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Banker Compensation, Relative Performance, and Bank Risk

Arantxa Jarque and Edward Simpson Prescott

A multi-agent, moral-hazard model of a bank operating under deposit insurance and limited liability is used to analyze the connection between compensation of bank employees (below CEO) and bank risk. Limited liability with deposit insurance is a force that distorts effort down. However, the need to increase compensation to risk-averse employees in order to compensate them for extra bank risk is a force that reduces this effect. Optimal contracts use relative performance and are implementable as a wage with bonuses tied to individual and firm performance. The connection between pay for performance and bank risk depends on correlation of returns. If employee returns are uncorrelated, the form of pay is irrelevant for risk. If returns are perfectly correlated, a low wage can indicate risk. Connections to compensation regulation and characteristics of organizations are discussed.

Keywords: incentive compensation, relative performance, bank regulation.

JEL Codes: D82, G21, G28, J33.

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1 Introduction

This paper develops a multi-agent, moral-hazard model to analyze the connection between banker compensation and bank risk. It builds upon the standard model in banking, in which a bank makes investment decisions subject to deposit insurance and limited liability, by adding many loan officers whose decisions jointly determine the risk profile of a bank. Theoretical implications of the model are derived and used to identify distortionary effects on effort, the value of relative performance in optimal contracts, and the importance of correlation in loan officer returns for determining both the characteristics of optimal compensation and bank risk.

Controlling bank risk via regulation of compensation arrangements is a new focus of bank regulation. Motivated by the belief that bank compensation practices were a significant contributory factor to the recent financial crisis (Financial Stability Forum, 2009), several countries have adopted regulations on banker compensation. For example, in 2010 the Federal Reserve Board issued supervisory guidance to U.S. banks that their compensation arrangements “Provide employees incentives that appropriately balance risk and reward” (Federal Register, 2010). Similarly, the Dodd–Frank law requires that regulations be written that prohibit incentive–based compensation that encourages inappropriate risks. In Europe, caps on variable pay relative to base pay have been imposed by the European Parliament (European Banking Authority, 2015).

Conceptually, there are two classes of people in a bank who could materially contribute to the risk of a bank. The first is an individual, such as a CEO or a division head, whose individual decisions can materially affect the bank’s performance. The second is a group of individuals, such as loan officers, whose collective decisions can have a significant impact on the bank’s performance.

This paper analyzes the second class of people. We do this for two reasons. First, a

CEO is limited in his ability to directly control the actions of his subordinates. Instead, he has to rely on indirect methods, such as delegation of authority, internal controls, and compensation, to direct the actions of subordinates. In the end, a bank's risk profile is determined by the actions of its lending officers and other employees. Second, despite the high level of CEO pay, by far most labor compensation paid out by a bank goes to its other employees, so compensation regulations have the largest effect on them. For example, in 2012 the largest bank holding company in the United States was J.P. Morgan. As of December 31, 2012, it had 248,633 employees, measured at full-time equivalents, and paid them \$31 billion in salaries and benefits (source: FR Y-9C). Meanwhile, its CEO was paid \$18.7 million (source: Execucomp), a very small fraction of total compensation.

To study the connection between bank risk and compensation, we extend the single-agent, moral-hazard, principal-agent model to one with many agents. The principal represents bank equity owners, and the agents are the loan officers (or other employees) who are risk averse and who actually make the investment decisions.

Our model has three features that characterize large banks. First, large banks benefit from explicit and implicit government insurance of their liabilities, so their equity owners do not bear all the costs of a bank failure. Second, in large banks there are many employees, most of whom alone have a minuscule effect on the performance and risk of the bank. Third, optimal contracts are characterized by compensation that is tied to individual and firm performance, which resembles the form of compensation used at many large banks. For example, Board of Governors (2011, pg 14) describes the use of bonus pools at large banks prior to the financial crisis.¹

¹More generally, banking has long tied compensation to individual and firm performance. For an example from the 1970s, see Harvard Business School (1975, 1980). For the prevalence of their use for branch managers in the 1990s, see Nagar (2002). Barbosa, Bucione, and Souza (2014) study their use in Brazilian banks. In some banks, they have been used even at the teller level (Independent Directors of Wells Fargo & Company (2017)). Yamori and Yoneda (2019) report that Japanese financial institutions have traditionally used quantitative goals for lending and sales targets.

The model highlights three connections between compensation and risk. The first is that because each loan officer has an infinitesimal effect on the performance of a bank, bank risk is determined by the correlation of loan officers' returns, not the risk of an individual loan officer's project. The second is that compensation contracts will make heavy use of relative performance because comparing loan officers' returns can be highly informative about loan officer effort. Both of these implications are absent from the single-agent CEO model. The third connection is that effort is distorted relative to the social optimum. The limited liability distortion is a force for underprovision of effort, but risk aversion by loan officers can mitigate this effect because lower bank returns adds risk to loan officers, thus raising the cost of paying them.

Correlation is so important for determining bank risk that when it is exogenous, that is, when loan officer actions do not affect the correlation of their returns, there are some surprising connections between compensation and bank risk. For example, when loan officer returns are perfectly uncorrelated, there is no bank risk because the loan officer risk is entirely idiosyncratic and averages out. Consequently, compensation is *irrelevant* for bank risk, though it may matter for bank profits and it certainly matters for the risk to a loan officer. In contrast, when loan officer returns are perfectly correlated, loan officer effort can be perfectly inferred from bank output, so there is no moral hazard problem and the officer can be paid a wage. Here, the correlation in returns means that there is a *lot* of risk for the bank and it can be shown, under reasonable conditions, that a *low* wage creates more risk than a high wage.

Two features of compensation that we do not discuss in this paper are multiperiod contracts and monitoring. Multiperiod contracts can be used to study "claw backs," that is, compensation that is reduced if the loan or project performs badly in the long run. We leave this feature out, however, to focus on the connection between compensation and correlation of returns. For work addressing the timing question using dynamic moral-hazard

models with persistence, see Jarque and Prescott (2013). Lending and other activities, such as trading, are typically monitored by a bank and subject to limits and other controls. We leave these features out to focus on relative performance. Later, however, we discuss how the model can be extended to address these institutional features.

