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Abstract

Models of banks operating under limited liability with deposit insurance and employee incentive problems are used to analyze how banker compensation contracts can contribute to bank risk shifting. The first model is a multi-agent, moral-hazard model, where each agent (e.g. a loan officer) operates a risky lending technology. Results differ from the single-agent model; pay for performance contracts do not necessarily indicate risk at the bank level. Correlation of returns is the most important factor. If loan officer returns are uncorrelated, the form of pay is irrelevant for risk. If returns are correlated, a low wage causes risk. If correlation is endogenous, relative performance contracts that encourage correlation of returns can create bank risk. A sufficient condition for a contract to induce risk at the bank level is provided. The second model adds a loan review and risk management function that affects risk characteristics of loan officers' loans. Counter to common perception, paying loan reviewers and risk managers for performance does not necessarily create risk. The model also identifies the importance of evaluating the quality of bank controls as a means for limiting bank risk.

Keywords: incentive compensation, bank regulation, risk shifting

JEL Codes: D82, G21, G28, J33

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1 Introduction

This paper uses organizational economics to analyze the connection between banker compensation and bank risk. In a framework where a bank operates under limited liability with deposit insurance, a sequence of multi-agent, moral-hazard models is developed. Contracts that implement both safe and risky lending decisions by a bank's employees are provided. These contracts are then used to address the question of what characteristics of compensation arrangements encourage risk-taking behavior.

Controlling bank risk via regulation of compensation arrangements is a new focus of bank regulation. The Federal Reserve Board in 2010 issued supervisory guidance to 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.[1] These regulations are motivated by the belief that bank compensation practices were a significant contributory factor to the recent financial crisis (e.g., Financial Stability Forum (2009)).

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, like a CEO or some traders, whose individual decisions can materially affect the bank's performance. The second is a group of individuals like loan officers whose decisions together 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, usage of 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, most labor compensation paid out by a bank goes to its employees, so compensation regulations have the largest effect on them.

Our approach is to develop static, multi-agent, moral-hazard models where employees'

[1] There is a precedent in that the Federal Deposit Insurance Corporation Improvement Act of 1991 gives bank supervisors authority to prevent banks from paying "excessive" compensation, but this feature of the Act is not directly connected with bank risk-taking.

interests are not necessarily aligned with those of bank equity or of society. The multi-agent feature allows us to analyze the impact of compensation on bank risk when each individual has a minuscule effect on the performance of the entire organization. As we show, this factor alone implies that the degree to which pay depends on an individual's performance is *not* a primary factor in determining bank risk. The reason is that the idiosyncratic risk of loan-officer loans averages out, regardless of how risky their individual loans are or how they are paid. Instead, the main way in which loan-officer compensation affects bank risk is through the degree to which it makes loan returns correlated. We then show how relative performance contracts and monitoring mechanisms, like loan review, can increase or decrease the correlation of loan returns.

One feature of compensation that we do not consider is how the timing of payments to bankers affects bank risk. The timing of compensation is important, partly because regulations are pushing banks to use more deferred compensation that can be "clawed back," 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 (2010).

Section 2 reviews the literature on banker compensation. Section 3 develops a multi-agent moral-hazard model where each agent has a small effect on the bank's total return. Section 4 analyzes the importance of correlation in returns. Section 5 studies monitoring and bank controls. Section 6 concludes.

2 Literature

There are two theoretical literatures relevant for this paper. The first one is the literature about the incentives of a bank to make inefficient investments. Both Merton (1977) and Kareken and Wallace (1978) showed that, due to deposit insurance, banks have incentives to take risky investment decisions in order to receive implicit transfers from the deposit insurer. The large number of thrift failures in the U.S. S&L crisis of the 1980s is often considered to be strong evidence of these incentives at work (e.g., White (1991)).

Much of the resulting theoretical banking literature on risk shifting incentives has focused on the use of capital requirements or franchise value to mitigate this distortion. Examples of papers along this line include Flannery (1989), Furlong and Keeley (1990), and Kim and Santomero (1988).[2] In this theoretical literature, management is implicitly assumed to act in the interests of bank equity owners.

The second relevant literature assumes that management does not necessarily act in the interests of bank equity owners. Jensen and Murphy (1990) is an early example of this problem. However, only a few papers such as John, Saunders, and Senbet (2000), Phelan (2009), and Bolton, Mehran, and Shapiro (2010) explicitly study this problem in the context of banking.

In contrast, the empirical literature on compensation and risk shifting in banking is bigger, but almost all of it looks at CEO compensation, mainly because of data availability. One portion of this literature uses as its sample period the banking problems of the 1980s and early 1990s. These papers often looked at proportions of pay that are variable, e.g., equity based, and examined whether this is correlated with bank risk. Their findings were mixed. For example, Houston and James (1995) studied commercial bank CEO pay from 1980-1990 and found that CEO compensation policies did not encourage excessive risk-taking in the 1980s. In contrast, Benston and Evans (2006) looked at a sample of highly levered banks over the period 1988-1994 and found evidence of more use of short-term compensation, like bonuses, at banks that failed. Using bank CEO data from 1976-1988, Crawford, Ezzell, and Miles (1995) found some mixed evidence that highly levered banks increased incentives for their CEOs, which is consistent with risk shifting.

Another portion of this literature looks at a sample period that includes the recent financial crisis. Fahlenbrach and Stulz (2011) investigate whether the performance of banks during the crises is related to incentives provided for their CEOs in the period leading up to it. They find some evidence that banks with CEOs whose objectives were better aligned with the interests of shareholders performed worse than other banks. Cheng, Hong and Scheinkman (2010) find important and persistent differences across firms in the level of pay and risk, with firms that took more risk also having the highest pay. Moreover, they find that the firms that take more risks performed worse during the crisis period. The authors

[2] Marshall and Prescott (2001, 2006) extend this work to allow more complicated capital structures that include warrants and convertible debt.

also interpret their results as evidence that firms have different risk cultures. In a related study, Balachandran, Kogut, and Harnal (2010) perform a similar analysis of the relation between pay and risk and find a positive and significant correlation.

