

Why Risk Managers?*

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November 25, 2018

[Job Market Paper]

Abstract

Banks rely on risk managers to prevent their employees from making high risk low value investments. Why can't the CEOs directly incentivize their employees by offering them the right contract instead of relying on the risk manager? I show that having a separate risk manager is more profitable for banks and is also socially efficient. 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. Incentivizing effort requires offering a high powered contract (convex payoff) which will incentivize the employee to indulge in risk shifting and choose riskier investments with lower value. 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 he suggests safe investments.

Key Words: Risk management; Institution design; Multi-task agency problem; Financial crisis

JEL Classification: G32; D02; D82; G01

*I thank my advisors Andrew Winton, Raj Singh, Martin Szydlowski and David Rahman for their continued support and guidance. I am also thankful to Andrey Malenko, Ronnie Clayton, David Rahman, Dasha Safanova, and seminar participants at University of Minnesota, Warwick University, American Finance Association Poster Session (2018), Financial Intermediation Research Society (2018) meeting, Financial Management Association (2018) meeting, Southern Finance Association (2017) meeting, Spanish Finance Association (2017) meeting, for helpful comments. An earlier version of the paper was circulated under the title “Why can't CEOs foresee a crisis?”. I alone am responsible for all remaining errors.

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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 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

¹For 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.

²For 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 \(2008\)](#)).

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

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 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 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.

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

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.

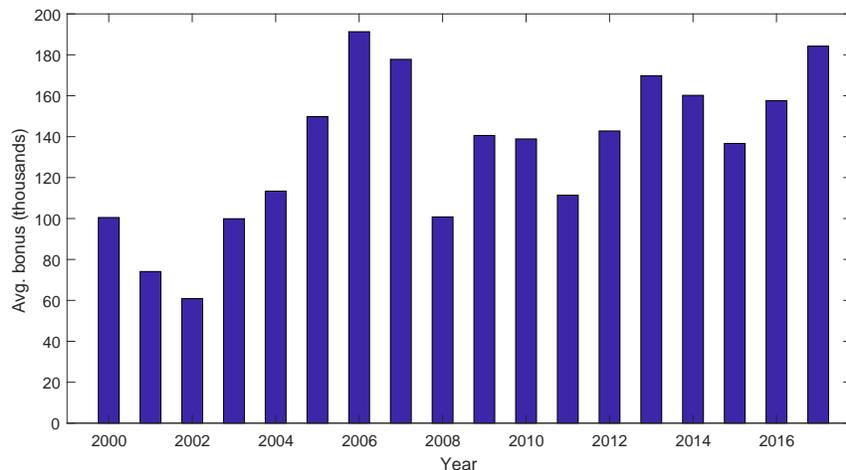
In a non-financial firm, a divergence of preference between division managers and the CEO occurs because the division managers want higher capital allocated to them than what is value maximizing for the firm. This is because they are assumed to be “empire builders” or receive higher perquisite consumption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

⁵See, 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 \(1995\)](#).

⁶Since 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.

⁷Also, 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.



Source: Office of the New York State Comptroller

Figure 1: Average annual bonus for New York City securities industry employees

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.

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. Kupiec (2013) shows that

⁸While 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).

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 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

⁹Banks 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.

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

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

higher probability of default 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.

2 Framework

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

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

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 1: Probability distribution of project given that the employee works

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 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.

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

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

¹⁶For 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.

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 assess 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.

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

$$w_2 \geq \frac{\Delta_1}{\Delta_2} w_1 + \frac{\Delta_0}{\Delta_2} w_0 + \frac{b}{\Delta_2}. \quad (1)$$

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.

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 3). σ^b is given by,

$$\sigma^b = \frac{\pi(S) - \pi(B)}{\pi(G) - \pi(B)}. \quad (2)$$

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

$$\Pi^b = \int_0^{\sigma^b} \pi(S) d\sigma + \int_{\sigma^b}^1 \pi(R|\sigma) d\sigma. \quad (3)$$

¹⁷The 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 $\pi(\theta) = \sum_i p_i^\theta X_i - p_2^\theta b/\Delta_2$.