2 Literature

The multi-agent, principal-agent model we use is based on the relative-performance model of Holmström (1982).² This model is characterized by multiple agents and joint production of either physical output or information relevant to contracting. It has been adapted to consider many aspects of organizational design such as monitoring, task assignment, and job rotation.³

In the banking literature, the bank’s investment decision is usually modeled as being chosen by a single agent. The single agent represents equity owners who maximize profits while enjoying limited liability and funding a portion of the investment with insured deposits.⁴ While keeping the limited liability and insured deposit assumptions, a smaller part of the banking literature follows the Jensen and Murphy (1990) approach in which the equity owners are the principal and the agent is typically a CEO with private information who makes the investment decisions. John, Saunders, and Senbet (2000), Phelan (2009), and Bolton, Mehran, and Shapiro (2015) use this approach to examine how to regulate compensation to limit the distortion caused by limited liability. Heider and Inderst (2012) study a multi-task problem where the agent generates soft information about borrowers.⁵ These models feature

²Other early work on multi-agent, principal-agent models includes Demski and Sappington (1984) and Mookherjee (1984).

³For examples, see Prescott and Townsend (2002, 2006) and the surveys in Bolton and Dewatripont (2005), Gibbons and Roberts (2013), and Mookherjee (2013).

⁴See, for example, Kareken and Wallace (1978), Kim and Santomero (1988), Flannery (1989), and Furlong and Keeley (1990). The savings and loan crisis in the United States during the 1980s is often viewed as evidence for this model (White, 1991).

⁵Thanassoulis (2012, 2014) also looks at CEO compensation and bank risk, but considers a market-assignment model in which in the absence of pay caps, compensation of CEOs is bid up to levels that make

a single agent who chooses bank risk and are appropriate for studying compensation of an individual who has a large impact on a bank such as a CEO. In this paper, instead, our focus is on compensation of lower-level employees such as loan officers.

Most of the empirical literature on banker compensation and bank risk looks at CEO compensation, mainly because of data availability.⁶ There are very few studies of compensation of lower-level bank employees because this data is proprietary.⁷ One exception is Agarwal and Ben-David (2018) who studied the results of an experiment that was run at a bank, which for a period of time paid half of its small business loan officers a wage and half with a wage plus an incentive. They found that the incentive plan increased the loan origination rate by 31 percent and the size of loans by 15 percent. Unfortunately for the bank, the plan also increased the default rate by 28 percent, so the plan was dropped.

Berg, Puri, and Rocholl (2019) studied the data input behavior by loan officers who are paid based on volume. These loan officers entered hard information, that is, non-judgmental information, into the bank's loan scoring system that determined approval. Berg, Puri, and Rocholl (2019) find evidence of selective entering of hard information into the scoring system to improve a borrower's chance of approval. Cole, Kanz, and Klapper (2015) ran laboratory experiments on commercial bank loan officers in which they varied the connection between compensation and incentives. They found that the compensation structure had a large effect on lending and the quality of the loans. Finally, Hertzberg, Liberti, and Paravisini (2010) examined the connection between pay, organizational structure, and reporting of information. They examined the use of loan officer rotation at a large international bank and argued that it alleviates incentives to hide the quality of poorly performing loans.

banks inefficiently risky.

⁶For analysis using data from the 1980s and early 1990s, see Houston and James (1995), Benston and Evans (2006), and Crawford, Ezzell, and Miles (1995). For analysis using data from the recent crisis, see Cheng, Hong, and Scheinkman (2010) and Fahlenbrach and Stulz (2011).

⁷While they do not have access to actual compensation contracts, Acharya, Litov, and Sepe (2014) document that total compensation for employees other than the top executives moves with U.S. bank holding company performance, which they interpret as evidence of the use incentive compensation at these firms.

3 The Model

There is a bank that consists of depositors, equity holders, and a continuum of loan officers of measure one, each of whom has an infinitesimally small effect on the performance of the bank. Each loan officer takes an action $a \in A \subset \mathfrak{R}_+$ that produces a return r as a function of an idiosyncratic shock and a common shock θ . Both shocks occur after the action is taken. There is a finite number of possible returns for each loan officer. For most of the analysis there is also a finite number of actions, though in one subsection we allow for a continuum of actions. The common shock can take on a continuum of values over the interval $[0, \Theta]$ and is drawn according to the probability density function $h(\theta)$ with cumulative distribution function $H(\theta)$. The probability of a loan officer's return is written $f(r|\theta, a)$. The expected return, $\sum_r f(r|\theta, a)r$, is increasing and concave in a for all θ . Finally, we also assume that given a the expected return is continuous and increasing in the common shock, that is, $\forall a$, $\sum_r f(r|\theta', a)r \geq \sum_r f(r|\theta, a)r$ if $\theta' > \theta$.

A loan officer's action and idiosyncratic shock are private information, while the common shock is observed by the bank. We could assume that θ is not observed by anyone, but as long as the mapping from a to the total return is an invertible function, then θ can be identified from the contract and the total return. For that reason, we simply assume that θ is public information.

A loan officer receives utility from consumption, $c \geq 0$, and action, a , of $U(c) - V(a)$, where U is concave and increasing, $U(0) \geq 0$, and V is increasing and weakly convex. Each loan officer has an ex ante reservation utility level of \bar{U} .

The bank finances the loan officers' investment projects with an investment of size one. The investment is financed by government insured deposits, $0 \leq D \leq 1$, and equity $1 - D$. Because of deposit insurance, depositors receive the face value of deposits at the end of the period no matter how the bank performs. For simplicity, we take the level of deposits as

given.

The bank operates in the best interest of the equity holders, so we will often refer to the bank and the equity holders interchangeably. The equity holders are treated as a single risk-neutral principal with limited liability. The bank receives a total return of $\bar{r}(\theta)$, which is the sum of the loan officers' returns, and pays out funds to depositors and compensation to loan officers. The total compensation paid out is called $\bar{c}(\theta)$.

The bank's expected profit is

$$\int_0^\Theta \max\{\bar{r}(\theta) - \bar{c}(\theta) - D, 0\}h(\theta)d\theta.$$

The total return to the bank is the sum of the individual loan officers' returns, which is

$$\forall\theta, \quad \bar{r}(\theta) = \sum_r f(r|\theta, a)r. \quad (1)$$

The bank gives each loan officer the same compensation schedule, $c(r, \theta)$, where r is the return produced by a loan officer.⁸ The total compensation bill is then

$$\forall\theta, \quad \bar{c}(\theta) = \sum_r f(r|\theta, a)c(r, \theta). \quad (2)$$

Finally, we assume that in the event of bankruptcy, depositors are paid before loan officers, so if $\bar{r}(\theta) < D$ then $c(r, \theta) = 0$.

