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BANK RISK TAKING AND COMPETITION REVISITED:

NEW THEORY AND NEW EVIDENCE

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Abstract

It has been a widely-held belief that more competition is associated with, *ceteris paribus,* greater instability (more failures) in banking. Yet, the existing empirical evidence is mixed, in part because most existing work has employed either good measures of bank risk or good measures of bank competition, but not both.

In this paper we extend two models analyzed in our previous work (Boyd and De Nicolò, Journal of Finance, 2005) by allowing banks to hold bonds in addition to loans, thereby generating implications for both bank risk and asset allocations. The first model is one embedding the "charter value hypothesis" with no loan market (CVH). The second model is our own, with strategic interaction in both loan and deposit markets (BDN). The two models imply opposite relationships between bank concentration and stability. The CVH model implies a positive relationship, indicating a trade-off between competition and stability. The BDN model implies a negative relationship, indicating such a trade-off does not exist. Both models imply an inverse relationship between loan-to-asset ratios and concentration for certain ranges of parameters.

We explore these implications empirically using two data sets: a 2003 cross-sectional sample of about 2,500 U.S. banks, and a panel data set with bank-year observations ranging from 13,000 to 18,000 in 134 non-industrialized countries for the period 1993-2004. The results obtained for these two samples are qualitatively identical. We find that a measure of risk monotonically associated with banks' probability of failure is positively and significantly related to concentration measures. Thus, the risk implications of the CVH model are rejected, those of the BDN model are not. The implications of both models for asset allocations are not rejected, as loan-to-asset ratios are negatively and significantly associated with concentration.

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I. INTRODUCTION

It has been a widely-held belief that more competition in banking is associated with, *ceteris paribus*, greater instability (more failures) in banking. Since bank failures are almost universally associated with negative externalities, this has been seen as a social cost of competition in that industry. Our previous work (Boyd and De Nicolò, 2005) reviewed the existing theoretical literature on this topic and concluded that it has had a profound influence on policy makers both at central banks and at international agencies. We next demonstrated that the conclusions of previous theoretical research are fragile, depending on the assumption that competition is only allowed in deposit markets, but suppressed in loan markets. We further showed that, by allowing for loan market competition in a very natural way, we could easily reverse the consensus result — that is, producing environments in which more competition was associated with improved banking stability.

A critical question in such models is whether banks' asset allocation decisions are best modeled as a "portfolio allocation problem" or as an "optimal contracting problem". By "portfolio allocation problem" we mean a situation in which the bank allocates its assets to a set of financial claims, taking all return distributions as parametric. Purchasing some quantity of government bonds would be an example of such a decision. By "optimal contracting problem," we mean a different situation that is often associated with bank lending. In these instances, there is private information and the borrowers' actions will generally depend on the availability of credit and other lending terms offered by banks. For example, the environment we employed in our earlier work allowed for entrepreneurs optimally responding to higher loan rates by increasing the risk of their own asset allocations.

Realistically, we know that banks are generally involved in both kinds of activity. They acquire bonds and other traded securities in competitive markets in which they are price takers. At the same time, they make a variety of different kinds of loans in environments with private information, and in which there can be serious contracting problems. Therefore, an obvious extension of our previous work is to model such environments.

In this paper we extend two models analyzed in our previous paper (Boyd and De Nicolò, 2005) by allowing banks to hold bonds in addition to loans. The first model is one embedding the "charter value hypothesis" with no loan market (CVH), built on the model introduced by Allen and Gale (2000, 2004).[1] The second model is an extension of our own (Boyd and De Nicolò, 2005), with strategic interaction in both loan and deposit markets (BDN).

What seems like a simple modeling extension actually results in a good deal of increased complexity. First, the possibility of investing in riskless bonds allows banks to pay depositors out of bond's proceeds when lending revenues are exhausted (in the event a bad state is realized). In this case, banks' investment in bonds can be viewed as an implicit choice of "collateral". If bonds' holdings are sufficiently large, then deposits become "risk free". Second, the asset allocation between bonds and loans becomes a

[1] Keeley's (1990) influential work is a precursor. Other recent formulations of this model are in Hellman, Murdoch and Stiglitz (2000) and Repullo (2004).

strategic variable, since changes in the quantity of loans offered by banks will change the return on loans *relative* to the return on bonds (which is fixed by assumption).

The new theoretical environments produce an interesting insight that is invisible when either loan markets or bond markets are suppressed from the model. A bank's optimal quantity of loans, bonds and deposits will in general depend on the degree of competition it faces. Thus, the banking industry's aggregate supply of loans, its aggregate demand for bonds, and the demand for deposits will depend on both competitive conditions in the bond market and bank market structure.

A causal relationship from market structure to asset portfolio allocation is of more than theoretical interest. One of the key economic contributions of banks is believed to be their role in efficiently intermediating between borrowers and lenders in the sense of Diamond (1984) or Boyd and Prescott (1986). Banks play no such role if they raise deposit funds and use them to acquire risk-free bonds. Thus, to the extent that competition affects banks' choices between loans and (risk-free) investments, that is likely to have welfare consequences.[2] Banking asset portfolio allocations could be another margin at which to evaluate the social costs and benefits of bank competition. To our knowledge, this margin has not been recognized or explored elsewhere in the extensive literature on banks.

We analyze the implications of the models under two concepts of equilibrium outcomes. Under a standard Nash equilibrium concept, the CVH and the BDN models

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[2] For example, imagine that as the number of banks in a market falls, each bank allocates a higher fraction of its total assets to risk free bonds and as a result each bank becomes less likely to fail. The social benefit of a more stable banking industry could in this case be to some extent offset by the fact that, as banks become more stable, they are providing less valuable intermediation services.

yield opposite predictions with respect to bank risk shifting, but similar predictions concerning asset allocation. The CVH model produces a *positive* relationship between the number of banks and risk shifting, while the BDN model produces a *negative* relationship. In other words, the CVH model predicts higher banks' risk of failure as competition increases, while the reverse is true for the BDN model. By contrast, both models can predict a positive relationship between the number of banks in a market and the loan-to-asset ratio . That is, banks allocate relatively larger amounts of funds to lending activities as competition increases.

Under a Pareto-dominant equilibrium concept, in which banks' strategic interaction yield their most preferred equilibrium outcome, the implications of the CVH model for risk and asset allocation are reversed. The model predicts a decline in risk as competition increases (as in the BDN model), but also a decline in the loan-to-asset ratio. By contrast, the implications of the BDN model under this notion of equilibrium are not different from those obtained under a standard Nash equilibrium when banks' monopoly rents are not "too large".

We explore the implications of the two models empirically using two data sets: a cross-sectional sample of about 2,500 U.S. banks, and an International panel data set with bank-year observations ranging from 13,000 to 18,000 in 134 non-industrialized countries for the period 1993-2004. These data sets are constructed so as to ensure, to the extent feasible, consistency between theory and measurement, and to provide robust evidence regarding the relationship between bank risk, asset allocations and market concentration.

We present a set of regressions relating measures of concentration to measures of bank risk, their components, and the loan to asset ratio. The main results for the two samples are qualitatively identical. First, bank profits are greater in more concentrated markets (after controlling for market and bank size), indicating that concentration may be associated with banks' monopoly rents. Second, banks' probability of failure is positively and significantly related to concentration measures, indicating that banks operating in more concentrated markets are riskier. Third, the loan to asset ratio is negatively and significantly associated with concentration, i.e. the allocation of bank credit (relative to asset size) increases as competition increases. Thus, the risk implications of the CVH model under both notions of equilibrium are rejected by the data, those of the BDN model are not. Interestingly and importantly, our empirical results concerning asset allocations are consistent with, and complement the results obtained by Cetorelli and Strahan (2006) for the U.S., and those obtained by several other studies that have used international data reviewed by these authors: access to bank credit by potential firm entrants is more difficult the more banking markets are concentrated.

