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Incentives for effective risk management

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Abstract

Under the new Capital Accord, banks choose between two different types of risk management systems, the standard or the internal rating based approach. The paper considers how a bank's preference for a risk management system is affected by the presence of supervision by bank regulators. The model uses a principal–agent setting between a bank's owner and its risk management. The main conclusion is that previously unregulated institutions can be expected to switch to the lower quality standard approach subsequent to becoming regulated, i.e., the presence of regulation may induce a bank to decrease the quality of its risk management system.

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1. Introduction

Most financial institutions will, even in the absence of supervisory prompting, prefer to employ some form of risk management. Recently, financial regulators have codified this practice, and generally require financial institutions to measure market risk with statistical models, specifically value at risk (VaR) (see Basel Committee on Banking Supervision, 1996). Under the latest Basel-II proposals, the same general

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methodology will be applied to measuring credit, operational, and eventually liquidity risk. In other words, statistical risk modelling (termed internal rating based or IRB) will become the linchpin upon which the stability of the financial system rests. [1]

While the IRB approach has been actively studied, one aspect has received little attention: The effect of regulation on banks' choice of risk management systems. In particular the incentives the key parties have for accurately measuring risk, and the contractual relationship that binds the risk manager, the bank owner, and the regulatory supervisor. Our aim is to explicitly model how the imposition of financial risk regulation affects financial institutions preferences for different risk management systems. To this end, we propose a principal–agent model of the relation between a bank's risk manager and owners, in which the setting is complicated by the presence of regulators. The bank has a choice of two different types of risk management systems, i.e., the standard and IRB approach.

Presumably the bank supervisors prefer that financial institutions employ the IRB approach. There are several reasons for this, including a desire to measure risk more accurately and the reduction of regulatory arbitrage.The banks, however, have a different point of view since the IRB approach has the potential to give supervisors better insights into the internal operations of the bank. This preference is supported anecdotally by statements made by senior bank regulators. For example, Federal Reserve Bank (FRB) Governor Meyer (2000) stated that internal models may serve a dual function in the future for both supervisory and internal use within a financial institution.

Regulatory supervision of the risk management process may thus be viewed by some banks as a competitive disadvantage. Not only may it force risk to be measured differently than it would in the absence of regulation, but it would also imply changes to bank operations that may be suboptimal. As a result, banks have incentives to reduce the level of regulatory oversight.

That is, banks game the regulatory risk management process even if such gaming may not affect its overall capital, and may adversely adopt a lower quality system due to the very fact that they are being supervised.

Supervisors recognize that banks may be less than enthusiastic for such a regulatory environment. For example, Meyer (2000) has stated "We should all be aware that additional public disclosure is not a free good, especially if it works. Banks will find that additional market discipline constrains their options, and supervisors will be concerned about creditors' response to bad news". Indeed, the supervisors acknowledge that this may lead to possibly perverse outcomes: The European Central Bank (2001, p. 69) has stated this as "Banks with a higher-risk portfolio, by contrast, might stick to the standardized approach".

We model the bank as a principal–agent relation between a bank's board of directors (principal) and a dedicated risk manager (agent), in a setting in which the bank is subject to regulation. The board maximizes expected utility by making an offer to

[1] The IRB methodology has received widespread criticism, witness the comments currently at http:www.bis.org/bcbs/cacomments.htm. These criticisms range from individual banks commenting on a particular aspect of the 2001 Basel-II proposals, to academics criticizing the whole approach.

the manager and allocating resources to a risk management system. We consider two alternative categories of risk management systems, one where the risk manager is closely monitored, and the other with less monitoring. We label the first system *finer risk monitoring* and the second system *coarser risk monitoring*. These systems are based on the IRB and standard approaches, respectively. If the risk manager accepts the board's employment offer, he decides how much effort to put into managing risk, conditional on the quality of the risk management system. Finally, the board observes the outcome, and pays the manager the agreed-upon compensation. There is no room for renegotiation. The board has all the bargaining power and, in equilibrium, the manager accepts the offer and receives the certainty equivalent of zero from the optimal contract.

Since the risk manager is compensated for reducing risk, in the form of volatility, it is natural to assume that the agent's efforts cause a second order stochastic dominating shift. Some models have explicitly considered such contracts (see e.g., Hughes, 1982; Demski and Dye, 1999). This approach implies a separation between risk and return choices. Clearly this would hold if the hedging instruments available to the risk manager are priced fairly. More generally, Sung (1995) provides sufficient conditions under which our results generalize. Our focus is on the trade-off between the cost of risk management and the risk reduction achieved by risk monitoring, taking as given that some risk is unavoidable for a given expected return level.

The main objective of this paper is to consider the impact of risk-based regulation on the decisions of individual financial institutions. As such, we do not need to model the supervisors preferences, as this would take us too far astray from our main goal. Indeed, since scant information is publicly available about the preferences of the Basel Committee, beyond the most general, modelling regulatory preferences would be challenging. We therefore take the decisions of the supervisors as given. The supervisor is not able to directly influence what risk management system the bank chooses to implement, but may preannounce that conditional on a choice of a system, the parameterization or model assumptions would have to take a particular form. This corresponds to the present situation where the regulators are able to influence the specification of a banks IRB model.

