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Abstract

Using the industrial organization approach to the microeconomics of banking we model a large (Monti-Klein) bank which is risk neutral and faces credit uncertainty in its loan business. The impact of capital adequacy regulation and the effect of changes in risk on deposit and loan rates are analyzed. We then show that capital adequacy regulation induces the bank to behave as if it were risk averse. Finally, we examine risk management with credit derivatives in the framework of the proposed New Basel Capital Accord where such hedging operations are explicitly accounted as reducing the risk position of a bank. In this environment separation and full hedge results are derived.

Keywords: credit risk, capital adequacy, regulation, risk aversion.

JEL classification: G21, G28

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Credit Risk and Capital Adequacy Regulation

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Using the industrial organization approach to the microeconomics of banking we model a large (Monti-Klein) bank which which is risk neutral and faces credit uncertainty in its loan business. The impact of capital adequacy regulation and the effect of changes in risk on deposit and loan rates are analyzed. We then show that capital adequacy regulation induces the bank to behave as if it were risk averse. Finally, we examine risk management with credit derivatives in the framework of the proposed New Basel Capital Accord where such hedging operations are explicitly accounted as reducing the risk position of a bank. In this environment separation and full hedge results are derived.

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1 Introduction

Banks play a crucial role in modern economies due to their ability to transform liquid deposits from the liability side of their balance sheets into loans as illiquid assets on the asset side. Doing this, they create liquidity for both depositors and borrowers who in turn can then realize their most desired consumption or investment plans, respectively (cf. Diamond, Rajan, 2001). As is well–known, this kind of transformation provided by banks is a source of risks of which credit risk — the risk of borrower default — is probably the most important one.

Some recent theoretical work has focused on the impact of risk, such as credit risk or market risk, on bank behavior in markets for deposits and loans and in markets for hedging instruments (see e.g. Wong, 1997, Wahl, Broll, 2000). In these papers the so–called industrial organization approach to banking (Freixas, Rochet, 1997, ch. 3) is extended to an analysis under uncertainty, using a von–Neumann–Morgenstern utility function to represent a bank management's attitude towards risk in general and risk aversion in particular. A standard result derived in this framework is the following: Banks alter their decisions in the presence of uncertainty in order to reduce the exposure to risk (see e.g. Wahl, Broll, 2000). Furthermore it can be shown that risk management, i.e., using derivatives such as futures and swaps for hedging purposes, is beneficial. In some circumstances hedging permits banks to separate their production and risk management decisions. As a result, they need not care about risk when making production decision, i.e., buying deposits and selling loans, and are able to fully transfer their risk to derivatives markets. In the literature these results are labelled separation property and full hedge theorem.

However, this theoretical work in banking is subject to criticism put forward in a more general context by Froot et al. (1993) who pointed out that the hedging literature does not really explain why firms hedge against risk. From the existing literature the authors mention risk aversion of managers, a convex tax function, the cost of financial distress and capital market imperfections as explanations for hedging (see Froot et al., 1993, for references). These arguments for active corporate risk management seem applicable to the banking industry, but they are affected by the same logical weaknesses in this sector. For example, managers of a bank implicitly hold a relatively large stake of their wealth in the banking firm causing a high correlation between their personal wealth and the bank's wealth. Compared to outside stockholders their ability to diversify their claims is limited, and they will therefore prefer hedging to reduce the variance of the bank's value. The validity of this reasoning clearly hinges upon the assumption that bank managers face prohibitive costs of hedging for their own accounts (cf. Froot et. al, 1993) which may appear questionable in today's world of highly developed capital markets.

In order to establish a solid argument for risk averse behavior Froot et al. (1993) start out from an observed capital market imperfection, namely that externally obtained funds are more expensive than funds generated internally. They show that the optimal hedging strategy of a firm, and the fact that it uses hedging in the first place, depend upon the nature of its investment and financing opportunities. In Froot, Stein (1998) they provide an application where a per se risk neutral decision maker exhibits endogenous risk averse behavior. The authors call this "effective" risk aversion. We will speak of " as if" risk aversion.

Returning to the banking industry, we notice that the question of whether or not a bank can be considered risk averse also has implications for the debate about banking regulation. Given that the overall aim of regulating banks is "to improve the safety and soundness in the financial system" (Basel Committee on Banking Supervision, 2001b, p. 1), one can argue that a bank's risk aversion works exactly in this direction and therefore supports the regulator's objective. One could then wonder whether credit risk yields an independent motive for regulation or whether the prime arguments for regulating banks are systemic risk and "the inability of depositors to monitor banks" (Santos, 2000, p. 5).