We concluded our previous contribution by stating that we were unaware of any compelling theoretical arguments that banking stability decreases with the degree of competition in bank markets. In this paper we have shown that there exists compelling evidence that any model that yields a trade-off between competition and stability is unlikely to be supported by the data when theory informs measurement. Normative analyses based on CVH-type models should be seriously re-considered in the context of contracting models of banking.

The remainder of the paper is composed of three sections. Section II analyzes the CVH and the BDN models. Section III presents the evidence. Section IV concludes discussing the implications of our findings for further research.

II. THEORY

In the next two sub-sections we describe and analyze the CVH and BDN models. The last sub-section summarizes and compares the results for both models.

A. The CVH Model

We extend Allen and Gale's (2000, 2004) model with deposit market competition by allowing banks, and only banks, to invest in elastically supplied bonds that yield a gross interest rate r.

The economy lasts two dates: 0 and 1. There are two classes of agents, N banks and depositors, and all agents are risk-neutral. Banks have no initial resources. They can invest in bonds, and have also access to a set of risky technologies indexed by *S*. Given an input level *y*, the risky technology yields *Sy* with probability *p(S)* and 0 otherwise. We make the following

Assumption 1 *p(S) satisfies:* $p(0)=1, p(\overline{S})=0, p'<0$ *and* $p''\leq 0$ for all $S\in\left[0,\overline{S}\right]$.

This assumption implies that $p(S)S$ is a strictly concave function of *S* and reaches a maximum S^* when $p'\left(S^*\right)S^*+p\left(S^*\right)=0$. Given an input level *y*, increasing *S* from the left of S^* entails increases in both the probability of failure and expected output. To the right of S^*, the higher S, the higher is the probability of failure and the lower is expected output.

We also assume that the expected return associated with the most efficient technology is larger than the return on bonds:

Assumption 2 $p\left(S^*\right)S^* > r$

This assumption is sufficient to guarantee a positive investment in risky projects.

The bank's (date 0) choice of S is unobservable to outsiders. At date 1, outsiders can only observe and verify at no cost whether the investment's outcome has been successful (positive output) or unsuccessful (zero output). By assumption, contracts are simple debt contracts. In the event that the investment outcome is unsuccessful, outsiders (depositors) are assumed to have priority of claims on the bank's assets, given by the total proceeds of bond investment, if any.

The total supply of deposits is represented by an upward sloping inverse supply curve, denoted by $r_D\left(\cdot\right)$, with,

Assumption 3. $r_D\left(\cdot\right)$ *satisfies:* $r_D\left(0\right) \geq 0, r_D' > 0, r_D'' \geq 0$.

Total deposits of bank *i* are denoted by D_i, and total deposits by $\sum_{i=1}^{N} D_i$.

Deposits are insured, so that the relevant supply does not depend on risk, and, for this insurance, banks pay a flat rate deposit insurance premium, standardized to zero. We assume that the rate of interest on deposits is a function of total deposits:

$r_D = r_D(\sum_{i=1}^{N} D_i)$.

Banks are assumed to compete à la Cournot. In our two-periods context, this assumption is fairly general. As shown by Kreps and Scheinkman (1983), the outcome of this competition is equivalent to a two-stage game, where in the first stage banks commit to invest in observable "capacity" (deposit service facilities, such as branches, ATM, etc.), and in the second stage they compete in prices.

Under this assumption, each bank chooses the risk shifting parameter S, the investment in the technology L, bond holdings B and deposits D that are the best responses to the strategies of other banks. Let $D_{-i} \equiv \sum_{j \neq i} D_j$ denote total deposit choices of all banks except bank i. The bank's resource constraint is $L + B = D$. Substituting $B = D - L$ into the objective, the triplet $(S, L, D) \in [0, \overline{S}] x R_+^2$ is chosen to maximize:

$$p(S)\big((S-r)L + (r - r_D(D_{-i} + D))D\big) + (1 - p(S))\max\{0, (r - r_D(D_{-i} + D))D - rL\} \quad (1.a)$$

subject to $$L \leq D \quad (2.a)$$

As it is apparent by inspecting objective (1.a), banks can be viewed as choosing between two types of strategies. The first one results in $\max\{.\} > 0$. In this case there is no moral hazard and deposits become risk free. The second one results in $\max\{.\} = 0$. In this case there is moral hazard and deposits are risky. Of course, banks will choose the strategy that yield the highest expected profit. As detailed below, an important implication of allowing banks to invest in a risk free asset is that they may or may not endogenously choose to offer default risk-free deposits even though they have the option of risk shifting. We describe each strategy in turn.

No-moral-hazard (NMH) strategy

If $\max\{0,(r-r_D(D_{-i}+D))D-rL\}>0$, banks' investment in bonds is sufficiently large to pay depositors all their promised deposit payments and yield a positive return to the bank if the bad state (zero output) occurs. In other words, banks may "voluntarily" provide insurance to depositors in the bad state by giving up the opportunity to exploit the option value of limited liability (and deposit insurance). If they so choose, what they gain is the maximum achievable expected return attained by "pre-committing" to adopt the most efficient technology.

Under this strategy, a bank chooses $(S,L,D)\in\left[0,\overline{S}\right]xR_+^3$ to maximize:

$$(p(S)S-r)L+(r-r_D(D_{-i}+D))D \tag{3.a}$$

subject to $\quad rL<(r-r_D(D_{-i}+D))D$. (4.a)

It is evident from (3.a) that the optimal S, denoted S^*, is the one that maximizes $p(S)S$. Thus, S^* satisfies $p'\left(S^*\right)S^*+p\left(S^*\right)=0$. The absence of moral hazard implies that banks will choose the level of risk shifting that would be chosen under full observability of technology choices.

Differentiating (3.a) with respect to D, the optimal level of deposits, denoted by D^*, satisfies:

$$r-r_D(D_{-i}+D^*)-r_D'(D_{-i}+D^*)D^*=0 \tag{5.a}$$

Thus, a bank chooses $L\geq 0$ to maximize:

$$(p\left(S^*\right)S^* - r)L + (r - r_D(D_{-i} + D^*))D^* \tag{6.a}$$

subject to (4.a)

By Assumption 2 (the expected return on the most efficient technology is strictly greater than the return on bonds), it is optimal for a bank to set L at the maximum level consistent with constraint (4.a). To make this choice well defined, and without loss of generality, we allow constraint (4.a) to hold as weak inequality. This amounts to assuming that banks pre-commit to the risk-shifting choice S^* while at the same time minimize the amount of bond holdings necessary to make deposits risk-free. Under these assumptions, the optimal L^* satisfies $rL^* = (r - r_D(D_{-i} + D^*))D^*$.

Let the triplet $\{S^*, L^*(D_{-i}), D^*(D_{-i})\}$ denote the best-response functions of a bank when the NMH strategy is chosen. The profits achieved by a bank under the NMH strategy are given by:

$$\Pi^*(D_{-i}) \equiv \frac{p(S^*)S^*}{r}(r - r_D(D_{-i} + D^*))D^* \tag{7.a}$$

The following Lemma summarizes the properties of optimal choices and profits.

Lemma 1 **(a)** $-1 < \frac{dD^*}{dD_{-i}} < 0$**;** **(b)** $\frac{dL^*}{dD_{-i}} < 0$**;** **(c)** $\frac{d(L^*/D^*)}{dD_{-i}} < 0$**;**

(d) $\frac{d\Pi^*}{dD_{-i}} = -\frac{p(S^*)S^*}{r} r_D'(D_{-i} + D^*)D^* < 0$ **.**

Proof: Differentiation of conditions (5.a) and (4.a) at equality, and application of the Envelope Theorem.

Deposit and loan choices are both strategic substitutes, since they are decreasing in the deposit level chosen by competitors (conditions (a) and (b)). The ratio of loan to deposits decreases as well, since the increase in competition reduces rents per unit of loans, thereby increasing the return on bonds relative to loans (condition (c)). Finally, as total deposits of competitors increase, bank profits decrease (condition (d)).

