Regulation Incentives for Risk Management in Incomplete Markets

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Abstract

Implicit government guarantees induce moral hazard. The potential for moral hazard under the new Basel Capital Accord is explored with three different incomplete markets models. First, where investment decisions are affected by direct risk regulation causing more risky investments to be selected. Second, how risk regulation restricts banks' alternative (off–equilibrium) project selection. Third, principal–agent relationships between a bank's board and its risk manager. In all three cases the government intervention has the potential to increase unintended risk levels due to market incompleteness.

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1 Introduction

Financial institutions prefer, even in the absence of supervisory prompting, to employ management and monitoring of risks. Recently, financial supervisors have codified this practice, and generally require financial institutions to measure their exposure to market risks with statistical models, specifically Value–at–Risk (VaR) (see the Basel Committee, 1996). Under the latest Basel–II proposals, the same general methodology will be applied to measuring credit, operational, and eventually liquidity risk. In other words, statistical risk modelling (termed *Internal Rating Based*) will become the linchpin upon which the stability of the financial system rests.[1] While the Internal Rating Based approach has been actively studied, one aspect has received little attention: Introducing regulation can augment the incentives for moral hazard when markets are incomplete, where such regulation could not have such effects when markets are complete. In this chapter we study the potential for moral hazard in the management and regulation of financial institutions' risk.

We approach the topic from various directions. First, we analyze a bank's choice of projects, followed by a bank's choice of risk monitoring systems. Our objective is to document unintended consequences that may arise when a financial institution is subjected to external risk constraints, in particular the extent to which risk regulation helps in mitigating risk and the possibility that risk regulation may actually increase risk. This increase in risk, we argue, results from a combination of incomplete markets and moral hazard. It is well known that banks are subject to moral hazard whilst allocating funds due to implicit government guarantees which act as put options. Thus lending of last resort, deposit insurance, and capital adequacy regulations, among others all have been demonstrated to increase risk taking by banks. We augment this research area by studying the incentives for and effects of moral hazard when risk regulation is introduced in incomplete markets. We reach two main results regarding the effect of risk regulation on banks' risk management through choice of projects.

First, we consider risk direct regulation where a risk-averse bank purchases insurance for a fair premium from a risk-neutral supervisor. We establish that the introduction of this insurance, even though fairly priced, induces moral hazard in the bank's selection of projects, leading to excessive risk

[1] The IRB methodology has received widespread criticism, witness the comments currently at `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.

taking.

Second, we consider a setting where the introduction of regulation restricts the set of strategic decisions available to a bank. We establish that introducing such regulation that prohibits decisions that would not have been taken in the absence of regulation may, nonetheless, affect actual decision. Hence, even *non–binding* regulation can have real effects due to market incompleteness.

Third, we analyze the effect of regulation on banks' choice of risk monitoring systems. In particular, we investigate the incentives that key parties have for accurately measuring risk, and the contractual relationship that binds the risk manager, the bank owner, and the regulatory supervisor. Our objective is to explicitly model how the imposition of financial risk regulation affects financial institutions preferences for different risk monitoring 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. Each bank can chose the quality of its risk monitoring system. We reach three conclusions regarding banks' choice of risk monitoring system. First, we demonstrate in Proposition 3, 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 4, we demonstrate that the addition of supervision 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 monitoring 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.[2]

1.1 Complete and Incomplete Markets

Consider initially a regulatory system which has no real effects when markets are *complete*. We argue that if the markets are incomplete, the same regulatory system may induce moral hazard. The result can be understood from an analogy with elementary trade theory. Imposing a tariff in a complete market setting to favor domestic production, for example, can have a negative side effect on consumers and lead to additional welfare losses. These results

[2]Section 2.2 is based on Cumperayot et al. (2000) and Section 3 represents work originally published in Daníelsson et al. (2002).

have an analog in the literature that studies the effects of capital requirements. Since capital requirements are an instrument that does not directly regulate risk taking it, too, can have negative side effects (see e.g. Kim and Santomero, 1988; Rochet, 1992). In contrast, if a production tax or direct risk regulation (e.g. VaR) is imposed in a complete market setting, no such negative side effects ensues and, hence, no moral hazard.

In trade theory, second best results emerge when the same optimal instrument (e.g. a production tax) is applied in an incomplete markets' setting. In our first setting, direct risk regulation while having no negative side effects in complete markets leaves room for moral hazard in banks' choice of risky projects when markets are complete. The above observations also apply to our second setting, which focusses on the choice of risk monitoring systems. While most studies take banks' risk monitoring systems as given, we endogenize the type of risk monitoring system selected by the banks, taking as given a set of regulatory side constraints similar to the Basel–II proposals. Again, moral hazard appears.

