Delegated Monitoring and Bank Size Distribution

Justin Yifu Lin

(CCER, Peking University)

Xifang Sun

(CCER, Peking University)

(Still preliminary, comments welcome)

Abstract

There are evidences suggesting that large banks focus their business loans on large firms and small banks on small businesses. This paper develops a model of organizational banks to explain this phenomenon of bank-firm size match by introducing a commonsense notion that each individual banker has only limited capacity for monitoring and thus can only monitor a limited number of loans. Organizational banks emerge as a way to overcome the limit of individual bankers and utilize the benefits from diversification. But forming organizational bank generates organizational costs. Optimal bank size balances the diversification benefits of bank size against the monitoring and organizational costs. As monitoring costs and organizational costs are fixed, small projects are at disadvantage relative to large ones. As long as small projects are profitable enough some banks choose to stay small in order to loan to them while banks serving large projects become large. In equilibrium the banking structure in the economy depends on the distribution of projects.

0.1 Introduction

Many empirical findings consistently suggest that large and small banks tend to specialize in loans of different sizes, namely, large banks focusing their business loans on large firms and small banks on small businesses. There are several related strands of evidence. The extensive empirical literature on small business finance has established a strong link between banking institution size and the supply of small business credit, with larger financial institutions devoting less proportions of their assets to small businesses than smaller institutions (Nakamura,1994; Berger and Udell, 1995,1998; Berger,Klapper, and Udell, 2001; Berger, Kashyap, Scalise, 1995; Jayaratne and Wolken, 1999; Strahan and Weston, 1998; Peek and Rosengen, 1996). Many empirical papers concerns the effect of deregulation in the U.S. banking on the availability of credit to small businesses. Although occasionally with mixed results, these papers generally find that small-business lending of the consolidated bank tends to fall sharply when large banks acquire small banks, and many of the loans that are cut are picked up by other local small banks (Berger, Kashyap, Scalise, 1995; Berger, Saunders, Scalise, and Udell, 1998; Peek and Rosengren, 1998; Strahan and Weston, 1996 ; Keeton,1995,1997). Several papers find that the organizational complexity of the bank , such as the number of branches, whether owned by out-of state banking holding companies, is negatively related to its propensity for making loans to small businesses (Keeton, 1995; DeYoung, Goldberg, and White, 1997). Some other empirical papers suggest that small banks operate in different environments and use different lending technology from large banks. Brickley, Linck, and Smith Jr.(2003) find that large banks concentrate their offices in major metropolitan areas , whereas small banks focus more primarily on smaller urban and rural areas where it seems more important to grant significant decision rights to the local office managers. Cole, Goldberg, and White(2004) provide evidence that large banks employ standard criteria obtained from financial statements in the loan decision process, whereas small banks rely to a greater extent on information about the character of the borrower. Berger, Miller, Petersen, Rajan, and Stein(2005) find that large banks lend at a greater distance, interact more impersonally with their borrowers, have shorter and less exclusive relationships.

Then how to understand and explain this pattern?

To be in the right direction for this problem, we should start from the fundamental existence of bank-like financial intermediary in the first place. As the name indicated, financial intermediaries stand between the final borrowers and lenders in the savings-investment process. Why is this the case instead of borrowers and lenders transacting with each other directly? Financial transaction usually involves risk sharing and informational asymmetry between borrowers and lenders in addition to incurring pure transaction costs. Financial intermediaries come into existence to diversify risks by pooling non-perfectly related risks, alleviate informational asymmetry by producing information about borrowers, and thus reduce the total transaction costs and facilitate the savings-investment process which can improve the allocation of resources and promote economic growth. The literature has provided rich theoretical models to demonstrate the role of bank-like financial intermediaries in the economy. Among them, models of banks as delegated monitors (pioneered by Diamond(1984)) and information producers (initiated by Leland and Pyle (1977) and Boyd and Prescott(1986)) focus on the borrower-bank relationships while others (like Diamond and Dybvig(1983) and Allen and Gale(1997)) on the bank-depositor side stories.

With these basic understandings about the function of banks, how could we explain the bank-borrower size match?

To the extent that banks exist to facilitate risk sharing and mitigate informational asymmetry, the characteristics of borrowers with respect to risk, profitability, and informational transparency can , at least partially, determine the organizational form of banks and the way by which banks do their business. Then how small businesses are different from their large counterparts in these dimensions? First of all, small businesses are small and usually require small loans. But the costs at which banks screen, monitor, and transact with borrowers are mostly fixed, then small businesses are at disadvantage in terms of per unit of loans. Secondly, small businesses are more informationally opaque with less normative information such as audited financial statements, thus banks loaning to them have to rely on "soft" information, which is difficult to transmitted within the bank and thus requires banks to use different lending technology. Large banks are usually complex organizations and information communication within the bank is important for the bank to operate efficiently, so they are at a disadvantage in serving small businesses in terms of organizational costs. There are other reasons that make large banks unwilling or unable to lend to small businesses. For example, small firms can usually pledge less collateral, which implies that banks would have to monitor small borrowers more intensively.

This paper tries to formalize the two factors mentioned in last paragraph to explain the phenomenon of bank-firm size match. To reflect the effect of informational opaqueness of small businesses on bank-firm relations, we need to model the banks as organizations. However, most models of banks either treat the bank as if it were one banker or neglect the information problem within the bank even if they model banks as organizations. Thus we need to develop a model of organizational bank based on the existing theoretical models of banks before we further explore the banking structure problem. This paper extends the model of banks as delegated monitors, initiated by Diamond(1984) and developed by others, into a model of organizational banks, and then apply this model to explain the phenomenon of bank-firm size match.

In Diamond(1984)'s economy with ex post informational asymmetry, monitoring each borrower requires fixed costs from each lender. The bank is delegated the task for monitoring final borrowers by other lenders to avoid duplication of monitoring costs, and diversification of bank assets provides a mechanism to solve the "monitoring the monitor" problem. But in Diamond(1984) and other papers along this line, the bank is one banker who is implicitly assumed to have infinite capacity for monitoring and can monitor a very large number of loans at constant marginal cost, this makes the banker have a well diversified asset portfolio while saving monitoring costs. This paper introduces into this original model a commonsense notion that each banker has only limited capacity for monitoring, then each individual banker can only monitor a limited number of loans, so organizational banks appear as a way to overcome the limit of individual banker and utilize the benefits from diversification. But forming organizational banks will generate costs due to coordinating and monitoring unit bankers within the bank. Given any characteristics on the borrower side, optimal bank size will balance the diversification benefits of bank size against the monitoring and organizational costs. To the extent that monitoring costs and organizational costs are fixed, small projects are at disadvantage relative to large projects. But as long as small businesses are profitable enough compared to potential opportunity costs of capital and there is no outside regulations on banks' operating, some banks will provide loans to them. In equilibrium, those banks making small loans will optimally stay as small while banks serving large projects become large. Since both the benefits and costs of bank size depend on the size, risk, and informational characteristics of borrowers' projects, the distribution of bank size in the economy will depend on the distribution of projects.

This paper is based on the models about existence of financial intermediaries, especially the idea of Diamond(1984) and the basic model of Willamson(1986). By introducing limited capacity for monitoring of individual bankers, this paper develops a model of organizational banks, which could allow some interesting discussions about information frictions, agency problems, and other issues related to management within the bank and how those issues could affect the way that the bank behaves. It is also related to the existing papers on banking structure which focus on the competitiveness of banking system, such as Guzman (2000b), Cetorelli(1997),Smith (1998), Cetorelli and Strahan (2006), among others. Winton (1995,1997) has discussed the size distribution of banks, but focus on the coordination among depositors and so the banking equilibrium relies on depositors' beliefs. Departing from these papers, this paper focuses on the size distribution of banking industry and argues that borrowers' characteristics are the more fundamental determinants of banking structure. This paper also benefits from the idea on soft information in Stein(2002), who provides a theoretical model on the effect of organizational structure on information production and capital allocation in firms, and Petersen (2004) who gives a deep analysis of soft and hard information. But this paper analyzes a different informational problem from Stein(2002) and combines the idea on soft-hard information into a well defined model on the existence of banks.

The following part is organized in four sections: section two revises the model of banks as delegated monitors by introducing limited capacity of monitoring by individual bankers, section three develops the model of organizational bank, section four extends the model by introducing heterogeneous projects in terms of size and informational difference and discusses the size match between banks and projects; the final section concludes and discusses some policy implications of this paper.

0.2 Delegated monitoring and viability of the delegated monitor

0.2.1 Setup of the model

In this economy there is a countable infinity of agents who lives for two periods. Each agent is either a lender or an entrepreneur. Lenders account for α proportion of the total population and entrepreneurs account for the rest proportion $1-\alpha$.

At the beginning of period one, each lender is endowed with one indivisible unit of investment good, and also has access to one safe production technology which converts one unit input good into r units of consumption good in the second period. Each entrepreneur receives no endowment of investment good but has access to one fixed-scale risky production project. Each project requires K (K is an integer and $K \geq 2$) units of investment good and yields $K\widetilde{y}$ units of consumption good in the second period. $\widetilde{y}$ is a random variable with positive support $[0, \overline{y}]$, continuous density function $f(y)$ and distribution function $F(y)$. Returns are independently, identically distributed across the entrepreneur' projects. The risky project is profitable as $E(\widetilde{y}) > r$, or $E(K\widetilde{y}) > Kr$.