Against this background, the purpose of our paper is the following: We want to introduce capital adequacy regulation as an important factor to explain risk averse behavior of banks and to examine how this regulation interacts with the hedging motive of a bank. To achieve this, we use a microeconomic model of a bank with credit risk to show that capital adequacy regulation of the kind of both the existing Basel Capital Accord and the proposed New Basel Capital Accord (often labelled "Basel II") makes a per se risk neutral bank behave as if it were risk averse. This effect arises because the regulation relates equity capital to the volume of the risky asset and its risk. Our analysis is clearly related to Froot et al. (1993), since our results are also driven by the assumption that there are funds obtainable at different prices. Furthermore we show that in this context it is beneficial for the bank to engage in risk management — i.e., hedging — only if the regulatory rules treat hedging as risk reducing thereby lowering capital requirements. Such a treatment of hedging is part of the Basel II proposal.

The remainder of the paper is organized as follows. In section 2 we present the basic model and analyze bank behavior in the absence of regulation. In section 3 we introduce a capital adequacy regulation of the kind proposed for the Basel Capital Accord type into the model and compare the results to those of section 3. Some comparative–static results are presented. In section 4 we consider the opportunity to hedge the bank's risk and develop conditions for hedging being beneficial. Section 5 concludes.

2 Base model without regulation

To model bank behavior we apply the industrial organization approach to banking (cf. Freixas, Rochet, 1997, ch. 3), augmented by uncertainty of the credit risk type. Analyses of risk within this framework were also performed e.g. by Zarruk, Madura (1992), Wong (1997) and Wahl, Broll (2000). More specifically, we consider a one period setting with a large banking firm which enjoys market power in both the deposit and loan markets.[1]

Loans L and deposits D are assumed to be homogenous. The decisions on loans and deposits are made via the setting of loan and deposit rates r_L and r_D, respectively, at the beginning of the period. The bank faces a loan demand function $L = L(r_L)$ with $L'(r_L) < 0$ and $L''(r_L) < 0$ and a deposit supply function $D = D(r_D)$ with $D'(r_D) > 0$ and $D''(r_D) < 0$. In other words, demand for loans is assumed to be a concave function, and the supply of deposits ($D(r_D)$) is assumed to be concave,

[1]Notice that this (Monti–Klein) model of a monopolistic bank is a natural starting point for an analysis of oligopolistic banking industries which we address in other work.

too.[2]

The operational cost of financial intermediation is described by a cost function depending on the volumes of deposits and loans: $C = C(D, L)$ with $\partial C(D, L)/\partial D = C_D(D, L) > 0$, $\partial C(D, L)/\partial L = C_L(D, L) > 0$, $\partial^2 C(D, L)/\partial D^2 = C_{DD}(D, L) > 0$, $\partial^2 C(D, L)/\partial L^2 = C_{LL}(D, L) > 0$ and $\partial^2 C(D, L)/(\partial D \partial L) = \partial^2 C(D, L)/(\partial L \partial D) = C_{DL}(D, L) = 0$. I.e., we assume the cost function to be convex in loans and deposits and do not consider any economies or diseconomies of scope. In section 5 we briefly comment on changes to be made if we move away from this benchmark case.

The balance sheet constraint of the bank can now be written as

$$L + M = D + K \tag{1}$$

where K is the amount of equity held by the bank and M the amount of excess ($M > 0$ when $L < D + K$) or shortage ($M < 0$ when $L > D + K$) in liabilities which can be lent or borrowed at a risk free interest rate $r > 0$. If we interpret the bank under consideration as one of large number of local monopolists, this lending or borrowing would occur in a competitive interbank market for funds. Otherwise, r could be interpreted as interest rate in an international market for funds or as interest rate controlled by the central bank. All of these interpretations can be found in the banking literature. Since for our analysis it does not matter which one we use, we follow the majority of the literature and speak of a competitive interbank market. Finally, $r_K > 0$ denotes the cost of holding or extending equity.

The bank faces credit risk as a unique source of risk, i.e., we abstract from the interaction of different types of risk and focus on credit risk as the most important one in the traditional business of financial intermediation. For modeling credit risk we follow the lead of Wong (1997): Let the random variable $\tilde{\theta} \in [0, 1]$ denote the proportion of loans non–performing at the end of the period. A loan is defined as non–performing, if the borrower fully defaults on payment of interest and repayment of principal. Such non–performing loans have to be written off completely at the end of the period.[3]

With this information the random profit of the bank can be written as

$$\tilde{\Pi} = (1 - \tilde{\theta}) r_L L(r_L) - \tilde{\theta} L(r_L) + rM - r_D D(r_D) - r_K K - C(D, L). \tag{2}$$

where a "~" here and henceforth denotes a random variable. By substituting for M in (2) from the balance sheet constraint (1) the bank's random profit can be

[2]These concavity assumptions are made to simplify the exposition of our argument. They could be replaced by less restrictive conditions to ensure the concavity of the bank's objective function without changing the qualitative nature of our results.