Two caveats are in place. First, we do not to model the supervisors' preferences. Our objective in this chapter is to consider the impact of proposed risk–based regulation on the decisions of individual financial institutions. Indeed, since scant information is publicly available about the preferences of the Basel Committee, beyond the most general, modelling the preferences of government supervisors would be challenging. We therefore take the decisions of the supervisors as given. The supervisors are unable to directly influence what risk monitoring system the bank chooses to implement, but may pre-announce 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 supervisors are able to influence the specification of a bank's Internal Rating Based model.

As a second caveat, our analyses of moral hazard in two different settings share the assumption that economic agents' preferences can be separated into two components: a preference for higher expected payoff and a preference for lower variance. We make this simplifying assumption for expositional purposes, noting that it may not be descriptively valid. Supervisors have in the past revealed asymmetric preferences: they have been more concerned about downside risks that are viewed as more likely to be systemic in nature. Consider, as an example, the German Accounting Standard 5 (GAS 5) concerning risk disclosures in annual reports. In GAS 5 a *risk* is the possibility of a future *negative* impact, while an *opportunity* is defined as the possibility of a future *positive* impact on the economic position. This asymmetric language regarding uncertainty that results in gains or losses is consistent with conservatism of some accountants. Further, the recommended use of one-sided quantitative measures of market risk, such as, Value-at-Risk or Capital-at-Risk, may also reflect the asymmetric preferences of supervisors. While we do not deny the existence of such asymmetries, we view our settings as stylized representations of what might happen that are robust to the introduction of asymmetric perception of risk.

2 Moral Hazard Regarding Project Choice

Subjecting economic agents to external constraints in general alters their behavior and decision–making. Below we reconsider how financial institutions' choice of risky projects can be adversely affected by externally imposed risk regulations.

Our analysis is motivated by fundamental results from basic trade theory where a government supervisor, that wishes to promote domestic production, faces a choice among several policy instruments, each with their own pros and cons. For example, by imposing a tariff consumers are negatively affected leading to welfare loss, that may be avoided by production tax. In general, by employing an optimal policy instrument in complete market settings, i.e. an instrument which directly and only affects the intended goal variable has no side effects. Similarly, risk regulation which directly affects risk-taking behavior, cannot have unintended side effects. Thus, the analysis of Kim and Santomero (1988); Rochet (1992) can be understood to have negative side effects, since the regulatory instruments proposed do not only affect risk taking. In incomplete markets, though even direct instruments can have unintended consequences. This is the focus of this section.

Below we consider the related problem of a government supervisor wishing to control risk-taking by individual financial institutions. The government supervisors have a range of policy instruments at their disposal, each of which has the potential of adverse outcomes. Risk regulations have no impact in complete markets, which is not the case when markets are incomplete. Our main result can be summarized by the following Proposition:

Proposition 1 *Direct risk regulation aimed that reducing risk taking has the potential to increase risk when markets are incomplete.*

We prove this proposition by means of two models, the first considers the relationship between a bank's project choice and bank supervisors, while the second model employs a game theoretic framework of sequential decision-making by two banks where some outcomes may be ruled out by regulation.

2.1 Deposit Insurance and Moral Hazard

Consider an economy where banks must choose between three mutually exclusive projects with low, medium, or high risk. Further suppose that each bank chooses the lowest risk project in the absence of regulation. The government supervisors indirectly influence the banks' choice of projects by possibly regulating project choice and providing deposit insurance. Prior research finds that risk regulation through capital requirements can have adverse effects, since capital requirements are only an indirect instrument for controlling risk.[3]

Our specific setting is that of a recently deregulated banking sector. The supervisory authorities have the power to restrict banks' choice among projects and provide deposit insurance. The government supervisors provide deposit insurance for a flat fee without much monitoring of lending policies. The supervisor is unable to charge risk-adjusted insurance premiums, and cannot at the same time directly monitor lending. Such situations arose e.g., the Savings and Loan (S&L) crisis in the U.S. of the 1980s or the Scandinavian banking crisis of the early 1990s. In the US S&L crisis moral hazard played a key role.[4] The US government, represented by the Federal Savings and Loan Insurance Corporation (FSLIC), in effect underwrote risky lending by providing deposit insurance for a flat fee without much monitoring of lending policies. The inability of the FSLIC to charge risk adjusted insurance premiums prior to the crisis, and the regulator Federal Home Loan Bank Board (FHLBB) to supervise lending, was due to political factors, leading to regulatory capture which obstructed the FSLIC from either adequately supervising the industry or charging appropriately risk adjusted premiums.

2.1.1 Background

Suppose initially the banks are restricted to low risk projects (such as, mortgages). The sector is subsequently deregulated allowing banks to enter into more risky projects. However, the regulatory structure of the industry remains unaltered characterized by ineffective supervision of lending policies and no adjustments are made to deposit insurance premiums. We refer to this as *unbalanced deregulation*. It follows trivially, even in complete markets, that banks will migrate to more risky lending and investments.