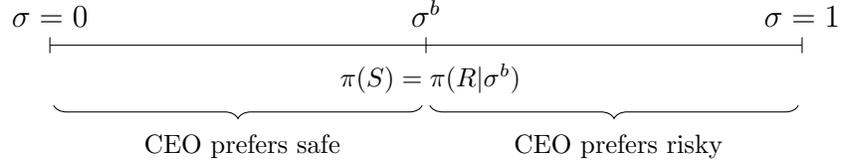


Figure 3: CEO's choice of project when she observes signal

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 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 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

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 .

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

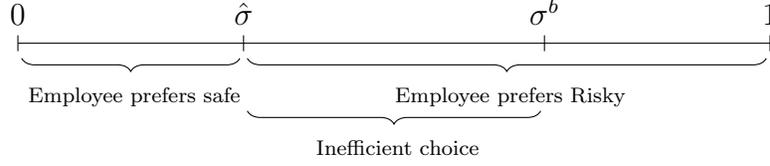


Figure 4: Employee's preferred project given wage w^b

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

$$p_i(\sigma^c) = \int_0^{\sigma^c} p_i^S d\sigma + \int_{\sigma^c}^1 (\sigma p_i^G + (1 - \sigma)p_i^B) d\sigma. \quad (4)$$

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

$$\sigma^c \in \operatorname{argmax}_{\sigma^c} \sum_i p_i(\sigma^c) w_i. \quad (5)$$

The first order condition is given by

$$E[w|S] - (\sigma^c E[w|G] + (1 - \sigma^c) E[w|B]) = 0. \quad (6)$$

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

$$E[w|G] - E[w|B] > 0. \quad (7)$$

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

$$\sum_i p_i(\sigma^c) w_i \geq \underline{u}. \quad (8)$$

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

$$\max_{w, \sigma^c \in [\bar{\sigma}, \sigma^b]} \sum_i p_i(\sigma^c) (X_i - w_i), \quad (9)$$

such that constraints (1), (6), (7) and (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 (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 (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 (1) and (6). We will see later that the cheapest contract which satisfies these two constraints will also satisfy the second order condition (equation (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 (6) and (1).

Lemma 3. *The wage contract which minimizes the expected wage payment and also satisfies constraints (1) and (6) will have equation (1) as a binding constraint and $w_0 = 0$.*

Proof: See Appendix.

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

$$w_2 \geq \frac{\Delta_1}{\Delta_2} w_1 + \frac{b}{\Delta_2}. \quad (10)$$

The IC for cutoff σ^c , also referred to as IC Project (see figure 5), can be rewritten as

$$M(\sigma^c) w_1 + N(\sigma^c) w_2 = 0, \quad (11)$$

where

$$\begin{aligned} M(\sigma^c) &= p_1^S - Pr(X_1|R, \sigma^c), \\ N(\sigma^c) &= p_2^S - Pr(X_2|R, \sigma^c). \end{aligned}$$

Note that $M(\sigma^c) > 0$ and $N(\sigma^c) < 0$.²¹ So, equation (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 (10) and (11) (see figure 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

$$r(\sigma^c) = p_1(\sigma^c)w_1(\sigma^c) + p_2(\sigma^c) \frac{\Delta_1}{\Delta_2} w_1(\sigma^c). \quad (12)$$

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 (7)). The slope of IC project is $-M/N$ and it can be written as²²

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

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 (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 .

²¹This 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.

²³We 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, $E[w|G] > E[w|B]$.

