)A_0 - pD_0\right]$$

and the maximum is found at β^* where

$$V(\beta^*) = \max_{\beta}\left\{(1 - df(\beta))^{-1}d\left[g(\beta) + f(\beta)(\mu_r - 1)A_0 - pD_0\right]\right\}$$

6.2 Appendix A.2: Derivation of k^G and k^B, First-Best Values for the Capital Requirements

Given the fixed-rate (p) insurance premiums, the first-best values are obtained by setting the expected loss of providing deposit insurance equal to zero as follows.

$$E(InsurancePremium_t^i - Loss_t^i) = 0$$

$$pD_o^i + \Pr(Default^i)E(Loss^i|Default^i) = 0,$$

where $i \in \{G, B\}$. For the corresponding parameters of G and B banks,

$$\begin{aligned}\Pr(Default) &= \Pr\left[A_0 r_t < D_0\right] \\ &= \Pr\left[r_t < 1 - k\right] \\ &= \Phi\left[\frac{1 - k - \mu_r}{\sigma_r}\right],\end{aligned} \tag{29}$$

where (29) uses the assumption that capital requirements are binding for the banks (i.e., $Eo = kAo$).

$$\begin{aligned}E(Loss|Default) &= E\left[A_0 r_t - D_0)|A_0 r_t < D_0\right] \\ &= E\left[A_0(r_t - k - 1)|A_0 r_t < A_0(1-k)\right] \\ &= E\left[A_0(r_t - \mu_r)|A_0(r_t - \mu_r) < A_0(1 - k - \mu_r)\right]\end{aligned}$$

With a similar derivation to the previous section,

$$E(Loss|Default) = -\frac{\frac{A_0\sigma_r}{\sqrt{2\pi}}\exp\left[\frac{-(1-k-\mu_r)^2}{2\sigma_r^2}\right]}{\Phi\left[\frac{1-k-\mu_r}{\sigma_r}\right]} + A_0(\mu_r + k - 1).$$

Thus, plugging $D_0 = (1-k)A_0$ we get

$$p(1-k^G)+(k^G+\overline{r}_L-1)\Phi\left[\frac{1-(k^G+\overline{r}_L)}{\sigma_L}\right]-\frac{\sigma_L}{\sqrt{2\pi}}\exp\left[\frac{-(1-(k^G+\overline{r}_L))^2}{2\sigma_L^2}\right]=0 \quad (30)$$

and hence,

$$p(1-k^B)+k^B\Phi\left[\frac{-k^B}{\sigma_M}\right]-\frac{\sigma_M}{\sqrt{2\pi}}\exp\left[\frac{-(k^B)^2}{2\sigma_M^2}\right]=0, \quad (31)$$

completing the derivation.

6.3 Appendix A.3: Derivation of $V^{IRB}(\beta = 0, k^G, C_S)$, Value of a B bank under the IRB Approach

The value of a B bank after switching to the IRB approach is

$$\begin{aligned} V^{IRB}(\beta=0,k^G,C_S) &= E\left\{\sum_{\tau=1}^{\infty} d^\tau(Div_{t+\tau})\right\} \\ &= dDiv_{t+1} + (1-\theta)V^{IRB}(\beta=0,k^G,C_S) + \theta V(\beta=0,k^B) \\ &= d\Pr\left[A_0 r_{t+1} + k^G A_0 > D_0\right] \\ &\cdot \left\{E\left[A_0(r_{t+1}-p-1)|A_0 r_{t+1} + k^G A_0 > D_0\right]\right. \\ &+ \left.(1-\theta)V^{IRB}(\beta=0,k^G,C_S) + \theta V(\beta=0,k^B)\right\}. \quad (32) \end{aligned}$$

When the capital requirement is binding, we can rewrite (32) replacing A_0 with $\frac{Eo}{k^G}$ and D_0 with $(1-k)\frac{Eo}{k^G}$

$$\begin{aligned} V^{IRB}(\beta=0,k^G,C_S) &= d\left[\frac{E_0}{k^G}\frac{\sigma_M}{\sqrt{2\pi}}\left[\exp(\frac{-(k^G)^2}{2\sigma_M^2}\right] + \Phi\left(\frac{k^G}{\sigma_M}\right)\right. \\ &\cdot \left.\left[(1-\theta)V^{IRB}(\beta=0,k^G,C_S) + \theta V(\beta=0,k^B) - (c_s+p)\frac{E_0}{k^G}\right]\right]. \end{aligned}$$

With further simplification, we get

$$V^{IRB}(\beta=0,k^G,C_S)=\frac{d\left[\frac{E_0}{k^G}\frac{\sigma_M}{\sqrt{2\pi}}\left[\exp(\frac{-(k^G)^2}{2\sigma_M^2}\right]+\Phi\left(\frac{k^G}{\sigma_M}\right)\left[\theta V(\beta=0,k^B)-(c_s+(1-k^G)p)\frac{E_0}{k^G}\right]\right]}{\left[(1-d(1-\theta)\Phi\left(\frac{k^G}{\sigma_M}\right)\right]}.$$

7 Appendix B

7.1 Appendix B.1: Proof of Proposition 1

Proposition 1: If the regulator cannot differentiate B banks from G banks, B banks always pool with G banks in order to have the fixed-rate (k^*) capital requirement.