[3] For analysis of indirect instruments, see, among others, Kim and Santomero (1988), Rochet (1992), Beaver et al. (1992), and Bernard et al. (1995)

[4] This has been documented by e.g. Mishkin (1995), Davis (1995), and Jackson and Lodge (2000).

If the supervisory authorities wish to retain deposit insurance after deregulation, they need to monitor banks' lending policies much more closely, and offer risk-weighted deposit insurance premiums. At the very least, insurance premiums need to increase to preserve the solvency of the insurance agency. Consider specifically the case where supervisors ban extreme risk taking by banks while at the same time moderately increase premiums. We refer to this as *balanced deregulation* and demonstrate that such a system may nevertheless trigger increased risk taking.

2.1.2 The Model

Our model is reminiscent of Merton (1977), where the supervisor is as a writer of an *unconditional* put option with strike at zero, on three risky projects available to the banks. Let B and F represent a bank and the deposit insurance agency (DIA), respectively. Both B, and F, have the following mean–variance utility functions:

$$EU_B = M - \alpha V,$$
$$EU_F = M - \beta V,$$

where M denotes the mean, V the variance, and α and β signify the attitudes towards risk. Since F is a government agency, we initially follow Arrow (1969) in assuming it is risk neutral, i.e., $\beta = 0$. Let L, M, and H refer, respectively, to low, medium and high risk projects. Any given project can result in one of two payoffs, the "up state" and "down state" that occur with an equal probability, 1/2. For ease of exposition, we present only a numerical example, which easily demonstrates that the set of possible decisions is non–empty. Suppose therefore that $\alpha = 1$ (in addition to $\beta = 0$ since the supervisors are risk neutral). The low risk project, L, results in payoffs of either $-1/30$ or $1/30$. Likewise, the high risk project, H, results in payoffs of either -1 or 1. On their own, each of these projects have expected payoff of zero, while the low risk project, L, has lower variance than the high risk project, H. This implies that any risk-averse decision maker would prefer the low risk project, L, over the high risk project, H. Finally, there is a medium risk project that pays $-1/10$ in the down state and (17/10) in the up state. Note that the medium risk project, M, has a positive expected payoff.

The DIA can write a put option with strike at 0 and earn the premium Π. The indirect utility function of B is $EU_B\,(i,j)$, where $i = L, M, H$, indicates the project selection, and $j = P, NP$, indicates whether the put option is Purchased, P, or Not Purchased, NP.

Prior to deregulation the banks are restricted to financing the low risk project. The DIA charges a fair premium for deposit insurance (put), i.e. in the long run it breaks even, and all the surplus goes to the buyer of the put option.[5] Hence, the benchmark is $EU_F(L, NP) = 0 = EU_F(i, P)$.

If the put option is purchased, then the risk neutrality of the supervisors implies that $EU_F(L, P) = -1/60$, and hence the price of the option, Π is $1/60$. For the banks the low risk project has mean 0 , and variance $1/900$, so without insurance, $EU_B(L, NP) = -1/900$ and with insurance $EU_B(L, P) = -1/3600$. Thus the banks prefer the deposit insurance system. Furthermore, straightforward computations yield the following $EU_B(M, NP) = -1/100$, $EU_B(H, NP) = -1$, and with the put option $EU_B(M, P) = 459/3600 - \Pi$, $EU_B(H, P) = 1/4 - \Pi$. These results are used the analysis below.

2.1.3 Unbalanced Deregulation

Suppose the banking industry is deregulated, while the DIA is constrained to provide deposit insurance at the pre–deregulation price, without the ability to affect project choice, due to regulatory capture. Consequently, $\Pi = 1/60$ as before. It follows that for the banks $EU_B(M, P) = 399/3600$ and $EU_B(H, P) = 840/3600$. Hence, the industry shifts into financing the high risk project H. But since the DIA only receives the pre–deregulation premia, it eventually goes bankrupt.

Suppose that the problem of underfunding is recognized, but that for political reasons the supervisor is unable to charge risk adjusted premiums or dictate project choice. In this case, the insurance premiums must be raised sufficiently so that the DIA provider remains solvent. Yet this induces moral hazard.

Result 1 (Potential for Moral Hazard) *Suppose the DIA charges a flat fee. Then the bank adopts the high risk project conditional upon buying the deposit insurance:*

$$EU_B(L, P) < EU_B(M, P) < EU_B(H, P).$$

To show this result note that $EU_B(H, P) - EU_B(M, P) = 441/3600$, and $EU_B(M, P) - EU_B(L, P) = 400/3600$, which holds regardless of the level of the put premium Π. Result 1 implies that the premium on the put option

[5] See e.g. Schweizer (1997) and Davis (1997) for other motives on this surplus sharing rule in incomplete markets.

must be conditional on the high risk project, so that $\Pi = 1/2$. Furthermore it follows that the put option is effective in reducing risk:

Result 2 (Effectiveness of Put) *The put option reduces the downside risk for the high risk project, since* $\Pi = 1/2 < 1$.