We reach three main results. First, we demonstrate in Proposition 2, that in the absence of regulatory supervision, financial institutions prefer the higher quality *finer* system, if the direct costs of such a system are sufficiently low. Hence, the finer system implies *first best* outcomes while the coarser regime results in *second best* outcomes. Second, in Proposition 3, we demonstrate that the addition of regulation may cause the financial institutions to reverse this choice. In other words, within our model, financial risk regulation provides incentives for banks to implement a lower quality risk management system than they would in the absence of regulation. Finally, when the supervisor decides to affect the implementation of the system, he affects asset volatility and hence (inadvertently) introduces procyclicality. We also extend the basic model in Appendix A. Instead of the choice of risk management systems being a binary choice for the bank, there is a continuous transition from one system to the other. This, however, does not qualitatively change our results. In summary, the results may explain the anecdotal evidence that some banks employ dual risk management systems, a finer system for internal control, and a scaled-down coarse version for reporting purposes.

2. The principal–agent relationships

A financial institution consists of multiple interested parties each with their own preferences and agendas. For example, traders are much more risk seeking than the owners of a bank, and left uncontrolled would lead to unacceptable levels of risk taking. A bank's board of directors, or board in short, therefore specifies acceptable risk levels for each unit within the organization. The monitoring of these risk levels are left to a separate entity, the risk manager, whose function is to measure risk and enforce risk limits set by the board. As such risk management is a cost center, and the board needs to split resources between risk management and profit centers. In general, the more resources are allocated to risk management the better risk is measured and managed.

Since our interest is in understanding the interplay between internal and external risk management, we model the bank as a principal–agent relationship between two separate entities, the board and the risk manager. The board incurs expenses by employing a risk manager and makes two related decisions: What resources to allocate to the risk management function and the degree of delegation to the risk manager. The risk manager in turn decides based on his compensation contract how much effort to put into actually managing risk. The actual effort chosen depends on both the actual resources allocated as well as the level of monitoring by the board, i.e., how much of the risk management function is delegated to the risk manager. In addition, the board is itself subjected to supervision. We chose to not cast the supervisor-board relationship in a principal agent setting for two reasons. First to maintain tractability and obtain closed form solutions. Second, the objective function of the regulators is not clearly defined. While this would be an interesting topic for future research, we follow the observed regulatory drive for containing risk exposures in banks, by exogenously varying the allowable degree of risk taking.

2.1. The basic model

Our basic setting is a standard principal–agent model between the board of directors of a bank (principal) and a risk manager (agent) with the following time line. First, the board, b, maximizes its expected utility, EU_b, by making an one time employment offer to a risk manager, m. The manager by rejecting the offer earns nothing. Consequently, his expected utility, EU_m, derived from working must always be nonnegative. Alternatively, by accepting the offer, the manager selects an effort, incurs personal disutility, and manages bank risk. Finally, the board observes the outcome, and pays the manager the agreed-upon compensation. There is no room for renegotiation. The board has all the bargaining power and, in equilibrium, the manager accepts the offer and receives the certainty equivalent of zero from the optimal contract.

Most principal–agent settings assume that the agent's effort causes a first order stochastic dominating shift in the distribution of the performance measure, see, among others, Holmstrom (1979) and Holmstrom and Milgrom (1987). Some models allow the agent to take an action that causes instead a second order stochastic dominating shift (see e.g., Hughes, 1982; Sung, 1995; Demski and Dye, 1999). We choose the latter modelling approach. We note that this approach implies a separation between risk and return choices. Clearly this would hold if the hedging instruments available to the risk manager are priced fairly. More generally, Sung (1995) provides sufficient conditions [2] under which our results generalize. Our focus is on the trade-off between the cost of risk management and the risk reduction achieved by risk monitoring, taking as given that some risk is unavoidable for a given expected return level.

The manager chooses an effort level, a, incurring unit cost of effort, k, measured in pecuniary terms. The bank earns profits Z, with the following distribution:

$$Z \sim N(\mu, \sigma^2(a)), \tag{1}$$

where the risk reduction technology exhibits decreasing marginal returns to effort. In particular we assume that $\sigma^2(a) = \Sigma a^{-1}$, where Σ is a given positive parameter.

To ensure a non-trivial solution and avoid wealth effects, we assume that both the manager and the board have negative exponential utility functions with constant absolute risk aversion coefficients α and β, respectively. We denote the contract offered to the agent by $s(Z)$. Hence, the expected utility of the manager is

$$E[U_{\mathrm{m}}(s(Z), a)|a] = -E[\exp(-\alpha(s(Z) - ka))|a].$$

In the absence of regulation, we consider two benchmark scenarios, a first-best and second-best outcomes.

2.1.1. First-best scenario

In the first-best scenario, the risk manager's choice of effort is observable and contractible to the board of directors, that is, the board solves the following problem:

$$\max_{a,s(Z)} \quad E[U_{\mathrm{b}}(Z - s(Z))|a],$$
$$\text{subject to} \quad \overline{U} \leqslant E[U_{\mathrm{m}}(s(Z), a)|a].$$

For reasons discussed below, the optimal contract offered to the agent is linear, that is, $s(Z) = s_0 + s_1 Z$. The board offers the contract parameters, s_0 and s_1, to maximize expected utility. Conditional on the choice of these parameters, we can analyze the behavior of the risk manager. The manager's expected utility is

$$\mathrm{EU_m} = -\exp\left(-\alpha E[s(Z)|a] + \alpha ka + \frac{\alpha^2}{2}\mathrm{VAR}[s(Z)|a]\right).$$

The first term is the manager's expected compensation, the second term is the disutility of effort, and the last term represents the risk premium. For the linear contract $s(Z) = s_0 + s_1 Z$, we can write

