Comparing Centralized and Decentralized Banking

A Study of the Risk-Return Profiles of Banks

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Abstract

This paper studies the risk-return profile of centralized and decentralized banks. We address the conditions that favor a particular lending regime while acknowledging the effects on lending and returns caused by the course of the business cycle. To analyze these issues, we develop a model which incorporates two stylized facts; (i) banks in which lending decisions are decentralized tend to have a lower cost associated with screening potential borrowers and (ii) decentralized decision-making may generate inefficient outcomes because of lack of coordination. Simulations are used to compare the two banking regimes. Among the results, it is found that asymmetric markets (in terms of the proportion of high ability entrepreneurs) tend to favor centralized banking while decentralized banks seem better at lending in the wake of an economic downturn (high probability of a recession). In addition, we find that even though a bank group where decisions are decentralized may end up with a portfolio of loans which is (relatively) poorly diversified between regions, the ability to effectively screen potential borrowers may nevertheless give a decentralized bank a lower overall risk in the lending portfolio than when decisions are centralized.

Keywords: lending, screening, business cycle, portfolio diversification, risk, organization, simulations.

JEL classification: C63, E30, G01, G11, G21, G32

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1 Introduction

An important aspect of a bank's lending activity is the ability to assess the risk-return profile of its investments. Failure to do so may result in substantial credit losses in the case of an unanticipated event. A recent example is the subprime crisis of 2008 where the five largest U.S. investment banks either went bankrupt, were taken over by other companies or were bailed out by the U.S. government. Although nearly all banks suffered from reduced profitability during this period, there was a large variation between banks in terms of how exposed their balance sheets were to risky credits/investments and how large losses they actually experienced during the crisis. Partly, these differences may reflect differences in corporate culture and different attitudes towards risk but since banks are forced to deal with excessive information asymmetry problems, such differences may also reflect the superiority of some banks in assessing the risk profiles and probabilities of default within their respective pools of potential clients and investment opportunities.

A natural question is then why some banks seem to be more effective than others in limiting their credit losses when hit by a negative shock. In this paper we argue that a potentially important factor is whether lending/investment decisions are decentralized (meaning that the lending decisions are taken at the local branch level) or centralized (meaning that the lending decisions are taken higher up in the organization). The purpose of this paper is to develop a stylized theoretical model to analyze this issue.

Our paper relates to the relatively new strand in the corporate finance literature dealing with organizational structure. In this field, an important question is how effective different organizational structures are in terms of handling intangible "soft information" (e.g., ability, honesty, etc.) and "hard information" (e.g., data form credit scoring models and balance sheet data).[1] However, the effects of organizational structure on a bank's risk-return profile have not yet been studied and this is the focus of this paper. To address this issue, we develop a model that allows us to study the potential trade-off that a bank may face between (i) being effective in terms of selecting high-quality clients (which is achieved by having a decentralized decision-making structure) and (ii) being effective in terms of ending up with a well diversified portfolio of loans on the aggregate level (which is achieved by having a more centralized decision-making structure). We also take into

[1]Stein (2002) contrasted decentralized and centralized (hierarchical) firms from an internal capital markets perspective. He found that hierarchical firms are better suited to deal with hard information since such information is easily handed upwards in the hierarchy whereas decentralized firms handle soft information more effectively. Takáts (2004), in turn, focused exclusively on the difference between centralized and decentralized banks in terms of their abilities to handle soft information and he found (among other things) that information asymmetries are especially important in small business lending.

account that a possible consequence of decentralized decision-making is that the decision-maker in one local branch may not recognize that his/her choices may affect the situation for the other local branches. As such, local decision-making may generate "externalities" within the bank group. Here we will focus on (iii) financing externalities, which occur if the decision on how many loans to grant in one local branch affects the cost of raising funds in other branches within the bank group.

Point (i) can be motivated from two perspectives. On one hand, it is well known that banks screen and monitor potential borrowers (Allen, 1990; Winton, 1995) in order to reduce their exposure to counter party risk. In this context, the concept of relationship banking has been put forward as an effective strategy (at least in the longer term) to harvest the information needed to attain high-quality clients (see Boot, 2000, for an excellent review on relationship banking). The underlying concept in relationship banking is to develop comprehensive working relations with each client by assessing his/her individual situation. This means that a bank practicing relationship banking has the ability to collect intangible soft information about the potential client which may improve the bank's client quality estimates (Petersen, 2004), thereby increasing the bank's ability to discriminate between good and bad clients. We will refer to this discrimination procedure as client targeting. Typically, relationship banking is associated with small banks, or large banks that have a decentralized decision-making structure. One rationale for this is that managers of small banks, and branch managers of decentralized banks, have a greater autonomy over adjudication and lending decisions (Stein, 2002). As such, branch managers in decentralized banks have a strong incentive to act on soft information. In contrast, branch managers in centralized banks tend to rely more on hard information (Canales and Nanda, 2011) which means that their incentive to act on soft information may be less strong compared with their decentralized counterparts.

Another explanation for why decentralized banks tend to rely more on relationship banking than centralized banks is that soft information is hard to quantify (Petersen, 2004). This implies that soft information gathered through a relationship with a client may not easily be communicated along the chain of command within a centralized bank, especially if the communication relies on formalized procedures such as score sheets, etc. We will refer to this as information erosion and a consequence of this potential failure to communicate effectively is that a multi-layered centralized bank needs to put in more effort to maintain the quality of the soft information that has been gathered. This adds an extra cost to the client targeting activity in a centralized organizational structure.

A consequence of the arguments presented above is that decentralized banks are likely to put in more effort into screening their potential customers than do centralized banks and this is supported by empirical findings. Liberti (2009) found that the transmission and reliance of soft information is larger in a decentralized organizational structure, whereas Berger et al. (2005) found that small banks tend to have a comparative advantage in processing soft information. As such, small and decentralized banks may be better at alleviating credit constraints for small businesses (Stein, 2002) and they are likely to lend more heavily to small and opaque firms, as previously suggested by Berger et al. (2001, 2005). Further, a recent study by Uchida et al. (2008) on Japanese data, confirmed the findings of Berger et al. (2005), suggesting that the comparative advantage in relationship lending experienced by small banks, is likely to be universal.

Point (ii) is related to portfolio diversification (in the spirit of Markowitz, 1952) whereby large banks are able to finance a wider range of firms (Takáts, 2004) than small banks. Here the argument is that under decentralized decision-making, the aggregate portfolio of clients that the bank group as a whole ends up with (which is the sum of the portfolios of loans over all local branches in the bank group) need not be as well diversified between regions as it might have been if the lending decisions where made at the central level. For example, if the local branch in one region ends up with a small portfolio of clients (because the local bank office predicts that the overall quality of the potential borrowers in that region is low) whereas the local branch in another region ends up with a large portfolio of clients (because the local bank office predicts that the overall quality of the potential borrowers in that region is high), then the bank's aggregate portfolio has a heavy weight on lending in the other region. Depending on how the bank profit in the first region correlates with the bank profit in the other region, the bank group's aggregate portfolio of clients/investment projects need not be "optimal" in terms of risk diversification between the two regions. By referring to this as aggregate portfolio risk, it follows that a bank which has a decentralized decision-making structure may lack the ability to diversify effectively between regions. However, this problem need not arise in a bank with a centralized decision-making structure since centralized lending decisions makes it possible for the central management to take the aggregate portfolio risk into account.

Turning to point (iii), a financing externality may arise if the bank group's cost of financing is an increasing function of the total amount of funds that needs to be raised within the bank group. For example, this may reflect that the supply of deposits is an increasing function of the interest paid by the bank group. Under decentralized decision-making, each local branch may fail to recognize that its need to raise funds will affect the borrowing cost for the other branches. This creates an externality within the bank group which will lead to a too high borrowing cost from the perspective of the bank group as a whole.

The arguments underpinning points (i) - (iii) suggests a potential trade-off between, on one hand, effective client targeting and on the other hand aggregate portfolio risk and

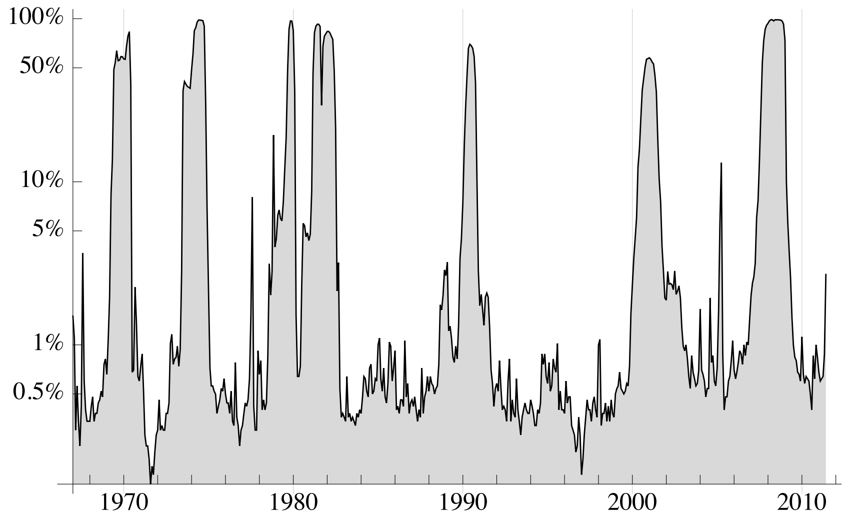


Figure 1: Logarithmic scaled plot of the historical U.S. recession probabilities from a dynamic-factor markov-switching model as in Chauvet and Piger (2008).

financing externalities. These trade-offs are likely to be intrinsically related to the organizational structure of a bank. Acknowledging this, we develop a theoretical banking model which incorporates the specific characteristics that are unique for a centralized and a decentralized bank respectively. Due to the complexity of the model, we use simulations to determine under what circumstances, and to what extent, the trade-offs presented in points (i) - (iii) work in favor of a centralized or a decentralized organizational structure.