Note that the uniform premium $\Pi = 1/2$ is quite high, in particular, Π exceeds the downside risk of the medium and low risk projects. In fact, this premium is so high that the bank refuses to buy insurance or undertake the higher risk projects, i.e. $EU_B(H, P|\Pi = 1/2) = -1/4 < EU_B(L, NP) = -1/900$. In fact one can show:

Result 3 (Project Choice) *The bank's preferences are as follows:*

$$\begin{aligned} EU_B(L, NP) &> EU_B(i, j) \\ \text{where } i &= L, M, H;\ j = P, NP \text{ and } i, j \neq L, NP. \end{aligned}$$

Direct computation gives $EU_B(L, NP) = -4/3600 > EU_B(M, NP) = -36/3600 > EU_B(H, NP) = -1$. While from Result 1 we have $EU_B(H, P) = -900/3600 < EU_B(L, NP)$. Hence the bank only runs the lower risk projects without regulation, but with the possibility of deposit insurance.

2.1.4 Balanced Deregulation

The outcome in Result 3 implies the deregulated industry acts as if it were regulated. This is probably not the desired result of deregulation. Therefore we assume that only a moderate increase in the insurance premiums is politically feasible, while at the same time the supervisors are allowed to control some aspects of risk taking. Suppose premiums increase from $\Pi = 1/60$ to $\Pi = 1/20$, in conjunction with a VaR constraint stipulating that $\Pr\{\text{loss} < 1/15\} \leq 40\%$. This particular constraint appears rather innocuous, since it is above the level of risk assumed in the previously regulated market with uniform premium. Since $1/30 < 1/15$ we get:

Result 4 (Constraint 'non–binding' for l) *The low risk project satisfies the VaR constraint.*

Moreover as $1/2 > 1/15$:

Result 5 (VaR precludes the high risk projects) *The high risk project with the put option violates the VaR constraint set by the supervisory authorities due to the high risk premium* $\Pi = 1/2$.

Thus with risk regulation, the high risk project, H, is ruled out and, hence, the insurance agency can condition the pricing of the insurance on this fact. Thus the DIA is still allowed to charge risk adjusted insurance premia. However, the regulatory constraint does affect the the medium risk project. Note that without insurance the M project does not meet the VaR constraint as $1/10 < 1/15$. But with the premium on the put option conditional on running M, $\Pi = 1/20$, it follows that:

Result 6 (Impact of Conditional Put) *The medium risk project* only *violates the VaR constraint without the insurance and is effective in reducing risk.*

The project choice is also affected.

Result 7 (Potential for Conditional Moral Hazard) *With the put premium conditional on not executing the H project, the M project is preferred over the L project:*

$$-4/3600 = EU_B\left(L, NP\right) < EU_B\left(M, P|\Pi = 1/20\right) = 279/3600.$$

Moreover, with the put premium conditioned in this way,

$$-121/3600 = EU_B\left(L, P|\Pi = 1/20\right) < EU_B\left(M, P|\Pi = 1/20\right) = 279/3600.$$

Finally, overall risk for the banks increases because $1/20 > 1/30$:

Result 8 (Adverse Outcome) *The downside risk of the M project with the put option conditioned on the bank selecting the medium risk project, M, exceeds the downside risk of the low risk project L without a put option.*

These numerical results demonstrate the conclusion of Proposition 1. A more general and explicit set of conditions under which Results (1)-(8) and Proposition 1 hold, can easily be demonstrated. But the main point is that the moral hazard in this example is not triggered by the usage of an indirect instrument which has negative side effects, since the VaR constraint directly impinges on the risk taking by banks. Rather, market incompleteness prevents fine-tuning and thereby leaves the scope for moral hazard.

2.2 Threat of an Alternative Project Choice

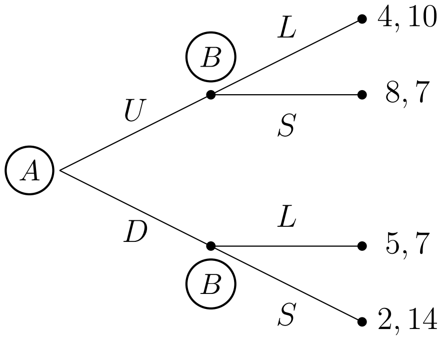
We now turn to an incomplete market case in which the VaR constraint effectively works as a collusion device which reduces the risk disciplining by competitors. As a result, systemic risk can increase even though individual banks are constrained in their risk taking by the regulatory VaR. We follow the case as presented by Cumperayot et al. (2000) who demonstrate that even in the case when the VaR constraint is not binding in the unregulated case, it may have adverse effects. The example is motivated by Baye (1992) analysis of Stackelberg leadership and trade quota.

