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Risk Management and Regulation in Incomplete Markets*

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Abstract

Financial institutions operate under both internal and external risk constraints. The impact of external risk constraints is investigated, both its impact on firm value, as well as the potential for risk reduction. The results from two incomplete markets models, i.e. a principal–agent and a moral hazard model, demonstrate that current regulatory systems may actually induce risk taking, while at the same time impose significant costs on the financial industry. In general, the impact of regulatory risk constraints is unpredictable and the scope for unintended results considerable.

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1 Introduction

Most market risk regulations are based on the Basel Committee on Banking Supervision (1996) recommendations, regarding Value–at–Risk (VaR) reporting for financial institutions. Since these regulations represent a hard fought compromise reached by the supervisory authorities in the largest banking nations, they are both difficult to change and relatively simple in nature. The VaR framework appears to have been originally chosen because it was felt at the time that a more flexible regulatory regime was needed than previously was in place. No evidence exists that the choice of VaR was the result of an elaborate financial economic optimizing framework.[1] Recent literature has considered the issue of risk management systems and regulations in more detail.[2] This literature has, however, not modelled directly the interrelationship between the regulators, bank owners, and risk managers which is the main theme of this paper.

It is well known that risk management is not particularly relevant to firm value in a complete markets setting, since investors can undo the financial structuring according to their preferences.[3] However, such an environment does not capture many relevant and interesting motives for risk management due to information asymmetries and other transaction costs. In the context of bank regulations, if markets are incomplete, risk constraints can have real effects on bank value, see e.g. Froot et al. (1993). These constraints might have positive externalities for a bank, and hence be welcomed by its owners, but the constraints might just as well impose real costs on the bank. In the latter case, the negative externalities should be offset elsewhere in economy. Indeed, a crudely implemented risk constraint may fail to work as advertised or even, perversely, increase risk.[4] We

[1]The choice of the multiplication factor three is partially due to statistical arguments advanced by Stahl, ultimately published in Stahl (1997).

[2]See e.g. Basak et al. (2000) and Cumperayot et al. (2000) who address the suitability of risk measures, Matutes et al. (2000) who discuss bank regulation in the context of deposit insurance, or Daníelsson and Zigrand (2000) who discuss risk regulation in a general equilibrium model, explicitly incorporating welfare considerations. In earlier papers Rochet (1992) discusses how risk regulation through capital requirements can have adverse effects, and Diamond and Dybvig (1983) who discuss deposit insurance.

[3]See, among others, Modigliani and Miller (1958), Stiglitz (1969a,b, 1974), Merton (1977), DeMarzo (1988) , Grossman (1995), and Leland (1998).

[4]It is also conceivable that an intelligent regulator who desires to promote risk taking (perhaps more venture capitalism) would implement a risk constraint which leads to more risk taking, without informing the public that this was the intention. Given the open and lengthy consulting process prior to the VaR regulations, it is unlikely that regulators had any motive beyond the simple desire to contain risk taking in the financial industry. The stated objective by the General Manager of the Bank for International Settlements Crockett (2000) is that financial regulations are needed because financial instability results in output loss.

analyze the impact of exogenously imposed risk constraints within two different settings; credit risk due to incomplete contracting with different regulatory constraints and moral hazard with market risk regulations.

First, we consider a principal–agent relationship between a bank's board of directors (principal) and a risk manager (agent). The setting is complicated by the presence of external supervision which affects both the agent and the principal. It is costly for the principal to measure risk, and costly for the agent to reduce risk. This gives rise to an optimal intensity of risk measurement and management. By introducing supervision, and hence disclosure, into a previous unregulated setting, we find that supervision may have a real impact. In general, supervision may motivate the principal to adopt a lower quality risk model than otherwise, thus leading to an increase in overall bank risk. There is evidence that the regulators have realized this. FRB Governor Laurence H. Meyer (2000) publicly states:

> "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."

The Governor proceeded by proposing specific alterations to the present regulatory system:

> "Supervisors, of course, cannot simply take whatever banks are using in their internal risk classifications. ... I suspect that a new, and I think evolutionary, supervisory vehicle — one that supplements the evaluation of risk–management systems — will soon be a required part of supervision for all of us. ... As they [internal credit–risk–rating systems] improve, these systems can increasingly be expected to figure prominently in our supervisory process. That dual use — for both management and supervision — is a dramatic innovation, creating a link between bank management and supervisory standards that has been needed for some time."

