Quantitative Finance

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rquf20

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To cite this article: Ensar Yilmaz & Burak Ünveren (2012): Capital regulation and auditing, Quantitative Finance, 12:10, 1467-1475

To link to this article: http://dx.doi.org/10.1080/14697688.2011.570369

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Capital regulation and auditing

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(Received 11 August 2009; revised 13 September 2010; in final form 7 March 2011)

1. Introduction

The experience from banking crises in several countries over the last few decades has made regulators, supervisory authorities, banks themselves, as well as probably their shareholders, more aware of the importance of capital regulation. In addition to these developments, the 1988 Basel Capital Accord (Basel I) and the new proposals from the Basel Committee on Banking Supervision (Basel II) have focused on minimum capital requirements and supervision requirements.

Basel II has focused primarily on setting the capital requirements, commonly referred to as Pillar One. However, good capital requirements mean little if they cannot be enforced. For this reason, more attention needs to be focused on Pillar Two, that is, supervisory review. Supervisory review is fundamental to the success of capital regulation. In accordance with the main concerns of Basel II, in this paper we discuss both capital regulation and auditing policies in our model.

Traditional approaches to bank regulation emphasize the positive features of capital adequacy requirements. They argue that capital, or net worth, serves as a buffer against losses and failure. Along with deposit insurance, official capital adequacy regulations play a crucial role in aligning the incentives of bank owners with depositors and other creditors (e.g., Furlong and Keeley (1989), Keeley and Furlong (1990), Kaufman (1991), and Berger and Udell (1994)). Hence, it is often advised that the riskier a bank’s assets, the more capital it should hold. However, some researchers disagree over whether the imposition of capital requirements actually reduces risk-taking incentives for various reasons (e.g., Kahane (1977), Kim and Santomero (1988) and Besanko and Kanatas (1996)).

On the other hand, numerous scholars (inter alia Baron (1984), Baron and Besanko (1984), Demski et al. (1987), and Kofman and Lawarree (1993)) have shown that auditing a contract plays an important role in mitigating incentive problems. Most of these studies assume that the principal commits to an auditing policy—announced probability of an audit. However, commitment to auditing suffers from a time-consistency problem. Thus, if the firm being audited never cheats, the audit never reveals any cheating and there are no ex post incentives to audit.

Therefore, because of the time-inconsistency problem of the commitment strategy, the no-commitment strategy

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has become a well-recognized issue for auditing. An early example of this line of research that focuses on commitment issues can be found in Gratz et al. (1986), who study a game between taxpayers and a tax collector wherein the auditing strategy of the tax collector cannot be committed ex ante. The work of Bester and Strausz (2001) modifies and extends the revelation principle in more general environments in which the principal cannot commit to an outcome induced by a mechanism. In the generalized equilibrium, the optimal strategy of the agent does not need to entail truthful reporting with certainty. Picard (1996) constructs a similar model for an insurance market. The model analyzes whether truth-telling is not always achieved because of the insurer’s inability to commit credibly ex ante to an audit strategy ex post. This means that, in equilibrium, some agents commit fraud.

Khalil (1997) approaches the same problem from the standpoint of a regulator who cannot commit to an auditing strategy of a monopolist’s cost. We are inspired mainly by this study, albeit his model is somewhat different from ours. In this model, the principal can choose to audit or not, to determine if in fact the agent has produced the contractual output corresponding to his type. In a banking framework, Khalil and Parigi (1998) address similar issues of commitment and incentives to audit. Both papers obtain a result similar to ours, showing that mixed strategies are employed in equilibrium. In an insurance market, Boyer (2003) characterizes the optimal contract in an environment where an informed agent can misrepresent the state of the world to a principal who cannot commit to auditing. Because the principal cannot commit, the optimal strategy of the agent is not to tell the truth all the time. The optimal contract is such that higher losses are over-compensated while lower losses are, on average, under-compensated.

Some recent papers, which study the no-commitment problem in a principal–agent format, also show results similar to our study here. For example, Khalil and Lawree (2006) show that auditing suffers from a time-consistency problem. They argue that, without commitment, auditing a firm only takes place if it is optimal ex post. Cheating must occur in equilibrium so that the principal can expect to collect a penalty to cover auditing costs. Similarly, Finkle and Shin (2007) demonstrate that the principal conducts an audit only if the expected net gain from auditing is positive using a standard model in which the agent has private information on the cost of production. Since the audit frequency and accuracy are costly, the principal is reluctant to conduct an accurate audit ex post. Thus, by inducing the agent to cheat with some probability, the principal provides herself with an ex post incentive to conduct an audit with some level of accuracy.

On the other hand, there are a few studies modeling bank-capital regulation in conjunction with auditing. Following Merton (1978), a branch of the academic literature has studied the complementarity between capital requirements and regulatory audits. In this literature, the value of the bank’s assets is privately known to the banker. It can only be observed by the regulator if a costly audit with an intensity chosen by the regulator is performed, which is generally modeled by a Poisson process. For example, Bhattacharya et al. (2002) model such a case. They show that the capital threshold can be reduced by an increase in the intensity of auditing, thus suggesting substitutability between supervision and capital requirements. In a continuous-time structure model, Milne and Whalley (2001) demonstrate that desired bank capital holdings are a function of cash-flow uncertainty, franchise value, audit frequency, recapitalization costs, and cost of equity relative to deposits. Prescott (2004) also looks at the results of stochastic and deterministic auditing in the context of capital regulation and concludes that stochastic auditing is more efficient. However, none of these studies discuss the case of no-commitment to auditing in contrast to our study here.