Since the regulator can not differentiate B banks from the G banks, the only way for the B banks to choose a higher capital requirement than k^* would be their voluntary incentive to do so. We can easily show that, given the natural upper bound that the capital requirement creates on size, the maximized value of the B banks ($V(\beta^*=0,k)$) is a declining function of k.[25] Thus,

$$\frac{d}{dk}(V(\beta^*=0,k)<0,\ \forall k.$$

Let E_0 be the constant value for the initial amount of equity, k be the required capital ratio, d be the discount factor, σ_M be the variance of the return on risky loans, and Φ and ϕ be the normal cdf and pdf, respectively. Note that we set $p=0$ in this analysis just for simplicity. The result does not change for $p>0$ also. We have

$$V(\beta^*=0,k)=\left[(1-d\Phi\left(\frac{k}{\sigma_M}\right)\right]^{-1}d\left[\frac{E_0}{k}\frac{\sigma_M}{\sqrt{2\pi}}\left[\exp(\frac{-(k)^2}{2\sigma_M^2}\right]\right].$$

[25]See also Figure 4 for the numerical simulations, showing that the value of the B bank is a declining function of the capital requirement, k.

Then $\frac{d}{dk}V(\beta^* = 0, k)$ is equal to

$$
\begin{aligned}
& -\frac{dE_0 \exp(\frac{-(k)^2}{2\sigma_M^2})(k^2+\sigma_M^2)}{\sqrt{2\pi}k^2\sigma_M(1-d\Phi\left(\frac{k}{\sigma_M}\right))} + \frac{d^2E_0\phi(\frac{k}{\sigma_M})\exp(\frac{-(k)^2}{2\sigma_M^2})}{\sqrt{2\pi}k(1-d\Phi\left(\frac{k}{\sigma_M}\right))^2} \\
= & \frac{dE_0 \exp(\frac{-(k)^2}{2\sigma_M^2})\left[dk\sigma_M\phi(\frac{k}{\sigma_M}) - (k^2+\sigma_M^2)\left(1-d\Phi\left(\frac{k}{\sigma_M}\right)\right)\right]}{\sqrt{2\pi}k^2\sigma_M(1-d\Phi\left(\frac{k}{\sigma_M}\right))^2} \\
= & \frac{dE_0 \exp(\frac{-(k)^2}{2\sigma_M^2})\left[d\frac{\sigma_M}{k}\phi(\frac{k}{\sigma_M}) - (1+\frac{\sigma_M^2}{k^2})\left(1-d\Phi\left(\frac{k}{\sigma_M}\right)\right)\right]}{\sqrt{2\pi}\sigma_M(1-d\Phi\left(\frac{k}{\sigma_M}\right))^2}. \qquad (33)
\end{aligned}
$$

The derivative is negative if the term inside the square brackets in (33) is negative. Let $\varkappa = \frac{k}{\sigma_M}$. Then the term in square brackets can be written as

$$
\begin{aligned}
\left[d\frac{\sigma_M}{k}\phi(\frac{k}{\sigma_M}) - (1+\frac{\sigma_M^2}{k^2})\left(1-d\Phi\left(\frac{k}{\sigma_M}\right)\right)\right] &= d\frac{\phi(\varkappa)}{\varkappa} - \left(1+\frac{1}{\varkappa^2}\right)(1-d\Phi(\varkappa)) \qquad (34) \\
&= \left(1+\frac{1}{\varkappa^2}\right)\left[d\frac{\varkappa}{1+\varkappa^2}\Psi(\varkappa) - (1-d\Phi(\varkappa))\right] \\
&= \left(1+\frac{1}{\varkappa^2}\right)\left[\underbrace{\left[d\frac{\varkappa}{1+\varkappa^2}\Psi(\varkappa) + d\Phi(\varkappa)\right]}_{L(\varkappa)} - 1\right]
\end{aligned}
$$

For the expression (34) to be negative, $L(\varkappa)$ should be less than 1. Since $L(\infty) = 1$, it suffices to show $L(\varkappa)$ is monotonic increasing to conclude the proof. Hence,

$$
\begin{aligned}
\frac{d}{d\varkappa}L(\varkappa) &= \frac{2d\phi(\varkappa)}{\varkappa^2+1} \\
&> 0,
\end{aligned}
$$

concluding the proof.

7.2 Appendix B.2: Proof of Corollary 2

Corollary 2: Social welfare function is expected to decrease as the economy switches from the first best capital requirements to the pooling equilibrium capital requirement, k^*.

Social welfare function, in any period t, is defined as

$$SW_t = s^G(\gamma_t + r_{L,t} - 1)\frac{E_0}{k^G}.$$

Then,

$$\frac{d}{dk}\left(E(SW_t)\right) = -s^G(\overline{\gamma} + \overline{r}_L - 1)\frac{E_0}{k^2} < 0,$$

where $\overline{\gamma}$ and $\overline{r}_L$ are the expected return on good loans to the entrepreneurs and the G banks, respectively.