We specifically consider a setting where the regulators directly observe and influence the internal risk management process in a bank, and find that this has the potential for an increase in risk taking. In our Proposition 2 we argue that in the absence of regulation it is the banks best interests to install a high quality internal risk management system. However, subsequent to be regulated, we find in Proposition 3 that the bank might actually prefer less internal risk control activity. In other words, regulation has the potential to decrease risk control. Since, given the current regulatory regime, banks internal models are used to calculate regulatory risk capital, regulations may increase instability. Perhaps this result explains the anecdotal evidence that some banks employ dual risk management systems, an elaborate system for internal control, and a scaled–down version for reporting purposes. This is possibly what Governor Meyer was hinting at in his speech, and indeed this is a serious flaw in the present regulatory structure. Furthermore, this implies it may be impossible to regulate risk taking because banks have incentives to misreport risk to the authorities since disclosure is costly.

In the second part of the paper we consider a credit risk model where the implicit underwriting of a bank's obligations through deposit insurance affects the choice of lending projects. A bank has the choice between financing several different risky projects while a government agency offers deposit insurance. This gives rise to a classic moral hazard outcome where a more risky project may be chosen once insurance is acquired. In the extant literature it is known that in complete markets indirect measures such as capital requirements can increase risk taking. We show that this can also occur when direct risk regulation is used in incomplete markets. In the specific case considered, deregulation of a banking sector in the absence of proper adjustment in regulatory policy, can lead to unintended consequences such as increased risk taking and a drop in bank value. In Proposition 4 we find that direct risk regulation conceivably increases risk taking in the presence of incomplete markets. In other words, a well intentioned policy aiming at containing risky activities by banks has the potential to have exactly the opposite effect.

Our results indicate the potential for unintended consequences when financial institutions are subjected to risk regulations. Even if it is possible that regulations may have the intended effect of reducing risk, in general, the complex interrelations between the various agents in the banking sector, implies the scope for perverse outcomes is substantial. As a result, we feel that regulatory policy should take into account secondary effects, i.e., how bank behavior changes subsequent to regulations, and not simply be based on the motivation that too much risk is costly and must be contained. By simply applying blunt regulatory instruments, like VaR, the ultimate result is unpredictable, and without detailed study of market incompleteness, the supervisory authorities may impose substantial and unnecessary costs on society.

The structure of the paper is as follows. The principal–agent model is presented in Section 2, while the credit risk model is investigate in Section 3. Some details and proofs are relegated to the Appendix.

2 The Principal Agent Relationship

We propose a principal–agent model for the relationship between a regulator, a bank's board of directors, and a dedicated risk manager. The bank's activities result in risk, where in general increased risk taking leads to higher expected profits. The board of directors, having a risk return profile in mind, contracts the risk manager to control overall risk taking. 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. We discuss four different cases:

Indirect Risk Monitoring The risk manager's decision is unobservable to the board of directors and is non–contractible, but the earnings are observable and contractable.

- 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.

Direct or Continuous 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.

2.1 The Basic Model

Consider a standard principal–agent setting with the following time line. First, the board of directors, b, of a bank (principal) maximizes its certainty equivalent utility, CEU_b, by making an one time employment offer to a risk manager (agent), m. The manager by rejecting the offer earns a reservation utility of zero in terms of certainty equivalent. Consequently, her certainty equivalent utility, CEU_m, derived from working must always be weakly higher than zero. 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) Holmstrom and Milgrom (1987). Recent 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 second approach.