[2] The disutility of efforts associated with risk and return are assumed to be additively separable.

$$\mathrm{EU_m} = -\exp\left(- \alpha s_0 - \alpha s_1 \mu + \alpha k a + \frac{\alpha^2}{2} s_1^2 \Sigma a^{-1} \right).$$

Since both board and manager have constant absolute risk aversion and the random variables are normally distributed for any given effort level, we can conveniently transform the manager's expected utility to certainty equivalents:

$$\mathrm{CEU_m} = -\alpha^{-1} \ln(-\mathrm{EU_m}) = s_0 + s_1 \mu - ka - \frac{\alpha}{2} s_1^2 \Sigma a^{-1}.$$

The expected utility of the board is

$$\begin{aligned}\mathrm{EU_b} &= \exp\left(- \beta E[Z - s(Z)|s_0, s_1] + \frac{\beta^2}{2} \mathrm{VAR}[Z - s(Z)|s_0, s_1, a] \right) \\ &= \exp\left(- \beta(1 - s_1)\mu + \beta s_0 + \frac{\beta^2}{2}(1 - s_1)^2 \sigma^2(a) \right),\end{aligned}$$

and the certainty equivalent of the board's expected utility is

$$\mathrm{CEU_b} = (1 - s_1)\mu - s_0 - \frac{\beta}{2}(1 - s_1)^2 \sigma^2(a).$$

When effort is costlessly observable and contractible, the board can implement the first-best solution by basing the reward directly on the observed volatility. To attain the first-best solution, the contract parameters (s_0, s_1) are chosen as follows. The board pays the manager such that he is indifferent between working or not working, i.e., $\mathrm{EU_m} = -1$ or the manager's certainty equivalent of $\mathrm{CEU_m} = 0$:

$$-s_0 = s_1 \mu - ka - \frac{\alpha}{2} s_1^2 \Sigma a^{-1}.$$

Substituting this into the board's utility function yields the certainty equivalent of

$$\mathrm{CEU_b} = \mu - ka - \frac{\alpha}{2} s_1^2 \Sigma a^{-1} - \frac{\beta}{2}(1 - s_1)^2 \Sigma a^{-1}.$$

The board maximizes $\mathrm{EU_b}$ with respect to s_1 and a resulting in the solution to the board's first-best problem being

$$\begin{aligned} a^{\text{first best}} &= \sqrt{\frac{\Sigma}{2k}} \sqrt{\frac{\alpha\beta}{\alpha + \beta}}, \\ s_1^{\text{first best}} &= \frac{\beta}{\alpha + \beta}, \\ s_0^{\text{first best}} &= -\frac{\beta}{\alpha + \beta}\mu + (\alpha + 2\beta)\sqrt{\frac{(\alpha + \beta)\alpha k \beta \Sigma}{2}}. \end{aligned}$$

The slope of the manager's first-best contract depends on the relative risk aversions, which is the optimal risk sharing in agencies in the absence of moral hazard (see Wilson, 1968). Further, the optimal effort is increasing in risk, decreasing in the marginal cost of effort and increasing in the risk aversion parameters. In all cases below, the fixed component of the manager's compensation is determined by making the manager indifferent between working and not working. The first-best variance is

$$\sigma^2(a^{\text{first best}}) = \sqrt{2k\Sigma}\sqrt{\frac{(\alpha+\beta)}{\alpha\beta}}$$

and the board's first-best certainty equivalent is

$$\mathrm{CEU}_{\mathrm{b}}^{\text{first best}} = \mu - \sqrt{2k\Sigma}\sqrt{\frac{\alpha\beta}{\alpha+\beta}},$$

both of which are increasing in the variance and the marginal cost of effort, while decreasing in the risk aversions.

2.1.2. Second-best scenario

In the second-best scenario, the risk manager's choice of effort is neither observable nor contractible to the board of directors. In this scenario, the board's problem can be formalized as

$$\begin{aligned} &\max_{a,s(Z)} && E[U_{\mathrm{b}}(Z - s(Z))|a], \\ &\text{subject to} && \overline{U} \leqslant E[U_{\mathrm{m}}(s(Z),a)|a], \\ & && E[U_{\mathrm{m}}(s(Z),a)|a] \geqslant E[U_{\mathrm{m}}(s(Z),a^{+})|a^{+}] \text{ for all } a^{+}. \end{aligned}$$

In a single period principal–agent model, the second-best optimal contract would not be linear because a sequence of bang–bang contracts approximates the first-best solution arbitrarily well (see Mirrlees, 1999). However, we follow Holmstrom and Milgrom (1987) in considering our model a simplified representation of the continuous choice of effort. Under this assumption, Sung (1995) demonstrates that the optimal second-best solution can be implemented using linear contract when the manager controls the variance of the performance measure. As alternative rationales for restricting attention to linear contracts, Diamond (1998) shows asymptotic optimality, while Palomino and Prat (2002) solve a binomial risk management problem under risk neutrality and limited liability, so that payoff is convex. Finally one could argue that linear contracts are closer approximations of observed compensation contracts. To maintain tractability we abstract from limited liability issues (see e.g., Palomino and Prat, 2002).

2.2. Supervision

Our main interest is in understanding the impact that regulatory supervision has on internal risk modelling within a financial institution. Therefore one would ideally model regulatory preferences in addition to the principal's and the agent's preferences discussed above. Unfortunately, regulatory preferences are not well understood, with the most cited rational for regulation being "lowering systemic risk".