Example 1 *Suppose A and B are banks who have to decide whether to invest abroad. Bank A is the lead bank and B follows. The project choices decisions are interdependent. The decision trees in payoff space and utility space are given in Figures 1 and 2. Bank A has to decide between strategy U and D respectively. After observing this action chosen by bank A, bank B decides on its investment strategy through choosing L or S. Nature plays a role in determining the chances and the outcomes in two states of the world, labelled G and J; positive returns occur with probability* 0.8, *and negative returns have probability of* 0.2.

Assume further that the binomial distributions of returns and the risk aversion parameters are known among the banks, but not by the supervisors. In this example we maintain that banks possess a mean–variance utility function that is separable in the preference for more mean and less standard deviation. Recall that one moves from variances to standard deviations by replacing V by $\sqrt{V}$. The risk aversion parameters are respectively $\alpha = 0.5$ and $\beta = 1.0$ pertaining to bank A and B respectively. Expected utilities corresponding to each strategy profile are represented in Figure 1. By backward induction, the strategy combination (U, L) is the only subgame perfect Nash equilibrium in the unregulated case. Suppose, however, that risk regulation bars banks from losing more than 35. *Note such a loss may only occur if the banks would select (D, S), which however is not selected. Nevertheless, such a seemingly innocuous VaR restriction has the effect of changing the equilibrium to (D, L). Since, if bank A selects D, bank B can no longer respond by choosing S. It is then optimal for the lead bank A to switch to D.*

Although it is not an intention of the supervisors to influence the unregulated Nash equilibrium, since the restriction is non–binding in that particular equilibrium, it can nevertheless alter the equilibrium. In the example, regulation obviously induces moral hazard: It provides bank A a chance to achieve higher expected utility by bearing the higher risk and meanwhile forcing bank

Figure 1: Project Choices with Expected Utilities



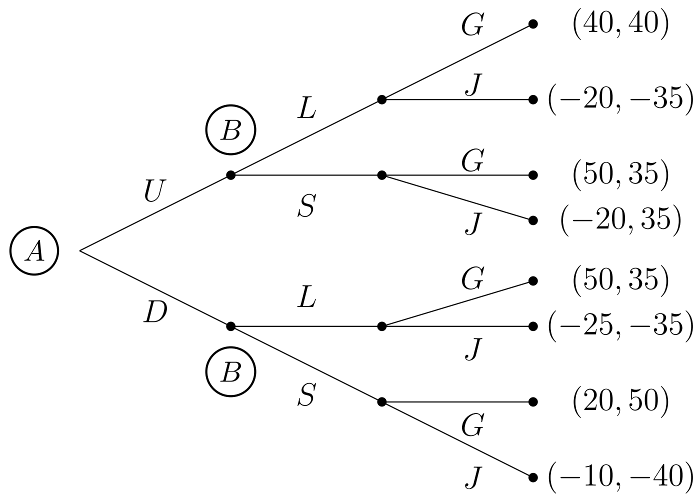
B to end up at lower utility. While the VaR of bank B is fixed in both equilibria, an increase in the VaR of bank A raises risk and deteriorates social welfare. In fact, the total sum of the maximal possible loss of the two banks is minimized if (D, S) and maximized if (D, L). The new equilibrium maximizes systemic risk. Paying too much attention to individual parties' risk, may lead to ignoring the social aspect and consequently systemic risk. Of course we could also have the apparent non–binding VaR regulation produce a reduction in risk in the regulated equilibrium. Suppose that the payoff to bank A in the bad state of (D, L) is raised from -25 to -15, then the out off equilibrium VaR constraint barring (D, S) unambiguously reduces the risk in society.

3 Moral Hazard Regarding Risk Management

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, may take unacceptable risks. 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 delegated to a separate risk management center, led by a risk manager, that measures risk and enforces the 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, more resources allocated to risk management results in higher quality measurement and management of risks.

Since our interest is in understanding the interplay between internal and

Figure 2: Project Choices with Payoffs



external risk management, we model the bank as a principal–agent relationship between its board of directors (principal) and a dedicated risk manager (agent) in a setting where the bank is subject to supervision. The board maximizes expected utility 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 subject to supervision. Current supervision allows the bank flexibility in the choice of the quality of risk monitoring system between either the standard approach or Internal Rating Based (IRB) approach. Presumably, 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 allow supervisors better insights into the internal operations of the bank. This preference is supported anecdotally by statements made by senior bank supervisors. For example, Federal Reserve Bank 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 could regulation force risks to be measured differently than in the absence of regulation, but regulation might also imply changes to bank operations that reduce expected profitability. As a result, banks have incentives to reduce the level of regulatory oversight. That is, banks correctly anticipate the regulatory process and in anticipation hereof, selectively choose its risk management and risk measurements. Consequently, banks may adversely adopt lower quality risk monitoring exactly because of supervision. Supervisors recognize that banks may be less than enthusiastic for such a regulatory environment. For example, Meyer (2000) states that "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 consider two alternative categories of risk monitoring systems, one where the risk manager is closely monitored, and another 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 exert on managing risk, conditional on the quality of the risk monitoring 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 zero expected utility from the optimal contract. Since the risk manager is compensated for reducing risk, we assume that the risk manager's effort reduces variance. Our focus is on the trade–off between the cost of risk management and the benefits from risk reduction achieved by risk monitoring, taking as given that some risks are unavoidable for a given expected return level.