The manager chooses an effort level, a, incurring cost of effort c measured in pecuniary terms. To ensure a non–trivial solution, we assume that both the board and manager are risk averse with constant absolute risk aversion coefficients α and β, respectively. The bank earns profits Z, with the following distribution:

$$Z \sim N\left(0, \sigma^2(a)\right). \tag{1}$$

Since we do not consider non–linear compensation contracts,[5] the contract is:

$$s(Z) = s_0 + s_1 Z.$$

The board offers the contract parameters s_0 and s_1 to maximize utility. The certainty equivalent of the manager's utility function can be represented as

$$CEU_m = \mathrm{E}\left[s(Z)|\, a\right] - c(a) - \frac{\alpha}{2}\mathrm{VAR}\left[s(Z)|\, a\right].$$

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

$$CEU_m = s_0 - c(a) - \frac{\alpha}{2}s_1^2\sigma^2.$$

We follow Holmstrom and Milgrom (1987) in assuming that the manager's personal cost of effort is linear in effort, i.e., $c = ka$. Moreover, we suppose that

[5] In a single period principal-agent model, the linear contract would *not* be optimal because a sequence of contracts approximates the first best solution arbitrarily well (See Mirrlees, 1999). However, we follow Holmstrom and Milgrom (1987, 1991) in considering a simpler representation of a continuous time game. Under this assumption, Sung (1995) demonstrates that the optimal contract is linear when the manager controls the variance of the performance measure. Diamond (1998) shows asymptotic optimality as an alternative rationale for restricting attention to linear contracts, while Palomino and Prat (1998) solve a binomial risk management problem under risk neutrality and limited liability, so that payoff is convex.

a unit of effort a lowers the risk through the following production function for risk control

$$\sigma^2(a) = \frac{\Sigma}{\tau + a},$$

where Σ and τ are given positive parameters. The risk control function features a decreasing marginal return on effort. Thus, for any contract characterized by the pair (s_0, s_1) the manager's certainty equivalent is

$$CEU_m = s_0 - ka - \frac{\alpha}{2} s_1^2 \frac{\Sigma}{\tau + a}.$$

2.2 Indirect Risk Monitoring: No Regulation

Consider the case in which the manager's risk management decision is unobservable to the board and hence is non–contractible. In this case, the risk manager solves the following problem:

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

From the FOC's, we get $a = -\tau + s_1 \sqrt{\frac{\alpha\Sigma}{2k}}$, and after substitution into CEU_m:

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

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 weak incentive to participate, i.e. $CEU_m = 0$. From (2),

$$s_0 + \tau k - \sqrt{2k\alpha\Sigma} s_1 = 0. \tag{4}$$

The net return to the board is $-s_0 + (1 - s_1)Z$, with certainty equivalent utility:

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

By substituting out s_0 and maximizing CEU_b with respect to s_1, we get

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

From (4) it follows that

$$s_0^{\text{second best}} = -\tau k + \sqrt{\frac{2k\alpha\beta\Sigma}{2\alpha+\beta}}.$$

Therefore the boards utility is:

$$CEU_b^{\text{second best}} = \tau k - \frac{\sqrt{2k\alpha\beta\Sigma}}{\sqrt{2\alpha+\beta}} \frac{2\alpha+\beta-\sqrt{\beta(2\alpha+\beta)}}{\alpha}.$$

From the manager's problem we have $a = -\tau + \sqrt{\frac{\alpha\Sigma}{2k}} s_1$. With the solution for s_1, this gives the *second best* solution for effort and volatility:

$$\begin{aligned} a^{\text{second best}} &= -\tau + \sqrt{\frac{\alpha\Sigma}{2k}}\sqrt{\frac{\beta}{2\alpha+\beta}}, \\ \sigma^2_{\text{second best}} &= \sqrt{\frac{2k\Sigma\,(2\alpha+\beta)}{\alpha\beta}}. \end{aligned}$$

2.3 Indirect Risk Monitoring with Regulation

Suppose that the bank is now subject to supervision and that the regulators have access to the same performance measure as the board, i.e., profit. The supervisor uses this information to determine bank capital, reflecting the 1988 Basel accord and its subsequent extensions. Since supervision is costly for the bank, e.g. due to lack of competitiveness, foregone earnings, or audit costs as in Merton (1978) we can model the capital requirements by means of 'tax' on bank profits.

Recall that the manager receives a pay of $s_0 + s_1 Z$. We represent the bank's cost of regulation by a proportion,[6] t, of the variable compensation $s_1 Z$ paid to the risk manager, i.e. the cost is $ts_1 Z$. This cost is transferred between the profit and an accounting reserve, which by assumption is self–financing, i.e. $\mathrm{E}[ts_1 Z] = 0$.[7] When $t > 0$ this corresponds with the procyclical nature of regulatory processes with has been widely observed, and also resembles the

[6] Which can be positive or negative.