That leaves one with the question of how to define systemic risk, but no single definition of systemic risk is available. Moreover, since the regulators systemic risk tolerance is not available, it is not possible extrapolate from it the actual risk constraints imposed on individual banks. Therefore, we take a positive approach and simply investigate different risk levels permitted by the regulator and its consequences for the bank, without entering into the objectives of the regulators and the efficiency of the current Basel-II proposals.

The board of directors contracts the risk manager to control overall risk taking at a given level of expected return. The manager will have to be compensated for this, and in general needs more compensation for a higher activity level. The regulator desires to contain overall risk taking in the financial sector, and therefore imposes risk constraints on the bank. We treat these regulatory risk constraints as exogenous to the decision-making process. These risk constraints are costly to the bank, e.g., the bank might be at a competitive disadvantage under regulation, or the bank might have to be at a lower risk–return profile than desired.

3. Risk management

We consider two alternative risk management systems, one with a high degree of delegation of responsibilities to the risk manager, and the other with a low degree of delegation. We label the first system *finer risk monitoring* and the second system *coarser risk monitoring*. When risk monitoring is finer, the board observes all decisions made by risk manager, while coarser monitoring implies that the board only observes outcomes, i.e., earnings. The finer system implies first-best outcomes while the coarser regime results in second-best outcomes.

Currently, financial intermediaries can choose between calculating their market risk in one of two ways. Either they adopt the Basel standardized approach, or they rely on an internal model subject to supervisory approval. Furthermore, the Basel Committee is proposing that credit, and operational risk also be regulated by either of the two methods. Typically, the resulting regulatory capital requirements implied by the two methods of calculation do differ and hence the institution may act strategically in choosing its risk management system. This is the central issue of this paper.

There are two possible interpretations of the above scenarios. First, the coarser risk monitoring system represents the standardized approach, while the finer risk monitoring system represents the IRB system. Alternatively, the two systems imply different levels of sophistication under the IRB approach. At the end of the paper we will relax the stark contrast between the two systems and allow for a sliding scale of sophistication to justify the observed heterogeneity of banks' risk management systems.

The regulator can either choose not to regulate, or to regulate within the context of each risk management system. In particular, the regulator has the same information as the board, and can influence the risk management system. This results in four different cases:

Coarser risk monitoring: The risk manager's decision is unobservable to the board of directors and is non-contractible, but the earnings are observable and contractible.

Case A (Second best): There is no external risk supervision.
Case B (Indirect supervision): The regulator monitors risk taking indirectly through earnings announcements, and possibly influences the risk management process.

Finer risk monitoring: The board of directors implements a costly risk system that reports on a continuous basis.

Case C (Costly first best): There is no external risk supervision.
Case D (Direct regulation): The regulator directly monitors the risk management process, and possibly influences it.

These four different cases are discussed in turn.

3.1. Coarser risk monitoring without regulation

The most common form of risk management within a financial institution is where the management of the bank, usually the risk committee, specifies allowable risk and dedicates the task of actually measuring and managing risk to a risk manager. The dilemma facing the board is its inability to observe how well the risk manager does his job except in extreme circumstances. As a result, the board only indirectly observes the risk managers decisions. Even if the risk manager reports VaR numbers to the board, these VaR numbers are determined by a model created by the risk manager, and as a result do not represent the actual riskiness of the financial institution but instead a subjective risk forecast from the risk manager.

We capture this in a stylized way by assuming that the manager's risk management decision is unobservable to the board and hence is non-contractible. This gives rise to a second-best solution. As discussed above, the risk manager solves the following problem:

$$\max_a \mathrm{CEU_m} = s_0 + s_1\mu - ka - \frac{\alpha}{2}s_1^2\Sigma a^{-1}.$$

From the first order conditions, we get $a = s_1(\alpha\Sigma/2k)^{1/2}$, and after substitution into $\mathrm{CEU_m}$:

$$\mathrm{CEU_m} = s_0 + s_1\mu - s_1\sqrt{2k\alpha\Sigma}. \tag{2}$$

The volatility level chosen by the manager is

$$\sigma^2(a) = \frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}}\frac{1}{s_1}. \tag{3}$$

The board chooses the contract parameters. Note that although the reward is based on the random return Z, control is on the variance of Z which is hidden from the board, who then chooses the contract parameters s_0 and s_1 such that the manager has a weak incentive to participate, i.e., $\mathrm{EU_m} = -1$ or $\mathrm{CEU_m} = 0$. From (2) this gives

$$-s_0 = s_1\mu - s_1\sqrt{2k\alpha\Sigma}. \tag{4}$$

Substituting the $\mathrm{CEU_b}$ from the previous section, we obtain

$$\mathrm{CEU_b} = \mu - s_1\sqrt{2k\alpha\Sigma} - \frac{\beta}{2}(1-s_1)^2\frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}}\frac{1}{s_1}.$$

Maximize $\mathrm{CEU_b}$ with respect to s_1 to get:

$$s_1^{\text{second best}} = \sqrt{\frac{\beta}{2\alpha+\beta}}$$

and

$$a^{\text{second best}} = \sqrt{\frac{\Sigma}{2k}}\sqrt{\frac{\alpha\beta}{2\alpha+\beta}}.$$

The sensitivity of pay to performance, s_1, is higher in the second-best case than the first-best case, while the effort is lower. The intuition is that in the second-best case, to implement the same effort level one has to impose more risk on the manager which is costly due to inefficient risk sharing. This leads the board to induce less effort and hence increased risk. Indeed, the volatility implied by the second-best solution,

$$\sigma^2(a^{\text{second best}}) = \sqrt{2k\Sigma}\sqrt{\frac{2\alpha+\beta}{\alpha\beta}},$$

is higher than the first-best volatility as a consequence of imperfect monitoring.