The key issue that we focus on is which type of organizational structure that tends to perform better in terms of producing lower risk and higher profits (or lower losses) when the economy is hit by a recession. Since the probability of a recession varies over the business cycle, as illustrated in Figure 1, and since the probability of firm default is highly dependent on which phase of the business cycle the economy is in (see Helwege and Kleiman (1997), Fridson et al. (1997) and Carey (1998) among others), the risk associated with a given credit portfolio will change over the course of the business cycle, thereby influencing the bank's lending decisions.

In the simulations, we acknowledge the business cycle and calculate the actual profits/losses if a recession or a boom actually occurs. This allows us to study whether a bank which has chosen a lending strategy which will produce high expected profits if the economy is expected to boom, will suffer relatively larger losses if this prediction turns on its head and the actual outcome is a recession.

The outline of the paper is as follows. In Section 2, we briefly present the outline of the model. This is followed by a characterization of the borrowers in Section 3 and a characterization of the bank's problem in Section 4. The simulation results are presented in Section 5 and the paper is concluded in Section 6.

2 Outline of the Model

Consider an economy (country) that is made up of two regions, 1 and 2. Each region is populated by a large number of entrepreneurs who need to borrow funds to finance risky projects. At the national level there is a bank group which has a local branch in each region that supplies funds to a selected group of entrepreneurs in each region.

The timing of events is as follows. In period 1, each entrepreneur contacts the regional (local) bank office and applies for a loan. At the same instant, the bank evaluates the quality of the potential borrowers and, based on this evaluation, decides on the number of applicants eligible for credit. In period 2, the rates of returns of the entrepreneurs projects are realized which, in turn, determines the performance of the debt and the bank's profit.[2]

3 The Entrepreneurs

Each entrepreneur has a project which requires an initial and indivisible investment of one dollar. Entrepreneurs differ in terms of ability and there are two ability types; high-ability (h) and low-ability (l) entrepreneurs. The proportions of h- and l-types in the population of entrepreneurs in region $k = 1, 2$ are θ_k (high-ability) and $1 - \theta_k$ (low-ability). Ability is not known before (ex ante) the enterprise is set up which means that in period 1, when an entrepreneur applies for funds to make the investment, neither the entrepreneur nor the bank knows the true ability of the entrepreneur.[3] This uncertainty will be referred to as ability risk. Ability is revealed (ex post) in period 2 when the rate of return on the investment is realized.

[2] This means that our model abstracts from the possible information advantages associated with repeated lending, see Sharpe (1990); Rajan (1992); Petersen and Rajan (1994, 1995) among others.

[3] From an entrepreneur's perspective this uncertainty reflects that before the enterprise is set up, the entrepreneur does not know exactly what qualities are required to be successful in the business. Hence, even though each entrepreneur potentially knows his/her skills, the entrepreneur does not know which skills are important for being successful in the business. The bank, in turn, can be viewed as having had prior experience with firms in the business. As such, the bank knows what qualities are required to be successful but the bank's problem is that some of these qualities are intangible (e.g., social competence, self confidence, effectiveness in handling stress, etc.) which cannot be determined without putting in some effort to learn more about the potential client.

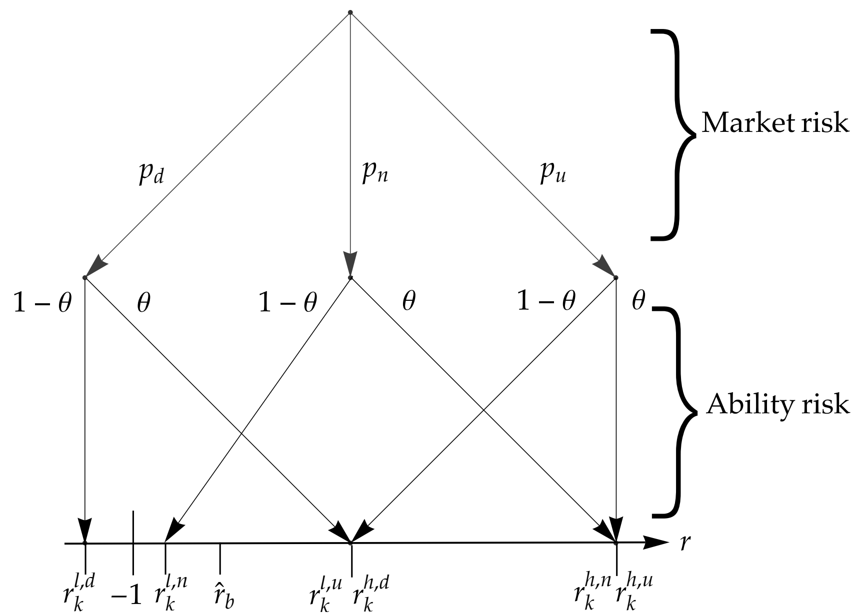


Figure 2: The projects' rate of return.

We let the projects' rate of return depend on whether the business cycle in period 2 features a boom, a recession or is somewhere in between these two extremes (henceforth referred to as a "normal" state). To model this market risk, we assume that with probabilities p_u, p_n and p_d the economy is in a boom (or upstate, u), in a normal state (n) or in a recession (or downstate, d), such that $p_u + p_n + p_d = 1$. Conditional on market condition j ($j = u, n, d$) realized in period 2, the project rate of return, $r_k^{i,j}$, for an entrepreneur of ability type i ($i = h, l$) in region k is illustrated in Figure 2.

There are two basic assumptions underlying this pay-off tree; high-ability entrepreneurs will never default on their loans whereas low-ability entrepreneurs will not be able to pay back the loan with full interest unless the economy is booming. This is illustrated in Figure 2 by incorporating the interest rate, $\hat{r}_k^b$, which is the interest rate charged by the bank that causes the entrepreneur's expected profit to be zero (see below). Thus, the first assumption implies $r_k^{h,u}, r_k^{h,n}, r_k^{h,d} \geq \hat{r}_k^b$ whereas the second implies $r_k^{l,u} \geq \hat{r}_k^b$ and $\hat{r}_k^b > r_k^{l,n}, r_k^{l,d}$. These two assumptions capture the essence of the empirically observed relationship between firm defaults and the phase of the business (see Helwege and Kleiman, 1997; Fridson et al., 1997; Carey, 1998, among others).

Note here that the rate of return is negative for l-entrepreneurs if the market condition is n or d. More specifically, if market condition n occurs, then the rate of low ability entrepreneur is $r_k^{l,n}$. Since $\hat{r}_k^b > r_k^{l,n} > -1$ (as illustrated in Figure 2), the bank has first priority on the rest value of an l-entrepreneur's firm, which is given by $1 + r_k^{n,l}$. On the other hand, if market condition d occurs, then the rate of low ability entrepreneur is $-1 > r_k^{l,d}$, in which case the bank's loss on the loan provided to an l-entrepreneur is 100 percent.

We normalize each entrepreneur's initial endowment of resources to zero which means that each entrepreneur needs to finance his/her investment by borrowing from the bank. Since each entrepreneur is oblivious about his/her ability type, and acknowledging that each entrepreneur needs one dollar to undertake the investment, the expected profit, $E(\pi_k)$, evaluated in period 1 for an arbitrary entrepreneur in region k is given by:

$$E(\pi_k) = [1 + E(r_k)] - \left(1 + r_k^b\right) = E(r_k) - r_k^b, \tag{1}$$

where:

$$\begin{aligned} E(r_k) &= p_u \cdot E^u(r_k) + p_n \cdot E^n(r_k) + p_d \cdot E^d(r_k) \\ E^u(r_k) &= \theta_k \cdot r_k^{h,u} + (1-\theta_k) \cdot r_k^{l,u} \\ E^n(r_k) &= \theta_k \cdot r_k^{h,n} + (1-\theta_k) \cdot r_k^{l,n} \\ E^d(r_k) &= \theta_k \cdot r_k^{h,d} + (1-\theta_k) \cdot r_k^{l,d}. \end{aligned}$$

Here, $E(r_k)$ is the unconditional expected rate of return of investing one dollar in an arbitrary entrepreneur's enterprise before ability and market condition have been revealed, whereas $E^i(r_k)$ is the expected value of r_k conditional on the economy being is in state i. As such, the upper branch in the pay-off tree in Figure 2 reflects the market risk associated with investing one dollar in the enterprise whereas the lower branch captures the ability risk.