[7] This accounting reserve is considered to be part of the capital base and e.g. in The Netherlands, banks are required to administer such an accounting reserve, the level of which is directly related to the risk of other balance sheet items. Such a 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 now show.

precommitment approach to regulation. We demonstrate that this serves as an instrument for inducing better risk management.

When the bank earns profit Z, it receives ts_1Z from the accounting reserve such that the net return to the bank becomes

$$-s_0 + (1 - s_1)Z + ts_1Z. \tag{5}$$

Because the utility of the board of directors is of the mean–variance type with risk aversion parameter β, its utility becomes

$$CEU_p = -s_0 - \frac{\beta}{2}\left(1 - (1-t)\,s_1\right)^2 \sigma^2.$$

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

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

The board maximizes CEU_p 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, $CEU_p(t)$. It is easily seen from (3) that the regulatory provision which minimizes risk taking entails maximizing s_1, i.e. setting $t = 1$. The regulatory effect of $t = 1$ is to undo, from the board of directors' perspective, the risk sharing with the manager, see (5). From the manager's point of view, the project risk combined with higher variable reward parameter s_1 increases the incentive 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. The doubling of the board of directors' exposure to compensation risk is optimal for mean–variance preferences.[8]

[8] 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.

2.4 Direct Risk Monitoring: No Regulation

Suppose that the bank is not content with only monitoring the final output of risk management process. The bank therefore installs a risk management system that reports continuously to the board the level of risk taking. *Continuous* risk reporting implies that the board controls the manager completely, leaving no room for hidden action, in effect the board runs the bank. 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 can then choose the contract parameters (s_0, s_1) to obtain a *'first best'* solution where the reward could be based directly on the observed volatility. Hence, the board pays the manager just enough to be willing to work, i.e., $CEU_m = 0$:

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

Substituting this into the boards CEU_b yields

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

The board maximizes CEU_p w.r.t. s_1 and a resulting in

$$s_1^{\text{costly first best}} = \frac{\beta}{\alpha + \beta}.$$

Indeed, this is the optimal risk sharing in agencies in the absence of moral hazard (See Wilson, 1968). Since this condition does not depend on managerial effort a, we can substitute into CEU_b to obtain the following simplification:

$$CEU_b = -ka - \frac{1}{2} \frac{\alpha\beta}{\alpha + \beta} \frac{\Sigma}{\tau + a} - F.$$

It follows from maximizing CEU_b with respect to choice of a that the *costly first best* solutions are

$$\begin{aligned} a^{\text{costly first best}} &= -\tau + \sqrt{\frac{\alpha\beta\Sigma}{2k\left(\alpha + \beta\right)}}, \\ \sigma^2_{\text{costly first best}} &= \sqrt{\frac{2k\Sigma\left(\alpha + \beta\right)}{\alpha\beta}}, \end{aligned}$$

resulting in the boards utility

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

2.5 Direct Risk Monitoring with Regulation

Since the project payoffs (1) are normally distributed, the variance $\sigma^2(a)$ is a sufficient statistic for VaR. Consequently, exogenous regulation needs to stipulate only an upper bound Ω on the admissable variance:

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

In 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. $\Sigma/(\tau+a)=\Omega$ it implies that effort necessarily equals

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

The certainty equivalent of the expected utility of the manager becomes

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

From the manager participation constraint we get

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

The boards utility then reads

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

Maximizing 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 contractible risk management. Hence, the optimal fixed part of the salary is

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

and the boards utility:

$$CEU_b^{\text{directly regulated}} = \tau k - \frac{k\Sigma}{\Omega} - \frac{\alpha\beta\Omega}{2(\alpha+\beta)} - F.$$

Under direct regulation, a continuous 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.

2.6 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:

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

In this situation the bank prefers no regulation:[9]

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

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

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

Proposition 2 *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 continuous risk management system.*

Proof. From $CEU_b^{\text{costly first best}} = CEU_b^{\text{second best}}$, 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 continuous risk management system.[10]

The decision whether to install the continuous risk measurement system, 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.

