A real options approach for evaluating the implementation of a risk sensitive capital rule in banks *

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Abstract

I evaluate a bank's incentives to implement a risk sensitive regulatory capital rule. The decision making is analyzed within a real options framework where optimal policies are derived in terms of threshold levels of risk. The bank's customers, lenders, and other outsiders may influence the optimal decision. Outsiders may make it optimal for the bank to implement the risk sensitive rule earlier than it otherwise would have preferred. I provide numerical example for the implementation of internal rating based models for credit risk (the IRB-approach) under the new Basel accord (Basel II).

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1 Introduction

In order to promote people's trust in the financial sector, authorities supervise banks and require that they hold a minimum level of capital[1]. The aim of this regulatory capital is to provide a cushion that can absorb large and sudden deficits in the bank's earnings and thereby avoid a bank failure. The bank's customers and lenders (outsiders) are also concerned with the bank's riskiness. The owners of the bank determine the preferred level of capital taking into account both the regulatory capital and outsiders' perception of the bank's riskiness. I study the situation where banks are given an option to select between two rules for the computation of regulatory capital. The bank can continue to apply the rule currently in use or switch to the new rule. The decision to switch to the new rule is irreversible, i.e., the bank has to use this rule both today and in the future. The irreversibility is imposed by the authorities because they do not want that banks shift back and forth between different rules. The application of the new rule may give more information to the outsiders about the bank's risk characteristics. The bank's decision of whether to implement the new rule will therefore take into account both the changes in regulatory capital and possible adjustments in the outsiders' risk perception. This situation may be viewed as a game between the bank and the outsiders. I analyze the bank's and the outsiders' decision making within a real options framework, where the bank always has an option to delay the implementation of the new rule. Implementation is optimal if the state variable representing risk is below a threshold level. The outsiders' role may either be an active or a passive one. When the outsiders play an active role, they may cause the bank to implement the new rule earlier than it otherwise would have preferred. This is an example of a situation where outsiders may have a disciplining

[1] I adhere to the convention in the banking literature and use the term capital. For non-banks it is customary to use the term equity.

effect on bank behavior.

The analysis is inspired by the option given to banks in the Basel accord (Basel II), see Basel Committee on Banking Supervision (2004), where banks can choose between a standard approach and an approach based on internal rating based models (IRB) to compute regulatory capital for credit risk. The latter alternative is more sensitive to changes in risk over time than the first alternative. Within the Basel II framework, a bank using the standard approach may be seen as using the current rule, here comparable to the non-rating based rule. Basel II is based on the so called three pillars. The first pillar covers minimum capital requirement, the second pillar deals with the supervisory review process, and the third pillar covers market discipline. My analysis covers obviously pillar one, but it also deals with a rating agency's, or outsiders', perception of the bank's riskiness. As such, the analysis is also relevant when considering the consequences of market discipline (pillar three) for a bank's selection of regulatory capital.

In the analysis the preferred capital ratio is the highest of either regulatory capital or the capital ratio that maximizes the market value of the bank. This latter capital ratio is comparable to the market capital requirement mentioned by Berger et al. (1995). They describe on page 395 a bank's market capital requirement as

> ".. the capital ratio that maximizes the value of the bank in the absence of regulatory capital requirements (and all the regulatory mechanisms that are used to enforce them), but in the presence of the rest of the regulatory structure that protects the safety and soundness of banks".

The implication is that the market value of the bank will decline if the the bank has too much or too little capital. The introduction of the risk sensitive rule may influence the bank in two ways. The first effect is *reduced regulatory capital*. A reduction in regulatory capital will increase the market value of the bank, provided that the bank is constrained by the current rule. Because the decision to use the new rule is irreversible, the bank must not only take into consideration the immediate change in capital due to the new rule, but also the future development in the difference in regulatory capital between the old and the new rule. The second effect is the *signalling effect*. In short, the signalling effect reflects changes in outsiders' required compensation for holding exposures or claims on the bank. This required compensation may be changed upon observing whether the bank switches to the new rule. As an example, under the Basel II rules the internal models are to be approved by regulators. Regulators will only approve models if they are of a sufficient standard. Such an approval may be a signal about the portfolio quality and the quality of the management of the bank. If the bank does not introduce the risk sensitive rule, i.e., does not get the regulator's approval, the external stake holders may suspect that they in the future will face negative surprises concerning losses in the bank's loan portfolio. If the bank does not introduce the new rule, the capital ratio that maximizes the market of the bank may therefore increase.

The premise of a unique optimal capital ratio is not trivial from a theoretical perspective. After all, if it was all the same which capital ratio the owners of the bank decided on, the owners would be indifferent when selecting the regulatory capital and the level of the capital in general. All capital ratios would be optimal. According to the result of Miller and Modigliani (M & M), see Miller and Modigliani (1958), the choice of level of capital does not influence the market value of the company ("the size of the pie"). Any change in the level of capital will only cause a redistribution of value between equity and bond holders (reflecting changing "shares of the pie"). There will be no gain to the shareholders from engaging in the activity of changing the capital ratio. If one makes other assumptions than those in the M & M, there may be an optimal capital ratio. Changing the capital ratio from a non-optimal to an optimal level will then cause the value of the shareholders' holding to increase. This increase may again be caused by an increase in the market value of the company, by a redistribution of wealth from bond holders, or a combination of the two effects. I will in the following present the main arguments that are put forward in the literature to explain the existence of an optimal capital ratio. This is not an exhaustive literature review, but rather a to-the-point presentation of the main arguments put forward in the literature.

Costs of financial distress make it optimal to avoid holding low levels of capital. Examples of such costs are bankruptcy costs and the costs of foregone business opportunities due to outsiders' unwillingness to conduct business with a company that may fail. Deadweight losses due to bankruptcy and reorganization were mentioned by Miller and Modigliani (1958). *Taxes* favor the use of debt. Interest payments are deductible in the company's taxable income. Increasing the level of debt will therefore reduce the authorities share of profit and leave more to the shareholders, see, e.g., Miller (1976). *Transaction costs* are costs of raising capital. In the presence of transactions cost, the arbitrage argument causing the M & M argument to hold may no longer be strictly valid. Transaction costs also form the basis for the pecking-order model of debt, see Myers (1984). According to this model, retained earnings are the ”cheapest” form of capital, followed by new debt and new equity. The capital ratio will then vary over time with the difference between necessary investment and internally generated funds. Several explanations for an optimal capital ratio are based on the argument of *asymmetric information*. As an example, managers of the bank may use the level of capital as a signal to financial markets about the quality of banks' assets. In Ross (1977) there are two types of companies. One company will have a higher final value than the other. The actual type of a company is not known by the market. If the manager has information about the true type, and with an appropriate incentive structure, the manager will take on relatively more debt in the best type of company in order to maximize his own reward. The market will then price the two types of companies differently. This signal causes an increase in the value of equity for the good company. Another example of asymmetric information is the agency cost argument that increased debt will lead to increased operational efficiency, see Jensen (1986). A requirement to service debt will discipline the managers and induce a more efficient operation of the firm. One argument applying specifically to banks is the presence of a *safety net* for banks' depositors. The safety net refers to the guarantee that authorities give to depositors for the safety of their bank deposits. If the price that banks pay to the authorities for this guarantee is too low relative to the actual risk, there is an incentive for banks to accept too much deposits. For discussions of the capital ratio related to financial institutions in particular, see, e.g. Berger et al. (1995) or Miller (1995). All the reasons mentioned above may, more or less, be present when a given bank is analyzed. An optimal capital ratio may therefore be the result of a trade-off between several factors. Such a mixture of explanatory factors may therefore be present in the analysis. This was, e.g., the approach taken by Fama and French (2002) when they tested the pecking-order model against what they named a trade-off model of debt.

My work adds to the literature covering the application of real options theory in different industries. The paper illustrates how real options theory may be used to analyze banks' timing of when to exercize the options they have to comply with different sets of regulatory rules. Textbook treatment of optimal investment timing for irreversible investments may, e.g., be found in Dixit and Pindyck (1994), Trigeorgis (1996), and Amram and Kulatilaka (1999). Smit and Trigeorgis (2004) provide many examples on how to combine real options and game theory. A recent literature review on options and games are presented in section two in Smit and Trigeorgis (2006). My work also contributes to the literature concerning the consequences of a risk sensitive regulatory capital regime. In particular, I describe how banks optimal policies depend on whether they are constrained by the current rule, the reduction in regulatory capital obtained by applying the new rule, and on possible changes in outsiders' capital requirement.

The model is presented in the next section. Section three provides a numerical example for the implementation of internal rating based rules under Basel II and the final section summarizes the main points.

2 The model

2.1 Optimal capital and capital regulation

The optimal capital ratio maximizes the market value of the bank. A lower or higher level of capital than the optimal capital causes therefore a reduction in value. The regulatory capital determines the lowest level of capital a bank can hold. If the regulatory capital is *higher* than the optimal capital, the bank is required to be at what it considers to be a suboptimal capital level. If the bank can choose between two regulatory rules that give different levels of regulatory capital, it will select the one that gives the highest market value of the bank. Figure 1 outlines the decision problem for two banks, bank A and B.