[3]Our approach could similarly used to examine the case of borrowers only defaulting on interest payments or other forms of partial default.

rewritten as

$$\tilde{\Pi} = (r_L - r)L(r_L) - \tilde{\theta}(1 + r_L)L(r_L) + (r - r_D)D(r_D) + (r - r_K)K - C(D, L). \quad (3)$$

Since we later want to show how risk averse behavior results from the interplay of uncertainty and capital adequacy regulation, we assume at this point that the bank is risk neutral, i.e., it simply maximizes its expected profit by simultaneously choosing r_D and r_L at the beginning of the period:

$$\max_{r_D, r_L} \mathrm{E}(\tilde{\Pi}) \quad (4)$$

where E is the expectation operator with respect to the probability distribution of $\tilde{\theta}$ and $\tilde{\Pi}$ is given by equation (3).

The first–order necessary conditions for (4) are given by

$$-\frac{D(r_D)}{D'(r_D)} - r_D + r - C_D(D, L) = 0 \quad (5)$$

$$(1 - \bar{\theta}) \left(\frac{L(r_L)}{L'(r_L)} + r_L \right) - (r + \bar{\theta}) - C_L(D, L) = 0 \quad (6)$$

where $\bar{\theta} = \mathrm{E}(\tilde{\theta})$. Equation (5) determines the optimal deposit rate, whereas equation (6) determines the optimal loan rate. The two interest rates can be set independently because of two reasons. First, our assumption of a zero cross–derivative $C_{DL}(D, L) = C_{LD}(D, L) = 0$ implies that the optimal deposit rate is not influenced by the loan rate via the cost of intermediation and vice versa. Second, the existence of the competitive interbank market separates the two sides of the balance sheet. There is no need to care about the liability side when choosing the amount of loans (via the loan rate) and vice versa. Credit risk has no impact on behavior on the deposit market and the risk neutral bank acts in the loan market as if the default rate were certain at the expected value $\mathrm{E}(\tilde{\theta})$.

As for the amount of equity K we can say the following: Depending on the sign of $r - r_K$ holding more equity can be beneficial for the bank or not. When $r - r_K > 0$ every additional unit of equity capital increases the expected profit. In this situation the bank holds as much equity as possible. In the case of $r - r_K < 0$ a higher amount of equity lowers the expected profit. Then the bank tries to get along without any equity.

3 Capital adequacy regulation

We now introduce capital adequacy regulation into the model. Our bank is required to hold a minimum level of equity depending on the amount of loans and their riskiness. More specifically, this means

$$K \geq K(\delta L(r_L)) \text{ with } K'(\delta L(r_L)) > 0 \text{ and } \delta > 0. \tag{7}$$

The regulatory instrument δ adds weight to the volume of loans outstanding. δ can be made dependent on the risk of loans which we will consider in more detail later. This kind of regulation considered in the model is a stylized representation of the regulatory approach for credit risk both under the existing Basel Capital Accord and under the proposed New Basel Capital Accord (cf. Basel Committee on Banking Supervision, 2001a, paragraphs 68-76).

Before conducting our formal analysis, it is necessary to take a second look at the cost of capital r_K. The consensus in the literature is that the cost of capital has to be above the riskless rate of return in the market. Agency costs are probably the most important explanation for this statement. Such agency costs arise because of asymmetric information between the bank's management and the owners of its equity capital (see Jensen, Meckling, 1976, and Myers, Majluf, 1984, for details). In other words, due to agency costs $r < r_K$ or $r - r_K < 0$. In this case an increase of equity K reduces expected profit as we just mentioned in the previous section. Therefore, given the volume of loans and the level of credit risk the bank is interested in employing the lowest level of equity possible. For that reason the regulatory constraint (7) can be considered as binding in the sequel.

The bank is again assumed to maximize its expected profit (4) with respect to the deposit rate and the loan rate, where $\tilde{\Pi}$ is now given by

$$\begin{aligned} \tilde{\Pi} = (r_L - r)L(r_L) \quad &- \quad \tilde{\theta}(1 + r_L)L(r_L) + (r - r_D)D(r_D) \\ &+ \quad (r - r_K)K(\delta L(r_L)) - C(D, L). \end{aligned} \tag{8}$$

The first–order necessary conditions are

$$-\frac{D(r_D)}{D'(r_D)} - r_D + r - C_D(D, L) = 0 \tag{9}$$

$$(1 - \bar{\theta})\left(\frac{L(r_L)}{L'(r_L)} + r_L\right) - (r + \bar{\theta}) - C_L(D, L) + (r - r_K)K'(\delta L(r_L)) = 0. \tag{10}$$

As in the previous section decisions about deposit and loan rates can be separated. Therefore, equation (9) defines the optimal deposit rate and equation (10) defines the optimal loan rate of the model with regulation.