[9]Regulation may also work as an entry deterrence, and hence may actually be liked by the management for this reason.

[10]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 3 *With regulation where the fixed cost of the continuous 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 sophisticated risk management system. From the following partial derivatives

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

and

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

we see that $CEU_b^{\text{direct regulation}}$ 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

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

Moreover

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

If the board has not installed the elaborate VaR reporting 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

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

Since $\tau k - 2\sqrt{k\alpha\Sigma} < \tau k - \sqrt{k\alpha\Sigma}$, but $\tau k - 2\sqrt{k\alpha\Sigma} > -\infty$, we can clearly find cases where $CEU_b^{\text{indirect supervision}} < CEU_b^{\text{direct regulation}}$, but also values of Ω for which $CEU_b^{\text{indirect supervision}} > CEU_b^{\text{direct regulation}}$.[11] ■

From these results we see that the bank's optimal risk monitoring intensity depends not only 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.

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

3 Risk Regulation, Deposit Insurance, and Moral Hazard

It is well known that risk regulation through capital requirements can have adverse effects, since capital requirements are only an indirect instrument for controlling risk and thus have unintended side effects.[12] We extend the existing analysis by considering the effects of *direct* policy instruments regulating risk taking in incomplete markets.

Direct risk regulation (e.g. VaR) cannot have unintended effects when markets are complete. We show that the VaR constraint can nevertheless induce risk taking in incomplete markets. In the specific situation considered below, where a bank has to choose between a low, medium, or high risk project, the agents choose the lowest risk project in the absence of regulation. If, however, regulation prevents banks from financing the *'off–equilibrium'* project, this induces the banks to switch to the medium risk investments.

We consider the deregulation of a banking industry where the supervisory authorities have the power to restrict project choice and provide deposit insurance. The specific context is the US S&L crisis where moral hazard played a key role.[13] The government, in the form of FSLIC (Federal Savings and Loan Insurance Corporation), 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 FHLBB (Federal Home Loan Bank Board) to supervise lending, was due to political factors, leading to regulatory capture which obstructed the FSLIC from either adequately supervising the industry or charging risk adjusted premiums.

The fact that deposit insurance premiums were not risk adjusted, was indicative of market *incompleteness*. Bank value (profits from lending) and hedging (deposit insurance) are however interdependent, as the pricing of primary and derivative securities occurs simultaneously (see e.g. Detemple and Selden, 1991) when markets are incomplete. In such an environment moral hazard can arise due to the fact that derivative securities cannot be priced state contingent.

In summary, we demonstrate below that, due to the market incompleteness, a regulatory risk constraint for a bank can have the potentially unintended consequence of increasing overall risk taking. This arises, moreover, even when the risk constraint would *not* be binding in the unregulated case. Formally this

[12]For analysis of indirect instruments, see, among others, Kim and Santomero (1988), Rochet (1992), Beaver, Datar, and Wolfson (1992), and Bernard, Merton, and Palepu (1995)

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

can be stated as:

Proposition 4 *Direct risk regulation aimed that reducing risk taking, can nevertheless increase risk when markets are incomplete.*

We prove Proposition 4 by constructing a stylized model of the S&L crisis.

3.1 Modelling the S&L Industry

If the supervisory authority is unable to charge risk adjusted premiums, or supervise lending practices, it may go bankrupt, as effectively happened to the FSLIC. Prior to the crisis, the S&Ls were restricted to low–risk projects (mortgages), but subsequent to deregulation, they could enter into more risky projects, however, the regulatory structure of the industry was not adjusted. There was no effective supervision of lending policies, and deposit insurance premiums were not adjusted either. We refer to this as *unbalanced deregulation*. It follows trivially, i.e. this is unrelated to the completeness of markets, that banks will increase risky lending.