(insert Figure 1 approximately here)

The optimal capital for bank A and B is γ^* and $\hat{\gamma}^*$, respectively. Bank A is *constrained* by the current regulatory rule C and is obliged to hold at least the regulatory capital $\underline{\gamma}^{(C)}$. If bank A chooses to be regulated by regulatory rule N, the new regulatory capital will be $\underline{\gamma}^{(N)}$. Under this rule the optimal capital γ^* is achievable, and the value of selecting rule N is the increase in market value of the bank, G. Bank B is not constrained by either of the regulatory rules and it will under both rules hold the optimal capital $\hat{\gamma}^*$.

The bank may choose when, if at all, to implement the new rule. The decision to use the new regulatory rule is, however, irreversible. This, coupled with the fact that the level of the future regulatory capital is uncertain, makes the new regulatory rule well suited for being analyzed as a real option. The banks hold an American option with an infinite exercise date to implement the new regulatory rule.

In order to focus attention on the capital ratio and to facilitate the derivation of the value of choosing between the regulatory rules, I make the following simplifying assumptions.

1. *Separability of operational decisions and the level of capital*. The profit potential of the bank is determined by operational decisions, such as lending and loan rate decisions, market and segment strategies, and selection of technological platforms. The separation of operational and financial decisions (capital ratio), is not novel. This separation also follows, e.g., from the results in Miller and Modigliani (1958).

2. *The capital ratio only influences fixed costs*. By fixed costs I mean costs that do not vary with the bank's activity level as measured, e.g., by sales or lending growth. This assumption is in the spirit of Jensen (1986) where the debt ratio influences operational efficiency, but here only fixed costs.

3. *Costless adjustment of capital*. In the case of an optimal capital ratio, there will be no timing considerations involved in capital adjustment, as in Fischer et al. (1989). The bank will always hold capital at the optimal level.

The regulatory capital will take into account the level of credit risk in a bank's loan portfolio. The credit portfolio's expected loss rate may be described as an Ito processes,

$$d\mu_t = f(\mu_t, t)dt + \sigma(\mu_t, t)dW_t, \tag{1}$$

where dW_t is an increment of a standard Brownian motion and where the drift $f(\cdot,\cdot)$ and volatility $\sigma(\cdot,\cdot)$ may be functions of the underlying loss rate and time. Realized losses on a portfolio may be decomposed into two parts, *expected* and *unexpected* losses[2]. This approach is incorporated into the Basel II rules, see, e.g., p. 48 in Basel Committee on Banking Supervision (2004) where this decomposition is used in relation to the use of internal credit risk models. In fact, tail events are categorized as unexpected losses. Capital buffers of banks, or regulatory capital, are supposed to absorb losses created by such events. Under the Basel II rules for internal models the computation of regulatory capital is based on the probability of default (*PD*) and loss given default (*LGD*). The product of these two parameters ($PD \times LGD$) represents, however, the expected loss rate. With assumptions about loss given default, it is therefore sufficient to focus on expected losses in order to compute the regulatory capital.

The cost rate $g(\gamma_t, \mu_t)$ is a function of the capital held in the bank and, possibly, the credit loss rate. In order to obtain a unique optimal capital rate, I assume that the cost rate is a strictly convex function of capital ($g_{\gamma\gamma}(\gamma_t, \mu_t) > 0$ for all μ_t). The optimal capital in absence of capital regulation, $\gamma^*(\mu_t)$, is the capital that minimizes the cost rate (and thereby maximizes the market value of the bank). The highest of this capital and the

[2] Accumulated realized losses L_t may, e.g., be modelled as an Ito process of the form $dL_t = \mu_t dt + \sigma_t^{(U)} dW_t^{(U)}$, where μ_t is the expected loss rate and where unexpected losses are captured by the "$\sigma_t^{(U)} dW_t^{(U)}$"-term, and where $dW_t^{(U)}$ is the increment of a standard Brownian motion, possibly correlated with the Brownian motion in equation (1).

regulatory capital with rule i is the optimal capital under this rule, i.e.,

$$\gamma_t^{(i)*} = \max\left[\gamma^*(\mu_t), \underline{\gamma}^{(i)}(\mu_t)\right], \;\; i \in \{C, N\}, \tag{2}$$

where $\underline{\gamma}^*(\mu_t)$ is regulatory capital, and where C and N refer to the ”current” and the ”new” regulatory rule. The present value of costs under regulatory rule i is

$$\mathrm{V}_t[K^{(i)*}] = \mathrm{E}_t^Q\left(\int_t^\infty e^{-r(s-t)} g(\max[\gamma^*(\mu_s), \underline{\gamma}^{(i)}(\mu_s)], \mu_s) ds\right) \;, \; i \in \{C, N\}, \tag{3}$$

where $\mathrm{E}_t^Q(\cdot)$ is the expectation operator under the equivalent martingale measure Q conditioned on information at time t and r is the constant instantaneous risk free interest rate.

The payoff from the option to implement the new rule at the exercise date τ equals the value of reduced costs less implementation costs I_t, i.e.,

$$Z_\tau = \mathrm{V}_t[K^{(C)*}] - \mathrm{V}_t[K^{(N)*}] - I_t \;, \; \tau = t \;. \tag{4}$$

The market value of the option at time t when exercised at a future time τ, Z_t^τ is then equal to

$$Z_t^\tau = \mathrm{E}_t^Q\left(e^{-r(s-t)} Z_\tau\right), \; t \leq \tau \;, \tag{5}$$

where Z_τ is the option's exercise payoff. With admissible exercise dates $\mathcal{T}$, the market value at time t with the optimal exercise strategy is

$$Z_t^* = \sup_{\tau \in \mathcal{T}} Z_t^\tau, \; t \leq \tau \;. \tag{6}$$

It is customary to express exercise policies in terms of threshold levels for the state variable μ_t. It is reasonable to assume that policies are such that the exercise of the options are optimal when the risk level μ_t is equal to or lower than a threshold level μ_t^{**}. Waiting, or non-exercise, will then be optimal at higher risk levels[3].

Analyzing the implementation decision by applying equations (3)-(6) is standard in the real options literature. It is well known, see, e.g., McDonald and Siegel (1986), that an option to delay the investment decision may create a positive hurdle that the value of the investment must pass before the investment is made. In our case it is worth noting that it will not be optimal for a bank that is constrained by rule C to implement the new rule if this leads to an immediate increase in regulatory capital.

Proposition 1 (Condition of non-increasing regulatory capital)**.** *If the implementation cost is zero and if the bank is constrained by regulatory rule C, it will only implement the new rule N if the new rule does not give an immediate increase in regulatory capital.*

Proof. See appendix. □

Large banks where the main investments already have been made may be considered to have approximately zero implementation costs. For these banks one would not expect to observe an increase in regulatory capital at the implementation time.

It is also worth noting that if a bank is unconstrained by the current rule C, it will not invest in rule N if the investment cost is larger than zero.

Proposition 2 (Non optimality of N if the bank is unconstrained by C)**.** *If the investment cost is larger than zero and if the bank is always unconstrained by rule C, it will not be optimal for the bank to implement rule N.*

[3]Conditions for securing that the exercise of the option is optimal for $\mu_t \leq \mu_t^{**}$, and waiting to be optimal otherwise, is, e.g., discussed on page 128 in Dixit and Pindyck (1994).

Proof. The result follows from the fact that the optimal capital ratio is not influenced by the choice of regulatory rule. The new regulatory rule may only cause an increase in the capital held by the bank. The value of the cost savings will therefore not be positive and the bank is therefore not willing to pay a positive implementation cost (investment). □

2.2 Signaling

At low capital levels it may be reasonable to assume that outsiders to the bank will require extra compensation for holding an exposure to the bank. At low capital levels the bank may then have to balance the benefits of increased efficiency (lower fixed costs) in the bank against the additional required compensation from outsiders. Introducing risk compensation relaxes the assumption that the capital ratio only is relevant in determining fixed costs. Figure 2 depicts the situation for two banks, *A* and *B*.

(insert Figure 2 approximately here)

Either bank may be of type *H* or *L*. The outsiders will require extra compensation if the level of capital is below $\underline{\gamma}^H$ or $\underline{\gamma}^L$, respectively. In order to minimize fixed costs, bank A would prefer to hold a capital level of γ^*. If the bank, however, is classified as a type *H* bank, it will be optimal to hold a capital level of $\underline{\gamma}^H$. At this capital level the bank has a higher cost rate than at the optimum, but it avoids paying additional compensation to outsiders. In this instance the bank is constrained by outsider's required risk compensation. Bank B is not influenced by the classification as a *H* or *L* bank. It will always hold the optimal capital level $\hat{\gamma}^*$. If the outsiders hold beliefs p_t that the bank is of type H, the price for exposure may generally be expressed as

$$\pi(\gamma_t, \mu_t, p_t) = \begin{cases} h(\gamma_t, \mu_t, p_t) & \text{if } \gamma_t < \underline{\gamma}(\mu_t, p_t) \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where $h(\cdot,\cdot,\cdot)$ is the required risk compensation when the capital is below the threshold level $\underline{\gamma}(\cdot,\cdot)$.