Comparing the first–order conditions (9) and (10) to the corresponding conditions (5) and (6) from the model without capital adequacy regulation reveals the equivalence between (5) and (9), i.e., the conditions for the deposit rate. Thus the introduction of the capital adequacy regulation does not influence the bank's deposit rate decision. Invoking the separation result this implies $r_D = r_D^R$, where r_D^R denotes the optimal deposit rate under regulation. However, a comparison of equations (6) and (10) shows that the first–order conditions for the optimal loan rate differ by $(r - r_K)K'(\delta L(r_L))$ which is negative due to our assumptions on regulation and on the cost of equity capital. Therefore the loan rate unambiguously increases as a result of the introduction of the regulation, i.e., $r_L < r_L^R$.

We can thus state our first proposition:

Proposition 1 *Due to the introduction of capital adequacy regulation the optimal loan rate increases and the optimal deposit rate remains unaffected. In consequence the level of loans decreases with regulation.*

Proof: To prove the proposition we adopt a similar proof from Wahl, Broll (2000). Due to $(r - r_K)K'(\delta L(r_L)) < 0$ condition (10) implies

$$(1-\bar{\theta})\left(\frac{L(r_L^R)}{L'(r_L^R)} + r_L^R\right) - (r+\bar{\theta}) - C_L(D, L(r_L^R)) > 0.$$

in the optimum. Using this expression and condition (6) we get

$$(1-\bar{\theta})(r_L^R - r_L) > (1-\bar{\theta})\left(\frac{L(r_L)}{L'(r_L)} - \frac{L(r_L^R)}{L'(r_L^R)}\right) - \left(C_L(D, L(r_L)) - C_L(D, L(r_L^R))\right).$$

Assume that the loan rate does not rise as a result of regulation ($r_L^R \leq r_L$). Due to the assumptions about $L(r_L)$ and $C(D, L)$ it is easy to see that in the present case $1 - \bar{\theta} > 0$, $L(r_L^R) \geq L(r_L)$, $L'(r_L^R) \geq L'(r_L)$ and $C_L(D, L(r_L^R)) \geq C_L(D, L(r_L))$. Considering $L'(r_L) < 0$ the above equation yields $r_L^R - r_L > 0$ which contradicts the assumption of $r_L^R \leq r_L$. Thus the loan rate rises due to the regulation.□

The intuitive reason for this result is the following: Introducing capital adequacy regulation creates a link between both sides of the bank's balance sheet. A higher level of r_L lowers the volume of loans and thereby reduces the capital requirement and with it the costs of equity capital. This can easily be seen from (8).

But as mentioned before the overall aim of capital adequacy regulation under the Basel Accord is to improve the safety of the banking system. The existence of regulation should therefore reduce the bank's exposure to risk. As a consequence even a risk neutral bank should be sensitive to risk, if there is capital adequacy regulation. To investigate whether this holds true we slightly modify our model. We follow Sandmo (1971) and replace $\tilde{\theta}$ by $\tilde{\gamma} = s\tilde{\theta} + (1-s)\bar{\theta}$. The parameter s is initially set to one. Changes in s shift risk to a higher level, if $s > 1$, or to a lower level, if $s < 1$, leaving the expected proportion of non–performing loans unchanged, i.e., $\mathrm{E}(\tilde{\gamma}) = \mathrm{E}(\tilde{\theta}) = \bar{\theta}$. In other words, we employ a mean preserving spread of the probability distribution of credit risk. Substituting $\tilde{\gamma}$ for $\tilde{\theta}$ yields the same first–order conditions for deposit rates, whereas in the conditions for loan rates $\tilde{\theta}$ is replaced by $s\tilde{\theta} + (1-s)\bar{\theta}$.

It is now easy to see that without capital adequacy regulation there is no influence of s on the optimal values of r_D and r_L, i.e., maximization of the expected profit is not affected by a mean preserving spread. The same result holds true for the deposit rate in the case of regulation. Since the mean preserving spread does not not change the first–order condition (9), the optimal deposit rate under regulation is not affected by a change in risk in the sense of a mean preserving spread. To investigate the impact of a change in risk on the loan rate under regulation (r_L^R) we apply the implicit function theorem to (10) to get

$$\frac{dr_L^R}{ds}\Big|_{s=1} = -\left(\frac{\partial^2 \mathrm{E}(\tilde{\Pi})}{\partial r_L \partial s}\right) \cdot \left(\frac{\partial^2 \mathrm{E}(\tilde{\Pi})}{(\partial r_L)^2}\right)^{-1}. \tag{11}$$

Differentiating (10) with respect to r_L and applying the envelope theorem yields for the denominator of this expression

$$\frac{\partial^2 \mathrm{E}(\tilde{\Pi})}{(\partial r_L)^2} = 2(1-\bar{\theta})L'(r_L) + (r - r_K)K''(\delta L(r_L))(\delta L'(r_L))^2 - C_{LL}(D,L)(L'(r_L))^2$$

which is negative as long as the regulation function is not concave in weighted loans, i.e., $K''(\delta L(r_L)) \geq 0$. This convexity of the regulatory rule which also covers the case of a linear function holds both for the existing and the New Basel Capital Accord (Basel Committee on Banking Supervion, 2001b, p. 3).