Moral-hazard (MH) strategy

If $\max\{0,(r - r_D(D_{-i} + D))D - rL\} = 0$, banks choose a bond investment level that is insufficient to pay depositors their promised deposit payments whenever the bad state (zero output) occurs. In contrast to the previous case, banks exploit the option value of limited liability (and deposit insurance), and therefore, there is moral hazard. In they so choose, they give up the opportunity to achieve a higher expected return, but they maximize their return in the good state.

Thus, a bank chooses the triplet $(S, L, D) \in [0, \bar{S}]xR_+^3$ to maximize:

$$p(S)((S - r)L + (r - r_D(D_{-i} + D))D) \qquad (8.a)$$

subject to $$(r - r_D(D_{-i} + D))D \le rL \qquad (9.a)$$

and $$L \le D \qquad (10.a)$$

Differentiating (8.a) with respect to S, the optimal level of risk shifting, denoted by $\tilde{S}$, satisfies

$$p'\left(\tilde{S}\right)(\tilde{S}L - rL + (r - r_D(D_{-i} + D))D) + p(\tilde{S})L = 0 \quad . \qquad (11.a)$$

Rearranging (11.a), it can be easily verified that $p'\left(\tilde{S}\right)\tilde{S} + p\left(\tilde{S}\right) < 0$ for any $\left(L, D\right) \in R^2_{++}$. Hence, $\tilde{S} > S^*$ by the strict concavity of the function $p(S)S$. Since $p\left(S^*\right)S^* > r$ (Assumption 2), $\tilde{S} > r$. Thus, the optimal loan choice is $L = D$. Such a choice exploits the benefits of limited liability by maximizing the return in the good state and minimizing the bank's liability in the bad state by setting $B = 0$.

In turn, bank deposits D are chosen to maximize $p\left(S\right)(S - r_D(D_{-i} + D))D$. By differentiating this expression, the optimal choice of deposits, denoted by $\tilde{D}$, satisfies:

$$\tilde{S} - r_D(D_{-i} + \tilde{D}) - r_D'(D_{-i} + \tilde{D})\tilde{D} = 0 \quad . \qquad (12.a)$$

Let the pair $\{\tilde{S}(D_{-i}), \tilde{D}(D_{-i})\}$ denote the best-response functions of a bank when the MH strategy is chosen. The profits achieved by a bank under the MH strategy are given by:

$$\tilde{\Pi}(D_{-i}) \equiv p(\tilde{S})(\tilde{S} - r_D(D_{-i} + \tilde{D}))\tilde{D} \qquad (13.a)$$

The following Lemma summarizes the properties of optimal choices and profits.

Lemma 2 **(a)** $-1 < \frac{d\tilde{D}}{dD_{-i}} < 0$ **;** **(b)** $\frac{d\tilde{S}}{dD_{-i}} > 0$ **;** **(c)** $\frac{d\tilde{\Pi}}{dD_{-i}} = -r_D'(D_{-i} + \tilde{D})\tilde{D} < 0$ **.**

Proof: Differentiation of conditions (11.a) and (12.a), and application of the Envelope Theorem.

Clearly, the comparative statics properties of the MH strategy are identical to those of the version of this model with no bonds, as in Allen and Gale (2000,2004). Deposits are strategic substitutes (conditions (a)), risk shifting is increasing, and bank profits decrease, as total deposits of competitors increase (conditions (b) and (c)).

Nash Equilibria

We focus on *symmetric* equilibria in pure strategies. From the preceding analysis, *Nash equilibria* can be of at most two types: either NMH (no-moral-hazard) or MH (moral-hazard) equilibria. An equilibrium is NMH if $D = D^*$, $D_{-i} = (N-1)D^*$, and there is no incentive for a bank to deviate to a moral-hazard strategy when all other banks adopt the no-moral-hazard strategy. This occurs when $\Pi^*((N-1)D^*) \geq \tilde{\Pi}((N-1)D^*)$. Likewise, a symmetric equilibrium is MH if $D = \tilde{D}$, $D_{-i} = (N-1)\tilde{D}$, and there is no incentive for a bank to deviate to a no-moral-hazard strategy when all other banks stick to a moral-hazard strategy. This occurs when $\tilde{\Pi}((N-1)\tilde{D}) \geq \Pi^*((N-1)\tilde{D})$.

The occurrence of one or the other type of equilibrium depends on the shape of the function $p(.)$, the slope of the deposit function, as well as the number of competitors. This can be readily inferred by comparing the bank profits under the NMH and MH strategy given by equations (7.a) and (13.a) respectively. Expected profits under the NMH will be likely larger than those under the MH strategy the larger is $p(S^*)S^*/r$, the lowest is $p(\tilde{S})$, and the smallest is the difference of the optimal choice of deposits under the two strategies. This intuition is made precise below. Recall that $\tilde{\Pi}(0)$ and $\Pi^*(0)$ denote the profits of a monopolist bank choosing the MH and NMH strategy respectively. The following proposition is illustrated in Figure 1:

Proposition 1

(a) *If* $\tilde{\Pi}(0) \geq \Pi^*(0)$*, then the unique Nash equilibrium is a moral-hazard (MH) equilibrium.*

(b) *If* $\tilde{\Pi}(0) < \Pi^*(0)$*, then there exist values* N_1 *and* N_2 *satisfying* $1 < N_1 \leq N_2$ *such that: for all* $N \in [1, N_1)$ *the unique equilibrium is a no-moral-hazard (NMH) equilibrium; for all* $N \in [N_1, N_2)$ *the equilibrium is either NMH, or MH, or both; for all* $N > N_2$ *the unique equilibrium is a moral-hazard (MH) equilibrium.*

Proof (sketch):

(a) By Lemmas 1(d) and 2(c), as D_{-i} increases, profits under the MH strategy decline at a slower rate than profits under the NMH strategy. Thus, if $\tilde{\Pi}(0) \geq \Pi^*(0)$, then profits under the MH strategy are always larger than those under the NMH strategy for any D_{-i}. (see Figure 1.A). Let $Z^*(N) \equiv (N-1)D^*$ and $\tilde{Z}(N) \equiv (N-1)\tilde{D}$. Since $\tilde{S} > S^*$, $D^* < \tilde{D}$

for all D_{-i}. Therefore, as $N \to \infty$, $Z^*(N) \to Z^*$, $\tilde{Z}(N) \to \tilde{Z}$. By Lemmas 1 and 2 $\tilde{\Pi}(\tilde{Z}(N)) \to 0$ and $\Pi^*(Z^*(N)) \to 0$. Thus, for all N, $\tilde{\Pi}((N-1)D^*) > \Pi^*((N-1)D^*)$.

(b) Since $\tilde{\Pi}(0) < \Pi^*(0)$, Lemmas 1(d) and 2(c) imply that the profit functions under the MH and the NMH strategies intersect (see Figure 1.B). Thus, there exists a $\bar{D}_{-i}$ such that $\tilde{\Pi}(\bar{D}_{-i}) = \Pi^*(\bar{D}_{-i})$. Let $Z^*(N_2) = \bar{D}_{-i} = \tilde{Z}(N_1)$. Since $D^* < \tilde{D}$, $N_2 > N_1 > 1$. For all N such that $Z^*(N) < \tilde{Z}(N) \le \bar{D}_{-i}$, $\Pi^*(Z^*(N)) > \tilde{\Pi}(Z^*(N))$. Thus, for $1 \le N < N_1$ the unique equilibrium is NMH. For all N such that $\bar{D}_{-i} \le Z^*(N) < \tilde{Z}(N)$, $\tilde{\Pi}(\tilde{Z}(N)) \ge \Pi^*(\tilde{Z}(N))$. Thus, for all $N > N_2$ the unique equilibrium is MH. For all N such that $Z^*(N) < \bar{D}_{-i} < \tilde{Z}(N)$, both $\Pi^*(Z^*(N)) > \tilde{\Pi}(Z^*(N))$ and $\tilde{\Pi}(\tilde{Z}(N)) \ge \Pi^*(\tilde{Z}(N))$ hold. Thus, for all $N \in [N_1, N_2]$ both NMH and MH equilibria exist. Q.E.D.

