ESSAYS ON BANKING

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To my family

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Chapter 1

Introduction

Risk management is an extremely important activity conducted by financial intermediaries. In order to manage their risk, banks rely on both their organizational structure as well as financial contracting with other parties. In my dissertation, I study these aspects of risk management and provide some reasons for risk management failure. The first essay focuses on how banks design their organization to manage their risks and shows that the efficient organization entails a separation of tasks between a risk manager who approves the investment and a risk taker who executes the investment. In the second essay I study credit insurance markets in presence of a regulator which face inconsistency problem and show how credit insurance markets can result in creation of systemic risk endogenously.

The title of the first essay is "Why Risk Managers?". In this essay, I explain why banks rely on risk managers to prevent their employees (such as loan offers or traders) from making high risk low value investments instead of directly incentivizing them by offering them the right contract. I show that having a separate risk manager is more profitable for banks and is also socially efficient. This is because there is conflict between proving incentive to choose the most profitable investment and providing incentives to exert effort on those investments. Hence, if the tasks are split between a risk manager who approves the investments and a loan officer (or trader) who exerts effort, then both optimal investment choice and optimal effort can be achieved. I further examine some reasons for risk management failure wherein a CEO may ignore the risk manager when the latter is risk averse and suggests safe investments. As is usually the case before a financial crisis, my model predicts that the CEO is more likely to ignore the risk manager when the risky investments are yielding higher profits.

In the second essay, “Credit Insurance, Bailout and Systemic Risk”, I study how credit insurance markets while helping banks hedge their idiosyncratic risk can also result in creation of systemic risk endogenously. The essay examines the impact of expectation of bailout of a credit insurance firm on the investment strategies of the counterparty banks. If the failure of credit insurance firm may result in the bankruptcy of its counterparty banks, then the regulator will be forced to bail it out. This imperfectly targeted time inconsistent policy incentivizes the banks to make correlated investments *ex ante*. All banks want their assets to fail exactly at the time when the bailout is occurring to indirectly benefit from the bailout of the insurance firm and hence they make correlated investments. I build a model in which correlated investment by banks, under priced insurance contracts and a systemically important insurance firm arise endogenously and show that while credit insurance helps in risk sharing during good times, it can also create systemic risk. I also show that putting a limit on size of insurance firm can mitigate this problem.

The dissertation is organized as follows. Chapter 2 contains the first essay “Why Risk Managers?” Chapter 3 contains the second essay “Credit Insurance, Bailout and Systemic Risk”. The proofs of the results are provided in the appendix.

Chapter 2

Why Risk Managers?

2.1 Introduction

Financial institutions usually have two kinds of employees. The first kind includes employees such as loan officers and traders—I call them *risk takers*—whose job is to suggest potential investments and exert effort to make the investments successful. For example, a loan officer exerts effort to monitor the loans and a trader exerts effort to execute the trade.[1] Their compensation structure is designed to incentivize them to take risk: traders are paid high bonuses for booking profits and loan officers are often compensated by the volume of loans they originate. The second kind of employees are the risk managers (RM) whose job is to approve the investments that can be made by the first kind of employees, so that excessively risky investments are not undertaken. For example, there are RMs who monitor traders so that they do not make risky low value investments.[2] Similarly, loan officers and insurance officers need the approval of an 'underwriting authority,' which evaluates the risks independently, before they can disburse loans and sell insurance products respectively.

The question that arises is why can't banks directly incentivize their employees to choose investments with the highest net present value (NPV)? What agency problems make it optimal to rely on separate agents, the RMs, to approve the investment decisions? Also, given the recent financial crisis, it becomes important to understand

[1] For example, once a trader decides to invest in CDOs, he will have to buy asset backed securities at the cheapest price, create tranches out of them to get the best ratings from the rating agencies and then either sell these tranches at the highest price or keep them on his books.

[2] For example, traders at UBS bank wanted to invest more in CDOs as late as May 2007, but were not allowed to do so by the RMs (see UBS (2008)).

the reasons for risk management failure. One of the reasons why risk management failed before the crisis of 2007 is that the CEOs ignored the suggestions of the RMs. There are numerous anecdotal examples of RMs whose warnings were ignored before the crisis.[3] If risk management is important, then why did the CEOs ignore their RMs?

This paper shows that having separate RMs, who are in charge of approving investment decisions, is not only more profitable for banks, but is also socially optimal. I study a multi-task principal agent problem where a bank employee has to be incentivized to do two tasks—choose the investment with the highest value and then exert effort on it—and show that there is a conflict between providing incentive for both tasks. The conflict arises because incentivizing effort requires offering high powered incentive contract, i.e. the employee gets paid only when high outcomes are realized. But such a contract would also incentivize him to indulge in risk shifting and choose the riskier investment even when it has lower NPV. So, it is optimal to split the tasks between two employees. The RM is only incentivized to approve the best investment and the risk taker (trader, commercial loan officer, commercial insurance officer) is only incentivized to exert effort after the investment is chosen.

To fix ideas, I first consider the case where there is only one employee who is incentivized to do both tasks. He has two investment choices, a safe project and a risky project. The risky project can turn out to be good or bad. The employee receives a private unverifiable signal which tells him the likelihood of the risky project being good or bad. Based on his private signal, he chooses one of the projects. After choosing the project, he has to exert an unobservable effort. So, to incentivize the employee to exert effort, the CEO (principal) needs to offer a high powered incentive contract (convex payoff). But in such a situation, he will indulge in risk shifting and choose the risky project even when it has lower value because its distribution has higher weight in the tails. To prevent this risk shifting, the CEO can offer a flatter wage contract, but then the employee will not exert the optimal effort. So, there is a conflict between providing incentives for both tasks.

Now consider what happens if the tasks are split between two employees, a trader (or loan officer) and a RM. The RM also observes the signal like the trader and he has a veto power over what investment the trader can make. Here the RM does not have

[3]Examples of RMs who warned their CEOs but were ignored are Madelyn Antoncic (Lehman Brothers), Paul Moore (HBOS), David A. Andrukonis (Freddie Mac) and John Breit (Merril Lynch).

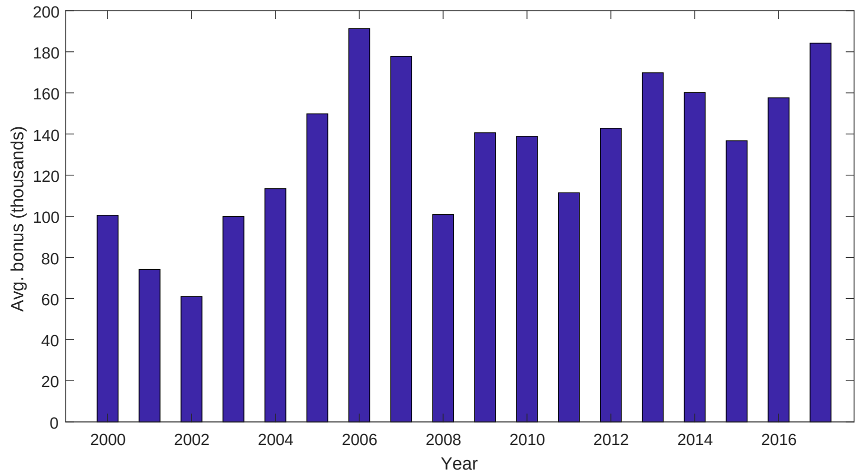
to exert effort after the project is chosen, which is the trader's job. As a result, the CEO does not have to offer the RM high powered incentives. So, the CEO can offer a contract such that the RM approves projects with perfect efficiency conditional on his signal observed. On the other hand, since the trader is only incentivized to exert effort, he is given a high powered wage contract and optimal effort can be achieved. Now if the trader wants to invest in the risky project even when it has lower NPV, then the RM can reject his decision. So, with the separation of tasks, projects are approved efficiently by the RM and optimal effort is exerted by the trader. Thus, this organizational structure is not only more profitable for banks but is also socially optimal.

After the financial crisis of 2007, academicians, regulators and politicians alike have argued that the high bonuses paid to bankers incentivize them to take excessive risk which may be value destroying.[4] Such bonus-based compensation structure has been a hallmark of financial firms and continues to be so today. Figure 2.1 shows that the average annual bonus for New York City securities industry employees are back to pre-crisis levels. If the CEOs know that such compensation structure can lead to excessive risk taking, then why do they offer such contracts to their employees? This paper argues that paying bonuses for performance without worrying about excessive risk taking is the optimal strategy for the banks as long as they have RMs to check the traders.

There are various agency problems within a firm, one of which is that a firm has to rely on the private information of the employees to make the optimal investment decisions. But this private information is not enough to create a divergence of preference regarding investment choices between the firm and its employee. The conventional frictions which create the divergence of preferences do not apply to financial firms (as discussed in the next paragraph), therefore a key contribution of my paper is to highlight the reason why banks cannot rely on its employees to make the optimal decisions. Furthermore, the paper addresses the question as to why the solution is not to offer optimal contracts but to have separation of tasks among agents.

In a non-financial firm, a divergence of preference between division managers and the CEO occurs because the division managers want higher capital allocated to them than what is value maximizing for the firm. This is because they are assumed to be

[4]Rajan (2008) argues that investment managers were creating fake alpha at the cost of taking hidden tail risks.



Source: Office of the New York State Comptroller

Figure 2.1: Average annual bonus for New York City securities industry employees

"empire builders" or receive higher perquisite consumption from higher allocations.[5] But this argument does not apply to the bank employees because they invest in financial assets which cannot provide perquisite consumption or utility from empire building. Another reason for misalignment of preference can arise because the manager may have career concerns (Holmstrom and Ricart I Costa (1986)).[6] But again, having separate RMs who are in charge of approving investment decisions would not alleviate the problem of career concerns because the RM may himself be concerned about his career.[7] Thus, my paper highlights a novel friction within banks and also offers insights regarding institution design and capital budgeting process within banks.

In the second part of the paper, I provide an explanation for why a CEO may ignore the RM's recommendation. As mentioned earlier, one of the reasons why risk management failed before the crisis of 2007 was that the CEOs ignored the warnings of their RMs and continued investments in securities backed by sub-prime mortgages. I show that if the RM is risk averse then there will be overinvestment in the safe project.

[5]See, for example, Antle and Eppen (1985), Harris and Raviv (1996, 1998, 2005), Dessein (2002), Marino and Matsusaka (2004). An alternative interpretation for why division managers like more capital is that it reduces the effort required to produce the same level of output. For this interpretation, see Harris et al. (1982) and Baiman and Rajan (1995).

[6]Since the manager is concerned about his career, his investment decisions take into account the return on human capital whereas the firm only cares about financial returns.

[7]Also, the outcomes of investment decisions by individual bank employees are usually not publicly available information and hence career concerns may not play a role in investment decisions.

This is because compensating the RM with the safe project which has lower variance is cheaper relative to compensating him with the risky project. Such overinvestment results in loss of value. To prevent this overinvestment, the CEO occasionally ignores the RM when he suggests the safe project. The optimal strategy of the CEO is to always agree with the RM if he suggests the risky project. But if he suggests the safe project, then the CEO plays a mixed strategy and sometimes disagrees with him by choosing the risky project. While this strategy is optimal *ex ante*, it can also result in risky project being undertaken even when the RM may have seen low signals, i.e. the CEO can make the mistake of choosing the risky project even when it is likely to be bad and has a high chance of failure.

The CEO is more likely to ignore the RM if the good project is much more profitable than the safe project. This is because whenever the relative profitability of the good project is high, the *ex ante* probability that the RM will observe a low signal such that the safe project should be chosen is small. So, when the CEO ignores the RM, then the likelihood of her making the mistake of choosing the risky project in place of the safe project is low. This is what may have happened before the crisis. The investments in mortgage backed securities (MBS) were yielding very high profits before the crisis, therefore the CEOs may have chosen to ignore the RMs' suggestions.

2.1.1 Related Literature

This paper is related to several strands of literature. First, it contributes to the nascent literature on RMs.[8] Landier et al. (2009) consider a hierarchical structure within banks where a trader selects an asset and the RM can decide to approve it or not. In their paper, the institutional structure and contracts are exogenous and they show that when trader's compensation is more convex, then risk management may fail. Bouvard and Lee (2016) show that risk management may fail when banks are in preemptive competition for profitable trading opportunities and the time pressure is high. Kupiec (2013) shows that the demand for risk management is lower if the intermediary relies on subsidized insured deposits. Jarque and Prescott (2013) study loan officer's and RM's contract and show that correlation of returns affects the relationship between pay for performance and bank's risk level. In all these papers the existence of RM is exogenously assumed. The main contribution of my paper

[8]While the literature on RMs is relatively new, there is a large literature on evaluation and management of risk. See, for example, Saunders and Cornett (2005), Hull (2012).

is to derive the hierarchical structure and contracts endogenously, and further show that risk management may fail because the CEOs may ignore the RMs.

Some empirical papers have highlighted the importance of risk management function. Berg (2015) shows that involvement of RMs reduces the likelihood of loan default. Ellul and Yerramilli (2013) build a risk management index and show that banks with better risk management had lower nonperforming loans before the onset of crisis. Aebi et al. (2012) show that banks in which the Chief Risk Officer reports to the board performed better during the crisis. Liberti and Mian (2008) show that a greater hierarchical or geographical distance between loan officer and the loan approving officer results in higher use of hard information to approve the loans.[9]

Several papers have studied contracting problems of agents within banks. In a related paper, Heider and Inderst (2012) model a loan officer who is incentivized to exert effort to prospect for loans and also disclose soft signals about the loan for it to be approved. They show that as competition increases the banks may disregard the disclosure of soft information and only rely on hard information to approve the loans.[10] Again, in their paper the loan underwriter is assumed to be exogenous. While their paper is more suitable to analyze mortgage loan officers where exerting effort *ex ante* to prospect for new customers is important, my model is more suitable to analyze traders and commercial loan (or insurance) officers where *ex post* effort to execute the trade and monitor the firms respectively is valued by the bank. Loranth and Morrison (2009) discuss the interaction between loan officer compensation contracts and the design of internal reporting systems.[11]

Some papers have argued that competition for managerial talent can result in inefficiently high wages. Bénabou and Tirole (2016) study a multitasking screening model and show that competing banks have to increase their pay for performance. As in Holmstrom and Milgrom (1991), there is an effort substitution problem and this results in shifting effort away from risk management activity. In Thanassoulis (2012), competition for bankers among banks generates negative externalities which manifests in the form of inefficiently large wages and higher probability of default

[9] Banks also use some risk management techniques after loans have been disbursed. Hertzberg et al. (2010) show that rotation of loan officers incentivizes them to reveal more information about loans and is thus a form of risk management after loans are disbursed. Udell (1989) show that banks invest more in loan review process when their loan officers have more discretion.

[10] See, also, Inderst and Ottaviani (2009) and Inderst and Pfeil (2012).

[11] For more on bank organizational form and use of information, see, for example, Berger and Udell (2002), Stein (2002), Berger et al. (2005), among others.

risk.[12] In my model, the labour market for bank employees is competitive. The CEO offers high bonuses to the employees (or traders) to simply incentivize them to exert effort. She does not worry about excessive risk taking because she has efficiently allocated the task of approving the investments to the RM.

My paper is also related to the literature on multitasking agency problem and job design which follows the seminal contribution of Holmstrom and Milgrom (1991). In their model, there are different tasks each of which requires effort. There is also an effort substitution problem, i.e. increasing effort for one task increases the marginal cost of effort for the other tasks. They show that tasks should be grouped into jobs in such a way that the tasks in which performance is most accurately measured are assigned to one worker and remaining task are assigned to the other worker. Dewatripont and Tirole (1999) argue that separation of tasks may be efficient when there is a direct conflict between two tasks such as finding evidence whether a person is guilty or not. In my paper, while employees need to exert effort after the project is chosen, the first task of choosing the right project does not require any effort. I argue that separation of tasks may still be efficient.

Finally, my paper contributes to the large literature on risk shifting which started with Jensen and Meckling (1976). Many papers such as Green (1984), John and John (1993), Biais and Casamatta (1999) and Edmans and Liu (2010) study the problem of designing securities to mitigate risk shifting. But in this paper, I discuss how institution design can prevent risk shifting by bank employees.

The rest of the paper is organized as follows. Section 2 describes the framework. Section 3 discusses the contracting problem and why having RMs is more efficient. Section 4 discusses why CEOs may ignore the RMs if they are risk averse. Section 5 describes that when there are multiple RMs, they may not be able to coordinate their disclosure. Section 6 and 7 discuss some extensions and section 8 concludes. The proofs are provided in the appendix.

[12] See also Acharya et al. (2016).

2.2 Framework

2.2.1 Agents, Preferences and Technology

Consider a financial intermediary, referred to as bank, which has a CEO (hereinafter referred to as she) and an employee (hereinafter referred to as he). All agents are risk neutral. There are four dates, $t = 0$, 1, 2 and 3. At $t = 0$, the bank has access to two investment projects, risky (R) and safe (S). The risky project can be of two types. It can be good, G, with probability α or bad, B, with probability $1 - \alpha$. Both projects require one unit of investment and yield a random cash flow $X \in \{X_0, X_1, X_2\}$ (the probability distribution is described later). I assume $0 \leq X_0 < X_1 < X_2$.

At $t = 1$, the employee receives a private unverifiable signal, denoted by σ, about the type of risky project. He chooses between the risky and the safe project based on signal observed. The signal is described in terms of the posterior probability that the risky project is good. I assume that $\alpha = 0.5$ and σ is uniformly distributed between 0 and 1, i.e. $\sigma \sim U[0, 1]$.[13]

At $t = 2$, the employee can either work (exert effort) on the project or shirk. The private benefit of shirking to the employee is b. The CEO cannot observe the employee's effort. So, at $t = 0$, she offers a wage contract such that the employee chooses the project with higher expected profit and also exerts effort.[14] At $t = 3$, the return X is realized and the employee is paid. The time line is shown in figure 2.2.

The probability distribution of the project returns given that the employee works is denoted by p_i^θ, where $\theta \in \{G, B, S\}$ is the type of the project and $i \in \{0, 1, 2\}$ corresponds to the value of the project return X_i. The probability of occurrence of X_i when risky project is undertaken depends on σ and is given by $Pr(X_i|R, \sigma) = \sigma p_i^G + (1 - \sigma)p_i^B$. For simplicity I assume that the good project and safe project do not yield return X_0, i.e. $p_0^G = p_0^S = 0$ (see table 2.1). I also assume that the good project first order stochastically dominates the safe project and the safe project first order stochastically dominates the bad project.[15]

Remark 1. An example of safe project is investment in conventional loans or asset backed securities backed by prime mortgages. The CEO knows the distribution of

[13] Note that, by definition the expected value of σ must be α.

[14] I discuss the case where tasks are separated between two employees after discussing the one employee case (see section 2.3).

[15] This implies that $p_2^G > p_2^S > p_2^B$.

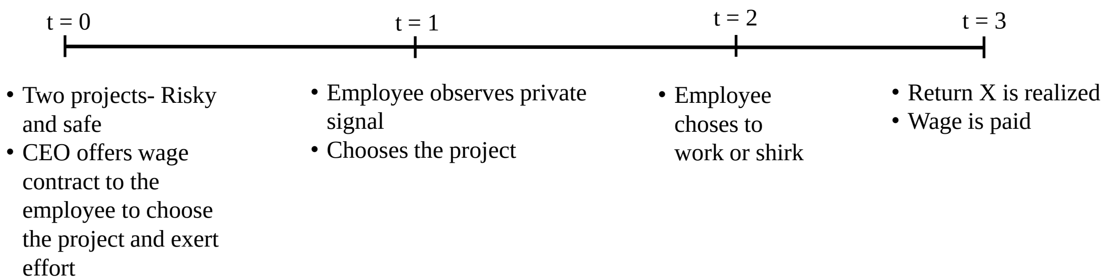


Figure 2.2: Time Line

their returns very well and that these projects have minimal chance of low return. She also knows that they are most likely to yield *average* return and less likely to yield high return. An example of risky project is taking unhedged positions in CDOs backed by sub-prime mortgages. Here, the CEO is not sure whether this investment strategy is good or bad. If the investment is good, then it is more likely to give high return but if it is bad then it is more likely to give low return.

If the employee shirks, for both risky and safe project, the probability of X_2 reduces by $\Delta_2 (> 0)$, the probability of X_0 increases by $\Delta_0 (> 0)$ and probability of X_1 increases by $\Delta_1 = \Delta_2 - \Delta_0$. Note that Δ_1 can be positive or negative. I assume that the probability distribution conditional on working and on shirking follow monotone likelihood ratio property (MLRP).[16] I also assume that the loss in value from shirking is large enough such that even the good project has negative NPV. So, the CEO must incentivize effort on any project that the employee may choose.