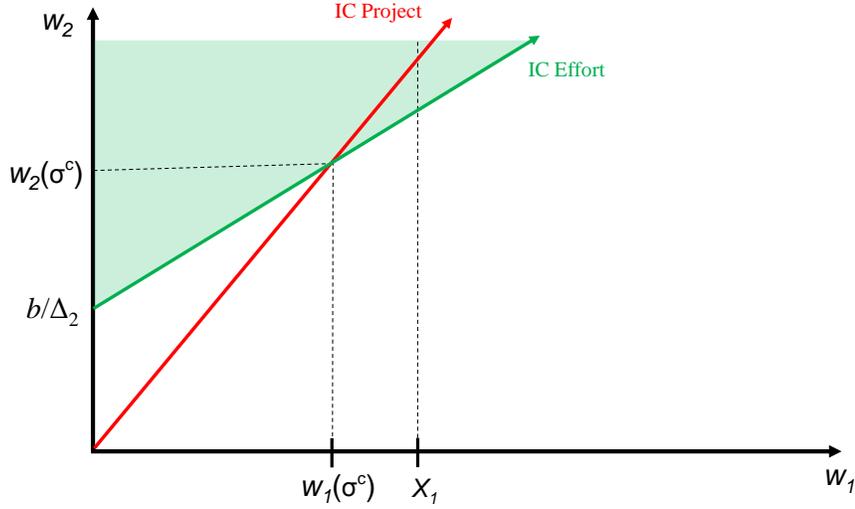


Figure 5: Rent extraction by employee

Lemma 4. *The slope of constraint (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, $Pr(X_2|\sigma^c)$ 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 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 higher expected

²⁴This 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.

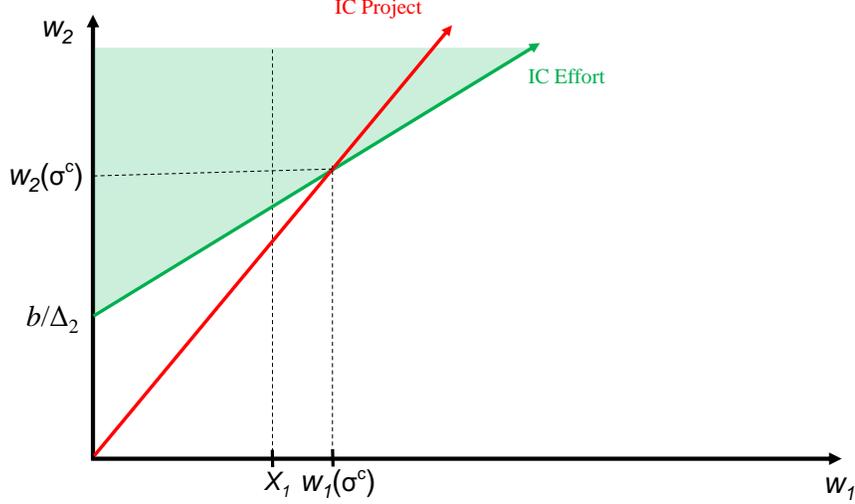


Figure 6: $w_1(\sigma^c) > X_1$. σ^c cannot be implemented.

profits than the latter. This benefit is given by

$$B(\sigma^c) = \int_{\hat{\sigma}}^{\sigma^c} [\pi(S) - \pi(R|\sigma)] d\sigma. \quad (13)$$

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

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

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 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 (6) and the participation constraint (8). If the RM is offered zero wage when X_0 is realized i.e. $w_{0,RM} = 0$, equation (6) can be written as equation (11). This equation then has a positive slope for any $\sigma^c \in [\hat{\sigma}, \sigma^b]$ (see figure 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

²⁵To 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.

²⁷The IC for σ^c (equation 6) and participation constraint (equation 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

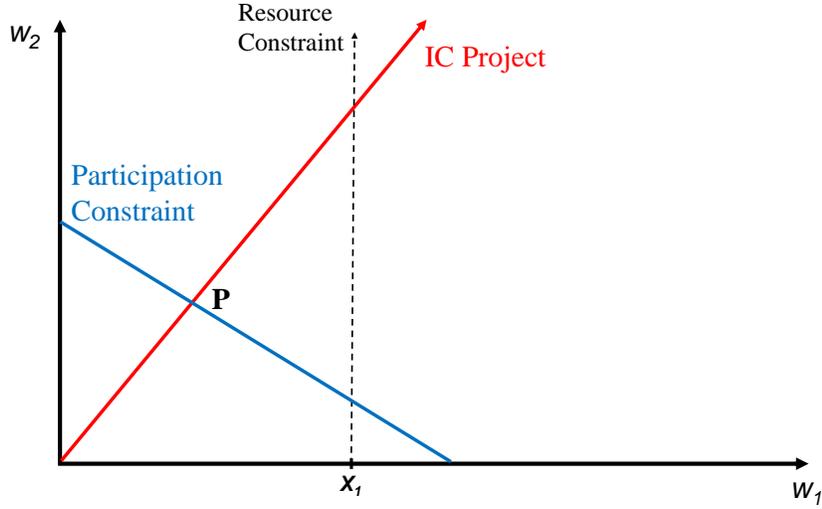


Figure 7: Risk Manager's contract is given by point P

$w_{0,RM} = 0$, 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.