2.1 Empirical literature on non-CEO banker pay

There are very few studies of compensation of lower-level bank employees because this data is proprietary. One exception is Agarwal and Wang (2009) 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 paid the other half with a wage plus an incentive. They found that the incentive plan increased the loan approval rate by 47 percent and the size of loans by 45 percent. Unfortunately for the bank, the plan also increased the default rate by 24 percent, so the plan was dropped.[3]

Berg, Puri, and Rocholl (2012) 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 a bank's loan scoring system that determined approval. They find evidence of selective entering of hard information into the scoring system to improve a borrower's chance of approval. Cole, Kanz, and Klapper (2011) ran laboratory experiments on commercial bank loan officers where 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 (2011) 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. In their analysis, the bank's policies effectively tie pay to loans under management, and they argue that the loan rotation along with career concerns mitigate the incentive loan officers have to under report the risk in their portfolio of loans.

[3]Interestingly, the incentive bonuses in the experiment were relatively small, only 15 percent of total pay, and in the data most loan officers seemed to hit a volume amount that was labeled as 100 percent of the bonus. The loan officers could earn more if they exceeded this volume, but earned proportionally less above this threshold. Given the relatively small size of the bonuses, it may be that loan officers interpreted the volume incentive as a target they had to reach rather than a pure commission type arrangement.

3 Loan Officer Compensation and Bank Risk

There is a bank that consists of depositors, equity holders, and a large number of loan officers. There is a continuum of loan officers each of whom has an infinitesimally small effect on the performance of the bank. Together, the size of the loan officers are measure one. Each loan officer takes an action $a \in A$ that produces a return r as a function of an idiosyncratic shock and a common shock θ. The probability of a loan officer's return is written $f(r|\theta, a)$. Both shocks occur after the action is taken. There is a finite number of realizations of the common shock, and the probability of shock θ is $h(\theta)$. There is also a finite number of possible returns for each loan officer. Also, for most of the analysis there is a finite number of actions, though in one subsection we allow for a continuum of actions.

A loan officer's action and idiosyncratic shock are private information, while the common shock is observed by the bank.[4] 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.[5]

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 output of $\bar{r}(\theta)$, which is the sum of the loan officer's returns, and pays out funds to depositors and compensation to loan

[4] 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 could be identified from the contract. For that reason, we simply assume that θ is public information.

[5] The model can be extended to include franchise value, the value of a bank being a continuing concern. A positive franchise value reduces risk-taking incentives because it is lost in the event of failure. The empirical banking literature finds that franchise value has a significant impact on risk-taking. Keeley (1990) argued that the low rate of bank failure pre-1980, before deregulation, was due to banks' incentive to preserve the positive franchise value that came with monopoly profits. The second half of the savings and loan crises is often attributed to savings and loans institutions gambling for resurrection when they had negative franchise value (e.g., White (1991)). Demsetz, Saidenberg, and Strahan (1996) find that franchise value is negatively correlated with risk-taking in bank data from the 1990s. We leave franchise value out to keep the problem simpler.

officers. The total compensation bill is $\bar{c}(\theta)$. The principal's utility is $\sum_\theta h(\theta) \max\{\bar{r}(\theta) - \bar{c}(\theta) - D, 0\}$.

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

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

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

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

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

$$\max_{a, c(r,\theta) \geq 0, \bar{c}(\theta) \geq 0, \bar{r}(\theta)} \sum_\theta h(\theta) \max\{\bar{r}(\theta) - \bar{c}(\theta) - D, 0\} \tag{3}$$

subject to (1), (2),

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

$$\sum_\theta h(\theta) \sum_r f(r|\theta, a) U(c(r, \theta)) - V(a) \geq \bar{U}, \tag{5}$$

$$\sum_\theta h(\theta) \sum_r f(r|\theta, a) U(c(r, \theta)) - V(a) \geq \sum_\theta h(\theta) \sum_r f(r|\theta, \hat{a}) U(c(r, \theta)) - V(\hat{a}), \;\; \forall \hat{a}. \tag{6}$$

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 non-differentiable. In order to derive results about compensation from first-order conditions, we consider the subproblem of implementing a given action. For each a, there is a set of bankruptcy states, $\Theta_1(a)$, where $\bar{r}(\theta) \leq D$. Note that in these states

$c(r,\theta) = \bar{c}(\theta) = 0$. There is also a set of solvency states, $\Theta_2(a)$, where $\bar{r}(\theta) > D$. These latter states are those in which limited liability does not bind. Now consider the subproblem of implementing action a and choosing $c(r,\theta)$ for $\theta \in \Theta_2$. This subproblem is

Bank Subprogram

$$\max_{\forall\theta\in\Theta_2(a), c(r,\theta)\geq 0, \bar{c}(\theta)\geq 0, \bar{r}(\theta)} \sum_{\theta\in\Theta_2(a)} h(\theta)(\bar{r}(\theta) - \bar{c}(\theta) - D) \tag{7}$$

subject to

$$\forall\theta \in \Theta_2(a), \quad \bar{r}(\theta) = \sum_r f(r|\theta,a)r. \tag{8}$$

$$\forall\theta \in \Theta_2(a), \quad \bar{c}(\theta) = \sum_r f(r|\theta,a)c(r,\theta). \tag{9}$$

$$\forall\theta \in \Theta_2(a), \quad \bar{c}(\theta) \leq \bar{r}(\theta) - D, \tag{10}$$

$$\sum_{\theta\in\Theta_1} h(\theta)U(0) + \sum_{\theta\in\Theta_2(a)} h(\theta) \sum_r f(r|\theta,a)U(c(r,\theta)) - V(a) \geq \bar{U}, \tag{11}$$

$$\begin{aligned} &\sum_{\theta\in\Theta_1(a)} h(\theta)U(0) + \sum_{\theta\in\Theta_2(a)} h(\theta) \sum_r f(r|\theta,a)U(c(r,\theta)) - V(a) \\ \geq &\sum_{\theta\in\Theta_1(a)} h(\theta)U(0) + \sum_{\theta\in\Theta_2(a)} h(\theta) \sum_r f(r|\theta,\hat{a})U(c(r,\theta)) - V(\hat{a}), \forall\hat{a}. \end{aligned} \tag{12}$$

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 defined by a loan officer's deviating action because in equilibrium all loan officers choose the recommended action a and that determines the aggregate return and thus whether there is bankruptcy in state θ.