[16]For risky project this assumption implies that $\frac{Pr(X_0|R)}{Pr(X_0|R)+\Delta_0} < \frac{Pr(X_1|R)}{Pr(X_1|R)+\Delta_1} < \frac{Pr(X_2|R)}{Pr(X_2|R)-\Delta_2}$. Similar property holds for the safe project.

Project	X_0	X_1	X_2
Safe	$p_0^S = 0$	p_1^S	p_2^S
Good	$p_0^G = 0$	p_1^G	p_2^G
Bad	$p_0^B > 0$	p_1^B	p_2^B

Table 2.1: Probability distribution of project given that the employee works

2.2.2 Contracts

There is no agency problem between the CEO and the investors. So, the CEO takes decisions to maximize the expected profit, where profit equals return minus the wage payments. She offers a wage contract $w = (w_0, w_1, w_2)$ at $t = 0$ to the employee in which the employee is paid w_i if return X_i is realized. The contract needs to incentivize the employee to achieve two objectives. First, the employee should choose the project with higher value conditional on the signal observed by him and second the employee must exert effort on the project after choosing it. The expected wage of the employee should also be greater than his reservation wage denoted by $\underline{u}$. I assume limited liability for the employees, i.e. $w_i \geq 0$. There is also a resource constraint, i.e. $w_i \leq X_i$.

Note that the contract is incomplete. First, the CEO cannot write a contract that specifies which project should be chosen contingent on the signal observed by the employee. This is because the signal is private and unverifiable. Second, the wage contract is also not contingent on the signal observed by the employee. This is because wage contracts are usually long term and are not renegotiated for every investment. In a bank, a trader or a loan officer makes many investment decisions, therefore it will be very costly to renegotiate the contract for each investment.

Finally, the contract is also not contingent of whether the employee chooses the safe or the risky project. This assumption can be justified by the fact that in a bank wage contracts are written before investment opportunities arrive. New investment opportunities keep arriving within banks and the CEO *ex ante* does not know which new investment opportunity will arrive and whether it will be risky or safe. For example, there are many companies in the market any of them may demand a loan. This company may be risky or safe. So, the CEO cannot write a contract contingent on whether the loan is risky or safe. Also, the risk profiles of investment portfolios in banks can change very fast. The exact risks can be hard to asses and verify given the complex nature of products such as CDOs. So, it is difficult for the CEO to write a contract contingent on the exact risk profile.

2.3 Solving the model

This model has two information frictions. The CEO does not observe the employee's signal and his effort. So we have a multi-task principal agent problem. I first consider the benchmark case where the CEO can also observe the signal but cannot observe employee's effort.

A. *Benchmark: CEO can observe the signal*

When the CEO can observe the signal, she can choose the project with higher expected profit conditional on the signal. So, in this case she only needs to incentivize the employees to exert effort. The incentive compatibility constraint for exerting effort (IC effort) is given by

$$w_2 \geq \frac{\Delta_1}{\Delta_2} w_1 + \frac{\Delta_0}{\Delta_2} w_0 + \frac{b}{\Delta_2}. \tag{2.1}$$

The cheapest wage contract which satisfies this constraint is $(0, 0, b/\Delta_2)$. This is obvious if $\Delta_1 > 0$. But when $\Delta_1 < 0$, then the MLRP ensures that w_1 is still zero for the cheapest contract (see proof of lemma 1 for details). I assume that reservation wage $\underline{u}$ is low enough such that the participation constraint of the employee is satisfied at wage $(0, 0, b/\Delta_2)$ for both type of projects.[17] So, when the CEO is able to observe the signal she will offer the benchmark wage denoted by $w^b = (0, 0, b/\Delta_2)$.

Lemma 1. *When the CEO observes the signal, she offers the contract w^b to the employee.*
Proof: See appendix.

When wage is w^b, the expected profit of the project θ is denoted by $\pi(\theta)$.[18] I assume that the expected profit for the good project is greater than safe project. For $\pi(G) > \pi(S)$, the following assumption should hold.

[17]The sufficient condition for this is $p_2^S b/\Delta_2 > \underline{u}$. This is sufficient condition because, as will be shown below, whenever risky project is preferred, $Pr(X_2|R)$ will be greater than p_2^S.
[18]$\pi(\theta) = \sum_i p_i^\theta X_i - p_2^\theta b/\Delta_2$.

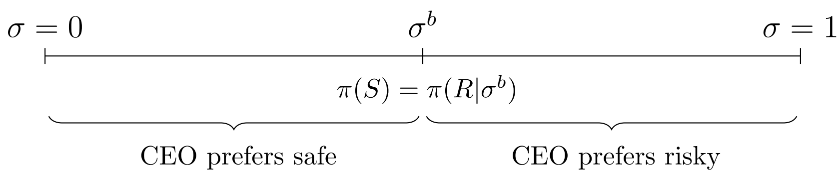


Figure 2.3: CEO's choice of project when she observes signal

Assumption 1. $X_2 - b/\Delta_2 > X_1$.

This assumption will also imply that $\pi(G) > \pi(B)$. This assumption is necessary because otherwise the CEO will always choose the safe project and the problem of project selection is irrelevant. The expected profit of the risky project for a given signal σ is denoted by $\pi(R|\sigma) = \sigma\pi(G) + (1-\sigma)\pi(B)$ and it is increasing in the signal observed by the CEO. Therefore, there will be a benchmark cutoff signal, σ^b, at which the expected profit from the safe project will be equal to the expected profit from the risky project ($\pi(S) = \pi(R|\sigma^b)$). So, the CEO will choose the risky project above σ^b and the safe project below σ^b (see figure 2.3). σ^b is given by,

$$\sigma^b = \frac{\pi(S) - \pi(B)}{\pi(G) - \pi(B)}. \tag{2.2}$$

To resolve the indifference I assume that the CEO prefers the safe project at σ^b.

Proposition 1. *If the CEO can observe the signal, then she will offer wage w^b and will choose the risky project when her signal is greater than σ^b and the safe project when her signal is less than or equal to σ^b.*

The benchmark expected profit, Π^b, is given by

$$\Pi^b = \int_0^{\sigma^b} \pi(S) d\sigma + \int_{\sigma^b}^1 \pi(R|\sigma) d\sigma. \tag{2.3}$$

I will now show that given wage w^b, the preferred project of the employee is different from that of the CEO for some values of σ. In particular, for a range of signals below σ^b, he prefers the risky project over the safe project. An implication of definition of σ^b is that at σ^b the probability of occurrence of X_2 is greater for risky project

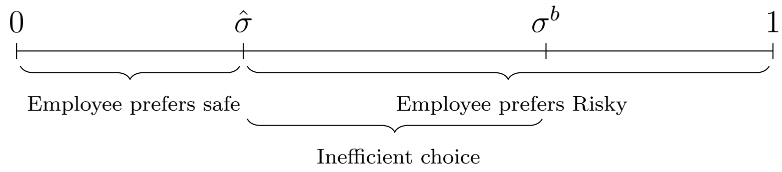


Figure 2.4: Employee's preferred project given wage w^b

than the safe project.

Lemma 2. *At the signal σ^b, $Pr(X_2|R,\sigma^b) > p_2^S$.*
Proof: See appendix.

The intuition for the lemma is simple. The probability of occurrence of X_0 is positive for risky project and zero for safe project. Since, at σ^b the expected profits are same, the higher probability of X_0 for risky project must be compensated with a higher probability on X_2. So at σ^b, the probability distribution of the profit of risky project is a mean preserving spread of probability distribution of profit of the safe project, i.e. the safe project second order stochastically dominates the risky project.

Note that $Pr(X_2|R,\sigma)$ increases with sigma.[19] For a signal below σ^b, the CEO prefers the safe project. But in the benchmark wage, the employee receives a positive wage only when X_2 occurs. So just below σ^b, he will prefer the risky project. In fact, he will prefer the risky project as long as $P(X_2|R,\sigma) > p_2^S$. I define $\hat{\sigma}$ as the signal at which the probability of X_2 is same for the two projects, i.e. $Pr(X_2|R,\hat{\sigma}) = p_2^S$. So, for $\sigma \in [\hat{\sigma}, \sigma^b]$, the employee prefers the risky project which is the inefficient project (see figure 2.4).[20] Thus there is a conflict between providing incentives for effort and choosing the higher value safe project. This is the standard risk shifting result. Next I analyze the scenario where the CEO does not observe the signal.

B. *CEO does not observe the signal*

When the CEO does not observe the signal, given that employee's preference of

[19] $Pr(X_2|R,\sigma) = \sigma p_2^G + (1-\sigma)p_2^B$ and $p_2^G > p_2^B$ because good project first order stochastically dominates the bad project. Hence $Pr(X_2|R,\sigma)$ increases with σ.

[20] To resolve indifference, I have assumed that the employee chooses the risky project when he is indifferent.

projects differs from that of the CEO's, she will need to incentivize the employee to choose the efficient project. I will show that in doing so the CEO will have to offer rent to the employee. The CEO's problem will be to optimally choose a cut off signal, $\sigma^c \in [\hat{\sigma}, \sigma^b]$, above which the employee chooses the risky project and below which he chooses the safe project. If the optimal cutoff signal is an interior solution, then the marginal benefit of efficient project choice will be equal to the marginal cost of rent extracted by the employee.

I define $p_i(\sigma^c)$ as the *ex ante* probability of occurrence of X_i given cutoff σ^c. Therefore,

$$p_i(\sigma^c) = \int_0^{\sigma^c} p_i^S d\sigma + \int_{\sigma^c}^1 (\sigma p_i^G + (1-\sigma)p_i^B) d\sigma. \tag{2.4}$$

Given wage contract w, the employee will choose a cutoff signal to maximize his expected wage. This cutoff signal is given by

$$\sigma^c \in \underset{\sigma^c}{\operatorname{argmax}} \sum_i p_i(\sigma^c) w_i. \tag{2.5}$$

The first order condition is given by

$$E[w|S] - (\sigma^c E[w|G] + (1-\sigma^c)E[w|B]) = 0. \tag{2.6}$$

This has a unique solution for a given wage contract. The term in the brackets is the expected wage from the risky project. So, at the cutoff signal the expected wage from the safe project is same as that from the risky project. The second order condition is given by

$$E[w|G] - E[w|B] > 0. \tag{2.7}$$

The second order condition implies that the expected wage from the risky project is increasing in σ so that above the optimal cut off the employee chooses the risky project.

The wage contract must also satisfy the participation constraint of the employee, that is

$$\sum_i p_i(\sigma^c) w_i \geq \underline{u}. \tag{2.8}$$

The CEO offers the wage contract w which implements the cutoff σ^c and which maximizes the expected profit, that is the CEO's objective function is

$$\max_{w,\sigma^c \in [\hat{\sigma},\sigma^b]} \sum_i p_i(\sigma^c)(X_i - w_i), \tag{2.9}$$

such that constraints (2.1), (2.6), (2.7) and (2.8) are satisfied. Recall that w^b is the wage contract which offers the minimum expected payment to the employee such that incentive for effort (equation (2.1)) is satisfied. I have also assumed that at this wage the participation constraint is satisfied (see footnote 17). So, any other contract which provides incentive for effort will also satisfy the participation constraint. Therefore, I can ignore the participation constraint of the employee (equation (2.8)).

The problem is solved in two steps. The first step is to find the cheapest contract which implements a given cutoff and also provides incentive to exert effort, i.e. it satisfies equations (2.1) and (2.6). We will see later that the cheapest contract which satisfies these two constraints will also satisfy the second order condition (equation (2.7)). The second step is to find the optimal σ^c.

The cheapest contract will have $w_0 = 0$. The reason for this is that if $w_0 > 0$, then a cheaper contract can be found which satisfies constraints (2.6) and (2.1).

Lemma 3. *The wage contract which minimizes the expected wage payment and also satisfies constraints* (2.1) *and* (2.6) *will have equation* (2.1) *as a binding constraint and* $w_0 = 0$.
Proof: See Appendix.

Given $w_0 = 0$, the IC for effort can be rewritten as

$$w_2 \geq \frac{\Delta_1}{\Delta_2} w_1 + \frac{b}{\Delta_2}. \tag{2.10}$$

The IC for cutoff σ^c, also referred to as IC Project (see figure 2.5), can be rewritten as

$$M(\sigma^c) w_1 + N(\sigma^c) w_2 = 0, \tag{2.11}$$

where

$$M(\sigma^c) = p_1^S - Pr(X_1|R,\sigma^c),$$
$$N(\sigma^c) = p_2^S - Pr(X_2|R,\sigma^c).$$

Note that $M(\sigma^c) > 0$ and $N(\sigma^c) < 0$.[21] So, equation (2.11) is a line passing through origin with a positive slope. For notational simplicity, going forward, I drop the argument σ^c from functions M and N. The cheapest contract is given by the point of intersection of equations (2.10) and (2.11) (see figure 2.5) and is denoted by

$$w_1(\sigma^c) = \frac{b/\Delta_2}{-\frac{M}{N} - \frac{\Delta_1}{\Delta_2}}, \quad w_2(\sigma^c) = w_1(\sigma^c)\frac{\Delta_1}{\Delta_2} + b/\Delta_2.$$

Comparing this wage with the benchmark wage, the expected rent extracted by the employee if the CEO incentivizes him to choose σ^c as the cutoff, $r(\sigma^c)$, can be written as

$$r(\sigma^c) = p_1(\sigma^c)w_1(\sigma^c) + p_2(\sigma^c)\frac{\Delta_1}{\Delta_2}w_1(\sigma^c). \tag{2.12}$$

The rent extracted is positive even for $\Delta_1 < 0$, because the cheapest contract which incentivizes effort is w^b which pays 0 when X_1 is realized. Any other contract which satisfies the incentive for effort will pay a higher expected wage, so the rent extracted from any other contract will be positive.

I will now show that the above wage contract also satisfies the second order condition (equation (2.7)). The slope of IC project is $-M/N$ and it can be written as[22]

$$-M/N = \frac{Pr(X_2|R,\sigma^c) - p_2^S + Pr(X_0|R,\sigma^c)}{Pr(X_2|R,\sigma^c) - p_2^S}.$$

Note that the slope is greater than 1. This implies that at the optimal contract $w_2(\sigma^c)$ must be greater than $w_1(\sigma^c)$ and hence equation (2.7) is automatically satisfied.[23] Also note that the slope $-M/N$ is decreasing in σ^c because $Pr(X_0|R,\sigma^c)$ is decreasing and $Pr(X_2|R,\sigma^c)$ is increasing in σ^c. At $\hat{\sigma}$, $N = 0$ so the slope is infinite. The decreasing slope implies that $w_1(\sigma^c)$ is increasing in σ^c.

Lemma 4. *The slope of constraint* (2.11) *decreases and* $w_1(\sigma^c)$ *increases as* σ^c *increases.*

$w_1(\sigma^c)$ is increasing in σ^c because of the following reason. As σ^c increases,

[21] This is because $p_2^S < Pr(X_2|R,\sigma^c)$ in the interval $[\hat{\sigma},\sigma^b]$. Also, $M(\sigma^c) = -N(\sigma^c) + Pr(X_0|R,\sigma^c)$. So, it is positive.

[22] $M = p_1^S - Pr(X_1|R,\sigma^c)$. Substituting $p_1^S = 1 - p_2^S$ and $Pr(X_1|R,\sigma^c) = 1 - Pr(X_2|R,\sigma^c) - Pr(X_0|R,\sigma^c)$, we get the expression.

[23] We have $w_2(\sigma^c) > w_1(\sigma^c) > w_0(\sigma^c) = 0$, therefore the wage from the good project first order stochastically dominates the wage from the bad project. Hence, $E[w|G] > E[w|B]$.

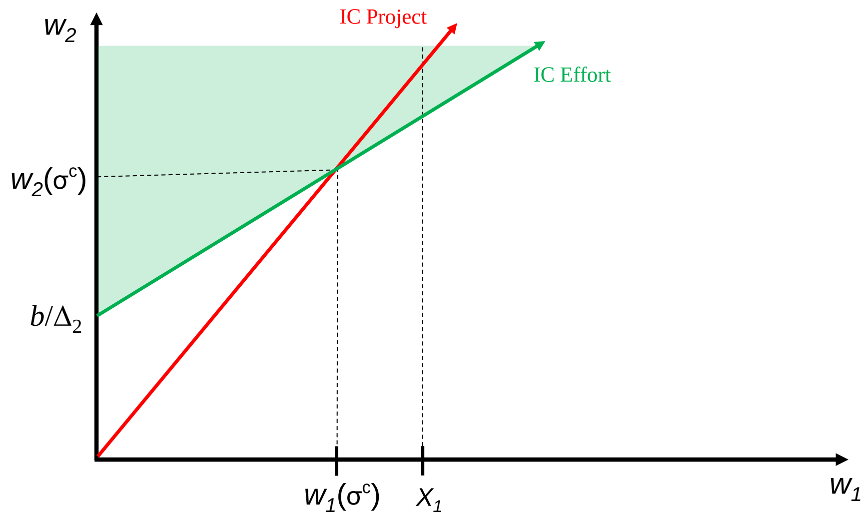


Figure 2.5: Rent extraction by employee

$Pr(X_2|\sigma^c)$ also increases. Therefore the wage w^b which pays only when X_2 is realized becomes more lucrative for risky project relative to the safe project. The safe project has higher weight on X_1 relative to risky project (since $M > 0$), therefore to compensate for the risky project becoming more lucrative, the CEO will have to increase the wage when X_1 is realized. Recall that in the benchmark case, no wage was being paid on the realization of X_1. But now the CEO is forced to pay a positive wage to incentivize employees to choose the safe project. This results in rent extraction by the employee relative to the benchmark wage.

Also note that $w_1(\sigma^c)$ may be greater than X_1 (see figure 2.6). If this is so, then the CEO will not be able to implement that σ^c as cutoff. For simplicity I assume that for all $\sigma^c \in [\hat{\sigma}, \sigma^b]$, $w_1(\sigma^c) \leq X_1$, that is the CEO can implement any cutoff. This will be true if $w_1(\sigma^b) \leq X_1$ because $w_1(\sigma^c)$ increases with σ^c (lemma 4). If this assumption does not hold true then the results will only get stronger.[24]

The CEO benefits from implementing the cutoff σ^c because now the employee chooses safe project over the risky one in the interval $[\hat{\sigma}, \sigma^c]$ where the former has

[24]This is because the CEO will be forced to maximize the profit only over that subset of $[\hat{\sigma}, \sigma^b]$ where σ^c is implementable.

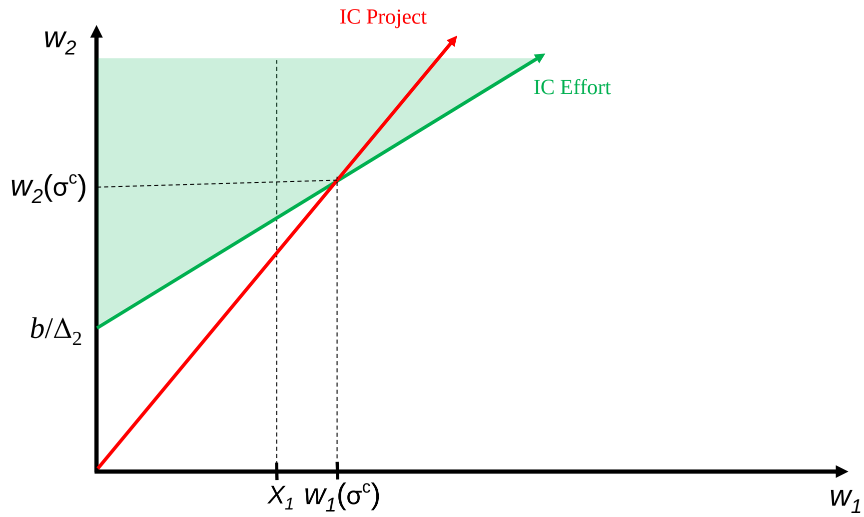


Figure 2.6: $w_1(\sigma^c) > X_1$. σ^c cannot be implemented.

higher expected profits than the latter. This benefit is given by

$$B(\sigma^c) = \int_{\hat{\sigma}}^{\sigma^c} [\pi(S) - \pi(R|\sigma)] d\sigma. \tag{2.13}$$

Now I solve for the optimal cutoff. The CEO chooses σ^c to maximize the benefit minus the rent extracted, i.e. optimal cutoff, denoted by σ^*, is given by

$$\sigma^* \in \underset{\sigma^c \in [\hat{\sigma}, \sigma^b]}{\text{argmax}} B(\sigma^c) - r(\sigma^c).$$

Since here a continuous function is maximized over a closed and bounded interval, an optimal cutoff signal, $\sigma^c = \sigma^*$, will exist. The marginal benefit $\partial B(\sigma^c)/\partial \sigma^c$ is $\pi(S) - \pi(R|\sigma)$, which is decreasing in σ^c and at the cutoff σ^b it becomes 0. The marginal cost is $\partial r(\sigma^c)/\partial \sigma^c$ is always positive (see proof of proposition 2). So, σ^b cannot be the optimal solution.