$$\Pi_{RM} = \Pi^b - \underline{u}. \quad (14)$$

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

$$\underline{u} < \int_{\sigma^*}^{\sigma^b} [\pi(S) - \pi(R|\sigma)]d\sigma + r(\sigma^*), \quad (15)$$

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 (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

satisfies the limited liability constraint and also the resource constraint can be offered to the RM.

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.

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 does 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 (6), the incentive compatibility constraint to choose this cutoff can now be written as

$$E[U(w_{RM})|S] - (\sigma^c E[U(w_{RM})|G] + (1 - \sigma^c)E[U(w_{RM})|B]) = 0. \quad (16)$$

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

$$E[U(w_{RM})|G] - E[U(w_{RM})|B] > 0. \quad (17)$$

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 (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 (16) is satisfied, so (17) must hold true.

The participation constraint can now be written as

$$\sum_i p_i(\sigma^c)U(w_{i,RM}) \geq \underline{u}. \quad (18)$$

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

$$\max_{\sigma^c, w_{RM}} \sum_i p_i(\sigma^c)(X_i - w_{RM,i}) - p_2(\sigma^c)b/\Delta_2, \quad (19)$$

such that constraints (16), (17) and (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

²⁸Similar assumption is made by Lambert (1986).

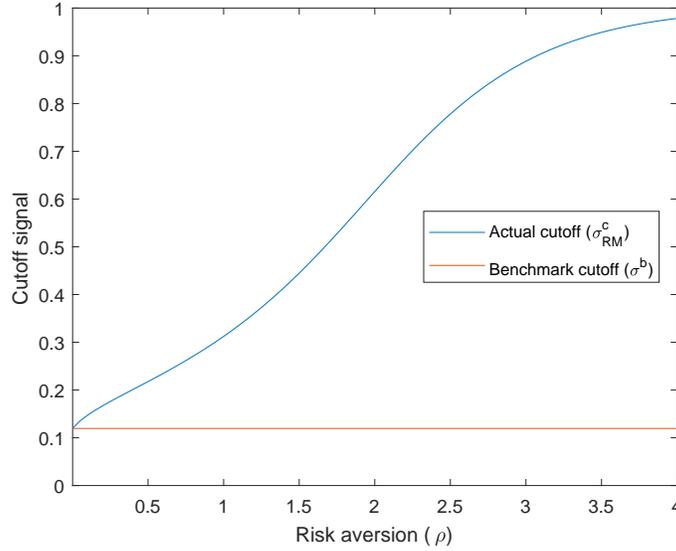


Figure 8: σ_{RM}^c as a function of risk aversion (ρ)

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_{RM}^c , is greater than σ^b . The next proposition summarizes this result. For the exact condition on how high p_1^S must be to get the result, see the proof of the proposition.

Proposition 4. *If p_1^S is large enough then the risk manager's cutoff signal $\sigma_{RM}^c > \sigma^b$.*

Proof: See Appendix.

B. An Example

Consider the following parameter values. $X_2 = 100$, $X_1 = 10$, $X_0 = 1$, $b/\Delta_2 = 40$, $p_2^G = 0.8$, $p_1^G = 0.2$, $p_2^S = 0.9$, $p_1^S = 0.1$, $p_2^B = 0.03$, $p_1^B = 0.75$, $p_0^B = 0.2$. The RM has CRRA utility function $\frac{c^{\rho-1}-1}{\rho-1}$. 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_{RM}^c) will be higher. This is shown in figure 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 (18), the participation constraint of the RM is

$$\sum_i p_i(\sigma^c, q) U(w_{i, RM}) \geq \underline{u}. \quad (20)$$

The incentive constraint to implement σ^c is same as (16) and second order condition is same as (17).²⁹ The CEO's objective is

$$\max_{\sigma^c, w_{RM}, q} \sum_i p_i(\sigma^c, q) (X_i - w_{RM, i}) - p_2(\sigma^c, q) b / \Delta_2, \quad (21)$$

such that (16), (17) and (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_{RM}^c) 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)).