Assume $(1-\alpha) > K\alpha$ so that the demand for investment good is potentially satisfied.

Suppose that all agents know the distribution of projects ex ante and thus there is no informational asymmetry in the first place. However, in period two, the realization of the random return to each risky project $\widetilde{y}_i$, denoted by y_i, is costlessly observable only to the entrepreneur i. A lender needs to spend e units of effort in order to observe and verify the return of a particular project, and such observation is private information. Therefore the information problem is one of costly state verification (CSV).

All agents are risk neutral with respect to consumption in the second period. Monitoring one project will cause disutility to the monitor. Each lender has only limited capability for monitoring in the sense that the marginal cost of monitoring increases with the number of projects the monitor monitors at one time. We capture this idea by assuming a disutitlity function $V(k, e)$ with $V_k'(\cdot) > 0$ and $V_k''(\cdot) > 0$[1].

[1] For example, $V(k, e) = (ke)^2$ .Another example is $V(k, e) = ke^2 + ck(k-1)e^2, c > 0$.

0.2.2 Direct lending and duplicated monitoring

Since the risky project is profitable, trading between lenders and entrepreneurs is potentially beneficial. But the entrepreneur will misrepresent the true value of the realized return to lenders if they do not monitor. So lenders have to monitor the entrepreneur for the trading to be feasible although monitoring is costly. The optimal direct lending contracts will be designed to economize the monitoring costs while facilitating trading. Without loss of generality, it is assumed that these contracts are identical for each lender.

It is well established that the optimal contract is a standard debt contract in this environment(Townsend, 1979; Diamond, 1984; Gale and Hellwig,1985; Williamson,1986,1987). The contract typically specifies a fixed payment for per unit of borrowed input, denoted by R^d , which an entrepreneur should pay to each lender if the realized return is higher or equal to KR^d , otherwise he will default and each lender will monitor and receive y. The contract is fully characterized by the promised fixed payment R^d.That is, the borrower's payment function $R(y)$ is

$$R(y) = \begin{cases} KR^d & \text{if } y \geq R^d \\ Ky & \text{otherwise} \end{cases}$$

Then the expected profit of the entrepreneur is

$$\pi_f\left(R^d\right) = K\int_{R^d}^{\overline{y}} \left(y - R^d\right) dF(y) \tag{1}$$

And each lender's expected payoff is

$$\begin{aligned} r\left(R^d\right) &= \int_0^{R^d} y dF(y) + R^d\left[1 - F\left(R^d\right)\right] - V(1,e)\, F\left(R^d\right) \\ &= R^d - \int_0^{R^d} F(y)\, dy - V(1,e)\, F\left(R^d\right) \end{aligned} \tag{2}$$

The second term represents the expected risk premium and the third term is the expected monitoring cost. As Williamson(1987) emphasizes, one distinguished characteristic of $r\left(R^d\right)$ is that it is non-monotonic in the interest rate R^d while $\pi_f\left(R^d\right)$ is strictly decreasing in R^d because

$$
\begin{aligned}
\frac{\partial \pi_f\left(R^d\right)}{\partial R^d} &= -K\left[1-F\left(R^d\right)\right]<0 \\
\frac{\partial r\left(R^d\right)}{\partial R^d} &= 1-F\left(R^d\right)-V\left(1,e\right)\cdot f\left(R^d\right)
\end{aligned}
$$

To avoid multiple equilibria, we assume that $F\left(\cdot\right)$ has monotonically increasing hazard rate $\frac{f\left(y\right)}{1-F\left(y\right)}$ [2], and so $r\left(R^d\right)$ is quasi-concave in R^d with a unique global and local maximum.

We consider the symmetric equilibrium of this economy. The equilibrium interest rate R^d solves

$$
\max_{R^d} \pi_f\left(R^d\right) = K\int_{R^d}^{\overline{y}}\left(y-R^d\right)dF\left(y\right) \tag{3}
$$

$$
s.t. r\left(R^d\right) = R^d-\int_0^{R^d}F\left(y\right)dy-V\left(1,e\right)F\left(R^d\right)\geq r \tag{4}
$$

Let R^{d*} be the interest rate such that $R^{d*}=\arg\max_{R^d} r\left(R^d\right)$.

As $\frac{\partial r\left(R^d\right)}{\partial R^d}<0$ at the point $R^d=\overline{y}$, it must be true that $R^{d*}<\overline{y}$ and $\pi_f\left(R^{d*}\right)>0$. There are two kinds of possibilities: $r\left(R^{d*}\right)\geq r$ or $r\left(R^{d*}\right)<r$,which depends upon the distribution of the returns to the project and the monitoring technology. If $r\left(R^{d*}\right)<r$, then no lender will lend to any entrepreneur no matter what interest rate the entrepreneur offers and the market for direct lending collapses. If $r\left(R^{d*}\right)\geq r$, let R^0 be the unique equilibrium interest rate for the above problem, then $R^0\leq R^{d*}<\overline{y}$.

Given the monitoring technology, one reason for infeasibility of direct lending is duplicated monitoring since each entrepreneur needs to contract with K lenders and each lender has to

[2] Examples of distribution with this property include the uniform, exponential, normal, gamma with parameter greater than one, and their truncted versions. This assumption is adopted from Winton(1995).

incur monitoring costs in case of defaults. Even direct lending is possible, the equilibrium also involves duplicated costly monitoring . To see this, just notice that the sum of expected payoffs of the K lenders from financing each project with equilibrium interest rate R^0 is

$$K\left[R^0-\int_0^{R^0}F(y)\,dy\right]-K\cdot V(1,e)\cdot F\left(R^0\right)=Kr \tag{5}$$

0.2.3 Delegated monitoring and viability of individual bankers

As Diamond(1984) and Williamson(1986) argue, the duplicated monitoring in direct lending provides one basic raison d'etre for financial intermediation which delegates the monitoring task to one lender(the banker). The banker borrows from other lenders (depositors) and lend to entrepreneurs. However, delegated monitoring lengthens the chain of transaction in the provision of finance and so may not be viable. In a more richer environment, delegated monitoring could entail several kinds of moral hazard problems. For example, the banker could shift risks to depositors by choosing the pool of borrowers, the contracts with borrowers, the intensity with which to monitor borrowers after the loans are made, as well as the way to monitor borrowers when they default. Within the simple economy specified above, the banker could also misreport to the lenders of whom he is on behalf since the monitored information by the banker is private. Thus similar CSV problem emerges between depositors and the banker in addition to the CSV problem between the banker and entrepreneurs.

The optimal contract between the banker and entrepreneurs are still standard debt contracts while the problem between the banker and depositors is more subtle. If the banker can somehow commit the number of entrepreneurs to whom she makes loan, the depositors would be able to figure out the distribution of the bank portfolio, then standard debt contract should be still the optimal contract between depositors and the banker. Diamond(1984) and Willamson(1986) shows that delegated monitoring could dominate direct lending and be viable if the banker could perfectly diversify the bank asset portfolio, which implies that the bank should be of infinite size in their limit economy. Krasa and Villamil(1992a) show that delegated monitoring with two-sided standard debt contracts strictly dominate direct lending if the banker could contract with a sufficiently large number of borrowers in an finite economy. Krasa and Villamil(1992b) extend this conclusion into an environment with investment projects bearing correlated macro risks. All these models have a key assumption that the marginal monitoring cost for the delegated banker to monitor entrepreneurs is constant as the number of borrowers under her supervision increases. In the real world, it is difficult to argue for this assumption even monitoring requires other kinds of costs(such as some direct financial costs) in addition to the monitor's efforts. Then the viability of financial intermediation will be a serious concern if this crucial assumption is relaxed.

Next we shall discuss the viability of the one-banker bank, which appears in all the mentioned papers and many other papers.

Let the two-sided debt contracts for the banker be (R, D) ,where R denotes the interest rates per unit of loan required by the banker and D is the promised fixed payment from the banker to depositors. Suppose the banker lends to n entrepreneurs and borrows from $nK-1$ depositors.