We set up a model to argue for auditing policies in the context of capital regulation. To this end, we consider in our model a structure having a bank and a regulator, in which the bank has private information about its own risk level and state verification by the regulator is costly. The bank has an incentive to understate the risk as long as it wants to save on capital costs. The regulator designs a risk-based-capital schedule that takes into account the bank’s private information. In addition to the capital requirement, the regulator can also use auditing strategies concerning whether the bank complies with optimal capital requirements determined by the regulator. These strategies are commitment and no-commitment to auditing.

As stated above, although there are some studies modeling bank capital regulation in conjunction with auditing, none of these studies discusses the case of no-commitment to auditing. And the models studying this case are discussed in different contexts rather than that of capital regulation. However, the auditing concerns in the financial sector, specifically those about banks, are extremely important for mitigating the prevalence of financial crises all over the world. Hence, the interrelation between information and efficiency problems in banking regulation using both auditing and capital requirement should be scrutinized more profoundly. This study aims to fill this gap.

If the regulator commits to auditing (an announced auditing probability) and designs a truth-revealing mechanism, then we observe that she reduces capital requirement for a high-risk bank, increases the capital requirement for a low-risk bank, and announces a positive probability of auditing. Thus, the existence of asymmetric information creates inefficient results for both types of risk relative to full information (first best). This mainly stems from the fact that the regulator disallows the bank from taking advantage of information rent at high risk, i.e. inducing truth-telling by the high-risk bank by reducing the gain for a high-risk bank from an undetected false announcement and announcing a positive probability of auditing.

The regulator does not expect to find any underreporting under commitment when she audits. Thus, the
auditing policy plays a purely deterrent role. However, commitment to auditing is not time consistent, thus not ex-post efficient. We next look at the no-commitment case. By no-commitment to auditing, we mean that the auditing probability is based on whether it is ex-post optimal or not. There is no predetermined probability of auditing as in the commitment case.

Following the approach of Khalil (1997) and Khalil and Parigi (1998), we assume that the regulator cannot commit to an auditing strategy and the interaction between the regulator and the bank is modeled as a two-stage problem. In the first stage of the game, the regulator chooses capital requirement levels. Then in the second stage, the regulator’s equilibrium auditing strategy and the bank’s equilibrium compliance strategy are determined, given the capital requirements chosen in the first stage of the game. Thus, in the second stage, the regulator and the bank play a simultaneous Nash game to decide on their auditing and reporting strategies, respectively. Under this setup, the auditing strategy is not announced in the first stage as a part of the contractual terms due to the lack of auditing commitment. The equilibrium auditing and misreporting strategies are simultaneously determined as the mutual best responses to each other in the second-stage Nash game. Thus, auditing at equilibrium is no longer subject to the time-inconsistency problem. It will be further clear that the Nash equilibrium in the second-stage game is characterized by mixed strategies for both the regulator and the bank, which implies that both auditing and misreporting will take place with positive probabilities in equilibrium.

Analogously, the probability of compliance makes the expected penalty to be collected by the regulator equal to the audit cost. Thus, while an audit has no benefit to the regulator ex post, the threat of an audit indirectly helps to reduce the bank’s information rent. These results are compatible with the findings of Khalil (1997), Khalil and Lawree (2006) and Finkle and Shin (2007) in which the principal conducts an audit only if the expected net gain from auditing is positive at that point and cheating is permitted in equilibrium.

We also discover that the optimal capital level for a low-risk bank under no-commitment is higher than its capital level under full information. This result basically arises from the fact that the no-commitment case does not use the truth-telling constraint, which implies that the bank’s risk report is not totally reliable. When the regulator cannot commit, the equilibrium contract entails some underreporting by the bank with high risk, which in turn will lower the regulator’s social payoff in the high-risk state. As a result, the regulator has to charge a higher capital rate for the bank who reports low risk in order to compensate for the social loss arising from the underreporting bank in this state. Thus, the regulator needs to increase the capital requirement level to compensate for the loss arising from the possibility of non-compliance. On the other hand, the optimal capital level for a high-risk type under no-commitment is the same as that under full information.

The paper is organized as follows. The model is introduced in section 2. In section 3, the optimal capital rule is defined under full information. Then, section 4 discusses optimal capital rules with commitment and no-commitment strategies to auditing under asymmetric information. Section 5 concludes.

2. The model

Consider a typical bank representing the preferences of all banks. The bank takes funds from two sources: deposits and capital, which are denoted by D and K, respectively. The financing budget constraint is \( L = D + K \), where \( L \) is the aggregate value of loans made by the bank at the beginning of the period. The net return on loans if all loans are repaid is \( v_L \), where \( v \) is the average interest rate charged by the bank on these assets. We assume that the bank does not price discriminate between borrowers and firms or entrepreneurs with similar projects facing the same interest rate. For ease of notation we define the return on a bank’s loan book if no loans default as \( R(v) = vL \).