From (4) it follows that

$$s_0^{\text{second best}} = \sqrt{\frac{\beta}{2\alpha+\beta}}\left(\sqrt{2k\alpha} - \mu\right).$$

Therefore the board's certainty equivalent is

$$\mathrm{CEU_b^{second\ best}} = \mu - \left(\sqrt{(2\alpha+\beta)} - \sqrt{\beta}\right)\sqrt{2k\beta\Sigma/\alpha}.$$

Remark 1. We assume that the parameters α, Σ, β, k, μ are such that $\mathrm{CEU_b^{second\ best}} > 0$. Note that the board is always interested in hiring a risk manager.

Remark 2. While not incorporated in this paper, it is easy to make explicit the trade-off faced by the board between risk and return in selecting investment opportunities (the analysis in the paper is carried out under the presumption that the projects have already been selected). In the current setup we assume that the board is faced with running projects with a given level of expected return. A simple way to capture the trade-off is to make μ a sufficiently concave function of Σ, and to let the board optimize with respect to Σ as well. One easily verifies that this leaves the above derivations essentially unaffected, except for the fact that μ is now endogenously determined.

3.2. Indirect risk monitoring with regulation

The risk manager estimates the riskiness of the financial institution, and reports the risk forecasts to the board regulators. While the regulators do audit the internal risk models, for most parts these models represent the subjective decisions made by the risk manager. The regulators supposedly note that the bank's activities create negative externalities that must be corrected by means of risk regulation. An example of this arises when excessive risk taking, while individually optimal, destabilizes the economy. While supervision can be costly for several reasons, e.g., due to lack of competitiveness, foregone earnings, or audit costs as in Merton (1978), supervision may also increase the rents from monopoly power due to increased barriers to entry. We capture the effect of supervision by means of a tax on bank profits. Specifically, we consider a proportional tax on the abnormal bank profits (unexpected), t, related to the unexpected part of the variable compensation paid to the risk manager, $s_1(Z-\mu)$, that is, the total tax is $ts_1(Z-\mu)$. When $t>0$, this captures a fundamental aspect of the risk regulation, i.e., their procyclicality. Under such regulation, the bank records higher profits in upswings and more losses in downturns than it would if left unregulated.

The regulatory cost, $ts_1(Z-\mu)$, is transferred between the profit and an accounting reserve. [3] If the regulatory tax is placed in an accounting reserve where the supervisors neither retain part of the accounting reserve nor top it up, the reserve is self-financing. The account will have a zero balance on average since $E[ts_1(Z-\mu)]=0$. If, however, the government serves as the *lender of last resort* then it effectively contributes a call option to the accounting reserve.

When the bank earns profit Z, it receives $ts_1(Z-\mu)$ from the accounting reserve such that the net return to the board becomes

$$-s_0+(1-s_1)Z+ts_1(Z-\mu). \tag{5}$$

The utility of the board becomes

$$\mathrm{CEU_b}=-s_0+(1-s_1)\mu-\frac{\beta}{2}(1-s_1+ts_1)^2\sigma^2(a).$$

From the solution of the manager's problem (4) we can substitute out s_0, and use (3) to rewrite this as

[3] This accounting reserve is considered to be part of the capital base, the level of which is directly related to the risk of other balance sheet items. In The Netherlands for example, banks are required to administer such an accounting reserve. This requirement works effectively like a tax on capital since it changes the effective amount of profits distributed to the owners. To the regulators such an account is an instrument for inducing better risk management, as we show below.

$$\text{CEU}_\text{b} = \mu - \sqrt{2k\alpha\Sigma}s_1 - \frac{\beta}{2}(1-(1-t)s_1)^2\frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}}\frac{1}{s_1}.$$

The board maximizes CEU_b with respect to s_1. From the first order condition, the solution for s_1 follows:

$$s_1^{\text{indirect supervision}} = \sqrt{\frac{\beta}{2\alpha+(1-t)^2\beta}}.$$

By insertion, we get the certainty equivalent utility, $\text{CEU}_\text{b}(t)$. Moreover, volatility becomes

$$\sigma^2 = \frac{\sqrt{2k\Sigma}}{\sqrt{\beta\alpha}}\sqrt{2\alpha+(1-t)^2\beta}.$$

It is easily seen from this latter expression or from (3) that the regulatory provision which minimizes risk taking entails maximizing s_1, i.e., setting $t = 1$. The regulatory effect of $t = 1$ undoes the risk sharing between the board and the manager. From the manager's point of view, the project risk combined with higher variable reward parameter s_1 increases the incentives for risk reduction.

The risk minimizing solution $t = 1$ is independent of both the effort aversion and risk reduction capabilities of the manager, as well as the risk aversion of the board of directors or the manager. This system exposes the board to more volatility in order to induce the appropriate risk reduction on the manager. The increase of the board of directors' exposure to compensation risk is optimal for mean–variance preferences. [4] Note, moreover that with $t = 1$ the regulatory measure is procyclical. It has been argued that Basel-II proposals, would have this effect (see e.g., European Central Bank, 2001, pp. 64–68).