We opt to not cast the relationship between the supervisors and the board in a principal-agent setting for two reasons. First, we wish to maintain tractability and obtain closed form solutions. Second, the objective function of the supervisors 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.

3.1 The Basic Principal-Agent 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 a one time employment offer to a risk manager, m. The manager by rejecting the offer earns nothing. Consequently, for the manager to accept employment, his expected utility from working, EU_m, must be non–negative. Alternatively, by accepting the employment offer, the manager chooses an effort that determines the level of the bank's risk management. 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 expected utility of zero from the optimal contract.

From the perspective of the board, the problem is that the manager is both effort averse and risk averse and needs to be motivated by imposing the optimal amount of risk. 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), or Demski and Dye (1999). We choose the latter modeling 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[6] 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 effort averse manager chooses an effort level, a, while incurring unit cost of effort, k, measured in pecuniary terms. The bank earns profits Z, with the following distribution:

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

where the risk reduction technology exhibits decreasing marginal returns to effort. In particular we assume that $\sigma^2(a) = \Sigma a^{-1}$, where $\Sigma > 0$ is an exogenously given parameter. We assume that the expected utility of the

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

manager can be expressed on mean-variance form:

$$E\left[U_m\left(s\left(Z\right),a\right)\middle|\,a\right]=E\left[s\left(Z\right)\middle|\,a\right]-ka-\frac{\alpha}{2}VAR\left[s\left(Z\right)\middle|\,a\right].$$

where $\alpha > 0$ denotes the board's risk preference and $s(Z)$ represents the manager's compensation. The first term in the manager's expected utility is the expected compensation to the manager, the second term is the manager's direct disutility of effort, and the third term is the risk premium associated with the variation in the manager's compensation. We assume that the board of directors of the bank also exhibit mean-variance preferences, that is,

$$E\left[U_b\left(s\left(Z\right),a\right)\middle|\,a\right]=E\left[\left(Z-s\left(Z\right)\right)\middle|\,a\right]-\frac{\beta}{2}VAR\left[\left(Z-s\left(Z\right)\right)\middle|\,a\right]$$

where $(Z - s(Z))$ is the bank's profits net of the manager's compensation, $\beta > 0$ denotes the board's risk preference. For reasons discussed below, we exogenously restrict the contracts that the board can offer to the manager to be linear in the total profits of the bank, that is, $s(Z) = s_0 + s_1 Z$, where s_0 is the manager's fixed component of compensation to the manager and s_1 is the variable component of the manager's compensation.[7] As is common, we refer to s_1 as the sensitivity of the manager's compensation to the bank's profitability.

3.1.1 First–Best Scenario

In the first–best scenario, the risk manager's choice of effort level, a, is observable and contractible to the board of directors. In this case, there is no moral hazard problem because the board can simply instruct the manager regarding what effort level to select. The sole reason that the bank manager's contract depends on total bank profits is to facilitate risk sharing between the board and the bank manager. In this first–best scenario, the board solves the following problem:

$$\max_{a,s(Z)} E\left[U_b\left(Z-s\left(Z\right)\right)\middle|\,a\right],$$

subject to the constraint that the manager accepts the contract:

$$E\left[U_m\left(s\left(Z\right),a\right)\middle|\,a\right]\geq 0.$$

[7] Given these assumptions, mean-variance preferences would arise as the certainty equivalent if both the manager and the board have negative exponential utility functions with constant absolute risk aversion coefficients α and β, respectively. This means that all our results arise in the absence of wealth effects. In the absence of regulation, we consider two benchmark scenarios, a first–best and second–best outcomes.

Recall that the optimal contract offered to the agent is restricted to be linear, that is, the board chooses two contract parameters, s_0 and s_1, to maximize expected utility. For any choice of these parameters, s_0 and s_1, we can analyze the behavior of the risk manger. First, the manager's expected utility is

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

for any effort level. Likewise, the expected utility of the board is

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

In the first–best scenario, where effort is costlessly observable and contractible, the board can implement the first–best outcome by basing the reward directly on observed volatility which reveals the manager's effort level. To attain the first–best outcome, the board must choose the compensation contract parameters (s_0, s_1) optimally. This implies that the board pays the manager a fixed compensation, s_0, such that he is indifferent between working or not working, i.e., $EU_m = 0$, or:

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

Substituting this lowest possible fixed compensation into the board's expected utility yields:

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

The board maximizes EU_b with respect to s_1 and a resulting in the solution to the board's first best problem being

$$\begin{aligned}
s_1^{1^{\text{st}}} &= \frac{\beta}{\alpha+\beta} = \frac{1}{\beta^{-1}\alpha+1}, \\
a^{1^{\text{st}}} &= \sqrt{\frac{\Sigma}{2k}}\sqrt{\frac{\alpha\beta}{\alpha+\beta}} = \sqrt{\frac{\Sigma}{2k}}\frac{1}{\sqrt{\beta^{-1}+\alpha^{-1}}}, \\
s_0^{1^{\text{st}}} &= -\frac{\beta}{\alpha+\beta}\mu + (\alpha+2\beta)\sqrt{\frac{(\alpha+\beta)\alpha k\beta\Sigma}{2}}.
\end{aligned}$$

The sensitivity of the manager's first–best compensation contract, $s_1^{1^{\text{st}}}$, depends on the relative risk aversion parameters, which is the optimal risk sharing in agencies in the absence of moral hazard, see Wilson (1968). The intuition is that the higher the manager's risk aversion, the less risk is imposed on him, that is, the lower the sensitivity of his compensation to total bank profits. Further, the first–best optimal effort level is decreasing in the manager's marginal cost of effort, k, and increasing in the prior variance, Σ, and increasing in the risk aversion parameters of the manager, α, and the board, β. 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

$$\sigma^2\left(a^{1^{\rm st}}\right) = \sqrt{2k\Sigma}\sqrt{\frac{(\alpha+\beta)}{\alpha\beta}},$$

and the board's first best expected utility is

$$EU_b^{1^{\rm st}} = \mu - \sqrt{2k\Sigma}\sqrt{\frac{\alpha\beta}{\alpha+\beta}},$$

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

3.1.2 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 signifying contract (market) incompleteness. In this scenario, the board's problem can be formalized as

$$\max_{a,s(Z)} \mathrm{E}\left[\left.U_b\left(Z - s\left(Z\right)\right)\right| a\right],$$

subject to

$$\begin{aligned} E\left[\left.U_m\left(s\left(Z\right),a\right)\right| a\right] &\geq 0, \\ \mathrm{E}\left[\left.U_m\left(s\left(Z\right),a\right)\right| a\right] &\geq \mathrm{E}\left[\left.U_m\left(s\left(Z\right),a^+\right)\right| a^+\right], \text{ for all } a^+. \end{aligned}$$

In a single period principal-agent model, the second best optimal contract would *not* be linear because a sequence of bang–bang contracts can approximate the first best outcome arbitrarily well, (see Mirrlees, 1999). Nonetheless, 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 (2001) 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 (2001).

3.2 Supervision

Our main interest is in understanding the impact that regulatory supervision has on internal risk modeling 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 to extract the actual risk constraints imposed on individual banks. Therefore, we take a positive approach and simply investigate different risk levels permitted by the supervisor and its consequences for the bank, without entering into the objectives of the supervisors 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 supervisor 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.

4 Risk Monitoring and Risk Management

We consider two alternative risk monitoring 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 monitoring system. This is a central issue of this chapter.

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 section, 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 monitoring systems.

The supervisor can either choose not to regulate, or to regulate within the context of each risk monitoring system. In particular, the supervisor has the same information as the board, and can influence the risk monitoring 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 supervisor 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 supervisor directly monitors the risk management process, and possibly influences it.

These four different cases are discussed in turn.

4.1 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 consequently 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:

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

From the first order conditions, we get $a = s_1\sqrt{\alpha\Sigma/2k}$, and after substitution into the manager's expected utility, EU_m:

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

The volatility level chosen by the manager is

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

Again, the board chooses the contract parameters, s_0 and s_1. 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. $EU_m = 0$. From (2) this gives

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

Substituting the EU_b from the previous section, we obtain

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

Maximizing EU_b with respect to s_1 yields the result that:

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

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 expected utility is:

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

Remark 1 *We assume that the parameters $\alpha, \Sigma, \beta, k, \mu$ are such that $EU_b^{\text{second best}} > 0$. Note that the board is always interested in hiring a risk manager.*

Remark 2 *While not incorporated here, it is easy to make explicit the trade-off faced by the board between risk and return in selecting investment opportunities (the analysis in this section 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 in 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.*

4.2 Indirect Risk Monitoring with Regulation

The risk manager estimates the riskiness of the financial institution, and reports the risk forecasts to the board supervisors. While the supervisors do audit the internal risk models, for most parts these models represent the subjective decisions made by the risk manager. The supervisors 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 of supervision, $ts_1(Z - \mu)$, is transferred between the profit and an accounting reserve.[8] 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 $\mathrm{E}[ts_1(Z - \mu)] = 0$. 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

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

[8]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.

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

$$EU_b = \mu - \sqrt{2k\alpha\Sigma}s_1 - \frac{\beta}{2}\left(1-(1-t)\,s_1\right)^2 \frac{\sqrt{2k\Sigma}}{\sqrt{\alpha}}\frac{1}{s_1}.$$

The board maximizes its expected utility, EU_b, by choosing 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 substitution, we get the expected utility, $EU_b\,(t)$. 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.[9] 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. The European Central Bank (2001, p. 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*

[9] 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.