The regulatory rule applied by the bank may give outsiders information about the bank's type. This information may be obtained from observing the level of regulatory capital, or perhaps, the additional information that the bank is required to make public. The regulatory capital is

$$\underline{\gamma}_t^{(i)} = \begin{cases} \underline{\gamma}^{(C)}(\mu_t) & \text{if } i = C \\ \underline{\gamma}^{(N)}(\mu_t, \beta) & \text{if } i = N \ , \ \beta \in \{L, H\} \ , \end{cases} \tag{8}$$

where the bank's type β may determine the regulatory capital with the new rule N.

With no strategic interaction between the outsiders and the bank, the optimal capital under a regulatory rule is according to equation (2) the highest of the efficiency maximizing capital and the regulatory capital. The bank may, however, also be constrained by the capital level implicit in the the outsiders' required compensation. The following assumption simplifies this argument.

4. *It is optimal for banks to hold enough capital to avoid additional exposure compensation from outsiders*. This will be the case if the increased costs of exposure compensation due to a reduction in capital below the threshold level always are larger than the increased efficiency benefits (reduced fixed costs).

When outsider's exposure compensation is included, the optimal capital ratio under regulatory rule i is

$$\gamma_t^{(i)*} = \max\left[\gamma^*(\mu_t), \underline{\gamma}(\mu_t, p_t), \underline{\gamma}_t^{(i)}\right],\ i \in \{C, N\}, \tag{9}$$

i.e., the highest of the efficiency maximizing capital $\gamma^*(\mu_t)$, the capital necessary to avoid exposure compensation $\underline{\gamma}(\mu_t, p_t)$, and the regulatory capital $\underline{\gamma}^{(C)}(\mu_t)$ or $\underline{\gamma}^{(N)}(\mu_t, \beta)$.

Because the optimal capital ratio in equation (9) always secures that the risk compensation in equation (7) is zero, the capital ratio will onfly influence fixed costs. The value of the fixed costs is now

$$\mathrm{V}_t[K^{(i,\beta)*}] = \mathrm{E}_t^Q\left(\int_t^\infty e^{-r(s-t)} g(\max\left[\gamma^*(\mu_s), \underline{\gamma}(\mu_s, p_s), \underline{\gamma}_s^{(i)}\right], \mu_s)ds\right),\ i \in \{C, N\}, \tag{10}$$

where the regulatory capital is given by equation (8). Equation (10) is identical to equation (3), except for the inclusion of possible constraints in capital induced by the outsdiers and the regulatory capital that may depend on the bank's type. The outsiders' belief p_t may depend on the bank's decision of whether to introduce the new regulatory rule. If the new rule fully reveals the bank's type, then the outsiders simply can observe the bank's required capital and update their belief about the bank. The strategic interaction between the bank and the outsiders may be modelled as a signaling game. The bank first decides whether to implement the new rule at time t or to continue to use the old rule. The outsiders observe the bank's action. If the bank chooses to implement the new rule, the outsiders observe the regulatory capital and update the belief accordingly. If the bank does not implement, the outsiders update the belief based on this. One way to solve this game, i.e., to derive strategies for the bank and the outsider, is to apply the concept of a Perfect Bayesian Equilibrum. In this equilibrium both players' strategies are optimal (perfect) and the updating of beliefs is based on Bayes' rule, wherever possible. A formal presentation of the interaction between the bank and the outsiders and the definition of a Perfect Bayesian Equilibrium is given in the appendix. It is worth noting that the action of the outsiders is to select a pricing schedule based on the belief, $\pi(\cdot,\cdot,p_t)$. Outsiders are indifferent between being exposed to banks with different p's as long as they receive the required compensation. In this sense, the optimal action chosen by the outsiders (the pricing schedule) is totally determined by the beliefs.

Will the outsiders' beliefs and actions influence the bank's decision of whether to introduce the new rule? If the outsiders play a *passive role*, their actions do not influence the bank's decision. There may, however, also be situations with an *active role* for the outsiders. Consider the case where only a type L bank would implement the new rule. If the implementation threshold for a type L bank that wrongly is considered to be a type H bank, $\mu^{**}(L \mid H)$, is higher than the implementation threshold for a type L bank that is classified to be a type L bank, $\mu^{**}(L \mid L)$, then the outsiders' classification of the bank may influence the implementation decision if the expected loss rate is between the two thresholds, i.e., $\mu^{**}(L \mid L) < \mu_t \leq \mu^{**}(L \mid H)$. Figure 3 shows this situation, and it also shows how the path of the state variable may influence the time when the implementation of rule N takes place.

(insert Figure 3 approximately here)

Assume initially that the belief is that the outsiders are facing a type L bank ($p_0 = 0$). None of the bank types would implement the new rule at first. If the belief is not updated before the bank implements the new rule, the bank will implement the new rule the first time that expected losses is equal to $\mu^{**}(L|L)$, i.e., at time t'''. If, however, the belief is such that ”all banks that do not implement the first time that credit losses are equal to $\mu^{**}(L|H)$ are type H banks”, it will be optimal for the outsiders to increase the required exposure compensation at this time. The bank knows the belief, and with the knowledge about the outsiders’ action in case it does not implement, it will be optimal for the bank to implement the new rule. This happens at time t'. There are, however, several possible equilibria in the game pictured in Figure 3. Consider the case where the belief is that the non implementing bank at time t'' is a type H bank. The type L bank will implement at this date, provided that the expected credit loss is not higher than the maximum threshold $\mu^{**}(L|H)$. In signalling games solved by selecting a Perfect Bayesian Equilibrium, there is a circular relationship between beliefs and strategies[4]. One method for selecting between equilibria may be to pick the equilibrium with the earliest implementation date. This would be the equilibrium where the new rule is implemented at time t' in Figure 3.

The role of the outsiders depends on how they influence the bank’s optimal capital level. If the bank’s type is revealed when it implements the new regulatory rule N, the most interesting question is how outsiders may influence the capital ratio under the current regulatory rule C. ”Good quality” banks (type L banks) unable to convey its proper type to the outsiders, may see the new rule N as a means of correcting the outsiders’ perception of the bank. If the banks do not implement the new rule, they risk that the outsiders reconsider and think that they are facing ”bad quality” banks (type H banks). In order for the outsiders’ change in perception to influence the implementation decision, it is necessary for the capital to increase under rule C.

Proposition 3 (Active role for outsiders)**.** *If the bank’s type is revealed by the new rule*

[4]Fudenberg and Tirole (1996) comment on this circularity on page 326: ”Note the link between strategies and beliefs: The beliefs are consistent with the strategies, which are optimal given the beliefs”.

N, the outsiders may only influence the implementation decision by making the bank constrained by the outsiders' required compensation under the current regulatory rule C.

Proof. See the appendix. □

”Bad quality” banks know that their type will be revealed if they implement the new rule. If the banks are perceived to be of a better quality than they actually are, the benefits of introducing the new rule will therefore be caused by a reduction in regulatory capital and not by a reevaluation of the banks' type. If the bank is always constrained by the outsiders' exposure compensation under the current rule when it is correctly classified, i.e., when $\gamma_t^{(C)} = \underline{\gamma}(\mu_t, 1)$ for all t and μ_t, the bank will not implement the new rule.

Proposition 4 (Non optimality of N if the bank is always constrained by outsiders' required compensation)**.** *If the investment cost is larger than zero and if a correctly classified bank always is constrained by the outsiders' required compensation under the current rule C, it will not be optimal for the bank to introudce rule N.*

Proof. As in Proposition 2, the result follows from the fact that the optimal capital ratio is not influenced by the choice of regulatory rule. The new regulatory rule may only cause an increase in the capital held by the bank. The value of the cost savings will therefore not be positive and the bank is therefore not willing to pay a positive implementation cost (investment). □

3 Internal models for credit risk under Basel II

3.1 Internal models

The regulatory capital ratio at time t, γ_t, is computed as

$$\gamma_t = \frac{S_t}{\sum_k A_t^{(k)}} \ , \tag{11}$$

where S_t is the acknowledged regulatory capital and $A_t^{(k)}$ is the risk base, or "amount of potential losses" attributed to risk type k. A regulatory rule specifies the minimum level of the regulatory capital ratio, the rules for specifying aknowledged capital, the types of risk (k) included in the risk base, and the specific rules for computing the risk base. The risk types may, e.g., be operational risk, credit risk, and market risk. The risk base for credit risk is a weighted sum of the individual loans, i.e.,

$$A_t^{(cr)} = \sum_i w_t^{(i,cr)} L_t^{(i,cr)}, \tag{12}$$

where $L_t^{(i,cr)}$ is loan i and $w_t^{(i,cr)}$ is the corresponding risk weight. Note that if the denominator in equation (11) equals the nominal value of total assets, the regulatory capital equals the book capital (equity) ratio, provided that the acknowledged capital is equal to book capital[5]. Note also that the authorities in a country may make descritionary decisions regarding the level of capital that banks should hold. In such cases banks are constrained by these discretionary rules, but not necessary by the minimum capital level computed according to equation (11).