The distribution of return to the banker's portfolio

The distribution of return to the banker's portfolio depends on both the loan interest rate, R, and number of loans she has made, n. Let $\widetilde{X_i}(R)$ denote the repayment per unit of loan from entrepreneur i to the banker under contracts (R, D), and $G_R(x)$ and $g_R(x)$ be the distribution and density functions for $\widetilde{X_i}(R)$. Then $\widetilde{X_i}(R)$ has positive support $[0, R]$ and

$$G_R(x) = \begin{cases} 0 & \text{if } x \leq 0 \\ F(x) & \text{if } 0 < x < R \\ 1 & \text{if } x \geq R \end{cases} \tag{6}$$

Denote the expectation and finite variance of $\widetilde{X_i}(R)$ as $\mu(R)$ and $\sigma^2(R)$. The repayment from borrower i is $K \cdot \widetilde{X_i}(R) \triangleq \widetilde{W_i}(R)$ .The distribution of $\widetilde{W_i}(R)$ is $H_R(w) = G_R\left(\frac{w}{K}\right)$ .Then let the average repayment per borrower be $\widetilde{W}_n(R) = \frac{1}{n}\sum_{i=1}^{n} \widetilde{W_i}(R)$. Since $\widetilde{y_i}\,'s$ are independent across entrepreneurs, $\widetilde{W_i}'s$ are also independent across projects, similarly for $\widetilde{X_i}'s$.Then the average return per unit of bank portfolio is $\widetilde{X_n}(R) = \frac{1}{n}\sum_{i=1}^{n} \widetilde{X_i}\ (R)$ with support $[0, R]$ and distribution $G_{R,n}(x)$, so $E\left(\widetilde{X_n}(R)\right) = \mu(R)$ and $Var\left(\widetilde{X_n}(R)\right) = \frac{1}{n}\sigma^2(R)$. Define the payoff to the bank's portfolio in terms of per unit of deposit as

$$\widetilde{Y_n}(R) = \frac{1}{nK-1}\sum_{i=1}^{n}\widetilde{W_i}(R) = \frac{1}{nK-1}\sum_{i=1}^{n}\widetilde{X_i}(R)\cdot K = \frac{nK}{nK-1}\widetilde{X_n}(R)$$

Then the support of $\widetilde{Y_n}(R)$ is $\left[0, \frac{nK}{nK-1}R\right]$,and its distribution function is $F_{R,n}(y)$, has mean $E\left(\widetilde{Y_n}(R)\right) = \frac{nK}{nK-1}\mu(R)$ and variance $Var\left(\widetilde{Y_n}(R)\right) = \frac{nK^2}{(nK-1)^2}\sigma^2(R)$. We have $F_{R,n}(y) = G_{R,n}\left(\frac{nK-1}{nK}y\right)$,the difference between $\widetilde{Y_n}(R)$ and $\widetilde{X_n}(R)$ reflects the role of banker's own capital.

Lemma 1 *If $R_1 > R_2$, $\widetilde{X_i}(R_1)$ dominates $\widetilde{X_i}(R_2)$ in the sense of first stochastic dominance. The same is true for $\widetilde{X_n}(R_1)$ and $\widetilde{X_n}(R_2)$, as well as $\widetilde{Y_n}(R_1)$ and $\widetilde{Y_n}(R_2)$.*

The proof of this lemma is straightforward. Raising loan interest rate shifts the distribution of the repayment per unit of loan to the right, thus $G_{R_1}(x) < G_{R_2}(x)$ if $R_2 \leq x < R_1$,and $G_{R_1}(x) = G_{R_2}(x)$ for other value of x. This feature will be carried to $G_{R,n}(x)$ and $F_{R,n}(y)$.

Lemma 2 *For any R, if $n_1 > n_2$, $\widetilde{X}_{n_1}(R)$ dominates $\widetilde{X}_{n_2}(R)$ in the sense of second stochastic dominance. The same is true for $\widetilde{Y}_{n_1}(R)$ and $\widetilde{Y}_{n_2}(R)$.*

The proof for this lemma is in the Appendix. This lemma shows the diversification effect of increasing number of loans on the return to bank portfolio. Increasing the number of independent loans will make the distribution of return per unit of loan more centered around its mean μ_R. In the limit case, Law of Large Number will apply.

Expected payoffs of agents

Now consider the expected payoffs of involved agents when the banker contracts with n entrepreneurs and borrows from $nk-1$ depositors with contracts (R, D).

Each entrepreneur's expected profit only depends on the loan interest rate, that is,

$$\pi_f(R, D; n) = \pi_f(R) = K\int_{R}^{\overline{y}}(y-R)\,dF(y) \tag{7}$$

Each lender's expected utility would be

$$
\begin{aligned}
r(R, D; n) &= \int_0^D y dF_{R,n}(y) + D\left[1 - F_{R,n}(D)\right] - V(1, e) F_{R,n}(D) \\
&= D - \int_0^D F_{R,n}(y) dy - V(1, e) F_{R,n}(D) \qquad (8)
\end{aligned}
$$

The banker's monitoring costs will be a random variable $V_{n,R}(\xi, e)$, where ξ is the number of defaulted loans occurred to the banker who has made n loans.ξ has a binomial distribution, denoted as $B(n, F(R))$. Let $p = F(R)$, then

$$
\begin{aligned}
E\left[V_{n,R}(\xi, e)\right] &= \sum_{k=0}^{n} C_n^k \cdot p^k \cdot (1-p)^{n-k} \cdot V(k, e) \\
&= \sum_{k=0}^{[np]} C_n^k \cdot p^k \cdot (1-p)^{n-k} \cdot V(k, e) + \sum_{k=[np]+1}^{n} C_n^k \cdot p^k \cdot (1-p)^{n-k} \cdot V(k, e) \\
&\triangleq \underline{v}(n, p) + \overline{v}(n, p) \qquad (9)
\end{aligned}
$$

The first term is decreasing in p while the second term is increasing in p. But since $V(k, e)$ is convex in k, the second term should dominate. To get a flavor of the expected monitoring costs, let's take some examples.

Example one: $V(k, e) = ke$.Then $E[V_n(\xi, e)] = e \cdot E(\xi) = e \cdot np$.This is the case with constant monitoring cost used in Wliiamson(1986) and some other papers.

Example two: $V(k, e) = (ke)^2$.Then $E[V_n(\xi, e)] = e^2 \cdot E(\xi^2) = e^2 \cdot np(1 - p + np)$.

Example three: $V(k, e) = ke^2 + ck(k-1)e^2, c > 0$.Then $E[V_n(\xi, e)] = e^2 \cdot np[1 + c(n-1)p]$

The last two examples show that if the cost function for monitoring is convex in n,the size of the banker's asset portfolio, the expected monitoring cost for the banker is also convex in n and at the same magnitude of convexity.

Therefore, the banker's expected profit is

$$\pi_b (R, D; n) = nK \cdot E \left(\widetilde{X}_n (R) \right) - (nk - 1) \cdot \left(D - \int_0^D F_{R,n} (y) \, dy \right) - E \left[V_{n,R} (\xi, e) \right] \tag{10}$$

Lemma 3 *Ceteris paribus, raising loan interest rate will reduce the expected profits of entrepreneurs and increase depositor's expected utility, but has ambiguous effects on the banker's profit.*

Ceteris paribus, raising deposit rate will leave entrepreneurs' profit unchanged and decrease the banker's expected profit, but has ambiguous effects on depositors' expected utility.

Ceteris paribus, increasing banker's asset size has no effect on entrepreneurs' profit, but increases depositors's expected utility and decreases banker's expected profit when the banker's asset size is sufficiently large.

The proof comes directly from the above lemmas. Entrepreneur's expected profit is strictly decreasing in loan interest rate but does not depend upon deposit interest and banker's asset size. Higher loan interest rate and loan number will make the banker's asset more profitable and safer and so decreases the probability that banker defaults on deposit payment. But depositors' expected utility is non-monotonic in deposit interest rate just as the case in direct lending, that is, raising deposit rate will increase the expected payment from the banker but also increase the probability of default by the banker. Increasing loan interest rate will raise the expected payment per unit of loan from entrepreneurs to the banker, but also increase the expected payment from the banker to depositors, and raise the probability of default by entrepreneur and so the expected monitoring costs of the banker. Thus the net effect of increasing loan interest rate on banker's profit is ambiguous and depends on which effect dominates. When n is small, increases in n will weaken the effect of banker's own capital although strengthen the effect of diversification on banker's asset portfolio. But as n is sufficiently large, diversification effect will dominate and thus benefit the depositors if deposit interest rate is less than the mean of return per unit to the banker's asset. As n becomes larger, the banker's marginal monitoring costs will increase in addition to increased expected payment per unit of deposit, thus decrease the banker's expected profit.

Viability of delegated monitoring with individual bankers

The maximizing problem facing the banker can be written as

$$\max_{R,D,n} \quad K\int_{R}^{\overline{y}} (y-R)\,dF(y) \tag{11}$$

$$s.t. \qquad D-\int_{0}^{D} F_{R,n}(y)\,dy - V(1,e)\,F_{R,n}(D) \geq r \tag{12}$$

$$nK\cdot E\left(\widetilde{X}_n(R)\right)-(nk-1)\cdot\left(D-\int_{0}^{D}F_{R,n}(y)\,dy\right)-E\left[V_{n,R}(\xi,e)\right]\geq r \tag{13}$$

Notice that both $r(R,D;n)$ and $\pi_b(R,D;n)$ are continuous in (R,D) if $D<R$ (see Krasa and villamil, 1992a).

Now comparing this problem with that under direct lending regime. Consider the case where direct lending is feasible and the optimal lending rate is R^0 [3]. Set the loan interest rate $R=R^0$.Then whether delegated monitoring with individual bankers dominates direct lending or not is equivalent to whether the banker can choose deposit interest rate and bank size to have the two constraints (12) and (13) satisfied.