The problem for the bank is:

Bank Program

$$\max_{a, c(r, \theta) \geq 0, \bar{c}(\theta) \geq 0, \bar{r}(\theta)} \int_0^\Theta \max\{\bar{r}(\theta) - \bar{c}(\theta) - D, 0\}h(\theta)d\theta \quad (3)$$

subject to (1), (2),

$$\forall\theta, \quad \bar{c}(\theta) \leq \max\{\bar{r}(\theta) - D, 0\}, \quad (4)$$

⁸In Section 4, we will show how the contract can be interpreted as a relative performance contract in which compensation is a function of the individual loan officer's return and the performance of other loan officers, that is, $c(r, \bar{r})$.

$$\int_0^\Theta \sum_r f(r|\theta, a)U(c(r, \theta))h(\theta)d\theta - V(a) \geq \bar{U}, \quad (5)$$

$$\int_0^\Theta \sum_r f(r|\theta, a)U(c(r, \theta))h(\theta)d\theta - V(a) \geq \int_0^\Theta \sum_r f(r|\theta, \hat{a})U(c(r, \theta))h(\theta)d\theta - V(\hat{a}), \quad \forall \hat{a}. \quad (6)$$

Equation (4) limits total compensation to be less than bank revenue, net of payments to depositors. Equation (5) is the participation constraint for a loan officer, and equation (6) is the incentive constraint.

The piecewise linear objective function and the piecewise linear constraint, (4), make this optimization problem nondifferentiable. In order to derive results about compensation from first-order conditions, we consider the subproblem of implementing a given action. Because we assumed that the expected return is continuous and increasing in θ , for each a there is a $\underline{\theta}(a)$ such that for all $\theta < \underline{\theta}(a)$, $\bar{r}(\theta) < D$, that is, the bank is bankrupt and limited liability binds. Note that in these states $c(r, \theta) = \bar{c}(\theta) = 0$. Furthermore, because the expected value of a loan officer's return increases with a , $\underline{\theta}(a)$ is decreasing in a .

Now consider the subproblem of implementing action a and choosing $c(r, \theta)$ for $\theta \geq \underline{\theta}(a)$.

This subproblem is

Bank Subprogram

$$\max_{\forall \theta \geq \underline{\theta}(a), c(r, \theta) \geq 0, \bar{c}(\theta) \geq 0, \bar{r}(\theta)} \int_{\underline{\theta}(a)}^\Theta (\bar{r}(\theta) - \bar{c}(\theta) - D)h(\theta)d\theta \quad (7)$$

subject to

$$\forall \theta \geq \underline{\theta}(a), \quad \bar{r}(\theta) = \sum_r f(r|\theta, a)r, \quad (8)$$

$$\forall \theta \geq \underline{\theta}(a), \quad \bar{c}(\theta) = \sum_r f(r|\theta, a)c(r, \theta), \quad (9)$$

$$\forall \theta \geq \underline{\theta}(a), \quad \bar{c}(\theta) \leq \bar{r}(\theta) - D, \quad (10)$$

$$H(\underline{\theta}(a))U(0) + \int_{\underline{\theta}(a)}^\Theta \sum_r f(r|\theta, a)U(c(r, \theta))h(\theta)d\theta - V(a) \geq \bar{U}, \quad (11)$$

$$\begin{aligned}
& \int_{\underline{\theta}(a)}^{\Theta} \sum_r f(r|\theta, a) U(c(r, \theta)) h(\theta) d\theta - V(a) \\
& \geq \int_{\underline{\theta}(a)}^{\Theta} \sum_r f(r|\theta, \hat{a}) U(c(r, \theta)) h(\theta) d\theta - V(\hat{a}), \forall \hat{a}.
\end{aligned} \tag{12}$$

Equation (10) is the simplified form of (4) and we will refer to it as a resource constraint. Also, note that in the incentive constraint, the bankruptcy states on the right-hand side of (12) are a function of a and not the deviating action \hat{a} . The bankruptcy states are not influenced by a loan officer's deviating action because in equilibrium all other loan officers, who are of measure one, choose the recommended action a and that determines the aggregate return and thus whether there is bankruptcy in state θ .⁹ This is one difference from the single-agent problem, in which the agent's deviating action does affect the probability of default.

The objective function and constraints in the subproblem are differentiable, so we can use the Lagrangian multipliers to characterize an optimal compensation contract. Let $\nu(\theta)$ be the multiplier on (10), λ on (11), and $\mu(\hat{a})$ on (12). The first-order condition on $c(r, \theta)$ gives

$$\frac{h(\theta) + \nu(\theta)}{h(\theta)U'(c(r, \theta))} = \lambda + \sum_{\hat{a} \neq a} \mu(\hat{a}) \left(1 - \frac{f(r|\theta, \hat{a})}{f(r|\theta, a)} \right), \tag{13}$$

where $\lambda \geq 0$ and $\mu(\hat{a}) \geq 0$, and when $c(r, \theta) > 0$.¹⁰

The subsequent analysis will make frequent use of the likelihood ratio in (13). Let $LR(r, \theta, \hat{a}; a)$ be the likelihood ratio corresponding to the incentive constraint, where a is recommended and \hat{a} is the deviating action; that is,

$$LR(r, \theta, \hat{a}; a) \equiv \frac{f(r|\theta, \hat{a})}{f(r|\theta, a)}.$$

If $\nu(\theta) = 0$ (and $c(r, \theta) > 0$), then the first-order condition is the same as in the standard single-agent moral-hazard problem. High values of the likelihood ratio weighted by the $\mu(\hat{a})$ lower consumption.

⁹This also allows us to drop the agent's utility in bankruptcy states because the $H(\underline{\theta}(a))U(0)$ term cancels out on both sides of (12).

¹⁰If $c(r, \theta) = 0$, then (13) holds at an inequality.

When $\nu(\theta) > 0$, the connection between consumption and the likelihood ratio is the same as the unconstrained case. However, consumption levels are shifted down relative to what they would be otherwise. They are also shifted down so that relative marginal utilities are unchanged from what they would be if the resource constraint did not bind. In particular, given θ , for any two returns r_1 and r_2 , the relative marginal utilities satisfies

$$\frac{U'(c(r_1, \theta))}{U'(c(r_2, \theta))} = \frac{\lambda + \sum_{\hat{a} \neq a} \mu(\hat{a})(1 - LR(r_1, \theta))}{\lambda + \sum_{\hat{a} \neq a} \mu(\hat{a})(1 - LR(r_2, \theta))},$$

which does not depend on $\nu(\theta)$.¹¹

From the principal's perspective, the binding resource constraint raises the cost of implementing the action because the binding resource constraint limits his ability to use the information contained in the likelihood ratios. To see this, take the expectation of (13) over r for each θ , which gives

$$E \left[\frac{1}{U'(c(r, \theta))} \right] = \frac{\lambda}{1 + \nu(\theta)/h(\theta)}.$$

In states where the resource constraint does not bind, the expectation of inverse marginal utilities equals λ , the shadow price of relaxing the participation constraint. In each unconstrained state, the cost to the bank of paying compensation to the loan officers is the same in expectation.¹² In contrast, in each constrained state, the value of the right-hand side is lower because $(1/(1 + \nu(\theta)/h(\theta))) < 1$, so the expected payments contribute less to satisfying the participation constraint, which in turn raises the overall cost to the principal.