Proposition 2. *There exists an optimal $\sigma^* \in [\hat{\sigma}, \sigma^b)$ which maximizes the profit of the CEO.*

The total expected profit, Π^*, is given by

$$\Pi^* = \Pi^b - \int_{\sigma^*}^{\sigma^b} [\pi(S) - \pi(R|\sigma)] f(\sigma) d\sigma - r(\sigma^*).$$

The first term is the benchmark profit. The second term is loss in profit due to inefficient project choice in interval (σ^*, σ^b).[25] The third term is rent extracted by the employee. The inefficiency is arising because there is a conflict between giving incentives to the employee to work on the project and choosing the right project *ex ante*.

But what if the two tasks are split between two employees? Suppose the task of choosing the project is assigned to the risk manager (RM) and the task of exerting effort once the project is chosen is assigned to the trader. As in the real world, the RM may not directly choose the project, but the trader is required to get the approval of the RM before he can invest in any project. The RM has a veto power over any project chosen by the trader and thus has effective control over the choice of the project. In this case the two incentive constraints will be split and I show that more efficient outcomes can be reached. This is because once the tasks are split, the RM will not be able to extract any rents and is only paid his reservation wage. If the reservation wage is small then splitting the tasks may be a more efficient outcome. I analyze these ideas next.

C. *Splitting the tasks: Trader and Risk Manager*

Suppose there are two employees, a trader and a RM. The trader first proposes a project to the RM. The job of the RM is to approve the project that should be undertaken based on his signal (σ_{RM}) about the type of the risky project. σ_{RM} is drawn from the same probability distribution as the employee discussed earlier, i.e $\sigma_{RM} \sim U[0, 1]$. The trader then exerts effort to execute the chosen project. The reservation wage of both employees is same ($\underline{u}$).

Now, since there is no need to incentivize the trader to choose the right project, the CEO will offer him the cheapest wage contract such that he exerts effort. So the wage contract of the trader will be $w_T = w^b = (0, 0, b/\Delta_2)$.[26] If the CEO wants the RM

[25] To resolve the indifference I have assumed that the employee chooses the risky project at σ^*.

[26] Recall that the participation constraint is satisfied at this wage.

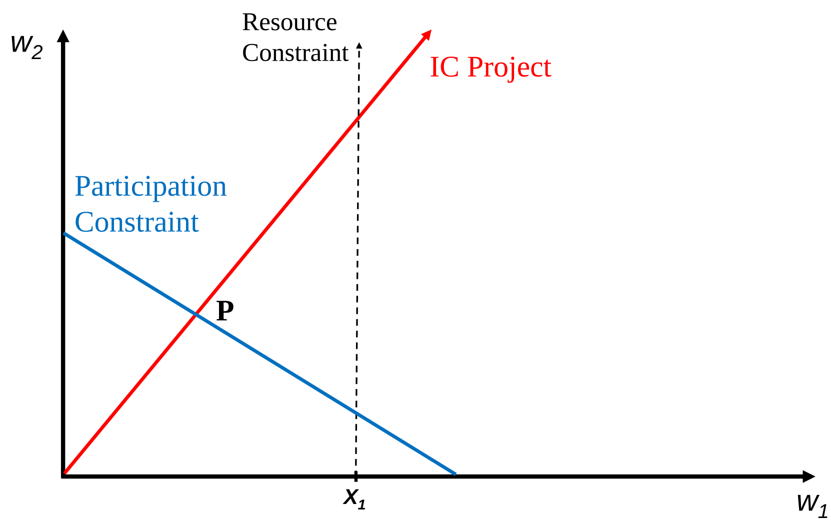


Figure 2.7: Risk Manager's contract is given by point P

to choose a particular cutoff σ^c, then his wage, $w_{RM} = (w_{0,RM}, w_{1,RM}, w_{2,RM})$, must satisfy incentive constraint (2.6) and the participation constraint (2.8). If the RM is offered zero wage when X_0 is realized i.e. $w_{0,RM} = 0$, equation (2.6) can be written as equation (2.11). This equation then has a postive slope for any $\sigma^c \in [\hat{\sigma}, \sigma^b]$ (see figure 2.7). Also, the participation constraint has a negative slope $(-p_1(\sigma^c)/p_2(\sigma^c))$. So any cutoff can be implemented by offering the RM his reservation wage. Hence the CEO will provide incentives to the RM to implement the benchmark cutoff σ^b and his expected wage payment is $\underline{u}$. Note that the exact wage is indeterminate.[27] But if $w_{0,RM} = 0$, then

$$w_{1,RM} = \frac{\underline{u}N}{p_1(\sigma^b)N - p_2(\sigma^b)M}, \quad w_{2,RM} = \frac{-\underline{u}M}{p_1(\sigma^b)N - p_2(\sigma^b)M}.$$

The expected profit, Π_{RM}, is benchmark profit minus the expected wage paid to the RM, i.e.

$$\Pi_{RM} = \Pi^b - \underline{u}. \tag{2.14}$$

[27] The IC for σ^c (equation 2.6) and participation constraint (equation 2.8) are equations of plane in three dimensional coordinate system. Their intersection is a line and not a point. Any wage on this line which satisfies the limited liability constraint and also the resource constraint can be offered to the RM.

Now comparing Π_{RM} with Π^*, it is clear that if $\underline{u}$ is low enough such that

$$\underline{u} < \int_{\sigma^*}^{\sigma^b} [\pi(S) - \pi(R|\sigma)] d\sigma + r(\sigma^*), \tag{2.15}$$

then $\Pi_{RM} > \Pi^*$. So, it is better to have a RM than directly incentivize the trader to choose the right project.

Proposition 3. *If* $\underline{u}$ *is low enough such that* (2.15) *is satisfied, it is more profitable to rely on the RM to chooses the efficient project than directly offer incentives to the trader.*

Note that having a RM not only increases the profit, but is also socially efficient. From the perspective of the social planner, the rent, $r(\sigma^*)$, is merely a transfer from the bank to the employee. But there is also a loss in efficiency because the less profitable project gets chosen in the interval $[\sigma^*, \sigma^b]$ which the social planner would not prefer. Thus, having a RM is not only profit maximizing but also increases social welfare.

The RM may not have as accurate signal as the trader. But even if the RM's signal is more noisy, it may be more efficient to rely on the him. Suppose that with probability z, the RM receives the same informative signal, but with probability $1-z$, his signal is a pure noise drawn from uniform distribution. Then a corollary of proposition 3 is that as long as z is close enough to 1, it is still better to have a RM. This will be true because any loss will be proportional to $(1 - z)$

Corollary: Having a RM is more efficient as long as z is close to 1.

D. *Discussion*

Financial institutions make investments which are information sensitive. To resolve this information problem, they delegate the task of information acquisition to their employee such as loan officers, insurance officers and traders. The process of information acquisition and the optimal actions conditional on them is dynamically determined. Making investment decisions conditional on the information available is only the first step. After the investment decisions are taken, the employees have to constantly exert effort to make those investments successful. Banks use the technology of ‘relationship lending’ (see Berger and Udell (2002)), in which the loan officers monitor their portfolio of loans and gather information about them. Traders have to exert effort to execute the trade and then monitor their portfolio so that they are able to liquidate or hedge their positions on time in case the situation deteriorates. This paper argues that there is an inherent conflict between incentivizing an employee to take the information sensitive step of deciding which investment to make and then continuously exert effort to make those investments successful.

I show that, to resolve this conflict, the banks have to rely on separate RMs to monitor their employees. RMs first get involved at the initial step in which they approve the investments. But risk management task does not stop there. They may keep monitoring the portfolio to check that their employees are taking the requisite action. For example, banks use loan review process so that they are able to monitor the loan officers (see Udell (1989)). A loan officer may receive information based on which the optimal safe decision could be to liquidate a loan early. But given his high powered contract, he may find it optimal to choose the risky option of not liquidating the loan hoping for a positive outcome in future. A loan review process would prevent such decisions. My paper thus provides an explanation for having separate agents as RMs.

In my model, the optimal contract offers the risk takers high powered incentives without worrying about their incentive to indulge in risk shifting. This provides an important insight regarding the debate on compensation contracts of bank employees which has been happening since the financial crisis. While a lot of blame has been assigned to the traders who were taking excessive risk incentivized by their high bonus contracts, there has been less focus on the role of RMs. But as per the institutional hierarchy, it is the RMs who are in charge of the investment decisions. The RMs at UBS prevented their traders from making investments in CDOs only in May of 2007 (UBS (2008)). But if they had taken this decision earlier, then the bank would have suffered much smaller losses. Since the RMs are ultimately in charge of approving the investment decisions, any blame for the crisis has to be equally shared by them or the CEOs who may have ignored the RMs’ suggestions. I turn to this issue next.

2.4 Risk Averse Risk Manager

I have shown that having a separate RM, who has a veto power over what project can be chosen is optimal. While at the lower levels of hierarchy, the RMs do enjoy a veto power, at the highest level they play more of an advisory role to the CEO and make recommendations regarding investment strategies. As mentioned in the introduction, there are numerous anecdotal evidences where the CEOs ignored their RMs particularly before the recent global financial crisis. So the question that arises is that if RMs are important, then why does the CEO ignore them when they recommend the safe investment strategy and goes ahead with the risky investment strategy? In this section, I show that if the RM is risk averse, then there will be overinvestment in the safe project. In such a case, it may not be optimal for the CEO to always agree with the RM. In particular, the CEO may be better off by occasionally ignoring the RM when he suggests the safe project. But if the RM suggests the risky project then the CEO always agrees with him.

A. Optimal contracting with risk averse risk manager when CEO doe not ignore him

To simplify the analysis I will continue to assume that the trader is risk neutral and is therefore offered benchmark wage w^b. The RM is risk averse with utility function U such that $U' > 0$, $U'' < 0$ and $U'(0)$ is infinite. His reservation utility is still denoted by $\underline{u}$. I define $\underline{w}$ as the wage which gives him his reservation utility, i.e. $U(\underline{w}) = \underline{u}$.

Now there can be two cases, $(i.)$ $X_0 \geq \underline{w}$ and $(ii.)$ $X_0 < \underline{w}$. If $X_0 > \underline{w}$, then full risk sharing is possible, that is the CEO can pay the RM a fixed wage $\underline{w}$ and ask him to choose the benchmark cutoff σ^b. Since the RM gets paid the same wage in all states, he will have no incentive to deviate. But if $X_0 < \underline{w}$, then the CEO cannot offer full risk sharing contract to the RM. In this case, the RM may be biased towards investing in the safe project. I will later argue that there may be over investment in safe project even when full sharing is possible when there are reputation concerns for the RM. I first analyze the case when full risk sharing is not possible.

Suppose the CEO offers wage contract to the RM to incentivize him to choose a cutoff σ^c. Analogous to equation (2.6), the incentive compatibility constraint to choose this cutoff can now be written as

$$E[U(w_{RM})|S] - (\sigma^c E[U(w_{RM})|G] + (1-\sigma^c)E[U(w_{RM})|B]) = 0. \tag{2.16}$$

At the cutoff the expected utility from the risky project equals the expected utility from the safe project. The second order condition is

$$E[U(w_{RM})|G] - E[U(w_{RM})|B] > 0. \tag{2.17}$$

This constraint implies that the expected utility from risky project is increasing in signal observed by the RM. If this constraint is satisfied then the first order condition (2.16) is necessary and sufficient for the RM to choose σ^c as the cutoff. I will assume that the second order condition holds true.[28] It will be true if $w_{2,RM} > w_{1,RM}$ because it implies that $E[U(w_{RM})|G] > E[U(w_{RM})|S]$, and since in any solution (2.16) is satisfied, so (2.17) must hold true.

The participation constraint can now be written as

$$\sum_i p_i(\sigma^c)U(w_{i,RM}) \geq \underline{u}. \tag{2.18}$$

The CEO's problem is to chooses w_{RM} and σ^c such that they maximize the expected profit, i.e.

$$\max_{\sigma^c, w_{RM}} \sum_i p_i(\sigma^c)(X_i - w_{RM,i}) - p_2(\sigma^c)b/\Delta_2, \tag{2.19}$$

such that constraints (2.16), (2.17) and (2.18) are satisfied.

I show that the optimal cutoff signal in this case may be greater than σ^b which implies over investment in the safe project. If the safe project has high weight on X_1, i.e. p_1^S is high, then the variance of safe project will be very low. In this case compensating the RM with the safe project will be cheaper than compensating him with the risky project. Recall that at σ^b, the expected profit from the safe and risky project when benchmark wage is paid to the trader is same, i.e. $\pi(S) = \pi(R|\sigma^b)$. So, if the CEO chooses the marginally greater cutoff than σ^b, then the marginal cost is zero but the marginal benefit is positive because compensating the RM with safer project is cheaper. Hence the CEO finds it optimal to overinvest in the safe project relative to the benchmark case and the optimal cutoff for the RM, σ^c_{RM}, is greater

[28] Similar assumption is made by Lambert (1986).

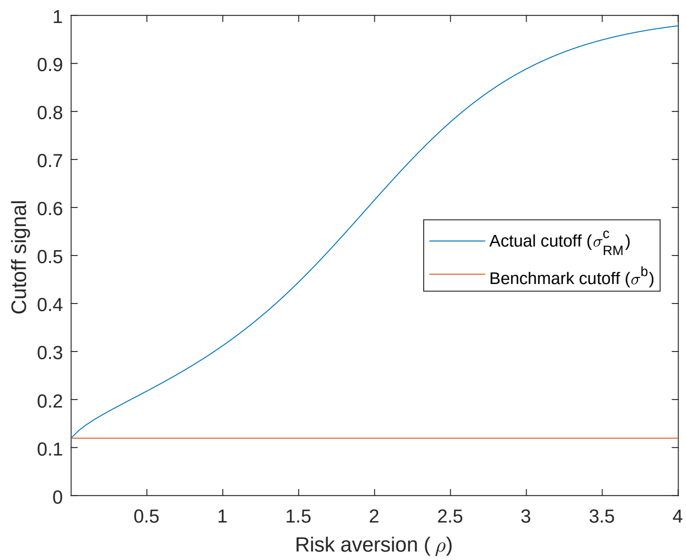


Figure 2.8: σ^c_{RM} as a function of risk aversion (ρ)

than σ^b. The next proposition summarizes this result. For the exact condition on how high p^S_1 must be to get the result, see the proof of the proposition.

Proposition 4. *If p^S_1 is large enough then the risk manager's cutoff signal $\sigma^c_{RM} > \sigma^b$.*
Proof: See Appendix.

B. An Example

Consider the following parameter values. $X_2 = 100$, $X_1 = 10$, $X_0 = 1$, $b/\Delta_2 = 40$, $p^G_2 = 0.8$, $p^G_1 = 0.2$, $p^S_2 = 0.9$, $p^S_1 = 0.1$, $p^B_2 = 0.03$, $p^B_1 = 0.75$, $p^B_0 = 0.2$. The RM has CRRA utility function $\frac{c^{1-\rho}-1}{1-\rho}$. These parameter values implies that the benchmark cutoff $\sigma^b = 0.109$. If the risk aversion (ρ) increases then it is costlier to compensate the RM with the risky project relative to the safe project. So the actual cutoff (σ^c_{RM}) will be higher. This is shown in figure 2.8. Note that when $\rho = 0$, then the actual cutoff is equal to benchmark cutoff.

C. CEO may ignore the risk manager when he suggests safe project

So far I have assumed that the CEO always agrees with the RM. I will now show that the CEO may find it optimal to ignore the RM when he suggests the safe project and instead invests in the risky project. But if the RM suggests the risky project then the CEO agrees with him. I denote by q the probability that the CEO ignores the RM whenever he suggest the safe project. Then the *ex ante* probability of occurrence of X_i depends on σ^c and q, and it is denoted by $p_i(\sigma^c, q)$ which can be expressed as

$$p_i(\sigma^c, q) = (1-q)\int_0^{\sigma^c} p_i^S d\sigma + q\int_0^{\sigma^c} Pr(X_i|R,\sigma)d\sigma + \int_{\sigma^c}^1 Pr(X_i|R,\sigma)d\sigma.$$

Analogous to (2.18), the participation constraint of the RM is

$$\sum_i p_i(\sigma^c, q)U(w_{i,RM}) \geq \underline{u}. \tag{2.20}$$

The incentive constraint to implement σ^c is same as (2.16) and second order condition is same as (2.17).[29] The CEO's objective is

$$\max_{\sigma^c, w_{RM}, q} \sum_i p_i(\sigma^c, q)(X_i - w_{RM,i}) - p_2(\sigma^c, q)b/\Delta_2, \tag{2.21}$$

such that (2.16), (2.17) and (2.20) are satisfied. The optimal q and σ^c are denoted by q^*_{RM} and σ^*_{RM}. I get the following result.

Proposition 5. *If X_2 is large relative to X_1, p_1^S is close enough to 1 and risk aversion is neither small nor large, then $q^*_{RM} > 0$.*
Proof: See appendix.

The intuition for this proposition is as following. Since p_1^S is large, so according to proposition 4, the cutoff signal when CEO does not ignore RM (σ^c_{RM}) is above first best cutoff σ^b. If X_2 is large relative to X_1 and p_1^S is large, then $\pi(G)$ is large relative to $\pi(S)$. This implies that σ^b is small (see equation (2.2)).

When the CEO ignores the RM and chooses the risky project instead of the safe project, then it is inefficient decision for $\sigma_{RM} \in [0, \sigma^b]$. So, if σ^b is small, then the cost of ignoring the RM will be small. Risk aversion has two opposing effects. First, as risk aversion increases, σ^c_{RM} also increases. So, the interval $[\sigma^b, \sigma^c_{RM}]$ in which inefficient

[29] At the cutoff the RM is indifferent between safe and risky project. This can be written as $qE[U(w)|S] + (1-q)E[U(w)|R,\sigma^c] = E[U(w)|R,\sigma^c]$ which is same as equation (2.16). Similarly the second order condition is also the same.

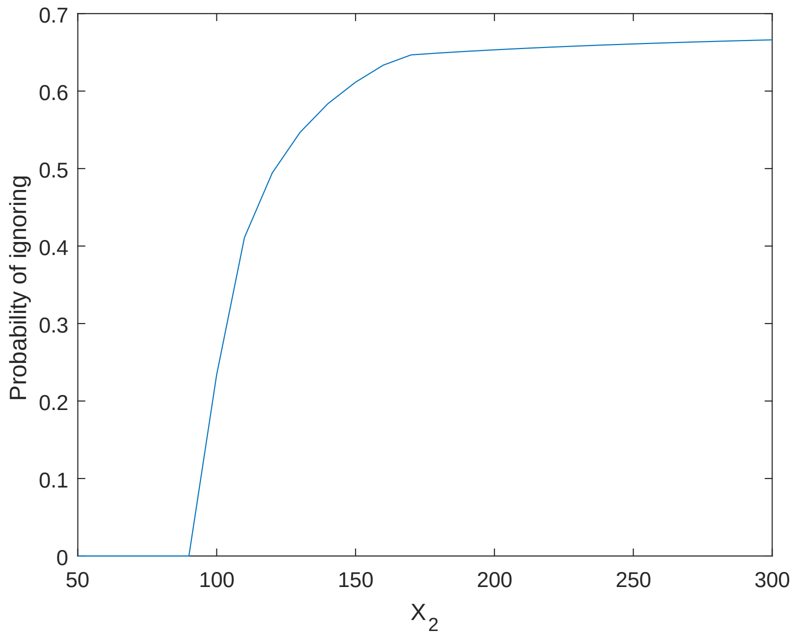


Figure 2.9: Probability of ignoring risk manager as function of X_2

safe project is recommended by the RM increases. Thus the benefit of ignoring the RM will be larger. But there is a cost of ignoring the RM as well which is that the CEO now has to compensate him with the risky project more often which is costlier for the CEO. This cost increases as risk aversion increases. So if X_2 is high relative to X_1, and risk aversion is neither very low or nor very high, then CEO will ignore the RM.

