Why can't CEOs foresee a crisis?*

Kaushalendra Kishore†

November 14, 2017

Abstract

This paper explains why CEOs are unable to curtail risky investments before a crisis. CEOs rely on the advice of their employees to understand the riskiness of their investments. When employees observe noisy signals, they may be reluctant to disclose their information for the fear of getting fired. So, the CEO needs to offer contracts which provide incentive to disclose their information. The paper shows that in presence of moral hazard with respect to effort, it may not be possible to offer contracts which also incentivizes disclosure. Even when CEOs are able to offer such contracts, there will be a coordination problem in disclosure of information. These frictions are accentuated when the prior beliefs about an investment strategy being good is high. If the task of disclosing signals is separated and assigned to a risk manager who receives signals of same quality, it can result in more efficient outcomes.

Key Words: financial crisis, personnel economics, disclosure, coordination problem
JEL Classification: D81, M52, G21

This is a preliminary draft. Please do not cite or circulate without the permission of the author.

---

*I thank David Rahman, Raj Singh, Martin Szydlowski, Andrew Winton, and seminar participants at University of Minnesota for helpful comments and suggestions. I alone am responsible for any errors.

†Department of Finance, University of Minnesota, Minneapolis, MN, 55455. Email: kisho012@umn.edu

1 Introduction

Before the recent financial crisis, banks made risky investments which *ex post* turned out to be bad. Given the losses incurred by the banks and also their employees during the crisis, it becomes important to understand why banks did not curtail these risky investments. One of the common explanations is based on misaligned incentives which could be present either within the bank itself due to poorly designed compensation structure or could result from the expectation of government interventions such as bailouts. If bankers take risks as a rational response to poor incentives, then they should know about the distortions that their strategies create. But there is some evidence from the recent crisis which suggests that the bankers may have systematically missed seeing the problems in the housing market (Cheng et al., 2014). Fahlenbrach and Stulz (2011) show that banks with CEOs whose incentives were better aligned with shareholders did not perform better. These evidences suggest that the CEO's of the banks may have taken the risks unknowingly.

The CEO of a firm relies on the advice of his employees to understand the quality of investments that the firm undertakes. If the CEO is taking the risks unknowingly, then it implies that either the employees also do not foresee the risks or if they do, then they either keep silent or are unable to convince the CEOs to discontinue the risky strategies. The natural question that follows is why does the management *appear* to be collectively unaware of the risks in their own investment strategy.

Foote et al. (2012) argue that before the housing market crash, the mortgage analysts had better understanding of the risks than the CDO analysts. The authors note:

> Why didn't the mortgage analysts tell their coworkers how sensitive the CDOs would be to a price decline? This question goes to the heart of why the financial crisis occurred. The answer may well involve the information and incentive structures present inside Wall Street firms. Employees who could recognize the iceberg looming in front of the ship may not have been listened to, or they may not have had the right incentives to speak up (p. 25).

This paper tries to answer these questions by studying frictions in disclosure of information within a firm. At the heart of the paper is a multitasking problem where the CEO (she) needs to incentivize both the disclosure of information and the provision of effort by the employees (he). I build a model where a "smart" CEO may rely on the advice of her employees who are either smart or "dumb." The employees are reluctant to disclose their signals because he does not want to appear dumb and lose his job. The CEO is also unable to observe the effort exerted by the employee and so needs to offer contracts that ensure that he does not shirk. I show that in such a scenario the CEO may not offer incentives to employees to disclose their information either because she is constrained by limited liability or because the employee is able to extract too much rents. I also show that even when the CEO is able to design incentive compatible contracts, the employees may not discloses their information because of coordination problem. [1] These frictions are particularly accentuated when the beliefs that an investment strategy is good is perceived to be high as is usually the case before a financial crisis.

If the informed employees in the firm do not disclose their information either because of the inability of the CEO to design incentive compatible contracts or because of coordination problem then the CEO and other uninformed employees in the bank will remain unaware of the quality of investments that bank is making. Their beliefs about the investment strategy will be more optimistic than is warranted by the aggregate information of all the employees in the firm.

I show that if the task can be split between employees, that is the task of disclosure of information is assigned to a separate employee (called the risk manager) who receives signals of same quality, then this can result in more efficient outcomes. The reason is that the CEO does not need to offer rents to the risk manager to disclose his information. Thus my paper also provides an explanation for why the banks need risk managers and contributes the organization design literature.

Several papers argue that bankers underestimated the risks in their investments before the recent crisis. Foote et al. (2012) argue that investors and banks may have attached a very low probability to occurrence of states where there would be a sharp decline in house prices. For example, Lehman Brothers attached only 5 percent probability to "meltdown" scenario (-5 percent growth in house prices for three year and 5 percent thereafter). They did not even consider scenarios of house price decline that actually happened during the crisis. Cheng et al. (2014) show that mid-level managers in mortgage securitization business were in denial of housing bubble and were more likely to buy houses than real estate lawyers or other financial managers. My paper provides an explanation for failure of employees to see the risks they were taking.

My model not only applies to financial intermediaries but can apply to any firm in general. Failure of firms which pursue aggressive growth strategies, like Enron, has partially been attributed to "groupthink" and false consensus.[2] My paper argues that beliefs which ex post appear to be a consensus, may actually have been heterogeneous because they were

[1] Paul Moore, ex-head of Group Regulatory Risk, HBOS, in his memorandum said, "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." See Moore (2009).

[2] On Enron, see Samuelson (2001); Pearlstein (2000); and Cohan (2002).

based on different information. However, since informed agents did not reveal their signals, uninformed agents could not update their beliefs and remained misinformed.

To fix ideas, consider a bank (or any firm) which has a CEO and some employees. The bank has a safe project and a risky project, which can be good or bad. The CEO and the employees may (or may not) also see a private signal, low or high, about the type of the risky project. The CEO is smart and always observes perfectly informative signal, and thus learns the type of project, if she observes it. But the employees differ in their ability and may be smart like the CEO, or may be "dumb" in which case his signals are noisy.[3] A dumb employee also results in some loss of value of the project. Employees also need to put costly effort into the project which cannot be observed by the CEO. So to incentivize employees to exert effort, they need to be paid higher wages for higher outputs (high powered incentives).

The employees have an option to disclose their signals to the CEO and she then chooses the risky or the safe project. The employees do not know whether the CEO has received any signal or not. When the employees disclose the low signal then, there can be two outcomes. In case the CEO does not observe any signal or observes the low signal, the employee is retained and she undertakes the safe project. But if the CEO observes the high signal, then she learns that the project is good and the employee is dumb. So, she fires the employee and chooses the good project. Thus, the employees miss out on the wages from the good project which they would have received had they not disclosed. The benefit from disclosure comes from wages when safe project is undertaken and loss comes from missing out on wages from the good project. Since a good project has higher chances of high returns than the safe project, high powered incentives may imply that the employee is better off not disclosing the low signal. Thus, there is a conflict between providing incentives for disclosing low signals and providing incentives for effort. I show that if the prior probability that the risky project is good is high, then it may be impossible to design contracts such that employees disclose their signals.

Even when the CEO is able to offer incentive compatible contracts to disclose information, with multiple employees, there can also be a coordination problem in disclosure of signals. Suppose there are two employees. If the likelihood that the risky project is good is high, then CEO is convinced to reject the risky project only when both employees disclose low signal. If only one employee discloses, it will not be enough to convince the CEO. So, if one employee discloses and other does not, the one who discloses only risks the chance of losing his job. Thus, there exists strategic complementarities in disclosure strategy. This results in multiple equilibrium, one of which is efficient where both disclose, and the other is inefficient where nobody discloses.

[3] This characterization is similar to Scharfstein and Stein (1990).

A key assumption that drives my results is that the contracts are incomplete. I assume that that wages can only be made contingent on returns realized and not on the riskiness of the project. This assumption can be justified by the fact that the risk profiles of the investment portfolios in banks can change very fast. The exact risks can also be hard to assess and verify by an outside court, given the complex nature of products such as collateralized debt obligations (CDOs). So it is difficult for the CEO to write a contract contingent on the exact risk profile of the project.

1.1 Related Literature

My paper is related to the literature on multitasking agency problem which follows the seminal contribution of Holmstrom and Milgrom (1991). A recent related paper where agents are incentivized to exert effort and also disclose private information is Heider and Inderst (2012).[4] In their paper they model a loan officer who is incentivized to exert effort to prospect for loans and also disclose soft signals about the loan. The key friction is that the agent gets the same wage when he is not able to find a loan or when the loan is rejected because of unfavorable signal. In my model the bank already has two investment strategies but the employees need to exert effort on them and also disclose information about them. The assumption driving the result is that the wages can not be made contingent on the riskiness of the project.

The paper is also adds to the ever growing literature on financial crisis.[5] It provides an alternative theory which explains risk taking by financial intermediaries, not because of distorted incentives or behavioral biases (Shiller (2015), Barberis (2011)),[6] but because of incorrect beliefs created due to frictions in disclosure by informed employees within the firm.

Gennaioli et al. (2012, 2015), Thakor (2015) and Bénabou (2012) emphasize the role of behavioral biases and cognitive dissonance in explaining why these banks were underestimating or ignoring the risks. Gennaioli et al. (2015) use the idea of representativeness heuristic where a series of good outcomes may make the agents overestimate the probability of good outcomes in future. So, before the crisis, high growth in real estate prices could have made the banks overestimate the profitability of mortgage related securities and issue excessive debt which they could not pay out ex post. Gennaioli et al. (2012) argue that agents suffer from "local thinking" where not all states of world come to the mind. So, the investors may assign zero probability to less likely states and buy securities which they assume to be safe

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

[5] For surveys on financial crisis, see, for example, Kindleberger (1978); Reinhart and Rogoff (2009); Brunnermeier and Oehmke (2012); among others.

[6] On incentive problems see, for example, Rajan (2006); Acharya and Yorulmazer (2007); Acharya et al. (2010); Stiglitz (2010); Farhi and Tirole (2012); among others.

but are actually not. Once they realize that the securities they invested in are not safe, they dump these securities into the market and move to more traditional ones. Their model requires that all agents must be behaving in the same manner. My paper argues that even when some agents do see the possibility of such a state, he may not disclose this to other agents.

Thakor (2015) builds a model where availability heuristic can make bankers over estimate their skills after high returns. This then leads the financial institutions to underestimate the true risk. In this paper, high returns result in coordination problem in disclosure of information and if there is no disclosure then the bankers underestimate the risks. The difference in my paper is that there are at least some agents who have noisy information about the project being bad where as in Thakor (2015) all agents are fooled by high returns due to availability heuristic. Bénabou (2012) builds a model of groupthink where they show that denial of bad news or wishful thinking can be contagious. In my model, informed agents may not disclose at all and so the CEO and the uninformed employees do not get any bad news, making the entire organization appear as if they were all collectively optimistic.

A common theme running in these papers is that entire firm must be suffering from some behavioral bias or cognitive limitation. But, this paper tries to look at firms as organizations with heterogeneous agents having different information and beliefs.[7] The paper analyses the interaction between CEOs and employees and argues that there can be frictions in information collation process within a firm. Foote et al. (2012) have argued that information and incentive problems may have existed "between different floors of the same Wall Street firm." This paper provides a theoretical explanation for their claims.