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

²⁹At 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 (16). Similarly the second order condition is also the same.

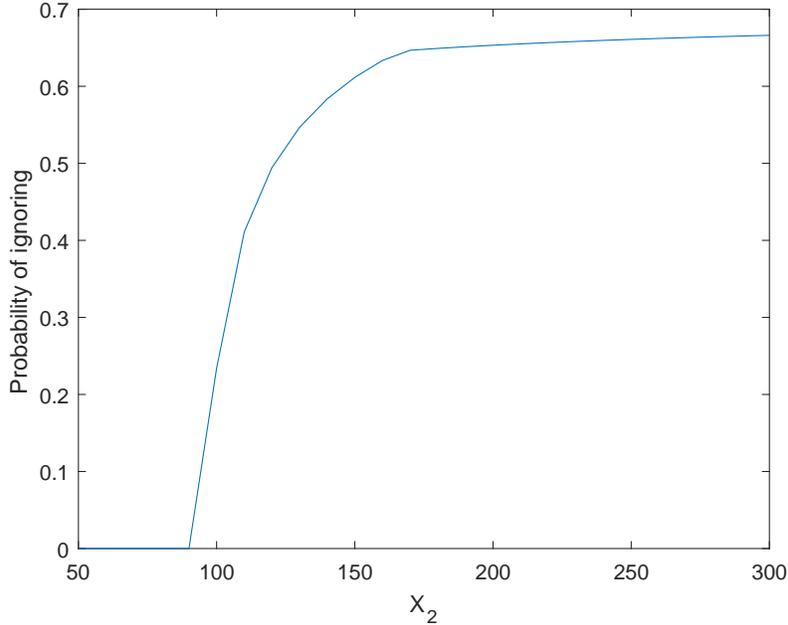


Figure 9: Probability of ignoring risk manager as function of X_2

RM will be small. Risk aversion has two opposing effects. First, as risk aversion increases, σ_{RM}^c also increases. So, the interval $[\sigma^b, \sigma_{RM}^c]$ in which inefficient 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 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 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 $[\sigma^b, \sigma_{RM}^c]$ is small as shown in figure 8. So, the region in which inefficient decision 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

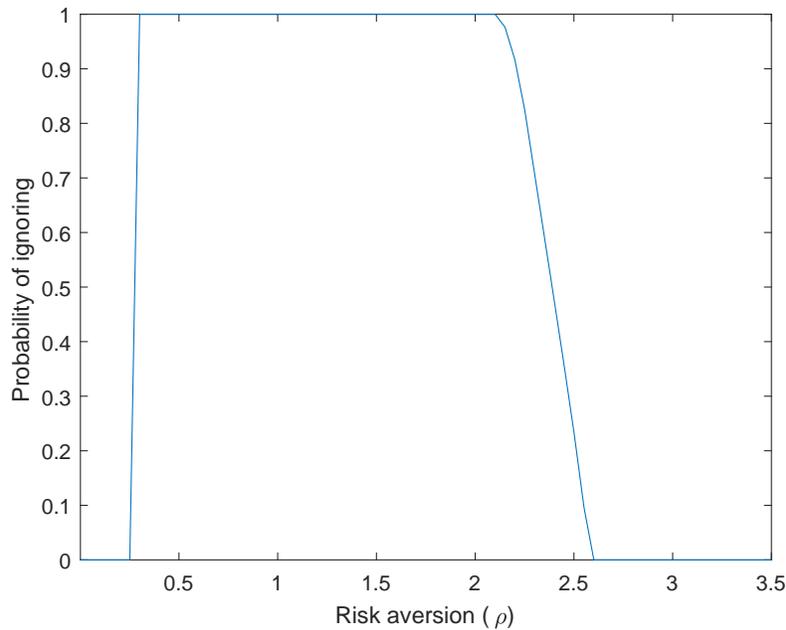


Figure 10: Probability of ignoring risk manager as function of ρ

ρ , compensating the RM with risky project is very costly, so again the CEO does not ignore him.