Proposition 4 *The banker who makes one loan and borrows from K-1 lenders will strictly dominates direct lending.*

Proof. *The main reason for one-loan banker to be viable is the "capital cushion effect". As n=1 and* $R=R^0, R_{R^0,1}(y)=G_{R^0,1}\left(\frac{k-1}{k}y\right)=F\left(\frac{k-1}{k}y\right)<F(y)$ *,for all* $y<\frac{k}{k-1}R^0$. R^0 *satisfies* $R^0-\int_0^{R^0}F(y)\,dy-V(1,e)\,F\left(R^0\right)=r$ *and* $1-F\left(R^0\right)-V(1,e)\,f\left(R^0\right)\geq 0$. *Then if* $D=R^0$ *, constraint (12) becomes slack, since* $R^0-\int_0^{R^0}R_{R^0,1}(y)\,dy-V(1,e)\,R_{R^0,1}\left(R^0\right)>r$ *and* $\frac{\partial r\left(R^0,R^0;1\right)}{\partial D}=1-R_{R^0,1}\left(R^0\right)-V(1,e)\cdot f_{R^0,1}\left(R^0\right)>0$. *Therefore, lowering deposit interest rate D such that* $r\left(R^0,D;1\right)=r$*, so* $D<R^0$.*Then constraint (13) becomes*

[3] When direct lending is not feasible, there are cases where delegated monitoring is feasible. Here we focus on the more interesting situation in which direct lending is feasible.

$$\pi_b\left(R^0, D; 1\right) K \cdot \mu\left(R^0\right) - (k-1) \cdot \left(r + V(1,e) R_{R^0,1}(D)\right) - V(1,e) F\left(R^0\right) > r \tag{14}$$

Then the banker can reduce loan interest rate a little and attracts entrepreneurs. ■

The key factor for a banker of large size to be viable is diversification, as emphasized by Diamond(1984, 1996), Williamson(1986), Krasa and Villamil(1992a, 1992b), and Winton(1995). If the banker could oversee a larger number of independent loans, the Law of Large number would drive the probability of default by the banker to approach zero, and thus lenders do not need to monitor the delegated monitor, therefore delegated monitoring could economize on monitoring costs and dominate direct lending. However, this seemingly obvious logic should be taken with a grain of salt if the banker is unable to handle such a large number of loans. The following proposition tries to show this idea.

Proposition 5 *There exists $\overline{n}$ such that, for all $n > \overline{n}$, the banker of size n is not viable. And $\overline{n}$ is increasing in project size K.*

The proof strategy for this proposition is to show that the necessary conditions for the banker to be viable may not be satisfied when loan number is very large. Set $R = R^0$. Then for the banker of size n to be viable, the banker must find deposit interest rate D such that constraints (12) and (13) are satisfied. Now define $D(n)$ as

$$r\left(R^0, D(n); n\right) = D(n) - \int_0^{D(n)} F_{R^0,n}(y)\, dy - V(1,e) F_{R^0,n}(D(n)) = r \tag{15}$$

Substituting this equation into (13) generates

$$nK \cdot \mu\left(R^0\right) - nKr \geq (nK-1) \cdot V(1,e) \cdot F_{R^0,n}(D(n)) + E\left[V_{n,R}(\xi, e)\right] \tag{16}$$

From equation (5), we have

$$nK \cdot \mu\left(R^0\right) - nKr = nK \cdot V(1,e) \cdot F\left(R^0\right) \tag{17}$$

Combining (16) and (17),

$$(nK-1)\cdot V(1,e)\cdot F_{R^0,n}(D(n))+E[V_{n,R}(\xi,e)]\leq nK\cdot V(1,e)\cdot F\left(R^0\right) \tag{18}$$

This condition says that if the banker of size n is viable the gross monitoring costs under delegated monitoring should be no larger than the costs under direct lending. In the Appendix we show that such $D(n)$ may not exist, or $D(n)$ exists but the condition (18) will not hold for large n.

Corollary 6 *When direct lending is feasible in this economy, there exists some optimal size 1≤ $n^*\leq\overline{n}$, for an independent banker in the sense of leading to the least gross monitoring costs , and the banker strictly dominates direct lending.*

This corollary comes directly from the last two propositions. But as $r(R,D;n)$ is non-monotonic in deposit interest rate D and $\pi_b(R,D;n)$ is non-monotonic in loan interest rate R, there might be more than one optimal size n^*, all of which lead to the same gross monitoring costs but have different deposit interest rates. If the banker can somehow commit the size of the bank and convince the depositors about that, then the participation constraint for depositors should bind in equilibrium. Therefore, all optimal banker size n^* will also lead to lowest loan interest rate. Free entry and competition among bankers can arrive at the equilibrium with optimal bank size(or sizes). Therefore, even in a infinite economy, in equilibrium the economy will be characterized with a lot of bankers of finite size.

0.3 Delegated monitoring and organizational banks

We have established that the limited monitoring capability of one banker can restrict her ability to enjoy the potential benefits from diversification of bank asset. However, the bank need not to be "one banker". One obvious solution to resolve this problem is for many bankers to gather together and form some kind of bankers' coalition.

Consider m bankers in the environment specified above. Combining these m bankers to form one large bank will produce one better diversified asset portfolio while each banker oversees a small number of loans. But CSV problem and other problems will emerge among individual bankers since each banker can not directly observe other bankers' actions and realization of loans under other bankers' supervision. Efficient organizational arrangement will balance the benefits and costs.

There are many potential ways for m bankers to get united. Whatever the specific form of the consolidated bank is, its one crucial feature should be that the loan assets overseen by m bankers are consolidated together, thus the deposit contract held by any depositor of this bank becomes one claim over the asset of the whole bank instead of that of some individual banker. This is exactly how the bankers can commit to rescue each other and enjoy diversification benefits, and so convince the depositors to accept lower deposit interest rates and capture some benefits from diversification, which in turn gives the incentive for bankers to cooperation. But this process also shifts market discipline over every individual banker to the whole bank. Cross-subsidiary among unit bankers will induce "free-riding"problems. When a borrower claims default, the unit banker who supervises this borrower may choose not to monitor, because giving up monitoring will save monitoring costs for this unit banker while the consequence will be shared by all bankers in the bank. For diversification effect to work well, the bank has to design and implement some mechanisms to motivate and monitor each unit banker's actions, which require information about all realization of each unit's performance instead of only bad cases. Thus bankers need to share information and coordinate actions among themselves and monitor each other. Of course, these bankers could delegate the monitoring task within the bank to one banker, the CEO, and others become as unit bankers. But CEO also needs to monitor each unit banker and obtain at least some coarse information about loan projects. Therefore, some organizational costs are necessarily incurred along with the consolidation of bankers. This paper will not get into the detail about the specific way by which the bank are organized and managed , but focus on how organizational costs can affect the viability of the bank. The following extends the basic model to capture these ideas.

0.3.1 The model of organizational banks

Suppose the bank with m bankers will make N loans and borrow from $NK - m$ depositors. All unit bankers are symmetric, so each unit banker will supervise $\frac{N}{m-1}$ loans with same contracts$\left(R^B, D^B\right)$. Let $\widetilde{X}_N\ \left(R^B\right)$ with distribution $G_{R^B,N}(\cdot)$ and support $\left[0, R^B\right]$denote the return to per unit of bank asset, and $\widetilde{Y}_N\ \left(R^B\right)$ with distribution $F_{R^B,N}(\cdot)$ and support $\left[0, \frac{NK}{NK-m}R^B\right]$ denote the return to bank asset portfolio per borrower. Thus $F_{R^B,N}(y) = G_{R^B,N}\left(\frac{NK-m}{NK}y\right)$. Entrepreneurs' expected profits will be $\pi_f\left(R^B\right)$, each depositor's expected utility is $r\left(R^B, D^B; N\right)$ and the bank's expected profits $\Pi\left(R^B, D^B; N\right)$, as defined in last section. To capture the idea that the bank needs to monitor unit bankers intensively to cope with the moral hazard problem and CSV problem, suppose each banker needs to spend $a > 0$ units of efforts to communicate with and monitor other bankers. Then the bank's problem[4] is

$$\max_{R^B, D^B, N} \quad K \int_{R^B}^{\overline{y}} (y - R)\, dF(y) \tag{19}$$

$$s.t. \qquad D^B - \int_0^{D^B} F_{R^B,N}(y)\, dy - V(1, e)\, F_{R^B,N}\left(D^B\right) \geq r \tag{20}$$

$$\begin{aligned} NK \cdot E\left(\widetilde{X}_N\left(R^B\right)\right) - (Nk - m) \cdot \left(D^B - \int_0^{D^B} F_{R^B,N}(y)\, dy\right) \\ -m\left[E\left[V_{\frac{N}{m}, R^B}(\xi, e)\right] + (m-1)\, a\right] \geq mr \end{aligned} \tag{21}$$

In this problem, (19) is the same as in banker's problem, while some discussion of (20) and (21) is worthwhile. There are two types of monitoring costs now: $E\left[V_{\frac{N}{m}, R^B}(\xi, e)\right]$ denotes monitoring cost occurred to each unit banker when she monitors loans, $(m-1)\, a$ is the cost she spends on communicating with and monitoring other unit bankers, then $m(m-1)\, a$ can be thought as organizational cost of the bank with m bankers. While unit bankers' monitoring costs are in terms of expected costs, organizational cost is not, reflecting the complexity of monitoring within the bank. Another important thing is that the m bankers have one consolidated balance sheet now and each depositor holds claims over the whole bank's asset, as shown in (20).

[4] In practice, the bank is often hierarchical and some bankers will specialize in administrating and coordinating within the bank. Then the model specification will be a little different, but the main idea should still hold.