The interpretation of this proposition is as follows. If $\tilde{\Pi}(0) \ge \Pi^*(0)$ (part (a), Figure 1.A), it is always optimal for a deviant bank to set both their deposits and the risk shifting parameters high enough so that the it can capture a large share of the market. Its profits in the good state under MH will be high enough to offset the lower probability of a good outcome. This is why the MH equilibrium is unique. In such an equilibrium, bank profits monotonically decline as N increases. Note that in this case, banks always allocate all their funds to loans, that is, the loan-to-asset ratio is always unity. This result is illustrated for some economies with $p(S) = 1 - AS$, where $A \in (0,1)$, and $r_D(x) = x^{\beta}$, where $\beta \ge 1$. The three panels of Figure 2 show the risk shifting parameter, bank profits under an NMH deviation minus profits under an MH equilibrium, and bank profits under a MH deviation minus profits under an NMH equilibrium respectively, as a function of N. Risk shifting increases in the number of banks, and an NMH deviation is never profitable when all banks choose an MH strategy, while the reverse is always true.

If $\tilde{\Pi}(0) < \Pi^*(0)$ (part(b), Figure 1.B), the relative profitability of deviations will depend on the size of the difference between deposits under MH and deposits under NMH. The larger (smaller) this difference, the larger (smaller) is the profitability of a MH (NMH) deviation. When this difference is relatively small, no deviation is profitable, and multiple equilibria are possible. This is the reason why for small values of N the NMH equilibrium prevails, for intermediate values of N both equilibria are possible, and for larger values of N the unique equilibrium is MH. Importantly, this case shows that for values of N not "too large", the relationship between the number of banks and bank profits or scaled measures of profitability, such as returns on assets (in the model, profits divided by total deposits), *is not monotone.* With regard to asset allocations, in this case a monotonically increasing relationship between the loan-to-asset ratio and the number of banks may arise, since as N increases, such a ratio tends to unity. Figure 3 illustrates a case for an economy identical to that of Figure 2, except that the elasticity of deposit demand is higher ($\beta = 5$). Multiple equilibria exist when the number of banks is between 2 and 7. For all $N > 7$, we are back to unique MH symmetric equilibria. As shown in the first panel, which reports the ratio of profits under the NMH strategy relative to profits under the MH strategy, it is evident that bank expected profits (and profits scaled by deposits) exhibit a non-monotonic relationship with N (profits jump up when N increases from 6 to 7).

Pareto-dominant equilibria

Under the standard Nash equilibrium concept banks are assumed to be unable to communicate. Suppose banks can communicate and form any coalition. If there exists a commitment technology that prevents any bank deviation from a coalition agreement, then the industry symmetric outcome is a "Pareto-dominant" equilibrium[3]. Thus, a symmetric NMH (MH) equilibrium is Pareto-dominant if $\Pi^*((N-1)D^*) > \tilde{\Pi}((N-1)\tilde{D})$ ($\Pi^*((N-1)D^*) < \tilde{\Pi}((N-1)\tilde{D})$).

It turns out that the monotonically increasing relationship between risk and competition predicted by the model in a conventional Nash equilibrium is reversed under Pareto-dominance, as shown in the following:

Proposition 2 *There exists a finite value* $\tilde{N} \geq 1$ *such that for all* $N \geq \tilde{N}$ *the unique Pareto-dominant symmetric equilibrium is a no-moral-hazard (NMH) equilibrium.*

Proof: Let $G(N) \equiv \Pi^*((N-1)D^*)/\tilde{\Pi}((N-1)\tilde{D})$ be the ratio of a bank profits when all banks adopt the NMH strategy to the bank profits when all banks adopt the MH strategy. Also, let $Z^* \equiv ND^*$ and $\tilde{Z} \equiv N\tilde{D}$. By (5.a) and (12.a), $G(N) = \dfrac{p(S^*)S^* r_D'(Z^*)Z^{*2}}{rp(\tilde{S})r_D'(\tilde{Z})\tilde{Z}^2}$. As $N \to \infty$, $p(\tilde{S}) \to 0$, $p(S^*)S^* r_D'(Z^*)Z^{*2} \to C < +\infty$, therefore $G(N) \to \infty$. Since $G(N)$ becomes arbitrarily large as N increases, it becomes larger than unity for some finite N. Thus, there exists a value $\tilde{N}$ such that $\Pi^*((N-1)D^*) - \tilde{\Pi}((N-1)\tilde{D}) \geq 0$ for all $N \geq \tilde{N}$.

[3] This is, essentially, the "strong equilibrium" introduced by Aumann (1959).

Q.E.D.

This model now predicts an outcome exactly opposite to that obtained under standard Nash competition. That is, it predicts a positive relationship between competition and bank risk taking beyond some threshold N . As competition increases, banks will choose the first best level of risk shifting, that is, the *lowest*, rather than the highest, risk profile. Note also that the implication for asset allocation is also reversed, since the loan-to-asset ratio now monotonically *declines* as the number of competitors increases. Figure 4 illustrates these facts for the economy of Figure 3, where the NMH equilibrium Pareto-dominates the MH equilibrium for all sets in for all $N \geq 13$.

B. The BDN Model

We extend the model used in our previous work (Boyd and De Nicolo', 2005) by allowing banks, and only banks, to invest in elastically supplied bonds that yield a gross interest rate r .

Consider many entrepreneurs who have no resources, but can operate one project of fixed size, normalized to 1, with the two-point random return structure previously described. Entrepreneurs may borrow from banks, who cannot observe their risk shifting choice *S*, but take into account the best response of entrepreneurs to their choice of the loan rate.

Given a loan rate r_L, entrepreneurs choose $S \in \left[0, \overline{S}\right]$ to maximize: $p(S)(S - r_L)$. By the strict concavity of the objective function, an interior solution to the above problem is characterized by

$$h(S) \equiv S + \frac{p(S)}{p'(S)} = r_L. \qquad (1.b)$$

Let $L = \sum_{i=1}^{N} L_i$ denote the total amount of loans. Consistent with our treatment of deposit market competition, we assume that the rate of interest on loans is a function of total loans: $r_L = r_L(L)$. This inverse demand for loans can be generated by a population of potential borrowers whose reservation utility to operate the productive technology differs. The inverse demand for loans satisfies

Assumption 4. $r_L(0) > 0, r_L' < 0,\ r_L'' \leq 0$ and $r_L(0) > r_D(0)$.

with the last condition ensuring the existence of equilibrium.

With Assumption 4, equation (1.b) defines implicitly the equilibrium risk shifting choice S as a function of total loans. Specifically, since $h'(.) > 2$, equation (1.b) can be inverted to yield $S(L) = h^{-1}(r_L(L))$. Simple differentiation of (1.b) yields $S'(L) = h^{-1'}(r_L(L))r_L'(L) < 0$ for all L such that $S(L) < \overline{S}$. Provided that banks are willing to lend, an increase in the interest rate on loans causes an entrepreneur to choose more risk through an increase in S.

Let $L_{-i} \equiv \sum_{j \neq i} L_j$ denote the sum of loans chosen by all banks except bank i. Each bank chooses deposits, loans and bond holdings so as to maximize profits, given similar choices of the other banks and taking into account the entrepreneurs' choice of *S*. Thus, each bank chooses $(L, B, D) \in R_+^3$ to maximize

$$p\left(S(L_{-i}+L)\right)\left((r_L(L_{-i}+L)-r)L+(r-r_D(D_{-i}+D))D\right)+$$

$$(1-p(S(L_{-i}+L))\max\{0,(r-r_D(D_{-i}+D))D-rL\} \qquad (2.b)$$

subject to $\quad L \leq D \qquad (3.b)$

As before, we split the problem above into two sub-problems. The first problem is one in which a bank adopts a no-moral hazard strategy (NMH), which results in $\max\{.\}>0$. If no loans are supplied, we term this no-moral hazard strategy a *credit rationing* strategy (CR) for the reasons detailed below. The second problem is one in which a bank adopts a moral hazard (MH) strategy, which results in $\max\{.\}=0$.