D. Example continued

Figure 2.9 shows that as X_2 increases, the probability that the CEO will ignore the RM increases. The figure has been calculated assuming $\rho = 2.5$. The CEO is effectively playing a mixed strategy, i.e. when the RM recommends the safe project she ignores his proposal with some probability and accepts with complementary probability.

Figure 2.10 shows the probability of ignoring the RM when he recommends the safe project as a function of risk aversion (ρ). When ρ is low, then the interval $[\sigma^b, \sigma^c_{RM}]$ is small as shown in figure 2.8. So, the region in which inefficient decision

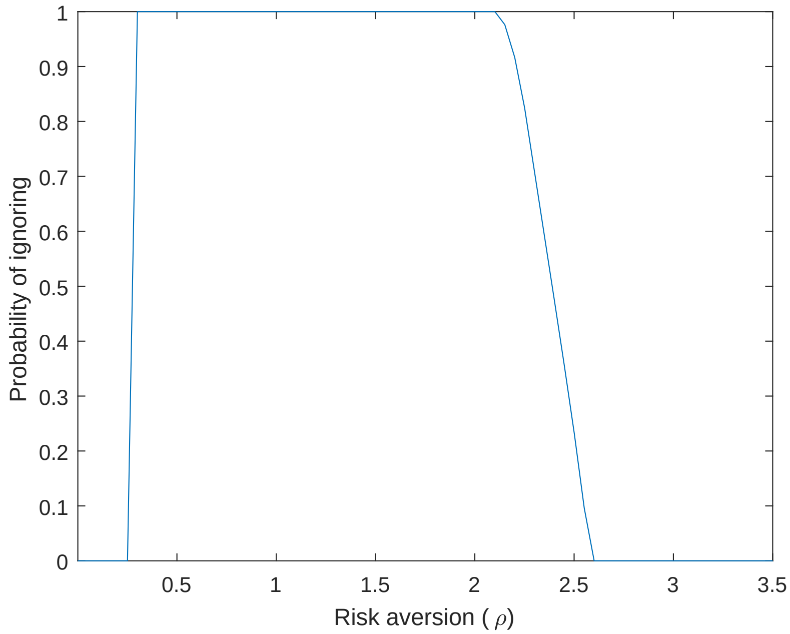


Figure 2.10: Probability of ignoring risk manager as function of ρ

is taken is small and the CEO does not find it optimal to ignore the RM and pay the extra cost of compensating him with risky project. But as ρ becomes larger CEO finds it optimal to ignore the RM. At high values of ρ, compensating the RM with risky project is very costly, so again the CEO does not ignore him.

2.5 Multiple Risk Managers and Coordination Problem

I have discussed one reason for failure of risk management, which is that the CEO may ignore the RMs when he suggests the safe project. I now discuss another reason why risk management may fail. The second reason for risk management failure may have been that the RMs in the banks may not have disclosed their information to the CEOs. Paul Moore, the ex-head of Group Regulatory Risk at HBOS, in his memorandum said:[30]

I am quite sure that many many more people in internal control func-

[30]See Moore (2009).

tions, non-executive positions, auditors, regulators who did realise that the Emperor was naked but knew if they spoke up they would be labelled "trouble makers" and "spoil sports" and would put themselves at personal risk.

The statement suggests that many people in risk management and control functions may not have come forward and warned the CEO about the risks involved in the bank's investment strategy. I extend the model where there are multiple RMs and show that there can be coordination problem in disclosure of information to the CEO even when they have been offered incentive compatible contracts to do so.

To illustrate the coordination problem I make some changes in the model. The bank now has two RMs.[31] They differ in their ability and are of two kinds, smart with probability β and incompetent with probability $(1-\beta)$. The RMs do not know whether they are smart or incompetent. Each RM privately observes a signal about the type of risky project with probability ψ_{RM} and he does not observe any signal with probability $(1-\psi_{RM})$. I assume that the signals are discrete rather than continuous. The signal can take two values, *low* (l) and *high* (h). Observing no signal is denoted by n. The smart RM observes perfectly accurate signal when he see it, i.e.

$$Pr(h|G, \text{smart sees}) = Pr(l|B, \text{smart sees}) = 1.$$

The incompetent RM observes noisy signals with accuracy $z \in (1/2, 1)$ when he sees it, i.e.

$$Pr(h|G, \text{incompetent sees}) = Pr(l|B, \text{incompetent sees}) = z.$$

The assumption $z \in (1/2, 1)$ implies that the signal seen by a RM, with the prior that he is incompetent with probability $1-\beta$, is informative as well. I will refer to the signal seen by the RM (n, h or l) as the *type* of the RM.[32] The signal observed by first (second) RM is denoted by σ_1 (σ_2).

I assume that the CEO also privately observes the signal (high or low), denoted by σ_{CEO}, with probability ψ_{CEO}, and does not observe any signal with probability $(1-\psi_{CEO})$. The CEO is always smart and like the smart RM observes perfectly accurate signal when she sees it. The CEO knows that she is smart. So when she

[31]The model can be generalized to any number of RMs.

[32]This is not to be confused with the ability of the RM. I do not refer to different abilities of the RM as his type because the risk manger does not know his ability where as in incomplete information games we assume that an agent knows his type.

observes the signal, she knows whether the risky project is good or bad. But when she does not observe any signal, then she has to rely on the signal disclosed by the RMs. After he discloses his signal, the CEO updates her beliefs about the RM being incompetent. If the RM discloses a signal opposite of that seen by the CEO, i.e. if he discloses low signal (high signal) when the CEO has seen the high signal (low signal), then the CEO is able to learn that the RM is incompetent. In this case the CEO may fire the RM. When the RMs discloses no signal, the CEO can never be sure that the RM is incompetent and may not replace him. So this provides an incentive to the RM to lie and disclose that he has not observed any signal. Hence the CEO needs to provide incentives to him to disclose the signal. I make the following assumption.

Assumption 2.

i. If the RM discloses the opposite signal as that seen by the CEO, then he is fired and does not receive any wage.

ii. If he discloses that he has not observed any signal, then he is retained.

iii. If the CEO does not observe any signal, then she does not replace the RM irrespective of the signal he discloses.

The assumption can be justified as following. There may be an expected continuation value of keeping the RM depending on the posterior belief that he is incompetent. There is also a cost of replacing him.[33] Here assumption 2 says that if the CEO is sure that the RM is incompetent, then the continuation value of keeping an incompetent RM is less than the replacement cost. On the other hand, when the CEO knows that the RM has either seen no signal or seen the opposite signal, then the posterior that he is incompetent is less than 1.[34] In this case the expected continuation value is more than the replacement cost. Similarly if the CEO does not observe any signal, then she cannot be sure that the RM is incompetent, and therefore he is not replaced.

When the CEO does not observe any signal then she has to rely on the signals of the RM. The coordination problem in disclosure of low signal will exist at high values

[33]The replacement cost could be the cost of posting an advertisement to hire a new RM or the cost of training a new RM.

[34]When the CEO observes a signal, say h (l) and she knows that the employee has either seen no signal or has seen the opposite signal l (h), then she is not sure that the employee is incompetent. The probability that he is incompetent is $(1-\beta)((1-\beta)+\beta(\frac{1-\psi_{RM}}{1-\psi_{RM}\beta}))^{-1}$.

of α. I make the following assumption on α.

Assumption 3. *α is high such that the CEO chooses the safe project only when both RMs have seen the low signal. If the CEO knows that one manager has observed low signal and the other has not observed any signal then she prefers the risky project.*

Given these assumptions it can be shown that a full separating equilibrium in which each type of employee discloses truthfully cannot exist. The reason for this is that when a RM observes the high signal, he knows that the CEO (when $\sigma_{CEO} = n$), will choose the risky project whether he discloses h or deviates and disclose n, irrespective of the signal disclosed by other employee. But if he discloses h, then there is a chance that he will get fired if the CEO observes the low signal. Thus the h type employee will never disclose.

Lemma 5. *Given assumptions 2 and 3, a separating equilibrium cannot exist.*
Proof: See appendix.

The set of equilibrium that may exist are described in table 2.2. The pair of signals observed the RMs is called a node. 'Pooling LL' is the equilibrium in which RMs disclose the low signal but not the high signal. It is a pooling equilibrium because the h type RM does not disclose and pools with the n type. Pooling NN is the equilibrium where the l type also does not disclose. Although separating equilibrium can not be implemented, Pooling LL is efficient equilibrium because the CEO takes efficient decisions regarding the project choice.[35] Pooling NN is the inefficient equilibrium because CEO invests in the risky project even when both RMs observe low signal.

Since the CEO wants to make efficient decisions, she will design contracts to implement Pooling LL. Note that in Pooling LL, CEO prefers the safe project only when both employees disclose l and not otherwise.

As in the one RM, case it can be shown using very similar analysis that his participation constraint is binding. I do not repeat the analysis again. Here I focus on another friction, that is the coordination problem in disclosure of signals, which

[35] Although these equilibria are efficient with respect to project choice, they are less efficient than the separating equilibrium because separating equilibrium will result in efficient firing of employee which does not happen in Pooling LL. For example, if an employee observes h, then he does not disclose in Pooling LL and does not get fired even when CEO observes l.

Equilibrium	Nodes	RM Disclosure	Project choice
	ll	ll	Safe
Pooling LL	lh/hl, ln/nl	ln/nl	Risky
	hh, hn/nh, nn	nn	Risky
Pooling NN	all	nn	Risky

Table 2.2: Pooling equilibrium with two employees

will exist in spite of incentive compatible contracts. I will show that whenever Pooling LL exists, Pooling NN will also exist. This is the coordination problem where multiple equilibrium can exist together.

The reason for coordination problem is that there is strategic complementarity in disclosure strategy of the employees. If assumption 3 holds, then the CEO will be convinced to choose the safe project only if both disclose l and not otherwise. If only one RM discloses then he only risks the chance of getting fired if the CEO observes h without changing her decision if she observes n. So if one employee believes that the other will not disclose then he is better off not disclosing his signal as well. Thus, whenever Pooling LL will exist Pooling NN will also exist.

Proposition 6. *Even if the CEO designs contracts to implement Pooling LL, if assumptions 2 and 3 hold, then Pooling NN will always exist alongside Pooling LL.*
Proof: See appendix.

This result is similar to Diamond and Dybvig (1983), where we also have a coordination problem in spite of having incentive compatible contracts. In their paper, there are strategic complementarities between actions of the late consumers. If one late consumer believes that the others will run on the bank then he is better off withdrawing as well resulting in the inefficient bank run equilibrium.

I have shown that for coordination problem to exist, the beliefs have to be more extreme in the sense that it requires both employees to disclose the same signal to convince the CEO to take an action. But what if the beliefs are less extreme. In that case it can be shown that coordination problem in disclosure of information may not exist. The reason is simple. If the beliefs are less extreme, then even if only one RM discloses the low signal, it will be enough to convince the CEO to choose the safe project. In that case there is no strategic complementarity in disclosure of signal because a RM does not have to rely on the disclosure strategy of the other to convince the CEO.

My paper provides an explanation for why economic booms may be followed by a crisis. During the period of economic booms, profits are high and beliefs that the current investment strategy is good is also high. In such a scenario, even when some RMs may receive signals which make them believe that the strategy may not be good, they may not disclose their information to the CEO because of coordination problem. This results in CEO having more optimistic beliefs about the investment strategy than is justified by the aggregate information of all the agents in the firm.

2.6 Wage contingent on riskiness of project

So far I have conducted all the analysis assuming that the wage is contingent only on the outcome and not on whether the risky or safe project is chosen. I will now relax this assumption. There is only one risk neutral employee and CEO offers wage contract $w^S = (w_0^S, w_1^S, w_2^S)$ when safe project is chosen and $w^R = (w_0^R, w_1^R, w_2^R)$ when risky project is chosen. The contract incentivizes the employee to choose cutoff σ^c and exert effort on the chosen project. The optimal contract will again be solved in two steps, first find the cheapest contract which implements σ^c and then find the optimal σ^c.

The incentive constraint to implement cutoff σ^c is given by

$$E[w^S] = E[w^R|\sigma^c].$$

The wages must also satisfy the incentive to exert effort which will give us equations analogous to (2.1). Recall from lemma 1 that the cheapest contract which satisfies the incentive for effort is w^b. At this wage the employee will prefer the risky project for any signal above $\hat{\sigma}$. So the optimal contract will have $w^R = w^b$ and the CEO will have to offer some rent when safe project is selected to incentivize the employee to choose the cutoff σ^c. The IC constraint can therefore be written as

$$E[w^S] = Pr(X_2|R, \sigma^c)\frac{b}{\Delta_2}.$$

Thus the rent extracted by the employee when safe project is chosen is $E[w^S] - p_2^S b/\Delta_2$, which equals $(Pr(X_2|R, \sigma^c) - p_2^S)b/\Delta_2$. This rent is paid only when safe project is chosen which happens with probability σ^c, therefore the expected rent extracted is

$$r'(\sigma^c) = \sigma^c(Pr(X_2|R, \sigma^c) - p_2^S)b/\Delta_2.$$

Note that rent extracted is clearly increasing in cutoff signal. This is lesser than rent extracted when wage contract was not contingent on projects (equation (2.12)) for two reasons. The first reason is that earlier the employee extracts rent when both safe and risky projects are chosen. The second reason is that when the risky project is chosen, the cheapest contract is not being offered to incentivize effort. So when at σ^c the expected wage from safe project equals that from risky project (equation (2.6)), a higher expected wage has to be offered for the safe project.

The optimal cutoff with one employee will maximize $B(\sigma^c) - r'(\sigma^c)$. The net loss will be much lower than before because the rent extracted is much lower. When the tasks are split, optimal cutoff σ^b can be achieved but the RM has to be paid his reservation wage $\underline{u}$. Since losses are much lower, the likelihood that the RM is optimal is lower. But if b is high, then the rent $r'(\sigma^c)$ will also be high. So, for a sufficiently high b, it may still be optimal to have a separate RM. Thus the main result may still hold true.

2.7 Extentions

I discuss two extensions of my paper. I have so far assumed that there is no effort required to acquire the signal. I relax this assumption and show that the main result of the paper, i.e separations of tasks is optimal, still holds. Next I discuss the case where the RM is concerned about his reputation regarding ability. In section 4, I showed that if the RM is risk averse and perfect risk sharing is not possible ($X_0 < \underline{w}$), then there will be overinvestment in the safe project, which will result in the CEO ignoring the suggestions of the RM. Now I will argue that when the RM is risk averse with respect to his reputation, then there can be overinvestment in the safe project even when perfect risk sharing is possible.

2.7.1 Signal acquisition requires costly effort

In the model so far, the cost of acquiring the signal has been assumed to be 0. If the signal acquisition requires costly effort, then the agents also have to be provided incentives to exert to acquire the signal. I analyze this scenario now and assume that the agents are risk neutral. I assume that effort to acquire signal, e, can take two values, i.e. $e \in \{0, 1\}$. The cost of effort for $e = 1$ equals c and is 0 otherwise. If an agent exerts effort then he observes the signal σ, otherwise he does not observe any signal. I show that as long as c is small, the main result of the paper that tasks should be separated among two agents remains unchanged.

The incentive constraint for exerting effort to acquire the signal will depend on the cutoff signal, σ^c, that the CEO wants to implement. In particular, the incentive constraint will depend on whether σ^c is greater than or less than the prior probability α (recall that $\alpha = 0.5$). The wage contract must incentivize an agent not only to acquire the signal but also to implement the cutoff σ^c, i.e. it must also satisfy equation (2.6). At the equilibrium wage, the agent prefers the risky project for signal above σ^c and safe project below σ^c. Now if $e = 0$ and therefore the agent does not observe the signal, then his belief about risky project being good is same as prior and equals α. So, if $\sigma^c > \alpha$ and if he does not exert effort, then he will prefer the safe project. The incentive to acquire the signal can then can be written as

$$\int_0^{\sigma^c} E[w|S]d\sigma + \int_{\sigma^c}^1 E[w|R,\sigma]d\sigma - c > E[w|S]. \tag{2.22}$$

The left side is the expected utility when he has observed the signal and implements a cutoff σ^c.[36] The right side is his utility if he does not exert effort to acquire signal because then he chooses the safe project.

Similarly, if $\sigma^c < \alpha$ and if he does not exert effort, then he will prefer the risky project. The incentive to acquire signal can then can be written as

$$\int_0^{\sigma^c} E[w|S]d\sigma + \int_{\sigma^c}^1 E[w|R,\sigma]d\sigma - c > \int_0^1 E[w|R,\sigma]d\sigma. \tag{2.23}$$

The left side is the expected utility when $e = 1$. The right side is his utility if he does not exert effort to acquire signal because then he chooses the risky project.

Here I only analyze the case when $\sigma^* > \alpha$. Similar analysis and result can be obtained when $\sigma^* < \alpha$.[37] Let us first consider the case when there is only one employee who is incentivized to do all three tasks—exert effort to acquire signal,

[36]The private benefit of shirking b does not appear in this equation.

[37]See online appendix for analysis of this case and for detailed proofs. The online appendix can be found at https://sites.google.com/view/kaushalendrakishore/research

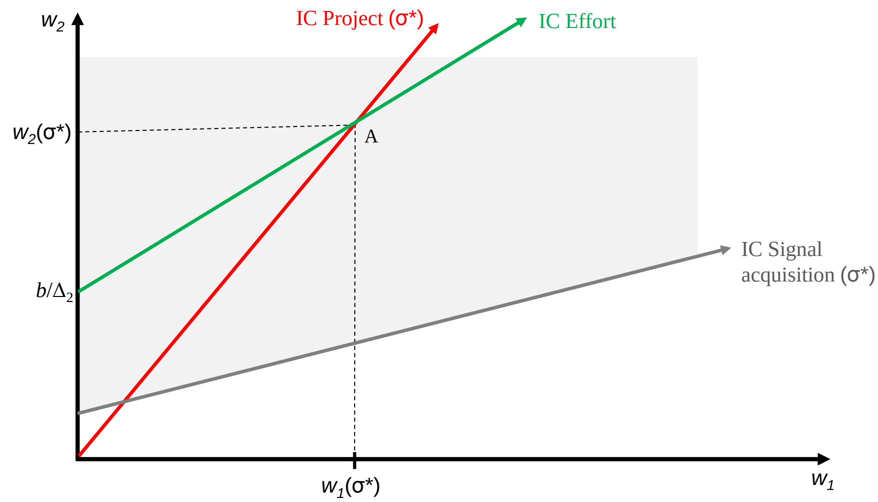


Figure 2.11: Incentive constraints for one employee with signal acquisition

choose σ^c as cutoff and then exert effort on the project. When no effort was required to acquire the signal, the optimal cutoff was σ^*. I will argue that the same cutoff will be chosen even in this case. The incentive constraint (2.22) is depicted in figure 2.11 for $\sigma^c = \sigma^*$. It can be shown that it has a positive intercept proportional to cost of effort, c, and has a positive slope which is less than the slope of IC Project. Point A in figure 2.11 is the optimal contract ($w = (0, w_1(\sigma^*), w_2(\sigma^*))$ when signal acquisition is costless. If c is small, then the intercept will be small. Therefore, point A will satisfy all the constraints. Thus the optimal contract for one employee remains the same.

When the tasks were split between two employees, optimal cutoff σ^b was achieved. Note that $\sigma^b > \sigma^*$, therefore $\sigma^b > \alpha$. Now if the tasks are split between two employees, where the RM exerts effort to acquire signal and chooses cutoff σ^b and the risk taker only exerts effort to execute the project, then again same contract will be offered and optimal cutoff is implemented. The trader has to exert effort after project is chosen, so he is offered contract w^b. The RM's contract was earlier given by point of intersection of participation constraint and IC Project (Point P in figure 2.7). This same contract is also depicted by point P in figure 2.12. Again, if c is small, this contract satisfies IC for signal acquisition.