Subsequent to deregulation, regulatory policy should ideally adjust to reflect the new environment. However, banking deregulation without adjustment in policy, as in the S&L case, seems to be rather common, e.g., the Scandinavian banking crisis in the 1980's had similar roots. If the authorities wish to retain deposit insurance after deregulation, they need to supervise lending policies much more closely, and/or risk weigh deposit insurance premiums. At the very least, insurance premiums should increase to preserve the solvency of the insurance agency. Consider specifically the case where supervisors rule out extreme risk taking while at the same time moderately increase premiums: refer to this case as *balanced deregulation*. We demonstrate that while well–intentioned, balanced deregulation may nevertheless trigger increased risk taking.

3.2 The Model

Similar to Merton (1977), we model the supervisor (FSLIC) as a writer of an *unconditional* put option with strike at 0, on three risky projects available to the S&Ls. Let B and F, represent respectively a S&L and the FSLIC. The agencies 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 that pay $-l$, $-m$, and $-h$ in the down–states, where $0 < l < m < h$; and l, $m + 2c$, and h, where $c > 0$, are respectively the payoffs in the up–states. The up and down states have an equal probability 1/2 of occurrence. Note that the medium risk project has a positive mean payoff c. The government agency F can write a put 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, NP.

We demonstrate Proposition 4 first numerically by showing that the set of possible decisions is non–empty, subsequently in Appendix A we give more general analysis. To proof the Proposition suppose $\alpha = 1$, $\beta = 0$ (a risk neutral agency F), $l = 1/30$, $m = 1/10$, $h = 1$, and $c = 4/5$. The case has to meet a number of conditions, so as to capture the specific aspects of the S&L type of risk management environment, and to satisfy the conditions of Proposition 4 that the regulation be direct and non–binding.

3.2.1 Prior to Deregulation

Prior to deregulation the S&L industry was restricted to financing low risk fixed–rate mortgages, in our notation the low risk, L, project. The FSLIC could condition its insurance premium on this project selection. Assume that because the FSLIC was a governmental organization it charged fair premiums, i.e. in the long run it breaks even, and that all the surplus goes to the buyer of the put.[14] Hence, the benchmark is $EU_F(L, NP) = 0$. If the put is purchased, we get due to the supervisors risk neutrality, $EU_F(L, P) = -l/2 = -1/60$, which is also the price of the option, Π. For the S&L the low risk project has mean 0, and variance 1/900, so that without insurance, $EU_B(L, NP) = -1/900$ and with insurance $EU_B(L, NP) = -1/3600$. Thus the S&L prefers the deposit insurance system.

3.2.2 Unbalanced Deregulation

Suppose the banking industry is deregulated, while the regulator is constrained to provide deposit insurance at the pre–deregulation price, without the ability to affect project choice due to regulatory capture. Hence $\Pi = l/2 = 1/60$ as

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

before. It follows that for the S&L's $EU_B(M,P) = 999/3600$ and $EU_B(H,P) = 840/3600$. Hence the industry shifts into financing the medium risk projects M. But since the FSLIC only receives the pre–deregulation premia, it eventually will go bankrupt.

3.3 High Uniform Premia

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

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

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

To prove 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 premium Π. Result 1 implies that the put premium must be conditional on the high risk project, so that $\Pi = h/2 = 1/2$. Furthermore it follows that the put is effective in reducing risk:

Result 2 (Effectiveness of Put) *The put reduces the downside risk for the high risk project, i.e.* $\Pi < h$.

Note that the uniform premium $\Pi = h/2 = 1/2$ 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.

Result 3 (Project Choice) *Agent's B's preference rankings are as follows:*

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

Direct computation gives $EU_B(L,NP) = -4/360 > EU_B(M,NP) = -36/3600 > EU_B(H,NP) = -1$. 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.

3.4 Balanced Deregulation

The outcome in Result 3 implies the 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 risk taking. Suppose premiums increase from $\Pi = 1/60$ to $\Pi = 1/20$, in conjunction with a VaR constraint stipulating that $\Pr[\text{loss} < 1/15] = 40\%$. This particular constraint appears rather innocuous, since it is above the level of risk assumed in the unregulated market with uniform premium. Since $l = 1/30 < 1/15$ 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 violates the VaR constraint set by the authorities.*

Thus with risk regulation, project H is ruled out and, hence, the insurance agency can condition the pricing of the insurance on this fact. However, the regulatory constraint does affect the the medium risk project. Note that without insurance the M project does not meet the VaR constraint. But with the put premium conditional on running H, $\Pi = 1/20$, 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:*

$$-4/3600 = EU_B\left(L, NP\right) < EU_B\left(M, P|i \neq H\right) = 279/3600.$$

Moreover, with the put price conditioned in this way,

$$-121/3600 = EU_B\left(L, P|i \neq H\right) < EU_B\left(M, P|i \neq H\right) = 279/3600.$$

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 conditioned on M exceeds the downside risk of the low risk project L without a put;* $P|i \neq H > l$.