No-moral-hazard (NMH) strategies

If $\max\{.\}>0$, a bank chooses the pair $(L, D) \in R_+^2$ to maximize:

$$(p(S(L_{-i}+L))r_L(L_{-i}+L)-r)L+(r-r_D(D_{-i}+D))D. \qquad (4.b)$$

subject to $\quad rL \leq (r-r_D(D_{-i}+D))D$ [4] $\qquad (5.b)$

[4] As done previously, we allow this constraint to hold as weak inequality.

Differentiating (4.b) with respect to D, the optimal choice of deposits, denoted by D^*, satisfies:

$$r - r_D(D_{-i} + D^*) - r_D'(D_{-i} + D^*)D^* = 0 \tag{6.b}$$

Let $\overline{\Pi}(D_{-i}) \equiv (r - r_D(D_{-i} + D^*))D^*$. A bank chooses $L \geq 0$ to maximize:

$$(p(S(L_{-i} + L))r_L(L_{-i} + L) - r)L + \overline{\Pi}(D_{-i}). \tag{7.b}$$

subject to (5.b).

Let the pair $\{L^*(L_{-i}), D^*(D_{-i})\}$ denote the best-response functions of a bank.

If $L^*(L_{-i})$ =0, then there is no lending. As we will show momentarily, banks' choice of providing no credit to entrepreneurs may occur as an equilibrium outcome for values of N not "too large". As a preview, the intuition for this is as follows. If the return to lending for a monopolist is lower than the return on bonds, then there may exist a range of values of total loans low enough so that the expected return on lending never exceeds the return on bonds. In this case, there is no lending. With few competitors in the loan market, it may be the case that even though entrepreneurs are willing to demand funds and pay the relevant interest rate, loans will not be supplied. This happens since the high rent banks are willing to extract from entrepreneurs would force them to choose a level of risk so high as to make the probability of a good outcome small. If this probability is small enough, holding bonds only would be banks' preferred choice. For these reasons, we term a NMH strategy that results in no positive loan supply a *credit* *rationing* (CR) strategy. In our two-asset world, this strategy results in banks investing in bonds only and being default-risk free. The occurrence of this case will ultimately depend on the relative slopes of functions $p(.)$, $S(.)$ and $r_L(.)$.

If $L^*(L_{-i})>0$ (subject to constraint (5.b)), the following Lemma shows that loan strategies are strategic substitutes[5]:

Lemma 4 *If* $L^*(L_{-i}) \in (0, r^{-1}(r - r_D(D_{-i} + D^*))D^*)$ *then* $\dfrac{dL^*}{dL_{-i}} < 0$.

Proof : Straightforward differentiation of condition (7.b) Q.E.D.

Recall that when the supply of loans is positive, banks will also hold bonds in quantities large enough to guarantee depositors their promised payments in the bad state.

Moral-hazard (MH) strategy

Under this strategy, a bank chooses $\left(L, D\right) \in R_+^2$ to maximize:

$$(p(S(L_{-i} + L))[(r_L(L_{-i} + L) - r)L + (r - r_D(D_{-i} + D))D]. \tag{8.b}$$

subject to $$(r - r_D(D_{-i} + D))D \leq rL \tag{9.b}$$

and $$L \leq D \tag{10.b}$$

[5] Note that the properties of $D^*(D_{-i})$, and the fact that deposits are also strategic substitutes, are established in Lemma 1(a).

It is obvious that for this strategy to be adopted (i.e. $L > 0$), $r_L(L_{-i} + L) - r > 0$ must hold. If $r_L(L_{-i} + L_i) - r > 0$ and constraint (9.b) is satisfied at equality, then the objective would be $(p(.)r_L - r)L + (r - r_D(D_{-i} + D))D$, which is never higher than the profits achievable under a NMH strategy. Thus, for an MH strategy to be adopted, constraint (9.b) is never binding.

Let λ denote the Kuhn-Tucker multiplier associated with constraint (10.b). The necessary conditions for optimality of $\tilde{L}$ and $\tilde{D}$ are respectively given by:

$$p'(S(L_{-i} + L))S'(L_{-i} + L)[(r_L(L_{-i} + L) - r)L + (r - r_D(D_{-i} + D))D]$$

$$+ p(S(L_{-i} + L))[r_L(L_{-i} + L) + r_L'(L_{-i} + L)L - r] - \lambda = 0 \qquad (11.b)$$

$$p(S(L_{-i} + L))[r - r_D(D_{-i} + D) - r_D'(D_{-i} + D)D] + \lambda = 0 \qquad (12.b)$$

$$\lambda \geq 0, \quad \lambda(L - D) = 0 \qquad (13.b)$$

The following Lemma shows that the MH strategy generates a choice of deposits (and loans) that maximizes the objective of the version of this model without bonds.

Lemma 5 *Under a moral-hazard (MH) strategy,* $\tilde{L} = \tilde{D}$

Proof: Substituting (11.b) and (12.b) in objective (8.b), profits are given by $\tilde{\Pi}(L_{-i}, D_{-i}, \lambda) \equiv \dfrac{p(\lambda - p(r_L + r_L'\tilde{L} - r))}{p'S'} \geq \tilde{\Pi}(L_{-i}, D_{-i}, 0)$, where the inequality holds since

$\lambda \geq 0$. The complementary slackness condition (13.b) implies that if $L < D$, then $\lambda = 0$. Thus, setting $L < D$ is never optimal. Q.E.D.

The following Lemma summarizes the properties of optimal choices and profits under the MH strategy.

Lemma 6 **(a)** $\frac{d\tilde{D}}{dD_{-i}} < 0$**; (b)** $\frac{d\tilde{S}}{dD_{-i}} < 0$**; (c)** $\frac{d\tilde{\Pi}}{dD_{-i}} < 0$

Proof: Differentiation of conditions (11.b) and (12.b), and application of the Envelope Theorem.

Clearly, the comparative statics properties of the MH strategy are identical to those of the version of this model with no bonds, as in Boyd and De Nicolò (2005).

Nash Equilibria

Symmetric Nash equilibria in pure strategies can be of at most of three types: no-moral hazard without lending (i.e. credit rationing, CR), no-moral hazard with positive lending (NMH), or moral hazard (MH) equilibria. The occurrence of one or the other type of equilibrium depends on the shape of the function $p(.)$, the slope of the loan and deposit functions, as well as the number of competitors.

Let $\Pi^{CR}(0)$ and $\Pi^{MH}(0)$ denote the profits of a monopolist bank choosing the CR and the MH strategy respectively. Denote with $\Pi^{NMH}(D_{-i})$ the maximum profits achieved by a bank under a NMH strategy as a function of total deposits of competitors, and with $\Pi^{NMH}(0)$ those attained by a monopolist. The following proposition identifies some properties of symmetric Nash equilibria, and it is illustrated in Figure 5.

Proposition 3

(a) *If* $\Pi^{CR}(0) \geq \max\{\Pi^{NMH}(0), \Pi^{MH}(0)\}$ *and for all* $D_{-i} \in R_+$ *the inequality*

$d\Pi^{CR} / dD_{-i} < \min\{d\Pi^{NMH} / dD_{-i}, d\Pi^{MH} / dD_{-i}\}$ *holds, then there exists an* $\bar{N} \geq 1$ *such that the unique symmetric Nash equilibrium is a moral-hazard (CR) equilibrium for all* $N \leq \bar{N}$

(b) *There exists a finite* $\hat{N}$ *such that for all* $N \geq \hat{N}$ *the unique equilibrium is MH.*

Proof (sketch):

(a) By the maintained assumptions, there exists a $\bar{D}_{-i}$ such that for all $D_{-i} \leq \bar{D}_{-i}$ $\Pi^{CR}(D_{-i}) \geq \max\{\Pi^{*}(D_{-i}), \tilde{\Pi}(D_{-i})\}$. Thus, profits under the CR strategy are always larger than those attainable under both the NMH and MH strategies for all values of N such that $Z^{*}(N) \equiv (N-1)D^{*} \leq \bar{D}_{-i}$ (see figure 5.A). Thus, as $Z^{*}(N)$ is strictly increasing in N, the unique symmetric Nash equilibrium is a moral-hazard (CR) equilibrium for all $N \leq \bar{N}$, where $\bar{N}$ satisfies $Z^{*}(\bar{N}) = \bar{D}_{-i}$.