This paper also adds to the literature on strategic disclosure by agents. While there is large literature describing how self interested managers would time the disclosure of information to investors,[8] my paper analyses disclosure by employees within a firm, and its implications on investment strategies.

The rest of the paper is organized as follows. Section 2 describes the framework. Section 3 discusses the contracting problem. Section 4 describes the coordination problem with multiple employees. Section 5 discusses how a risk manager can be helpful in solving the conflict in contracting problem. Section 6 shows why the contracts would be renegotiation proof and section 7 discusses extention with continuous signals. Section 8 concludes. The proofs are provided in the appendix.

[7]There are several examples of employees who warned their firms before the crisis, such as Madelyn Antoncic and Michael Gelband at Lehman Brothers, David A. Andrukonis at Freddie Mac and Jeff Kronthal at Merrill Lynch.

[8]See, for example, Rajan (1994); Dye and Sridhar (1995); Beyer et al. (2010); Acharya et al. (2011); among many others.

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 some employees (hereinafter referred to as he). Although I use the word bank, the model is quite general and applies to any firm. All agents are risk neutral and hence maximize the expected value of their payoffs. I assume that agents differ in their ability and are of two types, high ability referred to as "smart" and low ability referred to "dumb". A CEO is always smart but an employee can be either smart with probability β or dumb with probability $1 - \beta$. A smart agent observes more accurate accurate signals than the dumb agents (as will be described later).[9] Apart from this a dumb agent will also results is loss of value (as will be described later). It is common knowledge that an employee can be dumb but neither the CEO nor the employees know who is dumb.

There are 4 dates $t = 0$, 1, 2, and 3. At $t = 0$, the bank has access to two investment projects, *risky* and *safe* (S). Both projects require one unit of investment and yields a random return $X \in \{X_0, X_1, X_2\}$ (the probability distribution is described later). Without loss of generality I assume that $X_0 = 0$ and $X_2 > X_1 > X_0$. The risky project can be of two types. It can be good, G, with probability α or bad, B, with probability $1 - \alpha$.

At $t = 1$, the employees and CEO may receive signals about the project type and the employees will have an option to disclose those signals to the CEO. The CEO invests in either the risky or the safe project based on her own signal and also the signals disclosed by the employees.

At t=2, the employees can either work (exert effort) on the project or choose to shirk. The private benefit of shirking (or alternatively the cost of exerting effort) to the employee is b. The CEO cannot observe the employee's effort and needs to provide incentive so that employees work. From here on I assume that the firm has only one employee to illustrate the problems in designing incentive compatible contracts. I will introduce multiple employees when I discuss the coordination problem (see section 4). Conditional on employee working, the good project and the safe project has positive NPV while the bad project has negative NPV. At $t = 3$ the returns are realized and employees are paid.

The probability distribution of the project returns given that the employee is smart and works is denoted by p_i^θ, where $\theta \in \{G, B, S\}$ is the type of the project and $i \in \{0, 1, 2\}$ corresponds to the value of the project return X_i. The probability distribution is shown in table 1. For simplicity I have assumed that the good project and safe project do not yield

[9] Scharfstein and Stein (1990) use a similar characterization to study herding behavior among CEOs.

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

Table 1: Project returns given that the employee is smart and he works

return X_0, i.e. $p_0^G = p_0^B = 0$. The value of the project given that the employees is smart and works is $V(\theta)$ and I assume that

$$V(G) > V(S) > 0 > V(B).$$

This implies that $p_2^G > p_2^S$ and $p_1^G < p_1^S$. In our simple setting this also implies that the good project first order stochastically dominates the safe project. I also that the safe project, and thus the good project, first order stochastically dominates the bad project. This implies that $p_2^S > p_2^B$.

Remark 1. The safe project can be interpreted as investment in conventional loans, asset backed securities backed by prime mortgages or collateralized debt obligations (CDOs) backed by subprime mortgages which are completely hedged for default risk (taking into account the counterparty risk). The CEO knows the distribution of these returns very well and that these projects are not going to fail. He also knows that they are very likely to yield *average* returns and very less likely to yield high returns. In our model this implies that p_1^S is very high and p_2^S is very low. The risky project can be interpreted as taking unhedged positions in CDOs backed by subprime mortgages. This is a risky investment strategy and the CEO is not sure whether it is good or bad. If these investments are good, then they are very likely to give high return but if they are bad then they are very likely to give low return. In terms of our model, this implies that p_2^G and p_0^B are high. Thus the good, safe and bad projects can be interpreted to have a relatively high weight on X_2, X_1 and X_0 respectively.

If the employee shirks, then there is a loss in value of the project. Conditional on shirking, for any type of project, the probability of X_2 is reduced by Δ and that of X_1 is increased by Δ. So loss in value from shirking, denoted by L^s, is given by

$$L^s = \Delta(X_2 - X_1)$$

I assume that if the employee shirks then even the good project has negative NPV. This trivially implies that the safe and bad project also has negative NPV when the employee shirks. Thus a CEO must offer a contract to the employee such that he prefers to work and not shirk.

Assumption 1. $V(G) - L^s + b < 0$.

A dumb employee also results in loss of value even if he works because he is of low ability (or productivity). If the employee is dumb but exerts effort, then for any type of project, the probability of occurrence of X_2 is reduced by κ and the probability of occurrence of X_1 is increased by κ. Thus the loss in value if the employee is dumb, denoted by L^d, is given by

$$L^d = \kappa(X_2 - X_1).$$

I assume that κ is low enough such that the safe and good project have positive NPV even when employee is dumb.

Assumption 2. $V(G) - L^d > V(S) - L^d \geq 0 > V(B) - L^d$.

Since *ex ante* the employee is dumb with probability $1 - \beta$, the *ex ante* value of any project θ, given that the employee does not shirk, is $V(\theta) - (1 - \beta)L^d$.[10] So the good and safe project have positive NPV.

2.2 Signals

At $t = 1$ agents may receive signals about the type of the project. CEO and employees independently receive a private and unverifiable signal with probability ψ and do not receive any signal (denoted by n) and with probability $(1 - \psi)$. The signal can take two values, high (h) or low (l). I denote the CEO's signal by s^c and the employee's signal by s^e. A smart agent (CEO or employee) observes a perfectly accurate signal, given that he receives it.[11]

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

On the other hand, a dumb employee observes noisy signals when he sees it.

$$Pr(h|G; dumb\ sees) = Pr(l|B; dumb\ sees) = z.$$

[10] The *ex ante* probability of occurrence of X_2 is $p_2^\theta - (1 - \beta)\kappa$ and of X_1 is $p_1^\theta + (1 - \beta)\kappa$.

[11] This is not a necessary assumption and results will be qualitatively unchanged as long as the smart agents see sufficiently more accurate signals that dumb agents.

I assume that although the signal seen by the dumb employee is noisy, they are still informative, that is $1/2 < z < 1$. This assumption implies that the signal seen by an employee, with the prior that he is dumb with probability $1 - \beta$, is informative as well.

I will often refer to the signal seen by the employees (n, h or l) as the *type* of the employee.[12] Since the CEO is smart, whenever she sees the signal she is able to learn the type of the project with certainty. But an employee is not sure whether he has seen the correct signal or the wrong signal because he may be dumb.

2.3 Contracts

There is no agency problem between the CEO and the owners of the bank, and so the CEO takes the decision to maximize the value of the bank. Since the CEO is smart, so if she observes the high signal (low signal), she learns that the risky project is good (bad) and invests in the risky (safe) project. If she does not observe any signal then she has to rely on the signal disclosed by the employee.

The employee's signal is noisy because he may be dumb. After he discloses his signal, the CEO updates her belief about the employee being dumb. For example if the employee discloses the low signal (high signal) and the CEO observes the high signal (low signal), then she is able to learn for sure that the employee is dumb. Based on her posterior probability of employee being dumb, the CEO decides whether to fire the employees. If the employee is fired then he is replaced with a new employee who may again be dumb with probability $1 - \beta$. The replacement cost is C.[13] I assume that if the employee is fired then he can not immediately find a job or has to take a pay cut because the market learns that he is dumb.[14] For simplicity I assume that the employees get 0 utility if he is fired. The fear of getting fired may make the employee reluctant to disclose his signal. Thus the CEO needs to offer contracts such that the employees prefer to disclose their information in spite of the chance of getting fired. The contract must also be incentive compatible for the employees to work because if the employee shirks the projects have negative NPV (assumption 1).

The CEO offers a wage contract at $t = 0$ to the employee in which the employee is paid w_i if return takes value X_i. A key assumption that I make is that the contracts are incomplete in the sense that wages can only be made contingent on returns and not on whether the project is risky or safe. This assumption can be justified by the fact that the risk profiles of

[12] This is not to be confused with the ability of the employee. I do not refer to different abilities of the employees as his type because the employees do not know their ability where as in incomplete information games we assume that an agent knows his type.

[13] This could be the cost of posting an advertisement or training the new employee.

[14] See Gibbons and Katz (1991) for evidence of how workers who are laid off are interpreted by the market as having low ability and hence are paid lower wages.

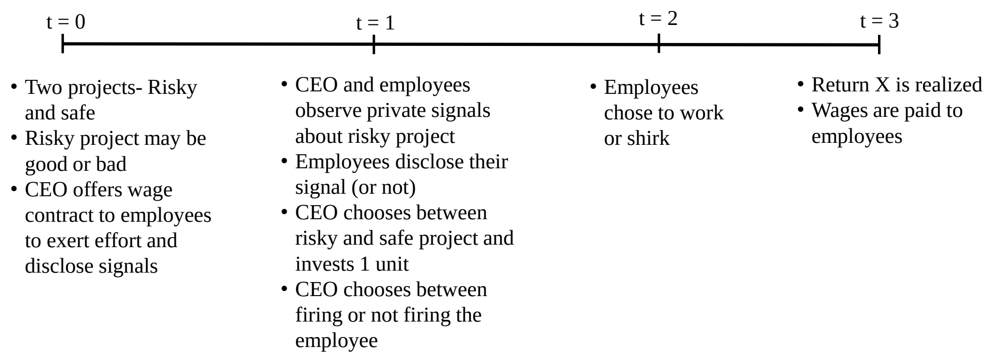

Figure 1: Time Line

investment portfolios in banks can change very fast. The exacts risks can be hard to asses and verify given the complex nature of products such as CDOs. So it is difficult for the CEO to write a contract contingent on the exact risk profile. The reservation wage of the employees at $t = 0$ is $\underline{u}$.

I assume limited liability for the employees and also for the investors. This implies that if the project is financed using debt D, then $0 \leq w_i \leq [X_i - D]^+$, where $[X - D]^+$ equals $(X - D)$ if it is positive and 0 if it is negative. This further implies that $w_0 = 0$. I assume D to be exogenously given in our model and also that it is less than X_1 such that the safe and good project never fail and positive wage can be offered if X_1 is realized.[15]

The employee is reluctant to disclose his information because of the fear of getting replaced. The CEO in our model cannot commit to not fire the employee once she knows that he is dumb. I assume that if the CEO explicitly mentions in the contract that the employee will not be fired then other kinds of moral hazard problems may appear. For simplicity I abstract from the details of such problems and assume that the CEO cannot commit to not fire the employees.