[5]It may be possible that the regulatory capital increases while the book capital decreases. Consider the case when both the risk base (the denominator) and the capital (numerator) decreases, but that the risk base decreases more than the capital. If total assets are unchanged, the regulatory capital ratio will increase, while the book capital ratio will decrease.

Basel Committee on Banking Supervision (2004) recommends new rules for capital measurement and capital standards. These rules are often referred to as Basel II. Basel II rests on tree pillars. The first pillar is minimum capital requirement, the second pillar covers the supervisory review process, and the third pillar is market discipline. Under the first pillar, financial institutions may choose between three alternatives for computing necessary capital related to credit risk; the standardized approach, the Internal rating based (IRB) foundation approach, and the IRB advanced approach. Under the standardized approach the weights in equation (11) are constants. Under the IRB approaches the weights are computed based on estimates of probabilities of default (PD) and expected loss given default (LGD). With the IRB foundation approach it is assumed that the loss given default is 45 per cent of the exposure. Under the IRB advanced approach, the bank also uses own estimates for LGD. The IRB approach can be reconciled with value-at-risk models for credit risk, see Gordy (2003). For completness, a short summary of the IRB approach under Basel II is given in the appendix. The standardized approach may be compared to the ”current regulatory rule C” described in the previous section, while the IRB foundation or advanced approach refer to the ”new regulatory rule N”.

In order to simplify the exposition I base my computation only on expected percentage credit losses μ_t on an underlying portfolio. I extract the average probability of default at time t from expected losses by dividing by the parameter LGD, i.e.,

$$PD_t = \max\left[0, \min\left[1, \mu_t / LGD\right]\right], \ 0 < LGD \leq 1 \ . \tag{13}$$

3.2 Credit risk

I consider the case where the instantaneous change in expected percentage credit losses on the portfolio develops according to an Ohrnstein-Uhlenbeck process,

$$d\mu_t = \kappa(\theta - \mu_t)dt + \sigma dW_t, \tag{14}$$

where θ, κ, and σ are nonnegative constants and where dW_t is the increment of a standard Brownian motion. The parameter θ is the long term mean of expected losses. The speed of reversion to the long run mean is captured by the parameter κ. The process (14) corrected for the price of risk is

$$d\mu_t = \kappa(\theta - \frac{\lambda\sigma}{\kappa} - \mu_t)dt + \sigma dW_t^* , \tag{15}$$

where W_t^* is a Brownian motion under an equivalent martingale measure, and λ is the price of risk related to unexpected changes in expected losses. The price of risk equals the required compensation beyond the risk free interest rate $(\eta - r)$ per unit of risk σ, i.e.,

$$\lambda = \frac{\eta - r}{\sigma}. \tag{16}$$

One procedure to determine the price of risk is to compute the required expected return (η) on holding an asset influenced by the specific risk (σ) by applying the CAPM, see, e.g., p. 115 in Dixit and Pindyck (1994) or Nordal (2001) for an application. I would expect the price of risk in (16) to be negative because it is likely that expected losses (losses are measured as a positive number) are negatively correlated with the return on the market portfolio. I may alternatively write (15) as

$$d\mu_t = \kappa(\theta^* - \mu_t)dt + \sigma dW_t^*, \tag{17}$$

where $\theta^* = (\theta - \lambda\sigma/\kappa)$, see, e.g., Bjerksund and Ekern (1995) or Schwartz (1997). The effect of the correction for the price of risk is therefore to reduce (increase) the "long term mean" if the price of risk is positive (negative).

3.3 Value and threshold levels

I build a trinomial tree for the state variable μ_t as in Hull and White (1994). Table 1 shows the assumptions for the benchmark example. In the benchmark example I do not differ between types of banks. The unregulated optimal capital is a constant γ^* equal to 6 per cent. I have used a risk free interest rate of 4 per cent, a price λ per unit of risk in the development in expected losses of -1 per cent, and a volatility of expected losses σ equal to 0.5 per cent. I have further used a time step of 0.25 (quarters). The long run mean of expected losses in the risky portfolio is 0.5 per cent. The long run mean under the risk neutral probability is 0.51 per cent. The value of the new rule is found by using an evaluation period of 50 years. For every node in the tree the present value of the advantage of using the new rule instead of the old during the next time period Δt is computed as[6]

$$V_t\left(\int_t^{t+\Delta t} e^{-r(s-t)}\left(\gamma^{(C)*}(\mu_s) - \gamma^{(N)*}(\mu_s)\right)ds\right) \approx \frac{(1-e^{-r\Delta t}}{r})\left(\gamma^{(C)*}(\mu_t) - \gamma^{(N)*}(\mu_t)\right). \tag{18}$$

[6]This means that the reduction in the cost rate, $g(\gamma_t^{(C)*}) - g(\gamma_t^{(N)*})$, is approximated to be equal to $\gamma_t^{(C)*} - \gamma_t^{(N)*}$ over the relevant interval of the state variable μ_t.

The regulatory capital is 8.0 per cent for loans under the current rule C. The bank is assumed to hold a buffer b of 2 per centage points above the regulatory capital. The bank will therefore hold a minimum capital level of 10.0 per cent. The regulatory capital under the new rule is derived by using the IRB model in Basel II with and without a reduction for small and medium size entities (SMEs), see the appendix. Figure 4 shows the regulatory capital for different levels of expected losses. The break even level of expected losses μ_t making the regulatory capital with rule C equal to the regulatory capital with rule N with no reduction for SMEs is approximately 0.6 per cent. This corresponds to a PD of approximately 1.3 per cent.

(insert Table 1 approximately here)

(insert Figure 4 approximately here)

Figure 5 shows the value of the ”immediate implementation” and the ”option to implement” alternatives for different levels of current expected losses μ_t. The values decrease when the level of current expected losses increase. I have shown the values for different levels of the parameter representing the force of mean reversion κ. The curves showing the values become less sensitive to the current level of risk when the half life is reduced (i.e., when the force of mean reversion increases). With strong mean reversion, the current risk level means less for the value. The implementation thresholds are approximately 0.9 and 0.6 per cent when the half lives are, respectively, 1 and 5 years. Table 2 shows the implementation thresholds with and without a ”wait” option for different assumptions about SME compensation, the force of mean reversion, the size of the implementation cost I_0, and the rate of reduction δ in implementation costs over time. The investment threshold is much lower when the bank has an option to wait (μ^{**})

compared to situation where it has no such option (μ^*). Future reductions in implementation costs reduces the implementation thresholds further. Note that this reduction is not included in the evaluation of the "now or never" implementation alternative. The investment thresholds are generally higher with full SME compensation. This reflects that the value of the option to use the new rule is higher with full SME compensation.

Figure 6 shows the implementation threshold for a type L bank that faces a non-implementation capital requirement from the outsider of $\underline{\gamma}(p_t = 1)$. The bank will be assigned an outside capital requirement of 6 per cent when its type is known. The implementation threshold does not increase and is approximately 0.7 per cent as long as the bank is constrained by rule C. In this case there is no active role for the outsider. There is an active role for the outsider only when the bank becomes constrained by outsiders' required exposure compensation. This happens when the outside capital requirement is higher than 10 per cent. If the capital requirement is 11 per cent, the investment threshold is approximately 1.3 per cent.

(insert Figure 5 approximately here)

(insert Table 2 approximately here)

(insert Figure 6 approximately here)

3.4 IRB implementation by Norwegian banks

Banks in Norway were allowed to start using the IRB approach on January 1st 2007, provided that the Finanical Supervisory Authority of Norway (FSAN) had approved the banks' internal models. Observations of which of the banks that implemented the IRB approach during the initial period in 2007 may give some information about the assumptions and the implications of the model presented in the previous section. According to the model, banks want to implement the IRB approach in order to reduce capital. This reduction in capital allows the banks to increase the efficiency (reduce fixed costs) and thereby to increase the market value of the bank. In order for the level of capital to matter for fixed costs, it seems reasonable that the bank should be sufficiently large. Managers and owners in small banks are probably more able to control efficiency (cost control) without adjusting the capital level. Based on this I would expect that only relatively large banks with low regulatory capital levels (an indication that the bank is constrained by the current regulatory capital) are candidates for implementing the IRB approach. Table 3 shows summary statistics for the twenty banks with the lowest regulatory Tier 2 capital at December 31 2006. The mean capital ratio among the 139 Norwegian banks was 17.0 per cent and the median was 15.9 per cent. The lowest capital ratio was 9.2 per cent and the highest was 60.1 per cent. If one, e.g., assumes that banks with Tier 2 capital less than 11 per cent and with total assets larger than NOK 50 billion (approximately EUR 6.1 billion) are candidates for implementing the IRB approach, we are left with six banks. These banks are written in bold in Table 3. Two of these banks, Fokus Bank and Nordea Bank Norge, are, however, affiliated with foreign bank groups. The implementation of the IRB approach is likely to be coordinated centrally within these groups. The remaining four banks among the ”most likely candidates” have implemented the IRB approach. Sparebank 1 Midt-Norge also implemented the IRB approach, even though the Tier 2 capital at the end of 2006 was 12.2 per cent. According to the transition rules, the banks cannot reduce the regulatory capital for the years 2007, 2008, and 2009 more than to a level of, respectively, 95, 90, and 80 per cent of the required capital under the Basel I rules. According to the half year accounts for the five implementing banks, the regulatory capital under the transition rules and under the old rule (in parantheses) were 11.1 (10.6) per cent for DnB NOR, 10.7 (10.2) for Sparebank 1 SR-Bank, 10.4 (9.9) for Sparebank 1 Nord Norge, 12.3 (11.7) for Sparebank Midt-Norge, and 9.3 (8.9) for Sparebanken Vest[7]. This means that the IRB approach has given lower risk weights and has made the denominator in the computation of the capital ratio (equation (11)) lower. It is too early to determine whether the lower level of risk weighted assets will lead to a reduction in the capital level (the numerator in equation (11).