(b) By (6.b), (11.b) and (12.b), $D^{*} < \tilde{D}$ for all D_{-i}. Using $Z^{**}(N) \equiv (N-1)D^{**}$ (under CR), $Z^{*}(N) \equiv (N-1)D^{*}$ (under NMH) and $\tilde{Z}(N) \equiv (N-1)\tilde{D}$ (under MH), there exists a value of $\hat{N}$ such that for all $N \geq \hat{N}$ the inequality

$\Pi^{MH}(\tilde{Z}(N)) > \max\{\Pi^{CR}(Z^{**}(N)), \Pi^{NMH}(Z^{*}(N))\}$ holds, where $\Pi^{CR}(Z^{**}(N))$ and $\Pi^{NMH}(Z^{*}(N))$ denote profits under a CR and an NMH strategy respectively (see Figure 5.B). Thus, for all $N \geq \widehat{N}$, the unique equilibrium is MH. Q.E.D.

The interpretation of Proposition 3 is straightforward. Part (a) (Figure 5.A) says that if the expected return on loans if the bank were a monopolist is *lower* than the return on bonds, than for a range of low values of N, the CR equilibrium would prevail. Thus, this model can generate credit rationing as an equilibrium outcome. Note again that in such equilibria, entrepreneurs are willing to demand funds and pay the relevant interest rate but loans will not be supplied. The reason is that the high rent (few) banks are willing to extract from entrepreneurs would force them to choose a level of risk so high as to make the probability of a good outcome small. When this probability is sufficiently small, holding bonds only will be banks' preferred equilibrium choice. This result is similar to the credit rationing equilibria obtained in the bank contracting model analyzed by Williamson (1986), but it differs from Willliamson's, and complements its result. In our model credit rationing arises exclusively as a consequence of bank market structure, and the risk choice is endogenous. By contrast, Williamson's result arises from specific constellations of preference and technology parameters and there is no risk choice by entrepreneurs.

Part (b) (Figure 5.B) establishes that for all Ns larger than a certain threshold, the unique equilibrium is one in which banks invest all their funds in lending. As a result, the relationship between asset allocations and the number of banks can be, as in the previous model, monotonically increasing beyond certain threshold values of N . In other words, banks' allocation of credit rises as competition increases.

Figure 6 illustrates Proposition 3 for an economy with $p(S)=1-AS$, $r_L(x)=x^{-\alpha}, \alpha \in (0,1)$ and $r_D(x)=x^{\beta}, \beta \geq 1$. The first panel shows the risk shifting function, which indicates credit rationing (S is set equal to 0) when $N \leq 23$. Beyond that point, the economy switches to a MH equilibrium, with the risk shifting function jumping up, and then decreasing as N increases. At the same time, the loan-to-asset ratio jumps from 0 to unity (second panel) . As shown in the third panel, the ratio of bank profits to deposits (the return on assets in our model) declines as the number of banks increases from 1 to 22, then jumps up and declines again as the number of banks increases when $N \geq 23$. Thus, in this economy the return on assets is *not* monotonically related to the number of banks.

Pareto-dominant equilibria

It turns out that the implications of the model under Pareto-dominance are similar to those under the conventional Nash equilibrium for values of N not "too small", as shown in the following:

Proposition 4 *There exists a finite value $\tilde{N} \geq 1$ such that for all $N \geq \tilde{N}$ the unique Pareto-dominant symmetric equilibrium is a moral-hazard (MH) equilibrium.*

Proof: (similar to proposition 2, under construction)

Figure 7 illustrates Proposition 4 for the economy of Figure 6. As shown in the first panel, the MH equilibrium Pareto-dominates the MH equilibrium for all $N \geq 36$. The second and third panels show equilibrium risk shifting and asset allocations. It is apparent that their behavior is qualitatively identical to that obtained for the same economy in a standard Nash equilibrium.

C. Summary

With regard to risk, the predictions of the CVH model under the standard Nash equilibrium concept are not different from those of its version without bonds: risk shifting is strictly *increasing* in the number of firms, and becomes maximal under perfect competition. With regard to asset allocation, this model predicts a loan-to-asset ratio either monotonically increasing in the number of firms (with a jump, Proposition 1(a)), or a non-monotonic relationship (Proposition 1(b)), which however leads banks to invest in loans only when N becomes sufficiently large. Yet, under Pareto dominance, the positive relationship between competition, risk and the loan-to-asset ratio breaks down, as perfect competition would lead to the first best (lowest) risk level, while the loan to asset ratio is predicted to decrease as competition increases.

The predictions of the BDN model with regard to risk are the opposite of the model without a loan market under the standard Nash equilibrium concept, and they are not different from those of the model without bonds: risk shifting is strictly *decreasing* in the number of firms. With regard to asset allocation, the BDN model predicts a loan-to-asset ratio either monotonically increasing in the number of firms, from 0 to a positive value if credit rationing occurs, or for larger values of *N* if it does not. For this model, identical predictions are obtained under Pareto dominance.

Thus, under the standard Nash equilibrium concept, both models produce divergent predictions concerning risk, but similar implications for asset allocation. Under Pareto dominance, they produce similar implications concerning risk, but divergent predictions concerning asset allocations. Next, these predictions are confronted with the data, using measurement consistent with theory.

III. EVIDENCE

As discussed in Boyd and De Nicolo (2005), previous empirical work on the relationship between competition and risk in banking has reached mixed conclusions. A serious drawback with most existing work is that it has employed *either* good measures of bank risk *or* good measures of bank competition, but not both. In the present study we attempt to overcome many of these problems.

Theory and measurement

We use theory to identify measures of bank risk and competition. Our risk measure will be the "Z-score" which is defined as $Z = (E/A + P/A) / \sigma_{P/A}$, where E/A is the ratio of equity to assets, P/A is an estimate of the rate of return on assets, and $\sigma_{P/A}$ is an estimate of the standard deviation of the rate of return on assets, P/A. This risk measure is monotonically associated with a measure of a bank's probability of failure and has been widely used in the empirical banking literature. It represents the number of standard deviations below the mean by which profits would have to fall so as to (just) deplete equity capital. It does not require that profits be normally distributed to be a valid probability measure, indeed, all it requires is existence of the first four moments of the return distribution. (Roy, 1952). In addition, statitistics of Z-scores for a set of firms in a given market may be viewed as simple proxy measures of systemic risks.[6]

Consistent with our theory, we measure competition with concentration measures inclusive of all banks analyzed, given by Hirschmann-Hirfendahl Indices (HHIs).[7] As we have illustrated previously, theory predicts that the relationship between the number of competitors and bank profit need not even be monotonic in a Cournot-Nash environment. A full empirical investigation of non-monotonic and possibly discontinuous relationship between concentration and profits is beyond the scope of this study. However, the finding of a positive relationship between concentration and profits for some HHI ranges

[6] It is easy to show that changes of Z-scores for a set of firms operating in the same market in response to a change in a market specific characteristics, such as a concentration measure, are equal to the change in the average Z-score for this set of firms. This latter measure may be viewed as providing a simple measure of "systemic" risks, similar to that used in De Nicolò et al. (2004).