0.3.2 Viability of organizational banks

Suppose that the economic conditions are such that each banker, if operating individually, will make n^* loans and borrow from n^*K-1 depositors with two-sided contracts (R^*, D^*) , which solve the banker's problem(specified by (11) − (13) with constraints (12) and (13) binding). $\widetilde{X}_{n^*}(R^*)$ with distribution function $G_{R^*,n^*}(\cdot)$ and $\widetilde{Y}_{n^*}(R^*)$ with distribution $F_{R^*,n^*}(\cdot)$ are defined similarly as in section two. That is, $(R^*, D^*; n^*)$ satisfies

$$\pi_f(R^*) = K\int_{R^*}^{\overline{y}}(y-R^*)\,dF(y) \tag{22}$$

and

$$D^* - \int_0^{D^*} F_{R^*,n^*}(y)\,dy - V(1,e)\,F_{R^*,n^*}(D^*) = r \tag{23}$$

$$n^*K\cdot E\left(\widetilde{X}_{n^*}(R^*)\right) - (n^*k-1)\left(D^* - \int_0^{D^*} F_{R^*,n^*}(y)\,dy\right) - E\left[V_{n^*}(\xi,e)\right] = r \tag{24}$$

To discuss the viability of the hierarchical bank with m bankers, set $R^B = R^*$, then check whether the bank can find $\left(D^B; N\right)$ which satisfies the two constraints (20) and (21). For simplicity, we assume that $\overline{n}'''(R^*) = 1$[5], i.e. diversification effect always dominates capital cushion effect.

Advantage of organizational banks

Next we show that uniting bankers into big bank does work. The analyzing strategy is setting $N = mn^*$ to see if there exists D^B that satisfies (21) and (22). There are two cases, $D^* < \mu(R^*)$ and $D^* \geq \mu(R^*)$.

First consider the case $D^* < \mu(R^*)$, that is, $n^* \geq \overline{n}''(R^*)$. For any $y < \mu(R^*)$, $F_{R^*,n^*}(y) >$

[5] $\overline{n}''', \overline{n}''$,as defined in the proof of Proposition 5 in the Appendix.

$F_{R^*,N}(y)$. Then from (24), we have that

$$D^* - \int_0^{D^*} F_{R^*,N}(y)\,dy - V(1,e)\,F_{R^*,N}(D^*) > r \tag{25}$$

Thus choose D^B such that constraint (21) is binding, then $D^B < D^*$. Then substitute (20) into (21), whether the bank is viable is equivalent to

$$\begin{aligned} NK \cdot E\left(\widetilde{X}_N(R^*)\right) - NKr \geq (NK-m) \cdot V(1,e) \cdot F_{R^*,N}\left(D^B\right) \\ + m\left[E\left[V_{\frac{N}{m}}(\xi,e)\right] + (m-1)\,a\right] \end{aligned} \tag{26}$$

From (23) and (24), we have

$$NK \cdot E\left(\widetilde{X}_{n^*}(R^*)\right) - NKr = (NK-m) \cdot V(1,e)\,F_{R^*,n^*}(D^*) + mE\left[V_{n^*}(\xi,e)\right] \tag{27}$$

Combining (26) and (27) generates

$$\begin{aligned} & m\,(n^*K-1) \cdot V(1,e) \cdot \left[F_{R^*,n^*}(D^*) - F_{R^*,mn^*}\left(D^B\right)\right] \\ \geq \;& m\,(m-1)\,a \end{aligned} \tag{28}$$

For the case $D^* \geq \mu(R^*)$, where individual bankers will be very risky if they operate individually, we still can get (27) from (23) and (24). Notice that $F_{R^*,N}(y) = G_{R^*,N}\left(\frac{NK-m}{NK}y\right) = G_{R^*,N}\left(\frac{n^*K-1}{n^*K}y\right)$, while $F_{R^*,n^*}(y) = G_{R^*,n^*}\left(\frac{n^*K-1}{n^*K}y\right)$. If m is large enough that $n^*m \geq \overline{n}''(R^*)$, D^B will exist and $D^B < \mu(R^*)$. Then follow similar steps, we still get (28).

Condition (28) is both necessary and sufficient condition for bank with m bankers and operating n^*m loans to be viable. The left side of inequality (28) is the benefits from consolidation through diversifying bank asset portfolio, which reduces the risk of bank failure and so depositors accept lower interest rate. The right side is the organizational costs incurred by transforming banking regime from m independent bankers into one large bank. Given the distribution of projects and m, n^* , the benefits is also given while the right side depends on organizational cost a .When consolidating bankers only entail low organizational cost , the organizational bank is viable. The lower is a, the more advantage can the bank enjoy. Define $\overline{a}(m)$ such that condition (28) holds as an equality.

$$\overline{a}(m) = \frac{(n^*K-1)\cdot V(1,e)\cdot\left[F_{R^*,n^*}(D^*) - F_{R^*,mn^*}\left(D^B\right)\right]}{m-1} \tag{29}$$

Since $F_{R^*,n^*}(D^*) - F_{R^*,N}\left(D^B\right) > 0$, $\overline{a}(m) > 0$.Then the bank can improve the outcomes produced by m independent bankers if it can be managed at lower organizational cost than $\overline{a}(m)$.These discussions are summarized as the next proposition.

Proposition 7 *There exists $\overline{a}(m)$,such that for all $a < \overline{a}(m)$, the organizational bank with m bankers strictly dominates m independent bankers.*

Of course the bank with m bankers can do better by choosing its operating scale N. Then condition (28) becomes:

$$\begin{aligned} \eta \triangleq V(1,e)\cdot\left[\frac{n^*K-1}{n^*K}F_{R^*,n^*}(D^*) - \frac{NK-m}{NK}F_{R^*,N}\left(D^B\right)\right] \\ -\left\{\frac{m}{NK}\left[E\left[V_{\frac{N}{m}}(\xi,e)\right] + (m-1)a\right] - \frac{1}{n^*K}E\left[V_{n^*}(\xi,e)\right]\right\} \geq 0 \end{aligned} \tag{30}$$

Here η describes the net benefits of consolidation in term of per unit of funding. The following shows that there are some finite $N(m,a)$ such that η arrives at its maximum for given m and a. When $a < \overline{a}(m)$, condition (30) holds as an strict inequality. Even for some $a \geq \overline{a}(m)$, condition (30) will also hold if setting $N = N(m,a)$ and so the consolidated bank dominates m independent bankers. Now we prove the existence of $N(m,a)$.

Given any m and a, $m(m-1)a$ is given. This reflects the phenomenon in the real world that organizational costs have important fixed components for an organization with a fixed number of members. Rewrite (30) as $\eta = \eta_1 - \eta_2$, where η_1 and η_2 denote the first and second term respectively.

With our assumption, diversification effect dominates capital effect, so we just focus on $F_{R^*,N}\left(D^B\right)$ for first term in (29). Applying similar arguments to that for condition(34) in the appendix, as long as $N > \overline{n}''(R^*)$,we can get that

$$\frac{dF_{R^*,N}\left(D^B(N)\right)}{dN} = \frac{\partial F_{R^*,N}\left(D^B\right)}{\partial N} + f_{R^*,N}\left(D^B(N)\right)\frac{\partial D^B(N)}{\partial N} < 0$$

As N increases, the probability of default by the bank, $F_{R^*,N}\left(D^B(N)\right)$ will be smaller, but the amount by which an increase in N can reduce $F_{R^*,N}\left(D^B(N)\right)$ is limited since deposit interest rate $D^B(N)$ can not be less than depositors' opportunity cost r and $F_{R^*,N}\left(D^B(N)\right)$ can not be negative. Actually, $F_{R^*,N}\left(D^B\right) \leq G_{R^0,N}\left(D^B\right) \leq \exp\left\{-\tau\left(D^B\right)N\right\}, \tau\left(D^B\right) > 0$, for given $D^B < \mu(R^*)$. It should not be too inaccurate to consider $F_{R^*,N}\left(D^B(N)\right)$ as an convex function in N , at least when N is rather large. Thus the first term η_1 is concave in N.

The second term η_2 is also convex in N.Here the trade-off is between organizational costs and monitoring costs. As N increases, average organizational cost $\dfrac{m(m-1)a}{NK}$ decreases and average monitoring costs $\dfrac{m}{NK}E\left[V_{\frac{N}{m}}(\xi,e)\right]$ increase while $\frac{1}{n^*K}E\left[V_{n^*}(\xi,e)\right]$ does not depends on N. Therefore, the second term η_2 is convex in N. For small N, η_2 may decreases and then increases after some point as N increases.

As a whole, the net benefits from consolidating , η, is concave in the bank's operating scale N. As N is small, increasing N not only generates diversification benefits but may also reduce average operating costs. But this net benefits from consolidation will always be exhausted and η approaches zero and even turn to negative since the increasing overload costs to unit bankers will eventually dominate when N is very large. Thus there is some $\overline{N}(m,a)$ such that for all $N > \overline{N}(m,a), \eta < 0$.

These discussions can be expressed in another way: choosing N to maximize η is equivalent to minimize the total transaction costs under the consolidated bank regime, i.e.,

$$\begin{aligned}\frac{\partial\eta}{\partial N} &= -V(1,e)\cdot\left[\frac{NK-m}{NK}\cdot\frac{dF_{R^*,N}\left(D^B\right)}{dN} + \frac{m}{N}\frac{F_{R^*,N}\left(D^B\right)}{NK}\right] \\ &\quad + \frac{m(m-1)a}{N^2K} - \frac{1}{NK}\left[\frac{\partial E\left[V_{\frac{N}{m}}(\xi,e)\right]}{\partial\left(\frac{N}{m}\right)} - \frac{E\left[V_{\frac{N}{m}}(\xi,e)\right]}{\left(\frac{N}{m}\right)}\right] \qquad (31)\end{aligned}$$

The first term in the expression of $\frac{\partial\eta}{\partial N}$ can dominate and $\frac{\partial\eta}{\partial N} > 0$ when N is small. But the last term will dominate and $\frac{\partial \eta}{\partial N}<0$ for very large N.Then there is some $N(m,a) \leq \overline{N}(m,a)$ which maximizes η given (m,a).