I will show later that the contract offered will be renegotiation proof. This is important because of the following reason. The friction in disclosure arises because the CEO can not credibly convey to the employee what signal she has seen and also can not commit to not fire the employees. I will show later that in equilibrium the employee will never be fired

[15]The qualitative nature of my results do not depend on the value of debt as long as it is less than X_1.

when the CEO does not observe any signal, so, if at $t = 1$, the CEO is able to offer a new contract and can credibly convey to the employees that she has not seen any signal and the employee will not be fired, then he will disclose his signal without the fear of losing his job. But this can not happen because in case CEO observes the signal, she still has an incentive to behave as if she has not seen any signal so that she can find out whether the employee is dumb and fire him. This is the basic intuition why the contracts are renegotiation proof. More details are discussed in section 6.

3 Solving the model

My model has two information frictions. First the CEO can not observe the effort put in by the employee and second neither the CEO nor the employee can observe the signal seen by each other. The CEO's objective is to take decisions to maximize the value of the bank. Since I have assumed that if the employee shirks then the project has negative NPV, the CEO must offer a contract that is incentive compatible for the employee to work. Also, the CEO may not observe any signal in which case she has to rely on the signal disclosed by the employee to take the decision. But the employee risks the chance of getting fired if he discloses his signal. So the CEO needs to provide incentives such that the employee discloses his signal. In this paper I will show that in presence of moral hazard with respect to effort it may not be possible to design contracts which are incentive compatible for the employees to disclose their information.

I use Perfect Bayesian Equilibrium as the equilibrium concept. This has the following implications. First the CEO will choose the project and take the firing decision to maximize the value of the project. Second, the employees decision to disclose truthfully or hide his signal must be taken to maximize his utility taking as given the CEO's optimal decisions and the wage contract offered. Third given her information set, CEO's beliefs are updated using Bayes' rule whenever possible. I solve the model backwards. I first discuss the CEO's decision regarding the project choice and replacing the employee given her own signal and the signal disclosed by the employee. I then discuss how the contract may be designed to incentivize the employee to disclose his signal and whether the CEO will choose to offer such a contract in equilibrium.

The optimal decision regarding the project choice is trivial after the CEO observes any signal because her signals are perfectly accurate. So whenever I discuss the optimal decision regarding project choice, it is only for the case where CEO has not seen any signal. The CEO will choose the risky project if the posterior probability (after observing s^c and employee disclosure) that the project is good is greater than $\underline{\alpha}$ where $\underline{\alpha}$ is defined by equation

$$\underline{\alpha}V(G) + (1-\underline{\alpha})V(B) = V(S).$$

To resolve the indifference, I assume that the CEO chooses the risky project when she is indifferent between choosing the risky and safe project.

The prior probability that the project is good, α, can either be greater than $\underline{\alpha}$ or less than $\underline{\alpha}$. When $\alpha \geq \underline{\alpha}$, then the CEO will take the risky project when she observes n and the employee observes either n or h. If α is so high that the CEO will choose the risky project even when the employee observes l, then the problem of employee disclosure is irrelevant because CEO's decision regarding project choice is same irrespective of the signal seen by employee. So I only consider scenarios when it is optimal to choose the safe project if $s^e = l$, that is α satisfies

$$Pr(G|s^e = l, s^c = n) = \frac{\alpha(1-z)}{\alpha(1-z) + (1-\alpha)(\frac{\beta}{(1-\beta)} + z)} < \underline{\alpha} < \alpha. \tag{1}$$

The term on the left is the probability that project is good given that $s^e = l$ and $s^c = n$. This term being less than $\underline{\alpha}$ implies that the risky project has lower value than the safe project and hence the CEO chooses the safe project.

When $\alpha < \underline{\alpha}$, then the CEO will take the safe project when she observes n and the employee observes either n or l. If α is so low that the CEO will choose the safe project even when the employee observes h, then again as above, the problem of employee disclosure is irrelevant. So I only consider scenarios when it is optimal to take the risky project if $s^e = h$, that is α satisfies

$$\alpha < \underline{\alpha} < \frac{\alpha(\frac{\beta}{1-\beta} + z)}{\alpha(\frac{\beta}{1-\beta} + z) + (1-\alpha)(1-z)} = Pr(G|s^e = h, s^c = n). \tag{2}$$

The term on the right is the probability that project is good given that $s^e = l$ and $s^c = n$. This term being greater than $\underline{\alpha}$ implies that the risky project has higher value than the safe project and hence the CEO chooses the risky project.

Lemma 1. *If α satisfies (1), then the CEO chooses the safe project if the employee observes l, otherwise she chooses the risky project. If α satisfies (2), then the CEO chooses the risky project if the employee observes h, otherwise she chooses the safe project.*

To characterize the decision to replace the employee I make the following assumptions. I assume that if the CEO is sure that the employee is dumb then she will fire him and replace him with a new one, who may be dumb with probability $1-\beta$. The loss in value from a dumb employee is L^d, so the benefit of replacing the employee is βL^d. This is not the only benefit of replacing the dumb employee. I later show that when the CEO offers contracts to the employees which incentivizes him to disclose his signal, then the employee is able to extracts rents. If the employee is replaced, then the CEO need not pay this rent to the new employee and so there is an additional benefit of replacing the employee. The maximum value of the rent extracted is $X_1 - D$ (as will be shown later). I make the following assumption.

Assumption 3. $\beta L^d + (X_1 - D) > C$. Thus if the CEO knows that the employee is dumb he is replaced.

When the CEO observes a signal, say h (l) and she knows that the employee has either seen no signal or has seen the opposite signal l (h), then she is not sure that the employee is dumb. The probability that he is dumb is

$$\frac{1-\beta}{(1-\beta)+\beta(\frac{1-\psi}{1-\psi\beta})}.$$

This term is greater than $(1-\beta)$ and less than 1. I assume that in this case the employee is not fired.

Assumption 4.

$$[\frac{1-\beta}{(1-\beta)+\beta(\frac{1-\psi}{1-\psi\beta})} - (1-\beta)]L^d + (X_1 - D) < C.$$

As in assumption 3, the first term on left side is the reduction in value loss and the second term is the prevention in rent extraction. A corollary of assumption 4 is that an employee in not fired if the CEO knows that the employee has seen the same signal as the CEO or if the employee has seen n.[16]

Corollary 1. *If the CEO knows that the employee has seen the same signal as her or if the employee has seen n then he is not fired.*

Similarly if the CEO does not observe any signal then irrespective of the signal that

[16]This is because the when the CEO knows that employee has seen the same signal as her, then the posterior probability that he is dumb is less than $(1-\beta)$.

employee may observe, the CEO can not be sure that the employee is dumb. If the $s^c = l$, then the probability that he is dumb is

$$\frac{1-\beta}{(1-\beta)+\beta\frac{1-\alpha}{\alpha(1-z)+(1-\alpha)z}},$$

and if the $s^e = h$, then the probability that he is dumb is

$$\frac{1-\beta}{(1-\beta)+\beta\frac{\alpha}{\alpha z+(1-\alpha)(1-z)}}.$$

I assume that the CEO does not replace the employee if she does not observe any signal.

Assumption 5.

$$[max\{\frac{1-\beta}{(1-\beta)+\beta\frac{1-\alpha}{\alpha(1-z)+(1-\alpha)z}}, \frac{1-\beta}{(1-\beta)+\beta\frac{\alpha}{\alpha z+(1-\alpha)(1-z)}}\} - (1-\beta)]L^d + X_1 - D < C.$$

In summary, assumptions 3, 4 and 5 together imply than an employee is fired only if the CEO knows that the employee has seen a signal opposite of that seen by her and thus is sure that he is dumb, otherwise he is not fired.

I assume that when the employee is deciding which signal to disclose based on the signal observed by him, then he can hide his signal (disclose n) but not lie about their signal (disclose low (high) when he has observed high (low)). This assumption is made only for brevity of arguments. The reason is that any contract that is incentive compatible such that the employee prefers to disclose rather than hide his signal will also be incentive compatible such that he prefers not to lie. An employee who does not receive any signal will thus report the same. Since this is a signaling model where employee chooses to disclose based on his type (signal observed), there are two kinds of equilibrium, separating and pooling. I define separating equilibrium as the equilibrium where any type of employee (l, h or n) will disclose his signal truthfully, that is if the employee observes a signal then he discloses his signal truthfully and if he does not observe then he discloses that he did not see any signal.

I will first show that a separating equilibrium cannot exist. If α satisfies (1), it is optimal to invest in the safe project only if $s^e = l$. This implies that there is no value of disclosing the high signal, because the optimal decision is the same even when employee does not observe any signal. So an employee will never disclose if he observes h because then he only risks the chance of getting fired without changing the CEO's decision. In other words, it is impossible for the CEO to design a contract such that the employee will disclose h if α satisfies (1).

Similarly, if α satisfies (2), it is optimal to invest in the risky project only if $s^e = h$. So there is no value of disclosing l and if an employee discloses l then he only risks the chance of getting fired without changing the CEO's decision. So it is impossible for the CEO to design a contract such that the employee will disclose l if α satisfies (2). The above discussion results in the following lemma.

Lemma 2. It is impossible to design contracts to implement the separating equilibrium.

Given that the CEO cannot design a contract to implement the separating equilibrium, the CEO designs a contract such that the employee discloses the low signal if alpha satisfies (1) and discloses the high signal if α satisfies (2). I define 'Pooling L' as the equilibrium where l type employee discloses while the h type does not disclose and says that he did not observe any signal and thus pools with the n type employee. Similarly I define 'Pooling H' as the equilibrium where h type employee discloses while the l type does not disclose and says that he did not observe any signal and thus pools with the n type employee. The CEO thus offers a contract to implement Pooling L if α satisfies (1) and Pooling H if α satisfies (2). Thus the contract offered will depend on whether α satisfies (1) or (2). But before I discuss the more complicated incentive compatibility (IC) constrains for disclosing the signals, I first discuss the much simpler IC constraints for not shirking.

The contract offered must be incentive compatible for employees to exert effort at $t = 2$ because if the employee shirks then any project has negative NPV. The IC constraint for employee to work is given by

$$w_2 - w_1 \geq \frac{b}{\Delta}. \tag{3}$$

Equations 3 is similar to the familiar incentive constraint used by Holmstrom and Tirole (1997). This implies that w_2 must be greater than w_1. Figure 2 shows the region where this constraint is satisfied. Since the CEO is maximizing the value of the firm, so he will offer the wage that minimizes the expected wage payment to the employee. If there was no need to incentivize the employee to disclose the signals, the wage offered (assuming that participation constraint is satisfied) would be $w_1 = 0$ and $w_2 = b/\Delta$.