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 $c(r, \theta) > 0$.

There are two cases to consider. First, when $0 < \bar{c}(\theta) < \bar{r}(\theta) - D$, $\nu(\theta) = 0$ and the first-order condition is the same as in the standard moral hazard problem where consumption decreases as the likelihood ratio increases. Second, when $\bar{c}(\theta) = \bar{r}(\theta) - D \geq 0$, $\nu(\theta) > 0$, so the upper bound on the total compensation bill reduces what the bank would pay out if this constraint did not bind.

The subsequent analysis will consider the connection between compensation, $c(r, \theta)$, and the risk profile of the bank. The analysis will also 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 taken, that is,

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

4 The Importance of Correlation

In models with deposit insurance and limited liability, the bank's preferences are not aligned with those of society's. The bank's objective function is convex over profits and that can make it willing to undertake negative net present value projects if enough of the downside falls in the range where limited liability is binding. The more leveraged the bank is, the stronger is this effect. In our problem, the bank must use compensation to induce risk-averse loan officers to take actions that generate risk to the bank, if that is indeed, what the bank wants to do.

As we will see, there is not a direct mapping from the form of loan officer compensation to bank risk. Compensation is important for risk at the *individual* level, but it is not necessarily important for risk at the bank level. Instead, other factors, like correlation of returns, are far more important. For example, as we will show, if loan officer risk is idiosyncratic, then bank and social objectives are perfectly aligned.

When there is a common shock in addition to loan officer idiosyncratic risk, then the limited liability distortions can affect bank decisions. In the following analysis, we work through a sequence of functional forms of the production technology, $f(r|\theta, a)$, to study connections between compensation and bank risk-taking. For each technology, we solve for optimal contracts that implement actions that generate excessive risk and those that do not.

We then analyze what information an outsider would need to know to determine whether the compensation arrangement generated excessive risk.

4.1 Uncorrelated Returns

Consider the extreme case where there is no correlation in loan officer returns. All risk is idiosyncratic, so the gross return of the bank is a constant

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

The bank's return does not vary with the common shock θ. Consequently, the bank has no risk. All that the form of compensation does is to determine the bank's profits. Because there is no variation in bank profits, the bank cannot gain anything from failing, since if it fails it does so with probability one.

More formally, let $\bar{r}(a)$ be the bank's gross return and let $\bar{c}(a)$ be the bank's wage bill, both as a function of a. The objective function for the bank is

$$\max_a \max\{\bar{r}(a) - \bar{c}(a) - D, 0\}$$

while the objective function for society is

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

As long as there exists an a such that bank profits are positive, a solution to the bank's problem is a solution to the society's problem.

Proposition 1 *When loan officer returns are uncorrelated, there is no connection between the form of loan officer compensation and bank risk.*

4.2 Perfectly Correlated Returns

Now consider the other extreme case, where 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. Interestingly, loan officer compensation matters for risk, but in a surprising way.

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. 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. We assume that the zero payment penalty is enough to induce the loan officer to take the recommended action. An alternative way of viewing this contract – and the way we view it – is as a relative performance contract. Each loan officer's return is compared with that of everyone else's. If his return is the same, he is paid a wage. If it differs, he is paid zero.

The contract has strong incentives in it, but the incentives are *not* directly tied to his own performance, but instead to how his performance compares with others. In equilibrium, loan officers do not deviate, so what is observed is a compensation contract that is a wage that does not vary with his return, though it may vary with the aggregate return if constraint (10) binds. In particular, from the participation constraint, (11),

$$a = V^{-1}\left(\bar{U} - \sum_{\theta\in\Theta_1(a)} h(\theta)U(0) - \sum_{\theta\in\Theta_2(a)} h(\theta)U(\bar{c}(\theta))\right).$$

The higher the compensation, the harder the loan officer works. Which effort level gives the bank the best opportunity to exploit the safety net depends on the tradeoff between the aggregate return and the aggregate wage bill. Indeed, it is possible that a bank pays a low wage to increase its probability of failure as Figure 1 illustrates. The idea in that figure is that the savings in wage payments increase the bank's profits when it is successful and this benefit outweighs the higher probability of failure, the cost of which, in any case, is borne by the deposit insurer.

To see this more formally, bank profits given action a are

$$\begin{aligned}
&\sum_{\theta\in\Theta_2(a)} h(\theta)(\bar{r}(\theta) - \bar{c}(\theta) - D) \\
&= \sum_{\theta} h(\theta)(\bar{r}(\theta) - \bar{c}(\theta) - D) - \sum_{\theta\in\Theta_1(a)} h(\theta)(\bar{r}(\theta) - \bar{c}(\theta) - D) \\
&= \sum_{\theta} h(\theta)(\bar{r}(\theta) - \bar{c}(\theta) - D) - \sum_{\theta\in\Theta_1(a)} h(\theta)(\bar{r}(\theta) - D),
\end{aligned}$$

where the last equation holds because for $\theta \in \Theta_1(a)$, $\bar{c}(\theta) = 0$. Substituting in for $\bar{r}(\theta)$ and

$\bar{c}(\theta)$, means that profits can also be written

$$\sum_{\theta} h(\theta)(\sum_{r} f(r|\theta,a)(r - c(r,\theta)) - D) + \sum_{\theta\in\Theta_1} h(\theta)(D - \sum_{r} f(r|\theta,a)r).$$

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

$$\begin{aligned} E(\bar{r}|a) &= \sum_{\theta} h(\theta) \sum_{r} f(r|\theta,a)r, \\ E(\bar{c}|a) &= \sum_{\theta} h(\theta) \sum_{r} f(r|\theta,a)c(r,\theta), \\ z(a) &= \sum_{\theta\in\Theta_1(a)} h(\theta)(D - \sum_{r} f(r|\theta,a)r). \end{aligned}$$

This last term in bank profits, $z(a)$, 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 the rest of this subsection, we make the following assumptions. First, we assume that a is chosen from a continuum. This assumption is not essential, but simplifies the analysis. Second, we assume that $E(\bar{r}|a)$ is differentiable and concave. This assumption is standard and reflects diminishing returns in expected production. Third, we assume that $z'(a) < 0$. This latter assumption will hold in many reasonable situations. For example, if the probability distribution of the aggregate return is single peaked, the bankruptcy state is to the left of the peak, and a shifts the distribution to the right, then the value of the deposit insurance put option decreases with the action.