As of June 30 2007, three Norwegian banks had applied for IRB approval in addition to the five implementing banks. Only one of these banks, BNbank, is not included in Table 3. BNbank had Tier 2 capital of 15.2 per cent and total assets equal to NOK 35.4 billion at year end 2006. The reason why Bank 1 Oslo applied, even though it relatively small, may be that it is cooperating with three of the implementing banks, Sparebank 1 SR-Bank, Sparebank 1 Midt-Norge, and Sparebank 1 Nord Norge, within the Sparebank 1 group.

(insert Table 3 approximately here)

4 Summary

I have analyzed banks' incentives to introduce a risk sensitive regulatory capital rule. The underlying premise is that the level of capital influences the market value of the bank. The level of credit risk in the bank's loan portfolio determines the regulatory capital under the risk sensitive rule. Uncertainty regarding the future level of credit risk influences the bank's decision. In general, banks' optimal policies will depend on

[7]The capital ratio applies to the Sparebanken Vest Group and not the parent bank.

whether they are constrained by the current rule and on the reduction in regulatory capital obtained by applying the new rule. The bank's customers and other stakeholders in the bank may also influence the decision. I explain how different assumptions regarding outsiders' required compensation for being exposed to the bank may influence the optimal policies. I present a numerical example for the use of internal models for measuring credit risk under the Basel II approach. The evaluation framework may more generally be used to evaluate banks' decision making in situations where banks are given an option to irreversibly select between a set of regulatory rules.

A A signaling game

This appendix formalizes the game between a bank (player 1) and an outsider to the bank (player 2). By the assumptions in section 2.1 of the paper, the optimal capital ratio at time t is the highest of the efficiency maximizing capital, the threeshold level implicit in the exposure compensation schedule, and regulatory capital. This optimal capital $\gamma_s^{(i)*}$ is defined by equation (9). The game concentrates on the interaction between player 1 and player 2 related to the implementation of the new regulatory rule. Player 1's strategy is to pick the optimal implementation time τ. Player 2's strategy is to demand the proper exposure compensation conditioned on the belief, the level of credit losses and the capital held by player 1. The strategies at time t is the bank and the outsider's plan for how to play the game at time t, $S_t = \{S_t^{(1)}, S_t^{(2)}\}$. The strategies available to the parties depend on the history h_t of the game. The history at time t is

$$h_t = \{S_s, \mu_s, \underline{\gamma}_s^{(i)}, p_s\},\ 0 \leq s < t,\ i \in \{C, N\}, \tag{19}$$

i.e., the history contains the players' previous actions S_s, the history of expected credit losses μ_s, the regulatory capital $\underline{\gamma}_s^{(i)}$, and the history p_s of the belief that the bank is a type H bank. The action space at time t, $A(h_t)$ is

$$A(h_t) = \{a_t^{(1)}, a_t^{(2)}\} = \begin{cases} \{\tau, \pi(\gamma_s, \mu_s, p_s)\} & \text{if } \tau \notin h_s,\ s < t \\ \{\varnothing, \pi(\gamma_s, \mu_s, p_s)\} & \text{otherwise} \end{cases}, \tag{20}$$

where τ is the implementation date for regulatory rule N, and $\pi(\gamma_s, \mu_s, p_s)$ is player 2's required exposure compensation, see equation (7). We see from equation (20) that the history may only limit the bank's actions, because the decision to implement the new rule N is a one-time irreversible decision.

The bank's information set at time t, $F_t^{(1)}$ consists of the history and the time t realization of the state variable μ_t, i.e., $F_t^{(1)} = \{h_t, \mu_t\}$. Player 2's information set contains in addition player 1's action at time t and the bank's regulatory capital, i.e., $F_t^{(2)} = \{h_t, \mu_t, a_t^{(1)}, \underline{\gamma}_t^{(i)}\}$, $i \in \{C, N\}$.

The continuation game starting at time t contains the game played at time t and the games played at all future times. The players' payoff from future play depends on the future play and the future level of the state variable. The set of all possible histories is H^∞. Player 1's payoff from a particular history of the play, h^∞, is

$$\begin{aligned} U_{1,t}(h^\infty, \beta) &= \mathrm{E}_t^Q \left(\int_t^\infty e^{-r(s-t)} - g(\max\left[\gamma^*(\mu_s), \underline{\gamma}(\mu_s, p_s), \underline{\gamma}_s^{(i)}\right], \mu_s) ds \right), \\ & s.t. \ \{\tau, \mu_s, \underline{\gamma}_s^{(i)} : t \le s \le \infty\} \in h^\infty, \end{aligned} \tag{21}$$

and where $\underline{\gamma}_s^{(i)} = \underline{\gamma}_s^{(N)}$ only if $\tau \le s$ and $\underline{\gamma}_s^{(i)} = \underline{\gamma}_s^{(C)}$ otherwise[8]. Player 2's payoff is

$$\begin{aligned} U_{2,t}(h^\infty) &= \mathrm{E}_t \left(\int_t^\infty e^{-\alpha(s-t)} \pi(\max\left[\gamma^*(\mu_s), \underline{\gamma}(\mu_s, p_s), \underline{\gamma}_s^{(i)}\right], \mu_s, p_s) ds \right), \\ & s.t. \ \{\tau, \mu_s, p_s : t \le s \le \infty\} \in h^\infty, \end{aligned} \tag{22}$$

where α is a nonnegative discount rate and where the regulatory rule i is equal to N only if $\tau \le t$ and C otherwise. Note that the formula for the optimal capital ratio $\gamma_s^{(i)*}$ is included in the exposure compensation function in equation (22). This compensation function is optimal for player 2 (by assumption) condition on the capital held by player 1, the credit loss rate, and player 2's belief about player 1's type.

[8]The payoff according to equation (21) equals the present value of cash flow, where the cash flow rate is the negative of the cost rate. Except for this change of sign, equation (21) is equal to equation (10). With this change of sign an optimal strategy maximizes the cash flow, i.e., minimizes the present value of costs.

The players' strategies for this continuation game conditioned on the information set at time t is $S|F_t = \{S^{(1)}|F_t^{(1)}, S^{(2)}|F_t^{(2)}\}$. Player 1's payoff from a specific strategy combination is

$$U_{1,t}(S^{(1)}|F_t^{(1)}, S^{(2)}|F_t^{(2)}, \beta) \equiv U_{1,t}(h^{\infty}, \beta), \;\; s.t. \; \{S^{(1)}|F_t^{(1)}, S^{(2)}|F_t^{(2)}\} \in h^{\infty}, \tag{23}$$

and Player 2's payoff is, similarly,

$$U_{2,t}(S^{(1)}|F_t^{(1)}, S^{(2)}|F_t^{(2)}) \equiv U_{2,t}(h^{\infty}, \beta), \;\; s.t. \; \{S^{(1)}|F_t^{(1)}, S^{(2)}|F_t^{(2)}\} \in h^{\infty}. \tag{24}$$

With a Bayesian update of the belief that the bank is a type H bank, wherever such an update is possible, I may then define the Perfect Bayesian Equilibrium of the signaling game.

Definition. *A Perfect Bayesian Equilibrum of the game for the implementation of rule N is described by the strategy pair $\{S^{(1)*}|F_0^{(1)}, S^{(2)*}|F_0^{(1)}\}$ and the belief $p(\cdot \mid \cdot)$, where*

i) *(Player 1's optimal policy:) For both L and H,*

$$U_{1,0}(S^{(1)*}|F_0^{(1)}, S^{(2)*}|F_0^{(2)}, \beta) \geq U_1(S^{(1)}|F_0^{(1)}, S^{(2)*}|F_0^{(2)}, \beta), \; \textit{for all } S^{(1)}|F_0^{(1)} \in H^{\infty},$$

ii) *(Player 2's optimal policy:)*

$$U_{2,0}(S^{(1)*}|F_0^{(1)*}, S^{(2)}|F_0^{(2)})) \geq U_2(S^{(1)*}|F_0^{(1)}, S^{(2)}|F_0^{(2)}), \; \textit{for all } S^{(2)}|F_0^{(2)} \in H^{\infty},$$

and

iii) *(Belief:)*

$$p_t = \begin{cases} 1 & \text{if } \tau \le t \text{ and } \underline{\gamma}_t^{(N)} = \underline{\gamma}^{(N)}(\mu_t, H) \\ 0 & \text{if } \tau \le t \text{ and } \underline{\gamma}_t^{(N)} = \underline{\gamma}^{(N)}(\mu_t, L) \\ \frac{P(\tau>t|\beta=H)P(\beta=H)}{P(\tau>t)} & \text{if } \tau > t \end{cases}$$

where $P(\tau > t) = P(\tau > t \mid \beta = H)P(\beta = H) + P(\tau > t \mid \beta = L)P(\beta = L)$ *and* $P(\tau > t) > 0$.