Differentiating (10) with respect to s yields

$$\frac{\partial^2 \mathrm{E}(\tilde{\Pi})}{\partial r_L \partial s} = (r - r_K)L'(r_L)(K''(\delta L(r_L))\delta L(r_L) + K'(\delta L(r_L)))\frac{d\delta}{ds}.$$

for the numerator. Using $K''(\delta L(r_L)) \geq 0$ again the sign of this expression depends solely on the sign of $d\delta/ds$. Thus we get

$$\frac{\partial^2 \mathrm{E}(\tilde{\Pi})}{\partial r_L \partial s} \begin{array}{c} > \\ = \\ < \end{array} 0 \quad \Leftrightarrow \quad \frac{d\delta}{ds} \begin{array}{c} > \\ = \\ < \end{array} 0.$$

Therefore the reaction of the loan rate to a change in credit risk is given by

$$\frac{dr_L^R}{ds}\Big|_{s=1} \begin{array}{c} > \\ = \\ < \end{array} 0 \quad \Leftrightarrow \quad \frac{d\delta}{ds} \begin{array}{c} > \\ = \\ < \end{array} 0. \tag{12}$$

As a result we can now state the following

Proposition 2 *The optimal loan rate under capital adequacy regulation is affected by a mean preserving spread of credit risk if and only if* $\frac{d\delta}{ds} \neq 0$. *The deposit rate remains unaffected by changes in credit risk.*

Notice that under the existing Basel Capital Accord we have a positive relationship between s and δ implying a positive impact of risk on the interest rate on loans. For example, loans to central governments have a weight of $\delta = 0$, whereas corporate loans carry a weight of $\delta = 1$.[4] The proposal for the New Basel Capital Accord contains a more differentiated weighting scheme. For example, under the new standardised approach corporate loans can have risk weights of $\delta = 0.2$, $\delta = 0.5$, $\delta = 1.0$ or $\delta = 1.5$. To further analyze this proposition, we first differentiate the expected profit under regulation (8) with respect to s evaluated at the initial value of $s = 1$. Applying the envelope theorem yields

$$\frac{d\mathrm{E}(\tilde{\Pi})}{ds} \mid_{s=1} = (r - r_K) K'(\delta L(r_L)) L(r_L) \frac{d\delta}{ds}. \tag{13}$$

Again, given the above assumptions, the sign of (13) solely depends on the sign of $d\delta/ds$:

$$\frac{d\mathrm{E}(\tilde{\Pi})}{ds} \mid_{s=1} \; \begin{matrix} < \\ = \\ > \end{matrix} \; 0 \quad \Leftrightarrow \quad \frac{d\delta}{ds} \; \begin{matrix} > \\ = \\ < \end{matrix} \; 0. \tag{14}$$

From (13) we can observe an income effect due to regulation which is positive when δ increases in s and negative when δ decreases in s. In the case of δ independent from s this income effect disappears. The intuition is quite simple. Since raising and holding equity is costly — recall $r - r_K < 0$ — a higher required amount of equity because of a higher level of weighted loans increases the bank's costs and thus lowers expected profit. For a lower level of weighted loans the opposite is true. Given any amount of loans, changes in the level of weighted loans can only be caused by changes in δ. Thus when δ depends on risk s, a change in risk causes δ to change and in this way alters the level of weighted loans, creating regulatory costs for the bank. Therefore it is immediately clear that for the capital adequacy regulation to work it is necessary for δ to increase when s increases and to decrease when s decreases, i.e., $d\delta/ds > 0$. But this is precisely what existing and future banking regulation under the Basel Capital Accord requires (see e.g. Basel Committee on Banking Supervision, 2001b).

Moreover it is possible to derive a second insight from (13) and (14) above. Using a capital adequacy regulation of the Basel type, there is a negative relationship

[4] In the framework of our model, capital adequacy regulation operates with a linear function $K(\delta l) = 0.08\delta$L.

between the risk parameter s and the bank's objective function $\mathrm{E}(\tilde{\Pi})$. In other words, the increase in risk s lowers the expected profit of the bank all other things being equal. As a result, a risk neutral bank choosing from prospects offering the same expected share of nonperforming loans will always acting prefer the one with the lowest level of risk. In fact, due to the regulation the bank acts as if it were risk averse. Remember that a risk averse agent chooses a prospect with the lower risk from a pair of profit distributions with identical means (see Rothschild, Stiglitz, 1970). Thus we can state the following

Proposition 3 *A risk neutral bank maximizing its expected profit is induced by capital adequacy regulation of the Basel type (i.e.,* $\frac{d\delta}{ds} > 0$*) to behave as if it were risk averse.*

So we find a new interpretation of capital adequacy regulation. It creates in the context of risk neutral, expected profit maximizing banks an implicitly risk averse behavior. This arises because of the ability of the regulation to link the two sides of the balance sheet and in this way impose costs on the banks.