3.1 Welfare

In this model, there is the bank, the loan officers, depositors, and an unmodeled deposit insurer. Depositors always receive their deposits, loan officers receive their reservation utility,

¹¹If $c(r, \theta) = 0$, then compensation cannot be lowered, but the relative ordering will still hold and the relative marginal utilities will satisfy an inequality.

¹²If there were no incentive constraint, then the corresponding equation would hold for each r .

and the payment from deposit insurer is a transfer, so welfare is simply the present value of a bank's investment, net of compensation costs and payments to depositors, that is,

$$\int_0^\Theta (\bar{r}(\theta) - \bar{c}(\theta))h(\theta)d\theta - D.$$

The only difference from the bank's objective function, (3), is the absence of limited liability.

The existence of limited liability and deposit insurance will distort the bank's decision from the social optimum. One way to express the distortion is to explicitly describe the implicit transfer from deposit insurance as a function of the chosen action. This illustrates the basics of the distortion and will be useful for some of the analysis later.

Let $c^*(r, \theta)$ be the optimal compensation contract for a given a . Then, substituting for $\bar{r}(\theta)$ and $\bar{c}(\theta)$ into the objective function, (7), gives expected bank profits conditional on action a as

$$\begin{aligned} & \int_{\underline{\theta}(a)}^\Theta \sum_r f(r|\theta, a) (r - c^*(r, \theta) - D) h(\theta) d\theta \\ &= \int_0^\Theta \sum_r f(r|\theta, a) r h(\theta) d\theta - \int_0^{\underline{\theta}(a)} \left(\sum_r f(r|\theta, a) r - D \right) h(\theta) d\theta - \int_{\underline{\theta}(a)}^\Theta \sum_r f(r|\theta, a) c^*(r, \theta) h(\theta) d\theta - D. \end{aligned}$$

To simplify the notation, let $E(\bar{r}|a)$ be the expected return produced by the bank conditional on a , let $E(\bar{c}|a)$ be the expected compensation paid out by the bank conditional on a , and let $z(a)$ be the expected value of the implicit transfers from the deposit insurer to the bank conditional on a . Then,

$$\begin{aligned} E(\bar{r}|a) &= \int_0^\Theta \sum_r f(r|\theta, a) r h(\theta) d\theta, \\ E(\bar{c}|a) &= \int_{\underline{\theta}(a)}^\Theta \sum_r f(r|\theta, a) c^*(r, \theta) h(\theta) d\theta, \\ z(a) &= \int_0^{\underline{\theta}(a)} \left(D - \sum_r f(r|\theta, a) r \right) h(\theta) d\theta, \end{aligned}$$

so expected profits are $E(\bar{r}|a) - E(\bar{c}|a) - D + z(a)$. The term $z(a)$ is sometimes referred to as the value of the deposit insurance put option because the bank gets to put its losses onto the deposit insurer.

In this notation, the bank's problem is

$$\max_a E(\bar{r}|a) - E(\bar{c}|a) - D + z(a). \quad (14)$$

At a social optimum, society takes into account that $z(a)$ is a transfer. In this notation, the social welfare problem is

$$\max_a E(\bar{r}|a) - E(\bar{c}|a) - D.$$

The difference between the two objective functions, as represented here by $z(a)$, leads to the distortion. In particular, the bank equity owners don't bear the cost of failure nor do the depositors, so the bank may take an action that leads to more failure than is socially desirable.

3.2 The Effort Distortion

To analyze the effort distortion, we assume in this subsection that a is chosen from a continuum. This assumption is not essential, but simplifies the analysis. Second, we assume that for all θ , $\sum_r f(r|a, \theta)r$ is differentiable in a , in addition to the earlier assumption that it is increasing and concave in a . This assumption means that $E(\bar{r}|a)$ is differentiable, increasing and concave and that $z'(a) < 0$.¹³

Using the objective function defined earlier, the bank will choose an a that satisfies

$$\frac{\partial E(\bar{r}|a)}{\partial a} + z'(a) = \frac{\partial E(\bar{c}|a)}{\partial a}.$$

while a social optimum is a solution to

¹³To see this, use Leibniz's rule to get

$$z'(a) = \left[h(\underline{\theta}(a))(D - \sum_r f(r|\underline{\theta}(a), a)r) \right] - \int_0^{\underline{\theta}(a)} \sum_r \frac{\partial f(r|\theta, a)r}{\partial a} h(\theta) d(\theta).$$

By definition of $\underline{\theta}(a)$, the term in the brackets is zero. Furthermore, $\forall \theta$, $\sum_r \frac{\partial f(r|\theta, a)r}{\partial a} > 0$ by assumption, so $z'(a) < 0$.

$$\frac{\partial E(\bar{r}|a)}{\partial a} = \frac{\partial E(\bar{c}|a)}{\partial a}.$$

Proposition 1 *If $E(\bar{c}|a)$ is increasing and convex in a , then the bank chooses an a that is less than the social optimum.*

Proof: Follows directly from $z'(a) < 0$.

The assumption that the compensation bill is increasing and convex in a need not hold in general, but it will always hold in the unconstrained model — when there are no resource and incentive constraints — and it illustrates a force towards underprovision of effort in the model. Simply, if loan officers work harder, they need higher compensation to satisfy the participation constraint. More specifically, in the unconstrained model, loan officers are paid a wage, so if their effort increases then the wage needs to increase too to satisfy the participation constraint. Furthermore, with concavity of u and convexity of v , the compensation bill as a function of a is a convex function.

The unconstrained benchmark is a useful starting point to see when this assumption might not hold. To see how it might not hold, first consider adding the resource constraint, but for the moment continue to assume that there is no private information. The optimal contract in this case is

$$c(r, \theta) = \begin{cases} 0 & \text{if } \bar{r}(\theta) \leq D \\ \bar{r} - D & \text{if } 0 < \bar{r}(\theta) - D < c \\ c & \text{otherwise,} \end{cases}$$

where c is some constant amount. As a increases, there are two forces at work. The first is the one described above that increases the compensation bill, namely, loan officers have to be compensated for higher effort. The second force *lowers* the compensation bill. As a increases, the probability of states in which the bank is bankrupt declines, so the loan officer receives positive compensation more frequently, which allows the level of c to be lowered due to concavity of utility. Essentially, risk-averse employees need to be compensated for taking

on risk, which increases the cost to the bank of exploiting limited liability. This second force is not in the standard deposit insurance model because that model does not have risk-averse employees.