B Proof of Propositions

Proposition 1

Proof. I follow the approach on page 128 in Dixit and Pindyck (1994). The optimal exercize policy may be derived from the Bellman equation

$$\Omega(\mu_t) = \max\left[Z(\mu_t), \mathrm{E}_t^Q\left(\Omega(\mu_{t+dt})\right)e^{-rdt}\right], \tag{25}$$

where the value function $\Omega(\mu_t)$ is equal to the value of the implementation option. The present value of the cost reduction if rule N is implemented at time t is $Z(\mu_t)$. If the rule is not implemented, the bank gets the present value of the option value at time $t+dt$. The expected payoff is discounted by the risk free interest rate r for the time period dt, following the notation on page 122 in Dixit and Pindyck (1994). Exercise is optimal if the exercise value is larger than the continuation value. The exercise value may be split into the immediate benefit and the value of the future benefit, i.e.,

$$Z(\mu_t) = g(\gamma_t^{(C)*})dt - g(\gamma_t^{(N)*})dt + \mathrm{E}_t^Q\left(Z(\mu_{t+dt})\right)e^{-rdt}, \tag{26}$$

where $\gamma_t^{(i)}$ is given by equation (2). We may then rewrite (25) as

$$\begin{aligned} \Omega(\mu_t) - Z(\mu_t) \quad = \quad & \max[0, -g(\gamma_t^{(C)*})dt + g(\gamma_t^{(N)*})dt + \\ & \mathrm{E}_t^Q\left(\Omega(\mu_{t+dt}) - Z(\mu_{t+dt})\right)e^{-rdt}]. \end{aligned} \tag{27}$$

Because

$$\mathrm{E}_t^Q\left(\Omega(\mu_{t+dt}) - Z(\mu_{t+dt})\right)e^{-rdt}) \tag{28}$$

is nonnegative by the definition of the Bellman equation at time $t + dt$, continuation will always be optimal if $-g(\gamma_t^{(C)*}) + g(\gamma_t^{(N)*}) > 0$.

By assumption the bank is constrained by rule C, i.e., $\gamma_t^{(C)*} = \underline{\gamma}^{(C)}(\mu_t)$ according to equation (2). A higher capital requirement by rule N implies that the bank's capital will increase at the implementation date, i.e., $\gamma_t^{(N)*} = \underline{\gamma}^{(N)}(\mu_t)$. The immediate benefit from switching to the new rule will therefore be negative, and exercize of the option will not be optimal.

$\square$

Proposition 3

Proof. At time t the flow of cost reduction from using the new rule N, $g(\gamma_t^{(C)*}) - (\gamma_t^{(N)*})$, is determined by the optimal capital under the two rules. Because the optimal capital ratio with rule N, $\gamma_t^{(N)*}$, is known, the bank can always obtain the new rule and obtain the accompanying cost rate. The outsiders may only influence the cost rate under the current rule by increasing the capital held by the bank. It is clear from equation (9) that this can only be achieved if the bank becomes constrained, or more constrained, by the outsiders required compensiation, i.e., when $\gamma_t^{(C)*} = \underline{\gamma}(p_t, \mu_t)$. $\square$

C Capital adequacy regulation

For completeness this section contains the main equations used to compute the risk weights for business loans according to Basel II. A detailed presentation is given on pp. 59-60 in Basel Committee on Banking Supervision (2004). The procedure to compute the necessary capital under the IRB approach involves several steps. First the required capital S per unit of currency (corresponding to the risk weight per one unit of a loan) is computed according to the formula

$$S = [LGD\,\mathrm{N}(d) - LGD\,PD)]\frac{1+(M-2.5)b}{1-1.5b}, \tag{29}$$

where

$$d = \left(\frac{1}{1-R}\right)^{0.5}\mathrm{N}^{-1}(PD) + \left(\frac{R}{1-R}\right)^{0.5}\mathrm{N}^{-1}(0.999), \tag{30}$$

M is the effective maturity, and $\mathrm{N}(\cdot)$ is the cumulative normal standard distribution. The maturity adjustment factor b is

$$b = (0.11852 - 0.05478\ln(PD))^2\,. \tag{31}$$

The correlation factor R is[9]

$$R = 0.12\left(\frac{1-e^{-50PD}}{1-e^{-50}}\right) + 0.24\left(1 - \frac{1-e^{-50PD}}{1-e^{-50PD}}\right). \tag{32}$$

The correlation factor R^{SME} for small- and medium-sized entities (SME) is given by the formula

$$R^{SME} = R - 0.04\left(1 - \frac{s-5}{45}\right),\ 5 \leq s \leq 50, \tag{33}$$

where R is given by (C) and s is total annual sales.

Risk weighted assets RWA are computed according to the formula

$$RWA = S12.5EAD, \tag{34}$$

where EAD is exposure at default measured in units of currency.

[9]For residential mortgage exposures $R = 0.15$ and $S = [LGD\ \mathrm{N}(d) - LGD\ PD)]$, where d is given by (30).

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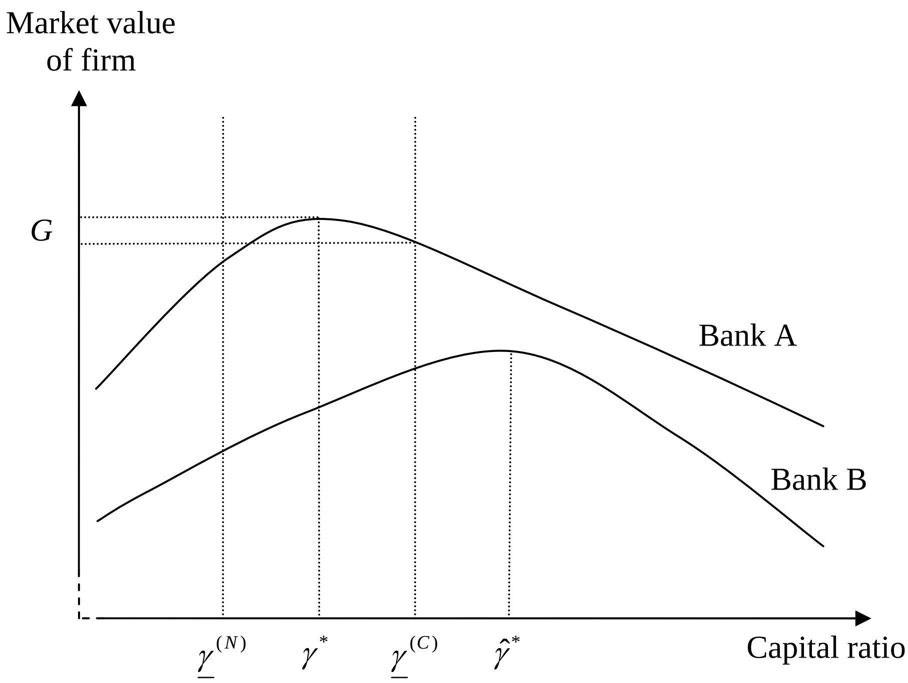
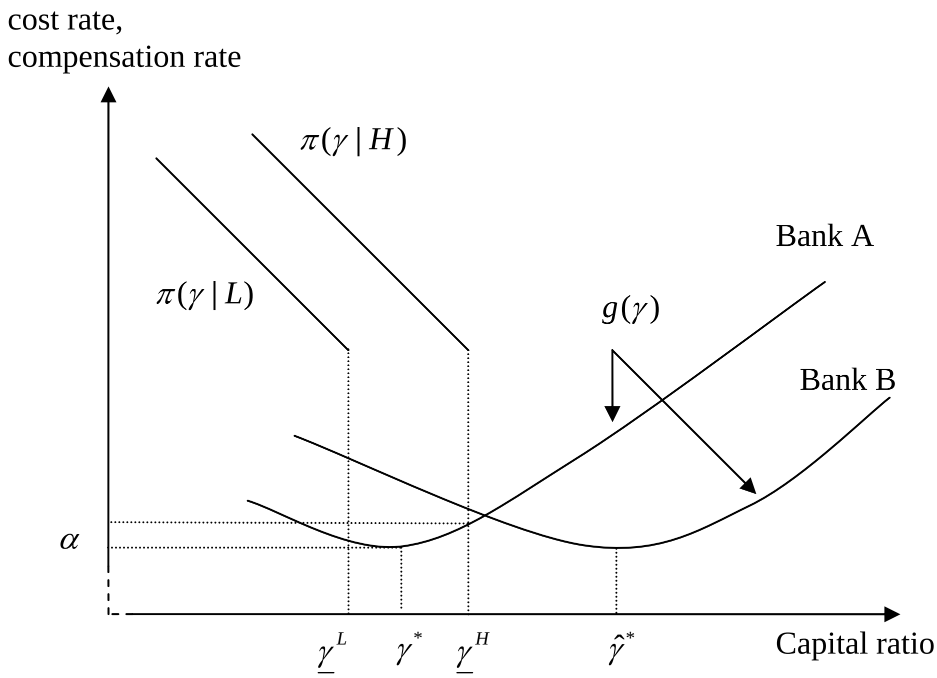
Figures