From equation (1), it follows that potential entrepreneurs will apply for loans as long as $E(r_k) - r_k^b \geq 0$ which means that this condition can be viewed as a *participation constraint* on behalf of the entrepreneurs. The interest rate which makes the entrepreneur's expected profit in equation (1) equal to zero is denoted $\hat{r}_k^b$. As such, $\hat{r}_k^b$ is exogenously determined by the parameters appearing in equation (1). In the simulations we set the parameter values in accordance with the pay-off tree in Figure 2 such that $\hat{r}_k^b$ satisfies the inequality:

$$r_k^{l,u}, r_k^{h,d}, r_k^{h,n}, r_k^{h,u} > \hat{r}_k^b > r_k^{l,n}, r_k^{l,d}.$$

4 The Bank

As mentioned above, the entrepreneurs contact the bank in period 1 to apply for loans. Since the bank cannot observe the true ability of an individual entrepreneur, it will screen the applicants to obtain an estimate of their ability. In this process potential *h*-entrepreneurs are sorted into the pool of borrowers whereas potential *l*-entrepreneurs are discarded. If the bank would not collect any background information about the applicants, this process would be a random draw where the expected proportion of *h*-entrepreneurs in the pool of borrowers in region k would be given by θ_k. However, by putting in some effort, e_k, to collect information about an applicant, the bank can detect and sort away some *l*-entrepreneurs, thereby increasing the proportion of *h*-entrepreneurs in the pool of borrowers. Here, the characteristics of an individual applicant can be used as predictors of ability, and the more information that is collected about an applicant, the better the prediction. Hence, the more effort that is put into the screening process, the larger will be the proportion, $z_k = z(e_k)$, of true *h*-entrepreneurs in the pool of borrowers in region k. The proportion of *l*-entrepreneurs who are incorrectly sorted into this pool is then given by $1 - z(e_k)$. Observe that the bank does not know the true ability of any given entrepreneur in the pool of borrowers. The sorting just increases the probability that any given entrepreneur in the pool is of high-ability. As such, the possibility to eliminate some *l*-entrepreneurs from the list of applicants can be viewed as changing the distribution of entrepreneurs from which the bank draws a sample when it lend funds. We require that the function $z_k = z(e_k)$ satisfies the following conditions:

$$z'(e_k) > 0, \quad z(0) = \theta_k, \quad \lim_{e_k \to \infty} z(e_k) = 1.$$

The first two properties follow from the discussion above, whereas the third reflects that for finite levels of effort, there will always be a random element in the sorting of agents into the pool of borrowers. A functional form that satisfies the criteria laid out above, and which will be used in the simulations, is:

$$z(e_k) = \theta_k + q(e_k) \cdot (1 - \theta_k),$$

where:

$$q(e_k) = 1 - \exp(-e_k).$$

We let $0 \leq e_k < \infty$ such that the function $q(e_k)$ lies in the interval $[0, 1]$.

To determine how many applicants, M_k, that needs to be screened in region k to obtain a pool of borrowers in which the expected proportion of *h*-entrepreneurs is $z(e_k)$, observe first that, conditional on the level of $z(e_k)$, the expected number of true *h*-entrepreneurs within the pool of N_k borrowers is given by $z(e_k) \cdot N_k$. We now ask the following question: from the population of entrepreneurs in region k, where the proportion of high-ability entrepreneurs is θ_k, how many applicants must be screened in order to obtain $z(e_k) \cdot N_k$ high-ability entrepreneurs? The answer[4] is obtained by setting $z(e_k) \cdot N_k$ equal to $\theta_k \cdot M_k$. Solving for M_k from this equality produces:

$$M_k = \frac{z(e_k) \cdot N_k}{\theta_k}. \tag{2}$$

Equation (2) shows that (i) the larger the bank requires the proportion of high ability entrepreneurs (z_k) to be within the pool of borrowers, (ii) the lower the proportion of high-ability entrepreneurs (θ_k) is within the population and (iii) the more loans (N_k) the bank wants to provide, the larger will be the number of persons that needs to be screened.

Since the effort put into screening a potential borrower in region k is e_k, it follows that the total screening effort made by the bank in region k is given by $e_k \cdot M_k$. The cost of this screening effort in region k is an increasing and (weakly) convex function $S_k(\cdot)$, where $S_k'(\cdot) > 0$ and $S_k''(\cdot) \geq 0$. In the simulations, we use a quadratic functional form:

$$S_k(e_k \cdot M_k) = \alpha_{k,1} \cdot (e_k \cdot M_k) + \alpha_{k,2} \cdot (e_k \cdot M_k)^2, \tag{3}$$

where $\alpha_{k,1} > 0$ and $\alpha_{k,2} \geq 0$ are parameters which capture the regional bank's cost effectiveness of handling intangible soft information. Since empirical studies have found that small and decentralized banks rely more heavily on soft information (Liberti, 2009) and since soft information may be hard to quantify (Petersen, 2004), it is reasonable to assume that centralized banks are subject to an additional screening cost when they move the information upwards in the hierarchy. In terms of our model framework, this indicates that the marginal cost of effort is lower under decentralized banking such that decentralized banks will but more effort into building relationships than do their centralized counterparts. This assumption basically reflects that, the shorter the chain of command is within the bank, the lower the cost of obtaining and transmitting information through the bank hierarchy. As such, we assume that $S_k'(\cdot)$ is lower for a decentralized bank (working through lower values of $\alpha_{k,1}$ and $\alpha_{k,2}$) than in a bank where the decisions are centralized. In the discussions below, we will refer to this as decentralized banks being more cost efficient with respect to screening than centralized banks.

We now characterize the bank's pay-off, R_k, of lending one dollar to an entrepreneur in region k. The pay-off of the loan is the amount the bank actually receives in period 2

[4]Recall that the screening process detects and eliminates l-entrepreneurs from the pool of borrowers. Therefore, among the M_k agents who are screened, no h-entrepreneurs are lost which means that the expected number of h-entrepreneurs, $\theta_k \cdot M_k$, is unchanged in the screening process.

when borrower default is taken into account. From Figure 2, it follows that if the bank charges the interest rate $\hat{r}_k^b$, then the set of possible pay-offs are given by:

$$R_k^{h,u} = R_k^{h,n} = R_k^{h,d} = R_k^{l,u} = 1 + \hat{r}_k^b$$
$$R_k^{l,n} = 1 + r_k^{l,n} < 1 + \hat{r}_k^b, \quad R_k^{l,d} = 0.$$

Given this pay-off structure, and conditional on e_k, the expected pay-off of lending one dollar is given by:

$$E\left(R_k\right) = \left(1 + \hat{r}_k^b\right) - \left[1 - z\left(e_k\right)\right] \cdot \left[p_n \cdot \left(\hat{r}_k^b - r_k^{l,n}\right) + p_d \cdot \left(1 + \hat{r}_k^b\right)\right].$$

Let us now turn to the bank's profit. Since we focus on the effects of organizational structure, we keep the model as simple as possible and assume that the accounting identity for the bank at the national level is written:

$$D + E = N. \tag{4}$$

Equation (4) shows that the bank group's total liabilities are made up of private equity, E, and total deposits, D, whereas total assets are made up of the amount of loans issued in the two regions, $N = N_1 + N_2$. Cash reserves are normalized to zero. Private equity is exogenously given and in the following, we will normalize E to be zero, which means that $D = N_1 + N_2$. The supply of deposits are an increasing function of the interest rate paid by the bank, ρ, henceforth referred to as the bank's financing rate. The positive relationship between ρ and D reflects that the bank has to pay a larger interest rate to attract more depositors. Hence $\rho'\left(D\right) > 0$, and in the simulations we use a quadratic form for this function:

$$\rho\left(D\right) = b_1 \cdot D + b_2 \cdot D^2,$$

where $b_1 > 0$ and $b_2 \geq 0$ are two exogenously given parameters that determine the bank's financing cost. The bank group's profit, Π, can then be written as:

$$\Pi = \sum_{k=1}^{2} \left[N_k \cdot \bar{R}_k - S_k\left(e_k \cdot M_k\right)\right] - \left[1 + \rho\left(D\right)\right] \cdot D,$$

where:

$$\bar{R}_k = \frac{1}{N_k} \cdot \sum_{m=1}^{N_k} R_{k,m} \quad \text{for } k = 1, 2.$$

We can use equations (2) and (5) to write the expected profit as:

$$E\left(\Pi\right) = E\left(\Pi_1\right) + E\left(\Pi_2\right),$$

where:

$$E(\Pi_1) = N_1 \cdot E(\bar{R}_1) - S_1\left(\frac{e_1 \cdot z(e_1) \cdot N_1}{\theta_1}\right) - [1 + \rho(N_1 + N_2)] \cdot N_1$$
$$E(\Pi_2) = N_2 \cdot E(\bar{R}_2) - S_2\left(\frac{e_2 \cdot z(e_2) \cdot N_2}{\theta_2}\right) - [1 + \rho(N_1 + N_2)] \cdot N_2.$$

4.1 Objective Function and Measures of Risk

We allow the bank to care both about the expected profit and the volatility of profit, where the latter is a measure of the risk associated with lending. The question is what measure of volatility to use to capture risk? One approach is to follow the bulk of the finance literature and use the variance of the profit. This implies that we can write the bank group's risk-adjusted expected profit as:

$$\Omega = E(\Pi_1) + E(\Pi_2) - \frac{1}{2} \cdot A \cdot Var(\Pi), \tag{5}$$

where:

$$\begin{aligned} Var(\Pi) &= Var(\Pi_1) + Var(\Pi_2) + 2 \cdot Cov(\Pi_1, \Pi_2) \qquad (6) \\ Var(\Pi_k) &= E[\Pi_k - E(\Pi_k)]^2 \text{ for } k = 1, 2 \\ Cov(\Pi_1, \Pi_2) &= E[(\Pi_1 - E(\Pi_1)) \cdot (\Pi_2 - E(\Pi_2))], \end{aligned}$$

and where $A \geq 0$ reflects the degree of risk-aversion. If $A = 0$, the bank is risk-neutral whereas a level of $A > 0$ indicates risk aversion. As such, the parameter A can be viewed as reflecting the risk culture within the bank group. The measure $Var(\Pi_k)$ will be referred to as the total risk in region k whereas $Var(\Pi)$ is the total risk within the bank group. These risk measures can be decomposed according to:

$$\begin{aligned} \text{total risk} &= \text{market risk} + \text{ability risk} \\ Var(\Pi_k) &= Var_m(\Pi_k) + Var_a(\Pi_k), \end{aligned}$$

where the market risk $Var_m(\Pi_k)$ is the variance associated with the first leg in Figure 2 in region k whereas the ability risk $Var_a(\Pi_k)$ is the variance associated with the second leg in Figure 2 in region k.