Finally, there is a third force that affects $E(c(a))$. When the incentive constraints are added to the model, changes in a can alter likelihood ratios, which can increase or lower the compensation bill, depending on the corresponding change in the informativeness of r . Without assumptions on $f(r|a, \theta)$, the effect of this factor on the compensation bill cannot be determined.

4 Optimal Compensation Contracts and Relative Performance

The compensation contract, $c(r, \theta)$, can also be represented as a relative performance contract, that is, where c is a function of r and the distribution of other loan officers' r 's. If given a , the mapping from θ to \bar{r} is described by an invertible function, then it can be further simplified to $c(r, \bar{r})$, since θ can be inferred from \bar{r} .¹⁴

This section works through two production technologies. The technologies will illustrate how relative performance is used in optimal contracts and will show how these contracts can resemble actual contracts often used in practice. Furthermore, the parameterization will highlight the role that correlation in returns plays in determining bank risk.

To highlight the compensation contract, we shut down the effort distortion that was the focus of the earlier analysis by restricting loan officers to two effort levels and focusing on the implementation of the high effort level. We also assume that each loan officer can only produce two returns. The two possible returns can be interpreted as a loan that either repays

¹⁴Relative performance contracts exist in other industries. See Tsoulouhas and Vukina (1999) and Hueth and Ligon (2001) for applications to agriculture. The latter paper describes how agricultural production contracts with compensation that depend on market prices can be interpreted as relative performance contracts. For recent theoretical work on relative performance models see Celentani and Loveira (2006) and Fleckinger (2012).

or does not.

Formally, each loan officer can take either a_l or a_h , with $0 < a_l < a_h < 1$. There are only two possible returns, failure, r_l , or success, r_h . As before, θ is the common shock. Its mean is $\bar{\theta}$. We assume that it is optimal for the bank to implement a_h .

4.1 Effort Is Additive

We first consider the case in which the marginal effect of the loan officers' actions is to only increase the bank's mean return. There are no complementarities in production between the action and θ . The probability of success for a loan officer is

$$f(r_h|\theta, a) = a + (\alpha\bar{\theta} + (1 - \alpha)\theta). \quad (15)$$

The parameter $(1 - \alpha)$ measures the importance of the common shock. For low values of α , the return of the bank will vary more with the realization of θ than for high values of α . Notice that a loan officer's expected return is $a + \bar{\theta}$, which does not depend on α . Furthermore, for the bank, $E(\bar{r}) = a + \bar{\theta}$ and $Var(\bar{r}) = (1 - \alpha)^2 Var(\theta)$. In this example, effort affects only the bank's mean return, not its variance. Furthermore, $\bar{r}(\theta) = a + (\alpha\bar{\theta} + (1 - \alpha)\theta)$, so θ can be identified from \bar{r} and the contract can be written as $c(r, \theta)$ or $c(r, \bar{r})$.

Compensation is determined by the likelihood ratios. When the recommended action is a_h , these are

$$\begin{aligned} LR(r_h, \theta, a_l; a_h) &= \frac{a_l + (\alpha\bar{\theta} + (1 - \alpha)\theta)}{a_h + (\alpha\bar{\theta} + (1 - \alpha)\theta)}, \\ LR(r_l, \theta, a_l; a_h) &= \frac{1 - a_l - (\alpha\bar{\theta} + (1 - \alpha)\theta)}{1 - a_h - (\alpha\bar{\theta} + (1 - \alpha)\theta)}. \end{aligned}$$

Proposition 2 *For the technology specified in (15), at an interior solution, consumption for r_h decreases with θ and consumption for r_l decreases with θ .*

Proof: Likelihood ratios comove with θ such that

$$\frac{\partial LR(r_h, \theta, a_l; a_h)}{\partial \theta} > 0 \Rightarrow \frac{\partial c(r_h, \theta)}{\partial \theta} < 0$$

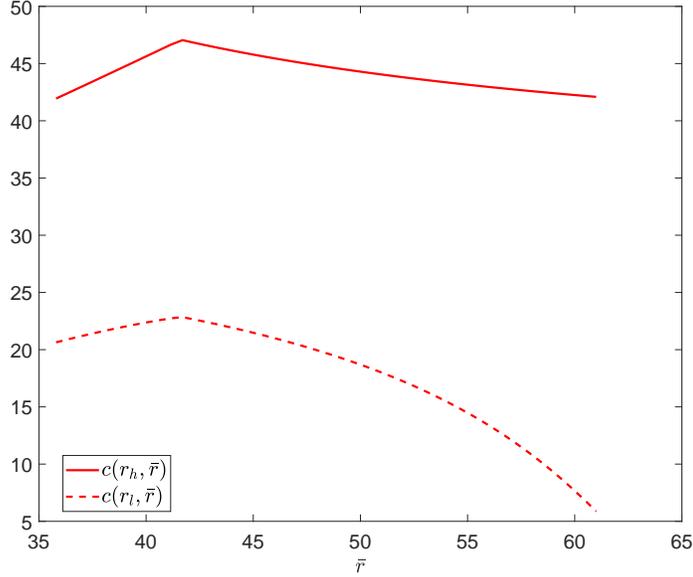


Figure 1: Optimal compensation in an example in which effort affects the mean of returns and a_h is implemented.

$$\frac{\partial LR(r_l, \theta, a_l; a_h)}{\partial \theta} > 0 \Rightarrow \frac{\partial c(r_l, \theta)}{\partial \theta} < 0.$$

Furthermore, it is not hard to show that $LR(r_h, \theta, a_l; a_h) < 1, \forall \theta$ and $LR(r_l, \theta, a_l; a_h) > 1, \forall \theta$. This implies that $c(r_l, \theta) < c(r_h, \theta'), \forall \theta, \theta'$; that is, the lowest level of consumption for r_h is more than the highest level of consumption for r_l .

Figure 1 shows the comovement of consumption with \bar{r} (and thus θ) for an example in which it is optimal to implement a_h .¹⁵ For both r_l and r_h , compensation starts low, increases in \bar{r} , and then starts declining. The reason for the hump shape is due to the likelihood ratio functions and the resource constraint.