I now analyze the contract offered by the CEO when α satisfies (1) and so she wants to implement Pooling L. In this equilibrium the employee discloses the low signal (if he receives it) so the contract must satisfy incentive constraint for disclosing low signal (ICDL). In equilibrium the employee discloses l and if he deviates then he hides the low signal. The decisions taken by the CEO will depend on the signal disclosed by the employee and the signal observed by the CEO. Table 2 describes the CEO's decisions for different signals seen by her. Column one is the signal observed by her. Column two describes the decisions taken

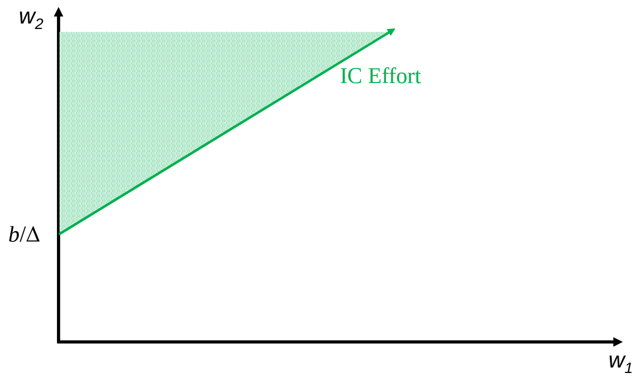

Figure 2: IC constrain for effort

CEO signal (s^c)	Disclose l	Disclose n	Utility
h	Fire & Risky	Retain & Risky	lower
l	Retain & Safe	Retain & Safe	same
n	Retain & Safe	Retain & Risky	higher

Table 2: CEO's actions when employee has seen l

by the CEO if the employee discloses l as will happen in Pooling L. Column three describes the CEO's decision when the employee deviates and hides his signal, that is he discloses n. Column four describes whether the utility of the employee in equilibrium is higher, lower or same compared to when he deviates.

Let us consider the first row. When $s^c = h$ and the employee discloses l then she learns that the project is good and the employee is dumb. So she fires the employee (assumption 3) and continues the project. But if the employee deviates and discloses n, then the CEO believes that the employee has either seen h or n. So she does not fire him (corollary 1) and invests in the risky project. Thus the employee gets less utility from disclosing than from hiding.

If the $s^c = l$ (second row) and the employee discloses l, then the CEO retains the employee (corollary 1) and choose the safe project. If the employee decides to deviate and does not disclose, then the CEO believes that the employee has either seen n or h. So she does not fire him (assumption 4) and chooses the safe project. Her decisions remain the same and hence the employee's utility is also the same.

When the $s^c = n$ (third row) and employee discloses l, then CEO does not fire him (assumption 5) and also takes the safe project because α satisfies (1). If the employee discloses n then the CEO retains him but chooses the risky project.

In order to provide incentive to disclose, the CEO must design contract such that the employee receives more utility from disclosing l than disclosing n when the CEO has observed n. So the incentive to disclose has to come from wages which offer more utility from the safe project. The loss from disclosing the low signal comes from the fact that employee may get fired when CEO observes h and miss out on the wages when the project is actually good. A good project puts higher probability on X_2 and lower probability on X_1 compared to the safe project (because $V(G) > V(B)$). So if the wage after occurrence of X_2 is much larger compared to wage after X_1 then the employee will not have the incentive to disclose the low signal. But to provide incentive to work and not shirk, wage after X_2 must be large enough compared to wage after X_1. This creates a conflict between providing incentives to disclose the low signal and incentive to work. If private benefits from shirking are large then it may be impossible to design contracts such that both incentive constrains are satisfied. In such a scenario, the CEO will only care about incentive for working because if the employee shirks then the project has negative NPV. I will now formalize these arguments.

Incentive constrain for disclosing l and thus implementing Pooling L is given by

$$\begin{aligned}(1-\psi)[Pr(X_1|S)w_1 + Pr(X_2|S)w_2] \geq (1-\psi)[Pr(X_1|Risky)w_1 + Pr(X_2|Risky)w_2] \\ +\psi Pr(G)[Pr(X_1|G)w_1 + Pr(X_2|G)w_2]. \qquad (4)\end{aligned}$$

All the probabilities are calculated conditional on $s^e = l$. The term on the left is the utility when safe project is undertaken after the CEO does not observe any signal (probability $(1-\psi)$) and employee discloses l. The first term on the right is the utility when CEO continues with the risky project after CEO has seen n and the employee deviates and discloses n. The second term on the right is the utility when the CEO observes h and the employee deviates and does not disclose and so the CEO retains him and takes the risky project (which is good as $s^c = h$).

The equation can be simplified and written as

$$Aw_1 + Bw_2 \geq 0, \qquad (5)$$

where[17]

$$A = [Pr(X_1|S) - Pr(X_1|B)Pr(B) - Pr(X_1|G)Pr(G)\{1 + \frac{\psi}{1-\psi}\}]$$
$$B = [Pr(X_2|S) - Pr(X_2|B)Pr(B) - Pr(X_2|G)Pr(G)\{1 + \frac{\psi}{1-\psi}\}].$$

[17] $Pr(X_i|Risky)$ has been replaced by $Pr(X_i|B)Pr(B) + Pr(X_i|G)Pr(G)$ in (4) and the terms have been

A	B	Contract
+	+	possible
-	+	possible
-	-	impossible
+	-	Conflict with ICE

Table 3: Feasibility of contract

Now there are 4 scenarios depending on the sign that A and B may have as shown in table 3. In row 1 and 2, B takes a positive value. In these scenarios constraint (3) and (4) can be satisfied together by simply increasing the value of w_2 and decreasing w_1 or simply making w_1 equal to 0. So moral hazard with respect to effort does not impede writing a contract which provides incentive for disclosing l. Hence, the CEO will offer the contract $w_1 = 0$ and $w_2 = b/\Delta$ and I assume that the reservation wage of the employee, $\underline{u}$, is small enough such that his participation constraint is satisfied at this wage.[18] The expression for B suggests that it is unlikely to be positive if $Pr(X_2|S)$, which equals $p_2^B + (1 - \beta)\kappa$, is small. As discussed in remark 1, this is likely to be the case because the safe project has high weight on X_1 and low weight on X_2, and also κ is small (assumption 2).

In row three both A and B are negative. In such a case, it is impossible to write a contract such that (5) is satisfied because of limited liability. Hence CEO cannot write a contract such that the employee discloses l. This scenario is likely to happen when the probability of the CEO observing the signal (ψ) is relatively high and so the likelihood of getting fired in case the signal is wrong is also high.

The most interesting scenario is when A is positive and B is negative. This will happen when the safe project has high weight on X_1 and low weight on X_2 which is in line with the discussion in remark 1. In this scenario we have two cases, (a) $A < |B|$ and (b) $A > |B|$. In case (a), w_1 must be greater than w_2 for (5) to be satisfied. But if w_1 is greater than w_2 then the employee will obviously shirk as (3) cannot be satisfied. This scenario can depicted in figure 3. Thus it is presence of moral hazard with respect to effort, it may be impossible to write a contract which provides incentives to disclose l.

For case (b), the slope of ICDL is greater than one and hence the two IC constraints can have an overlap. The point of intersection of the two IC constraints is given by

$$w_1^* = \frac{b}{\Delta(\frac{A}{|B|} - 1)} \text{ and } w_2^* = w_1^* + b/\Delta.$$

rearranged to obtain (5).

[18]The exact expression for this assumption is given in the appendix. If this assumption is not satisfied

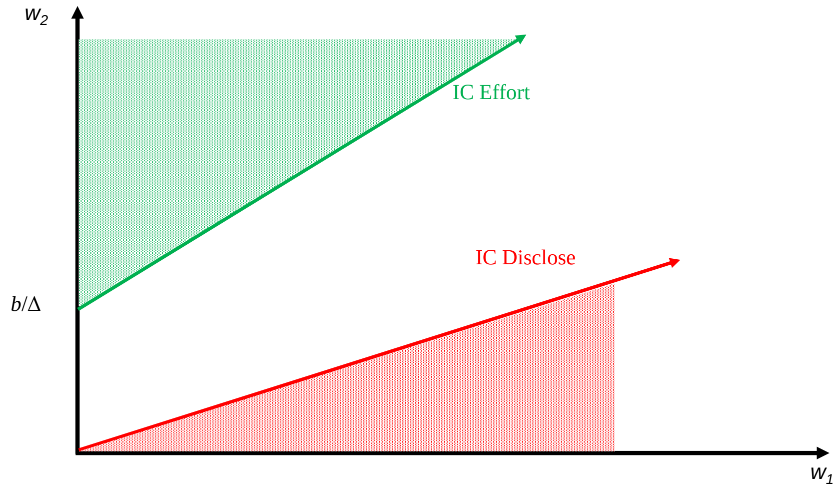

Figure 3: No overlap between IC effort and ICDE

But it may still be impossible to offer a contract because of limited liability constraint, that is w_1 must be less than $X_1 - D$.[19] This is shown in figure (4). This implies that for a contract to be feasible, we must have

$$\frac{b/\Delta}{(\frac{A}{|B|} - 1)} < X_1 - D. \tag{6}$$

If (6) is satisfied, then $w_1 = w_1^*$ and $w_2 = w_2^*$ represents the wage offer since the CEO's objective is to minimize the expected wage payments. Note that the participation constraint is also satisfied at this wage because it was satisfied at wage $w_1 = 0$ and $w_2 = b/\Delta$. The above discussion is summarized in the following proposition.

Proposition 1. *When the CEO wants to offer contracts which satisfy both (3) and (4), then*

i. if $B > 0$, then $w_1 = 0$ and $w_2 = b/\Delta$;

ii. if $A < 0$ and $B < 0$, then no contract can be offered;

iii. if $A > 0$, $B < 0$ and $A < |B|$, then no contract can be offered;

iv. if $A > 0$, $B < 0$ and $A > |B|$ and if (6) is satisfied then the contract offered is $w_1 = w_1^*$ and $w_2 = w_2^*$, else if (6) is not satisfies, then no contract can be offered.

then the CEO will offer a positive w_1 and w_2 will be equal to $w_1 + b\Delta$ such that expected utility equals $\underline{u}$.

[19] Here I am making the assumption that $X_2 > X_1 + b/\Delta$ and so the binding limited liability constraint will be at X_1 and not X_2. If $X_2 < X_1 + b/\Delta$, then my results will only get stronger.