Another approach frequently used in the finance literature is to incorporate the downside variance (also referred to as the semivariance) as a measure of risk. In the simulations, we have used both the variance and various semivariance measures as indicators of risk and they produce the same qualitative results. Therefore, when we present the results from the simulations, we only show the results associated with the variance of profits as a measure of risk.

4.2 Organizational Structure

Let us now characterize the choices made within the bank group. As mentioned earlier, we will consider two different organizational structures; centralized and decentralized banking.

4.2.1 Centralized Banking

In terms of this model, centralized banking implies that all decisions are taken at the national level. This means that the objective function coincides with equation (5). Thus, by using equation (5) and (6), we can write the centralized bank's objective function as:

$$\Omega^C = \Omega_1 + \Omega_2 - A \cdot Cov\left(\Pi_1, \Pi_2\right), \tag{7}$$

where super-index C stands for "centralized" and where:

$$\Omega_k = E\left(\Pi_k\right) - \frac{1}{2} \cdot A \cdot Var\left(\Pi_k\right) \text{ for } k = 1, 2, \tag{8}$$

is the risk-adjusted profit associated with region k. The decision variables are given by the vector $\left(r_1^b, e_1, N_1, r_2^b, e_2, N_2\right)$. However, from the entrepreneurial participation constraint in equation (1) it follows that r_k^b cannot exceed $E\left(r_k\right)$ and this constraint will be binding, i.e. $\hat{r}_k^b = E\left(r_k\right)$. This means that the actual decision variables are $\left(e_1, N_1\right)$ and $\left(e_2, N_2\right)$. This also applies under decentralized banking.

4.2.2 Decentralized Banking

Under decentralized banking, all decisions are taken at the regional level which means that the local bank in region k chooses the policy vector $\left(e_k, N_k\right)$ while it treats the choices made by the local bank in the other region as exogenous. From this perspective, the two local banks play a non-cooperative Nash game vis-a-vis each other. The only thing that takes place at the central level is the financing. This is assumed to work as follows. Once the local bank has determined N_k, the local bank office requests the central level of the bank to arrange the funds that are needed to lend the required amount. Hence, the funds that the bank at the central level needs to raise is $N = N_1 + N_2$.

The objective function for the local bank in region k is the local risk-adjusted profit defined in equation (8) which means that:

$$\Omega_k^{DC} = E\left(\Pi_k\right) - \frac{1}{2} \cdot A \cdot Var\left(\Pi_k\right), \tag{9}$$

where super-index DC stands for "decentralized". Since the bank group's risk culture may be the same regardless of organizational structure, we assume that the parameter A takes the same value in both banking regimes.

4.2.3 Centralized vs Decentralized Decision-Making

The decisions regarding lending and screening effort will differ between centralized and decentralized banks and there are three basic reasons for this;

(i). Decentralized banks may be more cost efficient with respect to screening than their centralized counterparts. We call this the *cost efficiency effect*.
(ii). A centralized bank may be more efficient in diversifying the lending portfolio between regions. We call this the *diversification effect*.
(iIi). Decentralized decision-making may give rise to *financing externalities* within the bank group.

To see clearly how the cost efficiency effect, the diversification effect and the financing externality cause the choices made by the bank in a centralized regime to differ from those made by the bank in the decentralized regime, let us consider the bank's optimal choice of N_k in the two regimes. When the decisions are centralized and the bank's objective function is Ω^C, the first order condition with respect to N_1 becomes (the first-order condition for N_2 is analogous):

$$\begin{aligned}\frac{\partial \Omega^C}{\partial N_1} = 0 =& E\left(\bar{R}_1\right) - \frac{\partial S_1^C}{\partial N_1} - A \cdot \left[\frac{1}{2} \cdot \frac{\partial Var\left(\Pi_1\right)}{\partial N_1} + \frac{\partial Cov\left(\Pi_1, \Pi_2\right)}{\partial N_1}\right] \\ & - \left[1 + \rho\left(D\right)\right] - \left[1 + \rho'\left(D\right)\right] \cdot \left(N_1 + N_2\right). \end{aligned} \tag{10}$$

On the other hand, when decisions are decentralized, then the local bank's objective function is given by Ω_k^{DC}. The first-order condition with respect to N_1 then becomes (the first-order condition for N_2 is analogous):

$$\begin{aligned}\frac{\partial \Omega_1^{DC}}{\partial N_1} = 0 =& E\left(\bar{R}_1\right) - \frac{\partial S_1^{DC}}{\partial N_1} - A \cdot \frac{1}{2} \cdot \frac{\partial Var\left(\Pi_1\right)}{\partial N_1} \\ & - \left[1 + \rho\left(D\right)\right] - \left[1 + \rho'\left(D\right)\right] \cdot N_1. \end{aligned} \tag{11}$$

In equation (10), the function S_1^C is the cost function associated with screening under centralized banking whereas S_1^{DC} in equation (11) is the cost function associated with screening under decentralized banking. These cost functions differ because decentralized banks may be more cost efficient with respect to screening than their centralized counterparts.

As mentioned earlier, the cost efficiency effect is incorporated into the model by setting lower values of the parameters $\alpha_{k,1}$ and $\alpha_{k,2}$ in equation (3) for a decentralized bank than for a bank where the decisions are centralized. As such, for given levels of e and N, it follows that $\partial S_1^C / \partial N_1 > \partial S_1^{DC} / \partial N_1$. All else equal, this cost efficiency effect provides the bank in the decentralized regime with an incentive to provide more loans than the bank in the centralized regime.

Second, comparing the last term in the first row of equation (10) with the corresponding term in equation (11), we see that the effect of N_1 on $Cov\left(\Pi_1, \Pi_2\right)$ is present in equation (10) but absent in equation (11). The reason is that the risk-adjusted objective function differs between the two banking regimes. Recall that when the decisions are centralized, then the risk-adjusted profit is given by equation (7), whereas when the decisions are decentralized, then each regional bank maximizes Ω_k^{DC} which means that the risk-adjusted profit summed over both regions becomes:

$$\Omega^{DC} = \Omega_1^{DC} + \Omega_2^{DC}. \tag{12}$$

As can be seen, equations (7) and (12) do not coincide and the difference lies in the fact that when decisions are decentralized, the regional banks do not take into account the covariation between Π_1 and Π_2 when they make their decisions. If $\partial Cov\left(\Pi_1, \Pi_2\right) / \partial N_1 > 0$ (as one would normally expect) then this term will, all else equal, provide the bank in the centralized regime with an incentive to provide fewer loans than the bank in the decentralized regime (see equation (10)). This is the diversification effect.

Third, equations (10) and (11) also differ with respect to the final term in the second row in each equation. In these equations, the final term reflects that an increase in the number of loans will lead to a higher cost per loan via a higher financing rate (ρ). The difference between the two banking regimes is that under decentralized decision-making, the local bank only recognizes the effect of a higher financing rate on its loans, N_1, whereas under centralized decision-making, the bank takes into account the effects of a higher financing rate in both regions. Since the local bank in each region fails to recognize how its decision affects the cost of lending in the other region, the local banks effectively impose an externality upon each other when decisions are decentralized. All else equal, this failure in coordination under decentralized decision-making will induce each local bank to provide more loans than is optimal from the perspective of the bank group as a whole. This is the financing externality.

5 Simulations

Because of the difficulties associated with obtaining analytical solutions from the theoretical model, we simulate outcomes using constrained numerical optimization.[5] The presentation of our results will be divided into four parts. As for the first three parts, we know from the analysis above that the cost efficiency effect, the financing externality and the diversification effect will influence decentralized (DC) decision-makers to choose different levels of e and N than centralized (C) decision-makers. Therefore, in Section 5.1 we analyze the difference in outcomes between centralized and decentralized banking when only the cost efficiency effect applies while the financing externality and the diversification effect are made redundant. In Section 5.2, we instead analyze the behavior when only the financing externality is present while the cost efficiency effect and the diversification effect are made redundant and in Section 5.3, we look at the diversification effect when the cost efficiency effect and the financing externality are made redundant. The parameter values used in the simulations are presented in the Appendix.

Having worked out these isolated effects, we continue in Section 5.4 by analyzing the full model, where the cost efficiency effect, the financing externality and the diversification effect simultaneously influence the choices made under centralized and decentralized decision-making, respectively.

In all simulations, a key question is how the outcome in the two banking regimes differ when the probability of a deep recession (which in this model corresponds to market condition downstate) is increased. In the full model, we also analyze how the profits in the two banking regimes are affected if a "black swan" hits the economy. By that we mean that a recession unexpectedly hits the economy, even though the initial probability for such an event was low.

5.1 The Pure Cost Efficiency Effect

To isolate the cost efficiency effect we need to eliminate the diversification effect and the financing externality from the model. To eliminate the former we set the degree of risk aversion (A) equal to zero in equations (7) and (9). This means that the bank effectively becomes risk-neutral in which case the incentive to diversify away risk is absent. To eliminate the financing externality from the model, we allow each local branch in the bank group to have a separate financing function which is independent of the other branch's amount of borrowing. As a consequence, the financing function in region k is given by $\rho(N_k)$ (instead of $\rho(N_1 + N_2)$). Having made these adjustments, only the cost efficiency

[5] Mathematica is used in the simulations. See the Appendix for details.

Table 1: Summarized effects; pure cost efficiency effect.