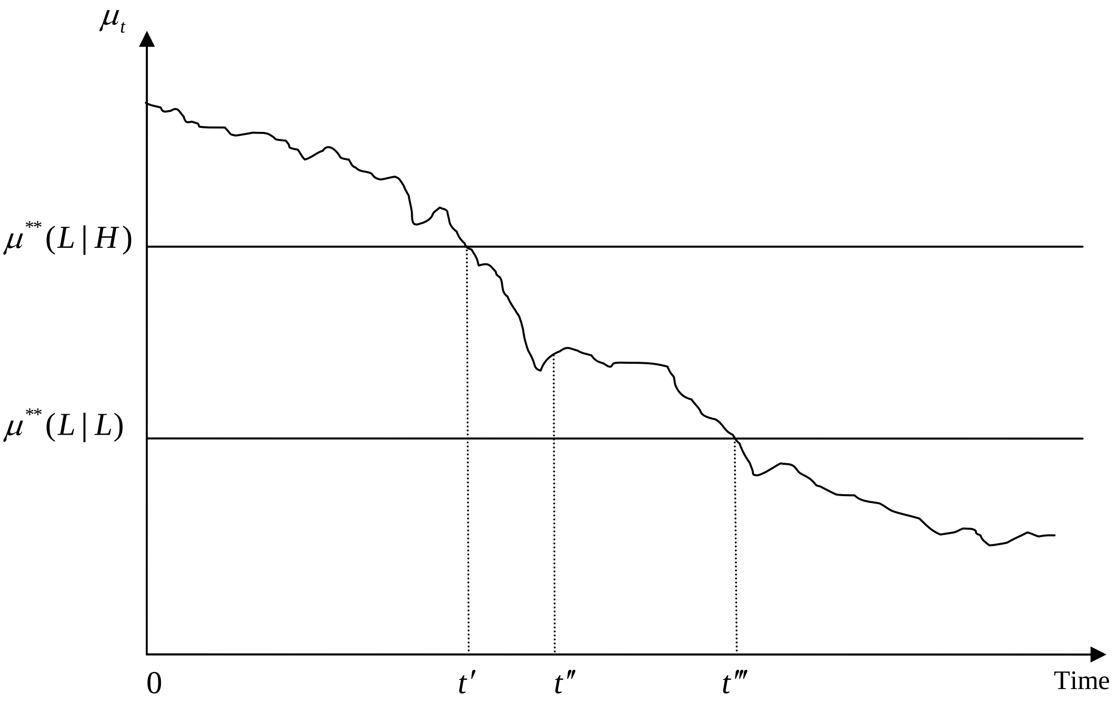
The Figure shows the relationship between the market value of total assets and the level of capital for bank *A* and *B*. Both banks have unique optimal levels of capital (γ^* and $\hat{\gamma}^*$) that maximize the market values of the banks. According to the current regulatory rule the minimum level of capital is $\underline{\gamma}^{(C)}$. Only bank *A* is constrained by this rule. If bank *A* selects the new rule, the minimum regulatory capital will be $\underline{\gamma}^{(N)}$. Bank *A* will then choose the optimal capital level γ^* and increase the market value by *G*. Bank *B* is not constrained by either of the two regulatory rules and will choose to hold capital equal to the optimal level $\hat{\gamma}^*$.

Figure 1: Optimal capital and regulatory capital



The Figure shows the relationship between the fixed cost rate $g(\cdot)$ and the level of capital for bank *A* and *B*. Both banks have a unique optimal levels of capital (γ^* and $\hat{\gamma}^*$) that minimizes the market values of the fixed costs. The required rate of compensation by outsiders for being financially exposed to the bank, $\pi(\cdot\mid\cdot)$, is dependent on the type of bank (*H* or *L*) and the level of capital. At high levels of capital, the outsiders do not require any *additional* compensation for being exposed to the bank. The outsiders do, however, require extra compensation if the capital level for a bank of type *H* and *L* is lower than $\underline{\gamma}^L$ or $\underline{\gamma}^H$, respectively. The classification of bank *A* as a type *H* or *L* bank, determines the optimal capital for the bank. If bank *A* is considered to be a type *H* bank by the outsiders, the cost rate of the bank will increase by α. Bank *B* is not constrained by being classified as either type *L* or *H*, and it will therefore always choose to hold capital equal to the optimal level $\hat{\gamma}^*$.

Figure 2: Optimal capital with exposure compensation



The Figure shows the implementation threshold $\mu^{**}(L|H)$ for a type L bank when the outsiders believe that it is a type H bank and the implementation threshold $\mu^{**}(L|L)$ when the outsiders believe it is a type L bank. The Figure shows one path of the state variable μ_t, expected credit loss.

Figure 3: Implementation thresholds dependent on the bank's type implementation decision

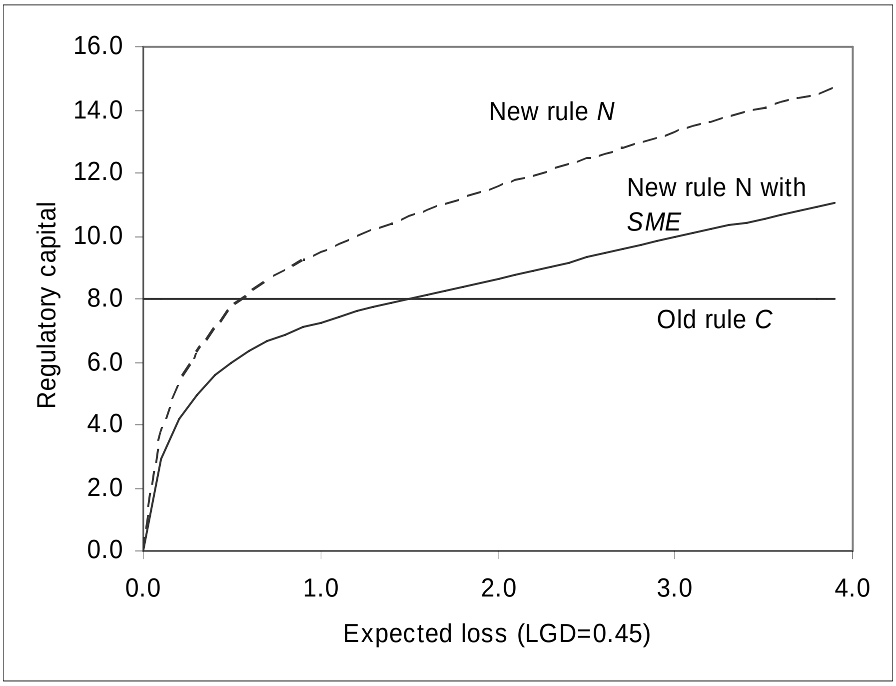


Figure 4: Regulatory capital with the current and the new regulatory rule

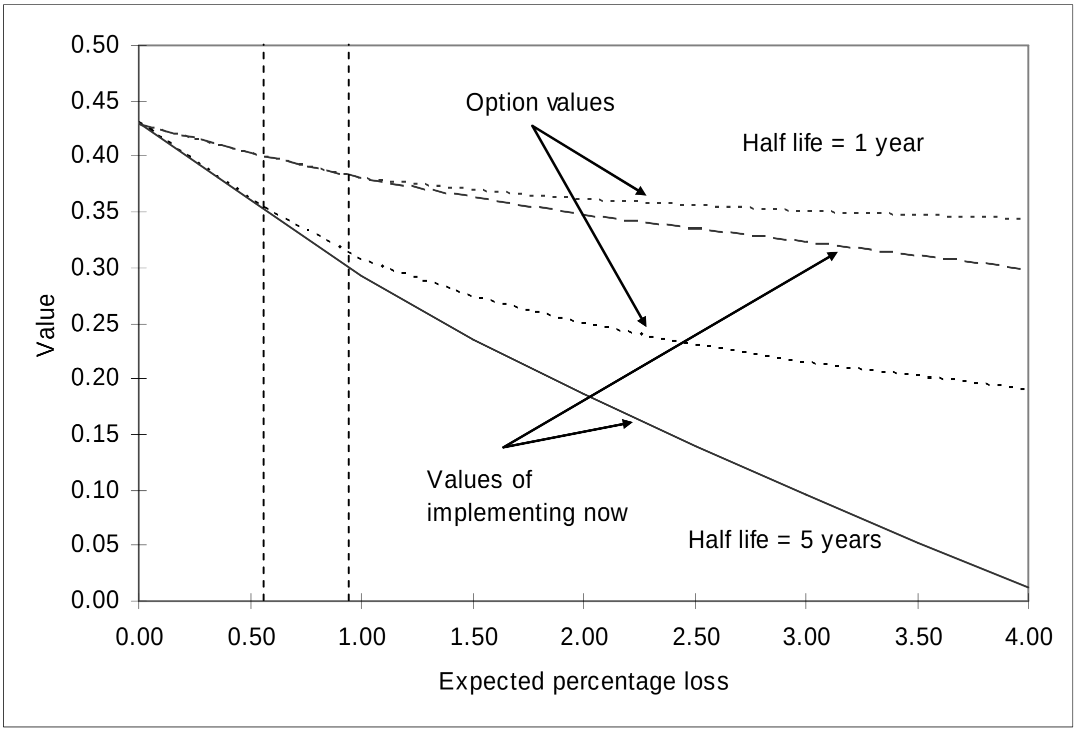


Figure 5: Exercise and option values for the option to implement the new regulatory rule