Figure 2 reports the likelihood ratio for r_l and r_h as a function of \bar{r} . Both likelihood ratios increase in \bar{r} , which means that for incentive reasons it is desirable to have compensation

¹⁵The parameters in the example are: uniform distribution of θ over $[-0.3, 0.3]$, $\alpha = 0.3$, $r_l = 10$, $r_h = 70$, $a_l = 0.60$, $a_h = 0.64$, $u(c) = c^{0.5}/0.5$, $v(a) = 4a^2$, $D = 6$, and $\bar{U} = 10$.

decreasing in \bar{r} . The likelihood ratio for r_h is well below one when \bar{r} is low, which means r_h has a high value as a signal that a_h was taken. Consequently, it is efficient to reward the loan officer with high consumption. As \bar{r} increases, the common shock becomes proportionally more important for determining a loan officer's success, so the likelihood ratio increases and gets closer to one, which means the signal value of r_h declines and consumption declines.

For r_l the likelihood ratio is at its lowest for the lowest value of \bar{r} . At that point, the common shock is proportionally more important than individual effort in determining failure, so the signal value of r_l is low and the loan officer is not punished that much for failure. As \bar{r} increases, the likelihood ratio increases and moves away from one, so the signal value of r_l increases. Consequently, it is efficient for the bank to punish the loan officer with low consumption.

For low values of \bar{r} , the resource constraint binds, which reduces the compensation paid out.¹⁶ As Figure 2 shows, the bank would like to pay the loan officers more in these states, but the resource constraint prevents it from doing that. However, as \bar{r} increases, the resource constraint becomes gradually less binding, so compensation increases for both realizations of r until the resource constraint no longer binds. Once it no longer binds, the increasing likelihood ratios become relevant and for both values of r compensation decreases in \bar{r} .

To tie this contract to compensation practices in banking, note that this contract can be implemented with a wage and a bonus that depends on individual and firm performance. Simply, set the wage to the lowest value of $c(r_l, \bar{r})$ and then use an individual and firm performance dependent bonus to reach the compensation schedule in Figure 1.¹⁷ As discussed earlier, a common practice in investment banking and some parts of traditional commercial banking is to pay employees in the form of a wage and a discretionary bonus that is tied to performance of the bank or a line of business. Along these lines, investment banks often

¹⁶In this example, the bank never fails.

¹⁷While not a problem in this example, in parametrizations in which the resource constraint limits compensation to be very low in some states, an allowance would be needed for pay cuts in these states.

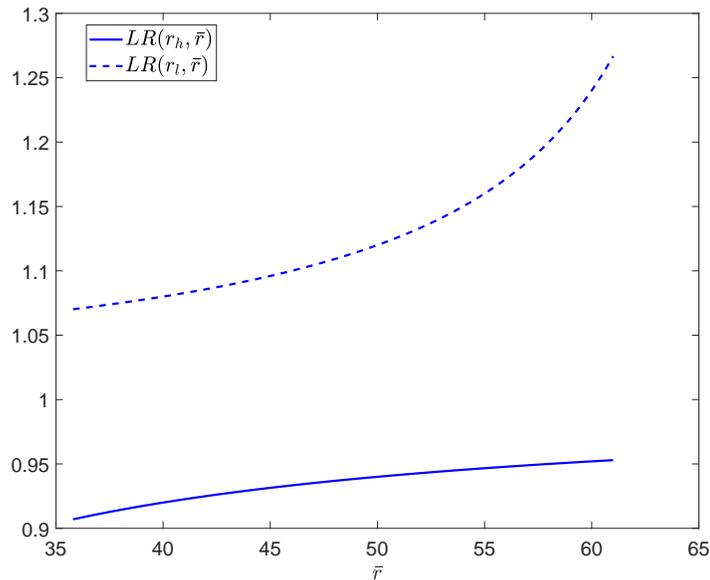


Figure 2: Likelihood ratios expressed as a function of bank revenue in example where effort affects the mean of returns and a_h is implemented.

report on total compensation as a percentage of revenue, thus tying compensation to firm performance.

4.2 Effort Increases the Variance of the Return

In this specification, loan officer effort affects the mean of the return and the variance of the bank's return. We introduce this complementarity by making effort and θ complements in the probability of success. In particular, the probability of success for a loan officer is

$$f(r_h|\theta, a) = a(\alpha\bar{\theta} + (1 - \alpha)\theta). \quad (16)$$

Notice that, as with the previous example, a loan officer's expected return is $a\bar{\theta}$, which does not depend on α . However, the bank's mean return is $E(\bar{r}) = a\bar{\theta}$ and $Var(\bar{r}) = (1 - \alpha)^2 a^2 Var(\theta)$. In this example, effort increases the bank's mean return and increases the variance of its return.

Compensation is determined by the likelihood ratios. When the recommended action is a_h , these are

$$\begin{aligned} LR(r_h, \theta, a_l; a_h) &= \frac{a_l}{a_h}, \\ LR(r_l, \theta, a_l; a_h) &= \frac{1 - a_l(\alpha\bar{\theta} + (1 - \alpha)\theta)}{1 - a_h(\alpha\bar{\theta} + (1 - \alpha)\theta)}. \end{aligned}$$

Proposition 3 *For the technology specified in (16), at an interior solution, consumption for r_h does not vary with θ and consumption for r_l decreases with θ .*

Proof: Likelihood ratios comove with θ such that

$$\begin{aligned} \frac{\partial LR(r_h, \theta, a_l; a_h)}{\partial \theta} = 0 &\Rightarrow \frac{\partial c(r_h, \theta)}{\partial \theta} = 0 \\ \frac{\partial LR(r_l, \theta, a_l; a_h)}{\partial \theta} > 0 &\Rightarrow \frac{\partial c(r_l, \theta)}{\partial \theta} < 0. \end{aligned}$$

Figure 3 reports the comovement of consumption with bank revenue (and thus θ too) for an example in which it is optimal for the bank to implement the high effort.¹⁸ Figure 4 reports the likelihood ratios. For low values of \bar{r} , the resource constraint binds, which limits the compensation paid to loan officers.¹⁹ As \bar{r} increases, compensation increases until the resource constraint no longer binds. At that point, compensation becomes flat for r_h because the likelihood ratio does not change with \bar{r} . For r_l , compensation decreases because the likelihood ratio increases with \bar{r} . If the loan officer deviates to a_l , the return r_l is less likely as \bar{r} increases, so a low level of compensation is an efficient way to punish a loan officer who deviates without punishing too frequently a loan officer who does not deviate.