This result is in the spirit of recent analyses in the literature on corporate finance and risk management. Froot et al. (1993) and Froot, Stein (1998) show that firms exhibit implicitly risk averse behavior when there exists an investment opportunity which can only be financed by a combination of costly equity and internal funds originating from uncertain revenues from previous investments. They argue that a random decrease in internal funds implies a need for more equity, thereby ceteris paribus increasing costs and decreasing profit. A risk neutral firm anticipating this possibility will be induced to invest less than in the case with no such uncertainty.

4 Incentives for risk management

Risk management can be defined as "the discipline of identifying risks [...], assessing their potential impact on critical performance measures, and employing direct and indirect means for either reducing the exposure of underlying economic activities to these risks or shifting some of the exposure to others" (Lessard, 1995, p. 5). Because of the growing importance of financial markets to trade financial risk, we focus on the latter part of the above definition. Thus risk management will be considered as a bank's active risk shifting policy using financial markets for derivatives.

Since credit risk is the only source of risk in our model, we consider a market for credit derivatives. More specifically, we assume the existence of a market for total return swaps which can be bought or sold by the bank to the amount of H at the beginning of the period. The market is assumed to be unbiased. The swap contracts mature at the end of the period. The bank is obliged to pay to the contracting party the amount of $(1-\tilde{\theta})r_L - \tilde{\theta}$ upon maturity per unit issued. In return the bank gets a riskless repayment from its counterpart to the amount of $(1-\bar{\theta})r_L - \bar{\theta}$ per unit of total return swap issued due to the unbiasedness of the market. Thus the total return swaps create a revenue of $H(r_L+1)(\tilde{\theta}-\bar{\theta})$. Notice that H is not constrained. Thus at $H > 0$ the bank would sell swap contracts, whereas at $H < 0$ it would be a buyer of total return swaps. Notice further that as off-balance activities the swaps do not alter the balance sheet constraint (1).

The random profit of the bank with hedging and under capital adequacy regulation can now be written as

$$\begin{aligned}\tilde{\Pi} = (r_L - r)L(r_L) &- \tilde{\theta}(1+r_L)L(r_L) + (r - r_D)D(r_D) \\ &+ (r - r_K)K - C(D,L) + H(1+r_L)(\tilde{\theta} - \bar{\theta}). \qquad (15)\end{aligned}$$

We again consider capital adequacy regulation of the type examined in the previous section, i.e., $K = K(\delta L(r_L))$ with $r_K > r$. The bank calculates

$$\max_{r_D, r_L, H} \mathrm{E}(\tilde{\Pi}) \qquad (16)$$

where $\tilde{\Pi}$ is given by equation (15) above.

The first–order necessary conditions for problem (16) are

$$\begin{aligned} -\frac{D(r_D)}{D'(r_D)} - r_D + r - C_D(D,L) &= 0 \qquad (17) \\ (1-\bar{\theta})\left(\frac{L(r_L)}{L'(r_L)} + r_L\right) & \\ -(r+\bar{\theta}) - C_L(D,L) + (r - r_K)K'(\delta L(r_L))\delta &= 0 \qquad (18) \\ (r_L + 1)(\bar{\theta} - \bar{\theta}) &= 0. \qquad (19) \end{aligned}$$

Notice that the first–order conditions for the optimal levels of deposit and loan rates (17) and (18) are the same as the first–order conditions under regulation without hedging (9) and (10) in the previous section. Equation (19) — the first–order condition for the optimal level of hedging – holds for all values of r_D, r_L and H. For that reason the bank is indifferent between all possible hedging volumes. In fact, due to the unbiasedness of the market for total return swaps hedging adds no value to the bank's objective function in this model.

However, we have not yet taken into account that according to the New Basel Capital Accord hedging operations with credit derivatives are explicitly acknowledged as reducing the bank's risk, thereby lowering its capital requirement (see Basel Committee on Banking Supervision, 2001a, paragraphs 88-90). To integrate this into our model of banking under capital adequacy regulation, we modify the regulatory condition (7)in the following way:

$$K \geq K(\delta f(L(r_L) - H)) \text{ with } K'(\delta f(L(r_L) - H)) > 0. \qquad (20)$$