(a) Implied relationships.

$$e^{DC} > e^{C} \quad N^{DC} > N^{C} \quad E(\Pi^{DC}) > E(\Pi^{C})$$

$$Var\left(\Pi^{DC}\right) < Var\left(\Pi^{C}\right) \quad Var_m\left(\Pi^{DC}\right) < Var_m\left(\Pi^{C}\right)$$

(b) Summarized effects; increase in the probability of a recession.

$$\overset{(+)}{e^{DC}} \quad \overset{(+)}{e^{C}} \quad \overset{(-)}{N^{DC}} \quad \overset{(-)}{N^{C}} \quad \overset{(-)}{\left(\frac{e_{DC}}{e_{C}}\right)} \quad \overset{(+)}{\left(\frac{N^{DC}}{N^{C}}\right)}$$

$$\overset{(+)}{\left(\frac{E(\Pi^{DC})}{E(\Pi^{C})}\right)} \quad \overset{(-\text{ then }+)}{\left(\frac{Var(\Pi^{DC})}{Var(\Pi^{C})}\right)} \quad \overset{(-\text{ then }+)}{\left(\frac{Var_m(\Pi^{DC})}{Var_m(\Pi^{C})}\right)}$$

effect (i.e. that $\alpha_k^C > \alpha_k^{DC}$ in the screening cost function defined in equation (3)) remains in the model.

In Table 1, we summarize the results in the presence of the pure cost efficiency effect. As can be seen in Table 1(a), the bank in the DC-regime chooses a higher screening effort than the (less cost efficient) bank in the C-regime which implies that the proportion of h-entrepreneurs among the borrowers will be larger in the former regime ($z\left(e^{DC}\right) > z\left(e^{C}\right)$). A consequence of this is that the expected marginal revenue of an increase in N will (from any given initial level) be larger under decentralized banking. This will induce the decentralized bank to lend more funds ($N^{DC} > N^{C}$) than the centralized bank which causes the expected profit to be larger in the DC-regime ($E(\Pi^{DC}) > (E(\Pi^{C}))$. Observe, however, that even though the portfolio of loans is larger under decentralized banking, the ability to be more effective in terms of sorting out poor clients means that the risk (measured both in terms of market risk and total risk) in the bank's portfolio of loans is smaller under decentralized banking than under centralized banking.

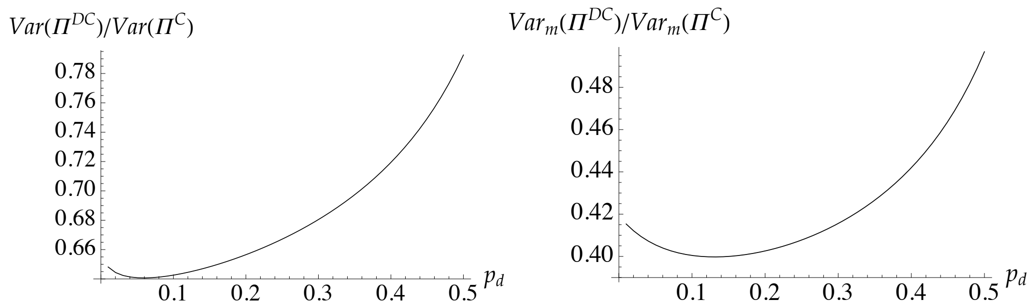
Next, recall from the introduction that the probability of a recession changes over the course of the business cycle (see Figure 1). Let us therefore take a closer look at how the two banking regimes' optimal choices of e and N, and the resulting profit and risk levels, are affected by an increase in the probability that a recession will occur (p_d). In our simulations, the increase in p_d is matched by a corresponding reduction in p_u while p_n is unchanged. The effects are summarized in Table 1(b) and the direction of change in each variable is indicated by the sign above the variable at hand. From Table 1(b), we see that when the probability of a recession increases, then the screening effort increases in both regimes because it is now more important than before to eliminate "rotten eggs" from the portfolio of loans. The increase in e is proportionally larger under centralized banking which causes the ratio e^{DC}/e^{C} to decrease, but our simulations show that e^{DC} will nevertheless exceed e^{C}. In addition, the increase in p_d has a negative effect on the number of loans granted in both regimes. Here, N^{C} is reduced proportionally more than N^{DC} which causes the ratio N^{DC}/N^{C} to increase but N^{DC} will still exceed N^{C}.

These results indicate that in the presence of the pure cost efficiency effect, the preventive response to an *expected* recession is stronger under centralized banking than under decentralized banking. The explanation is straightforward. Since the client targeting activity is less efficient under centralized banking, such a bank tends to be more exposed to credit losses if a recession actually occurs. Hence, it is this type of bank which is in greater need to cut its lending portfolio, if a recession becomes more likely to happen. Stretching our argument a bit, we may say that banks under centralized decision-making may be more inclined to "push the panic button" when the prospect of a recession looms large.

Let us now take a look at how these responses affect the profit and risk levels in the two banking regimes. From Table 1(b) it follows that the ratio of expected profits increases. This basically reflects that when a recession is more likely to occur, it becomes more important than before to have a large proportion of h-entrepreneurs in the pool of borrowers. Since the client targeting activity is more effective under decentralized banking, this favors the decentralized banking system when the likelihood of a recession is increased.

Turning to the risk levels, the indicator "$-$ then $+$" above the ratio of the total risk and the ratio of the market risks means that the ratio first decreases but after some level of p_d, the ratio instead increases. This is illustrated in Figure 3.

To explain the U-shaped effect on the risk ratios, observe that two opposite effects are at work here. On the one hand, the client targeting is more effective under decentralized banking, which means that for given levels of e and N, the increase in the market risk and the total risk following a larger value of p_d is relatively smaller under decentralized banking than under centralized banking. For given levels of e and N, this *conditional effect* works in the direction of reducing the risk ratios $Var\left(\Pi^{DC}\right)/Var\left(\Pi^{C}\right)$ and $Var_m\left(\Pi^{DC}\right)/Var_m\left(\Pi^{C}\right)$. On the other hand, when e and N change in response to the increase in p_d, then the simulations indicate that it is the bank in the centralized regime which adjusts its choices of e and N relatively more than the bank in the decentralized regime. This *response effect* works in the direction of increasing the market risk ($Var_m\left(\Pi\right)$) and the total risk ($Var\left(\Pi\right)$) but these increases are smaller under centralized banking than under decentralized banking. Hence, the response effect works in the direction of in-



(a) Ratio of total risk

(b) Ratio of market risk

Figure 3: The ratio of total risk (left) and the ratio of market risk (right) when the proportion of high ability entrepreneurs is equal between regions; pure cost efficiency effect.

creasing the risk ratios $Var(\Pi^{DC})/Var(\Pi^{C})$ and $Var(\Pi_m^{DC})/Var_m(\Pi^{C})$. As such, the total effect on the market risk and the total risk in the two banking regimes is ambiguous and our simulations indicate that the conditional effect dominates for low levels of p_d whereas the response effect dominates for larger levels of p_d.

5.2 The Pure Financing Externality

Let us now turn to the financing externality. To eliminate the diversification effect, the degree of risk aversion (A) is set equal to zero and to eliminate the cost efficiency effect, we set the parameters $\alpha_{k,1}$ and $\alpha_{k,2}$ in the screening cost function (equation (3)) at the same levels in the two banking regimes.

The simulation results are summarized in Table 2. As we argued earlier in the paper, the financing externality provides the bank in the decentralized regime with an incentive to over-provide the number of loans, and this is verified in the simulations where $N^{DC} > N^{C}$. As a consequence, the expected profit is lower under decentralized banking than under centralized banking. Another effect of the over-provision of loans is that it reduces the decentralized bank's screening effort ($e^{DC} < e^{C}$) because the screening cost is increasing in N. Even though this implies that the client targeting activity is more efficient in the centralized regime, this need not imply that the total risk and the market risk are lower compared with the decentralized regime. Rather, our simulations indicate that when the two regions are symmetric in terms of having the same proportion of h-entrepreneurs in the population (i.e., $\theta_1 = \theta_2$), then the risks are lower in the centralized regime. On the other hand, when $\theta_1 \neq \theta_2$, then the risks may be lower in the decen-

Table 2: Summarized effects; pure finance externality.

(a) Implied relationships.

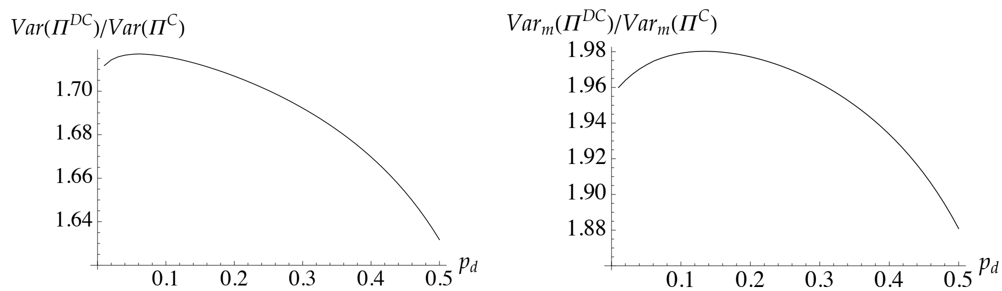
$e^{DC} < e^{C}$	$N^{DC} > N^{C}$	$E(\Pi^{DC}) < E(\Pi^{C})$
$Var\left(\Pi^{DC}\right) >< Var\left(\Pi^{C}\right)$	$Var_m\left(\Pi^{DC}\right) >< Var_m\left(\Pi^{C}\right)$	

(b) Summarized effects; increase in the probability of a recession.

$(+)$	$(+)$	$(-)$	$(-)$	$(+)$ or $(+$ then $-)$	$(-)$
e^{DC}	e^{C}	N^{DC}	N^{C}	$\left(\dfrac{e_{DC}}{e_{C}}\right)$	$\left(\dfrac{N^{DC}}{N^{C}}\right)$
$(+)$ or $(+$ then $-$ then $+)$	$(+$ then $-)$	$(+$ then $-)$			
$\left(\dfrac{E(\Pi^{DC})}{E(\Pi^{C})}\right)$	$\left(\dfrac{Var(\Pi^{DC})}{Var(\Pi^{C})}\right)$	$\left(\dfrac{Var_m(\Pi^{DC})}{Var_m(\Pi^{C})}\right)$			

tralized regime. This latter result can be explained by acknowledging that the centralized bank tends to focus its resources on the less risky region. By doing so, the centralized bank increases the variance of the profit associated with the less risky region by more than it reduces the variance in the profit associated with the riskier region.