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.

4.3 Finer Risk Monitoring: No Regulation

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

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

The board maximizes 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

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

4.4 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:

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

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 supervisors as well as the board of directors observe the VaR. This enables the supervisor 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

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

The expected utility of the manager becomes

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

From the manager participation constraint we get

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

The board's certainty utility can be expressed as

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

Maximizing EU_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 expected utility is

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

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.

4.5 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:

$$\begin{array}{lll} \text{Case A} \quad EU_b^{\text{second best}} & = & \mu - \sqrt{2k\alpha\Sigma}[\sqrt{3} - 1], \\ \text{Case B} \quad EU_b^{\text{indirect supervision}} & = & \mu - \sqrt{2k\alpha\Sigma}\sqrt{2}, \\ \text{Case C} \quad EU_b^{\text{costly first best}} & = & \mu - \sqrt{k\alpha\Sigma} - F, \\ \text{Case D} \quad EU_b^{\text{directly regulated}} & = & \mu - k\Sigma\Omega^{-1} - \frac{\alpha\Omega}{4} - F. \end{array}$$

In this situation the bank prefers no regulation:[10]

Proposition 2 *Since $EU_b^{\textit{indirect supervision}} < EU_b^{\textit{second best}}$, and $EU_b^{\textit{directly regulated}} < EU_b^{\textit{costly first best}}$, the board prefers no regulations.*

Proof. Direct since $\sqrt{3} - 1 < \sqrt{2}$, and $\sqrt{k\alpha\Sigma} < k\Sigma\Omega^{-1} + \frac{\alpha\Omega}{4}$, 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.

Proposition 3 *Suppose there is no external supervision. If $F < \sqrt{2k\alpha\Sigma}\left[\sqrt{3} - 1 - \frac{1}{\sqrt{2}}\right]$, the bank will install the finer risk monitoring system.*

Proof. From $EU_b^{\text{costly first best}} = EU_b^{\text{second best}}$, we obtain $F = \sqrt{2k\alpha\Sigma}\left[\sqrt{3} - 1 - \frac{1}{\sqrt{2}}\right]$. ■

Therefore, if the cost of the VaR reporting system F is moderate, the board of directors will opt for the finer risk monitoring system.[11]

The decision whether to install the finer risk monitoring system, also depends on the regulatory environment. As quoted above, Federal Reserve Bank Governor L. H. Meyer hinted that supervisors 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.

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

[11] 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 $F = \sqrt{2k\alpha\Sigma}\left[\sqrt{3} - 1 - \frac{1}{\sqrt{2}}\right]$.

Proposition 4 *With regulation where the fixed cost of the finer risk monitoring 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 monitoring system in the presence of supervision.*

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

$$\frac{\partial EU_b^{\text{direct regulation}}}{\partial \Omega} = k\Sigma\Omega^{-2} - \alpha/4$$

and

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

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

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

Moreover

$$\lim_{\Omega \to 0} EU_b^{\text{direct regulation}} = -\infty.$$

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

$$EU_b^{\text{indirect supervision}} = \mu - 2\sqrt{k\alpha\Sigma}.$$

Since $\mu - 2\sqrt{k\alpha\Sigma} < \mu - \sqrt{k\alpha\Sigma}$, but $-2\sqrt{k\alpha\Sigma} > -\infty$, there are cases where $EU_b^{\text{indirect supervision}} < EU_b^{\text{direct regulation}}$, but also values of Ω for which $EU_b^{\text{indirect supervision}} > EU_b^{\text{direct regulation}}$.[12] ■

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 monitoring systems. Yet 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 monitoring 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

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

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 monitoring system, since that can lower regulatory cost. As the quote by Governor Meyer indicates, supervisors are aware of this. Presently, anecdotal evidence indicates that some banks employ dual risk monitoring systems, one for external purposes 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 commit to not tighten excessively the restrictions on risk taking, once a finer system of risk management is installed.

We finally argue that the modeling approach taken above is quite general and does not hinge on the stark differences between the two alternative risk monitoring 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.

Alternatively, we could have allowed stochastic variance for any given level of effort. If for any given realized variance, bank profits are normally distributed, linear contracts can still be employed for the reasons outlined above.[13] 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.

5 Conclusion

This chapter is concerned with the effect of risk regulation, such as Basel–II, on risk management and risk monitoring in an incomplete market setting. The first part of this chapter establishes that risk regulation can adversely

[13]see Sung (1995) and the references therein

affect banks' choice among risky projects such that the net effect is an overall increase in risks. This might arise even though the regulation uses "direct" instruments or even if it appears "non–binding". The second part of this chapter shows how risk regulation can lead to a choice of a lower quality risk monitoring system. 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. Unfortunately, the interplay between the choice of risk monitoring systems by financial institutions and their particular regulatory regimes has received little attention.

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