Boundary of organizational banks

The preceding subsection shows that there can be advantages for some independent bankers to get united as one large bank by diversifying the bank portfolio and balancing organizational costs and monitoring costs to unit bankers. But as long as the bank incurs convex organizational cost [6], the viable bank will be of finite organizational size, i.e. m is a finite number. To see this, check the condition (30) again.

The diversification benefits from consolidation are bounded from above regardless of how the bank can adjust its operating scale, since

$$\begin{aligned}
& V(1,e)\cdot\left[\frac{n^{*}K-1}{n^{*}K}F_{R^{*},n^{*}}\left(D^{*}\right)-\frac{NK-m}{NK}F_{R^{*},N}\left(D^{B}\right)\right] \\
& < V(1,e)\cdot\frac{n^{*}K-1}{n^{*}K}F_{R^{*},n^{*}}\left(D^{*}\right)
\end{aligned}$$

But the organizational cost $m(m-1)a$ is convex in organizational size m and is not bounded from above. Condition (30) will not hold for very large number of bankers within one bank.

We can prove this point more formally. Since $N(m,a)$ is such that η defined in (30) arrives at its maximum for given m and a.Then applying Envelope Theorem, we get

$$\begin{aligned}
\frac{\partial \eta(m,a)}{\partial m} &= \frac{1}{NK}\left[V(1,e)\cdot F_{R^{*},N}\left(D^{B}\right)+\frac{N}{m}\left(\frac{\partial E\left[V_{\frac{N}{m}}(\xi,e)\right]}{\partial\left(\frac{N}{m}\right)}-\frac{E\left[V_{\frac{N}{m}}(\xi,e)\right]}{\left(\frac{N}{m}\right)}\right)\right] \\
& \quad -\frac{(2m-1)a}{NK}
\end{aligned} \tag{32}$$

This expression reflects the trade-off between organizational costs and unit bankers' monitoring costs when organizational size m changes. The first term is the savings of unit bankers' monitoring costs when m increases by reducing the work load of each unit banker. The second

[6] For example, CEO has limited capacity for management and monitoring.

is the amount of increased organizational costs. The first part is in terms of expected costs while the second part is not. Using the example of distutility function to rewrite this expression,

$$\frac{\partial \eta (m,a)}{\partial m} = \frac{1}{NK}\left[V(1,e)\cdot F_{R^*,N}\left(D^B\right) + ce^2 \left(\frac{N}{m}\cdot p\right)^2 - (2m-1)\,a \right]$$

In this expression, $N = N(m,a)$ and $p = F_{R^*,N}\left(D^B\right)$, $\frac{N}{m}\cdot p$ is the expected number of failed loans under each unit banker's supervision. The second term in the bracket will not change a lot while marginal organizational cost increases steadily. $\frac{\partial\eta(m,a)}{\partial m}$ will be negative for large m and so $\eta(m,a)$ will approaches zero as m goes up . Therefore, for a given a, there is some $\overline{m}(a)$ such that the benefits from consolidation of bankers will be offset completely by increased organizational costs if $m > \overline{m}(a)$. And the larger is a, the stronger is the effect of organizational cost . Thus $\overline{m}(a)$ should be decreasing in organizational cost a.

We summarize this result as the next proposition.

Proposition 8 *For some given organizational cost a, there is a limit of bank organizational size $\overline{m}(a)$. When $m > \overline{m}(a)$, the organizational bank is not viable. And $\overline{m}(a)$ is decreasing in the organizational cost a.*

0.4 Project scales and distribution of bank size

The foregoing two sections have established that organizational banks can have advantages over independent bankers which dominate direct lending between entrepreneurs and ultimate lenders, and their advantages are confined by bankers' limited capacity of management and monitoring, which should be an intrinsical feature of human being. The viable organizational size and operational scale of organizational banks depend on the costs at which bankers monitor loans and the costs spent on coordination and monitoring among bankers , as well as the size, profitability, and riskiness of investment projects.

In the real world, the monitoring costs and organizational costs of banks depend on many factors, among which are information technology available to bankers and the informational characteristics of projects that banks finance. When delivery of information relies on mails processed though postal system or even requires bankers to meet in physical presence, it is difficult for the bank to operate geographically spread-out branches. Modern electronic technology has conveniently facilitated the storage and communication of much information and so improved banks' productivity.

On the other hand, characteristics of investment projects and firms undertaking these projects can have substantial effects on the way by which the bank makes loans and thus on the size distribution of banks. Here we focus on the size of borrowing firms. Relative to smaller firms, larger firms tend to have more normative information and so be more informationally transparent. This is partly because compiling such normative information as formal financial statements requires at least some fixed costs which makes it more expensive to smaller firms. This is also because that the larger firm needs normative information, especially financial information, to coordinate and manage a large number of members and complex divisions within the firm while such need for small firms is much less. Such information is often hardened and easy to communicate among people. The systematically compiled information usually summarize and convey informative and important contents about the firm's performance in the past which can reflect the profitability, competitive power, and other quality features at the firm level. The difference in informational transparency across sizes of firms has significant implications for banks. When dealing with larger firms, unit bankers can obtain valuable information about the borrower firm by requiring these kinds of hard information which help them with loan decisions and subsequent monitoring over borrowers. Unit bankers, however, will have to contact personally with small borrowers so as to collect relevant information that is usually "soft". Thus bankers who make loans to small borrowers may use different lending technology from those who deal with large borrowers. When the bank is hierarchical, top managers at higher ladders need to acquire some information, although coarse, about each unit's loans in order to control the behavior of unit bankers. With "hard" information about borrowers, unit bankers and top managers can communicate and share information easily whereas "soft" information makes such communication rather difficult. Therefore, it is more costly for top managers to monitor unit bankers in a hierarchical bank where unit bankers are treating with small businesses. These differences related to large and small firms can affect the banking structure in a substantial way.

To capture these ideas in the simple framework of this paper, we extend the basic model into an environment with heterogenous projects.

Suppose that the economy has two types of entrepreneurs: type 1 and type 2, who account for β_1 and β_2 of the population respectively. Each of the type 1 entrepreneurs has access to a small-scale project , which requires K_1units os investment good in the first period and yields $K_1\widetilde{y}_1$ units of consumption good in the second period. Each of type 2 entrepreneurs is endowed with a large-scale project requiring K_2 units of investment and yielding $K_2\widetilde{y}_2$. Assume $K_2 > K_1$, and $1 - \beta_1 - \beta_2 \geq \beta_1 K_1 + \beta_2 K_{2.}$

For simplicity, we assume that the projects themselves are all the same except that one type is larger than the other, i.e., $\widetilde{y}_1$ and $\widetilde{y}_2$ has the same distribution, with positive support $[0, \overline{y}]$ and distribution function $F(\cdot)$. As before, there is no informational asymmetry ex ante, and all lenders and entrepreneurs can observe the scale of projects and know the distribution of each type of projects. The CSV problem is still present, i.e. the realization of each project is only observable directly to the entrepreneur himself and each lender needs to spend some fixed units of efforts in order to observe it.

In this environment, individual bankers always dominate direct lending both for small projects and large projects. But the relative advantages of organizational bank over individual bankers are different when financed projects are different. As we argued above, entrepreneurs with small projects can not provide hard information to bankers while those with large projects can do it. Therefore, bankers lending to small projects will use different lending technology from those lending to large projects. As long as learning each kind of lending technology requires some small fixed costs, each banker will specialize in lending to only one type projects. Furthermore, when this is true, bankers who make loans to small projects have more difficulty in communicating among themselves about the performance of the loans under each banker's supervision. Each banker dealing with small projects needs to expend a_{11} efforts to monitor another banker who also deal with small projects, and this cost is a_{12} if the other banker loans to large projects. A banker dealing with large projects needs to spend a_{22} units of efforts in communicating with another banker who also deals with large projects, and this cost is a_{21} if the other banker deals with small projects. Assume that $a_{22} < a_{11} < a_{12} = a_{21}$. As monitoring costs at which each banker monitor each loan might be different for different projects, but the direction of difference can not be assumed easily. So for simplicity, we assume that the monitoring effort spent on each loan is the same for large and small projects, denoted as e, and the monitoring effort at which each depositor monitors the bank is also the same, e. All lenders are risk neutral and have the same disutility function.

Specialization in lending is more efficient if non-specialization brings about much difficulty for management of banks and leads to very high organizational costs, $a_{22} < a_{11} < a_{12} = a_{21}$.Then this economy will be characterized with specialization equilibrium, in which some banks specialize in lending to small projects and others specialize in large projects, and banks for small projects tend to be smaller than those for large projects. We demonstrate these results in the next proposition.