5 Correlation, Compensation, and Bank Risk

In the previous two examples, bank risk was determined by the choice of a and the correlation of loan officer returns as indexed by α . In general, the connection between compensation

¹⁸The parameters in the example are: uniform distribution of θ over $[0, 1]$, $\alpha = 0.21$, $r_l = 50$, $r_h = 550$, $a_l = 0.53$, $a_h = 0.82$, $u(c) = c^{0.4}/0.4$, $v(a) = 2a^3$, $D = 50$, and $\bar{U} = 12$.

¹⁹In this example, the bank never fails.

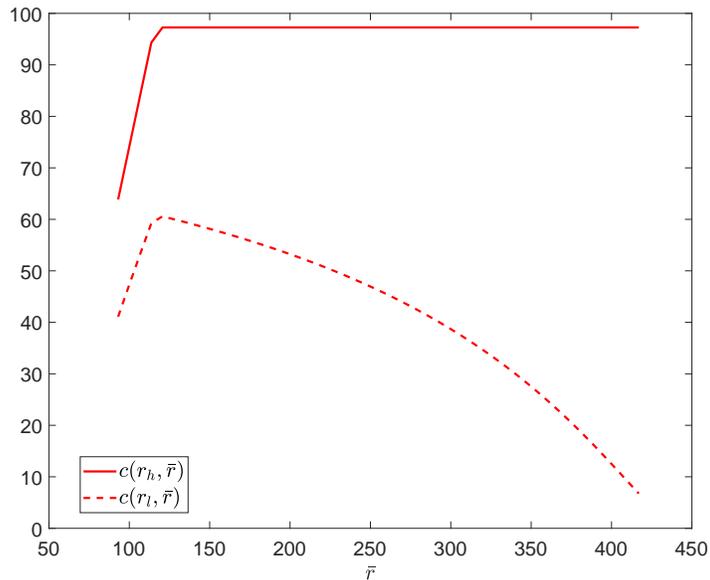


Figure 3: Optimal compensation as a function of bank revenue and individual performance in example where effort is complementary with θ and where a_h is implemented.

and bank risk will depend on the precise functional form of the technology. Nevertheless, two extreme cases illustrate how this connection can work.

5.1 Uncorrelated Returns

Consider the extreme case where there is no correlation in loan officer returns, that is, $f(r|a, \theta) = f(r|a)$. All risk is idiosyncratic, so the gross return of the bank is a constant $\bar{r}(a) = \sum_r f(r|a)r$, which depends only on the loan officers' action. Similarly, the total compensation bill is a constant $\bar{c}(a)$, which will depend only on the chosen action. Also, because the bank does not fail, the value of the deposit insurance option is $z(a) = 0$.

The bank's optimization problem is to choose an action a that solves

$$\max_a \bar{r}(a) - \bar{c}(a) - D.$$

As long as there exists an a such that bank profits are nonnegative, the action chosen

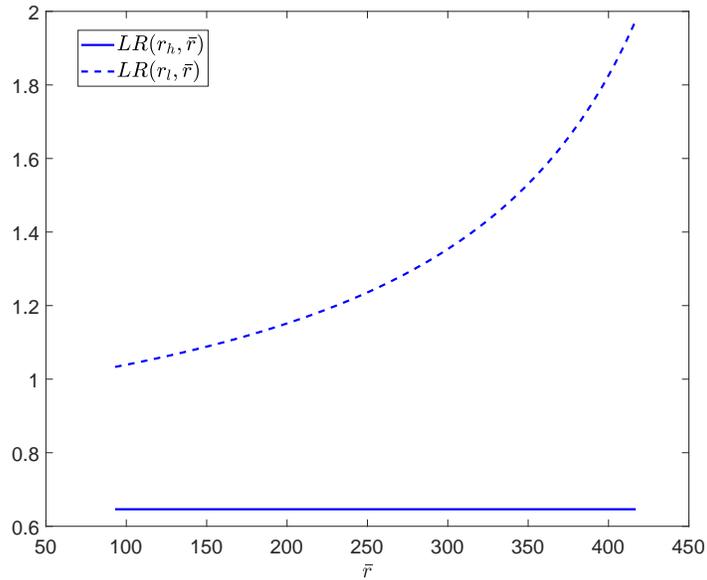


Figure 4: Likelihood ratios expressed as a function of bank revenue in example where effort is complementary with θ and where a_h is implemented.

by the bank will be the same as the one preferred by society. Basically, when there is no variation in a bank's total return, limited liability does not distort bank decisions, so compensation is socially optimal and there is no need to regulate it. Furthermore, there is no connection between compensation and bank risk. Compensation that is closely tied to individual performance, even if it creates a lot of risk for the loan officer, has no impact on bank risk.

5.2 Perfectly Correlated Returns

Now consider the other extreme case, in which loan officer returns are perfectly correlated. In this case, the bank's gross return does vary with θ and the bank may want to encourage its loan officers to take on risk due to the limited liability distortion analyzed earlier. Interestingly, loan officer compensation matters for risk, but in a surprising way.

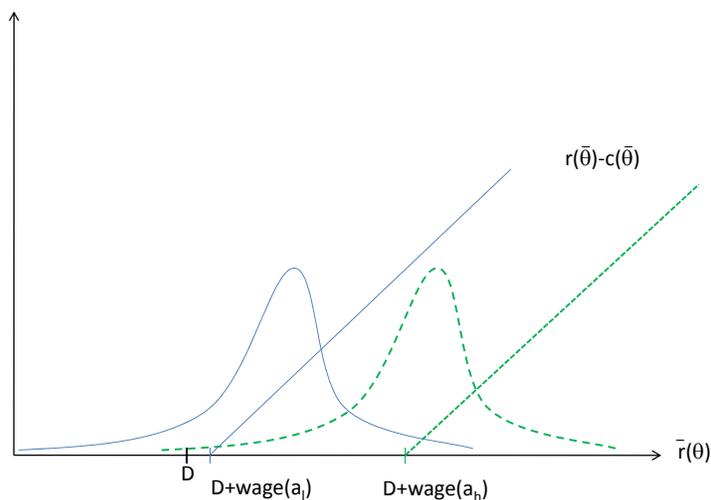


Figure 5: Example of a bank that pays a low wage to increase bank risk when loan officer returns are perfectly correlated. The variable $wage(a)$ is the wage paid to loan officers if a is taken and the bank has produced a high enough return to pay the full wage. The solid line that intercepts the x -axis is profits for the bank if a_l is taken and if $\bar{r}(\theta) \geq D + wage(a_l)$. (For lower values of $\bar{r}(\theta)$, either all the return net of deposits is paid to loan officers or limited liability binds and the bank receives zero profit.) The dashed line that intercepts the x -axis is profits if a_h is taken and $\bar{r}(\theta) \geq D + wage(a_h)$. The solid curve is the density function of $\bar{r}(\theta)$ when a_l is taken and the dashed curve is the corresponding density when a_h is taken. For each density, the area under the curve to the left of D is the probability of failure; it is much higher for a_l . In this figure, the wage to implement a_h is so large that the bank receives little profit if its return exceeds D . Consequently, the bank prefers to take a_l . It pays a low wage and it fails more frequently.