Remark 3. In the previous subsection we discussed a simple way to capture the board's trade-off between risk and return in selecting investment projects by letting the mean return μ depend on Σ. Suppose $\mu = \Sigma^\phi$, where $0 < \phi < 1/2$. Let the board optimize with respect to Σ as well as over s_1. It then follows that $\Sigma(t=0) < \Sigma(t=1)$, but $\sigma^2(t=0) > \sigma^2(t=1)$. Thus as a result of the regulatory capital requirements the board selects higher risk projects but the implied extra effort in containing the risk more than offsets this effect.

3.3. Finer risk monitoring: No regulation

Suppose that the bank is discontent with only monitoring the final output of the risk management process and therefore installs a finer risk management system that reports continuously to the board the level of risk taking. Finer risk reporting implies

[4] We considered more general regimes. Since, in principle, s_0, s_1, and Z are all observable to the supervisor a proportional provision could be imposed on each item (denoted by t_0, t_1, and t_2). The results of these different schemes are all qualitatively similar.

that the board controls the manager completely, leaving no room for hidden action. This risk reporting system comes at a fixed cost, F, and measures the variance, which is a sufficient statistic for VaR given the distributional assumptions. The VaR system thus reveals the volatility to both parties.

The board chooses the contract parameters (s_0, s_1) to obtain a *costly first-best* solution where the reward is based directly on the observed volatility. As before, the board pays the manager such that he is indifferent between working or not working, so that the board's utility function yields the certainty equivalent of

$$\mathrm{CEU_b} = \mu - ka - \frac{\alpha}{2}s_1^2\Sigma a^{-1} - F - \frac{\beta}{2}(1 - s_1)^2\Sigma a^{-1}.$$

The board maximizes $\mathrm{EU_b}$ with respect to s_1 and a resulting in the same solutions as in the case of first best. Thus the board's utility can be represented as

$$\mathrm{CEU_b^{costly\ first\ best}} = \mu - F - \sqrt{2k\Sigma}\sqrt{\frac{\alpha\beta}{\alpha + \beta}}.$$

3.4. Direct risk monitoring with regulation

Since $\sigma^2(a)$ is a sufficient statistic for VaR, exogenous regulation needs only stipulate an upper bound Ω on the admissible variance:

$$\sigma^2 \leqslant \Omega. \tag{6}$$

Note that the choice of the level of Ω by the supervisor is comparable to the choice of the tax rate t for the case of indirect regulation. In the case of contractible risk management, the regulators as well as the board of directors observe the VaR. This enables the regulator to directly supervise risk taking by enforcing the restriction (6). If the constraint (6) is set such that it is binding, i.e., $\Sigma a^{-1} = \Omega$ it implies that effort necessarily equals

$$a^{\mathrm{directly\ regulated}} = \Sigma\Omega^{-1}.$$

The certainty equivalent of the expected utility of the manager becomes

$$\mathrm{CEU_m} = s_0 + s_1\mu - k\Sigma\Omega^{-1} - \frac{\alpha}{2}s_1^2\Omega.$$

From the manager's participation constraint we get

$$s_0 = k\Sigma\Omega^{-1} - s_1\mu + \frac{\alpha}{2}s_1^2\Omega.$$

The board's certainty equivalent then reads

$$\mathrm{CEU_b} = \mu - k\Sigma\Omega^{-1} - \frac{\alpha}{2}s_1^2\Omega - \frac{\beta}{2}(1 - s_1)^2\Omega - F.$$

Maximizing $\mathrm{CEU_b}$ yields the optimal slope of the manager's compensation:

$$s_1^{\text{directly regulated}} = \frac{\beta}{\alpha+\beta},$$

just as in the case of first-best contractible risk management. Hence, the optimal fixed part of the salary is

$$s_0^{\text{directly regulated}} = k\Sigma\Omega^{-1} - \frac{\beta}{\alpha+\beta}\mu + \frac{\alpha}{2}\Omega\left(\frac{\beta}{\alpha+\beta}\right)^2$$

and the board's certainty equivalent is

$$\text{CEU}_{\text{b}}^{\text{directly regulated}} = \mu - k\Sigma\Omega^{-1} - \frac{\alpha\beta\Omega}{2(\alpha+\beta)} - F.$$

Under direct regulation, the finer VaR reporting system also reports risk to the supervisors, who in effect free ride on the internal VaR measures. This might, however, not be in the interest of the bank if the resulting restriction on risk taking constitutes a competitive disadvantage. The case is different from indirect regulation through the tax t, since in that case there is a limit to the amount of risk reduction, i.e., when $t = 1$. Here, since the supervisor free rides on the information system once in place, they can impose more risk reduction. The question that remains is which system will be implemented by the board.

3.5. Evaluation

In order to compare the four cases, consider the outcomes where the risk aversion is equal, i.e., $\alpha = \beta$, and the capital adequacy tax minimizes risk taking, i.e., $t = 1$ and Ω in (6) is set binding:

Case A $\text{CEU}_{\text{b}}^{\text{second best}} = \mu - (2k\alpha\Sigma)^{1/2}[\sqrt{3} - 1]$,
Case B $\text{CEU}_{\text{b}}^{\text{indirect supervision}} = \mu - (2k\alpha\Sigma)^{1/2}\sqrt{2}$,
Case C $\text{CEU}_{\text{b}}^{\text{costly first best}} = \mu - (k\alpha\Sigma)^{1/2} - F$,
Case D $\text{CEU}_{\text{b}}^{\text{directly regulated}} = \mu - k\Sigma\Omega^{-1} - (\alpha\Omega/4) - F$.