Since the capital requirement for the G banks increases from k^G to k^*, social welfare function decreases under the pooling equilibrium.

7.3 Appendix B.3: Proof of Proposition 3

Proposition 3: Every G bank will adopt the "IRB approach," and will hold their first-best capital amount, k^G.

We want to show that the value of the G banks increases under the IRB approach. By switching to the IRB approach, G banks will enjoy a decline in their capital requirements from k^* to k^G. Since the set-up costs are assumed to be zero for them, the only cost for the G banks in the IRB approach is the supervision cost, C_S^G, which is by definition very small compared to the value created by a decline in their capital requirements. Therefore, showing that the value of the G banks is a declining function of the capital requirement for $\forall k < k^*$ will conclude the proof.[26]

As explained in the proof of proposition 2, the decline in the capital requirement affects the value of the safe banks through two channels. First, it increases their value through increase in asset size. Remember that, holding the equity constant, the amount invested in risky assets (A_0) is bounded from above by $\frac{E_0}{k}$. Second, decline in the capital requirement increases the probability of bankruptcy ($p_G = 1 - \Phi\left(\frac{k+\overline{r}_L-1}{\sigma_L}\right)$), and consequently decreases the value of the bank. However, the net effect on value is positive. Recall that,

$$V(\beta = 1, k) = \frac{d\frac{E_0}{k}\left[\frac{\sigma_L}{\sqrt{2\pi}}\left[\exp\frac{-(1-(k+\overline{r}_L))^2}{2\sigma_L^2}\right] + \Phi\left(\frac{(k+\overline{r}_L)-1}{\sigma_L}\right)(\overline{r}_L - 1)\right]}{\left[1 - d\Phi\left(\frac{(k+\overline{r}_L)-1}{\sigma_L}\right)\right]}.$$

Note that we set $p = 0$ in this analysis just for simplicity, the result is unaffected with

[26] See also Figure 4 for my numerical simulations, showing that the value of the G bank is a declining function of the capital requirement, k.

$p > 0$. We would like to prove that

$$\frac{d}{dk}(V(\beta = 1, k)) < 0, \forall k < k^*.$$

Let $\alpha = \frac{(k+\overline{r}_L)-1}{\sigma_L}$. Then

$$V(\beta = 1, k) = \frac{Eo}{k}\left\{\underbrace{\frac{d\sigma_L \psi(\alpha)}{[1 - d\Phi(\alpha)]} + (\overline{r}_L - 1)\left[\frac{1}{[1 - d\Phi(\alpha)]} - 1\right]}_{A(\alpha)}\right\}$$

If we differentiate the value function with respect to the capital requirement, we get

$$\begin{aligned} \frac{d}{dk}(V(\beta = 1), k) &= -\frac{E_0}{k^2}A(\alpha) + \frac{Eo}{k}A'(\alpha) \\ &= \frac{E_0}{k}[A'(\alpha) - V(\beta = 1, k)], \end{aligned} \tag{35}$$

where

$$\begin{aligned} \frac{dA(\alpha)}{dk} &= \frac{dA(\alpha)}{d\alpha}\frac{d\alpha}{dk} \\ &= \frac{1}{\sigma_L}\frac{d\phi\left(\alpha\right)\left[(\overline{r}_L - 1) - \sigma_L\alpha + d\sigma_L\alpha\Phi\left(\alpha\right) + d\sigma_L\phi\left(\alpha\right)\right]}{\left[1 - d\Phi(\alpha)\right]^2} \\ &= \frac{d\phi\left(\alpha\right)}{\sigma_L\left[1 - d\Phi(\alpha)\right]^2}\underbrace{\left[-k + d\sigma_L\left(\alpha\Phi\left(\alpha\right) + \phi\left(\alpha\right)\right)\right]}_{L(\alpha)} \end{aligned} \tag{36}$$

and (36) follows by simply plugging $\alpha = \frac{(k+\overline{r}_L)-1}{\sigma_L}$.

The derivative $\frac{d}{dk}(V(\beta = 1), k) < 0$ if and only if

$$A'(\alpha) - V(\beta = 1, k) < 0.$$

We would like to find the region of parameter k for which the above holds. Instead, we focus on another region, which is in fact a subregion of the original one. Let it be composed of k such that $A'(\alpha) < 0$. Note that this condition is not a necessary but a sufficient condition for $\frac{d}{dk}(V(\beta = 1, k)) < 0$. From (36), an equivalent condition is

$$d\sigma_L\left(\alpha\Phi\left(\alpha\right) + \phi\left(\alpha\right)\right) < k \tag{37}$$

Recall that $\alpha = [(k + \overline{r}_L) - 1]/\sigma_L$ and thus both sides of (37) is a function of k. This non-linear inequality would determine the sub-region, i.e., the value $k_{\min}$ such that all $k > k_{\min}$ the derivative is negative. Instead of trying to evaluate $k_{\min}$, we check whether k^G is a part of the region, namely, we check whether $k^G > k_{\min}$. Note that based on equation (30), the value of k^G is determined by the non-linear equation

$$\alpha \Phi(\alpha) = \phi(\alpha). \tag{38}$$

Thus, to check whether (37) holds for $k = k^G$, it suffices to check

$$2 d \sigma_L \phi(\alpha) < k^G, \tag{39}$$

where $\alpha = \frac{(k^G + \bar{r}_L) - 1}{\sigma_L}$. We know that $\phi(\alpha) \approx 0$ for the G banks. Thus, for a reasonable value of k^G, $\frac{d}{dk}(V(\beta = 1), k) < 0$ for all $k > k^G$, including the pooling equilibrium capital requirement, $k^* > k^G$.