In terms of this new notation, the bank's problem is

$$\max_{a} E(\bar{r}|a) - E(\bar{c}|a) - D + z(a),$$

and the optimal a satisfies

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

At a social optimum, society takes into account that $z(a)$ is a transfer. The social optimum is the solution to

$$\max_{a} E(\bar{r}|a) - E(\bar{c}|a) - D,$$

so

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

Proposition 2 *When loan officer returns are perfectly correlated, if $E(\bar{c}|a)$ is increasing and convex, then the bank chooses an a that is less than the social optimum.*

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

Normally, the monotonicity and convexity of expected pay would not be assumptions requiring any justification. In this model, however, bankruptcy has an effect on the expected wage bill that could violate these assumptions in certain extreme situations. In the absence of bankruptcy, where loan officers receive a constant wage, the level of the wage is a convex function of the effort level. However, with bankruptcy, it is possible that as a increases and the number of bankruptcy states declines, the wage bill will drop (despite the higher effort) because there are fewer states where the loan officers receive zero. This possibility would seem mainly to be an issue when there is a high level of failure and increases in a lead to a substantial marginal decrease in the probability of failure.

The inability to pay employees when there is failure is *not* in the traditional corporate finance model of risk shifting and it illustrates an important point. As long as bank employees do not like risk, they have to be compensated to bear it, and that can make it more expensive for a bank to take risk, which in turn reduces its incentive to exploit risk shifting. Nevertheless, despite these costs, the bank will still not take the socially optimal a because of the deposit insurance safety net factor $z(a)$. In the case that we think is relevant most of the time, namely, that the assumptions on expected compensation in Proposition 2 hold, loan officers work less than is socially optimal and a bank fails more frequently than is socially optimal. In this case, the compensation arrangement that encourages excessive risk is a low wage!

4.3 Partial Correlation

When loan officer returns are partially correlated, there will be a trade off between the identified effects. The regulator likes diversification because it reduces risk. The bank likes correlation for two reasons, one bad and one good. The bad reason is that correlation allows

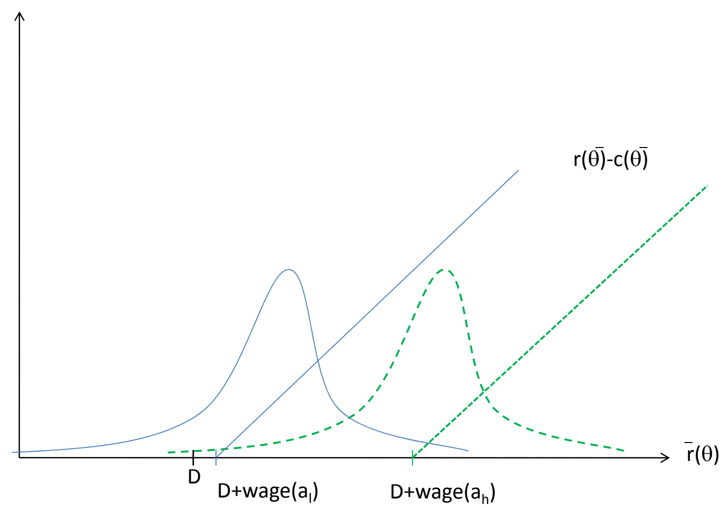

Figure 1: Example of a bank that pays a low wage to increase bank risk. The variable wage(a) is the wage paid to loan officers if a is taken and if the bank has positive profits. The solid line that intercepts the x-axis is profits for the bank if a_l is taken and if $\bar{r}(\theta) > D + \text{wage}(a_l)$. (For lower values of $\bar{r}(\theta)$, either all the return net of deposits goes to workers or limited liability binds.) The dashed line that intercepts the x-axis is profits if a_h is taken and $\bar{r}(\theta) > D + \text{wage}(a_h)$. The solid curve is the density function of a_l and the dashed curve is the density function of a_h. 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. Furthermore, wages are so large if a_h is taken that the bank gets little of the return in excess of D because so much of it goes to loan officers. Consequently, the bank prefers to take a_l.

it to exploit the safety net. The good reason is that correlation relaxes the loan officer's incentive constraint, which reduces the cost to the bank of compensating the loan officers.

4.4 Identifying Risk-Creating Contracts

What these results imply for identifying contracts that generate bank risk depends on what information is known about the bank. If a bank supervisor does not know the correlation of bank returns, then a low wage may signal that the bank's returns are highly correlated and it is trying to shift risk to the deposit insurer. In contrast, if this supervisor knew the correlation, then that information would be used in conjunction with the contract to assess risk. For example, if correlation is low, then the supervisor need not worry about compensation because the bank has limited ability to do risk shifting. In contrast, if correlation is high, then the supervisor needs to worry about risk shifting and should consider the details of the compensation contract. The supervisor will need to develop an understanding of the technology, $f(r|a, \theta)$, and how the compensation contract may generate correlation of returns.

In general, the relationship between compensation and risk mainly depends on the production technology, $f(r|a, \theta)$. However, a general simple test for risky compensation contracts can be created directly from the incentive constraints if we assume that there are only two actions for a loan officer to take, one that generates bank risk, a_l, and one that does not, a_h, where $V(a_l) < V(a_h)$. The incentive constraint that induces a loan officer to take the risky action is

$$\sum_{\theta} h(\theta) \sum_{r} f(r, \theta|a_l) U(c(r, \theta)) > \sum_{\theta} h(\theta) \sum_{r} f(r, \theta|a_h) U(c(r, \theta)) + V(a_l) - V(a_h). \tag{14}$$

Because $V(a_l) - V(a_h) < 0$, a *sufficient* condition to implement the risky action is

$$\sum_{\theta} h(\theta) \sum_{r} f(r, \theta|a_l) U(c(r, \theta)) > \sum_{\theta} h(\theta) \sum_{r} f(r, \theta|a_h) U(c(r, \theta)). \tag{15}$$

Equation (15) says that if the expected value of compensation – weighted by utility – is higher for the risky action than for the safe action, then the loan officer will take the risky action. It is not a necessary condition; there are compensation arrangements that do not satisfy (18), but still induce the risky action. Nevertheless, equation (15) provides a simple test that identifies a subset of the compensation arrangements that implement risk-taking.