[7] Some recent studies have interpreted the so-called "H-statistics" introduced by Panzar and Rosse (1987) as a *continuous* measure of competitive conditions, and tested whether it is related to some concentration measures. Yet, the unsuitability of this statistics as a continuous measure of competitive conditions is well known in the literature (see, for example, Shaffer, 2004). These tests are, at best, joint tests of a set of hypotheses, such as competitive input prices, *and* the set of conditions, if any, that may allow one to treat the Panzar and Rosse statistics as monotonically related to non-competitive pricing.. Perhaps unsurprisingly, these studies have found mixed results. For example, Bikker and Haaf (2002) find that concentration measures are significantly *negatively* related to the H-statistics, while Claessens and Laeven (2004) find a *positive* or *no* relationship.

may be indicative of the existence and relevance of monopoly rents. This is why we begin by investigating this relationship in our datasets using (unscaled) profits.[8]

Relating HHIs to bank profits across markets requires that we control for market as well as bank size (see Bresnahan, 1989). An HHI may be mechanically lower in larger markets, since a greater number of firms can profitably operate in them. Given a similar market size, a more concentrated market would typically be composed of larger banks. If large banks were more efficient than small banks, a positive relationship between bank profits and concentration could simply reflect differences in bank efficiency, rather than differences in monopoly rents. As shown below, when we control for both market and bank size, a positive relationship between concentration and bank profits is not rejected in our data

Samples

We employ two different samples with very different characteristics. Each sample has its advantages and disadvantages, and the idea is to search for consistency of results across the two.

The first sample is composed of about 2500 U.S. banks that operate only in rural non-Metropolitan Statistical Areas, and is a cross-section for one period only, June,

[8] To our knowledge, virtually all of existing empirical work has used a scaled profitability measure as a dependent variable (profit/assets, profit/equity, etc.) Yet, since profits and assets may be decreasing in concentration at different rates, it is entirely possible, as predicted by our models, that scaled measures of profit need not be monotonically related to concentration. A theoretical study by Hannan (1991) alludes to this point, but does not appear to have been taken into account by many subsequent empirical studies.

2003. The banks in this sample tend to be small and the mean (median) sample asset size is only $80.8 million ($50.2 million). For anti-trust purposes, in such areas the Federal Reserve Board (FRB) defines a competitive market as a county and maintains and updates Hirschmann-Hirfendahl Indices (HHIs) for each county market. These are computed with and without including savings and loan associations included as bank competitors. These computations are done at a very high level of dis-aggregation. Within each market area the FRB defines a competitor as a "banking facility," which could be a bank or a bank branch. This U.S. sample, although non-representative in a number of ways, exhibits extreme variation in competitive conditions.[9]

The U.S. sample has an important, interesting and unique feature. We asked the FRB to delete from the sample all banks that operated in *more than one market area.* This was a computationally-intensive task because it required multiple passes through the data, and we are grateful for their assistance.[10] By limiting the sample in this way, we are able to directly match up competitive market conditions as represented by the HHI and individual bank asset allocations as represented by balance sheet data. This permits a

[9] For example, when sorted by HHI, the top sample decile has a median HHI of 5733 while the bottom decile has a median HHI of 1244. The sample even includes 32 monopoly banking markets.

[10] The "banking facilities" data set is quite different from the Call Report Data which take a bank as the unit of observation. The banking facilities data set is not user-friendly and we thank Allen Berger and Ron Jawarcziski for their assistance in obtaining these data.

clean test of the link between competitive conditions and asset composition, as predicted by our theory.[11] [12]

The second sample is a panel data set of about 2700 banks in 134 countries *excluding* major developed countries over the period 1993 to 2004, which is from the *Bankscope* (Fitch-IBCA) database. The number of bank-year observations ranges from more than 13,000 to 18,000, depending on variables' availability. The advantage of this international data set is its sheer size, its panel dimension and the fact that it includes a great variety of different countries and economic conditions. The primary disadvantage is that bank market definitions are necessarily rather imprecise. It is assumed that the market for each bank is defined by its home nation. Thus, the market structure for a bank in a country is represented by a Hirshmann-Herfindahl Index for that country. To ameliorate this problem, we did not include in the sample banks from the U.S., Western Europe and Japan. In these cases, defining the nation as a market is problematic both because of the country's economic size and because of the presence of many international banks.

[11] Had we included multiple-market banks in the sample, we would have had to somehow aggregate competitive conditions across markets. It is not at all obvious how to do that.

[12] The FRB-provided HHI data also allow us to include (or not) savings and loans (S&Ls) as competitors with banks, which could be a useful robustness test. S&L deposits are near perfect substitutes for bank deposits, whereas S&Ls compete with banks for some classes of loans and not for others.

A. Results for the U.S. Sample

Table 1 defines variables, and Table 2 reports some statistics of the sample banks and their county areas. Here, the "Z-score" is defined as Z = (E/A + P/A) / SDPA, where E/A is the average ratio of equity to assets, P/A is the average rate of return on assets (net accounting profits after taxes / total assets), and SDPA is the standard deviation of the rate of return on assets, P/A, computed over the 12 most recent quarters. As shown in Table 2, the mean Z-score is quite high in the U.S. sample at about 36, reflecting the fact that the sample period is one of very profitable and stable operations for U.S. banks. The average HHI for the sample is 2856 if savings and loans are not included, and 2650 (not shown) if they are.[13] The average county in our sample is fairly prosperous with a median per-capital income of about $33,400. Table 3. shows simple correlation coefficients of all variables.

We estimate versions of the following cross-sectional regression:

$$X_{ij} = \alpha + \beta HHI_j + \gamma Y_j + \delta Z_{ij} + \varepsilon_{ij}$$

[13] To put these HHI's in perspective, suppose that a market has four equal sized banks. Then its HHI would be 4 x 25 ** 2 = 2500. As noted earlier, there is great diversity of competitive conditions in this sample.

where X_{ij} is bank profit, Z-score, the Z-score components and the loan-to-asset ratio of bank i in county j, HHI_j is a Hirschmann-Hirfendahl Index in county j, Y_j is a vector of county-specific controls, and Z_{ij} a vector of bank-specific controls.[14]

Profit regressions

As discussed earlier, although our theory predicts either a negative or a positive relationship between concentration and bank profits, a positive relationship is what one would expect if monopoly rents are relevant in a given market. Table 4 shows regressions in which the dependent variable is the log of bank profits, *Profit*.[15] Some sample banks report losses so, to avoid taking logs of a negative number, a constant (1500) is added to the profits of each bank. Unless otherwise noted, all regressions here and elsewhere include dummy variables for state, there being 46 states included in our sample. For obvious reasons we would have preferred to control for counties as our measure of location. However, in about 25 percent of our sample there is only one bank per county, and thus to include county dummy variables would effectively throw away about one quarter of the data.[16] Thus we settled for the less precise state location controls. For simplicity, coefficients of the state variables are not included in the tables, but towards

[14] Estimates of standard errors of these regressions, as well as those that follow using the international data, were also carried out using clustering methods where applicable, as recommended by Wooldridge (2003).

[15] Logs are employed as a simple way of allowing for a nonlinear relationship.

[16] Recall that in picking sample banks we reject any bank that has affiliates or branches in any other market. This procedure has the important advantages discussed earlier but it does eliminate a lot of data points.

the bottom of each table there is an F-statistic and probability statistic for the significance of the entire block of state dummy variables.

In 4.1 the only explanatory variable (besides state dummies) is HHI0, the Hirschman-Herfindahl index computed with banks only. It is positive and significant at a high confidence level. Qualitatively, the same result is obtained when we replace the banks-only measure HHI0 with the banks-and-savings-and-loans measure HHI100. Results with HHI100 are here and throughout summarized in the very last row of the table. In 4.2 we add four variables to control for systematic differences in county economic conditions that may not be captured by the state dummy variables. These are median personal income *lnmedy* which, as discussed earlier, controls for differences in the economic size of markets, percentage growth in the labor force *labgro*, the unemployment rate *unem*, and an indicator of agricultural in each county area, *farm. farm* is the ratio of rural farm population to total population as reported as by the Census Bureau. We also include two bank-specific control variables. One is a measure of size *Lnasset,* the natural log of total bank assets, which represents scale and thus could capture scale economies. The second is a measure of operating efficiency *Cti,* which is the ratio of non-interest expenses to total income of banks. This variable is included to control for differences in production technologies, or technical efficiency across banks.