Therefore, it is always better for the G banks to identify themselves by using the IRB approach, so that they can hold less capital, which is equal to their first-best ratio (k^G), and consequently can increase their size.

7.4 Appendix B.4: Proof of Proposition 5

Proposition 5: Given the supervision and set-up costs for the banks and the probability of being caught as a B bank pretending to a G bank under the IRB approach, there exists a k^*_{new} such that the following separating equilibrium exists.

1. G banks switch to the IRB approach, and their capital requirement is k^G.

2. B banks stay in the old system of standardized approach if their capital requirement will be $k^*_{new} - \varepsilon$, where $k^G < k^*_{new} < k^B$ and the following equation is satisfied.

$$\mathbf{V}^{IRB}(\boldsymbol{\beta} = \mathbf{0}, \mathbf{k}^G, \mathbf{C}^B_S) - \mathbf{C}^B_F = \mathbf{V}(\boldsymbol{\beta} = \mathbf{0}, \mathbf{k}^*_{new}).$$

We want to show that we can find a k^*_{new} such that the equilibrium, in which G banks choose to adopt the IRB approach, and B banks have an incentive to stay in the old system, is a separating Bayesian Nash Equilibrium. That means no bank type has an incentive to deviate, and bank actions on the equilibrium path are consistent with the beliefs. Equilibrium beliefs (μ) are,

$$\mu(\text{type=G}|\text{IRB Approach}) = 1$$

and

$$\mu(\text{type=B}|\text{Standardized Approach}) = 1.$$

For the first part of the proposition, see the proof for Proposition 3, where we showed that G banks always adopt the IRB approach in order to identify themselves to the regulator for the parameters of our interest. In other words, G banks have no incentive to stay in the standardized approach.

For the second part, we need to show that there exists a $k^*_{new} - \varepsilon$ such that k^*_{new} satisfies the following condition.

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B = V(\beta = 0, k^*_{new}) \tag{40}$$

where $k^G < k^*_{new} < k^B$.

Analytically, the existence of k^*_{new} that satisfies (40) such that $k^G < k^*_{new} < k^B$ is trivial. Since the left hand side of the above equality is declining in C_F^B and C_S^B, and under the standardized approach $C_F^B = C_S^B = 0$,

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B < V(\beta = 0, k^G). \tag{41}$$

Also, we assumed an upper bound on set-up costs (C_F^B) using

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B > V(\beta = 0, k^B) \tag{42}$$

Since, as we showed in Proposition 1, the value of the B bank is a declining function of k, equations (41) and (42) imply that there exists a k^*_{new}, where $k^G < k^*_{new} < k^B$, such that

$$V^{IRB}(\beta = 0, k^G, C_S^B) - C_F^B) = V(\beta = 0, k^*_{new}).$$

Therefore, there exists a $k^*_{new} - \varepsilon$ such that k^*_{new} satisfies the equation (40), concluding the proof.

7.5 Appendix B.5: Proof of Corollary 6

Corollary 6: Compared to the pooling equilibrium under the standardized approach (as described in Proposition 1), the separating equilibrium, in

which all the G banks adopt the IRB approach and all the B banks stay in the standardized approach (as described in Proposition 3), increases the social welfare function.

The proof is very similar to the proof of the Corollary 2. If the G banks adopt the IRB approach, their capital requirement decrease to the first-best value, k^G. Remember that the social welfare function, in any period t, is defined as

$$SW_t = s^G(\gamma_t + r_{L,t} - 1)\frac{E_0}{k^G}$$

and

$$\frac{d}{dk}\left(E(SW_t)\right) = -s^G(\overline{\gamma} + \overline{r}_L - 1)\frac{E_0}{k^2} < 0,$$

where $\overline{\gamma}$ and $\overline{r}_L$ are the expected return on good loans to the entrepreneurs and the "G" banks, respectively.

Therefore, holding equity constant the size of the G banks and consequently social welfare function increases under the separating equilibrium. This concludes the proof of the corollary.