On the other hand, collecting deposits and holding (or raising) capital are costly for the bank. At the end of the period, the bank makes a net payment of \( r_dD \) to depositors, where \( r_d \) is the deposit interest rate offered by the bank. The deposit rate \( r_d \) is assumed to be a riskless rate because depositors do not act in accordance with the risk structure of the bank. They do not demand a greater deposit rate when the bank invests in more risky assets because depositors are unable to assess the relative riskiness of the balance sheet of the bank and because of the existence of deposit insurance. This assumption is consistent with empirical observations.

Since the regulator imposes capital requirements on the bank, the bank’s holding cost is \( r_cK \), where \( r_c \) is the marginal cost of holding capital such that \( r_c > r_d \). Thus raising capital is more costly for the bank than collecting deposits, for which agency costs are probably the most important explanation. Such agency costs arise because of asymmetric information between the bank’s management and the owners of its equity capital (Myers and Majluf 1984).

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 type in the traditional business of financial intermediation). The proportion of repayments of loans determines the solvency probability of a bank. The expected value of repayments to the bank is \( \phi R(v) \), a value less than or equal to \( R(v) \) and only known during the period, where \( \phi \in (0, 1) \) represents the solvency probability of the bank. Since the repayment risk undertaken by the bank increases concurrent with the bank’s loan return rate, the loan return rate, \( r \), can be regarded as risk. Therefore, the solvency probability of the bank depends on \( \phi(v) \). For simplicity, we assume \( v \in \{ v_h, v_l \} \), i.e. the bank can be either of a high-risk, \( v_h \), or a low-risk type, \( v_l \), and \( v_h > v_l \) which depends on the risk level of loans given to projects. The solvency probability function with respect to the risk level is
assumed to be $\phi(r_i) < \phi(v_i)$. For notational clarity, $\phi(v_i)$ will be denoted by $\phi_i$ for each $i \in \{1, h\}$.

Shareholders of the bank put up funds at the beginning of the period and, in the case of solvency, receive returns at the end of the period. For simplicity, we also assume that shareholders are risk neutral and that the bank acts in the interest of the shareholders. We denote these expected excess returns to a bank’s shareholders as $W_b$, where

$$W_b(v, K) = \phi(v)(R(v) - r_cK - r_dD).$$  \hspace{1cm} (1)$$

We assume that the bank privately holds the information about its risk level, which is therefore unobservable but verifiable by the regulator. This can induce the bank to gain more by misreporting its risk level to the regulator, which we explain in detail in the following sections.

On the other hand, the main objective of the regulator (say the bank council) is to discover the optimal auditing and the social optimal of capital requirements for each type of bank that minimizes the expected social loss function, $W_s$.

$$W_s(v, K) = r_cK + (1 - \phi(v))(1 + \gamma)C(K).$$  \hspace{1cm} (2)$$

The first term of equation (2) represents the total capital holding cost that the bank incurs, $r_cK$, where $r_c$ is the marginal social cost of bank capital arising from the capital requirement imposed by the regulator. The marginal social cost of bank capital is one of the main concerns of the regulator. Another of the regulator’s concerns is represented by the second term of expression (2), which displays the total expected loss incurred by the regulator $(1 + \gamma)C(\cdot)$, when the bank fails with probability $(1 - \phi)$. Here, $C(\cdot)$ denotes the residual claim that remains and which the regulator must pay out in the default case due to the bank’s limited liability and deposit insurance. In addition to the residual claim, there is also a social cost associated with bank failure, which is assumed to be proportional to the residual claim, $\gamma C(\cdot)$. The coefficient $\gamma$ is the social cost factor, which is positive due to the negative externalities (systemic risk) and deadweight costs associated with bank failure. The payout by the regulator $C(K)$ is a function of capital, $K$. We stipulate that $C(\cdot)$ is a negatively sloped, strictly convex function that satisfies the Inada conditions. Assuming $C(\cdot)$ is smooth, these conditions formally correspond to

$$C_K < 0, \quad C_{KK} > 0, \quad \lim_{k \to 0} C_K(k) = -\infty, \quad \lim_{k \to \infty} C_K(k) = 0.$$  \hspace{1cm} (3)$$

In other words, when capital requirements are increased by the regulator, the payout decreases, $C_K < 0$, thus reducing residual claims. Also, the payout decreases faster as capital increases, $C_{KK} > 0$. The Inada conditions ensure an interior minimum solution. In order to avoid economically uninteresting cases, we also assume that $v_h > v_l > r_c > r_d$.

The regulator with such an objective function cares about a balance between the private costs of the bank and the social benefit of the system. We measure the effects of capital regulation by including proxies for the costs and benefits—both private and social—of capital regulation. High levels of capital may impose a cost on banks in addition to its social benefit to the whole financial system.

In our analysis, we use the level of bank capital as a measure of this cost similar to Pelizzon and Schaefer (2005). Thus, we need to consider measures of the negative externalities associated with bank failure, and some measure of the cost of regulation imposed by constraining bank activity.

As mentioned above, by choosing the optimal capital requirement and auditing policy, the regulator aims to minimize his expected loss function (2), which takes different forms under the regulator’s different auditing policies. We assume that even though the regulator does not know the bank’s risk level, the regulator knows the probability distribution of the bank’s risk. The regulator observes only the realization of a signal, that is, the risk level that the bank reports to the regulator. Therefore, the regulator forms a belief about the probabilities of a signal for any given risk level. The regulator has two different policies to audit the bank’s risk, by which the regulator induces the bank to report its risk level truthfully: commitment and no-commitment to auditing. In the following sections, we define the policies in more detail and obtain the optimal capital requirement levels under the cases of commitment and no-commitment to auditing.