Let us now turn to the effects of an increase in the probability that a recession will occur. These results are summarized in Table 2(b) from which we see that when the risk of a (deep) recession increases, then e increases and N decreases in both banking regimes (as they did in Section 5.1). However, the net effect on the ratios e^{DC}/e^{C} and $E(\Pi^{DC})/E(\Pi^{C})$ depends on whether the two regions in which the bank group is active have similar ($\theta_1 = \theta_2$) or different proportions ($\theta_1 \neq \theta_2$) of h-entrepreneurs in their respective populations. If the two regions are symmetric ($\theta_1 = \theta_2$) then the effect of an increase in p_d on e^{DC}/e^{C} is positive, but if the two regions are asymmetric ($\theta_1 \neq \theta_2$) then the ratio e^{DC}/e^{C} may be increasing in p_d for low levels of p_d but after some critical value of p_d, the ratio instead decreases. As for the ratios N^{DC}/N^{C}, $Var\left(\Pi^{DC}\right)/Var\left(\Pi^{C}\right)$ and $Var_m\left(\Pi^{DC}\right)/Var_m\left(\Pi^{C}\right)$, the signs in Table 2(b) are opposite to those presented in Table 1(b) in Section 5.1. The explanation is that (in contrast to the situation in Section 5.1) it is now the bank in the decentralized regime which is less effective in its client targeting activity. Hence, it is the decentralized bank that adjusts more strongly if the probability of a recession increases. By using the same type of arguments as in Section 5.1, we can explain why the ratios e^{DC}/e^{C}, N^{DC}/N^{C}, $Var\left(\Pi^{DC}\right)/Var\left(\Pi^{C}\right)$ and $Var_m\left(\Pi^{DC}\right)/Var_m\left(\Pi^{C}\right)$ in Table 2(b) have opposite signs compared with those presented in Section 5.1. As conse-



(a) Ratio of total risk

(b) Ratio of market risk

Figure 4: The ratio of total risk (left) and the ratio of market risk (right) when the proportion of high ability entrepreneurs is equal between regions; pure financing externality.

quence, the relationship between the risk ratios and the probability of a recession are now featuring an inverted U-shape, as illustrated in Figure 4.

Another result is that an increase in p_d has an ambiguous effect on the ratio of expected profits, $E(\Pi^{DC})/E(\Pi^{C})$. This is related to whether the two regions are symmetric ($\theta_1 = \theta_2$) or asymmetric ($\theta_1 \neq \theta_2$). Since it is the bank in the decentralized regime which increases its screening activity relatively more than the bank in the centralized regime when $\theta_1 = \theta_2$, it follows that the subsequent increase in the proportion of h-entrepreneurs that accompanies the increase in e tends to be larger in the decentralized regime than in the centralized regime. As a consequence, $E(\Pi^{DC})$ will be reduced by a relatively smaller amount than $E(\Pi^{C})$ following an increase in p_d. This explains why $E(\Pi^{DC})/E(\Pi^{C})$ is increasing in p_d when $\theta_1 = \theta_2$. On the other hand, if $\theta_1 \neq \theta_2$, this result need not hold because when the probability of a recession becomes sufficiently large, the bank in the centralized regime tends to cut back on lending altogether in the risky region whereas the bank in the decentralized regime continues to lend. As a consequence, $E(\Pi^{C})$ is reduced "faster" than $E(\Pi^{DC})$, resulting in an increase in the ratio $E(\Pi^{DC})/E(\Pi^{C})$.

5.3 The Pure Diversification Effect

Let us now turn to the pure diversification effect. To eliminate the financing externality, the financing function in region k is written $\rho\left(N_k\right)$ and to eliminate the cost efficiency effect, the parameters in equation (3) (i.e. the screening cost function) are set at the same levels in the two banking regimes.

The simulation results are summarized in Table 3. From Table 3(a) we see that in the presence of only the diversification effect, the market risk and the total risk will be smaller

Table 3: Summarized effects; pure diversification effect.

(a) Implied relationships.

$e^{DC} < e^{C}$	$N^{DC} > N^{C}$	$E(\Pi^{DC}) > E(\Pi^{C})$
$Var\left(\Pi^{DC}\right) > Var\left(\Pi^{C}\right)$	$Var_m\left(\Pi^{DC}\right) > Var_m\left(\Pi^{C}\right)$	

(b) Summarized effects; increase in the probability of a recession.

$\overset{(+)}{e^{DC}}$	$\overset{(+)}{e^{C}}$	$\overset{(-)}{N^{DC}}$	$\overset{(-)}{N^{C}}$	$\overset{(-\text{ then }+)}{\left(\frac{e_{DC}}{e_{C}}\right)}$	$\overset{(+\text{ then }-)}{\left(\frac{N^{DC}}{N^{C}}\right)}$
$\overset{(+\text{ then }-)}{\left(\frac{E(\Pi^{DC})}{E(\Pi^{C})}\right)}$	$\overset{(+\text{ then }-)}{\left(\frac{Var(\Pi^{DC})}{Var(\Pi^{C})}\right)}$	$\overset{(+\text{ then }-)}{\left(\frac{Var_m(\Pi^{DC})}{Var_m(\Pi^{C})}\right)}$			

for the bank in the centralized regime. The reason is that when decisions are centralized, the bank in the centralized regime has an opportunity to obtain a better diversified portfolio of loans between the two regions than the bank in the decentralized regime. As can be seen in Table 3(a), the possibility to effectively diversify between regions gives the bank in the centralized regime an incentive to provide fewer loans compared with when the lending decisions are uncoordinated, which is in line with the discussion in Section 4.2.3. Another result is that since the screening cost is increasing in N, it follows that a bank in the centralized regime will put in a larger screening effort than a bank in the decentralized regime ($e^{C} > e^{DC}$). This means that the ability to be more effective in diversifying the lending portfolio between regions leads to a more efficient client targeting activity in the centralized regime. Finally, observe that since the bank in the decentralized regime tends to over-provide the number of loans in the presence of the pure diversification effect, both the expected profit levels and the risk levels will be larger under decentralized banking than under centralized banking (i.e. $E(\Pi^{DC}) > E(\Pi^{C})$ and $Var\left(\Pi^{DC}\right) > Var\left(\Pi^{C}\right)$). However, the bank group's risk-adjusted expected profit in the centralized regime will, nevertheless, exceed that in the centralized regime ($\Omega^{C} > \Omega^{DC}$).

As for the effects of an increase in the probability that a recession will occur (p_d), they are summarized in Table 3(b). The intuition for these results are the same as for the corresponding outcomes in Section 5.2.

5.4 The Full Model

Let us now turn to the full model where the cost efficiency effect, the financing externality and the diversification effect are all present simultaneously. Observe that the full model is more than just the sum of the three effects in Section 5.1 - 5.3 because we kept the degree of risk aversion (A) equal to zero when we analyzed the cost efficiency effect and the finance externality effect in isolation. Therefore, when all three effects are included in a full model experiment where $A > 0$, we add an extra dimension to the analysis.

To achieve an easy overview of how centralized and decentralized banking may differ when all above mentioned effects are added together, we simulate the optimal choices of e and N using the experimental plan presented in Table 4. As can be seen, we vary five key parameters in two levels producing a total of $2^5 = 32$ data points. This, in turn, makes it possible to calculate the expected profit, $E(\Pi)$, the total risk, $Var\,(\Pi)$, the market risk, $Var_m\,(\Pi)$, and the expected value of the risk-adjusted profit, Ω, within the bank group for each of the 32 data points. We also calculate the actual profit levels if the market condition turns out to be "upstate", "normal" or "downstate" (i.e., Π_u, Π_n and Π_d) for each of the 32 data points.

We begin the analysis by calculating the "sample average" of the 32 data points for each variable mentioned above in the experiment. The first two rows in Table 5 show that the "average" value of e is larger in the decentralized regime than in the centralized regime whereas the number of loans provided in the decentralized regime exceeds the amount provided in the centralized regime. Since this outcome is qualitatively the same as the one that arose in the presence of only the pure cost efficiency effect, it indicates that with our choice of parameter values, the cost efficiency effect dominates over the financing externality and the diversification effect.

Let us now take a look at how these differences in behavior affect profit and risk levels in the two banking regimes. As can be seen in Table 5, the expected profit ($E(\Pi)$) tends to be larger in the centralized regime than in the decentralized regime. Although the difference is small, our simulations indicate that the negative effect on the expected profit in the decentralized regime, generated by the financing externality and the diversification effect, outweighs the decentralized regime's comparative advantage in terms of being more efficient in its client targeting activity. However, this is only half the story since the total risk ($Var\,(\Pi)$) and the market risk ($Var_m\,(\Pi)$) are considerably smaller in the decentralized regime. Since the size of the market risk and the total risk depends on (i) how effective the bank group is in its client targeting activity and (ii) how effective the bank group is in terms of diversifying the portfolio of loans between regions, our simulations show that it is possible for the client targeting effect to outperform the diversification effect in terms

Table 4: Experimental plan used for the simulations of the full model.