These numerical results demonstrate the conclusion of Proposition 4. A more general and explicit set of conditions under which Results (1)-(8) and Proposition 4 hold, follows in Appendix A.

3.5 Complete Markets

Suppose the supervisor is able to charge risk adjusted premia.

Proposition 5 *If the regulator charged risk adjusted premia, the medium risk project is selected, just as in the cases of unbalanced deregulation and the mixed policy regime.*

Proof. Since $EU_B(L, P|i \neq M, H) = -1/3600$, $EU_B(M, P|i \neq H) = 279/3600$ and $EU_B(H, P) = -900/3600$ the conclusion follows. ■

Furthermore in this case the insurance agency remains properly funded as in the case of balanced deregulation. Thus the two policy regimes are substitutes.

4 Conclusion

Regulation of the financial industry is primarily motivated by fear of systemic crisis where the clearing system collapses. Bank regulation takes place in an environment where rapid technological advancements and deregulation make it increasingly hard to prevent systemic crisis by regulatory means. Indeed, as the present regulatory structure appears to have been created without much regard to financial–economic developments, its suitability for its task remains in doubt.

A rapidly increasing body of literature on financial regulation and financial crisis is emerging, and hence our understanding of how to optimally regulate the finance sector has grown. We consider the financial–economic implications of externally imposed risk constraints in two imperfect market settings, one with a principal–agent relationship between a regulator, a bank board of directors, and a risk manager, and the other where asymmetric information between an oversight agency and a financial institution induces moral hazard.

In both models, the presence of external regulations has real effects. There is potential for a decrease in the banks' market value coupled with an increase in total risk as a consequence of regulatory actions. As a result, improperly crafted regulations can have serious unintended consequences, and a bad regulatory design may be worse than no regulation. Therefore, it is important to subject regulatory designs to rigorous financial–economic analysis prior to implementation. In particular, we recommend modelling the market incompleteness, and explicitly measuring the cost and benefits of regulation in incomplete markets in order to facilitate optimal policy making.

5 Appendix

In this appendix we provide a general set of parameter restrictions for the results of Section 3. We also allow the government agency F to be risk averse. Thus if F sells a put conditioned on the high risk project, it incurs

$$EU_F(H,P) = P - h/2 - \beta h^2/4.$$

Since the benchmark for the agency is $EU_F(H,NP) = 0$, it charges

$$P = h/2 + \beta h^2/4. \tag{7}$$

We first deal with the conditions from the subsection on uniform premia.

5.1 High Uniform Premium

The potential for moral hazard requires

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

To get $EU_B(L,P) < EU_B(H,P)$, requires

$$\begin{aligned} \frac{l}{2} - P - \alpha\frac{l^2}{4} &< \frac{h}{2} - P - \alpha\frac{h^2}{4}, \text{or} \\ h + l &< \frac{2}{\alpha}. \end{aligned}$$

The inequality $EU_A(L,P) < EU_A(M,P)$ can be rewritten by using the result that the variance of the M project is $1/4\ m^2 + mc + c^2$:

$$\begin{aligned} \frac{l}{2} - P - \alpha\frac{l^2}{4} &< \frac{m+2c}{2} - P - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right), \text{or} \\ \alpha\left(\frac{m^2 - l^2}{4} + mc + c^2\right) &< \frac{m-l}{2} + c. \end{aligned}$$

Moreover, $EU_A(M,P) < EU_A(H,P)$ implies the mirror image of the previous inequality

$$\frac{m-h}{2} + c < \alpha\left(\frac{m^2 - h^2}{4} + mc + c^2\right).$$

To conclude

Lemma 1 *Result 1 requires*

i	$h + l < \frac{2}{\alpha}$,
ii	$\alpha\left(\frac{m^2-l^2}{4} + mc + c^2\right) < \frac{m-l}{2} + c$,
iii	$\frac{m-h}{2} + c < \alpha\left(\frac{m^2-h^2}{4} + mc + c^2\right)$.