3. Full information

In this section, in order to better understand the case in which the regulator has asymmetric information about the risk level that a bank undertakes, we first analyse the full information case, our benchmark case. As mentioned earlier, the bank funds its loans by deposits and capital. However, while capital and deposits are perfect substitutes that have the same marginal returns, they have different marginal costs. Since the cost of raising capital is higher than the deposit rate $r_c > r_d$, the bank will not hold capital at all, and a given loan $L$ is financed totally by deposits $D$, if there is no capital regulation. However, by regulating capital requirements, the regulator ensures that the bank must hold a certain amount of capital, and, consequently, the regulator aims to constrain the risk that the bank undertakes as mentioned in the traditional approach to capital regulation.

If the regulator knows the bank’s risk level, then the regulator can determine the capital requirement level $K_i$ for each risk type $v_i$ that minimizes the expected social loss function. The regulator’s problem is

$$\min_{K_i \geq 0} W_s(v_i, K_i) = r_cK_i + (1 - \phi_i)(1 + \gamma)C(K_i),$$  \hspace{1cm} (4)$$

s.t.

$$W_b(v_i, K_i) \geq 0,$$

$$W_b(v_h, K_h) \geq 0,$$  \hspace{1cm} (5)$$

for each $i \in \{1, h\}$. The constraints of problem (3) are the individual rationality constraints (IRC) for the bank of each risk type. To induce participation, the capital requirement rule must ensure the bank’s opportunity profit level (normalized to zero) in each state of nature.
Note that \(v_h > v_l > r_c > r_d\) guarantees \(W_b(v_l, K_l) > 0, \ i \in \{l, h\}\), which can be verified by going back to (1). Moreover, \(\lim_{k \to -\infty} C_k(k) = -\infty\) rules out \(K = 0\) as a solution. Hence the first-order condition of the problem (3) is simply

\[r_k = -(1 - \phi_i)(1 + \gamma)C_k(K_i^k), \text{ for each } i \in \{l, h\}. \quad (4)\]

Observe that \(K_i^k\) for each \(i \in \{l, h\}\) is well-defined, i.e. the solution to (4) exists, since \(\lim_{k \to -\infty} C_k(k) = 0\).

We thus obtain the optimal capital requirement for each type under full information \(K_i^k\) that satisfies equation (4). The regulator equates the marginal cost of holding capital to the bank—the left-hand side of (4)—with the marginal benefit of capital requirements for the system, which is the right-hand side of (4).

4. Asymmetric information

In this section, we assume that the bank privately holds the information about its risk level. Therefore, the bank’s risk level is unobservable but verifiable by the regulator. This can induce the bank to gain by misreporting its risk level to the regulator. For a given loan, \(L\), the bank’s incentive is to hold less capital and more deposits since the marginal cost of deposits is less than that of capital.

The net gain of the bank in the case of misreporting can be characterized as follows:

\[\Delta W_b = W_b(v_l, K_l) - W_b(v_h, K_h), \quad (5)\]

where \(W_b(v_l, K_l)\) is the welfare of the bank when the bank reports low risk while having high risk and \(W_b(v_h, K_h)\) is the welfare of the bank when it reports high risk while having high risk.

Although the regulator does not know the bank’s risk level, the regulator knows that a low risk level \(v_h\) obtains with probability \(q_h\), and a high risk level \(v_l\) obtains with \(q_h\), with \(q_l + q_h = 1\).

The regulator observes only the realization of a signal, that is, the risk level that the bank reports to the regulator. The signals that the bank gives are imperfectly correlated with actual risk. Therefore, the regulator forms a belief about the probabilities of a signal for any given actual risk level. We represent this belief by the probability distribution \(\sigma_i, j = h, l, i.e. the probability of giving a signal of risk of \(i\) while having a risk of \(j\).

The regulator believes that if the bank’s risk level is high, then the bank gives the signal of high risk with a probability \(\sigma_{hi} = \mu\) (hereafter the compliance probability) and the signal of low risk with the probability \(\sigma_{hi} = 1 - \mu\) (the non-compliance probability). However, if the bank’s risk level is low, then the regulator believes that the bank certainly gives the signal of low risk, \(\sigma_l = 1\), and does not give the signal of high risk at all, \(\sigma_h = 0\). Thus, the bank truthfully reports whenever it selects a low risk level. In accordance with this probability structure, the regulator believes that the bank reports risk \(i\) with probability

\[\pi_i = q_i\sigma_{ii} + q_j\sigma_{ij}. \quad (6)\]

After the regulator observes signal \(i\), it audits the bank with a probability \(\alpha_i\) and expects to detect misreporting with probability

\[\pi_{ij} = \frac{q_j\sigma_{ij}}{\pi_i}, \quad (7)\]

which is the probability of the bank having a risk of \(j\) given that the bank reports a risk of \(i\). Since the bank reports truthfully when its risk level is low, the regulator does not audit when a high risk level is reported, \(\alpha_h = 0\). We denote \(\alpha = \alpha_i\) hereafter.