Given that the contracts offered and the cutoff signals are same as before, the prof-

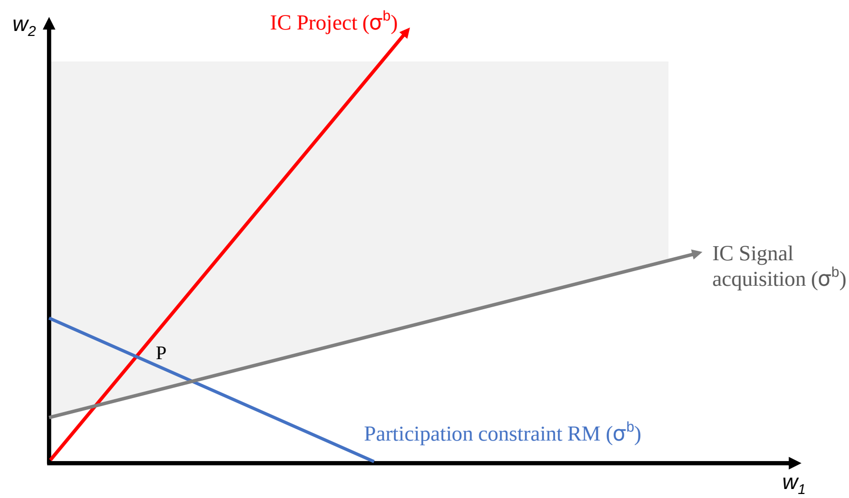


Figure 2.12: Contract of the RM with signal acquisition

its for the one employee and two employee case will also be same as before. Hence, if $\underline{u}$ is low enough such that (2.15) holds, it is profitable to separate the tasks between two employees. I summarize the result in the following proposition.

Proposition 7. *If c is small enough, then the contracts offered and the cutoff signal are unchanged when there is one employee or when there is separation of tasks between two employees. If* (2.15) *is satisfied, then it is optimal to split the tasks between two employees.*

Proof: See online appendix.

2.7.2 Risk Manager with reputation concerns

In section 4, I discussed that if perfect risk sharing is possible ($\underline{w} \leq X_0$), then the CEO can offer a fixed wage $\underline{w}$ and the employee will choose the efficient cutoff σ^b. I will now argue that if the RM is concerned about his reputation, there can be over investment in the safe project even when full risk sharing is possible. To introduce reputation concerns for the RM, I assume that he can be of two types. As discussed in the last section, he can either be smart (probability β) or incompetent (probability $(1-\beta)$). After the RM makes his suggestion and return X is realized, the CEO updates her belief about the RM being smart. This posterior belief is denoted by β'. I assume that the RM's utility function is $U(w) + V(\beta')$, where both U and V are strictly increasing and strictly concave.

If investment is made in the safe project, then the CEO's posterior belief remains same as β. This is because the safe project is information insensitive. But if the risky project is chosen, then she will revise her belief about the RM being incompetent after X is realized. So β' will depend on X. The expected value of β' is β and therefore by Jensen's inequality $E[V(\beta')] < V(\beta)$. So if CEO offers a fixed wage to the RM, then he will always recommend the safe project. Hence it becomes necessary to expose the RM to some 'wage risk' to incentivize him to recommend the right project and in equilibrium there will again be over investment in the safe project. Given this over investment, the CEO will again find it optimal to occasionally ignore the RM when he suggests the safe project.

2.8 Conclusion

In this paper, I provide an argument for existence of separate RMs. In a multi-task principal agent problem, I show that incentivizing the same employee to do the task of choosing the right project and also exerting effort is not efficient. Instead it is better to split the tasks between two employees and this gives rise to an institutional structure where one employee is only incentivized to exert effort and the other is responsible for ensuring that the right project gets chosen.

The key driving force behind the results is that the contracts are incomplete, i.e. it cannot be contingent on the riskiness of the projects or the signal observed by the employee. This assumption makes my paper particularly suited to financial institutions. The institution of a separate risk management team which has veto power over which projects get selected is very particular to financial firms. In a non financial firm risk profile of investments do not change very fast. For example, once a factory is set up, day to day management of the factory may not affect its cash flow variance significantly. So, there is no need for a separate RM to monitor daily activities of the person in charge of the factory. Thus my paper explains why banks in particular have separate risk management teams.

I also show that if the RM is risk averse, then the CEO may rationally ignore him if he suggests the safe project. There is a debate going on about whether the RM should report to the board of directors or the CEO. If the CEO is better informed than the board of directors about, say, the probability distribution of the cash flow of the projects, or the risk aversion of the RM, then it is better to allow the RM to report to her rather than to the board. The CEO will be in a better position to know when to ignore him. In summary, my paper presents a simple model to develop a theory of job design within banks.

Chapter 3

Credit Insurance, Bailout and Systemic Risk

3.1 Introduction

The financial crisis of 2007 was preceded by financial institutions making large investments in real estate sector, considerable portions of which were hedged by buying credit default swaps (CDS). AIG alone had CDS worth \$533 billion (notional amount) outstanding at the end of 2007. When the crisis started, AIG was unable to meet its obligation and was bailed out, receiving a bailout of worth over \$182 billion.[1] The reason AIG was bailed out was that it was considered a systemically important institution. Donald L Kohn, Vice Chairman of the Board of Governors of the US Fed, in his testimony said:

> The failure of AIG would impose unnecessary and burdensome losses on many individuals, households and businesses, disrupt financial markets, and greatly increase fear and uncertainty about the viability of our financial institutions.

While AIG was effectively nationalized with the government taking a 79.9% equity stake in it, the benefit of its bailout was mostly enjoyed by its counterparties. For example, Goldman Sachs received \$12.9 billion, Société Générale received \$11.9 billion, and so on.[2] So, effectively the banks which would have suffered large losses,

[1]For a detailed discussion on failure and subsequent bailout of AIG, see Harrington (2009) and McDonald and Paulson (2015).

[2]For a complete list of counterparties and the amount they received, see Harrington (2009).

had AIG gone bankrupt, got the benefit of the bailout.

It is well understood that systemically important firms under the expectation of bailout may indulge in excessive risk taking. But in our example, it is the counterparties who got the main benefit from the bailout. So the question that arises is what is the impact of expectations of such bailouts on the investment strategies of the counterparty banks. Also, why did AIG not have enough funds to meet its obligations once the crisis hit, i.e. why were the CDS contracts under priced? Apart from writing CDS contracts, AIG had also made large investments in the real state sector. At the end of year 2007, AIG had an investment of $85 billion in residential mortgage backed securities. The question is why did AIG double down on its long positions in real state which it had taken by writing CDS contracts instead of diversifying its risk?

In this paper, I show that expectations of such a bailout may lead banks to make investments in the same industry, i.e. they make correlated investments and thus create systemic risk. I build a model where correlated investments by banks, underpriced credit insurance contracts and a systemically important insurance firm, which needs to be bailed out in bad states, arise endogenously. In order to get the benefit of the bailout, banks want their assets to perform poorly *exactly* at the time when the bailout of credit insurance firm is occurring. If their assets are performing poorly at the time of bailout, then payment is due on the CDSs, and so the insurance firm uses the bailout money to pay the banks. Which ever bank's assets are performing well will not be able to get the benefit of the bailout. Since all banks want to benefit from the bailout, they all want their assets to performs poorly exactly at the time the bailout is occurring, and so the banks make correlated investments *ex ante*.

Given that the banks are making correlated investments, there will be aggregate risks. I show that the banks will only hedge the idiosyncratic risks for the good aggregate state when assets of few banks may perform poorly, and hence the insurance premium will be low. This premium will not be enough to insure them in the bad aggregate state when assets of many banks will have poor performance and so, the insurance firm will not be able to meet its obligations and will announce bankruptcy. The depositors of the banks do not observe the asset returns and hence do not know which banks' assets have defaulted. So, they will run on all the banks and withdraw their deposits. All banks, including the solvent ones whose assets have not defaulted, will be forced to sell the fraction of assets which are maturing late to outside investors. The price of the assets will be very low because of a large adverse selection discount owing to the bad aggregate state. If the sale price is low enough, then even the solvent banks will not be able to meet its depositor's demands and all banks will fail. This will force the regulator to bailout the insurance firm and the banks enjoy the benefit of bailout. The banks' *ex ante* profits are higher because they are able to insure themselves for both states even by writing cheap insurance contracts. Thus, my paper shows that expectations of bailout of a systemically important firm may result in the entire system indulging in moral hazard by making correlated investments and underpricing the risks.

In a financial crisis, there is a systemic run on the banks.[3] Failure of a systemic firm like AIG which is insuring the assets of banks would exacerbate this run and result in failure of not only insolvent but even solvent banks. Bailing out AIG helped all counterparty banks, irrespective of their solvency position. The important thing to note is that this policy is imperfectly targeted. A more targeted policy would allow the regulator to sell failed banks to solvent banks as in case of LTCM or Bear Sterns. Such a targeted policy would create an *ex ante* incentive for the banks to survive when a crisis is occurring to be able to buy assets at fire sale price. But an imperfectly targeted policy such as bailout of AIG implies that there is no benefit of performing well when others are performing poorly. In fact by performing well, they will only miss out on the benefit of bailout. This creates strategic complementarities in the investment strategies of the banks and results in them making correlated investments.

There are three main ingredients which drive my results. First, I assume that even the regulator cannot observe the asset returns. If he is able to observe the asset returns then he can act as a lender of last resort to the banks who are solvent and allow the insolvent banks to fail. These failed banks can then be sold to the successful banks at cash-in-market-prices.[4] The successful banks would gain and this will create an incentive to survive when the others are failing and so banks would make uncorrelated investments. The second ingredient is that assets do no mature together. If all assets matured together, then the banks whose assets do not default would not fail as there in no scope of a run. Failed banks can again be sold to successful ones and this would incentivize banks to make uncorrelated investments *ex ante*.

[3]See, for example, Gorton and Metrick (2012).

[4]Other papers where similar policy is adopted for resolution of banks failure are Acharya and Yorulmazer (2007a,b). For more on bank closure policies, see, for example, Mailath and Mester (1994), Freixas (1999), Santomero and Hoffman (1996), Kasa et al. (1999), among others.

The third friction which drives my result is that the regulator's policy is time inconsistent (similar to Kydland and Prescott (1977)). If the regulator can commit that he will not bailout the insurance firm even if its bankruptcy results in a systemic failure of banks, then the banks will not make correlated investments and under insure their risk. But the regulator cannot stick to this commitment once the crisis hits.

Next, I analyze policies which can mitigate this problem. I show that the problem of creation of systemic risk can be resolved by putting a cap on the notional value of assets that a single firm can insure. This cap will imply that there are many insurance firms in the market, none of which is systemically important. If the banks still make correlated investments and under insure their risks, then the regulator can bailout a few insurance firms. The counterparty banks of these insurance firms can then buy assets at fire sale prices and this will create an incentive to *ex ante* invest in uncorrelated assets.

Finally, I show that if the insurer can also choose an industry to invest its premium collected (in the benchmark model it can only invest in cash assets), it will invest in the same industry as the banks. Banks do not want to fail in the good aggregate state because there will be no bailout. So, they write the contract with a premium such that if the investment by insurer performs poorly, even then they are covered. So, when the insurer's investment performs well, it has some surplus left and earns positive profits. To maximize its expected profit, the insurer wants to maximize the probability that its assets perform well when the banks are in good state. This will happen if the bank invests in the same industry, because when the industry is in good state then it is more likely that the insurer's asset also performs well. The insurer does not care about the bad aggregate state because it will be bailed out irrespective of the industry it chooses to invest in. Thus my paper explains why AIG chose to invest in real estate sector, the very sector it had written insurance contracts on. If the sector had performed well, it would have made large profits, else it would be bailed out as was the case.

3.1.1 Related Literature

The fact that expectations of bailout of too-big-to-fail or too-systemic-to-fail institutions can result in excessive risk taking is well known. Several papers starting from

Bagehot (1873) have pointed this out.[5] The purpose of this paper is to study how expectations of bailout of a firm which has written insurance contract for other banks, and hence has become systemically important, will affect the investment strategy of the banks.

My paper is related to several strands of literature. First it contributes to the literature on systemic risk. In my paper systemic risk arises because banks make correlated investments and then write CDS contracts with a firm which becomes systemically important.[6] A recent related paper is Farhi and Tirole (2012) in which the regulator reduces the interest rate once the crisis hits to increase the size of the investments made by the banks. Reduction of interest rate being an imperfectly targeted policy leads the banks to engage in collective maturity mismatch and make correlated investments so that they get the benefit of reduced interest rates. In my paper the imperfectly targeted strategy which creates incentives to make correlated investment is bailing out the insurance firm to save the banks.

Acharya and Yorulmazer (2007a,b) also present a model where banks make correlated investments. In their paper, when many banks fail together, regulator is forced to bailout the banks and he cannot dilute their equity because of moral hazard. If only a few banks fail then they can be sold to surviving banks. My paper is similar in spirit, but the driving force is that regulators cannot observe the returns of the banks and hence cannot distinguish between solvent banks who are failing because of a run and insolvent banks. To prevent the run it is forced to bailout the insurance firm which allows even the insolvent banks to survive.

Acharya (2009) also shows that banks may make correlated investments because of limited liability and negative pecuniary externality of one bank's failure on other banks. Other models of bank herding include Rajan (1994) which relies on reputation concerns and Acharya and Yorulmazer (2008) which relies on information contagion.

While the purpose of credit insurance is risk sharing, in my paper credit insurance also results in creation of systemic risk. Allen and Carletti (2006) present another model where credit risk transfer can result in contagion between the banking sector and insurance sector and can be detrimental to welfare. The contagion happens

[5]For surveys on too-big-to-fail-problem, see Stern and Feldman (2004) and Strahan (2013). Rajan (2009) discusses the too-systemic-to-fail problem.

[6]There are may reasons why systemic risk can arise. One reason could be some form of contagion among banks, where one bank's failure can result in failure of other banks (Allen and Gale (2000), Freixas et al. (2000)). For survey on systemic risk, see, for example, De Bandt and Hartmann (2000), Bisias et al. (2012), Freixas et al. (2015).

because the banks and the insurance firms invest in the same long term asset. During bad states, these assets are sold at low prices due to cash-in-market-pricing affecting both banking and insurance sectors. Wagner and Marsh (2006) study credit risk transfer between banking and non-banking sector and examine conditions under which efficiency in credit risk transfer markets can reduce financial stability.

There is large literature which highlights how an insured party can indulge in moral hazard when they insure themselves by writing financial contracts.[7] Campello and Matta (2012) show that CDS contracts can lead to risk-shifting by banks. Credit insurance can also affect the bank's incentives to monitor the loans (see Morrison (2005), Parlour and Winton (2013)).[8] Bolton and Oehmke (2011) show that banks have lower incentive to renegotiate the loans after writing CDS contracts because their outside option is higher and this results in excessive liquidation and increases inefficiency. Unlike these papers which study moral hazard by individual banks, my paper studies how banks indulge in collective moral hazard by making correlated investments.

Counterparty risk has become an important concern after the crisis of 2007. There are some recent papers which study moral hazard by insuring agents which generates counterparty risk. Thompson (2010) builds a model where counterparty risk leads insured party to reveal information even in absence of a signaling device.[9] In Biais et al. (2016), the insuring party after observing poor signals can indulge in gambling for resurrection creating counterparty risk and limiting the benefits of risk sharing. In my paper, the counterparty risk is created not because of moral hazard problem on the side of the insurer but because of collective moral hazard on behalf of the banks who write underpriced insurance contracts with competitive insurers. The low premium in underpriced contracts is not enough to cover the bad state and results in counterparty risk.

The rest of the paper is organized as following. Section 2 discusses the model framework. In section 3, I analyze the model and present the main results. Section 4 discusses the policy implications. Section 5 discusses the investment strategy of the insurer. Section 6 concludes.

[7]For a survey on CDS, see Augustin et al. (2014).

[8]For discussion on use of loan sales as credit risk transfer and its subsequent impact on bank's incentives, see Pennacchi (1988), Gorton and Metrick (2012), Parlour and Plantin (2008), among others.

[9]See, also, Stephens and Thompson (2014, 2017).

3.2 Model

Consider an economy which has a continuum of banks (normalized to 1), depositors, insurance firms, outside investors and a regulator. All agents in the economy are risk neutral. There are two dates, $t = 0$ and 1. At $t = 0$ each depositor is assumed to receive an endowment of 1 unit and their outside option is storage technology which yields a return of 1 per unit of investment. In other words risk free interest rate is normalized to 1.

The banks can borrow from competitive depositors to invest in a risky asset which requires one unit of investment. The asset can be a portfolio of loans in an industry. It returns R when successful and L when it fails. For simplicity, I assume that $L = 0$. I will consider two cases regarding the maturity of the asset. In the benchmark case all assets will mature at the same time at $t = 1$. In the second case, all assets do not mature together, and rather a fraction $\gamma = 1/2$ of the assets mature at $t = 1$ and the remaining $1 - \gamma$ fraction of assets mature a little later at $t = 1 + \epsilon$ (see figure 3.1).[10] This case is more realistic as banks invest in long term assets. As we will see later, if the assets mature together at $t = 1$, then there will be no possibility of run on the banking system.

There are infinitely many industries and each bank can invest in one of them. An industry can be in good state with probability q or bad state with probability $1 - q$ (see figure 3.2). If the industry is in good state, then the probability that the asset succeeds and yields R is α, while if the industry is in bad state, then the probability that the asset succeeds is β. I assume that $\alpha > \beta$. Thus there is an idiosyncratic risk within each industry.

Given our technology, if all banks invest in the same industry, i.e. the correlation denoted by ρ, equals 1, then there are two aggregate states, good and bad. Note that $\rho = 1$ is used to denote investment in the same industry, but this does not necessarily imply that all banks have the same return because there is idiosyncratic risk within each industry. In good state α banks succeed and in bad state β banks succeed. But if the banks invest in different industries ($\rho = 0$), then there is only one aggregate state in which ω banks succeed, where $\omega = q\alpha + (1 - q)\beta$.

The contract between banks and depositors takes the form of a simple debt contract which matures at $t = 1$ irrespective of whether the assets mature together or

[10] I have assumed $\gamma = 1/2$ to economize on the notations. The results can be generalized to any value of $\gamma < 1$.

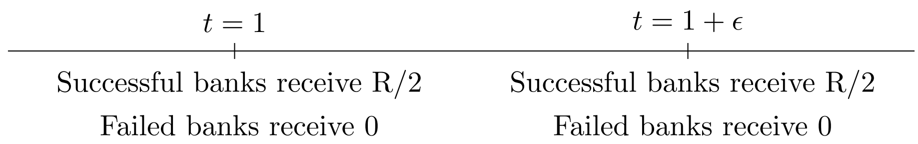


Figure 3.1: Half of assets mature at $t = 1$ and remaining at $t = 1 + \epsilon$

not. In the case where assets do not mature together, depositors can roll over this debt to $t = 1 + \epsilon$. The assumption of short term debt which matures before all assets do (at $t = 1 + \epsilon$) is necessary to create a run on the banks. While in this paper I assume short term debt to be exogenously given, there is large literature which provides explanation for why banks finance themselves with short term or demandable debt.[11] The face value of debt is denoted by D. Banks are generally financed with a mixture of insured and uninsured creditors. In this paper, I carry out the analysis assuming that the depositors are uninsured. The model can be extended to the case where some part of depositors are insured. For simplicity I also assume that there is no equity.[12]

If the asset succeeds, then the bank can pay off the creditors and continue their operation. I assume that there is a continuation value of the bank which is denoted by V.[13] If the asset fails, then the bank cannot pay its creditors and goes bankrupt in which case it looses its continuation value.

3.3 Model analysis

Banks make investments in an industry and decide whether to write a credit insurance contract in order to maximize their expected profit. I solve the model backwards. First I solve for banks' profits taking as given the correlation of the banks investments. There after I analyze what correlation the banks will choose ex ante. There are four scenarios to consider (see table 3.1). These scenarios correspond $\rho \in \{0, 1\}$ and assets maturing together (benchmark case) and not maturing together. The expected profit

[11]See, for example, Diamond and Dybvig (1983), Calomiris and Kahn (1991), Diamond and Rajan (2000, 2001), Brunnermeier and Oehmke (2013), among others.

[12]This assumption is to keep the model simple and to also highlight that equity can be costly to raise because of asymmetric information (Myers and Majluf (1984)).

[13]V can be easily endogenized. For example, I can assume that after paying the creditors, the banks can invest again by borrowing from depositors.