This sufficient condition is useful because it does not use knowledge of effort disutility. However, it still requires knowledge of the production function $f(r|a,\theta)$. The next section works out the implications of two different specification of the production function.

4.5 Example Where Effort Affects Mean of Returns

In this specification, loan officer effort affects the mean of the return. Each loan officer can take either a_l or a_h, with $0 < a_l < a_h < 1$. There are also only two possible returns, failure ($r = 0$) and success ($r = 1$). As before, θ is the common shock, though now it is restricted to take on values between 0 and 1. Its mean is $\bar{\theta}$. The probability of success for a loan officer is

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

The first term is the idiosyncratic component of the probability of success and the second term is the common shock component. Notice that a loan officer's expected return is $a\bar{\theta}$, which does not depend on α.

Compensation is determined by the likelihood ratios. These are

$$\begin{aligned} LR(r = 1, \theta, \hat{a}; a) &= \frac{\hat{a}}{a}, \\ LR(r = 0, \theta, \hat{a}; a) &= \frac{1 - \hat{a}(\alpha\bar{\theta} + (1-\alpha)\theta)}{1 - a(\alpha\bar{\theta} + (1-\alpha)\theta)}. \end{aligned}$$

Proposition 3 *For the technology specified in (17), at an interior solution, consumption for $r = 1$ does not vary with θ and consumption for $r = 0$ increases with θ.*

Proof: Likelihood ratios comove with θ such that

$$\frac{\partial LR(r = 1, \theta, \hat{a}, a)}{\partial \theta} = 0 \Rightarrow \frac{\partial c(r = 1, \theta)}{\partial \theta} = 0$$

$$\frac{\partial LR(r = 0, \theta, \hat{a}, a)}{\partial \theta} > 0 \Rightarrow \frac{\partial c(r = 0, \theta)}{\partial \theta} < 0.$$

Figure 2 illustrates the comovement of consumption with θ. Successful loan officers receive a constant level of pay, while unsuccessful ones see their pay drop with the success of the bank. The reason their pay drops is that failure is less likely when there is a high value of θ.

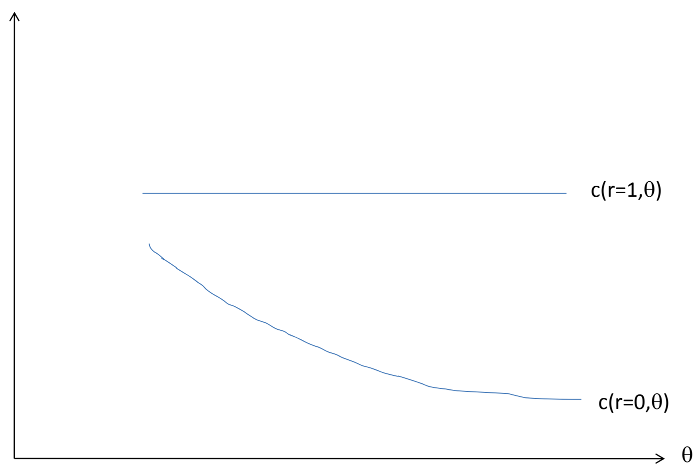

Figure 2: Optimal compensation in example where effort affects the mean of returns and under the assumption of an interior solution. Note that $\bar{\theta}$ moves one for one with θ. Thus, the x-axis also measure the total gross return of the bank.

Since output increases with θ, the comovement of compensation with θ directly corresponds to the comovement of total compensation with bank performance. This feature is interesting because in investment banking a substantial portion of pay is often tied to performance of the bank or the line of business. For example, investment banks often decide on and report on total compensation as a percentage of revenue.[6] The share of revenue distributed to loan officers – the only employees in this problem – is

$$WS(\theta) = \frac{r(\theta)c(r = 1, \theta) + (1 - r(\theta))c(r = 0, \theta)}{r(\theta)}$$

for the range of consumption that is interior.

Proposition 4 describes the relationship for this technology.

Proposition 4 *For the technology specified in this example and where consumption is interior*

$$\frac{\partial WS(\theta)}{\partial r(\theta)} < 0.$$

Proof: See the appendix.

In this example, at an optimum the employees' share of income decreases with bank performance.

4.5.1 Implication for regulation

In this example, the goal is to prevent the bank from taking the low action, which lowers the mean of output and increases the probability of failure. For that technology, a pay structure like that in Figure 2 would indicate a prudent compensation scheme. There are, however, alternative technologies where actions could affect risk in different ways. For example, loan officer actions could directly affect the correlation of the returns. And given our earlier finding that correlation in returns is the big risk to the deposit insurer, we consider an example where a loan officer's action directly affects this variable.

[6]There are other proposed explanations for this behavior, like sorting and retention of workers. See Oyer and Schaefer (2005).