The regulator aims at choosing the optimal capital requirement levels \(\{K_l, K_h\}\) and optimal auditing probability \(\alpha\) and tries to direct compliance with probability \(\mu\), thus inducing the bank to report truthfully. By choosing the optimal values of these parameters, the regulator aims at minimizing its expected loss function,

\[W^E = \pi_l(W_b(v_l, K_l) + \pi_{hl}(\Delta W^E_l + \alpha(\Delta W^E_h - P)) + \alpha) + \pi_h(W_b(v_l, K_h)), \quad (8)\]

where

\[\Delta W^E_l = W_b(v_l, K_l) - W_b(v_l, K_l) > 0, \quad \Delta W^E_h = W_b(v_l, K_h) - W_b(v_h, K_h) < 0.\]

The regulator’s expected loss is defined in expression (8) under each probable case. When the bank reports low risk with probability \(\pi_l\), the regulator audits with probability \(\alpha\) and detects cheating with probability \(\pi_{hl}\). If the regulator detects cheating, it collects penalty \(P\) and the bank is compelled to hold the right capital requirement, \(K_h\), that corresponds to the actual risk level, hence \(W_b(v_h, K_h)\). Thus, the bank has to pay a monetary fine and recapitalize without extra cost if it does not comply with the capital requirement rule.

The regulator incurs monitoring costs \((m < P)\). When the bank reports a high risk level with probability \(\pi_h\), the welfare of the regulator is just \(W_b(v_h, K_h)\) because of no auditing and untruthful reporting.

On the other hand, while \(\Delta W^E_l\) denotes an increase in social loss in the case of untruthful reporting and no auditing, \(\Delta W^E_h\) denotes a decrease in social loss in the case of untruthful reporting. Therefore, the decrease in social loss from an audit is \((\Delta W^E_l - P) + m\), or the net ex post gain in positive terms is \((-\Delta W^E_h + P) - m\).

Rewriting the complete problem of the regulator along with its constraints,

\[
\min_{K_l \geq 0, K_h \geq 0, \alpha \in [0, 1]} W^E = \pi_l(W_b(v_l, K_l) + \pi_{hl}(\Delta W^E_l + \alpha(\Delta W^E_h - P)) + \alpha) + \pi_h(W_b(v_l, K_h), \quad (9)
\]

s.t.

(i) \(W_b(v_l, K_l) \geq 0\),

(ii) \(\mu W_b(v_h, K_h) + (1 - \mu)((1 - \alpha)W_b(v_l, K_l) + \alpha(W_b(v_h, K_h) - P)) \geq 0\),

(iii) \(\mu \in \arg \max \{-\mu W_b(v_h, K_h) + (1 - \mu)((1 - \alpha)W_b(v_l, K_l) + \alpha(W_b(v_h, K_h) - P))\}

(iv) \(\alpha \in \arg \min \alpha(\pi_{hl}(\Delta W^E_h - P) + m).\)
While constraints (i) and (ii) of problem (9) are two individual rationality constraints, constraints (iii) and (iv) determine the values of $\mu$ and $\alpha$ given the capital requirement levels. The latter act as constraints because the regulator cares about the optimality conditions for $\mu$ and $\alpha$. These conditions represent how the regulator’s ability to choose the audit probability and the compliance probability is constrained by the requirement of sequential optimality. The probability of compliance $\mu$ is chosen by the bank to maximize the bank’s payoff in state $h$, and the probability of auditing $\alpha$ is chosen by the regulator to minimize the social loss given that the bank has signaled its low risk level.

In the following sections, we define the optimal capital requirement levels for the cases of commitment and no-commitment to auditing under the regulator’s main problem as proposed in (9).

4.1. Commitment to auditing

The regulator can commit to an auditing strategy. This means that it announces a probability of auditing and commits to this strategy (i.e. it is determined ex-ante). A commitment of this sort aims at compelling the bank to comply with the capital regulation. Therefore, we modify problem (9) by ignoring the audit incentive constraint (iv) and rewriting constraint (iii) in (9) as a typical truth-telling constraint under auditing. In this case, the regulator’s problem becomes the following:

$$\min_{k_h \geq 0, k_l \geq 0, a \in [0, 1]} W^E = q_h[W_s(v_h, K_h) + a] + q_h[W_s(v_h, K_h)],$$

s.t.

(i) $W_b(v_i, K_i) \geq 0$,
(ii) $W_b(v_h, K_h) \geq 0$,
(iii) $W_b(v_h, K_h) \geq (1 - \alpha)W_b(v_h, K_i) + \alpha(W_b(v_h, K_h) - P)$. 

(10)

Since truth telling is induced by auditing with commitment, the probability $\pi_h$ decreases to $q_i$ and an audit never leads to the collection of a penalty, $P$. After the fact, the regulator has no incentive to audit. Thus, the choice of probability of audit does not have to be ex post optimal. Therefore, auditing appears as a net cost in the objective function, but is carried out for its indirect benefit in reducing information rents.

Note that the optimal auditing probability is derived from the third constraint of (10), which is

$$\alpha^c = \frac{\Delta W_b}{\Delta W_b + P},$$

(11)

where $\Delta W_b = W_b(v_h, K_h^f) - W_b(v_h, K_h^c)$ is the bank's gain from non-compliance for optimal capital requirement levels $K_h^f$ and $K_h^c$ under commitment.