Variables	Treatments	
Risk aversion (A)	0.01	0.1
Probability of recession (p_d)	0.01	0.49
Market asymmetry (θ_1/θ_2)	1	1.5
Relative cost efficiency (α^C/α^{DC})	2	3
Financing cost (b)	10^{-5}	10^{-6}
Constants	**Value**	
Cost efficiency, centralized bank (α_C)	10^{-7}	
Proportion of high-ability entrepreneurs in region 2 (θ_2)	0.1	
Probability of a normal state (p_n)	0.5	

of achieving a portfolio of loans where the market risk and the total risk are low. Hence, our results show that even if a portfolio of loans in the decentralized regime appears to be poorly diversified in the "classical" sense, this portfolio may nevertheless contain less risk than a portfolio in the centralized regime which appears to be well diversified in the "classical" sense.

Since $E(\Pi)$ and $Var\,(\Pi)$ both tend to be larger in the centralized regime, our simulation results indicate that the centralized regime may deliver higher profits at the expense of higher risk. The question is then in which regime the trade-off between profit and risk is most efficient. To evaluate this, we look at the simulated levels of the risk-adjusted expected profits and as can be seen in Table 5, the centralized regime, "on average", produces a larger risk-adjusted expected profit than the decentralized regime.

However, since the full model results are highly dependent on our choice of parameter values, the results should be interpreted with some caution. Acknowledging this, we now proceed to fit a curve to the optimized values. Right-hand side variables in this curve fitting are p_d, A, θ_1/θ_2, α^C/α^{DC} and b (as before, the increase in p_d is matched by a corresponding reduction in p_u while p_n is unchanged). This enables us to take a closer look at how the two banking regimes' respective choices of e and N, and the resulting profit and risk levels, are affected by a change in each of these exogenous variables. The results from the curve fitting are presented in Table 6 and a summary of the effects due to an increase in the probability of a recession is given in Table 7.

We would like to emphasize the following general points. First, an increase in p_d tends to favor the decentralized banking regime in comparison with the centralized regime.

Table 5: Sample averages from the experiment.

	Centralized	Decentralized
e	10.11	10.41
N	154.94	195.87
$E(\Pi)$	26.15	25.26
Ω	25.61	24.83
$Var(\Pi)$	35.49	26.45
$Var_m(\Pi)$	0.60	0.29
Π_u	26.68	26.68
Π_n	25.96	25.12
Π_d	22.26	22.45

Reading off the second row in Table 6, we see that when p_d increases, both the expected profit and the risk-adjusted profit improves in the decentralized regime relative to the centralized regime. Also the actual profit ratios, Π_j^{DC}/Π_j^C, for $j = u, n, d$, increase with p_d. Second, if the banks become more risk-averse (i.e. A increases), this tends to favor the decentralized banking regime because both the expected, risk-adjusted and actual profit ratios increase with A. Third, if the asymmetry increases between the two regions (i.e. the ratio θ_1/θ_2 goes up), then it is more important than before to achieve an efficient allocation of lending portfolios between the two regions. This favors the centralized banking regime.

Finally, let us consider the possibility of a "black swan" hitting the economy. By that we mean that the actual outcome turns out to be a recession (i.e. market condition downstate) even if the probability p_d was initially low. Calculating the mean ratio of the actual profit, $\bar{\Pi}_d^{DC}/\bar{\Pi}_d^C$, when market downstate actually occurs shows that if $p_d = 0.01$ and $\theta_1 = \theta_2$, then $\bar{\Pi}_d^{DC}/\bar{\Pi}_d^C = 1.03$ whereas if $p_d = 0.01$ and $\theta_1 \neq \theta_2$, then $\bar{\Pi}_d^{DC}/\bar{\Pi}_d^C = 0.96$. As such, we conclude that when the economy enters a recession (downstate) then the decentralized bank, "on average", performs better if the markets are similar (when the cost efficiency effect dominates). However, if the markets differ in terms of the proportion of high ability entrepreneurs, then the centralized bank's ability to target the less risky market makes this bank better suited to handle an unexpected downturn in the economy. Recall that this result appears when the risk of a deep recession is very low ($p_d = 0.01$). On the other hand, if the probability of a recession becomes sufficiently large, then our simulations indicate that, "on average", the decentralized bank outperforms the centralized bank when a recession hits the economy ($\bar{\Pi}_d^{DC}/\bar{\Pi}_d^C = 1.042$), regardless of whether

Table 6: Fitted curve parameters on ratios of the full model outcomes. We use standardized values of the variables such that the magnitude of the changes can be compared between variables.

	$\frac{e^{DC}}{e^{C}}$	$\frac{N^{DC}}{N^{C}}$	$\frac{E(\Pi^{DC})}{E(\Pi^{C})}$	$\frac{\Omega^{DC}}{\Omega^{C}}$	$\frac{Var(\Pi^{DC})}{Var(\Pi^{C})}$	$\frac{Var_m(\Pi^{DC})}{Var_m(\Pi^{C})}$	$\frac{\Pi_u^{DC}}{\Pi_u^{C}}$	$\frac{\Pi_n^{DC}}{\Pi_n^{C}}$	$\frac{\Pi_d^{DC}}{\Pi_d^{C}}$
Intercept	5.60	24.63	13.46	12.39	7.93	7.12	14.03	14.46	14.00
Recession prob. (p_d)	0.13	0.51	0.53	0.55	0.11	-0.02	0.52	0.48	0.30
Riskaversion (A)	0.28	0.24	0.20	0.22	0.20	0.18	0.25	0.23	0.04
Asymmetry (θ_1/θ_2)	-0.23	-0.37	-0.41	-0.36	-0.62	-0.32	-0.40	-0.42	-0.56
Rel. screening cost (α^C/α^{DC})	0.34	0.26	0.10	0.13	-0.35	-0.62	0.08	0.09	0.21
Financing cost (b)	-0.40	-0.45	-0.53	-0.53	-0.44	-0.40	-0.53	-0.54	-0.56

Table 7: Summarized effects of an increase in the probability of a recession; full model.

$\overset{+}{\bar{e}^{DC}}$	$\overset{+}{\bar{e}^{C}}$	$\overset{-}{\bar{N}^{DC}}$	$\overset{-}{\bar{N}^{C}}$	$\overset{+}{\left(\frac{\bar{e}^{DC}}{\bar{e}^{C}}\right)}$	$\overset{+}{\left(\frac{\bar{N}^{DC}}{\bar{N}^{C}}\right)}$	$\overset{+}{\left(\frac{E(\bar{\Pi}^{DC}}{E(\bar{\Pi})^{C}}\right)}$	$\overset{+}{\left(\frac{\bar{\Omega}^{DC}}{\bar{\Omega}^{C}}\right)}$
$\overset{+}{\left(\frac{\bar{Var}(\Pi^{DC})}{\bar{Var}(\Pi^{C})}\right)}$	$\overset{-}{\left(\frac{\bar{Var}_m(\Pi^{DC})}{\bar{Var}_m(\Pi^{C})}\right)}$	$\overset{+}{\left(\frac{\bar{\Pi}_u^{DC}}{\bar{\Pi}_u^{C}}\right)}$	$\overset{+}{\left(\frac{\bar{\Pi}_n^{DC}}{\bar{\Pi}_n^{C}}\right)}$	$\overset{+}{\left(\frac{\bar{\Pi}_d^{DC}}{\bar{\Pi}_d C}\right)}$			

the markets are similar or not.

We end with some stylized facts about the Swedish banking sector and calculate the yearly growth in operating profits for the four main Swedish banks (Nordea, SEB, Svenska Handelsbanken and Swedbank) during the years 2006-2010. Since Svenska Handelsbanken (SHB) is the only major Swedish bank operating under a decentralized structure, we calculate the difference in growth rates, where a positive value indicates that the decentralized bank outperformed its centralized counterparts. By doing so, we are able to relate the results in Table 6 to the effects on operating profits caused by an actual recession as well as the effects caused by an increase in the probability of recession during the next coming fiscal year.

In Table 8, we present the mean difference in growth rates for three different cases. The mean difference in growth rates when the probability of recession was high the forthcoming fiscal year (2009) while the Swedish economy was in an actual recession (2008 and 2009) is presented in the upper left quadrant of the table. As can be seen, the mean difference in grow rates is positive, indicating that the decentralized bank performed better during these circumstances. Revisiting Table 6, while acknowledging that an increase in p_d affects the ratio Π_d^{DC}/Π_d^{C} positively, this finding is fully in line with the predictions from our theoretical model. Turning to the lower right quadrant of Table 8, we find that this difference is negative, indicating that the centralized banks (Nordea, SEB, Swedbank) tends to have a larger growth in operating profits, compared the decentralized bank (SHB), when the probability of a recession is low in the case of economic growth. Since our model predicts that a decrease in p_d tends to decrease the ratio $\bar{\Pi}_u^{DC}/\bar{\Pi}_u^{C}$, also this result is predicted by the theoretical model.

Finally, we turn to the case of when a "black swan" hits an economy, i.e. the case when the probability of a recession was low the forthcoming fiscal year but when the economy, nonetheless, entered a recession during the year of operations. As previously discussed, our theoretical findings concerning such a case are rather ambiguous and highly depen-

Table 8: Mean difference in growth rates in operating profits from 2006-2010 for the four major Swedish banks. Source: Datastream.

		Probability of a recession	
		High	Low
Actual recession	Yes	0.47	0.63
	No	-	-0.03

dent on if the proportion of high ability entrepreneurs are equal across regions or not. If $\theta_1 = \theta_2$, our results indicate that the decentralized bank tends to handle a "black swan" more efficiently while if $\theta_1 \neq \theta_2$, a bank operating under a centralized regime tends to outperform its decentralized counterpart. Returning to Table 8, and acknowledging that the mean difference in growth rates displayed in the upper right quadrant represents such a case, we find this mean difference to be positive. Since this suggests that the decentralized bank (SHB) tends to outperform its competitors, in relative terms, when an unexpected recession hits the economy; this finding suggests that SHB operates in markets characterized by a similar proportion of high performing entrepreneurs.