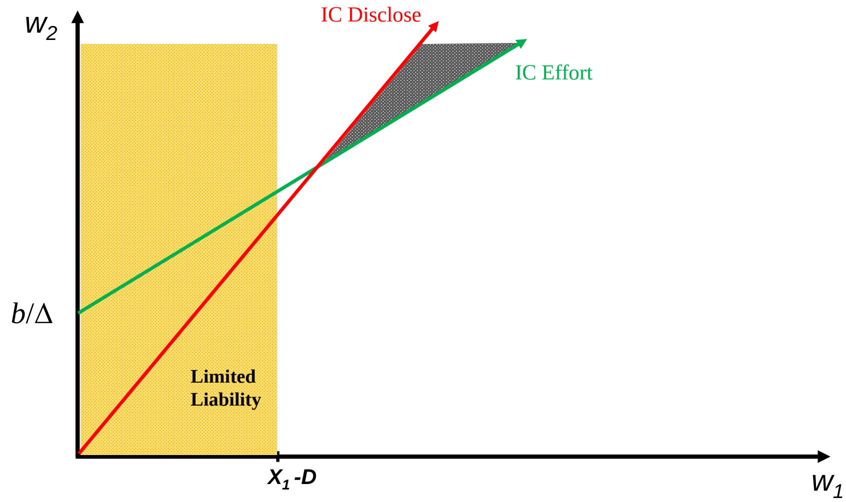

Figure 4: No contract because of limited liability

w_1^* captures the rent the CEO needs to offer the employees to incentivize him to disclose the low signal. The expected rent (r) paid is

$$r = w_1^*[1 - \underbrace{\alpha\psi^2(1-\beta)(1-z)}_{Pr(s^c=h,s^e=l)} - \underbrace{(1-\alpha)(1-\psi)(1-\psi+\psi(1-\beta)(1-z))p_0^B}_{Pr(B)Pr(s^c=n,s^e=n/h|B)Pr(X_0|B)}]. \tag{7}$$

The second term in the square bracket is the probability that the employee gets fired and the third term is the probability that the CEO chooses the bad project and the return is X_0. In these two scenarios the employee does not get paid. Before offering the wage contract at $t = 0$, the CEO will compare the rent extracted with the benefits of taking efficient decision when the employee discloses. If the rents outweigh the benefits then the CEO will not incentivize the employee to disclose the low signal but will only offer incentives to work. The first and obvious benefit of disclosure is that the when $s^c = n$ and the employee discloses l, then the CEO makes the efficient decision of investing in the safe project. The second benefit is that when the CEO observes h and the employee discloses l, then she learns that the he is dumb and replaces him. The exact expressions for these benefits is given in the proof of the following proposition.

Proposition 2. *If the benefit of disclosure is less than the rent extracted then the contract offered is $w_1 = 0$ and $w_2 = b/\Delta$, i.e. the CEO only provides incentive for effort.*

In summary, the analysis shows why the CEO may fail to incentivize employees to disclose their information. First, in presence of moral hazard with respect to effort and limited liability, the CEO may not be able to offer a contract such that the employee discloses the low signal. Second, even if such a contract is feasible, the rent extracted by the employee may outweigh the benefits and the CEO again does not incentivize disclosure. In such a case if the CEO does not observe any signal, then he has more optimistic beliefs about the project being good than is warranted by the aggregate information of all the agents in the firm.

I now discuss some comparative statistics for the case when there is a conflict between the two IC constraints and overlap is possible, that is $A > 0$, $B < 0$ and $A > |B|$. It is clear from equation (6), that as debt increases it becomes more difficult to satisfy the limited liability constraint. So it becomes more difficult to offer contracts to disclose the low signal.

Similarly if moral hazard as captured by b/Δ increase then the IC contract for effort (equation (3)) moves upward. So the point of intersection of the two IC constraints, ((3) and (5)), move to the right increasing w_1^* (see figure 4). As a result, the rent offered to the employee increases and if w_1^* exceeds $X_1 - D$, then the limited liability constraint will also not be satisfied. This is also clear if we look at equation (6). So the likelihood that the CEO incentivizes employees to disclose l decreases (weakly) as b/Δ increases. Intuitively as b/Δ increases, the wedge between w_2 and w_1 must increase to provide incentive for effort. This implies that expected wage from the safe project relative to the good project decreases because the safe project has a lower weight on X_2 compared to X_1. So the CEO needs to offer higher rents to the employee to incentivize him to disclose the low signal.

Another interesting comparative statistics is when we look at the impact of α on providing incentives to disclose l. To understand the effect of α we look at ICDL as represented in equation (4). As α increases the second term on the right increases because probability that the project is good given that the employee has observed l increases. The impact of α on the first term is less clear. The term equals the expected wage from the risky project (multiplied by $(1 - \psi)$). The probability of X_2 given risky project can be written as

$$Pr(X_2|Risky) = Pr(G)(p_2^G - p_2^B) + p_2^B - (1 - \beta)\kappa.$$ [20]

So the probability of X_2 given risky project increases unambiguously because the good project first order stochastically dominates the safe project ($p_2^G > p_2^B$) and $Pr(G)$ increases with α. $Pr(X_1|Risky)$ can be written as

$$Pr(X_1|Risky) = Pr(G)(p_1^G - p_1^B) + p_1^B - (1 - \beta)\kappa.$$

[20] $Pr(X_2|Risky) = (p_2^G - (1 - \beta)\kappa)Pr(G) + p_2^B - (1 - \beta)\kappa)Pr(B) = Pr(G)(p_2^G - p_2^B) + p_2^B - (1 - \beta)\kappa.$

While $Pr(G)$ increases with α, there is no restriction on $p_1^G - p_1^B$, which may be negative. I make the following assumption which ensures that the expected wage from risky project increases as α increases.

Assumption 6. $p_2^G - p_2^B > -(p_1^G - p_1^B)$.

The assumption implies that as α increases, the $Pr(X_2)$ increases more than $Pr(X_1)$ decreases. Since $w_2 > w_1$, so the assumption implies that the expected wage from risky project increases with α. Thus, in all the right side of (4) increases with α. In order to balance this increment w_1 must increase relative to w_2 since the safe project has higher weight on X_1 relative to good and bad projects. So we get that as α increases the slope of ICDL decreases ($A/|B|$ decreases).

Lemma 3. *If assumption 6 holds, then as α increases the expected wage from the risky project increases and the slope of ICDL ($A/|B|$) decreases.*

If $(\frac{A}{|B|})$ decreases then, then w_1^* increases. This is shown in figure 5. So, as α increases the point of intersection moves further to the right, making limited liability difficult to satisfy. If α increases even further then there may be no point of intersection at all (point *iii.* of proposition 1.)

So if we are at the margin for some α, that is $w_1^* = X_1 - D$, then for a higher value of α it is impossible to offer a contract. But if w_1^* is strictly less than $X_1 - D$, then we need to analyze the effect on the rent extracted by the employee as α increases marginally. There are three effects of increases in α (see equation 7). The first effect is that w_1^* increases and the second effect is that the probability that the project is bad and fails reduces. These effects increase r. But the third effect is that the probability that the employee is fired given that he discloses l increases. The following assumption ensures that the rent is monotonically increasing in α.

Assumption 7. $(1-\psi)^2 + \psi(1-\beta)(1-z)(p_0^B(1-\psi) - \psi)] \geq 0$.

If assumption 6 and 7 hold true, then as α increases the CEO is less likely (weakly) to incentivize the employee to disclose l, because either he becomes constrained by limited liability or the rent extracted by the employee may start dominating the benefits from disclosure.

Also recall that all probabilities are being calculated conditional on $s^e = l$.

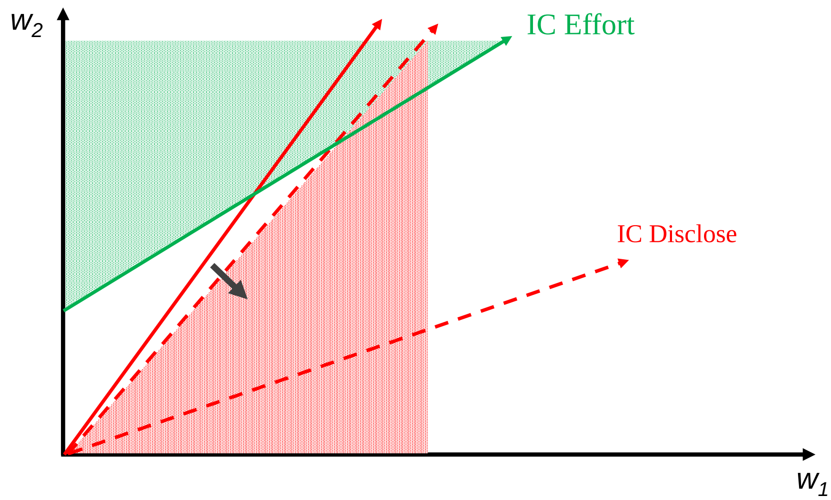

Figure 5: Slope of ICDL decreases as α increases

Proposition 3.

i. *If assumptions 6 and 7 hold, then as α increases the CEO is less likely (weakly) to offer incentives to disclose low signal.*

ii. *As b/Δ or D increases, the CEO is less likely (weakly) to offer incentives to disclose low signal.*

Before a crisis, the beliefs that an investment strategy is good is high. The paper shows why under such beliefs the CEO may to fail provide incentives to disclose low signal. In such a scenario she stops caring about employees disclosing their information and only provide high powered incentives for exerting effort. This is what we saw before the financial crisis. The traders and managers were being given large bonuses for high profits and this may have prevented them from disclosing any information. Although ex post such compensation structure turned out to be a bad strategy, ex ante providing incentives for disclosure may have been too costly because the employees are able to extract high rents when they are being incentivized to disclose information.

I now analyze the incentive compatibility constraints for implementing Pooling H if α satisfies (2). To recall, in Pooling H, the h type employee discloses his signal but the l type employee discloses n and thus pools with the n type employee. I call this constraint ICDH or incentive constraint for disclosing high signal. Analogous to table 2, table 4 shows the

CEO signal	Disclose h	Disclose n	Utility
h	Retain & Cont.	Retain & Cont.	same
l	Fire & Safe	Retain & Safe	lower
n	Retain & Cont.	Retain & Safe	higher

Table 4: CEOs actions when employee has seen h

decisions taken by the CEO for different signals seen by her when the employee has observed h.

When the CEO observes h, whether the employee discloses h as in the equilibrium or he deviates and discloses n, the CEO will choose the risky project and retain the employee (corollary 1). So the utility is same. When the CEO observes l and the employee discloses h, then she learns that the project is bad and the employee is dumb. So she fires the employee and invests in the safe project. But if the employee deviates and discloses n, then the CEO again takes the safe project but does not fire the employee. So the utility of the employee from disclosing h is lower compared to utility from disclosing n. The loss from disclosure occurs because the employee misses out on wage payments from the safe project.

If the CEO observes n and the employee discloses h, then the CEO continues the risky project project and does not fire the employee. But if the employee deviates and discloses n, then the CEO takes up the safe project and again retains the employee. In order to incentivize the employee to disclose the information, the CEO needs to offer more wage from the risky project compared to the safe project.

ICDH is given by equation

$$A'w_1 + B'w_2 \geq 0 \tag{8}$$

where

$$A' = [(Pr(X_1|Risky) - Pr(X_1|S)(1 + \frac{\psi}{1-\psi}Pr(B))$$
$$B' = [(Pr(X_2|Risky) - Pr(X_2|S)(1 + \frac{\psi}{1-\psi}Pr(B))].$$

All the probabilities are calculated conditional on employee signal h. Note that it is optimal to continue the risky project instead of taking the safe project if employee has seen

A	B	Contract
-	+	possible
-	-	impossible

Table 5: Feasibility of contract with ICDH

h (α satisfies (2)). This implies that

$$Pr(X_2|Risky) > Pr(X_2|S) \tag{9}$$

$$Pr(X_1|Risky) < Pr(X_1|S). \tag{10}$$

Using (9) and (10) and substituting them in expressions for A' and B', it become clear that $A' < 0$. So unlike ICDL, we have only 2 scenarios depending on the sign of B' as shown in table 5.