8 Appendix C

This appendix lists the parameter values used in the numerical simulations that produce the figures 1-4. Numerical simulations are run because β does not have a closed form solution, therefore $V(\beta)$ can be only numerically solved. Remember that

$$V(\beta) = (1 - df(\beta))^{-1}d\left[g(\beta) + f(\beta)(\mu_r - 1 - p(1-k))A_0\right] \quad (43)$$

where

$$f(\beta) = \Phi\left[\frac{(k+\mu_r) - 1}{\sigma_r}\right] \quad (44)$$

and

$$g(\beta) = A_0\frac{\sigma r}{\sqrt{2\pi}}\exp\left[\frac{-(1-(k+\mu_r))^2}{2\sigma_r^2}\right]. \quad (45)$$

The expected return and variance of the good loans are chosen based on the descriptive statistics of the loan spreads, covered by the Survey of Terms of Business Lending over four quarters of 2003. The survey provides quarterly loan-level data on commercial and industrial loan extensions of about 300 US banks. Risk-free gross return is normalized to 1 in the paper. Note that, in 2003, the 6-month and 1-year Treasury rates were, on average, 1.1% and 1.29%, respectively. The capital requirement is assumed to be binding for the bank, i.e.

$$E_0 = kA_0.$$

Below are the parameter values used in the numerical simulations resulted in the figures 1-4.[27]

- Initial Value of the Equity: $E_0 = 0.08$
- Capital Requirement Ratio: $k = 0.08$
- Value of the Risky Assets: $A_0 = \frac{E_0}{k} = 1$
- Expected Return on Good Loans: $\overline{r}_L = \{1.075, 3.075\}$
- Expected Return on Risky Loans: $\overline{r}_M = 1$
- Variance of the Good Loans: $\sigma_L^2 = 0.01$
- Variance of the Risky Loans:$\sigma_M^2 = 0.1$
- Probability that Next Period is *not* the Last Period of the Bank: $d = 0.99$
- Deposit Insurance Premium[28]: $p = \{0, 0.0015\}$

[27] The shape of the value function is robust to using other parameter values, as well.

[28] The fixed-rate premium charged by the FDIC is about 1.25% (See Pennacchi (2005)). Since the risk-free rate is normalized to zero in this paper, we set the insurance premiums either to zero or close to zero in our numerical simulations.