Proposition 4.1: Compared with full information, the regulator, under commitment, sets a higher capital requirement for the bank with low risk, $K_h^c > K_i^c$, and a lower capital requirement for the bank with high risk, $K_h^f < K_h^c$.

Proof: See appendix A.1.

The regulator ends up reducing $K_h$ and increasing $K_i$. Hence, the regulator aims to deter a high-risk bank from making an undetected false announcement, i.e. reducing the difference between two optimal capital requirements specified for different risk levels. The existence of asymmetric information, however, creates inefficient results for both types of risk relative to full information (first best). The inefficient results stem from the fact that the regulator disallows the bank from taking advantage of information rents at high risk, which is guaranteed by the third constraint of (10). But there is a trade-off between information rents and efficiency.

4.2. No-commitment to auditing

Since committing to auditing induces the bank to comply with the rule, the regulator has no incentive to audit. Hence, it is not ex post efficient. Therefore, we now look at the case of a no-commitment strategy to auditing. For this, we return to the original problem defined in (9). Consider a two-stage game. In the first stage, the regulator chooses the optimal capital requirements $\{K_i, K_h\}$. Then, in the second stage, the regulator chooses an optimal auditing probability $\alpha$ and implements a compliance probability $\mu$, thus inducing the bank to report truthfully. Therefore, the regulator begins to solve the parameters $\alpha$ and $\mu$ from the second stage using backward induction. The regulator determines its auditing policy depending on whether it is optimal or not. Therefore, the solution to the regulator’s problem may or may not involve audits with respect to the regulator’s parameter values. Consider first the case when the regulator does not audit and, second, the case when the regulator audits.

(i) No-audit case ($\alpha = 0$). If the regulator does not audit ($\alpha = 0$), we know from the revelation principle that the regulator can do no better than offer a capital requirement rule that leads to compliance. Thus, constraint (iii) of (9) should be rewritten in the typical form of an incentive-compatibility constraint to induce $\phi_{hh} = \mu = 1$,

$$W_b(v_h, K_h) \geq W_b(v_h, K_i).$$

(12)

However, condition (12) is not possible because a high capital requirement is always more costly for the bank than a low capital requirement given that the bank’s risk type is high. Therefore, without auditing, the bank cannot be induced to report truthfully and the auditing probability should be positive, $\alpha > 0$.

(ii) Positive audit case ($\alpha > 0$). It is generally accepted that auditing contracts induce a positive audit level. However, the case of $\alpha = 1$ is not an optimum. If the regulator always audits, $\alpha = 1$, implying that the bank does not cheat, and $\mu = 1$. But if the bank does comply, $\mu = 1$, then the regulator should not audit, and $\alpha = 0$. As a result, there is a positive auditing probability, $0 < \alpha < 1$ as long as there is a positive probability of
non-compliance, $0 < \mu < 1$. That is, if there is no cheating in equilibrium, an audit cannot be optimal. Therefore, there is a mixed-strategy equilibrium. Examining the optimal auditing and compliance probabilities, the last two conditions of (9) yield a mixed-strategy equilibrium if the following holds:

$$W_b(v_h, K_h) = (1 - \alpha)W_b(v_h, K_l) + \alpha(W_b(v_h, K_h) - P),$$

(13)

$$m \nu_h \delta = \delta = -\Delta W^s_b + P,$$

(14)

where $\delta = -\Delta W^s_b + P$, which is the regulator’s ex post gain from monitoring.

These are indifference conditions associated with mixed-strategy equilibria. The first condition states that the bank is indifferent between complying and not complying in the state of having high risk, $v_h$. The second condition states that the regulator is indifferent between auditing and not auditing following the bank’s signal of having low risk, $v_l$. Equation (13) yields the optimal auditing probability that keeps the bank indifferent between complying and not complying, depicted as follows:

$$a^{nc} = \frac{\Delta W^s_b}{\Delta W_b + P} > 0,$$

(15)

where $\Delta W_b = W_b(v_h, K^n_{nc}) - W_b(v_h, K^c_{nc}) > 0$ is the net gain of the bank if it does not comply under no-commitment. As can be seen, when the penalty increases, the optimal auditing probability declines, and $da^{nc}/dP < 0$. The higher penalty deters the bank from cheating and this in turn leads the regulator to audit less. However, when the bank’s net gain from cheating increases, the bank’s incentive not to comply increases. Therefore, the regulator must increase its auditing probability to decrease the bank’s incentive to cheat, $da^{nc}/d(\Delta W_b) > 0$.

Note that expression (14) yields a compliance probability $\mu$, which is a function of the regulation parameters. Therefore, the regulator can direct a specific compliance probability. Using equations (6), (7) and (14), we obtain

$$\mu = \frac{q_h \delta - m}{q_h(\delta - m)} > 0.$$  

(16)

It can readily be seen from (16) that if the regulator’s ex post gain $\delta$ increases, the optimal compliance probability also increases because the regulator has more of an incentive to force the bank to comply with the capital requirement rule. However, the compliance probability decreases when monitoring costs increase because the regulator is reluctant to monitor when monitoring is costly. This in turn leads the bank to comply less.