In the first row $B' > 0$. So as discussed earlier, a contract can be designed which satisfies incentive constraint for effort (equation 3) and ICDH (equation 8) by increasing w_2 and decreasing w_1. So there is no conflict between the two IC constraints and the CEO will offer a contract $w_1 = 0$ and $w_2 = b/\Delta$. If both A' and B' are negative as in row 3 then it is impossible to design a contract with satisfies (7).

The reason there is no conflict between the two incentive compatibility constrains is that, when the CEO needs to incentivize the disclosure of high signal and given that the employee has seen the high signal, the risky project has greater NPV than the safe project. Since the risky project has higher NPV, the probability of high values (X_2) is larger compared to the safe project. So a high powered incentive promotes the disclosure of high signal and thus creates no conflict with exerting effort.

4 Multiple Employees and Coordination Problem

4.1 Framework and Assumptions

When there are multiple employee there can be a coordination problem in disclosure of information. To show this I consider a model where the bank has a CEO and two employees. The model otherwise remains the same but the assumptions are slightly modified. The employees work in a team and one unit of investment in the risky project yields $X \in \{X_0, X_1, X_2\}$. They may independently observe signals (high or low) about the type of the project with probability ψ and do not observe any signal with probability $(1-\psi)$. Dumb employee observe noisy signals as before. I assume that the employees do not observe each others signals.

If both employees are smart and work then the probability distribution of returns for different project types are the same as in table 1. For each employee who is dumb the probability of X_2 reduces by κ and of X_1 increases by κ. I assume, analogous to assumption 2, that even when both employees are dumb the good and safe project have positive NPV.

Assumption 2′. $V(G) - 2L^d > V(S) - 2L^d \geq 0 > V(B) - 2L^d$

Similarly, as for one employee case, for each employee who shirks the probability of X_2 reduces by Δ and of X_1 increases by Δ. I assume that if any employee shirks the project has negative NPV, that is assumption 1 still holds. So the CEO must offer contracts to both employees such that they prefer working over shirking.

The coordination problem will exist at more extreme values of α. I will consider two cases. First, when α is such that it is optimal to invest in the safe project only when both employees observe low signal and not otherwise, that is α satisfies

$$\frac{\alpha(1-z)^2}{\alpha(1-z)^2 + (1-\alpha)(\frac{\beta}{(1-\beta)} + z)^2} < \underline{\alpha} < \frac{\alpha(1-z)}{\alpha(1-z) + (1-\alpha)(\frac{\beta}{(1-\beta)} + z)}. \tag{11}$$

The term on the left is the probability that the project is good given that both employees have seen l. This term being less than $\underline{\alpha}$ implies that it is optimal to discontinue the risky project if both employees observe l. The term on the right is the probability that the project is good when only one employee observes l and other observes n. This term being greater than $\underline{\alpha}$ implies that for any other set of signals that the employees may see, it is optimal to continue the risky project.

The second case is when α is such that it is optimal to invest in the risky project when only when both employees observe hign signal and not otherwise, that is α satisfies

$$\frac{\alpha(\frac{\beta}{1-\beta} + z)^2}{\alpha(\frac{\beta}{1-\beta} + z)^2 + (1-\alpha)(1-z)^2} > \underline{\alpha} > \frac{\alpha(\frac{\beta}{1-\beta} + z)}{\alpha(\frac{\beta}{1-\beta} + z) + (1-\alpha)(1-z)}. \tag{12}$$

The term on the left is the probability that the project is good if both employees observe h and the term on the right is the probability that the project is good if one employee observes h and other observes n. The interpretation is analogous to the discussion of equation 11.

Assumption 3, 4 and 5 continue to hold, that is an employee is fired only when the CEO is sure that he has seen a signal opposite of that seen by her.

4.2 Coordination Problem

I refer to the pair of signal observed by the two employees as a *node* and the signals disclosed by the two employees as the *outcome*. I define separating equilibrium as the equilibrium in which employees of all type (h, l or n) disclose their signal truthfully. As in the one employee case, it will be impossible for the CEO to offer contracts to implement the separating equilibrium.

Lemma 4. In two employee case, if α satisfies (11) or (12), then it is impossible to design contracts to implement the separating equilibrium.

The intuition is same as before. If α satisfies (11) then, whether a h type employee discloses or hides his signal, the decision of the CEO to continue the risky project (when she has seen n) will remain unchanged. So the employee only risks the chance of getting fired if the CEO observes l, without changing the CEO's decision when she observes n. So a h type employee will never disclose after X_2. Similarly a l type employee will not disclose if α satisfies (12).

The set of equilibrium that may exist are described in table 6. 'Pooling LL' is the equilibrium in which employees disclose the low signal but not the high signal. 'Pooling HH' is the equilibrium in which employees disclose the high signal but not the low signal. Although separating equilibrium can not be implemented, Pooling LL if α satisfies (11) and Pooling HH if α satisfies (12) are efficient equilibrium because the CEO takes efficient decisions regarding the project choice.[21]

Since the CEO wants to make efficient decisions, she will design contracts to implement Pooling LL if α satisfies (11) and Pooling HH if α satisfies (12). Note that in Pooling LL, CEO will discontinue the project only when both employees disclose l and not otherwise. Similarly in Pooling HH she will continue the project only when both employees disclose l and not other wise. The contracts will also have to be incentive compatible so that employees prefer working over shirking.

As in the one employee case it can be shown using very similar analysis that it may not be possible to design contracts such that employees disclose the low signal and also put in effort. I do not repeat the analysis again but instead rather assume that the CEO is able to design contracts which implement Pooling LL and Pooling HH and also incentivize employee

[21] Although these equilibrium 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 and Pooling HH. For example, if an employee observes h, then he does not disclose in Poolling LL and does not get fired even when CEO observes l.

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

Table 6: Pooling equilibrium with two employees

to work. Here I focus on another friction, that is the coordination problem, which will exist in disclosure of signals in spite of incentive compatible contracts.

Pooling NN and Pooling NN′ are equilibrium where employees never disclose their information irrespective of the signal they see. The difference between Pooling NN and Pooling NN′ is in the CEO's decision after both employees have disclosed n. In Pooling NN the CEO continues the project after the two employees disclose n while in Pooling NN′ she discontinues the project. I will show that whenever Pooling LL exists, Pooling NN will also exist. Similarly whenever Pooling HH exists, Pooling NN′ will also exist.

Note that CEO has designed contracts to implement Pooling LL if α satisfies (11). This makes Pooling NN an inefficient equilibrium because even when both employees observe l, they both disclose n and CEO invest in the risky project which is the inefficient action. Similarly Pooling NN′ is also an inefficient equilibrium because the CEO invests in the safe project after both employees observe h but choose to disclose n. This is the coordination problem where multiple equilibrium can exist together.

The reason for coordination problem is that there is strategic complementaries in disclosure strategy of the employees. If α satisfies (11), the CEO will be convinced to discontinue the project only if both employees disclose l and not otherwise. If only one employee discloses then he only risks the chance of getting fired if the CEO observes h without changing her decision if she observes n. So if one employee believes that the other will not disclose then he is better off not disclosing his signal as well. Thus, whenever Pooling LL will exist Pooling NN will also exist. By the same argument Pooling HH and Pooling NN′ exist together.

Proposition 4. *Even if the CEO is able to design contracts to implement Pooling LL if α satisfies (11) and Pooling HH if α satisfies (12), Pooling NN and Pooling NN' will always exist alongside Pooling LL and Pooling HH respectively.*

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 is 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 of 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 employee discloses the low signal (high signal), it will be enough to convince the CEO to choose the safe (risky) project. In that case there is no strategic complementarities in disclosure of information because an employee does not have to rely on the disclosure strategy of the other employee to convince the CEO. The less extreme beliefs on α are discussed in Appendix B.

My paper provides an explanation for why economic booms may be followed by a crisis and also why output recovery is slow once the crisis hits. 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 employees 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.

Similarly once the crisis hits and profits are low, the prior belief of any project being good may be low. In such a scenario there can be coordination problem in disclosure of signals which show that the project may be good. Thus CEO may not invest in many projects which have actually positive NPV conditional on the aggregate information available with all agents in the firm. Thus my paper explains why recovery may be slow once the crisis hit.

The coordination problem in disclosure of information is countercyclical, in the sense that during the booms the bad signals may not be disclosed and during the busts the good signals may not be disclosed. But during more *normal* times when the believes are more moderate, the coordination problem in disclosure of information will not occur. During such times an individual employee may feel more confident to approach the CEO and disclose his signal because he believes that even when he may be the only one to disclose the information, it will be sufficient for the CEO to update his beliefs and change any investment strategy if needed.

5 Risk Manager

CEO is unable to offer incentives to disclose the low signal because it conflicts with incentivizing effort. But what if the two tasks can be separated, that is the CEO hires two employees. The first one is exactly as before but he is only asked to put in effort, but now the CEO hires another employee and asks him to analyze the risky project and disclose signals. The conflict between the two incentives was created when in the ICDL, A is greater than zero and B is less than zero. I analyze this case when the tasks are split between two employees. I call the employee putting in effort as the "trader" and the employee disclosing the signals as the "risk manager." The wage offered to the trader and risk manager is denoted by $w_T = (w_{1,T}, w_{2,T})$ and $w_{RM} = (w_{1,RM}, w_{2,RM})$ respectively. Since the trader is only incentivized to put in effort the wage offered to him is $w_T = (0, b/\Delta)$.[22]

I assume that the risk manager can be smart with the same probability β and dumb with probability $1 - \beta$. Since the risk manager may have less information about the investment strategy than the trader his signals may be more noisy than the trader. But I first consider the benchmark case where he observes the signals of the same quality as the trader, so a smart risk manager observes perfectly accurate signals and the dumb one observes a signal with accuracy z. As before he may not receive any signal with probability $(1 - \psi)$. I also assume that risk manager is fired only if he discloses a signal opposite of that of the CEO, otherwise not. The outside option for the risk manager is $\underline{u}$ but if he is fired, then he gets 0 utility (same as that for the trader). The ICDL for the risk manager remains the same as before and can be written as

$$Aw_{1,RM} + Bw_{2,RM} \geq 0. \tag{13}$$

The participation constraint can be written as

$$Cw_{1,RM} + Dw_{2,RM} \geq \underline{u}, \tag{14}$$

where $C > 0$ and $D > 0$.[23] The point of intersection of the two lines can be written as

$$w^*_{1,RM} = \frac{-B\underline{u}}{AD - CB}, w^*_{2,RM} = \frac{A\underline{u}}{AD - CB}.$$

I assume that $\underline{u}$ is low enough such that $w^*_{1,RM}$ is less than $X_1 - D$. This is shown in figure 6. The exact contract to the risk manager is indeterminate because the CEO can offer any

[22] Recall that I had assumed that $\underline{u}$ is low enough such that participation constraint is satisfied at this wage.