6 Concluding Remarks

To our knowledge, this is the first paper that attempts to simultaneously address the question of how screening and lending decisions differ between banks having a centralized and decentralized decision-making structure. To analyze this issue, we develop a model where centralized and decentralized banks differ in three aspects; (i) the cost efficiency related to the screening of potential borrowers, (ii) the presence of a financing externality which arises because of lack of coordination when the lending decisions are decentralized and (iii) the inability to effectively diversifying the portfolio of loans between regions under decentralized decision-making.

We emphasize three main conclusions. First, in the presence of only the cost efficiency effect, decentralized banks will lend more funds and have lower risks than their centralized counterparts. It is also shown that in the presence of the pure cost efficiency effect, the bank in the centralized regime tend to react stronger than the bank in the decentralized regime, in terms of reducing the lending portfolio, in the wake of a recession. Second, when only the financing externality is present, then decentralized banks tend to over-provide loans while reducing the amount of effort put into the screening procedure, in comparison with centralized banking. This implies that the pure financing externality produces lower profits and higher risks under decentralized banking. Third, the pure diversification effect also favors centralized banking in the sense that the client targeting is more efficient, the expected profit larger and risks lower, compared with decentralized banking.

We also simulate a model where the cost efficiency effect, the financing externality and the diversification effect are present simultaneously. This allows us to study how these three effects combine to jointly influence the comparison between the two banking regimes. Here, we would like to emphasize that our results show that the client targeting effect may outperform the diversification effect in terms of achieving a portfolio of loans where the market risk and the total risk is low. As such, a portfolio of loans that appears to be poorly diversified under decentralized banking may actually contain less risk than a portfolio chosen by the bank in the centralized regime under the same conditions.

However, there are conditions that, in relative terms, are favorable to a particular lending regime's risk-return profile. Asymmetric markets (in terms of the proportion of high ability entrepreneurs) tend to favor centralized banking while decentralized banks are favored by an increase in the probability of a recession. In addition, our results indicate that decentralized banks are favored by an increase in risk aversion.

Future research may take several directions. For example, an interesting avenue would be to analyze how centralized and decentralized banking perform under different market forms. What are the profit and risk levels under oligopoly and in a perfectly competitive banking market? Another question that would be interesting to address is what the outcome would be in an duopoly where one bank has a centralized organizational structure whereas the other uses a decentralized decision-making. Will the aggregate risks in this duopoly be higher or lower compared to a duopoly made of two centralized or two decentralized banks?

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References

ALLEN, F. (1990): "The Market for Information and the Origin of Financial Intermediation," *Journal of Financial Intermediation*, 1, 3–30.

BERGER, A. N., L. F. KLAPPER, AND G. F. UDELL (2001): "The Ability of Banks to Lend to Infromationally Opaque Small Buisinesses," *Journal of Banking and Finance*, 25, 2127–2167.

BERGER, A. N., N. H. MILLER, M. A. PETERSEN, R. G. RAJAN, AND J. C. STEIN (2005): "Does Function Follow Organizational Form? Evidence From the Lending Practices of Large and Small Banks," *Journal of Financial Economics*, 76, 237–269.

BOOT, A. W. A. (2000): "Relationship Banking: What Do We Know?" *Journal of Financial Intermediation*, 9, 7–25.

CANALES, R. AND R. NANDA (2011): "A Darker Side to Decentralized Banks: Market Power and Credit Rationing in SME Lending," Harvard Business School Working Papers 08-101, Harvard Business School, working Paper. Harvard Buisness School.

CAREY, M. (1998): "Credit Risk in Private Debt Portfolios," *Journal of Finance*, 53, 1363–1387.

CARLING, K. AND S. LUNDBERG (2002): "Bank Lending, Geographical Distance, and Credit risk: An Empirical Assessment of the Church Tower Principle," Working Paper Series 144, Sveriges Riksbank (Central Bank of Sweden).

CHAUVET, M. AND J. PIGER (2008): "A Comparison of the Real-Time Performance of Business Cycle Dating Methods," *Journal of Business and Economic Statistics*, 26, 42 – 49.

FRIDSON, M. S. ., M. C. GARMAN, AND S. WU (1997): "Real Interest Rates and the Default Rate on High-Yield Bonds," *The Journal of Fixed Income*, 7, 29–34.

HELWEGE, J. AND P. KLEIMAN (1997): "Understanding Aggregate Default Rates of High-Yield Bonds," *The Journal of Fixed Income*, 7, 55–61.

LIBERTI, J. M. (2009): "Estimating the Effect of Hierarchies on Information Use," *The Review of Financial Studies*, 22, 4057 – 4090.

MARKOWITZ, H. (1952): "Portfolio Selection," *The Journal of Finance*, 7, 77–91.

MEHROTRA, S. (1992): "On the Implementation of a Primal-Dual Interior Point Method," *SIAM Journal on Optimization*, 2, 575 – 601.

NELDER, J. A. AND R. MEAD (1965): "A Simplex Method for Function Minimization," *The Computer Journal*, 7, 308 – 313.

PETERSEN, M. (2004): "Information: Hard and Soft," Working paper series, Kellogg School of Management.

PETERSEN, M. A. AND R. G. RAJAN (1994): "The Benefits of Lending Relationships: Evidence from Small Business Data," *Journal of Finance*, 49, 3–37.

——— (1995): "The Effect of Credit Market Competition on Lending Relationships," *The Quarterly Journal of Economics*, 110, 407–43.

RAJAN, R. G. (1992): "Insiders and Outsiders: The Choice Between Informed and Arm's-Length Debt," *The Journal of Finance*, 47, 1367–1400.

SHARPE, S. A. (1990): "Asymmetric Information, Bank Lending, and Implicit Contracts: A Stylized Model of Customer Relationships," *Journal of Finance*, 45, 1069–1087.

STEIN, J. C. (2002): "Information Production and Capital Allocation: Decentralized versus Hierarchical Firms." *Journal of Finance*, 57, 1891 – 1921.

TAKÁTS, E. (2004): "Banking Consolidation and Small Business Lending," Working Paper Series 407, European Central Bank.

UCHIDA, H., G. F. UDELL, AND W. WATANABE (2008): "Bank Size and Lending Relationships in Japan," *Journal of the Japanese and International Economies*, 22, 242 – 267.

WINTON, A. (1995): "Delegated Monitoring and Bank Structure in a Finite Economy," *Journal of Financial Intermediation*, 4, 158–187.

Appendix: Simulation procedure

We use the Mathematica function FindMaximum for the simulations presented in Section 5, using algorithms suitable for constrained numerical optimization (Nelder and Mead, 1965; Mehrotra, 1992). We proceed as follows.

First, we define the necessary functions from Section 3 and 4 and give the exogenous parameters of the model some suitable value. For the centralized bank, we then solve for optimal values of e_k^C and N_k^C by calling on the FindMaximum command on equation (5). This gives us the numerical global optimum of Ω^C as well as $E(\Pi^C), Var(\Pi^C), Var_m(\Pi^C)$. We then let the actual outcome of high ability entrepreneurs in region k be $Z(e_k^C)$. By doing so, we are able to call on the functions from Section 4 in order to calculate the actual profit for each market condition (Π_j^C).

Turning to the constrained numerical optimization problem for the decentralized bank, we acknowledge that the regional banks play a non-cooperative Nash game vis-a-vis each other. Thus, we start with the bank in region 1 and call on the FindMaximum command on equation (9), solving for the optimal levels of e_1^{DC} and N_1^{DC}, using given start values for e_2^{DC} and N_2^{DC}. We then apply the FindMaximum command on equation (9) for the local bank in region 2, while using the (conditionally) optimal values of e_1^{DC} and N_1^{DC} as given. This is followed by new numerical solution of the the bank in region 1's maximization problem, using the (conditionally) optimal values of e_2^{DC} and N_2^{DC} as given. This procedure is iterated until a stable solution is found, defining the global optimal values of $e_1^{DC}, e_2^{DC}, N_1^{DC}$ and N_2^{DC}. We then calculate the risk adjusted profits using equation (12) and call on the functions from Section 4 in order to calculate $E(\Pi^{DC}), Var(\Pi^{DC}), Var_m(\Pi^{DC})$. The same procedure as for the centralized bank is then used in order to derive the actual outcome in each market condition (Π_j^{DC}).

In Table A.1, we present the parameter values used for the simulations in Sections 5.1 - 5.3. Here, we solve for the optimal values using the method discussed above, over the span $p_d \in [0.01, 0.49]$ in increments of 0.01. We let an increase in p_d correspond to a decrease in p_u such that $p_u = 1 - (p_n + p_d)$. In addition to the parameter values presented in Table A.1, we have checked for robustness of the results by using a wide range of parameters in the simulations, all yielding the same qualitative results.

Table A.1: Parameter values used for the simulations in Sections 5.1 - 5.3.

Variables	Value
Risk aversion (A)	0 or 0.01
Proportion of high-ability entrepreneurs in region 1 (θ_1)	0.1 and 0.2
Proportion of high-ability entrepreneurs in region 2 (θ_2)	0.1
Cost efficiency, centralized bank (α^C)	10^{-7}
Cost efficiency, decentralized bank (α^{DC})	10^{-7} or 5×10^{-8}
Financing cost (b)	10^{-5} and 10^{-6}
Probability of a normal state (p_n)	0.5
Project rate of returns	**Value**
$r_k^{h,u}$	0.6
$r_k^{h,l}$	0.5
$r_k^{n,u}$	0.6
$r_k^{n,l}$	0.6
$r_k^{d,u}$	0.5
$r_k^{d,l}$	0