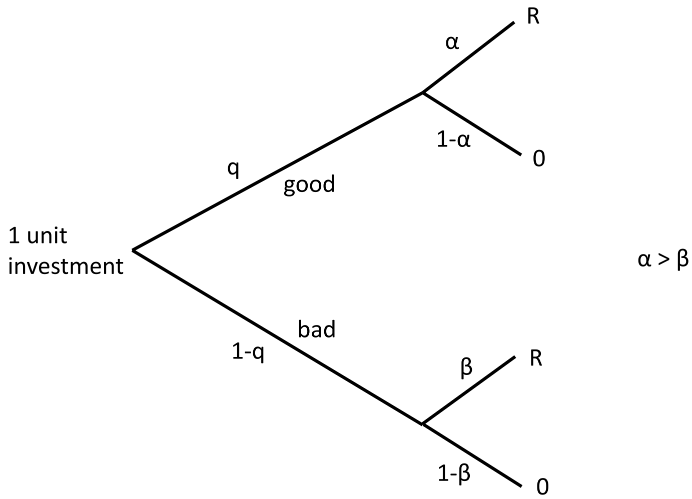


Figure 3.2: Asset returns

	Mature together	Do not mature together
$\rho = 0$	$\Pi_{\rho=0,T}$	$\Pi_{\rho=0,NT}$
$\rho = 1$	$\Pi_{\rho=1,T}$	$\Pi_{\rho=1,NT}$

Table 3.1: 4 scenarios corresponding to $\rho \in \{0, 1\}$ and assets maturing or not maturing together

of the bank is denoted $\Pi_{\rho,m}$. The subscript $m \in \{T, NT\}$, where $m = T$ denotes the case where assets mature *together* while $m = NT$ denotes *not together*. The subscript ρ denotes the correlation of banks assets.

I will show that if assets mature together, then banks will invest in different industries ($\rho = 0$) and investing in the same industry cannot be an equilibrium. But if the assets do not mature together then, the banks will prefer to invest in the same industry and write underpriced credit insurance contracts. I first analyze the case where $\rho = 0$, and the assets mature together at $t = 1$.

3.3.1 Banks invest in different industries and assets mature together

Let us first consider the scenario when the banks do not purchase any credit insurance. Since $\rho = 0$, ω banks' assets will succeed and $1-\omega$ banks' assets will fail. A bank with failed assets cannot pay off its depositors. I also assume that the failing bank cannot raise capital against its continuation value. This assumption will be particularly true when there is a run on the banks and the capital market may be rife with information frictions. Other reason that banks cannot raise money could be that their depositors do not have enough capital at $t = 1$.[14] Thus, when the bank's assets fail, then the bank is in default and its continuation value will be lost. To avoid failure, banks may want to write credit insurance contracts with insurers which will be discussed later.

The regulator's objective is to maximize the social surplus and so, to prevent the continuation value from being lost, it will take over the banks in the event of bankruptcy. The regulator will then try to sell the failed bank to the successful banks, who in turn pay off the depositors of the failed banks and continue the operations. Thus the net worth of each of the failed banks is $V - D$, that is the continuation value minus the amount thats needs to be paid to the existing depositors before the bank can resume operations.

The liquidity available with each successful bank is $R - D$. So, the total available liquidity with all banks is $\omega(R - D)$. The total liability of all the failed banks is $(1 - \omega)D$. If the total liquidity available is large enough such that the successful banks can pay off all the depositors of failed banks, then the regulator can sell all the failed banks to successful ones at a positive price for each unit of bank. I assume that this is the case, which means that the depositors always get paid. They are paid either directly if their bank succeeds or if their banks fail, then they are paid indirectly by the successful banks who purchase their failed bank. Therefore the face value of debt, D, equals 1. So, I am assuming that

$$\omega(R - 1) > (1 - \omega).$$

I also assume that the fair value of each failed bank is greater than 0, i.e. $V - 1 > 0$, which implies that the successful banks will be interested in buying the failed banks.

The price at which the failed banks are sold will depend on the total liquidity available with the successful banks. To buy the banks at fair price of $V - 1$, the total liquidity available should be at least $(1 - \omega)V$ because $(1 - \omega)(V - 1)$ is needed to buy the banks at fair price and $(1 - \omega)$ is needed to pay their depositors. So, if the available liquidity is less than $(1 - \omega)V$, then the failed banks will not be bought at

[14]Similar assumption is made by Acharya and Yorulmazer (2007a).

fair price and there will be "cash-in-market-pricing."[15] The price of each unit of failed bank will be

$$p = \frac{\omega(R-1) - (1-\omega)}{(1-\omega)}.$$

The numerator is cash available after paying the depositors and the denominator is the number of banks being sold. When there is cash-in-market pricing, then the successful banks will make a positive profit of $V - 1 - p$ for each unit of bank they buy. To summarize, the price is given by (also see figure 3.3):

$$p = \begin{cases} \frac{\omega(R-1)-(1-\omega)}{(1-\omega)}, & \text{if } (1-\omega) \leq \omega(R-1) < (1-\omega)V. \\ V-1, & \text{if } (1-\omega)V \leq \omega(R-1). \end{cases} \tag{3.1}$$

To keep the discussion succinct, I assume is that there is enough liquidity to purchase the failed banks at fair price and then pay the depositors in full.

Assumption 1. $\omega(R-1) \geq (1-\omega)V$.

When the banks succeed, which happens with probability ω, their expected profit is equal to $R-1+V$. Note that since the failed banks have been bought at fair price, they do not add to the profits of the successful banks. If the banks fail, then they get zero utility. So the bank's *ex ante* expected utility is

$$\omega(R-1+V). \tag{3.2}$$

Now let us consider the case when banks buy credit insurance. I assume that there are two insurance firms and they simultaneously offer credit insurance contracts to the banks. These insurance firms compete à la Bertrand and therefore they will charge an insurance premium which will earn them zero profits. The banks then sign the contract with one of the insurance firms.[16] Suppose that the banks fully insure their investment, i.e. they insure up to amount R. Since $(1-\omega)$ banks will fail, the insurance firm will charge a premium denoted by z, where z equals $(1-\omega)R$. Hence, in this case banks will raise $1+z$ from the depositors to finance their investment and

[15]For cash-in-market-pricing, Allen and Gale (1994, 1998, 2005).

[16]I assume that all banks sign the contract with the same firm because this may give benefits of diversification. While, there is no benefit of diversification if there are a continuum of banks as we have considered, if there are only a few discrete number of banks then benefits of diversification may be significant.

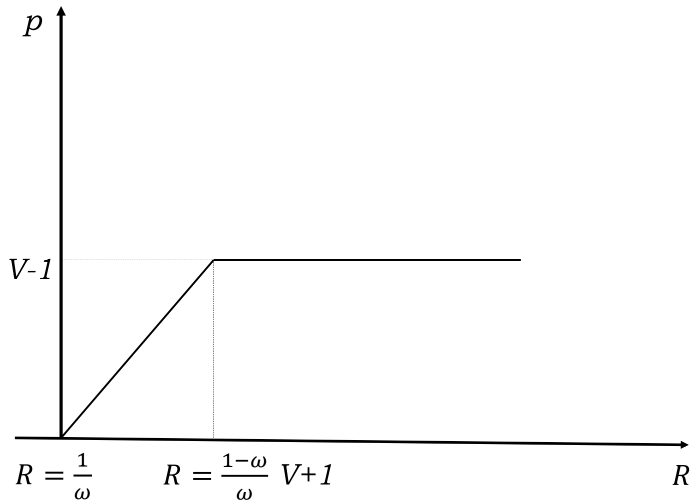


Figure 3.3: Price as function of R

also pay for the insurance premium. Since the debt is safe, so the face value D will equal $1 + z$. The banks may equally well have insured only up to the face value of debt and the result will be identical.[17]

When the banks buy credit insurance, they are always able to pay their depositors and then also obtain their continuation value. So, their expected profit is $R - D + V$, which equals

$$\Pi_{\rho=0,T} = \omega R - 1 + V. \tag{3.3}$$

Thus, the banks utility is the net present value (NPV) of the project $(\omega R - 1)$ plus the continuation value. The difference between the *ex ante* expected profits with and without credit insurance is

$$(1 - \omega)(V - 1). \tag{3.4}$$

This term equals the profits transfered to the regulator to buy the failed banks when banks do not buy the insurance.[18] Recall that when there was no insurance, the $(1 - \omega)$ failed banks were sold at the fair price of $V - 1$. So, the amount$(1 - \omega)(V - 1)$

[17]If the banks insure only up to their face value of debt, then z would be $(1 - \omega)D$. Since the debt is safe the face value of debt will be equal to $1 + z$. So $D = 1/\omega$ and $z = 1/\omega - 1$. Any level of insurance between face value of debt and R will result in the same expected profit.

[18]If assumption 1 does not hold and there is cash-in-the-market pricing then the profit transfer will be $(1 - \omega)p = \omega R - 1 - (1 - \omega)$.

is transfered to the regulator. Thus the banks are better off with credit insurance. If they do not have insurance, then the regulator is able to expropriate part of their profits.

Remark 1: In practice there are many ways in which the regulator may be able to expropriate some value from the banks. For example he may inject equity into the failed banks and take direct ownership. Even if the regulator does not take direct ownership of the bank and sell it to other banks, he can still expropriate some profits. For example, if there has been a run on a bank then the regulator may buy assets at prices below fair value to provide liquidity to the bank. Even if a bank may directly sell itself to other banks without intervention of the regulator preventing any transfer to him, still there may be other reasons to buy credit insurance to prevent bankruptcy. There may be dead weight loss if a bank goes bankrupt. This can be modeled by assuming that the continuation value of the bank is bank specific.[19] To prevent this dead weight loss, the banks may write credit insurance contracts.

Credit insurance prevents the banks from failing. But the banks have to pay a premium for insurance. I now discuss if the banks can rely on the bailout of insurance firm to prevent themselves from failing. If the regulator will bail out the insurance firm then the benefit to the banks will be that they only have to write an insurance contract with the insurer and pay no or lesser premium.

Let us consider the scenario when the banks only write insurance contract with the insurer with 0 premium and rely on bailout of the insurer. At $t = 1$, assets of $1 - \omega$ banks will fail and they will demand payment from the insurer. Since the insurer has no money, he will declare a bankruptcy. If the regulator does not bailout the insurer then $(1 - \omega)$ banks will fail. As before, the regulator can sell these banks to the successful ones. Hence the regulator has no incentive to bailout the insurance firm. This scenario is same as if the banks had written no credit insurance. Hence the banks cannot rely on the regulator for bailout. Similar analysis will follow if we consider any premium which is greater than 0 but is less than $(1 - \omega)R$. The above discussion is summarized in the following proposition.

Proposition 1. *If assumption 1 holds, assets mature together ($m = T$) and the banks*

[19] Similar assumption is made by Acharya et al. (2012).

invest in different industries ($\rho = 0$), then

i. *the banks prefer to buy fairly priced credit insurance with $z = (1-\omega)R$. In this case, the expected profit of the banks is $\Pi_{\rho=0,T} = \omega R - 1 + V$.*

ii. *if they do not buy credit insurance, then their ex ante expected profit is $\omega(R-1-V)$ and the regulator is able to expropriate $\omega(V-1)$*

3.3.2 Banks invest in different industries and assets do not mature together

I now discuss the case when banks invest in different industries, i.e. $\rho = 0$, and the assets do not mature together. Let us first consider what will happen if the banks do not write credit insurance contracts with the insurance firms. At $t = 1$, assets of ω banks will be successful because $\rho = 0$. Since only half of their assets mature at $t = 1$, so they will receive $R/2$ at $t = 1$ and the remaining $R/2$ at $t = 1 + \epsilon$ (see figure 3.4). The remaining $(1-\omega)$ bank's assets will fail and so they will receive 0 at both $t = 1$ and $t = 1 + \epsilon$. I assume that $R/2 < 1$, so the bank's with successful assets cannot meet the demand of their depositors only from their assets maturing at $t = 1$.

Assumption 2. $R/2 < 1$.

The banks with failed assets also cannot meet its obligation at $t = 1$ because they receive 0. I assume that the depositors cannot observe the returns of the banks. Since the depositors do not observe the returns, they do not know which bank's asset is successful and which is not. So, they will run on all the banks and withdraw their deposits at $t = 1$ (recall that the deposit contracts are short term, i.e. they mature at $t = 1$). If they could see the returns, then the depositors at the successful banks could have rolled over their debt and waited till date $t = 1 + \epsilon$ to withdraw.

Since there is a run on both type of banks, they will have to sell their assets to outside investors. I assume that the outside investors also cannot observe the asset returns and hence, they will pay a price equal to the expected value of the asset, which is ωR. Thus, there is an adverse selection discount. The total cash the successful banks can raise at $t = 1$ is $R/2 + \omega R/2$. If $R/2 + \omega R/2 > D$, then the bank's with successful assets can pay back the depositors and will not go bankrupt. The failed

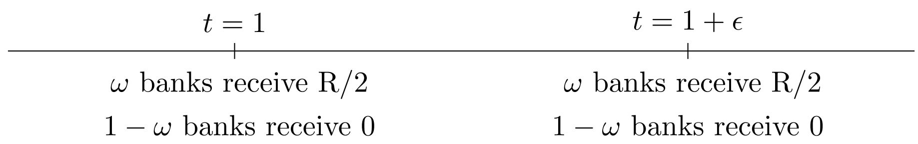


Figure 3.4: Cash flow when $\rho = 1$ and assets do not mature together

banks can only raise $\omega R/2$ at $t = 1$ and hence they will go bankrupt (since $\omega R/2 < 1$ by assumption 2).

As discussed in section 3.3.1, the regulator maximizes the social surplus and so it will not want the continuation value of the failed banks to be lost. So, it will take over these failed banks and sell them to successful ones, and hence will be able to expropriate some profits. Under assumption 1, as in section 3.3.1, the successful banks will be able to buy the failed banks at fair price and the regulator will be able to expropriate some profits which will be equal to $\omega(V - 1)$ (see proof of proposition 2). Also, the depositors of both type of banks are always paid, and so $D = 1$. I assume that the bank's with successful assets are indeed able to survive the run and pay its depositors.

Assumption 3. $R/2 + \omega R/2 > 1$. *This implies that the banks with successful assets can pay its depositors.*

Given that the regulator is able to expropriate some profits (under assumption 1, 2 and 3), it can be concluded that the banks will write credit insurance to prevent the regulator from expropriating their profits. It can shown as before that they will write fairly priced insurance contracts with $z = (1 - \omega)R$ and their *ex ante* expected profits will also be the same as before, i.e. $\Pi_{\rho=0,NT} = \omega R - 1 + V$.

It can also be concluded as before that they would not want to buy underpriced insurance contracts to rely on the regulator to bail them out. This is based on the same rationale as discussed in section 3.3.1. If the banks write an insurance contract with zero premium, then at $t = 1$, the insurance firm will declare bankruptcy. If the regulator does not bailout the insurer then this will be followed by a run on the banks as the depositors cannot observe the returns. The successful banks will sell their assets to pay off creditors and the regulator can sell the failed banks to the successful ones. So the regulator has no incentive to bailout the insurer. The above discussion is summarized in the following proposition.

Proposition 2. *If assumption 1, 2 and 3 hold, the assets no mature together ($m = NT$) and the banks invest in different industries ($\rho = 0$), then*

i. the banks prefer to buy fairly priced credit insurance with $z = (1 - \omega)R$. The expected profit of the banks is $\Pi_{\rho=0,NT} = \omega R - 1 + V$.

ii. if they do not buy credit insurance, then their ex ante expected profit is $\omega(R-1-V)$ and the regulator is able to expropriate $\omega(V - 1)$.

Proof: See appendix.

Note that when $\rho = 0$, the expected profit of the banks is same whether the assets mature together or not. It equals the NPV of the project plus the continuation value. The profits are same in both cases because the banks write fairly priced insurance and the regulator is not expropriating any profits. Also, note that the banks are indifferent between insuring amount R or any other amount above the face value of debt. Next I consider the case where $\rho = 1$ and assets do not mature together.

3.3.3 Banks invest in the same industry and assets do not mature together

Recall that when banks invest in the same industry, there are two aggregate states, good (probability q) and bad (probability $1 - q$). In the good state, α banks succeed while in the bad state β banks succeed, where $\alpha > \beta$. I will argue that banks will, under certain assumptions, insure only for the good state and not for the bad state, that is in equilibrium the insurance premium will be equal to $(1 - \alpha)R$. They will rely on bailout to insure themselves in the bad state. Also, so far I have argued that the banks are indifferent between insuring the full amount R or insuring up to any amount which is greater than the face value of debt. But in this case, the banks want to insure fully up to amount R so that they can get the maximum benefit of the bailout in the bad state.

Suppose the banks insure amount R for the good state, i.e. $z = (1 - \alpha)R$. The face value of debt satisfies $D \geq 1 + z$. In the good state the banks will be able to pay off their depositors and no bank fails. In the bad state, assets of β banks are successful and at $t = 1$ half their assets mature. So they will receive $R/2$ at $t = 1$

Figure 3.5: Cash flow in bad aggregate state when assets do not mature together

and $R/2$ again at $t = 1 + \epsilon$ (see figure 3.5). The assets of $1 - \beta$ banks fail and they receive 0 at both $t = 1$ and $t = 1 + \epsilon$. So at $t = 1$, the failed banks make a claim on insurance firms to remunerate them for half of their failed assets. The total demand by the failed banks is $(1-\beta)R/2$. I assume that the insurance firm cannot fulfill these claims with the premium collected which is $(1-\alpha)R$, and so it announces bankruptcy at $t = 1$.

Assumption 4. $(1 - \alpha)R < (1 - \beta)R/2$.

Assumption 4 capture the idea that if the insurance firm writes an underpriced contract then it will run out of money before the time that all its obligations are due. This is what happened with AIG before it was bailed out. On bankruptcy of the insurance firm, if the funds available are distributed equally among the claimant banks, then each bank will receive $\frac{(1-\alpha)R}{(1-\beta)}$. This amount is less than $R/2$ by assumption 4, and I have assumed that $R/2$ is less than 1 (assumption 2). So, the failed banks cannot pay off their depositors and are insolvent.[20] Since the depositors cannot see the returns, as soon as the insurance firm announces bankruptcy at $t = 1$, they will run on all the banks.

In case of a bank run, the banks with successful assets are forced to sell their assets which have not matured to the outside investors because at $t = 1$, they receive only $R/2$ which is less than 1 (assumption 2) and hence less than D. The banks with failed assets will also do the same. The outside investors do not observe returns and so, the sale price of each unit of asset will be βR. Hence in this case, the total liquid funds that the banks with successful assets can raise at $t = 1$ is $R/2 + \beta R/2$. Recall that for the case $\rho = 0$ and $m = NT$, when banks were selling their assets to outside investors, the price was ωR. Given that β is less than ω, the banks will have to sell their assets at a lower price since the adverse selection discount in the bad state is

[20]This is because $D \geq 1 + z > 1$.

higher. I assume that this sale price is low enough such that even the banks with successful assets will not be able to pay their depositors when they are forced to sell their assets during the run.

Assumption 5. $R/2 + \beta R/2 < 1 + (1-\alpha)R$. *This implies that the banks with successful assets cannot pay their depositors.*

As a result of assumption 5, both type of banks will go bankrupt. Since no bank survives, there is no bank that the regulator can sell the failed banks to, and continuation value of the entire banking sector will be lost. The regulator wants to prevent this continuation value from being lost. Now the regulator has three options, (*i.*) it can bailout the insurance firm to prevent the banks from failing, (*ii.*) it can provide liquidity to the banks with successful assets to withstand the run by the depositors and also buy banks with failed assets, or (*iii.*) it can sell all the banks to outside investors.

I assume that the regulator also cannot sell the banks to outside investors because they may not be best users of the asset. In our model this implies that the continuation value V is bank specific and so selling the banks to outside investors will result in loss of social surplus. This idea is similar to the idea of asset specificity discussed in Shleifer and Vishny (1992).

Remark 2: Note that I have assumed that assets which are to mature are $t = 1 + \epsilon$ and sold to the the outside investors are not bank specific. This assumption is not necessary. If these assets are bank specific, then their sale price will be even lower and we can replace the term $\beta R/2$ with $\kappa\beta R/2$ in assumption 5, where $\kappa < 1$ is a discount factor because of asset specificity. Similarly, the term $\omega R/2$ in assumption 3 can be replaced by $\kappa\omega R/2$.

I also assume that the regulator cannot observe the returns. This is an important assumption because if this assumption does not hold then the regulator can have a more *targeted* policy to prevent the systemic failure. The regulator can act as a lender of last resort to banks with successful assets. These banks are solvent and are failing only because they have to sell their assets at discounted price. If the regulator observes the returns then he can lend these banks taking as collateral the assets which will mature at $t = 1+\epsilon$. Thus the successful banks will survive and then they can buy the failed banks. This more targeted policy will allow the regulator to expropriate some profits.

Given its importance, the assumption that the regulator cannot bailout the banks because it does not observe their returns merits some discussion. During a banking crisis there is a run on the system. Under such a scenario the regulator does not have the time to evaluate each bank's balance sheet. This is because the bank's assets may be composed of complex assets which are hard to evaluate. The regulator also cannot rely on the market price of these assets to evaluate them because during the crisis the markets are illiquid and the assets may not be trading at fair value.