Proposition 9 *In equilibrium, the banks lend to large projects tend to be larger than banks lend to small projects.*

Proof. *Our proving strategy is to show that the relative advantages of organizational bank over individual bankers depend on which type of projects the bank lends to.*

Suppose that the equilibrium state for individual bankers who lend to small projects or larger projects would be $(R^*, D^*; n^*)$ *if all bankers operate individually*[7] *, that is, each banker would lend to* n^* *entrepreneurs with contracts* (R^*, D^*). *Then* $(R^*, D^*; n^*)$ *satisfy conditions (23)-(25).*

Step 1. *Consider whether* m *such individual bankers should merge into one organizational bank. From proposition 7, we know that there exist* $\overline{a}_j(m)$ *,such that for all* $a_j < \overline{a}_j(m)$, $j = 1$ *or 2, the organizational bank with* m *bankers lending to projects of type* j *strictly dominate* m *individual bankers who make same type of loans. That is, for all* $a_j < \overline{a}_j(m)$, *condition (28) holds. For given* m*,*

$$\overline{a}_j(m) = \frac{(n^* K_j - 1) \cdot V(1, e) \cdot \left[F_{R^*, n^*}(D^*) - F_{R^*, mn^*}\left(D^B\right)\right]}{m - 1} \tag{33}$$

where D^B *satisfies (21) that holds as an equality. Since* $K_1 < K_2$, *we have* $\overline{a}_1(m) < \overline{a}_2(m)$. *The main reason is that when project scale is larger, then the benefits of savings on*

[7] *The equlibrium state for individual bankers who lend to large projects should be different from that for bankers dealing with small projects. But the basic logic should be the same as the following proof.*

depositors' expected monitor costs through diversification of bank assets that reduces the probability of default by the bank is also larger. In other words, the benefits from diversification is magnified by project scale. As long as consolidation of bankers can diversify the assets of the bank, the benefits can more than offset the concomitant organizational costs. To the extent that $a_{22} < a_{11}$ *holds, we have* $\overline{a}_1(m) < \overline{a}_2(m)$ *in contrast with* $a_{22} < a_{11}$. *Then for the same organizational size m, it is more probable for the bank lending to large projects strictly dominate m individual bankers than for the bank loaning to small projects, because the benefits from consolidation is larger for the bank serving large projects.*

Furthermore,

$$\begin{aligned}\frac{\partial \overline{a}_j(m)}{\partial m} &= \frac{-(n^* K_j - 1) \cdot V(1,e)}{(m-1)^2} \\ &\quad \cdot \left[\left(F_{R^*,n^*}(D^*) - F_{R^*,mn^*}\left(D^B\right) \right) + \frac{dF_{R^*,mn^*}\left(D^B\right)}{dN} \cdot n^*(m-1) \right]\end{aligned}$$

Since $F_{R^*,n^*}(D^*) - F_{R^*,mn^*}\left(D^B\right) \geq \frac{dF_{R^*,mn^*}\left(D^B\right)}{dN} \cdot n^*(m-1)$, *we have* $\frac{\partial \overline{a}_j(m)}{\partial m} \leq 0$, $j = 1, 2$. *When the bank is already large and its asset is rather diversified, increasing bank size can only generate less benefits of diversification. Therefore, for both types of banks, the lower are the organizational costs, the larger is the organizational size of banks.*

Combining these two points, $\overline{a}_1(m) < \overline{a}_2(m)$, *and* $\frac{\partial \overline{a}_j(m)}{\partial m} \leq 0$, $j = 1, 2$, *and the assumption* $a_{11} > a_{22}$, *we can claim that banks serving large projects can be larger than banks serving small projects.*

Step 2. *Next we prove the proposition in another direction by showing that banks serving large projects can have a higher limit of organizational size.*

Rewrite condition (30) for the bank with m bankers to be viable, for $j = 1, 2$,

$$\begin{aligned}\eta_j &\triangleq V(1,e) \cdot \left[\frac{n^* K_j - 1}{n^* K_j} F_{R^*,n^*}(D^*) - \frac{N_j K_j - m}{N_j K_j} F_{R^*,N_j}\left(D_j^B\right) \right] \\ &- \left\{ \frac{m}{N_j K_j} \left[E\left[V_{\frac{N_j}{m}}(\xi, e) \right] + (m-1) a_{jj} \right] - \frac{1}{n^* K_j} E\left[V_{n^*}(\xi,e)\right] \right\} \geq 0\end{aligned}$$

When $N_j = N_j(m, a_{jj})$, *which satisfies* $\frac{\partial \eta_j}{\partial N_j} = 0$, *then*

$$\frac{\partial \eta_j (m, a_{jj})}{\partial m} = -\frac{m a_{jj}}{N_j K_j} - \left(\frac{N_j}{m} - \frac{1}{K_j}\right) \cdot V(1, e) \frac{dF_{R^*, N_j}(D^B)}{dN_j}$$

Fixing a_{jj}, *if project scale* , K_j , *is larger,* η_j *will decreases later as* m *increases, and once* $\frac{\partial \eta_j (m, a_{jj})}{\partial m}$ *becomes negative,* η_j *will decrease slower with increasing organizational size. There are two reasons for this point: one is the magnification effect of project scale on benefits of diversification, as discussed in step 1; the other is that organizational cost is fixed for each banker, which implies that the average organizational cost per unit of bank asset is lower when loaning to large projects. Fixing* K_j, *if organizational cost* a_{jj} *is higher, total organizational costs ,* $m(m-1) a_{jj}$, *more easily offset the benefits of diversification brought about by increasing organizational size, thus* η_j *will decreases earlier as* m *increases, and once* $\frac{\partial \eta_j (m, a_{jj})}{\partial m}$ *becomes negative,* η_j *will decrease quicker with increasing organizational size. Combining these two points, as long as serving small projects can incur higher organizational costs for the bank,* $a_{11} > a_{22}$,*the bank serving small projects should have a lower limit of viability , relative to banks serving to large projects. That is,* $\overline{m}_1 (a_{11}) < \overline{m}_2 (a_{22})$.

From the above two steps, we can infer that the optimal size of banks serving large projects tend to be larger than that of banks loaning to small projects. ■

0.5 Conclusion and policy implications

This paper tries to explain the phenomenon of bank-firm size match by developing a model of organizational banks based on the model of banks as delegated monitors, pioneered by Diamond (1984) and developed by Williamson(1986), Krasa and Villamil(1992a,1992b), Winton(1995,1997). Different from Diamond(1984) and other papers along this line, this paper assumes that each individual banker has only limited capacity for monitoring and thus can only monitor a limited number of loans. Organizational banks emerge as an outlet to overcome the limit of individual bankers and utilize more of the benefits from diversification. But forming organizational bank generates organizational costs. Optimal bank size balances the diversification benefits of bank size against the monitoring and organizational costs. As monitoring costs and organizational costs are fixed, small projects are at disadvantage relative to large ones. Since small projects are profitable enough some banks choose to stay small in order to provide loans to them while banks serving large projects become large. In equilibrium the banking structure in the economy depends on the distribution of projects.

This paper can generate interesting policy implications. In the developing economies where labor is more abundant relative to capital, labor-intensive industries enjoy comparative advantages compared to capital-intensive industries (Lin,2003). To the extent that businesses in labor-intensive industries tend to be small and capital-intensive firms tend to be large, the banking structure should match with the distribution of non-financial firms in the economy (Lin, Sun, and Jiang,2006). If there are regulations against small banks, such as interest rate ceiling or prohibitive requirements for entry into banking sector, small banks may not survive whereas large banks are protected, then banking system will be dominated by a few huge banks. Then small businesses in the labor-intensive industries will face more difficulties in financing their projects even they are more profitable than large and capital-intensive ones. As a result of this mismatch between banking structure and industrial structure which is determined by the endowment structure, the allocation efficiency can be harmed and the rate of economic growth can be slowed down. By embedding this paper in a growth model, these discussions could be displayed explicitly. These policy implications should be readily tested with appropriate data.

There are several directions in which this paper can be extended or modified. The small and large projects are assumed to be equally profitable here, allowing small projects to be more profitable than large ones will endue small projects some advantages over large ones although they are still at disadvantage in term of financing costs. Assuming that projects of different size belong to different industries that have uncorrelated risks and projects in the same industry have correlated risks will make the trade-off between diversification or specialization more interesting. Following the literature on banks as delegated monitors, this paper only analyzes the ex post information asymmetry while ex ante screening and on-going monitoring by banks are equally, or even more, important. Explaining the bank-size match with other models on banks, such as Boyd and Prescott(1986), should generate similar results. And only so, the arguments on bank-size match in the Introduction can be robust.

Next we will try to do some empirical tests over the policy implications of this paper in the following research. And combing this paper with a growth model and modeling the bank-firm size match with other informational frictions will be interesting future work.