The function $f(L(r_L) - H)$ is used to correct the volume of loans outstanding L for the quantity of credit derivatives sold H. We will refer to the value of this function as regulatory loans. To motivate this function, we refer the reader to the proposal for a New Basel Capital Accord (Basel Committee on Banking Supervision,2001a, paragraph 90). This proposal implies the following properties of f: For every realization of $L(r_L) - H$ the function takes a non–negative value, i.e., $f(L(r_L) - H) \geq 0$ which rules out negative values of regulatory loans. Furthermore $f'(L(r_L) - H) > 0 \Leftrightarrow L > H$ and $f'(L(r_L) - H) < 0 \Leftrightarrow L < H$ which means that the higher absolute value of the difference $L(r_L) - H$, the higher the regulatory loan volume. Finally, $f'(0) = 0$. In other words, at $L(r_L) = H$ there is a unique minimum in the volume of regulatory loans. This, in fact, is in the interest of the regulator. To see this, we transform (15) into

$$\begin{aligned}\tilde{\Pi} = (r_L - r)L(r_L) &- \tilde{\theta}(r_L + 1)(L(r_L) - H) \\ &+ (r - r_D)D(r_D) + (r - r_K)K - C(D, L) + H(r_L + 1)\bar{\theta}.\end{aligned}$$

As can be seen easily from this equation, for $L(r_L) = H$ the influence of the random variable disappears and the bank's profit is no longer uncertain. This is why it is rational for the regulator to set the lowest capital requirement to the point $L(r_L) = H$. In the literature this point is referred to as full hedge (see e.g. Wahl, Broll, 2000).

Using the modified capital adequacy regulation, one can derive the bank's first–order necessary conditions as

$$-\frac{D(r_D)}{D'(r_D)} - r_D + r - C_D(D, L) = 0 \tag{21}$$

$$\begin{aligned}(1 - \bar{\theta})\left(\frac{L(r_L)}{L'(r_L)} + r_L\right) - (r + \bar{\theta}) - C_L(D, L) \\ +(r - r_K)K'(\delta f(L(r_L) - H))\delta f'(L(r_L) - H) = 0\end{aligned} \tag{22}$$

$$(r - r_K)K'(\delta f(L(r_L) - H))\delta f'(L(r_L) - H) = 0 \tag{23}$$

As in the previous cases conditions (21) and (22) define the optimal deposit and loan rates, respectively, whereas condition (23) concerns the optimal hedging volume.

To determine the optimal interest rates, we first have a look at (21) and (22). Comparing (21) to the corresponding conditions in the previous sections, we recognize that the first–order condition for the optimal deposit rate remains the same. Thus r_D is unaffected by regulation and hedging. As for the optimal loan rate we first replace $(r - r_K)K'(\delta f(L(r_L) - H))\delta f'(L(r_L) - H)$ in (22) by the first–order condition (23) for the optimal hedging decision to yield

$$(1 - \bar{\theta})\left(\frac{L(r_L)}{L'(r_L)} + r_L\right) - (r + \bar{\theta}) - C_L(D, L) = 0.$$

Inspection of this equation shows equivalence to the first–order necessary condition (6) for the optimal loan rate in the case without capital adequacy regulation. Therefore, we can state that as a consequence of optimal hedging the bank's optimal loan rate is the same as without regulation.

The optimum hedging level is given by equation (23). From our previous assumptions we know $(r - r_K) < 0$, $K'(\delta f(L(r_L) - H)) > 0$ and $\delta > 0$. Thus for equation (23) to hold it is necessary that $f'(L(r_L) - H) = 0$ which is true if and only if $L(r_L) = H$ given our assumptions on f. Thus the bank fully hedges its exposure to risk. This leads us to our

Proposition 4 *When unbiased hedging is available, the risk neutral bank under capital adequacy regulation of the Basel II type sets deposit and loan rates equal to the levels prevailing without regulation.*

Our analysis shows that a full hedge will be optimal, if the regulatory function f has the properties suggested by paragraph 90 of Basel Committee on Banking Supervision (2001a). Furthermore, our results exhibit the separation property well–known from the literature, i.e., the bank can separate its production decision on r_D and r_L from its risk management decision on H.

There is still one open question: Is hedging in the bank's interest? Or, in other words, is it beneficial for the bank to hedge? To answer this question we differentiate the bank's objective function (15) with respect to the hedging volume H and use the envelope theorem to arrive at

$$\frac{d\mathrm{E}(\tilde{\Pi})}{dH} = -(r - r_K)K'(\delta f(L(r_L) - H))\delta f'(L(r_L) - H)). \qquad (24)$$

We know from our assumptions that $(r - r_K) < 0$, $K'(\delta f(L(r_L) - H)) > 0$ and $\delta > 0$. Hence the sign of (24) only depends on the sign of $f'(L(r_L) - H)$. There are now two cases to be distinguished. First, when $H < L(r_L)$, i.e., when the bank performs an under–hedge, we get $f'(L(r_L) - H) > 0$. Thus in this case the sign of (24) is unambiguously positive. An increase in the hedging volume increases expected profits. Second, when $H > L(r_L)$, i.e., when the bank over–hedges, we get $f'(L(r_L) - H) < 0$. Hence in this case the sign of (24) is negative. An increase in the volume of hedging lowers expected profits.