Remark 3: There can be other reason why the regulator may find it easier to bailout the insurance firm than bailing out many banks. For example, the regulator may find it politically easy to bailout one large institution rather than many large institutions. There can also be a timing issue, in the sense that while the insurance firm is failing, the counterparty banks may appear stable for a while; but after the insurance firm fails the counterparty banks may not be able to withstand a run which may happen later. So, to prevent a larger bailout later which may be more costly, the regulator prefers to bailout the insurance firm.

So, given the assumption that the regulator cannot observe returns and that he cannot sell the banks to outside investors, the only option for him is to bailout the insurance firm. When the regulator bails out the insurer, all banks will be able to pay their depositors in both good and bad state (in good state through insurance and in bad state through bailout), and their expected profit is $R - D + V$. Since the depositors always get paid, $D = 1 + (1 - \alpha)R$ and the expected profit of the bank is $\Pi_{\rho=1,NT} = \alpha R - 1 + V$.

Note that this profit is higher than the profits when banks were making uncorrelated investments and assets were maturing together ($\Pi_{\rho=0,NT} = \omega R - 1 + V$). The profits are higher by $(1 - q)(\alpha - \beta)R$. This term has the following interpretation. In the bad state, the insurance firm owes the $(1 - \beta)$ banks with failed assets an amount of $(1 - \beta)R$. But the premium available with it is only $(1 - \alpha)R$. So, when the insurance firm is bailed out, the regulator transfers the difference between what the insurers owes and what it has, i.e. $(\alpha - \beta)R$, to the banks. This happens only in the bad state which occurs with probability $(1-q)$. The reason for higher profits is that banks are only insuring for the good state and thus paying a lower premium. They rely on the bailout of the insurance firm for the bad state. So, they are able to insure fully even with lower insurance premium. The banks are thus writing underpriced credit insurance contracts with the insurance firm and are receiving a transfer from the regulator.

The insurance firm is ready to accept an underpriced contract, because it survives in both good and bad state and earns zero profits in both of them. The banks will not write a contract with higher insurance premium than $(1-\alpha)R$ because then it will imply that the insurer will earn a positive profit in the good state and so some of the surplus is transfered from the bank's to the insurer. Also, the insurer will not accept any premium less than $(1-\alpha)R$ because then it will earn negative profit in the good state and will go bankrupt.[21] Thus, in equilibrium the premium will be $(1-\alpha)R$. The above discussion leads to the following proposition.

Proposition 3. *If assumption 1, 2, 3, 4 and 5 hold, the assets do not mature together ($m = NT$) and the banks invest in same industry ($\rho = 1$), then*

i. *the banks buy underpriced credit insurance with $z = (1-\alpha)R$, and*

ii. *the regulator bails out the insurance firm in the bad state leaving the banks an expected profit of $\Pi_{\rho=1,NT} = \alpha R - 1 + V$.*

Having derived the profit of banks when the assets do not mature together for both correlated and uncorrelated investment, I now discuss the ex ante strategy of the banks. Since $\Pi_{\rho=1,NT} > \Pi_{\rho=0,NT}$ as discussed before, from an ex ante point of view when assets do not mature together, the banks will make correlated investments and will write under priced insurance contracts. Thus, they create systemic risk. This is the main result of the paper.

Theorem 1. *If assets do not mature together, then the banks will make correlated investment ex ante ($\rho = 1$).*
Proof: See appendix.

[21] Note that the regulator will not bailout the insurer in the good state. The reason is analogous to that discussed for the case when $\rho = 0$ and $m = NT$.

$\rho = 1$ is an equilibrium because no bank will want to deviate and invest in a different industry *ex ante*. This is because if a bank deviates and invests in a different industry then they will have to write more expensive insurance.[22] Also the deviating bank can never buy the continuation value of the other banks because if the good aggregate state is realized then all of them are directly insured and if the bad state is realized, then the regulator bails out the insurance firms and again all banks survive.

The main reason the banks prefer correlated investment is that the crisis resolution policy is imperfectly targeted. The regulator bails out the insurance firm because he cannot observe the asset returns. If he could observe the asset returns, then he could help the solvent banks by providing them liquidity and thereafter selling the failed banks to them. This policy would be beneficial to surviving banks and costly for failed banks and would create an incentive to survive when others are failing. The imperfectly targeted policy of bailing out the insurance firms creates strategic complementaries in the bank's investment strategy. A bank wants to invest in the same industry if all other banks are making correlated investments because then he can buy a cheaper insurance which insures only the good state and rely on bailout in the bad state. By performing better when others are failing, a banks will only miss out on getting the benefits of the indirect bailout.

Another reason that banks prefer correlated investments is that the regulator faces a commitment problem. If the regulator can commit that he will let all the banks fail, or sell them to outside investors then the banks will not rely on bailout and will insure fully. But regulator cannot make this commitment because it is time inconsistent. Once the banks have made correlated investments with under priced insurance, if the bad state occurs then the regulator will try to prevent the loss of continuation value and hence it cannot keep his commitment.

Proposition 4. *If the regulator can commit to not bailout the banks, then in equilibrium banks will invest in uncorrelated assets* ($\rho = 0$).
Proof: See appendix.

There is one more minor point I discuss for our scenario of $\rho = 1$ and assets not maturing together before discussing the next case. When the banks insure for the

[22]Without insurance the bank may fail and its continuation value will be sold to other banks in both good or bad aggregate state.

good state they will write insurance on the full amount R and not an amount between face value of debt and R. This is because of following reason. Suppose banks insure an amount $X \in [D, R]$ and pay insurance $(1-\alpha)X$. In the good state all banks earn $\alpha R - 1 + V$.[23] But in the bad state they are able to expropriate

$$(1-\beta)X - (1-\alpha)X = (\alpha - \beta)X$$

from the regulator. The term $(1-\beta)R$ is what the insurer owes the banks and the term $(1-\alpha)X$ is the premium with the insurer. So, the banks choose the highest X to be able to expropriate the maximum funds from the regulator.

3.3.4 Banks invest in the same industry and assets mature together

I now discuss the case when $\rho = 1$ and the assets mature together. I will show that if assets mature together then $\rho = 1$ may not be an equilibrium. The banks would ex ante want to deviate and invest in a different industry and by doing so will be able to earn higher profits. The reason for this is that by investing in a different industry, it can either buy cheaper insurance or will be able to buy continuation value of failed banks at prices below fair value and thus earn positive profits.

Since $\rho = 1$, there will be a good state and a bad state. Now the banks have two options, they can either insure for the bad state which will also provide insurance in the good state or they can only insure for the good state. Let us first consider the case when banks insure for the bad state and pay insurance premium $z = (1-\beta)R$. Now if the bad state occurs all banks will survive. In the good state as well all banks will survive but the difference is that now the insurance firm is able to earn positive profits. This is because in good state only $1-\alpha$ banks fail and the total insurance claim is only $(1-\alpha)R$, leaving a profit of $(\alpha-\beta)R$ to the insurer. The *ex ante* expected profit for the banks is

$$\Pi_{\rho=1,T}|_{z=(1-\beta)R} = \omega R - 1 + V - q(\alpha - \beta)R.$$

The last term is the profit transfer to the insurer which happens with probability q.

[23]With probability α, banks' assets succeed and their profits is $R-1-(1-\alpha)X$, while probability $(1-\alpha)$, their assets fail and their profits are $X - 1 - (1-\alpha)X + V$. So their expected profit is $\alpha R - 1 + V$.

Now consider the other scenario when banks only insure for the good state and pay premium $z = (1-\alpha)R$. In that case, they will all survive in the good state. But in the bad state, at $t = 1$ the $(1-\beta)$ banks with failed assets will demand a claim of $(1-\beta)R$ which the insurance firm will not be able to fulfill. If the premium is divided among the banks each of them will receive $\frac{(1-\alpha)R}{1-\beta}$ which is less than 1 as discussed in section 3.3.3. So these banks will fail. Note that since all assets mature at the same time, the banks whose assets succeed will survive. Hence the regulator can sell the failed banks to surviving banks and there will be no bailout. The total liquid cash available with the successful banks is $\beta(R-D)$. The total cash needed to pay off the depositors of failed banks is $(1-\beta)D$. I assume that the total liquidity available is larger than total liability of the failed banks. This implies $D = 1+z$ and I have assumed $\beta(\alpha R - 1) > (1-\beta)(1+(1-\alpha)R)$. The total cash needed to pay off the depositors of failed banks and buy them at fair price is $(1-\beta)V$, so if liquidity available is greater than this amount, then the failed banks will be sold at fair price. If liquidity is less than $(1-\beta)V$, then there will be cash-in-market-pricing. The ex ante expected profit of the banks will be

$$\Pi_{\rho=1,T}|_{z=(1-\alpha)R} = \omega R - 1 + V - min\{\beta R - 1, (1-\beta)(V - 1 - (1-\alpha)R)\}(1-q).$$

The last term is the value expropriated by the regulators. If there is cash-in-the-market pricing, then the value expropriated is

$$\beta(\alpha R - 1) - (1-\beta)(1+(1-\alpha)R) = \beta R - 1.$$

Else the value expropriated is $(1-\beta)(V - 1 - (1-\alpha)R)$.[24] In summary, if the banks will insure for the bad state, then they transfer profits to the insurance firm. If they insure only for the good state, then they transfer profits to the regulator. They will choose between the two to maximize their profits.

Because there is always some loss to the banks, ex ante this will create an incentive to invest in a different industry. If a bank invests in a different industry and buys a fairly priced insurance from a different firm with premium $z = (1-\omega)R$, then its profit will be $\omega R - 1 + V$. If the other banks choose to insure only for the good state and there is cash-in-the-market pricing then the bank which deviated ex ante

[24]The depositors of the failed banks need to be paid $(1-\beta)D$. The resource available with the insurers is $z = (1-\alpha)R$. So, when there is cash in market pricing, total amount paid is $\beta R - 1$. When the price is fair, then the total amount paid is $(V - 1 - z)(1-\beta)$.

can buy failed banks at below fair price and increase his profit even higher. Thus this will provide the banks an incentive to deviate ex ante. I get the following result.

Theorem 2. *When the assets mature together then $\rho = 1$ cannot be an equilibrium.*

The two cases of bankruptcy results in different ex ante correlation by the banks. When assets mature together some banks will always succeed. This allows the regulator to adopt a failure resolution policy that is targeted and bank specific. When the assets do not mature together, failure of some banks can lead to a run on all banks and a systemic failure. Since the regulator does not observe the returns, he is forced to bail out the insurance firm. This is imperfectly targeted policy and incentivizes the banks ex ante to herd together to be able to get the benefit of bailout.

3.4 Policy implications

There are many policies which have been suggested to solve the problem of lack of commitment to bailout a systemically important institution. One such policy is to put hard constraints on the size of the financial firms. For example, Johnson and Kwak (2011) suggest putting a cap any one bank's liabilities to 4% of GDP. Such size restrictions would put limits on the amount of spillover that one bank may create. In my model, a similar policy can prevent the banks from making correlated investments ex ante. I will show that putting a cap on the notional value of credit default swaps issued by a single insurance firm can help mitigate the problem of systemic risk.

When there are many insurance firms and all of them are failing together, then the regulator has an option of bailing out only some of them. The counterparty banks of the bailed out insurance firms will succeed while the counterparty banks of the failed insurance firms will go bankrupt. The failed banks can then be sold to successful banks and there will be a profit transfer to the regulator resulting in ex ante loss of profits to the banks. This may create an incentive to write fully insurance contracts in which case banks may prefer to make uncorrelated investments ex ante. Also, depending on the liquidity available, the failed banks may be sold at fire sale price. This will create an incentive for the banks to survive at the time others are failing so that they are be able to buy assets at fire sale price. I formalize these ideas next.

Suppose the regulator has put a cap, equal to R/n, on the notional value of credit default swaps issued by each insurance firm. So there will be n insurance firms in the market each insuring $1/n$ fraction of banks. I will only discuss the case when assets do not mature together. Consider the scenario when banks have made correlated investments and each bank has insured only the good aggregate state by paying a premium of $z = (1 - \alpha)R$. If the bad aggregate state occurs, then all the insurance firms will announce bankruptcy at $t = 1$ which will be followed by a run on all the counterparty banks. When there was only one insurance firm, the regulator had no option but to bail it out. But now the regulator can bailout only a few insurance firms and allow the others to fail. Suppose the regulator bails out m out of the n insurance firms. This will imply that m/n fraction of the banks will succeed and the remaining $(1 - m/n)$ will fail.

The regulator can sell these failed banks to surviving ones. The liquidity available with the surviving banks, given that $D = 1 + z$, is $\frac{m}{n}(\alpha R - 1)$.[25] To buy the failed banks this available liquidity must be larger than the obligations of the other failed banks, which is $(1 - m/n)D$. I assume that m/n is large enough such that this holds true. The sale price of the banks will be equal to the fair price $(V - D)$ if the liquidity available is greater than $(1 - m/n)V$, else there will be cash in market pricing and banks will be sold at fire sale price. Let us consider the scenario where m is *just* large enough such that the banks are sold at fair price, i.e. m is the lowest value which satisfies

$$\frac{m}{n}(\alpha R - 1) \geq (1 - \frac{m}{n})V. \tag{3.5}$$

Given that the regulator bails out m insurance firms, the ex ante expected profit of the banks will be

$$\omega R - 1 + V + (1 - q)[\frac{m}{n}(\alpha - \beta)R - (1 - \frac{m}{n})(V - 1 - \alpha R)].$$

The first term in the square bracket is bailout subsidy received by the banks and the second term is the profit transfered to the regulator to buy the failed banks. If the difference of these two terms is negative then, the a bank is better of deviating ex ante and investing in a different industry and writing a fair priced insurance. This gives the deviating bank a profit of $\omega R - 1 + V$. So, $\rho = 1$ cannot be an equilibrium. If the term in the square bracket is positive then the regulator can reduce m which

[25] $D = 1 + z$ because the depositors always get paid either directly by their own banks or indirectly by the banks who will be buy their banks. So liquidity available with each bank is $R - D = \alpha R - 1$.

will result in cash in market pricing. If The banks that survive will make profits from the sold banks. If m is low enough then the transfer from the regulator will be dominated by the profits from buying the assets at fire sale price. This will also create an incentive *ex ante* to survive and a bank may *ex ante* invest in a different industry. I get the following result.

Proposition 5. *The regulator can choose m and n such that banks will not make correlated investments ex ante.*

Thus, I have shown that putting a size cap on the insurance firms can prevent the banks from making correlated investments *ex ante*. An important point to note is that insurance is more efficient to with more diversification. So, putting a can on the size of insurance firms can reduce the benefit of diversification. In my model, I have not taken cost into account. But the regulator will take this cost into account when it decides the optimal size of the insurance firm.

3.5 Investment strategy of the insurance firm

So far I have assumed that the insurance firm can only invest in cash assets (or store) the premium it has received and it cannot invest it in any industry. I will now relax this assumption and show that the insurance firm will also make correlated investments, that is it will also prefer to invest in the same industry as the banks.

Let us consider the scenario when assets so not mature together and so banks have made correlated investments to get the benefit of the bailout in equilibrium. After receiving the premium the insurance firm can invest in industry $i \in \{s, d, c\}$, where $i = s$ denotes that the insurer invests in the same industry, $i = d$ denotes investment is different industry and $i = c$ denotes investment in cash. To keep the analysis simple, I assume that in good state all the assets mature together while in bad state the assets do not mature together. Also, to keep the algebra simpler so far I have assumed that $L = 0$, but now I relax this assumption, i.e I assume $0 < L < 1 < R$. When the insurer invests in an industry there can be 4 scenarios corresponding to whether the insurer's asset returns R (succeeds) or L (fails) and whether the bank's industry is in good state or bad state. Table 3.2 show that probability of occurrence of each scenario. The two panels correspond to the insurer investing is same or different

	R	L
$i = s$		
Good state	$q\alpha$	$q(1-\alpha)$
Bad State	$(1-q)\alpha$	$(1-q)(1-\alpha)$
$i = d$		
Good state	$q\omega$	$q(1-\omega)$
Bad State	$(1-q)\omega$	$(1-q)(1-\omega)$

Table 3.2: Probability of occurrence of state of bank's industry and return of insurer's asset

industry as the banks. To illustrate, the probability that the banks' industry is in good state and the insurer's asset returns R is $q\alpha$ ($q\omega$) if $i = s$ ($i = d$), and so on.

I now discuss the intuition for why insurers would prefer to invest in same industry. In bad state, irrespective of the industry the insurer will invest in, he will not be able to meet its obligations and will be bailed out, thus earning zero profits. In the good state, the banks want to insure that they do not fail so that the regulator is not able to expropriate the profits. So, they will write a contract with premium such that even when the insurer's asset fails (returns L), the resources with the insurer is *just* enough so that they do not go bankrupt. Now when the insurer's asset succeeds (returns R) it may have more resources than its obligations when banks' industry is in good state and will thus earn a positive profit. The joint probability of occurrence of good state and insurers asset returning R is larger when $i = s$ than when $i = d$ since $q\alpha > q\omega$ and so the insurer prefers to invest in the same industry as the banks. I formalize these ideas next.

If the banks know that the insurer will invest in an industry and not cash, it will write a contract with premium z such that insurer pays enough so that banks are able to pay its depositors even when insurer's asset returns L. The resources with the insurer is zL. The obligation of the insurer is $(1-\alpha)R$. So, z is given by,

$$z = (1-\alpha)R/L. \tag{3.6}$$

Given this insurance premium, the insurer will earn a positive profit when its asset returns R. So to maximize the expected profit, the insurer will invest in the same industry as the banks.

Proposition 6. *In equilibrium the insurer invests in the same industry as the banks*

and earns a positive profit.
Proof: See appendix.

AIG had a huge securities lending business. It invested a large part of collateral (about 60% of the U.S. pool) it received from lending securities in MBS. At the end of year 2007, AIG has an investment of $85 billion in residential mortgage backed securities. Thus, AIG had invested a large amount in the very asset that it was insuring. My paper provides an explanation for why AIG had large investments in MBS.

3.6 Conclusion

The main contribution of my paper is to highlight the risk taking incentives of the counterparties of a too-systemic-to-fail institution. While too-systemic-to-fail problem is very well recognized by academicians and regulators, there is very limited understanding of how existence of such an institution affect the actions of other agents in the economy. In my paper, the systemically important institution which insures credit risk, and correlated risk taking by the banks arise endogenously.

The main driving force is that the regulators at the time of crisis do not have the capability to evaluate the problem of each bank separately and so is looking for a systemic solution. In my model this solution takes the form of bailing out the insurance firm. While credit insurance markets are relatively new and not well developed in many countries, they are here to stay as they provide the benefit of risk sharing. My paper argues that it is important to understand that a systemically important firm which provides credit insurance cannot be allowed to fail and may create systemic risk in the economy.

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Appendix A: Proof of Results in Chapter 2

A.1 Proof of Lemma 1

There can be two cases for Δ_1, (*a.*) $\Delta_1 \geq 0$ and (*b.*) $\Delta_1 < 0$. I consider case *a.* first. Δ_0 is always positive and if $\Delta_1 \geq 0$ then clearly the cheapest contract satisfying equation (2.1) is w^b. Now consider case *b*. If at the optimal contract $w_0 > 0$, then we can reduce w_0 by small amount ϵ and w_2 by $\epsilon\Delta_0/\Delta_2$ to get a cheaper contract which still satisfies the equation (2.1). So w_0 must be 0 in the optimal contract.

To show that w_1 will also be zero I use the monotone likelihood ratio property (MLRP). Suppose the CEO chooses the safe project. The expected wage payment of the employee is $p_2^S w_2 + p_1^S w_1$. Equation (2.1) can be rewritten as

$$p_2^S(1 - \frac{p_2^S - \Delta_2}{p_2^S})w_2 \geq p_1^S(\frac{p_1^S + \Delta_1}{p_1^S} - 1)w_1 + b.$$

MLRP implies that

$$\frac{p_2^S - \Delta_2}{p_2^S} < \frac{p_1^S + \Delta_1}{p_1^S}.$$

Therefore the slope of IC constraint is more than the slope of the isoutility line of the employee. So again the cheapest contract is given by w^b.

Similar analysis can be done for risky project.

A.2 Proof of Lemma 2

$\pi(R|\sigma^b) = \pi(S)$ can be rewritten as

$$(Pr(X_2|R, \sigma^b) - p_2^S)(\frac{X_2 - b/\Delta_2}{X_1} - 1) - Pr(X_0|R, \sigma^b)(1 - \frac{X_0)}{X_1}) = 0.$$

Since $X_2 - b/\Delta_2 > X_1$ (by assumption 1) and $X_0 < X_1$, so $Pr(X_2|R, \sigma^b) - p_2^S > 0$.