0.6 Appendix

Proof of Lemma 2

Proof. Suppress temporarily $\widetilde{X_i}(R)$ into $\widetilde{X_i}$. Let $\left(\widetilde{X_1}, \cdots, \widetilde{X}_{n_2}, \widetilde{X}_{n_2+1}, \cdots, \widetilde{X}_{n_1}\right)$ be the independent, identically distributed payment variables. $\widetilde{X}_{n_1} = \frac{1}{n_1}\sum_{i=1}^{n_1}\widetilde{X_i}$ can be seen as payoff to investment strategy$\left(\frac{1}{n_1}, \cdots, \frac{1}{n_1}, \frac{1}{n_1}, \cdots, \frac{1}{n_1}\right)$and $\widetilde{X}_{n_2} = \frac{1}{n_2}\sum_{i=1}^{n_2}\widetilde{X_i}$.as payoff to investment strategy $\left(\frac{1}{n_2}, \cdots, \frac{1}{n_2}, 0, \cdots, 0\right)$. Then $E\left(\widetilde{X}_{n_2}\right) = E\left(\widetilde{X}_{n_1}\right)$.

$$\widetilde{X}_{n_2} = \widetilde{X}_{n_1} + \sum_{i=1}^{n_2}\widetilde{X_i}\cdot\left(\frac{1}{n_2} - \frac{1}{n_1}\right) + \sum_{i=n_2+1}^{n}\widetilde{X_i}\cdot\left(0 - \frac{1}{n_1}\right) \triangleq \widetilde{X}_{n_1} + \epsilon$$

$$\begin{aligned}
E\left(\epsilon \mid \widetilde{X}_{n_1}\right) &= E\left[\sum_{i=1}^{n_2}\widetilde{X_i}\cdot\left(\frac{1}{n_2} - \frac{1}{n_1}\right) \mid \widetilde{X}_{n_1}\right] + E\left[\sum_{i=n_2+1}^{n}\widetilde{X_i}\cdot\left(-\frac{1}{n_1}\right) \mid \widetilde{X}_{n_1}\right] \\
&= E\left(\widetilde{X_i} \mid \widetilde{X}_{n_1}\right)\cdot\left[\sum_{i=1}^{n_2}\left(\frac{1}{n_2} - \frac{1}{n_1}\right) + \sum_{i=n_2+1}^{n}\left(-\frac{1}{n_1}\right)\right] \\
&= E\left(\widetilde{X_i} \mid \widetilde{X}_{n_1}\right)\cdot(1-1) \\
&= 0
\end{aligned}$$

Therefore, $\widetilde{X}_{n_2} = \widetilde{X}_{n_1} + \epsilon$,with $E\left(\epsilon \mid \widetilde{X}_{n_1}\right) = 0$.Thus $\widetilde{X}_{n_1}(R)$ dominates $\widetilde{X}_{n_2}(R)$ in the sense of second stochastic dominance.

As $\widetilde{Y_n}(R) = \frac{nK}{nK-1}\widetilde{X_n}(R)$, the dominance for $\widetilde{X}_n(R)$ will be directly carried on to $\widetilde{Y_n}(R)$.
■

Proof of Proposition 5

Proof. **Firstly**, the proof of proposition 4 shows that such $D(n)$ exists and condition (18) holds if n=1.

Secondly, when n is very large, even there exists $D(n)$ as defied by (15), condition (18) may not hold due to the convexity of disutility function $V(k,e)$.

To see this, notice that the total expected monitoring costs under direct lending is linear in n while the expected monitoring costs to the banker , $E[V_{n,R}(\xi,e)]$, is convex in n. Then there must exists $\overline{n}'$ such that, for all $n \geq \overline{n}'$, $E[V_{n,R}(\xi,e)] > nK \cdot V(1,e) \cdot F(R^0)$.Since the first

term in (18) will never be negative, (18) does not hold for any $n \geq \overline{n}'$,. Here $\overline{n}'$ increases with project scale K and also depends on the form of $V(k,e)$. When K is large, delegated monitoring can save considerable duplicated monitoring costs occurred under direct lending.

For example, if $V(k,e) = ke^2 + ck(k-1)e^2, c > 0$, then $E[V_{n,R}(\xi,e)] = e^2 \cdot np[1 + c(n-1)p]$.Then $\overline{n}' = \left[1 + \frac{K-1}{cF(R^0)}\right]$ decreases with c, which measures the limit of banker's capability for monitoring.

Thirdly, $D(n)$ may not exist when the probability of default by the banker is not trivial.

Although (5) holds for R^0, (15) may not hold for $n > 1$, which depends on how $F_{R^0,n}(\cdot)$, will change as n increases. Notice that as R is set to R^0, for any given n, $F_{R^0,n}(\cdot)$,the distribution of return to banker's asset per depositor $\widetilde{Y}_n(R^0)$ with support $\left[0, \frac{nK}{nK-1}\right]$ is also given. There are two offsetting effects about the change of $F_{R^0,n}(\cdot)$ with n, the capital cushion effect and diversification effect.

The former effect states that, $R_{R^0,n}(y) = G_{R^0,n}\left(\frac{nk-1}{nk}y\right) < G_{R^0,n}(y)$, for all $y < \frac{nk}{nk-1}R^0$, in which $G_{R^0,n}(y)$ with compact support $[0, R^0]$ is the distribution function for $\widetilde{X}_n(R^0)$, the return to per unit of banker asset. Given any K, this cushion effect will be diluted as n increases. But how strong the capital cushion effect is and the dilution degree of this effect as n increases depend on project scale K. When K is large, even for very small n, $R_{R^0,n}(y) \approx G_{R^0,n}(y)$ as $\frac{nk-1}{nk} \approx 1$. For sufficiently large K, $\frac{K-1}{K} \approx 1$.So the capital cushion effect is very weak and diversification effect will dominate. But if K is very small, $\frac{K-1}{K}$ is much less than 1, the capital effect is strong when n is small and decreases as n increases, diversification effect can be dominated for small n.

The diversification effect deals with how $G_{R^0,n}(\cdot)$ will change as n increases. For all n, $E\left(\widetilde{X}_n(R^0)\right) = \mu(R^0)$. But as n increases, the distribution of $\widetilde{X}_n(R^0)$ will concentrated around $\mu\left(R^0\right)$ and $G_{R^0,n}(y)$ decreases for $y<\mu\left(R^0\right)$. From Law of Large Number, $G_{R^0,n}(y)\rightarrow 0$ as $n\rightarrow\infty$, for all $y<\mu\left(R^0\right)$.Krasa and Villamil(1992a) further prove that the speed of convergence in Law of Large Number is exponential as n increases. That is, for all $y<\mu\left(R^0\right)$,

$$G_{R^0,n}(y)\leq\exp\{-\tau(y)n\},\tau(y)>0.$$

where $\tau(y)=\sup_{\theta\in\Re}[\theta y-\log M(\theta)]$ is the rate function giving the speed of convergence of $G_{R^0,n}(\cdot)$ and $M(\theta)=\int_0^{R^0}e^{\theta t}dG(t)$ is the moment generating function for $\widetilde{X}_i\left(R^0\right)$. For given R^0 and n, $\tau'(y)<0,y<\mu\left(R^0\right)$.

Taking the two effects into consideration, there exists a modest number $\overline{n}'''$, such that for all $n\geq\overline{n}'''$, $\dfrac{\partial F_{R^0,n}(D)}{\partial n}<0$, if $D<\mu\left(R^0\right)$,that is, diversification effect will always dominate for large n even it is not so when n is small.

Now we need to show when $D(n)$ exists and how it will change as n increases. From definition of $D(n)$ and Law of Large Number, as $n\rightarrow\infty,F_{R^0,n}(D)$ goes to zero as long as $D<\mu\left(R^0\right)$; and so expected monitoring costs and risk premium will goes to zero, and so D can be lowered to r,which is less than $\mu\left(R^0\right)$.Since $\dfrac{\partial F_{R^0,n}(y)}{\partial n}<0$ for $y<\mu\left(R^0\right)$, there exists $\overline{n}''$,such that, for all $n\geq\overline{n}''$, there exists $D(n)<\mu\left(R^0\right)$ for (16) to hold . For $1<n<\overline{n}''$, either $D(n)\geq\mu\left(R^0\right)$; or $D(n)$ does not exist, that is, for all D, $r\left(R^0,D;n\right)<r$.

Furthermore, when $n\geq\overline{n}'',D'(n)\leq 0$ since $\dfrac{\partial F_{R^0,n}(D(n))}{\partial n}<0$ and $\dfrac{\partial r\left(R^0,D(n);n\right)}{\partial D}\geq 0$ at $D(n)$ .Then we can obtain the benefits from diversification:

$$\frac{dF_{R^0,n}(D(n))}{dn}=\frac{\partial F_{R^0,n}(D)}{\partial n}+f_{R^0,n}(D(n))\frac{\partial D(n)}{\partial n}<0 \tag{34}$$

Fourthly, there exists $\overline{n}<\overline{n}'$, for all $n>\overline{n}$, delegated banker of size n is not viable. If $\overline{n}'$ is so small that $\overline{n}'\leq\overline{n}''$, then for $1<n<\overline{n}'$,either $D(n)$ does not exist, or $D(n)\geq\mu\left(R^0\right)$, which implies that the banker involves considerable default risk and (18) can not hold. In some special cases, it can be that $\overline{n}=1$. If $\overline{n}'>\overline{n}''$, either $\overline{n}\leq\overline{n}''$ because the overload costs are so high for the banker that she can not enjoy the benefits from diversification; or $\overline{n}''<\overline{n}<\overline{n}'$, the banker can capture some diversification benefits but eventually be restrained by the overload costs.

Finally, $\overline{n}$ tends to increase with the project scale K. One reason is that $\overline{n} < \overline{n}'$ and $\overline{n}'$ increases with K . Another reason is that diversification effect more easily dominates capital cushion effect when K is larger. ■

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