In this situation the bank prefers no regulation: [5]

Proposition 1. *Since* $\text{CEU}_{\text{b}}^{\text{indirect supervision}} < \text{CEU}_{\text{b}}^{\text{second best}}$, *and* $\text{CEU}_{\text{b}}^{\text{directly regulated}} < \text{CEU}_{\text{b}}^{\text{costly first best}}$, *the board prefers no regulations.*

Proof. Direct since $\sqrt{3} - 1 < \sqrt{2}$, and $\sqrt{k\alpha\Sigma} < k\Sigma\Omega^{-1} + (\alpha\Omega/4)$, if the constraint (6) is binding. □

Consider the unregulated industry. Even in the absence of regulation, the industry might self-enforce a comprehensive VaR reporting system.

[5] Alternatively, regulation may work as an entry deterrence, and hence might actually be liked by the management.

Proposition 2. *Suppose there is no external supervision. If* $F < (2k\alpha\Sigma)^{1/2} \times [\sqrt{3} - 1 - 1/\sqrt{2}]$, *the bank will install the finer risk management system.*

Proof. From $\mathrm{CEU}_\mathrm{b}^\text{costly first best} = \mathrm{CEU}_\mathrm{b}^\text{second best}$, we obtain $F = (2k\alpha\Sigma)^{1/2}\ [\sqrt{3} - 1 - 1/\sqrt{2}]$. □

Therefore, if the cost of the VaR reporting system F is moderate, the board of directors will opt for the finer risk management system. [6]

The decision whether to install the finer risk measurement system, also depends on the regulatory environment. In the quote in the introduction, FRB Governor L.H. Meyer hinted that regulators may in the future incorporate the internal risk management process more closely into the supervisory process. However, this might not be in the interest of the board of directors if the resulting restriction on risk taking constitutes a competitive disadvantage. We compare two cases of regulation.

Proposition 3. *With regulation where the fixed cost of the finer risk management system is negligible, i.e.,* $F = 0$ *so that in the absence of regulation the VaR system is implemented, the board of directors may nevertheless choose not to install the risk management system in the presence of supervision.*

Proof. Consider the regulated case where the supervisor benefits from the presence of the finer risk management system. From the following partial derivatives,

$$\frac{\partial \mathrm{CEU}_\mathrm{b}^\text{direct regulation}}{\partial \Omega} = k\Sigma\Omega^{-2} - \alpha/4$$

and

$$\frac{\partial^2 \mathrm{CEU}_\mathrm{b}^\text{direct regulation}}{\partial \Omega^2} = -2k\Sigma\Omega^{-3} < 0,$$

we see that $\mathrm{CEU}_\mathrm{b}^\text{direct regulation}$ is concave in the imposed risk level Ω, and attains its maximum at $\Omega = \sigma^2_\text{first best} = 2(k\Sigma/\alpha)^{1/2}$. In that case

$$\mathrm{CEU}_\mathrm{b}^\text{direct regulation} = \mathrm{CEU}_\mathrm{b}^\text{first best} = \mu - \sqrt{k\alpha\Sigma} > 0.$$

Moreover

$$\lim_{\Omega\to 0} \mathrm{CEU}_\mathrm{b}^\text{direct regulation} = -\infty.$$

If the board has not installed the finer VaR system, the supervisors cannot directly observe risk taking. Hence they attempt to regulate indirectly via the capital requirements ts_1Z, and choose the optimal rate $t = 1$, therefore

$$\mathrm{CEU}_\mathrm{b}^\text{indirect supervision} = \mu - 2\sqrt{k\alpha\Sigma}.$$

[6] Note that, absent competition in the market for risk management systems, it is conceivable that the dominant risk management consultant is able to extract all the surplus until $F = (2k\alpha\Sigma)^{1/2}\left[\sqrt{3} - 1 - \frac{1}{\sqrt{2}}\right]$.

Since $\mu - 2(k\alpha\Sigma)^{1/2} < \mu - (k\alpha\Sigma)^{1/2}$, but $-2(k\alpha\Sigma)^{1/2} > -\infty$, there are cases where $\mathrm{CEU}_{\mathrm{b}}^{\text{indirect supervision}} < \mathrm{CEU}_{\mathrm{b}}^{\text{direct regulation}}$, but also values of Ω for which $\mathrm{CEU}_{\mathrm{b}}^{\text{indirect supervision}} > \mathrm{CEU}_{\mathrm{b}}^{\text{direct regulation}}$.[7] □

In other words, the last proposition means that for any $t \in [0, 1]$ there is a Ω such that the board is indifferent between the two risk management systems. But there are low values of Ω and corresponding low values of σ^2, which would not be achievable under a system of indirect regulation. As long as the management can choose between the different risk management systems, low values of Ω may nevertheless have no impact if the management decides against the finer system.

From these results we see that the bank's optimal risk monitoring intensity depends not simply on market conditions and bargaining power with the risk manager, but also on the actions of the supervisory agencies. If the bank perceives the cost of regulation to be too high, it may opt for a lower quality risk management system, since that can lower regulatory cost. As the quote by Governor Meyer indicates, regulators are aware of this. Presently, anecdotal evidence indicates that some banks employ dual risk management systems, one for external and another for internal purposes. If the supervisory authorities then demand access to the internal control system, banks might find yet another way to avoid disclosing too much information about their risk taking activities. The issue thus becomes how supervisors can precommit not to excessively tighten the restrictions on risk taking, once a finer system of risk management is installed.