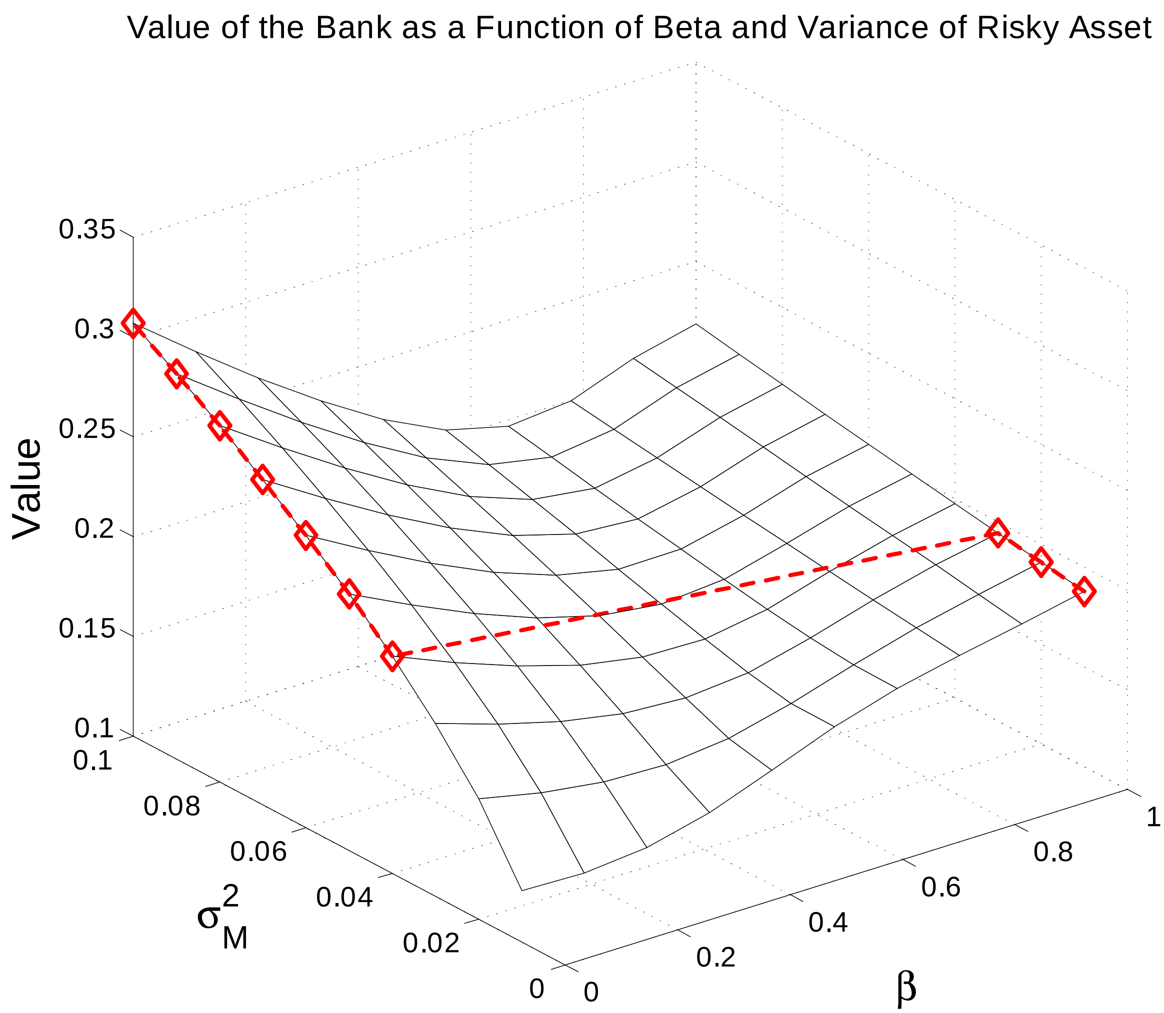

FIGURE 1

This figure shows how the value of the bank, $V(\beta)$, changes as the ratio of the investment in safe asset (β) changes from 0 to 1 and the variance of the return on risky asset (σ_M^2) changes from 0.01 to 0.01. The values of the other parameters used are as follows: $E_0 = 0.08$, $k = 0.08$, $A_0 = 1$, $\overline{r}_L = 1.0175$, $\overline{r}_M = 1.0$, $\sigma_L^2 = 0.01$, $d = 0.99$, and $p = 0.0015$. The value of the bank, $V(\beta)$, is as defined in equation (43). Note that, when the variance of the risky loan is equal to the variance of the good loan, the bank optimally sets $\beta^* = 1$ because the expected return on the good loan is higher. However, holding other parameters constant, as the variance of the risky loan increase, β^* changes from 1 to 0. See the points, corresponding to $V(\beta^*)$ and β^*, identified by diamonds in the figure.