4.6 Example Where Effort Affects Correlation of Returns

The production technology is similar to the previous one, but where the loan officer chooses the degree to which his loan is correlated with the bank's performance. The loan officer chooses the correlation of his loan by choosing either a low correlation loan, α_l, or a high correlation one, α_h. The agent is not allowed to choose a, so for simplicity we drop it from the technology. Formally,

$$f(r=1|\theta,\alpha) = (\alpha\bar{\theta} + (1-\alpha)\theta). \tag{17}$$

Recall that $\bar{\theta} = E(\theta)$, so in this example the loan officer's action does *not* affect the mean of his return, but just its correlation with the performance of the firm. Finally, to reflect the new choice variable, we write the utility function as

$$U(c) - V(\alpha).$$

If the bank tries to implement the safe action, α_h, then the likelihood ratios are

$$\begin{aligned} LR(r=1,\theta,\alpha_l;\alpha_h) &= \frac{\alpha_l\bar{\theta} + (1-\alpha_l)\theta}{\alpha_h\bar{\theta} + (1-\alpha_h)\theta}, \\ LR(r=0,\theta,\alpha_l;\alpha_h) &= \frac{1-(\alpha_l\bar{\theta} + (1-\alpha_l)\theta)}{1-(\alpha_h\bar{\theta} + (1-\alpha_h)\theta)}. \end{aligned}$$

Proposition 5 *For the technology specified in (17), at an interior solution consumption for $r=1$ decreases with θ and consumption for $r=0$ increases with θ.*

Proof: Likelihood ratios comove with θ such that

$$\frac{\partial LR(r=1,\theta)}{\partial\theta} > 0 \Rightarrow \frac{\partial c(r=1,\theta)}{\partial\theta} < 0.$$

Similarly,

$$\frac{\partial LR(r=0,\theta)}{\partial\theta} < 0 \Rightarrow \frac{\partial c(r=1,\theta)}{\partial\theta} > 0.$$

Figure 3 illustrates the comovement of consumption with θ. The consumption spread between success and failure declines with bank performance. When a loan officer's return is high and the bank does poorly, the bank rewards the loan officer because his performance is a signal that the loan officer's return was not correlated with everyone else. In contrast,

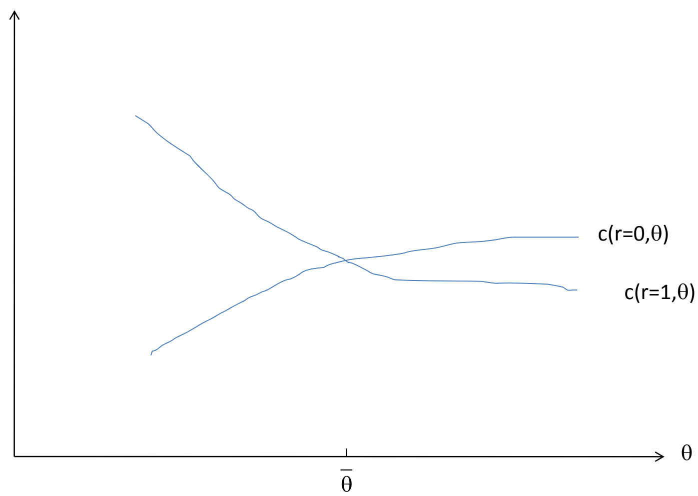

Figure 3: Optimal contract that induces a loan officer to make a low correlation loan. Note that $\bar{\theta}$) moves one for one with θ. Thus, the x-axis also measure the total gross return of the bank.

if the loan officer does poorly and the bank does poorly then that is a signal that the loan officer's return is correlated, so the bank punishes him. In general, the bank wants to reward the loan reviewer when the signal indicates no correlation and punish him when the signal indicates correlation.

The effect of relative performance is so strong in this example that for $\theta \geq \bar{\theta}$ the optimal contract is characterized by the loan officer being paid more for $r = 0$ than $r = 1$! This result is specific to this example and need not be the case for technologies that also allow for lower levels of effort that reduce the probability of success. We used this example to starkly illustrate how correlation pushes contracts towards the use of relative performance.[7]

[7]A guaranteed way to eliminate this result is to allow the loan officer to secretly destroy his own output at no cost as in Innes (1990). This additional source of private information adds an incentive constraint that takes the form $\forall\theta$, $c(r = 0, \theta) \leq c(r = 1, \theta)$. The constraint imply that compensation is weakly monotonically increasing in r, which is very appealing on empirical grounds. Optimal compensation would look similar to that in Figure 3 for $\theta \leq \bar{\theta}$, but compensation would be a constant for $\theta > \bar{\theta}$.

4.7 Relative Performance and Risk

The previous example provided a relative performance contract that reduced bank risk. Do all relative performance contracts have this feature? The answer is no. The previous analysis showed that an optimal contract that reduced risk is one that decreases pay for performance – the spread between failure and success – as the bank's overall performance improves. But what kind of contracts would induce risk-taking? For the production function analyzed in the previous example, the incentive constraint that implements the *risky* action simplifies to

$$\sum_{\theta} h(\theta)\left((\bar{\theta}-\theta)(U(c(r=1,\theta))-U(c(r=0,\theta)))\right) \leq \frac{V(\alpha_h)-V(\alpha_l)}{\alpha_h-\alpha_l}. \tag{18}$$

Equation (18) provides two characteristics of contracts that encourage risk

1. Pay for performance is small when the bank performs poorly, that is, for a low θ;

2. Pay for performance is high when the bank performs well, that is, for a high θ.

Relative performance that increases pay for performance when the bank does well, and decreases it when the bank does poorly, is a type of compensation arrangement that encourage risk taking.

5 Loan Review and Team Production

In all but the smallest banks, a bank will typically employ people who monitor lending and risk. For example, in trading, there are risk managers who attempt to monitor and limit trader risk exposure. In mortgage lending, a loan that is originated by a loan officer is evaluated by a loan underwriter who is a different person. In commercial lending, individuals or groups other than the loan officer are required to approve a loan, particularly if it is a larger loan. Loan review is not a new function. For example, Udell (1989) surveyed a large number of Midwestern banks and found extensive use of loan review in the 1980s.

There are several classes of models that are applicable to aspects of loan review. These include models where the loan reviewer audits the loan officer or where the loan reviewer creates a signal that is used to help determine whether the loan is made. To keep the notation and analysis simple, we consider a less general production function; we also assume that for each loan officer there is one loan reviewer.

The loan reviewer takes an action, b, that is simply an input into the production function $g(r|\theta, b, \alpha)$. The loan reviewer's utility function is $U(c_2) - V(b)$, where c_2 denote the loan reviewer's compensation. The loan reviewer's reservation utility is $\bar{U}_2$.