It is easy to see that the put is effective as required by Result 2, once $2 > \beta h$.

Lemma 2 *Result 2 is satisfied if* $2 > \beta h$.

For Result 3 we need $EU_B(L, NP) > EU_B(M, NP)$ or

$$-\alpha l^2 > c - \alpha(m + c)^2.$$

Moreover, $EU_B(L, NP) > EU_B(H, NP)$

$$-\alpha l^2 > -\alpha h^2 \Leftrightarrow l < h$$

which is already embedded in the assumption that $l < h$. If F just charges the fair premium, then $EU_B(L, NP) > EU_B(H, P)$ if

$$\begin{aligned} -\alpha l^2 &> \frac{h}{2} - P - \alpha\frac{h^2}{4} \Leftrightarrow \\ 4\frac{\alpha}{\alpha+\beta} &< \frac{h^2}{l^2}. \end{aligned}$$

Finally, Result 3 also requires $EU_B(L, NP) > EU_B(L, P)$ and $EU_B(L, NP) > EU_B(M, P)$. These two conditions are already ensured by the previous inequality $EU_B(L, NP) > EU_B(H, P)$ and the Lemma 1. To show this, assume to the contrary $EU_B(L, NP) < EU_B(L, P)$, then, by Result 1, the agent adopts H since $EU_B(L, P) < EU_B(M, P) < EU_B(H, P)$. But this violates $EU_B(L, NP) > EU_B(H, P)$. In summary, we need:

Lemma 3 *Result 3 requires*

i	$-\alpha l^2 > c - \alpha(m + c)^2$,
ii	$4\frac{\alpha}{\alpha+\beta} < \frac{h^2}{l^2}$.

5.2 Balanced Deregulation

Result 4 requires $l < VaR$. Result 5 stipulates $P > VaR$, or $2h + \beta h^2 > 4VaR$, by (7) above. The impact of the conditional put must satisfy $m > VaR$, and

$P|i \neq H < VaR$ or $2m + \beta m^2 < 4VaR$ to meet Result 6. Finally we need that risk taking increases if the insurance can be conditioned on the M project. Thus according to Result 8 we need $P|i \neq H > l$, or $2m + \beta m^2 > 4l$. These restrictions are recorded in the following lemma:

Lemma 4 *Results 4, 5, 6 and 8 require:*

Condition		*Restriction*
4		$l < VaR,$
5		$2h + \beta h^2 > 4VaR,$
6	*i*	$m > VaR,$
	ii	$2m + \beta m^2 < 4VaR,$
8		$2m + \beta m^2 > 4l.$

Finally, Result 7 for conditional moral hazard is satisfied if $EU_B(L, NP) < EU_B(M, P|i \neq H)$, or

$$\begin{aligned} -\alpha l^2 &< \frac{m+2c}{2} - P - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right) \Leftrightarrow \\ -\alpha l^2 &< \frac{m}{2} + c - \left(\frac{m}{2} + \beta\frac{m^2}{4}\right) - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right) \Leftrightarrow \\ -\alpha l^2 &< c - \beta\frac{m^2}{4} - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right), \end{aligned}$$

and if $EU_B(L, P|i \neq H) < EU_B(M, P)$, or

$$\begin{aligned} \frac{l}{2} - P - \alpha\frac{l^2}{4} &< \frac{m+2c}{2} - P - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right) \Leftrightarrow \\ \frac{l}{2} - \alpha\frac{l^2}{4} &< \frac{m}{2} + c - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right). \end{aligned}$$

Thus, we need

Lemma 5 *Result 7 is satisfied if*

i	$-\alpha l^2 < c - \beta\frac{m^2}{4} - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right)$
ii	$\frac{l}{2} - \alpha\frac{l^2}{4} < \frac{m}{2} + c - \alpha\left(\frac{1}{4}m^2 + mc + c^2\right)$

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