If the penalty increases dramatically or auditing costs decrease substantially, no-commitment will be the same as commitment because non-compliance will not be realized under no-commitment. Thus, the compliance probability $\mu$ approaches 1, which can be seen from (16). Hence, if the monitoring technology is taken as given, the penalty becomes crucial to non-compliance.

Using the indifference conditions in (13) and (14) to substitute $\alpha$ and $\mu$ in the objective function of the regulator and in the individual rationality constraints, and replacing them with constraints (iii) and (iv) of problem (9), the regulator’s problem reduces to the following:

$$\min_{K_l \geq 0, K_h \geq 0} W^s = \pi(l) (\nu \mid W_b(v_l, K_l) + \pi_h \Delta W^s_b) + \pi_h W_b(v_h, K_h),$$

s.t.

$$W_b(v_l, K_l) \geq 0,$$

$$W_b(v_h, K_h) \geq 0,$$

(17)

where $\pi_l = q_l \delta/(\delta - m)$, $\pi_h = (q_h \delta - m)/(\delta - m)$ and $\nu_l = \mu \delta$. These are indifference conditions associated with mixed-strategy equilibria. The first condition states that the bank is indifferent between complying and not complying, depicted as (13) and (14). Auditing helps induce compliance by keeping the bank indifferent between complying and not complying in state $h$ as defined in (13).

The regulator’s payoff under no-commitment (17) depends on the penalty, the ex post social gains from auditing and the audit cost, whereas the regulator’s payoff under commitment (10) depends only on the audit cost.

The bank cannot extract rent under no-commitment when its risk level is high. This can better be understood by returning to the original problem (9) and replacing constraints (iii) and (iv) of (9) by the two indifference conditions (13) and (14). Since the bank is indifferent between complying and not complying when risk is high, the bank’s rent, given by constraint (ii) of (9), reduces to its payoff under compliance, $W_b(v_h, K_h)$. Also, although the regulator does not permit any rent under no-commitment, the regulator’s welfare suffers when the bank does not comply. The probability of $v_h$ being reported declines with respect to the commitment case, $\pi_h = (q_h \delta - m)/(\delta - m) < q_h$.

We now characterize optimal capital requirements under the no-commitment case.

**Proposition 4.2:** Compared with the context of full information, the regulator under no-commitment sets a higher capital requirement for a low-risk type, $K^n_{nc} > K^n_l$, but the same capital requirement for a high-risk type, $K^n_{nc} = K^n_h$.

**Proof:** See appendix A.2

This result can be understood by returning to the audit constraint (14), which is crucial for the result of the higher capitalization rule for a low-risk bank. Since the no-commitment case does not have the constraint of truth.
telling, the bank’s low-risk report is not totally reliable. Hence, the regulator needs to increase the capital requirement level for a low-risk bank to compensate for the welfare loss arising from non-compliance. If \( K \) is increased, then the probability of compliance must increase to keep the regulator indifferent between auditing and not auditing. Consequently, the information rent is reduced and the bank is compelled to comply, but efficiency is sacrificed.

5. Conclusion

Although risk-based optimal capital schemes for banks have been well-covered in the literature, in this study we have combined a risk-based optimal capital requirement with two auditing strategies—commitment and no-commitment to auditing. We have focused particularly on the optimal audit policy when the regulator does not commit to auditing, which has allowed us to analyse the implications of the audit strategy when the regulator’s ability to commit varies. We show that the nature of the distortions under commitment differ from the distortions under no-commitment. The differences originate in the fundamental trade-off between non-compliance and efficiency, that is, the presence of a truth-telling constraint under commitment and an audit constraint under no-commitment.

Our study concerns an adverse selection problem (hidden information). We remain aware, however, that moral hazard problems also have great importance in the bank–regulator relationship. Even though the regulator can identify how risky the bank is, it may be extremely difficult to monitor the bank’s daily activities and therefore the ways in which the bank constructs the riskiness of its portfolio. The bank may tend to undertake higher risk over time, thus leading to moral hazard.

However, the fundamental problem for Basel I and II is to determine the risk of bank assets: the bank knows that its complicated accounting structure requires the regulator to incur a cost to verify whether the bank’s reporting is true. Pricing risks are very complicated, and hence can be concealed. The problem for Basel II is that banks have an incentive to understate their risk as long as they want to save on capital costs. Basel II is based on the belief that banks know their risk exposure better than regulators and, while regulators can gather some information on these risks, the regulator can never know as much as the bank. For this reason, the bank’s incentive to misreport its risk level seems unavoidable. Auditing and capital requirement policies should consequently be designed to take into consideration this problem and both capital requirements and auditing strategies should be considered as a unified policy. The efficiency problem arising from the time inconsistency of commitment to auditing can be mitigated by using a no-commitment strategy supported by optimal capital requirement levels.

On the other hand, this article omits some dimensions that remain relevant to the problem. In fact, in order to concentrate on the no-commitment strategy in the context of capital regulation, we have not emphasized implementation issues and the institutional structures of regulation. For example, penalties to the bank are taken as given rather than derived endogenously, although this does not prevent us from obtaining the main insights of the model. In addition, audits are assumed to be perfect. However, auditing information may be incorrect. Another important dimension is to consider dynamic capital schedules. Supervisors interact over time with banks and may have latitude to generate the equivalent of penalties through their future treatment of the bank. The literature on dynamic costly state verification models should be relevant here.