Compensation for both the loan officer and the loan reviewer can depend on the return and θ, so compensation for the loan officer is $c(r,\theta)$ and compensation for the loan reviewer is $c_2(r,\theta)$. The bank's problem with loan review is only slightly different than the earlier problem. It is

Bank's Problem with a Loan Reviewer

$$\max_{c(r,\theta)\geq 0, c_2(r,\theta)\geq 0, \alpha, b, \bar{c}(\theta)\geq 0, \bar{r}(\theta)} \sum_\theta h(\theta) \max\{\bar{r}(\theta) - \bar{c}(\theta) - D, 0\} \tag{19}$$

subject to resource constraints

$$\forall \theta, \;\; \bar{r}(\theta) = \sum_r g(r|\theta, b, \alpha) r, \tag{20}$$

$$\forall \theta, \;\; \bar{c}(\theta) = \sum_r g(r|\theta, b, \alpha) \left(c(r,\theta) + c_2(r,\theta) \right), \tag{21}$$

$$\bar{c}(\theta) \leq \max\{\bar{r}(\theta) - D, 0\}, \tag{22}$$

the participation constraints

$$\sum_\theta h(\theta) \sum_r g(r|\theta, b, \alpha) U(c(r,\theta)) - V(\alpha) \geq \bar{U}, \tag{23}$$

$$\sum_\theta h(\theta) \sum_r g(r|\theta, b, \alpha) U(c_2(r,\theta)) - V(b) \geq \bar{U}_2, \tag{24}$$

and the incentive constraints

$$\begin{aligned} &\sum_\theta h(\theta) \sum_r g(r|\theta, b, \alpha) U(c(r,\theta)) - V(\alpha) \\ &\quad \geq \;\; \sum_\theta h(\theta) \sum_r g(r|\theta, b, \hat{\alpha}) U(c(r,\theta)) - V(\hat{\alpha})), \;\; \forall \hat{\alpha}. \end{aligned} \tag{25}$$

$$\begin{aligned} &\sum_\theta h(\theta) \sum_r g(r|\theta, b, \alpha) U(c_2(r,\theta)) - V(b) \\ &\quad \geq \sum_\theta h(\theta) \sum_r g(r|\theta, \hat{b}, \alpha) U(c_2(r,\theta)) - V(\hat{b}), \;\; \forall \hat{b}. \end{aligned} \tag{26}$$

Notice that in incentive constraint (25) the loan officer takes the loan reviewer's action as given and that in incentive constraint (26) the loan reviewer takes the loan officer's action as given.[8]

We do not write out the bank subproblem, but instead write out the first-order conditions for an interior solution. For loan officers, they are

$$\frac{1}{U'(c(r,\theta))} = \lambda + \sum_{\hat{\alpha}} \mu(\hat{\alpha}) \left(1 - \frac{g(r|\theta, b, \hat{\alpha})}{g(r|\theta, b, \alpha)}\right), \tag{27}$$

where λ is the multiplier on the bank subproblem constraint that corresponds to (23) and $\mu(\hat{\alpha})$ on the incentive constraints that correspond to (25). For loan reviewers, they are

$$\frac{1}{U'(c_2(r,\theta))} = \lambda_2 + \sum_{\hat{b}} \mu(\hat{b}) \left(1 - \frac{g(r|\theta, \hat{b}, \alpha)}{g(r|\theta, b, \alpha)}\right), \tag{28}$$

where λ_2 is the multiplier on the bank subproblem constraint that corresponds to (24) and $\mu(\hat{b})$ on the incentive constraints that correspond to (26).

For both loan officers and loan reviewers, the first-order conditions show that optimal compensation depends on the return r as a function of the likelihood ratios. The team aspect can be seen in that the action of the other agent affects the likelihood ratio and thus compensation. For loan reviewers, there is the interesting finding that loan reviewers and risk managers should be paid based on the performance of the projects that they monitor. While not surprising from standard incentive theory, it does go against the common perception among bank regulators that risk management and other similar positions should not have their pay tied to the performance of the line of business that they monitor.

5.1 A Loan Review and Risk Control Example

This subsection works through a specific functional form to derive some implications of loan reviewer pay for risk control. We build on the same basic production function used earlier, namely, that

$$f(r = 1|\theta, \alpha) = \alpha\bar{\theta} + (1 - \alpha)\theta, \tag{29}$$

and where the loan officer can make a risky loan, α_l, or a safe one, α_h.

[8] An interesting variation to consider is to allow the loan reviewer and loan originator to collude. That would generate a different set of incentive constraints.

The loan reviewer's role is to review a loan originated by the loan officer and accept or reject it. If accepted the probability of success of the loan is described by (29). If rejected, the bank receives $0 < \tilde{r} < 1$ with certainty, which reflects the value of the funds being allocated to some safe activity.

Acceptance or rejection is determined probabilistically as a function of the loan type and the loan reviewer's action b. If the loan officer originates an α_l loan opportunity then it is rejected with probability b. Loan review is not perfect, so if the loan officer generates an α_h loan opportunity, then the loan reviewer rejects it with probability $z(b)$, where $z(b) < b$. We also assume that $z'(b) < 0$, which means that if the loan reviewer works more, he rejects risky loans more frequently and safe loans less frequently.

There are three possible outcomes:

1. The loan is rejected, so $r = \tilde{r}$;

2. The loan is not rejected and $r = 0$;

3. The loan is not rejected and $r = 1$.

The production function is

$$\begin{aligned} g(r=0|\theta,b,\alpha_l) &= (1-b)f(r=0|\theta,\alpha_l) \\ g(r=1|\theta,b,\alpha_l) &= (1-b)f(r=1|\theta,\alpha_l) \\ g(r=\tilde{r}|\theta,b,\alpha_l) &= b. \end{aligned}$$

$$\begin{aligned} g(r=0|\theta,b,\alpha_h) &= (1-z(b))f(r=0|\theta,\alpha_h) \\ g(r=1|\theta,b,\alpha_h) &= (1-z(b))f(r=1|\theta,\alpha_h) \\ g(r=\tilde{r}|\theta,b,\alpha_h) &= z(b). \end{aligned}$$

For loan officers, the likelihood ratios are

$$\begin{aligned} LR(r=1,\theta,b,\alpha_l;\alpha_h) &= \frac{(1-b)f(r=1|\theta,\alpha_l)}{(1-z(b))f(r=1|\theta,\alpha_h)}, \\ LR(r=0,\theta,b,\alpha_l;\alpha_h) &= \frac{(1-b)f(r=0|\theta,\alpha_l)}{(1-z(b))f(r=0|\theta,\alpha_h)}, \\ LR(r=\tilde{r},\theta,b,\alpha_l;\alpha_h) &= \frac{b}{z(b)}. \end{aligned}$$

The comparative statics for $r = 0$ and $r = 1$ are exactly the same as in the earlier analysis of Section 4.6. For $r = \tilde{r}$, the loan officer receives a fixed level of compensation that does not depend on bank performance, at least for interior solutions. This amount could be interpreted as a fixed retainer for the loan officer, which is common in sales jobs.