[23] $C = Pr(s^c = l \text{ or } (s^c = n, s^{RM} = l))Pr(X_1|S) + Pr(s^c = h, s^{RM} = n/h)Pr(X_1|G) + Pr(s^c = n, s^{RM} = n/h)Pr(X_1|Risky)$
$D = Pr(s^c = l \text{ or } (s^c = n, s^{RM} = l))Pr(X_2|S) + Pr(s^c = h, s^{RM} = n/h)Pr(X_2|G) + Pr(s^c = n, s^{RM} = n/h)Pr(X_2|Risky)$

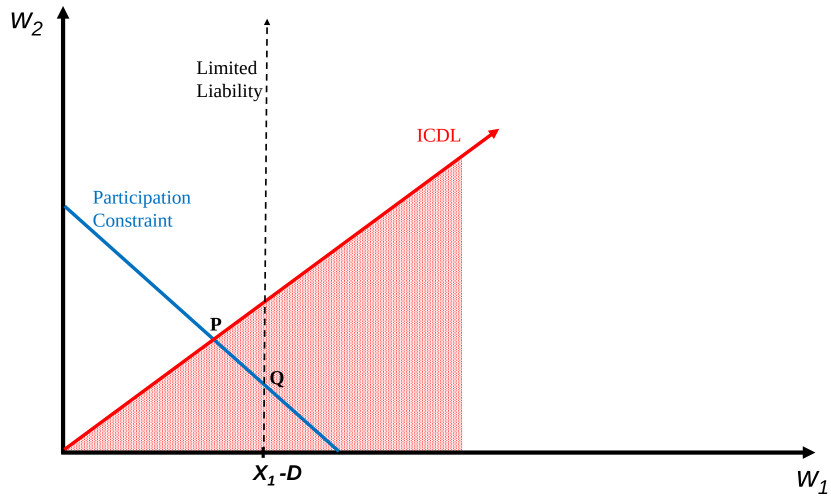

Figure 6: Contract for risk manager

contract on the participation constraint line such that $w^*_{1,RM} < w_{1,RM} < X_1 - D$. This is line segment PQ in the figure 6.

The benefit of a risk manager is that now CEO may be able or willing to offer a contract to disclose the low signal. Recall that for $A < |B|$, it is impossible to offer a contract to the trader to disclose the low signal (point iii of proposition 1). But now the CEO can offer a contract to the risk manager to disclose the signal. This is because the he does not have to be incentivized to put in effort and so he does not require high powered incentive ($w_2 > w_1$).

For the case $A > |B|$, whenever the CEO provided incentive to disclose l, the employee was able to extract a rent r which is increasing in α. If the rent is large then the CEO would not offer the employee a contract to disclose the signal. But with the risk manager, the expected wage paid to him is $\underline{u}$ which is independent of α. So there may be a scenario when $r > \underline{u}$, in which case the CEO is willing to offer a contract for disclosure with a risk manager but not with just one employee. Thus separating the two tasks may result in more efficient disclosure and project choice. The paper thus adds to the theory of organization design and provides a theoretical explanation why banks may need risk managers.

However, as mentioned above the risk manager may have less information than the trader about the project. I model this as the dumb risk managers receiving signals less accurate than the dumb traders so on average the risk manager's signal is more noisy than trader's signal.[24] The accuracy of dumb risk manager's signal is denoted by z_{RM} which is less than

[24] Alternatively I could have assumed that even the smart risk manager receives noisy signals and the results would have remained qualitatively unchanged.

z. I denote the risk manager's signal by s^{RM} and trader's signal by s^T. Since $z > z_{RM}$, so the posterior probability that the project is good given low signal is lower in case of trader than in case of risk manager, i.e.

$$Pr(G|s^T = l) < Pr(G|s^{RM} = l).$$

If the the prior probability that the project is good, α, is not too high, such that it is optimal to invest in the safe project when the risk manager observes the low signal, he remains useful and we have efficient outcome. But if α is high enough, then the risk manager's low signal may become useless because the CEO will invest in the risky project even if $s^{RM} = l$. But since the trader's signal is more accurate, so his signal may still be useful, that is the CEO invests in the safe project if $s^T = l$. This will be true if

$$Pr(G|s^T = l) < \underline{u} < Pr(G|s^{RM} = l). \tag{15}$$

If (15) is satisfied then the risk manager is useless and the CEO has to offer contracts to the trader to disclose his signal which again he may not be able to do. So again we see that high α will create disclosure frictions.

6 Renegotiation Proof Contracts

The problem of designing contracts which should satisfy constraints that incentivize employee to disclose their signals arises because the employees can not observe what signal the CEO has seen and because the CEO cannot commit to not fire the employees once she learns that they are dumb. If the employees were able to observe the CEO's signal, then whenever the CEO does not observe any signal, the employees would disclose their signal without the fear of getting fired. So the natural question that arises is whether the CEO can convince the employees that he has not seen any signal by offering a new contract at $t = 1$. If she is able to do so then the problem of the employee not disclosing his signal will disappear.

In this section I will argue that the CEO can commit to the contracts offered at $t = 0$ and that she will not try to renegotiate the contract once she observes or does not observe her signal (at $t = 1$). A new contract offered by the CEO will be accepted by the employees only if the employee gets at least as much utility as the old contract.

There can be two scenarios at $t = 0$. In the first scenario the CEO is able to offer contracts such that they satisfy incentive constraints for exerting effort as well as disclosing the signals and in the second scenario he is unable to offer contracts which satisfy incentive constraints for disclosing signals and instead they only satisfy incentive constraints for exerting effort. In the first scenario, since the employees are risk neutral, the CEO cannot offer new contracts which increase the value of the firm without decreasing the expected wage payments of the employees. So the CEO has no incentive to deviate and offer new contracts even after she has observed her signal.

The contracts will be renegotiation proof even in the second scenario. To understand why this will be so let us consider the case when α satisfies (1). Suppose the CEO observes the low signal. Since she has already seen the signal, she has already decided that she is going to take the safe project and hence she has no value of the low signal disclosed by the employee.[25] She also knows that even if the employees disclose low signal she is not going to fire him. So she has no incentive to deviate and offer a new contract.

If the CEO does not observe any signal, she wants to offer a new contract to convince the employees to disclose the low signal if they have seen it. Suppose she deviates and offers a new contract, which I denote $\mathbb{C}^n$, to convince the employee that she has not seen any signal. Then the CEO who observes the high signal will also deviate to this new contract. The reason the CEO who observes h wants to offer a new contract $\mathbb{C}^n$ in spite of having learnt the type of the project is that she wants the employees to disclose the low signal so that she can fire them because they are dumb. So this implies that the CEO who did not observe any signal will not be able to *separate* herself but in fact will find herself *pooling* with the CEO who observes the high signal. This will make offering incentive compatible contract for disclosing low signal even more difficult than before. The reason is that now the employee knows that the CEO has either seen h or n, where as in the contract offered at $t = 0$, the CEO could have seen l, h or n. So, in the new contract offered the probability of getting fired is higher implying that if the old contract was not able to incentivize employees to disclose the low signal, the new contract will not be able to do so either. Thus, no new contracts will be offered.

The same story will repeat if α satisfies (2) but with one difference. If the CEO who did not see any signal tries to offer a new contract to separate herself, then she will actually find herself pooling with the CEOs who observe the low signal. So she will not be able to offer a new contract which is incentive compatible to disclose high signal.

[25] Recall that the employees who see the high signal will never disclose.

7 Extentions

7.1 Continuous signals

In the paper so far, I have considered signals to take three discrete values (h, l and n). But the model can be extended to continuous signals. While most of the basic results remain the same, using continuous signal provides with some additional insights. I discuss them next.

A. One employee

With the continuous signals, I assume that the probability of project being good increases as the value of the signal increases. It can be shown that in such a case, there will be a switching equilibrium where if the employee receives a signal below a cutoff value, he will disclose his signal but if the signal is above this cutoff value he will not disclose his signal and all the employees above the cutoff value pool together. In presence of moral hazard with respect to effort, the CEO will be unable to execute a cutoff which is most efficient. The higher the cutoff she wants, the less steep the incentive constraint will get which is similar to the effect of increase in α (see figure 5 and proposition 3). So either there is no intersection between the two IC constrains (figure 3), or she is constrained by limited liability (figure 4) or she does not want to give the employee too much rents. The higher the prior α, the lower will be the cutoff and thus lesser will be the disclosure.

B. Multiple employees

With multiple employees the coordination problem disappears and I again get a unique switching equilibrium where employees disclose signals below a cutoff signal and pool together above the cutoff. Again the higher the cutoff signal the CEO desires the lower is the slope of the IC constraints. The CEO decides the equilibrium cutoff balancing the benefit of disclosure with the rent extracted by the employees. As in the one employee case, the higher α is, the lower is the cutoff.

8 Conclusion

This paper builds a simple model of a financial intermediary (or any firm) which has a CEO and some employees, who can be dumb, and shows how there can be problems in disclosure of information either due to inability of the CEO to write incentive compatible contracts or due to coordination problem. The coordination problem occurs particularly when the beliefs are at the extreme. The key assumption creating the contracting problem is incompleteness of contracts and the inability of the CEO to commit not to fire the employee.

In my paper I have also assumed that when there are multiple employees, they do not communicate with each other and thus there is no possibility of collusion. While this may be an odd assumption if there are only two employees in the firm, in reality there are many employees and any of them could receive the signals. So an employee who has received a signal will not know who to communicate with and it may be too costly to talk to every one. This may also open up the possibility that the CEO may come to know about the beliefs of the employee even before he may have disclosed it, and that the employee may be replaced. We leave the analysis of such scenarios for future research.

References

Acharya, V. V., Cooley, T., Richardson, M., Walter, I., et al. (2010). Manufacturing tail risk: A perspective on the financial crisis of 2007–2009. *Foundations and Trends® in Finance.*

Acharya, V. V., DeMarzo, P., and Kremer, I. (2011). Endogenous information flows and the clustering of announcements. *The American Economic Review.*

Acharya, V. V. and Yorulmazer, T. (2007). Too many to fail—an analysis of time-inconsistency in bank closure policies. *Journal of financial intermediation*, 16(1):1–31.

Barberis, N. (2011). Psychology and the financial crisis of 2007-2008.

Bénabou, R. (2012). Groupthink: Collective delusions in organizations and markets. *The Review of Economic Studies*, page rds030.

Beyer, A., Cohen, D. A., Lys, T. Z., and Walther, B. R. (2010). The financial reporting environment: Review of the recent literature. *Journal of accounting and economics.*

Brunnermeier, M. K. and Oehmke, M. (2012). "bubbles, financial crises, and systemic risk. *NBER.*

Cheng, I.-H., Raina, S., and Xiong, W. (2014). Wall street and the housing bubble. *The American Economic Review.*

Cohan, J. A. (2002). " i didn't know" and" i was only doing my job": Has corporate governance careened out of control? a case study of enron's information myopia. *Journal of Business Ethics.*

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy.*

Dye, R. A. and Sridhar, S. S. (1995). Industry-wide disclosure dynamics. *Journal of Accounting research*, pages 157–174.

Fahlenbrach, R. and Stulz, R. M. (2011). Bank ceo incentives and the credit crisis. *Journal of Financial Economics.*

Farhi, E. and Tirole, J. (2012). Collective moral hazard, maturity mismatch, and systemic bailouts. *The American Economic Review.*

Foote, C. L., Gerardi, K. S., and Willen, P. S. (2012). Why did so many people make so many ex post bad decisions? the causes of the foreclosure crisis. Technical report, National Bureau of Economic Research.