We finally argue that the modelling approach taken above is quite general and does not hinge on the stark differences between the two alternative risk management systems. We chose a specific parameterization of the relation between risk management activities and the reduction in variance. We could have allowed for a distinction between actual bank profits and the observable and contractible profitability measure based on which the risk manager is compensated. The measurement error in the contracting relationship would tend to exacerbate the difference between the indirect and direct risk monitoring. Nonetheless, we can show that the qualitative results remain, but giving a continuous variation in risk management quality varying with the cost structure of a particular bank. This is shown in Appendix A.

Alternatively, we could have allowed a stochastic variance for any given level of effort. If for any given realized variance, firm profits are normally distributed, linear contracts can still be employed for the reasons outlined above (see Sung, 1995). Under indirect risk management, the main difference is that the risk manager must be compensated for the additional risk associated with uncertain variance. This is intuitive because of the induced fatter tails in the distribution. Under direct risk management, however, the observed, realized variance no longer perfectly reveals the risk manager's action and could overstate or understate the intended risk exposure of the bank.

[7] Note that if the fixed costs F are non-zero, this conclusion is only reinforced.

4. Conclusion

The dual use of risk models for both internal and regulatory purposes is poised to become a significant component of future regulatory systems, especially with Basel-II. It is therefore unfortunate that the interplay between the choice of risk management systems by financial institutions and their particular regulatory regimes has received little attention.

We consider the financial-economic implications of externally imposed risk constraints in an imperfect market setting: A principal–agent relationship between a regulator, a bank's board of directors, and a risk manager. In our setting, a bank has a choice between a coarser (cheap and low quality) and a finer (expensive and high quality) risk management system, loosely modelled on the standard and IRB approaches in the Basel-II proposals, respectively. We model explicitly the strategic choice between alternative risk management systems and the influence of regulation on this choice. An important aspect of the present regulatory structure is that the bank chooses itself whether to adopt the standard or IRB approach.

Our results indicate that an unregulated financial institution chooses the finer system if the costs of installing such a system are sufficiently low. However, when faced with having to share the output of the model with the supervisors, the financial institution may opt for the lower quality coarser risk management system. In other words, inappropriately chosen regulation may, perversely, induce banks to put less effort into risk management. This is the key result of our paper. Furthermore, we demonstrate that the presence of external regulation can have real effects such as being procyclical.

Since a financial institution makes the ultimate choice of the quality of its risk management system, it may have to be *compensated* by the regulator in the form of a slightly lax risk constraint. Too tight a risk constraint may render the finer risk management system less attractive to the institution compared to the coarser system. We are not aware that the Basel Committee has considered the impact the Basel-II regulations may have on banks incentives, except in the most general terms. In particular, the possibility that a financial institution may be willing to go to some lengths to avoid sharing its system with the supervisors seems to have escaped the committee. The regulator is prone to moral hazard once the banking industry has installed the finer system. An interesting question for future research is to study regulatory institutional environments in which the regulator is able to precommit not to abuse its powers. This appears highly relevant given the opposition voiced to the current Basel-II proposals.

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Appendix A

Suppose the risk manager can only measure the banks positions with error. This reflects the real world where the bank can only approximate its holdings in real time due to administrative hurdles. As before let Z represent the real return, and let r be a noisy signal with precision γ. The measured return is then $\widehat{Z}$ where

$$\widehat{Z} = Z + r.$$

The distribution of the signal is

$$r \sim N\left(0, \frac{1}{\gamma}\right).$$

As a result, the perceived production function for volatility is therefore

$$\hat{\sigma}^2(a) = \Sigma a^{-1} + \frac{1}{\gamma} = \sigma^2 + \frac{1}{\gamma}, \quad \gamma \geqslant 0,$$

where σ is the *real* volatility while $\hat{\sigma}$ is the *perceived* volatility, with $\hat{\sigma} \geqslant \sigma$, where γ is known to the agent, and is determined by the principal. The cost of the risk model for the principal is assumed to be proportional to the signal precision, i.e., γF. In this case it is prohibitively expensive for the principal to exactly measure risk, and infeasible not to allocate any resources to risk management.

The board of directors pay the manager just enough to be willing to work, that is, $\mathrm{CEU_m} = 0$:

$$-s_0 = s_1 \mu - ka - \frac{\alpha}{2} s_1^2 \left(\Sigma a^{-1} + \frac{1}{\gamma} \right).$$

Since both the principle and agent perceive volatility and hence risk as the same, as before from the manager's problem

$$\hat{\sigma}^2(a) = \frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}} \frac{1}{s_1}.$$

Use this to obtain the board of directors' objective:

$$\mathrm{CEU_b} = \mu - s_1\sqrt{2k\alpha\Sigma} - \gamma F - \frac{\beta}{2}(1 - s_1)^2 \frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}} \frac{1}{s_1} - \frac{\beta}{2} \frac{1}{\gamma} s_1^2 - \frac{\alpha}{2} \frac{1}{\gamma} s_1^2.$$

Maximize $\mathrm{CEU_b}$ with respect (s_1, γ). The solution from the first order necessary conditions is

$$s_1 = \sqrt{\frac{\beta}{\beta + 2\alpha[1 + \sqrt{(\alpha + \beta)F/k\alpha\Sigma}]}}$$

and

$$\gamma = \sqrt{\frac{\beta(\alpha + \beta)/2}{\beta F + 2\alpha[1 + \sqrt{(\alpha + \beta)/k\alpha\Sigma}]F^{3/2}}}.$$

It follows that $\mathrm{d}(1/\gamma)/\mathrm{d}F > 0$.

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