For loan reviewers, the likelihood ratios are

$$\begin{aligned} LR(r=1,\theta,b_l,\alpha_h;b_h) &= \frac{1-z(b_l)}{1-z(b_h)}, \\ LR(r=0,\theta,b_l,\alpha_h;b_h) &= \frac{1-z(b_l)}{1-z(b_h)}, \\ LR(r=\tilde{r},\theta,b_l,\alpha_h;b_h) &= \frac{z(b_l)}{z(b_h)}. \end{aligned}$$

Loan reviewer compensation depends on whether a loan is made, but, if it is made, not on how it performs.[9] Furthermore, because $\frac{z(b_l)}{z(b_h)} > \frac{1-z(b_l)}{1-z(b_h)}$, pay is lower if the loan reviewer rejects the loan.

If the bank was trying to implement the risky strategy, by encouraging loan officers to take α_l, and then encouraging loan reviewers to supply less effort screening, then likelihood ratios would be

$$\begin{aligned} LR(r=1,\theta,b_h,\alpha_l;b_l) &= \frac{1-z(b_h)}{1-z(b_l)}, \\ LR(r=0,\theta,b_l,\alpha_l;b_l) &= \frac{1-z(b_h)}{1-z(b_l)}, \\ LR(r=\tilde{r},\theta,b_l,\alpha_l;b_l) &= \frac{z(b_h)}{z(b_l)}. \end{aligned}$$

Here a pay structure that rewarded loan reviewers for rejecting loans would suggest a risk problem.

More generally, however, the analysis in this section points to an alternative strategy to regulating compensation for controlling risk. The loan review process could be evaluated to determine how well it identifies and manages risk. Indeed, bank supervisors spend a lot of resources evaluating the "controls," that is, the quality of the processes used by banks to approve loans, and in this model that would be reflected by evaluating rejection rates as well as the quality of the loan reviewer's assessment.

[9] As noted in the previous analysis, this is not true in general. It is true in this example because loan review probabilistically determines acceptance or rejection, so that decision is what contains information on the loan reviewer's action.

6 Conclusion

This paper worked through several organizational models of banker incentive compensation. We found that the contribution of banker pay to bank risk depends on the amount of correlation in loan officer returns. If returns are uncorrelated, the form of banker pay is irrelevant. If they are correlated, then low wages could be risk-creating. When the correlation of returns is endogenous, the structure of relative performance contracts greatly influences risk. Pay for individual performance that increases with total bank performance was a source of bank risk. A sufficient condition for a compensation arrangement to create bank risk was provided.

A model of an organization with monitoring and controls in the form of loan review was also introduced. The analysis indicated that monitoring and evaluating the loan review process was an effective alternative to regulating compensation for controlling bank risk and that paying risk managers for the performance of the employees they monitor does not necessarily create risk.

More generally, the analysis illustrated an important principle of organizational economics: Compensation and its effect on the performance of a bank depend on the way that the bank organizes its production. Looking at pay in isolation without considering the effects of the bank's monitoring and controls could not only lead to bans on compensation arrangements that do not necessarily create risk, but could also permit forms of compensation that in isolation look harmless, but instead, generate excessive risk.

A Proofs

Proof of Proposition 4

Let $WS(\theta)$ be the workers' share of total revenue. Also, recall that $\bar{r}(\theta)$ is not only the total revenue, but also the fraction of workers who produce the high return of one. First,

$$\begin{aligned} WS(\theta) = \frac{\bar{c}(\theta)}{\bar{r}(\theta)} &= \frac{\bar{r}(\theta)c(r=1,\theta) + (1-\bar{r}(\theta))c(r=0,\theta)}{\bar{r}(\theta)} \\ &= c(r=1,\theta) + \frac{c(r=0,\theta)}{\bar{r}(\theta)} - c(r=0,\theta). \end{aligned}$$

Differentiating with respect to π gives

$$\frac{dWS(\theta)}{d\bar{r}(\theta)} = \frac{\partial c(r=1,\theta)}{\partial \bar{r}(\theta)} + \frac{\bar{r}(\theta)\frac{\partial c(r=0,\theta)}{\partial \bar{r}(\theta)} - c(r=0,\theta)}{\bar{r}(\theta)^2} - \frac{\partial c(r=0,\theta)}{\partial \bar{r}(\theta)}$$

Note: $\frac{\partial c(r=1,\theta)}{\partial \bar{r}(\theta)} = 0$ because $\frac{\partial c(r=1,\theta)}{\partial \theta} = 0$. Therefore,

$$\frac{dWS(\theta)}{d\bar{r}(\theta)} = \frac{\partial c(r=0,\theta)}{\partial \bar{r}(\theta)}(\frac{1}{\bar{r}(\theta)} - 1) - \frac{c(r=0,\theta)}{\bar{r}(\theta)^2} < 0.$$

The term $\frac{\partial c(r=0,\theta)}{\partial \bar{r}(\theta)} = \frac{\partial c(r=0,\theta)}{\partial \theta}\frac{\partial \theta}{\partial \bar{r}(\theta)} < 0$ because $\frac{\partial c(r=0,\theta)}{\partial \theta} < 0$ and $\frac{\partial \theta}{\partial \bar{r}(\theta)} > 0$. Furthermore, $\bar{r}(\theta) < 1$, so the first term is negative. The second term is also negative.

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