The intuition of this result is straightforward. When the bank under–hedges ($H < L(r_L)$), its profit is still subject to risk. That is why the regulatory rules force the bank to use more equity which in turn causes costs to the bank. Raising the hedging volume reduces the exposure to risk — until at $L(r_L) = H$ profits are riskless — which in turn decreases the costs of capital hence raising expected profits. However, when the bank over–hedges ($H > L(r_L)$), profit is risky, too. Here the risk arises because the bank may have to hand over some of its (fully hedged) revenue from the loan business to the contracting party in the market for credit derivatives. In this case raising the hedging volume increases risk, and thereby due to the regulation the cost of equity capital also increases. Thus in this situation expected profit only increases when hedging is reduced and hence risk decreases.

5 Conclusion

Regulation of banks aims at increasing the safety of the banking sector. One of the most important instruments is a capital adequacy regulation which relates a bank's equity to its exposure to risk on the asset side of the balance sheet. In this paper we used an industrial organization approach to model a large risk neutral bank in order to investigate consequences of this kind of regulation. We found that a capital adequacy regulation of the type included both in the existing Basel Capital Accord and in the proposed New Basel Capital Accord induces a risk neutral bank to behave as if it were risk averse. This is caused by an income effect from linking the bank's exposure to risk to the equity capital required for performing banking activities. The only necessary condition for this mechanism to work is that holding and extending equity is more costly than the risk free interest rate in the (interbank) capital market.

Furthermore it was shown that because of this effect of capital adequacy regulation there exists an incentive for banks to engage in active risk management, i.e., hedging, if regulatory rules accept such hedging operations as risk reducing which part of the proposal of the New Basel Capital Accord. In this case the banks fully hedge their exposure to risk and can separate decisions on interest rates from hedging decisions. Otherwise hedging is not beneficial for banks and thus there is no need for performing such activities. Looking back at our model we frankly admit that life was made considerably easier by our assumptions on the operational costs of banking. However, we are convinced that the substance of the argument would not change with a more general specification of the cost function. If we had included a positive cross–derivative in the cost function — i.e., a sufficient condition for diseconomies of scope between the deposit business and the loan business of the bank —, our case would have been strengthened. A negative cross–derivative — indicating economies of scope — would weaken our case, but only reverse our results for sufficiently strong economies of scope. A similar point can be made with respect to economies of scale.

References

Basel Committee on Banking Supervision (2001a), Overview of the New Basel Capital Accord, Bank for International Settlements, Basel.

Basel Committee on Banking Supervision (2001b), The New Basel Capital Accord: an explanatory note, Bank for International Settlements, Basel.

Diamond, D.W., Rajan, R.G. (2001), Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking, Journal of Political Economy 109, 287-327.

Freixas, X., Rochet, J.-C. (1997), Microeconomics of Banking, Cambridge, MA: MIT Press

Froot, K.A., Scharfstein, D.S., Stein, J.C. (1993), Risk Management: Coordinating Corporate Investment and Financing Policies, Journal of Finance 48, 1629-1658.

Froot, K.A., Stein, J.C. (1998), Risk Management, Capital Budgeting, and Capital Structure for Financial Institutions: An Integrated Approach, Journal of Financial Economics 47, 55-82.

Jensen, M.C., Meckling, W.H. (1976), Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure, Journal of Financial Economics 3, 305-360.

Lessard, D.R. (1995), Financial Risk Management for Developing Countries: A Policy Overview, Journal of Applied Corporate Finance 8, 4-18.

Myers, S.C., Majluf, N.S. (1984), Corporate Financing and Investment Decision when Firms have Information that Investors do not have, Journal of Financial Economics 13, 187-221.

Rothschild, M., Stiglitz, J.E. (1970), Increasing Risk: I. A Definition, Journal of Economic Theory 2, 225-243.

Sandmo, A. (1971), On the Theory of the Competitive Firm under Price Uncertainty, American Economic Review 61, 65-73.

Santos, J.A.C. (2000), Bank Capital Regulation in Contemporary Banking Theory: A Review of the Literature, BIS Working Paper No. 90, Bank for International Settlements, Basel.

Wahl, J.E., Broll, U. (2000), Financial Hedging and Banks' Assets and Liabilities Management, Forschungsbericht 0002, Europa-Institut, Sektion Wirtschaftswissenschaften, Universität des Saarlandes, Saarbrücken.

Wong, K.P. (1997), On the Determinants of Bank Interest Margins Under Credit and Interest Rate Risk, Journal of Banking and Finance 21, 251-271.

Zarruk, E.R., Madura, J. (1992), Optimal Bank Interest Margin under Capital Regulation and Deposit Insurance, Journal of Financial and Quantitative Analysis 27, 143-149.