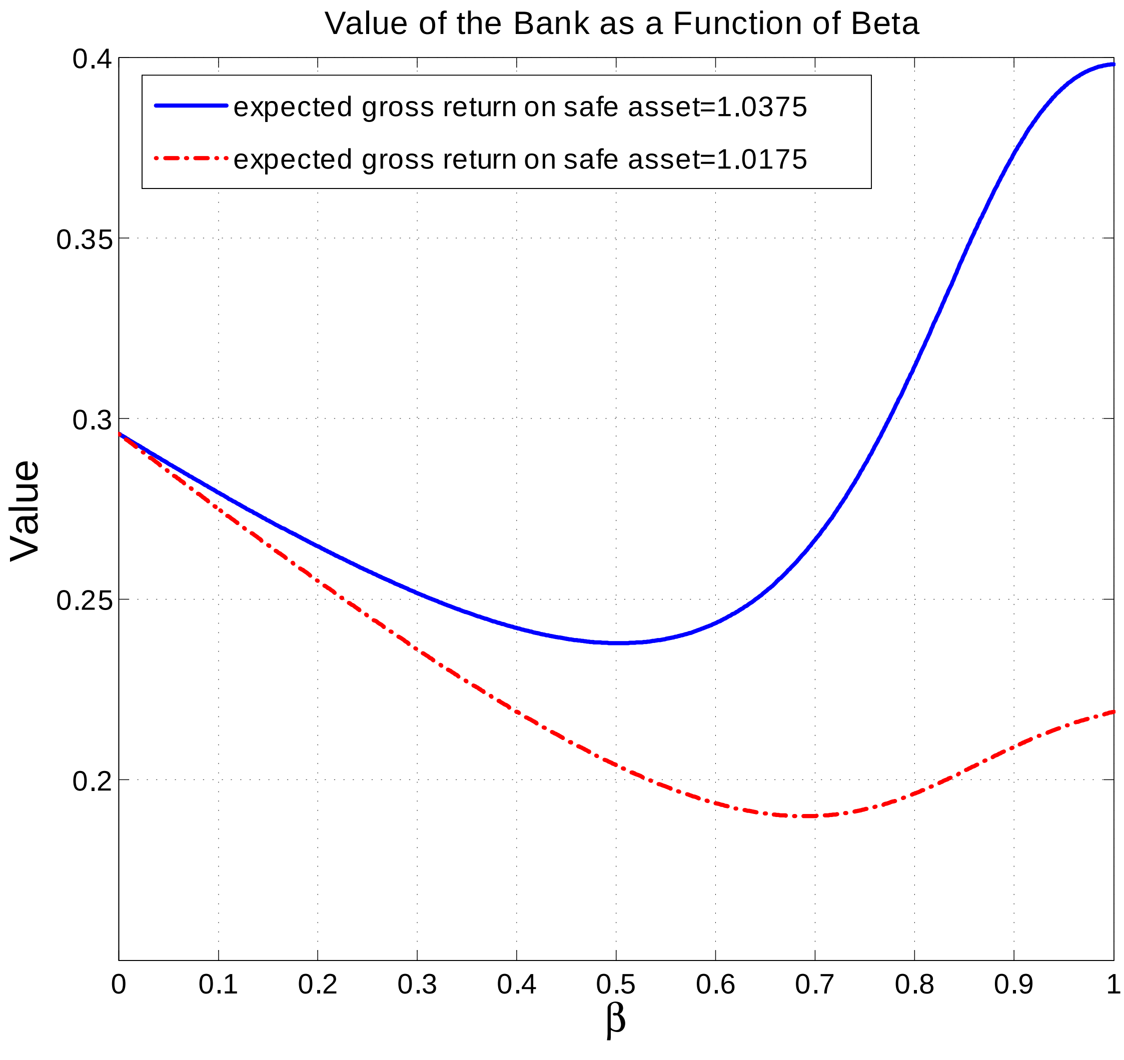

FIGURE 2

This figure shows how the value of the bank, $V(\beta)$, changes as the ratio of the investment in the safe loan (β) changes from 0 to 1 for two different values of the expected return on good loans: $\overline{r}_L = 1.0175$ and $\overline{r}_L = 1.0375$. The values of the other parameters used are as follows: $E_0 = 0.08$, $k = 0.08$, $A_0 = 1$, $\overline{r}_M = 1$, $\sigma_L^2 = 0.01$, $\sigma_M^2 = 0.1$, $d = 0.99$, and $p = 0.0015$. The value of the bank, $V(\beta)$, is as defined in equation (43). Note that, holding other parameters constant, as the expected return on the safe loan increase by 2%, the bank's optimal investment switches from $\beta^* = 0$ to $\beta^* = 1$.

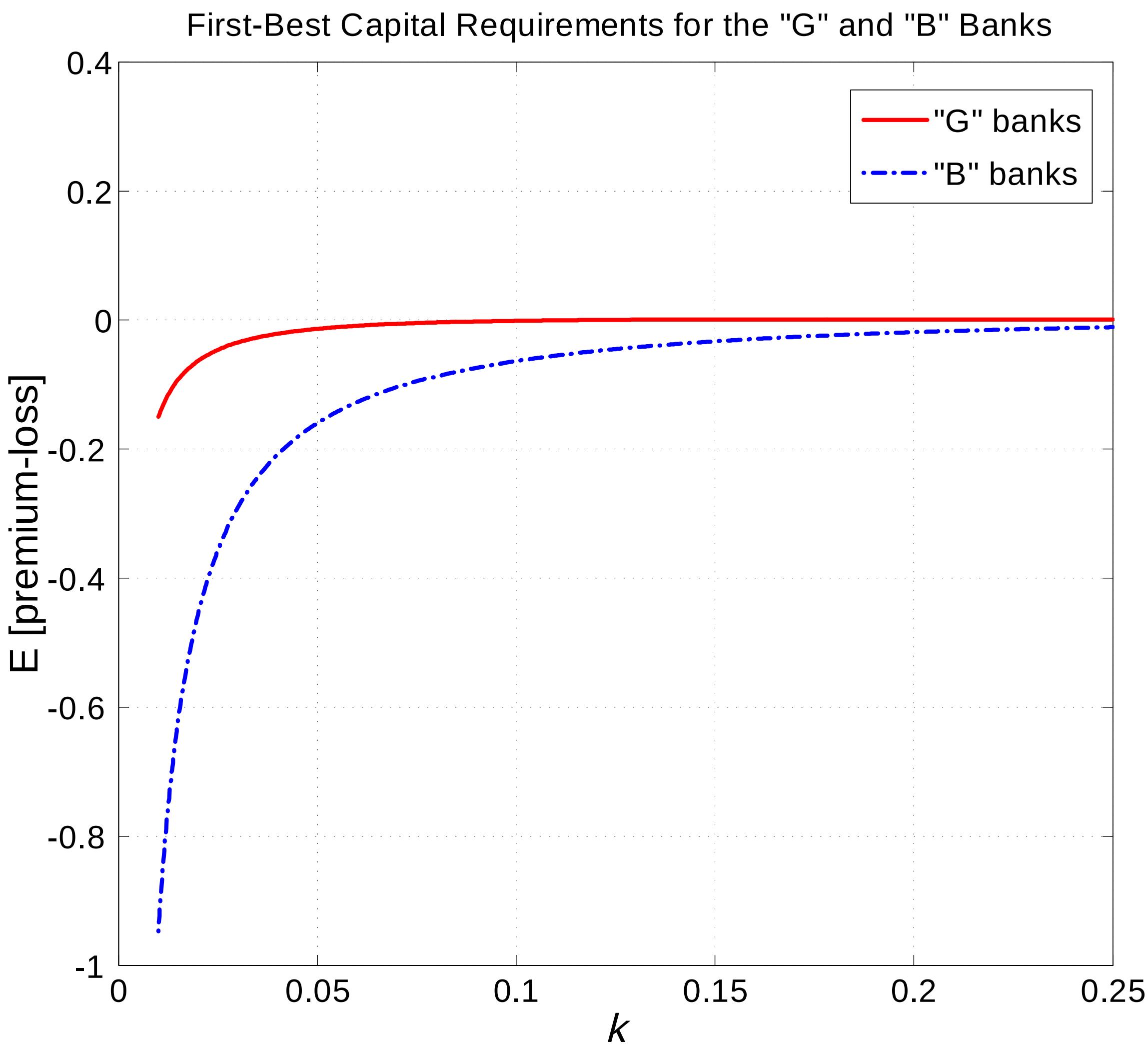

FIGURE 3

This figure shows the first-best values of the capital requirements for the "G" and "B" banks, k^G and k^B, that satisfy the equations (20) and (21), respectively. On the y-axis is the "expected premiums minus loss" to the deposit insurance fund, $E(InsurancePremium_t^i - Loss_t^i)$, and on the x-axis is the capital requirement ratio, k. First-best value of the capital requirement for the G and the B bank, k^G and k^B, make the expected premiums minus loss on the y-axis equal to zero. The values of the other parameters used are as follows: $E_0 = 0.08$, $k = 0.08$, $A_0 = 1$, $\overline{r}_L = 1.0375$, $\overline{r}_M = 1.0$, $\sigma_L^2 = 0.01$, $\sigma_L^2 = 0.1$ $d = 0.99$, and $p = 0.0015$. Note that, $k^G << k^B$.