References

Appendix A: Proofs

A.1. Proof of proposition 4.1

Proof: First, recall that \( v_h > v_l > r_c > r_d \) guarantees \( W_s(v_l, K_l) > 0 \), \( i \in \{l, h\} \). Furthermore, the Inada conditions rule out \( K_l = 0 \), \( i \in \{l, h\} \). Thus setting up the Lagrangian according to the regulator’s problem under commitment as defined in (10), we maintain

\[
L(K_l, K_h, \alpha) = q_l[W_s(v_l, K_l) + \alpha m] + q_h[W_s(v_h, K_h)] + \lambda((1 - \alpha)(W_s(v_h, K_h) - W_s(v_h, K_l)) + \alpha P).
\]

The first-order conditions (FOC) of the above problem are

\[
\frac{\partial L}{\partial K_l} = q_l \frac{\partial W_s(v_l, K_l)}{\partial K_l} - \lambda(1 - \alpha) \frac{\partial W_s(v_h, K_l)}{\partial K_l} = 0
\]

and

\[
\frac{\partial L}{\partial K_h} = q_h \frac{\partial W_s(v_h, K_h)}{\partial K_h} + \lambda(1 - \alpha) \frac{\partial W_s(v_h, K_l)}{\partial K_h} = 0.
\]

Hence we have

\[
\frac{\partial W_s(v_l, K_l)}{\partial K_l} = \frac{\lambda}{q_l} \frac{(1 - \alpha)}{\partial K_l} > 0
\]

and

\[
\frac{\partial W_s(v_h, K_h)}{\partial K_h} = -\frac{\lambda}{q_h} (1 - \alpha) \frac{\partial W_s(v_h, K_h)}{\partial K_h} < 0,
\]

where

\[
\frac{\partial W_s(v_h, K_l)}{\partial K_l} = \frac{\partial W_s(v_h, K_h)}{\partial K_h} = \phi(v_h)(v_h - r_c) > 0
\]

and \( \lambda > 0 \). Hence \( \partial W_s(v_l, K_l)/\partial K_l > 0 \) and \( \partial W_s(v_h, K_h)/\partial K_h < 0 \). Therefore, the convexity of \( W_s(v_l, K_l) \) implies that \( K_l^* > K_l^c \) and \( K_h^c < K_h^* \). \( \square \)

A.2. Proof of proposition 4.2

Proof: Under no-commitment, the regulator’s problem is defined as

\[
\min_{K_l \geq 0, K_h \geq 0} W_s^c = \frac{q_h}{\delta - m} \left[ W_s(v_l, K_l) + \frac{m}{\delta} \Delta W_s^c \right] + q_h \delta - m W_s(v_h, K_h),
\]

s.t.

(i) \( W_s(v_l, K_l) \geq 0 \),
(ii) \( W_s(v_h, K_h) \geq 0 \).

Since the constraints are not binding as stated above the FOCs of (A1) are as follows:

\[
(i) \frac{\partial W_s^c}{\partial K_l} = \frac{q_h m}{(\delta - m)} \left( W_s(v_l, K_l) - W_s(v_h, K_l) + 1 \right) + \frac{\partial W_s(v_h, K_l)}{\partial K_l} \frac{q_h}{\delta - m} (1 - m) = 0,
\]

(ii) \( \frac{\partial W_s^c}{\partial K_h} = -\frac{\partial W_s(v_h, K_l)}{\partial K_h} \frac{q_h}{\delta - m} (1 - m) = 0. \)

It can be seen from (A2) that

\[
\frac{q_h m}{(\delta - m)} \left( W_s(v_l, K_l) - W_s(v_h, K_l) + 1 \right) > 0,
\]

\[
\frac{q_h}{\delta - m} (1 - m) > 0.
\]

Note also that

\[
\frac{\partial W_s(v_h, K_l)}{\partial K_l} = r_c + (1 - \phi(v_h))(1 + \gamma)C_h(K_l)
\]

and

\[
\frac{\partial W_s(v_l, K_l)}{\partial K_l} = r_c + (1 - \phi(v_l))(1 + \gamma)C_h(K_l).
\]

Since \( \phi(v_h) < \phi(v_l) \) and \( C_h(K_l) < 0 \), we have

\[
\frac{\partial W_s(v_l, K_l)}{\partial K_l} < \frac{\partial W_s(v_h, K_l)}{\partial K_l}.
\]

From this condition together with (A2) and (A4), it follows that \( \partial W_s(v_l, K_l)/\partial K_l \leq 0 \) is impossible, so that it must be \( \partial W_s(v_l, K_l)/\partial K_l > 0 \) given that the convexity of \( W_s \) implies the result. Therefore, \( K_l^{nc} > K_l^{c} \).

As for the capital requirement level for high risk, look at (A3), since

\[
\frac{q_h m}{(\delta - m)} \left( W_s(v_h, K_h) - W_s(v_h, K_l) \right) - \frac{q_h}{\delta - m} \neq 0,
\]

where \( \Delta W_s^c = W_s(v_h, K_h) - W_s(v_h, K_l) \). Therefore, it is clearly \( \partial W_s(v_h, K_h)/\partial K_l = 0 \). This implies that the full-information level for high risk is \( K_h^{nc} = K_h^{c} \). \( \square \)