When returns are perfectly correlated, there is no idiosyncratic risk, so the bank can infer a loan officer's action from the common shock, θ , and the loan officer's return r . The relative performance contract in this problem is to simply compare a loan officer's return with that of other loan officers and to pay him zero if it differs. Since the bank essentially knows the action, it can pay each loan officer a wage if his return is what it is supposed to be and zero otherwise. (If the resource constraint binds, then the bank pays out all of its net revenue to loan officers.) We assume that the zero payment penalty is enough to induce the loan officer to take the recommended action.

The implications of the contract are exactly the same as those that we derived earlier in the analysis of the effort distortion. The bank wants to reduce effort to save on its compensation bill though this can possibly be offset by the effect of less frequent bankruptcy on compensation. Nevertheless, the analysis highlights an interesting implication of the connection between compensation and bank risk. In the extreme case of perfect correlation, the bank pays a wage, yet it can have a lot of risk. Furthermore, low pay indicates a socially inefficient probability of failure. Figure 5 illustrates the case in which the first force is more important than the second, namely, that the savings in wage payments from lowering a increase the bank's profits when it is successful and this benefit outweighs the higher probability of failure, the cost of which is borne by the deposit insurer.

6 Discussion of Regulation and Extensions

The analysis shows that the use of incentives in compensation, measured by something like the size of a bonus, does not necessarily directly correspond to bank risk. In the idiosyncratic risk case, compensation was incentive based, but it did not matter for bank risk. In contrast, in the case of perfect correlation, the compensation contract that prevailing wisdom would think is the safest, namely a wage, was associated with bank risk.

The two technologies analyzed in detail can be used to think about how bonuses may

operate in practice. Each of the optimal contracts shown in Figures 1 and 3 can be implemented via a bonus arrangement. Simply, set the wage to be the lowest level $c(r_l, \theta)$ and then pay a bonus that depends on r and \bar{r} .²⁰ In practice, employees of large banks and investment banks are often paid with discretionary bonus schemes in which bonus pools are determined by bank performance and division performance and then each division allocates bonuses among its employees, presumably, with some connection to performance. Implicitly, these arrangements are relative-performance-type schemes and could be used to implement the types of contracts studied here. In these two models, bonuses are a natural feature of the optimal contract. Thus, constraints on bonuses potentially lead to the bank not using all of its available information to determine compensation.

Our analysis also emphasizes that limited liability and deposit insurance create a force for the underprovision of effort. This was most starkly illustrated in the perfect correlation case, where lower effort simply shifted the distribution of returns down. If that force predominates then low levels of compensation correspond to increased bank risk, mainly because the loan officers are not working hard enough at making good loans.

Our analysis left out a dimension of bank risk in that we did not consider the effects of actions that increase the correlation of loan officer returns.²¹ The first thing to note about this source of bank risk is that regulatory practices typically manage this risk through loan concentration rules that limit lending to a single borrower or to a single industry. Whether compensation rules can affect correlation in loan officer returns would seem to depend on how much ability a loan officer has to control the correlation in a loan that they make.²² It is possible that a loan officer could do this, but that is less intuitive than purely affecting the success probability. Instead, correlation would seem to be more controlled by decisions

²⁰Of course, subject to the caveat that pay cuts may be necessary if the resource constraint binds.

²¹The multiplicative example did contain a feature in which the action increased the variance of the bank's return, but it was not the focus of that example.

²²For an analysis along these lines see the earlier working paper version of this paper, Jarque and Prescott (2013).

made by risk managers and other control functions within a bank.²³

Along these lines, one direction in which to extend our approach is to model the bank as more than just isolated loan officers by adding people who review loans, manage risk, and audit operations. In practice, large banks have large numbers of employees who do these functions. Large loans are reviewed by a loan committee, the risk management department measures department risk, and auditing randomly checks departments to see if they are complying with bank rules. The monitoring provided by these functions will affect the private information of loan officers, put limits on their choices, and thus impact their compensation. Furthermore, the employees who monitor will have their own set of incentive problems, which will have implications for the form of their compensation.

There is some research along these lines. Ang, Lauterbach, and Schreiber (2001) consider a model in which bank executives monitor each other. Lóránth and Morrison (2010) look at internal reporting systems and loan officer incentives. In the earlier working paper version of this paper, Jarque and Prescott (2013) analyze the loan review function.²⁴ Related, Kupiec (2013) studies incentive compensation in a model in which a loan officer determines the risk of a loan and a risk manager determines the losses in case of default.

7 Conclusion

This paper models a bank as a large number of independent loan officers subject to a common shock and then analyzes optimal compensation. The optimal contract is a relative-performance contract. We show how information contained in the common shock impacts

²³In our model, all loan officers were recommended the same action. An extension along a different direction would be to give bank employees private signals about θ before they take an action and limit their reporting on the θ , which when faced with a relative performance contract, might create coordination problems along the lines of the analysis of fund manager incentives in Morris and Shin (2016). Related, Acharya and Yorulmazer (2008) study a model with a systemic shock in which inference of this shock and idiosyncratic shocks from bank performance by the market leads to herding, that is, banks choosing to make correlated investments.

²⁴Also, see the discussion in Prescott (2016) as well as Udell (1989) and Berg (2015).

the signal value of a loan officer's performance and thus compensation. In the optimal contract, compensation is tied to both individual and bank performance.

The paper also shows that limited liability and deposit insurance are a force for the underprovision of effort relative to the social optimum. However, relative to the standard model we also show that risk-averse loan officers add an additional cost to exploiting the safety net because they need to be compensated for the extra risk. Furthermore, the mapping from bank risk to the optimal contract suggests that the commonly held perception that high bonuses create risk is not necessarily true. We show that with only idiosyncratic risk, compensation contracts are irrelevant for bank risk and with perfect correlation, a low wage is what creates an inefficient amount of risk.

The analysis demonstrates that the connection between compensation and bank risk is not straightforward and depends on the production technology. Evaluation of bank risk requires a detailed understanding of the production technology to identify precise effects. Nevertheless, the analysis shows the importance of relative-performance schemes in compensation and suggests that identifying ways that relative performance can increase correlation in returns is a productive strategy for identifying risky compensation practices.

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