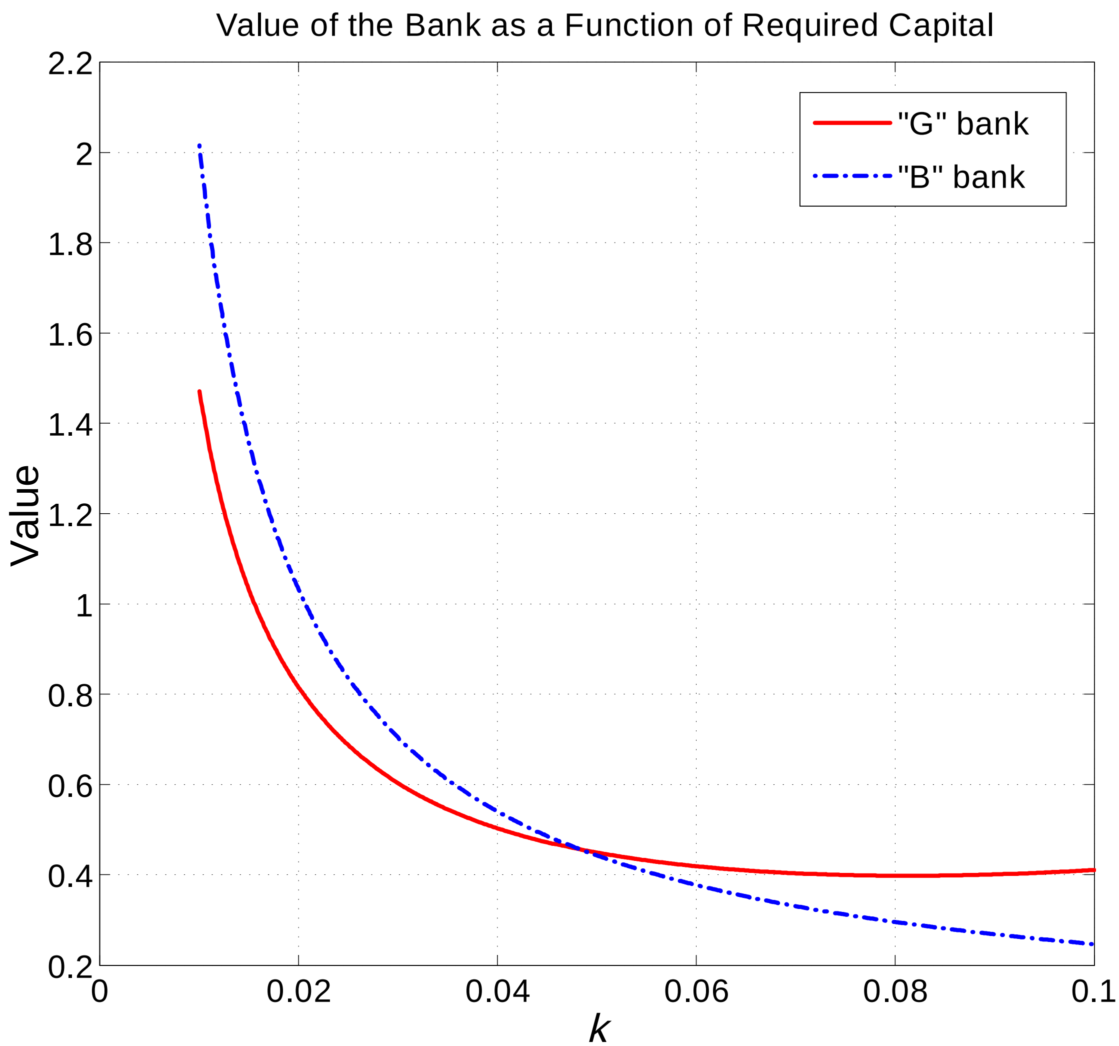

FIGURE 4

This figure shows how the value of the bank, $V(\beta)$, changes as the capital requirement, k^*, changes from 0.01 to 0.10 for the two types of banks: "G" banks (with $\beta^* = 1$ and $\overline{r}_L = 1.0375$) and "B" banks (with $\beta^* = 0$ and $\overline{r}_M = 1$). The values of the other parameters used are as follows: $E_0 = 0.08$, $A_0 = kE_0$, $\sigma_L^2 = 0.01$, $\sigma_M^2 = 0.1$, $d = 0.99$, and $p = 0.0015$. The value of the bank, $V(\beta)$, is as defined in equation (43). Note that $V(\beta)$ is a declining function of k for both type of banks.