Gennaioli, N., Shleifer, A., and Vishny, R. (2012). Neglected risks, financial innovation, and financial fragility. *Journal of Financial Economics*.

Gennaioli, N., Shleifer, A., and Vishny, R. (2015). Neglected risks: The psychology of financial crises. *The American Economic Review*.

Gibbons, R. and Katz, L. F. (1991). Layoffs and lemons. *Journal of labor Economics*.

Heider, F. and Inderst, R. (2012). Loan prospecting. *The Review of Financial Studies*.

Holmstrom, B. and Milgrom, P. (1991). Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics, & Organization*.

Holmstrom, B. and Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *the Quarterly Journal of economics*.

Inderst, R. and Ottaviani, M. (2009). Misselling through agents. *The American Economic Review*.

Inderst, R. and Pfeil, S. (2012). Securitization and compensation in financial institutions. *Review of Finance*.

Kindleberger, C. P. (1978). *Manias, panics, and crashes.* (Macmillan, New York.

Moore, P. (2009). Paul moore's memo in full. Financial Times.

Pearlstein, S. (2000). Enron's creative obscurity. The Washington Post.

Rajan, R. G. (1994). Why bank credit policies fluctuate: A theory and some evidence. *The Quarterly Journal of Economics*, 109(2):399–441.

Rajan, R. G. (2006). Has finance made the world riskier? *European Financial Management*.

Reinhart, C. M. and Rogoff, K. S. (2009). *This time is different: Eight centuries of financial folly.* princeton university press.

Samuelson, R. J. (2001). Enron's creative obscurity. The Washington Post.

Scharfstein, D. S. and Stein, J. C. (1990). Herd behavior and investment. *The American Economic Review*, pages 465–479.

Shiller, R. J. (2015). *Irrational exuberance.* Princeton university press.

Stiglitz, J. E. (2010). *Freefall: America, free markets, and the sinking of the world economy.* WW Norton & Company.

Thakor, A. (2015). Lending booms, smart bankers, and financial crises. *The American Economic Review.*

Appendix A

A.1 Assumption for satisfying participation constraint

In ICDL, if $B > 0$ then the wage offered is $w_1 = 0$ and $w_2 = b/\Delta$ and I have assumed that the $\underline{u}$ is low enough such that the participation constraint is satisfied at this wage. The condition for this is

$$\frac{b}{\Delta}[a_h + a_l + a_n] \geq \underline{u}, \tag{16}$$

where a_h corresponds to the case when CEO observes h and equals

$$\underbrace{\psi\alpha(1-\psi(1-\beta)(1-z))}_{Pr(s^c=h \ \& \ s^e=h \text{ or } n)}(p_2^G - (1-\beta)\kappa),$$

a_l corresponds to the case when CEO observes l and equals

$$\underbrace{\psi(1-\alpha)}_{Pr(s^c=l)}(p_2^S - (1-\beta)\kappa),$$

and a_n corresponds to the case when CEO observes n and equals

$$\underbrace{(1-\psi)}_{Pr(s^e=n)}[(\underbrace{\psi\alpha(1-\beta)(1-z)+(1-\alpha)\beta z}_{Pr(s^e=l)})(p_2^S-(1-\beta)\kappa) + \underbrace{(1-\psi)}_{Pr(s^e=n)}(Pr(X_2|Risky)) + \underbrace{\psi(\alpha\beta z + (1-\alpha)(1-\beta)(1-z))}_{Pr(s^e=h)}(Pr(X_2|Risky, s^e=h))]$$

A.2 Proof of Lemma 2

Suppose a separating equilibrium exists if α satisfies (1). In the equilibrium, employees who observe l disclose their signal and CEO chooses the safe project when she observes n. But when she observes h, the employees are fired. Suppose the employee deviates and in stead discloses n, then he prevents himself from getting fired but the other decisions of the CEO remain the same. So the deviation is profitable and equilibrium will not exist.

Similarly separating equilibrium will not exist if α satisfies (2) because the h type employees will find it profitable to deviate.

A.3 Proof of Proposition 1

i. If $B > 0$, then $w_1 = 0$ and $w_2 = b/\Delta$ satisfy both (3), (5) and limited liability constraint. It is also the wage that minimizes the expected payoff to the employee.

ii. If $A < 0$ and $B < 0$ then (5) can not be satisfied as $w_1 \geq 0$ and $w_2 \geq 0$ due to limited liability of the employee.

iii. If $A > 0$, $B < 0$ and $A < |B|$, then w_1 must be greater than w_2 for (5) to be satisfied. But then (3) cannot be satisfied.

iv. If $A > 0$, $B < 0$ and $A > |B|$, then the point of intersection of (3) and (5) is given by w_1^* and w_2^*. If w_1^* satisfies (6), then this is the wage offered as it minimizes the expected payoff to the employee. If (6) is not satisfied, then no contract can be offered as any wage which satisfies both (3) and (5) will have $w_1 > w_1^*$.

A.4 Proof of Proposition 2

The total expected benefit of disclosure is given by

$$\underbrace{(1-\psi)(\psi(\alpha(1-\beta)(1-z)+(1-\alpha)(\beta+(1-\beta)z))}_{Pr(s^c=n,s^e=l)}[V(S)-V(Risky|s^c=n,s^e=l)] \\ +\underbrace{\alpha\psi^2(1-\beta)(1-z)}_{Pr(s^c=h,s^e=l)}[\beta L^d+w_1^*-C]$$

If this is less than the expected rent then the CEO will not provide incentive to disclose the low signal. In this scenario the CEO only provides incentive to exert effort and offers wage $w_1 = 0$ and $w_2 = b/\Delta$.

A.5 Proof of Lemma 3

$Pr(X_2|Risky)$ can written as

$$Pr(X_2|Risky) = (p_2^G - (1-\beta)\kappa)Pr(G) + (p_2^B - (1-\beta)\kappa)Pr(B) = Pr(G)(p_2^G - p_2^B) + p_2^B - (1-\beta)\kappa,$$

and $Pr(X_1|Risky)$ can be written as

$$Pr(X_1|Risky) = (p_1^G - (1-\beta)\kappa)Pr(G) + p_1^B - (1-\beta)\kappa)Pr(B) = Pr(G)(p_1^G - p_1^B) + p_1^B - (1-\beta)\kappa.$$

So the expected wage from the risky project $Pr(X_1|Risky)w_1 + Pr(X_2|Risky)w_2$ can be written as

$$Pr(G)[\underbrace{(p_2^G - p_2^B)w_2 + (p_1^G - p_1^B)w_1}_{\text{positive}}] + (p_2^B - (1-\beta)\kappa)w_2 + (p_1^B - (1-\beta)\kappa)w_1.$$

Given assumption 6, the multiplicand of $Pr(G)$ is positive because $w_2 > w_1$.

Now the $\frac{\partial A/|B|}{\partial \alpha}$ can be written as

$$\frac{-1}{B^2}[\frac{\partial Pr(G)}{\partial \alpha}\{\underbrace{\big(A(p_2^G - p_2^B) - B(p_1^G - p_1^B)\big)}_{\text{term 1}} + \frac{\psi}{1-\psi}\underbrace{\big(A(p_2^G - (1-\beta)\kappa) - B(p_1^G - (1-\beta)\kappa)\big)}_{\text{term 2}}\}]$$

Since $A > |B|$, so by assumption 6, term 1 is positive. Also $A > 0$ and $B < 0$, so term 2 is positive. Hence the entire expression is negative.

A.6 Proof of Proposition 4

Suppose that Pooling NN exists if α satisfies (1). The h type employee obviously has no incentive to disclose so they will not deviate. Suppose the first employee 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 continue the project when she observes n but fires the employees if she observes h. So the deviation for the employee is unprofitable. And hence the equilibrium exists. Similarly Pooling NN′ will if α satisfies (2).

Appendix B

In the following analysis I will assume that the CEO is able to design contract to implement the efficient equilibrium and analyze if there will be a problem of multiple equilibrium. Let us consider different beliefs that may exist when $\alpha > \underline{\alpha}$. This is shown in table 7. A symmetric analysis can also be done for beliefs when $\alpha < \underline{\alpha}$.

The first row corresponds to beliefs when α satisfies (11). As already discussed, in this case we will have an efficient Pooling LL and an inefficient Pooling NN. Thus coordination problem exists. In the second row, I have beliefs which are less extreme. I assume α is such that it is efficient to invest in the safe project after one employee observes l and other observes n, but not if one employee observes l and the other has observed n or h but CEO does not know which. This means that it is efficient to continue the project if nodes ln and lh are pooled together. In this case the efficient equilibrium is the separating equilibrium which, unlike before, can be implemented because now there is a value of disclosing high signal as well. It can be shown that under such beliefs Pooling NN will still exist. This is because if l type employee believes that h type employee will not disclose, then he is better off not disclosing because on disclosure he only risks the chance of getting fired. So we still have coordination problem.

Belief	Eff Eqlm	Ineff Eqlm	Coordination Prob
Safe if efficient when node ll but not otherwise	Pooling LL	Pooling NN	Yes
Safe is efficient when node ln but not when ln and lh are pooled	Separating	Pooling NN	Yes
Safe is efficient when ln and lh are pooled but not with node nn or lh/hl	Separating	None	No

Table 7: Beliefs and Coordination Problem

I consider even milder beliefs in the third row. I assume that , α is such that it is efficient to discontinue the project when one employee observes l and the other observes n or h, but the CEO does not know which, i.e. the nodes ln and lh are pooled together. But it is optimal to continue when both observe n (node nn) or when one employee observes h and other l (node hl/lh).[26] Again the separating equilibrium is the efficient equilibrium. But now Pooling NN will not exist and there is no coordination problem. This is because the l type employee does not have to depend on the decision of the other employee to convince the CEO to discontinue the project.

Thus we see that coordination problem disappears at less extreme beliefs. The results shown in table 7 is summarized in the next proposition.

Proposition 5. *If the CEO is able to design contracts to implement the efficient equilibrium then,*

i. If α is such that it is efficient to invest in the safe project if node ln but not if ln and lh are pooled, then the CEO will design contracts to implement the separating equilibrium but the inefficient Pooling NN will also exist. So we have coordination problem.

ii. If α is such that it is efficient to invest in the safe project when ln and lh are pooled but not with node nn or lh/hl, CEO will design contracts to implement the separating equilibrium but now Pooling NN will not exist. Thus there is no coordination problem.

Proof: Proof for existence of Pooling NN under beliefs in second row of table 7 is analogous to that discussed in proof of proposition 4. I now show that under beliefs as in third row of table 7, Pooling NN will not exist. Since contracts have been designed such

[26] Because of the symmetry of accuracy of signals, posterior probability about risky project being good is same after node nn and node hl/lh.

that separating equilibrium exists, it must not profitable for l type to deviate. Now suppose Pooling NN exists. If the l type deviates, then the actions taken by the CEO for different signals that she may see, are exactly the same as that taken in the separating equilibrium. So this deviation must be profitable. Hence the equilibrium does not exist.