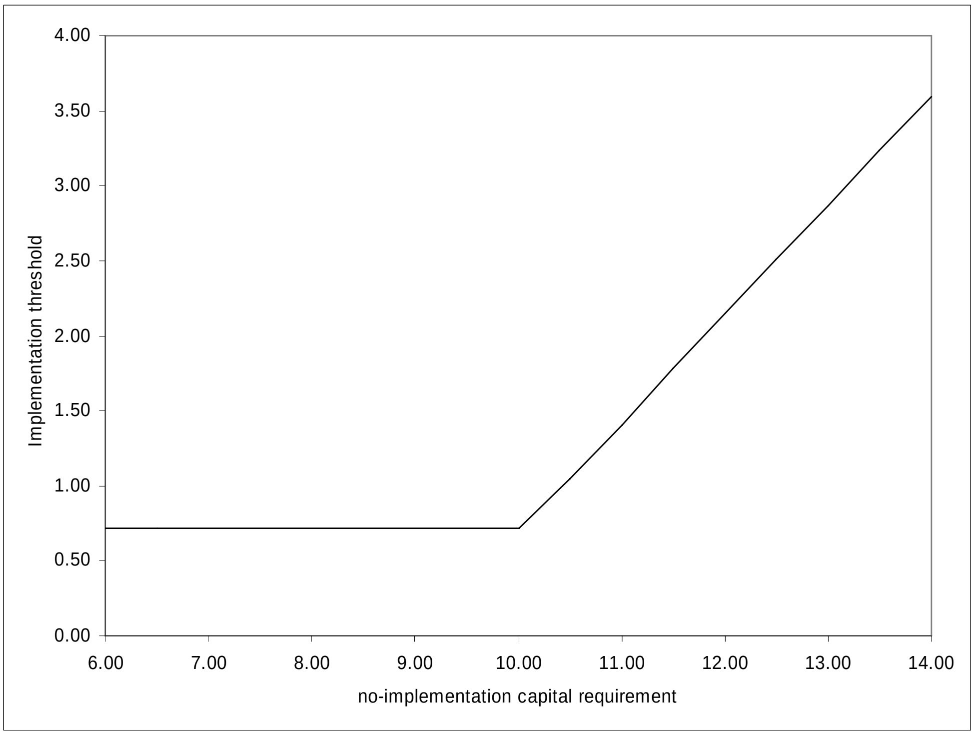


Figure 6: Implementation threshold as a function of non-implementation capital requirement

Tables

Parameter	Numerical value	Description
Δt	0.25	time step
r	0.040	risk free interest rate
λ	-0.010	price of risk
T_N	10	length of option to implement in years
T	50	evaluation period in years
I	0.100	investment expenditure
δ	0.000	depreciation rate for investment expenditure
θ	0.005	long run mean in percentage losses
κ	0.231	speed of mean reversion
σ	0.005	volatility of percentage losses
LGD	0.450	loss given default
b	0.020	buffer capital
γ^*	0.060	unregulated optimal capital

Table 1: Parameter values used in the numerical example

		No SME				Only SME			
		Half life = 3		Half life = 5		Half life = 3		Half life = 5	
I_0	δ	μ^*	μ^{**}	μ^*	μ^{**}	μ^*	μ^{**}	μ^*	μ^{**}
10	0.0	1.0	0.1	0.7	-0.1	6.8	0.7	4.1	0.6
	-1.0	1.0	-0.1	0.7	-0.2	6.8	0.5	4.1	0.4
	-2.0	1.0	-0.2	0.7	-0.2	6.8	0.4	4.1	0.3
	-3.0	1.0	-0.2	0.7	-0.3	6.8	0.3	4.1	0.2
5	0.0	1.4	0.1	1.0	0.0	7.9	0.9	4.8	0.7
	-1.0	1.4	0.1	1.0	0.0	7.9	0.7	4.8	0.6
	-2.0	1.4	0	1.0	-0.1	7.9	0.6	4.8	0.5
	-3.0	1.4	0	1.0	-0.1	7.9	0.6	4.8	0.5

Numbers are in per cent. Threshold levels μ^* without an option to wait are found by setting the implementation value equal to zero. Threshold levels μ^{**} with an option to wait are found by finding the highest value of expected losses making the value of the ”implement now” alternative equal to the value of the option to implement. In both cases the threshold levels are approximate. No *SME* means that there is no adjustment for small and medium size enterprises. Only *SME* means that there is full adjustment for small and medium size enterprises.

Table 2: Implementation thresholds with and without a delay option

Bank name	Type[1]	Applied?[2]	Implemented?[2]	Size[3]	Corp. loans[4]	2006 Tier 1	2006 Tier 2	Avg. 04-06 Tier 2	Credit losses[5] 2006	Credit losses[5] Avg. 04-06
Spareb. 1 Nord Norge	S	Y	Y	55	34	8.5	9.2	10.7	-0.1	0.2
Nordlandsbanken	C			24	47	7.0	9.4	11.2	-0.1	0.1
Nordea Bank Norge	C			351	53	6.7	9.4	9.9	-0.3	-0.3
Fokus Bank	C			120	-	8.7	9.7	10.9	0.0	-
Santander Cons. Bank[6]	C			24	48	8.8	10.0	10.1	0.2	0.2
Spareb. Vest	S	Y	Y	59	22	9.6	10.3	11.0	-0.1	0.0
Sandnes Sparebank	S			25	46	8.1	10.3	11.2	0.0	0.0
Landkreditt Bank	C			5	23	10.6	10.6	12.8	0.1	0.1
DnB NOR Bank ASA	S	Y	Y	1 041	49	7.1	10.7	10.9	0.0	0.0
Spareb. 1 SR-Bank	S	Y	Y	84	36	7.5	10.7	11.6	-0.1	0.0
Storebrand Bank	C	Y		34	34	8.8	11.0	12.0	-0.2	-0.1
Bank 1 Oslo	C	Y		17	29	10.2	11.0	11.7	-0.1	-0.1
Spareb. 1 Vestfold	S			10	33	10.9	11.5	14.1	0.0	0.1
SEB Privatbanken	C			12	-	9.3	11.5	-	-0.2	-
Klepp Sparebank	S			4	41	11.3	11.8	13.1	0.0	0.0
Spareb. Møre	S			32	38	10.5	11.9	12.9	0.0	0.2
Totens Sparebank	S			9	21	8.7	11.9	12.0	0.0	0.2
Spareb. 1 Midt-Norge	S	Y	Y	63	34	8.7	12.2	12.0	-0.2	0.0
Spareb. Sogn og Fjordane	S			18	37	12.3	12.2	12.0	-0.2	-0.1
Verdibanken	C			1	-	8.6	12.2	-	-0.1	-

Sources: The Norwegian Financial Services Asssociation (FNH), The Norwegian Savings Banks Association, The Financial Supervisory Authority of Norway (FSAN), and the banks' financial reports. All data is public. The numbers refer to the accounts for the parent bank (not group accounts). Banks with Tier 2 capital less than 11 per cent and size larger than NOK 50 billion are written in bold. [1]Savings banks (S) or commercial banks (C). [2]The banks that have applied for approval or have given notice of application (Y) according to FSAN's 2006 annual report, and those that have implemented (Y) the IRB models in their financial reports as of June 30 2007. One bank that is not included in the table, BNbank, has applied for approval. The size of BNbank was NOK 35.4 billion and the Tier 2 capital was 15.2 per cent at year end 2006. Nordlandsbanken is a daughter company of DnB NOR Bank ASA. According to information in Nordlandsbanken's financial report, the implementation of IRB in the bank is planned as a part of introduction in the group. Nordea Bank Norge is a part of the Nordea Group. The work on approving Nordea's application is coordinated between the supervisory authorities in Norway, Sweden, Denmark, and Finland. Fokus Bank became in 2007 a branch of the foreign company Danske Bank AS. [3]Total assets in Billion NOK as of December 31 2006. The NOK/EUR rate of exchange at year end 2006 was 8.238. [4]Percentage of gross loans to borrowers not characterized as households. The definition may vary between banks. [5]Book losses as a per cent of gross loans. [6]Only data for the years 2005-2006 are included.

Table 3: The 20 Norwegian banks with the lowest Tier 2 capital - December 31 2006