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 functions, 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

³⁰See Moore (2009).

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 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

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

³²This 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.

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 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

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

³⁴When 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 $(1 - \beta)((1 - \beta) + \beta(\frac{1 - \psi_{RM}}{1 - \psi_{RM}\beta}))^{-1}$.

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: Pooling equilibrium with two employees

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. 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 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

³⁵Although 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 .

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.

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 (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 (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 (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.

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.

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 (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 be written as

$$\int_0^{\sigma^c} E[w|S]d\sigma + \int_{\sigma^c}^1 E[w|R, \sigma]d\sigma - c > E[w|S]. \quad (22)$$

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.

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

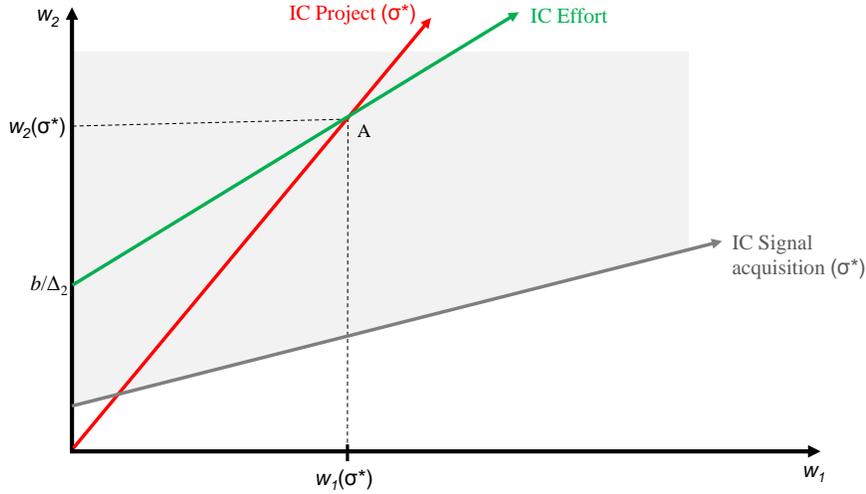


Figure 11: Incentive constraints for one employee with signal acquisition

The incentive to acquire signal can then be written as

$$\int_0^{\sigma^c} E[w|S]d\sigma + \int_{\sigma^c}^1 E[w|R, \sigma]d\sigma - c > \int_0^1 E[w|R, \sigma]d\sigma. \quad (23)$$

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, 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 (22) is depicted in figure 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 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

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

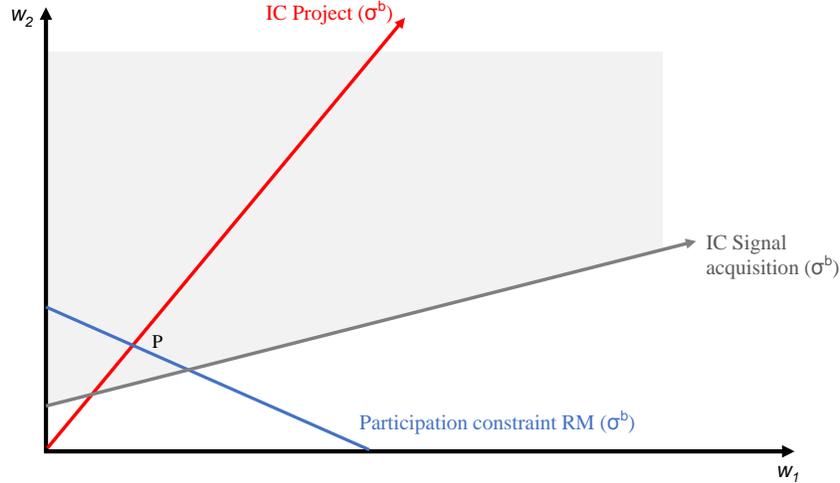


Figure 12: Contract of the RM with signal acquisition

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 7). This same contract is also depicted by point P in figure 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 profits for the one employee and two employee case will also be same as before. Hence, if \underline{u} is low enough such that (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 (15) is satisfied, then it is optimal to split the tasks between two employees.*

Proof: See online appendix.

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.

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.