A.3 Proof of Lemma 3

I first show that the IC for effort (equation (2.1)) will be binding. Suppose that the constraint is not binding. Then we offer a new contract such that each w_i is reduced by a small fraction. This new contract will still satisfy equations (2.6) and (2.1), and will also also be a cheaper contract. Hence IC for effort must be binding.

Next we prove that $w_0 = 0$. Equation (2.6) can be written as

$$(p_2^S - Pr(X_2|R, \sigma^c))w_2 + (p_1^S - Pr(X_1|R, \sigma^c))w_1 - Pr(X_0|R, \sigma^c)w_0 = 0.$$

Suppose the cheapest contract has $w_0 > 0$. Now that contract can have $w_1 = 0$ or $w_1 > 0$. If $w_1 = 0$, then the above constraint cannot be satisfied because $(p_2^S - Pr(X_2|R, \sigma^c)) \leq 0$ for $\sigma \in [\hat{\sigma}, \sigma^b]$. So $w_1 > 0$ must be true. Consider a new contract where w_0 is reduced by small amount ϵ and w_1 is reduced by $\frac{Pr(X_0|R,\sigma^c)}{p_1^S - Pr(X_1|R,\sigma^c)}\epsilon$ so that equation (2.6) is satisfied. After these reductions, the change in right side of equation (2.1) is

$$-\frac{\Delta_1}{\Delta_2}\frac{Pr(X_0|R, \sigma^c)}{p_1^S - Pr(X_1|R, \sigma^c)}\epsilon - \frac{\Delta_1}{\Delta_2}\epsilon.$$

Substituting $\Delta_1 = \Delta_2 - \Delta_1$, $p_1^S = 1 - p_2^S$ and $Pr(X_1|R, \sigma^c) = 1 - Pr(X_0|R, \sigma^c) - Pr(X_2|R, \sigma^c)$ in the term above we get

$$-\frac{1}{\Delta_2}(\Delta_0(1 - \lambda) + \Delta_2\lambda)\epsilon,$$

where

$$\lambda = \frac{Pr(X_0|R, \sigma^c)}{Pr(X_0|R, \sigma^c) + (Pr(X_2|R, \sigma^c) - p_2^S)}.$$

Note that $0 < \lambda \leq 1$ because $Pr(X_2|R, \sigma^c) - p_2^S > 0$, so the term is negative. Hence equation (2.1) is also satisfied. So, we have a cheaper contract which is a contradiction. Hence w_0 must be 0.

A.4 Proof of Proposition 2

All I need to show is that the rent is monotonically increasing in σ^c. The rent is given by

$$r(\sigma^c) = (p_1(\sigma^c) + p_2(\sigma^c)\frac{\Delta_1}{\Delta_2})w_1(\sigma^c).$$

I denote the multiplicand of $w_1(\sigma^c)$ by F. Since $w_1(\sigma^c)$ is increasing in σ^c (lemma 4), rent is increasing in σ^c if F is increasing in σ^c. Partial derivative of F w.r.t σ^c is

$$\frac{\partial F}{\partial \sigma^c} = \frac{\partial p_1(\sigma^c)}{\partial \sigma^c} + \frac{p_2(\sigma^c)\frac{\Delta_1}{\Delta_2}}{\partial \sigma^c}.$$

Now $\frac{\partial p_1(\sigma^c)}{\partial \sigma^c} = M$ and $\frac{p_2(\sigma^c)}{\partial \sigma^c} = N$ and $\Delta_1 = \Delta_2 - \Delta_0$. So we have $\frac{\partial F}{\partial \sigma^c}$ can be written as

$$M + N\frac{\Delta_1}{\Delta_2} = -N(-\frac{M}{N} - 1 + \frac{\Delta_0}{\Delta_2}),$$

which is positive since $-M/N > 1$, $N < 0$, $\Delta_0 > 0$ and $\Delta_2 > 0$.

A.5 Proof of Proposition 4

The exact conditions on how high p_1^S should be for $\sigma^c_{RM} > \sigma^b$ is as following.

i. If $p_2^S p_1^B - p_1^S p_2^B > 0$, then p_1^S is large enough such that $(p_1^G + p_1^B)(p_2^S - p_2^B) - (p_2^G + p_2^B)(p_1^S - p_1^B) < 0$ and $p_1^S > p_1^B$,

ii. else if $p_2^S p_1^B - p_1^S p_2^B < 0$, then p_1^S is large enough such that $p_2^B p_1^G - p_2^G p_1^B < 0$.

The *ex ante* probability of X_i, $p_i(\sigma^c)$, depends on σ^c. For notional simplicity I drop the argument σ^c from $p_i(\sigma^c)$. Given that $\sigma \sim U[0,1]$, using equation (2.4), p_i can be written as

$$p_0 = 0.5p_0^B(1 - (\sigma^c)^2), \tag{3.7}$$

$$p_1 = 0.5(p_1^G + p_1^B) + (p_1^S - p_1^B)\sigma^c - 0.5(p_1^G - p_1^B)(\sigma^c)^2, \tag{3.8}$$

$$p_2 = 0.5(p_2^G + p_2^B) + (p_2^S - p_2^B)\sigma^c - 0.5(p_2^G - p_2^B)(\sigma^c)^2. \tag{3.9}$$

The Lagrange multiplier for constraints (2.16) and (2.18) are denoted by μ and λ respectively. I will first show that if $\mu < 0$, then there will be over investment in the safe project. There after I will find the conditions under which $\mu < 0$.

The first order condition (f.o.c.) w.r.t. σ^c is

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} X_i - \frac{\partial p_2}{\partial \sigma^c}\frac{b}{\Delta_2} = \sum_i \frac{\partial p_i}{\partial \sigma^c} w_i + \lambda[\sum_i \frac{\partial p_i}{\partial \sigma^c} U(w_i)] + \mu(E[U(w)|G] - E[U(w)|B]) = 0. \tag{3.10}$$

Note that the multiplicand of λ is nothing but the f.o.c of employee's utility maximization problem as given in equation (2.16). Hence this term is 0. So the equation can be written as

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} X_i - \frac{\partial p_2}{\partial \sigma^c}\frac{b}{\Delta_2} = \sum_i \frac{\partial p_i}{\partial \sigma^c} w_i + \mu(E[U(w)|G] - E[U(w)|B]) \tag{3.11}$$

The first term on the right can be written as

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} w_i = E[W|S] - \sigma^c E[W|G] - (1-\sigma^c)E[W|B].$$

Since U is concave, using (2.16) and Jensen's inequality we get $\sum_i \frac{\partial p_i}{\partial \sigma^c} w_i < 0$.

If $\mu < 0$, then the left side of equation (3.11), $\sum_i \frac{\partial p_i(\sigma^c)}{\partial \sigma^c} X_i - \frac{\partial p_2(\sigma^c)}{\partial \sigma^c}\frac{b}{\Delta_2}$, will be negative. By definition of σ^b,

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} X_i - \frac{\partial p_2}{\partial \sigma^c} b/\Delta_2|_{\sigma^c=\sigma^b} = 0.$$

Also $\sum_i p_i X_i - p_2 b/\Delta_2$ is concave in σ^c. So, since left side of equation (3.11) is negative at the σ^c_{RM}, it implies $\sigma^c_{RM} > \sigma^b$.

I will now find the conditions under which $\mu < 0$. The first order conditions w.r.t w_2 and w_1 are as following:

$$\frac{1}{U'(w_2)} = \lambda + \mu[\frac{p_2^S - \sigma^c p_2^G - (1-\sigma^c)p_2^B}{p_2}]. \tag{3.12}$$

$$\frac{1}{U'(w_1)} = \lambda + \mu[\frac{p_1^S - \sigma^c p_1^G - (1-\sigma^c)p_1^B}{p_1}]. \tag{3.13}$$

Eliminating λ from these equations, I get

$$\frac{1}{U'(w_2)} - \frac{1}{U'(w_1)} = \frac{\mu}{p_1 p_2}[\underbrace{p_1(p_2^S - \sigma^c p_2^G - (1-\sigma^c)p_2^B) - p_2(p_1^S - \sigma^c p_1^G - (1-\sigma^c)p_1^B)}_{K}] \tag{3.14}$$

Since $w_2 > w_1$ and U is strictly concave, so μ will be negative if the multiplicand of μ/p_1p_2, denoted by K, is negative. Substituting the values of p_1 and p_2, the multiplicand can be written as

$$K = A + B\sigma^c + C(\sigma^c)^2,$$

where $A = 0.5[(p_1^G + p_1^B)(p_2^S - p_2^B) - (p_2^G + p_2^B)(p_1^S - p_1^B)]$, $B = p_2^B p_1^G - p_2^G p_1^B$ and $C = [(p_2^S - p_2^B)(p_1^G - P_1^B) - (p_1^S - p_1^B)(p_2^G - p_2^B)]$. C can also be written as

$$-p_0^B(p_2^G - p_2^S),$$

which is negative as $p_2^G - p_2^S > 0$ because good project first order stochastically dominates the safe project. Now $A - C$ can be also be written as $p_2^S p_1^B - p_1^S p_2^B$. And $B - (C - A)$ can be written as

$$-(p_1^B + p_2^B)(p_2^G - p_2^S).$$

Clearly $B - (C - A) < 0$. If $A - C = p_2^S p_1^B - p_1^S p_2^B > 0$, then $B < (C - A) < 0$. So sufficient condition for K to be negative is $A < 0$. I will now show that if $p_1^S \to 1$ and $p_1^B < p_1^S$, then $A < 0$. If $p_1^S \to 1$, then $p_2^S \to 0$ and also $p_2^B \to 0$ because safe first order stochastically dominates the bad project. So if $p_1^S \to 1$ and $p_1^B < p_1^S$, then A can be written as

$$\lim_{p_1^S \to 1} A = -0.5(p_2^G - p_2^B)(1 - p_2^B),$$

which is less than 0. This proves the first part of the proposition.

Now the second part. If $A - C = p_2^S p_1^B - p_1^S p_2^B < 0$, then $A < C < 0$. So sufficient condition for K to be negative is for B to be negative. Now if $p_1^S \to 1$, then $B = -p_2^G p_1^B$ which is negative.

A.6 Proof of Proposition 5

I start by treating q as a parameter. I define $V(q)$ as the expected profit when the CEO chooses σ^c and w_{RM} to maximize expected profits taking the value of q as given, i.e.

$$V(q) = \max_{\sigma^c, w_{RM}} \sum_i p_i(\sigma^c, q)(X_i - w_{RM,i}) - p_2(\sigma^c, q)b/\Delta_2,$$

such that constraints (2.16), (2.17) and (2.20) are satisfied. Using envelope theorem, the partial derivative of $V(q)$ is

$$\frac{\partial V(q)}{\partial q} = \frac{\partial}{\partial q}\Bigg[\sum_i p_i(\sigma^c,q)X_i - p_2(\sigma^c,q)\frac{b}{\Delta_2} - \sum_i p_i(\sigma^c,q)w_i + \lambda[E[U(w_{RM})|S] - E[U(w_{RM})|R,\sigma^c]$$
$$+\mu[\sum_i p_i(\sigma^c,q)U(w_{i,RM}) - \underline{u}]\Bigg].$$

If $\frac{\partial V(q)}{\partial q}|_{q=0} > 0$, then q^*_{RM} must be positive.

For proposition 4, I have assumed that X_2 is large, risk aversion is not small and p_1^S is close to 1. Since I have assumed $p_1^S \to 1$, so by proposition 3, the cutoff σ^c evaluated at $q = 0$ must be greater than σ^b. I write $\sigma^c = \sigma^b + \delta$, where $\delta > 0$. Since I have assumed that risk aversion is not small, so δ is not small. Also by definition, σ^b can be written as

$$\begin{aligned}\sigma^b &= \frac{\pi(S) - \pi(B)}{\pi(G) - \pi(B)} \\ &= \frac{(p_2^S - p_2^B)X_2 + (p_1^S - p_1^B)X_1 - p_0^B X_0}{(p_2^G - p_2^B)X_2 + (p_1^G - p_1^B)X_1 - p_0^B X_0}.\end{aligned}$$

Since X_2 is assumed to be large, I can say that $\frac{X_1}{X_2} \to 0$ and $\frac{X_0}{X_2} \to 0$. Also since $p_1^S \to 1$, so $p_2^S \to 0$ and $p_2^B \to 0$.

I now examine the first term inside the square bracket in the expression for $V(q)$, which I call Y, i.e.

$$Y = \frac{\partial}{\partial q}[p_2(\sigma^c,q)X_2 + p_1(\sigma^c,q)X_1 + p_0(\sigma^c,q)X_0].$$

I will show that Y can be infinitely large under our assumptions, and therefore $\frac{\partial V(q)}{\partial q}|_{q=0} > 0$. $p_i(\sigma^c,q)$ can be written as

$$p_i(\sigma^c,q) = (1-q)\int_0^{\sigma^c} p_i^S d\sigma + q\int_0^{\sigma^c} Pr(X_i|R,\sigma)d\sigma + \int_{\sigma^c}^1 Pr(X_i|R,\sigma)d\sigma.$$

So,

$$\frac{\partial}{\partial q}p_2(\sigma^c, q) = 0.5(p_2^G - p_2^B)(\sigma^c)^2 - (p_2^S - p_2^B)\sigma^c,$$
$$\frac{\partial}{\partial q}p_1(\sigma^c, q) = 0.5(p_1^G - p_1^B)(\sigma^c)^2 - (p_1^S - p_1^B)\sigma^c,$$
$$\frac{\partial}{\partial q}p_0(\sigma^c, q) = 0.5p_0^B(\sigma^c)(1 - 0.5(\sigma^c)^2).$$

Clearly $\frac{\partial}{\partial q}p_0(\sigma^c, q) > 0$, so the last term in Y is greater than 0. I now expand the first two terms in Y, substitute $\sigma^c = \sigma^b + \delta$, take the limits and ignore the second order terms to get the following.

$$\begin{aligned}&\frac{\partial}{\partial q}[p_2(\sigma^c, q)X_2 + p_1(\sigma^c, q)X_1]\\=&X_2(\sigma^b + \delta)(\delta - (p_2^S - p_2^B))\\=&X_2(\sigma^b + \delta)(\delta)\end{aligned}$$

Given that δ is not small and X_2 is assumed to be large, this term is also large. Hence $\frac{\partial V(q)}{\partial q}|_{q=0} > 0$.

A.7 Proof of Lemma 4

Suppose the separating equilibrium exists. In this equilibrium h type employee discloses. If he deviates and discloses n, then the CEO (when $\sigma_{CEO} = h/n$) will still choose the risky project, but he prevents himself from getting fired when $\sigma_{CEO} = l$. Hence the deviation is profitable.

A.8 Proof of Proposition 6

Suppose that Pooling NN exists if assumption 3 holds. As discussed in the paper, the h type risk manager has no incentive to deviate and disclose. Now suppose the first risk manager after observing l decides to deviate and discloses l. Then the CEO observes off path outcome ln. She believes that this deviation could have come node ll or ln and assigns probabilities to these nodes. If she put probability 1 on node ln then she will prefer the risky project when she observes n but fires the employees if she observes h. So the deviation for the employee is unprofitable. Hence the equilibrium exists.

Appendix B: Proof of Results in Chapter 3

B.1 Proof of Proposition 2

Let us first consider what happens if the banks do not write credit insurance contracts. At $t = 1$, ω banks whose assets succeed will each be able to raise $R/2+\omega R/2$. So, the liquidity available with each of them after paying the depositors is $R/2 + \omega R/2 - 1$ and the total liquidity available is

$$\omega(R/2 + \omega R/2 - 1).$$

The $(1 - \omega)$ banks with failed assets can raise $\omega R/2$ and which they will use to pay the depositors. But they cannot meet their obligations because $\omega R/2 < 1$ since $\omega < 1$ and $R/2 < 1$ (assumption 2). So $(1 - \omega)$ banks will go bankrupt and will be sold to the successful banks by the regulator.

The successful banks will be able to buy the failed ones at fair price if the total liquidity available is enough to pay the depositors of the failed banks and then buy then pay fair price $(V - 1)$. The remaining obligation of the depositors of the failed banks is $(1-\omega)-(1-\omega)\omega R/2$. The second term is the amount already paid by their banks by selling their assets. So, the condition for sale at fair price is

$$\underbrace{\omega(R/2 + \omega R/2 - 1)}_{\text{total liquidity}} \geq \underbrace{(1 - \omega)(V - 1)}_{\text{fair price}} + \underbrace{(1 - \omega) - (1 - \omega)\omega R/2}_{\text{remaining obligations}}$$

Rearranging the equation, I get $\omega(R - 1) \geq (1 - \omega)V$ which is same as assumption 1. Hence the banks will be sold at fair price and the regulator will expropriate $(1 - \omega)(V - 1)$.

Now let us consider what happens of the bank write the fairly prices insurance contract with $z = 1$. Since the assets are fully insured so their value is R. Both types of banks will be able to meet its obligations and there will be no run. Each bank earns $R - D + V$, where $D = 1 + z$. So, the profits are $\omega R - 1 + V$. Hence banks prefer to buy credit insurance.

B.2 Proof of Proposition 3.

The equilibrium insurance premium will not be less than $(1 - \alpha)R$ because then the insurance firm will earn negative profits in good state and zero profit in bad state. So, it will not accept the contract. The premium will not be greater than $z = (1 - \alpha)R$ because then the insurer earns positive profit in good state. Also, the profits of the banks will be lower because some profits are extracted by the insurer and also the transfer received from the regulator in the bad state will be lower. The transfer received in the bad state is $((1 - \beta)R - z)$.

The banks will also not write a CDS contact on value less than R to maximize their profit. Suppose banks insure an amount $X \in [D, R]$ and pay insurance $(1-\alpha)X$. In the good state all banks earn $\alpha R-1+V$. With probability α, banks' assets succeed and their profits is $R - 1 - (1 - \alpha)X$, while probability $(1 - \alpha)$, their assets fail and their profits are

$$X - 1 - (1 - \alpha)X + V.$$

So their expected profit is $\alpha R-1+V$. But in the bad state they are able to expropriate

$$(1 - \beta)X - (1 - \alpha)X = (\alpha - \beta)X$$

from the regulator. The term $(1 - \beta)R$ is what the insurer owes the banks and the term $(1 - \alpha)X$ is the premium with the insurer. So, the banks choose the highest X to be able to expropriate the maximum funds from the regulator.

B.3 Proof of Theorem 1

To prove that $\rho = 1$ is an equilibrium, I show that no bank with want to deviate *ex ante* and invest in an industry different from other banks. Suppose the bank deviates and invests in a different industry. Fist consider what happens when he does not write an insurance contract. In this case if its assets fail, then it will be sold to other banks in the good aggregate state and bad aggregate state. If its assets succeed, then it cannot buy the assets of the other banks. This is because if the good state is realized then the other banks are insured and no one fails. In bad state the insurer is bailed out and all banks survive. Thus its profits are lower without insurance.

When the bank insures itself, then it will pay a higher premium $z = (1 - \omega)R$. With insurance, the bank's always survives but again it cannot buy assets of the other banks. So, its profit is $\omega R - 1 + V$ which is lower than $\Pi_{\rho=1,NT}$. Hence the bank has no incentive to deviate.

B.4 Proof of Proposition 4

Suppose the regulator can commit not to bailout the banks. Also suppose that the banks make correlated investment and write an insurance contract with $z = (1-\alpha)R$. In the good state all banks will survive. But in the bad state all banks will fail because there will be no bailout and they will loose their continuation value V. Since the are not receiving any transfer from any agent, their expected profit is

$$\omega R - 1 + V.$$

$(1 - q)V$ is lost because there is no bailout in bad state.

If a bank deviates ex ante and writes a separate insurance contract, then its profit is $\omega R - 1 + V$. So, $\rho = 1$ cannot be an equilibrium. Hence, the banks will invest in different industries and $\rho = 0$ will be the equilibrium.

B.5 Proof of Proposition 6

First, the bank will not invest in cash because if the banks believe that the insurer is investing in cash and the premium covers the obligations of the banks and $z = (1-\alpha)R$ and the insurer makes 0 profit. But if this premium is charged then, the insurer will deviate and invest in the risky asset and earn positive profits if the asset succeeds.

If the insurer invest in an industry, then clearly to maximize profits it will invest in the same industry to be able to earn a positive profit with larger probability since $q\alpha > q\omega$.