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Appendix A

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 (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 (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 (1) can be rewritten as

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

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

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

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 (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 (6) and (1), and will also be a cheaper contract. Hence IC for effort must be binding.

Next we prove that $w_0 = 0$. Equation (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 (6) is satisfied. After these reductions, the change in right side of equation (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 $\Delta_1 = \Delta_2 - \Delta_0$, $p_1^S = 1 - p_2^S$ 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 (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

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

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 $\sigma_{RM}^c > \sigma^b$ 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 (4), p_i can be written as

$$p_0 = 0.5p_0^B(1 - (\sigma^c)^2), \quad (24)$$

$$p_1 = 0.5(p_1^G + p_1^B) + (p_1^S - p_1^B)\sigma^c - 0.5(p_1^G - p_1^B)(\sigma^c)^2, \quad (25)$$

$$p_2 = 0.5(p_2^G + p_2^B) + (p_2^S - p_2^B)\sigma^c - 0.5(p_2^G - p_2^B)(\sigma^c)^2. \quad (26)$$

The Lagrange multiplier for constraints (16) and (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

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} X_i - \frac{\partial p_2}{\partial \sigma^c} \frac{b}{\Delta_2} = \sum_i \frac{\partial p_i}{\partial \sigma^c} w_i + \lambda \left[\sum_i \frac{\partial p_i}{\partial \sigma^c} U(w_i) \right] + \mu (E[U(w)|G] - E[U(w)|B]) = 0. \quad (27)$$

Note that the multiplicand of λ is nothing but the f.o.c of employee's utility maximization problem as given in equation (16). Hence this term is 0. So the equation can be written as

$$\sum_i \frac{\partial p_i}{\partial \sigma^c} X_i - \frac{\partial p_2}{\partial \sigma^c} \frac{b}{\Delta_2} = \sum_i \frac{\partial p_i}{\partial \sigma^c} w_i + \mu (E[U(w)|G] - E[U(w)|B]) \quad (28)$$

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 (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 (28), $\sum_i \frac{\partial p_i(\sigma^c)}{\partial \sigma^c} X_i - \frac{\partial p_2(\sigma^c)}{\partial \sigma^c} \frac{b}{\Delta_2}$, 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 (28) is negative at the σ_{RM}^c , it implies $\sigma_{RM}^c > \sigma^b$.

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:

$$\frac{1}{U'(w_2)} = \lambda + \mu \left[\frac{p_2^S - \sigma^c p_2^G - (1 - \sigma^c) p_2^B}{p_2} \right]. \quad (29)$$

$$\frac{1}{U'(w_1)} = \lambda + \mu \left[\frac{p_1^S - \sigma^c p_1^G - (1 - \sigma^c) p_1^B}{p_1} \right]. \quad (30)$$

Eliminating λ from these equations, I get

$$\frac{1}{U'(w_2)} - \frac{1}{U'(w_1)} = \frac{\mu}{p_1 p_2} \underbrace{[p_1(p_2^S - \sigma^c p_2^G - (1 - \sigma^c) p_2^B) - p_2(p_1^S - \sigma^c p_1^G - (1 - \sigma^c) p_1^B)]}_K \quad (31)$$

Since $w_2 > w_1$ and U is strictly concave, so μ will be negative if the multiplicand of $\mu/p_1 p_2$, 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 $p_1^S \rightarrow 1$ and $p_1^B < p_1^S$, then $A < 0$. If $p_1^S \rightarrow 1$, then $p_2^S \rightarrow 0$ and also $p_2^B \rightarrow 0$ because safe first order stochastically

dominates the bad project. So if $p_1^S \rightarrow 1$ and $p_1^B < p_1^S$, then A can be written as

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

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 $p_1^S \rightarrow 1$, 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 (16), (17) and (20) are satisfied. Using envelope theorem, the partial derivative of $V(q)$ is

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

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 $p_1^S \rightarrow 1$, 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 $\frac{X_1}{X_2} \rightarrow 0$ and $\frac{X_0}{X_2} \rightarrow 0$. Also since $p_1^S \rightarrow 1$, so $p_2^S \rightarrow 0$ and $p_2^B \rightarrow 0$.

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,

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

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.