When the control variables are added, the coefficient of *HHI0* decreases but remains statistically significant at a high confidence level, as does the coefficient of *HHI100.* The cost efficiency variable *Cti* is highly significant and has the expected negative sign. The bank size variable *lnasset* has a positive and highly significant coefficient. This is expected since both *Profit* and *lnasset* are unscaled and thus capture pure size of organization.

As a robustness check, in equation 4.3 we drop the state dummy variables but employ clustering on the states. This reduces the significance of HHI0 to just above the 90% confidence level, and that of HHI100 to a bit less than 90% confidence. Finally, in equation 4.4 we reintroduce the state dummy variables and do an additional robustness check against the possibility that our measure of competition, HHI0, is partly reflecting the short run demand for banking services. What is done is an instrumental variables procedure. For instruments we chose a set of explanatory variables that are associated with banking structure but are unlikely to be related to demand for banking or bank profitability in the short to intermediate run. The three instruments we employ are a Gini index of the county income distribution, *gini*, the ratio of farm to non farm population, *farm*, and the natural logarithm of the county labor force in 2003, *lnlabor*. With the instrumental variables procedure, the coefficient of HHI0 is positive and significant at more than the 90% confidence level, as is the coefficient of HHI100.

Z-score regressions

In Table 5 we present regressions in which the Z-score, our risk of failure measure, is the dependent variable. 5.1 is a regression of Z-score against the HHI0 computed with banks only. The coefficient of the HHI index is negative but not statistically significant at usual confidence levels. The same is true in the regression with HHI100. Regression 5.2 includes as additional explanatory variables the same set of six control variables discussed earlier; four to control for regional (county) effects, and two to control for bank effects. With this addition, the coefficient of HHI0 becomes negative and significant at the 90% confidence level, (and the same is true of the coefficient of HHI100). This suggests that more concentration is associated, *ceteris paribus,* with higher risk of bank failure The coefficient of Cti is negative and highly significant, suggesting that cost inefficiency may adversely affect the risk of bank failure. Finally, the coefficient of *lnasset* enters with a negative and highly significant coefficient, suggesting that, for this sample of very small banks, the larger ones are on average riskier than the smaller ones.

As a robustness check, in regression 5.3 we retain the same explanatory variables as in 5.2, drop the state dummy variables, and cluster on states. With this change the coefficient of HHI0 becomes negative and significant at a high confidence level, (so does that of HHI100). Coefficients and significance of the other bank variables are not much affected. In 5.4. we employ the same instrumental variables procedure for HHI0 and HHI100 as discussed earlier. When this is done, the coefficients of both variables remain negative and highly statistically significant.

In sum, these tests suggest that more concentrated bank markets are *ceteris paribus* associated with greater risk of bank failures.

Regressions of Z-score components

In this set of regressions, we examine each of the three components of the Z-score, (PA, EA and SDPA), to see if we can determine which is principally driving the statistically significant relationship between HHI0 and Z-score. Table 6 shows regressions with the three individual components of Z-score, *P/A, E/A,* and SDPA as the dependent variables. In all these tests, we include the same six control variables as previously discussed.

In regressions 6.1 - 6.4 the dependent variable is the rate of return on bank assets, P/A. This is positively and highly significantly associated with HHI0 in the univariate regression 6.1, and when the controls are added, 6.2. When we do the robustness check with clustering on states, the coefficient of HHI0 remains positive but its t-value drops to 1.53, just below the 90% confidence level. Finally, when we employ the instrumental variables procedure for HHI0, its coefficient is positive and highly significant. In sum, it appears that more concentrated banking markets are associated, *ceteris paribus,* with higher rates of return on bank assets This finding, of course, is non inconsistent with our earlier finding that HHI0 is positively and significantly associated with the level of bank profits[17].

In regressions 6.5 – 6.9 the dependent variable is the EA, the bank ratio of equity to assets. We present the same progression of regression tests as earlier: 6.5 is univariate, 6.6 adds six control variables, 6.7 employs state clustering, and 6.9 employs the instrumental variables procedure for HHI0. In addition, in 6.8 we use a Cox transform on the dependent variable EA, since without transformation EA is bounded between zero and one. In all these tests the coefficient of HHI0 is positive but in no case is it statistically different from zero at any reasonable confidence level. In sum, there is

[17] Qualitatively similar results are obtained if the dependent variable is the accounting rate of return on equity (instead of assets).

no evidence that financial leverage as represented by EA is associated with market concentration.

Finally, in regressions 6.10 – 6.13 the dependent variable is SDPA, the standard deviation of the rate of return on bank assets. In the univariate regression 6.10 the coefficient of HHI0 is positive, but not statistically significance at usual confidence levels. When the control variables are added in 6.11 the coefficient of HHI0 becomes statistically significant at a high confidence level. This remains true (positive and highly significant) both when state clustering is employed (6.12) and with the instrumental variables procedure (6.13). In sum, it seems that the volatility of banks' return on assets is, *ceteris paribus,* positively associated with the degree of concentration in bank markets.

Asset Composition Regressions

Next, we turn to an investigation of the relationship between market structure as represented by the HHI and composition of banks' balance sheets as represented by the ratio of loans to assets, LA. As discussed earlier, both the CVH and BDN models predict a negative relationship: that is, higher concentration as measured by the HHI will be associated with a lower loan to asset ratio.

In Regression 7.1, the dependent variable is the ratio of loans to assets, *L/A* and the explanatory variable is *HHI0*. The relationship is negative and statistically significant at a high confidence level. The same is true with HHI100. Next, in 7.2 we add our usual set of control variables. Again, the coefficients of Both HHI0 and HHI100 are negative and significant at high confidences. In this test, the *lnasset* variable enters with a positive and highly significant coefficient, suggesting that on average larger banks tend to have higher loan to asset ratios. Also, the coefficient of *Cti* is negative and highly significant suggesting that less efficient banks tend to have lower loan to asset ratios. When in 7.4 we employ the state clustering procedure and in 7.5 the instrumental variables procedure, none of these conclusions is reversed. In particular, the relation between HHI0 (HHI100) and LA remains negative and highly statistically significant.

In sum, these tests suggest --- just as predicted by the two theoretical models presented earlier ---- that there is a significant negative relationship between concentration in banking markets and loan to asset ratios.[18]

B. Results for the International Sample

Table 8 reports some sample statistics for banks[19] and some macroeconomic variables. There is a wide variation of countries in terms of income per capita at PPP (ranging from US$ 440 to US$ 21,460), as well as in terms of bank size.

[18] In other tests (not reported) we investigated the relationship between the ratio of bank investments to assets, and market concentration. These results always tend to support what we have reported here. That is, *ceteris paribus,* in more highly concentrated markets banks tend to make more investments as a fraction of total assets.

[19] We considered all commercial banks (unconsolidated accounts) for which data are available. Coverage of the Bankscope database is incomplete for the earlier years (1993 and 1994), but from 1995 ranges from 60 percent to 95 percent of all banking systems' assets for the remaining years. Data for 2004 are limited to those available at the extraction time.

Here, the Z-score at each date is defined as $Z_t = (ROAA_t + EQTA_t)/Vol(ROAA_t)$, where $ROAA_t$ is the return on average assets, $EQTA_t$ is the equity-to-assets ratio and $Vol(ROAA_t) = |ROAA_t - T^{-1}\sum_t ROAA_t|$. When this measure is averaged across time, it generates a cross-sectional series whose correlation with the Z-score as computed previously is about 0.89. The median Z is about 19. It exhibits a wide range, indicating the presence of both banks that either failed (negative Z) or were close to failure (values of Z close to 0), and banks with minimal variations in their earnings, with very large Z values. The sample is unaffected by selection bias, as it includes all banks operating in each period, including those which exited either because they were absorbed by other banks or because they were closed.

We computed HHI measures based on total assets, total loans and total deposits. The median asset HHI is about 19, and ranges from 391 to the monopoly value of 10,000. The correlation between the HHIs based on total assets, loans and deposits is very high, ranging from 0.89 to 0.94.

Table 9 reports correlations among some of the bank and macroeconomic variables. The highest correlation is between the HHI and GDP per capita. This correlation is negative (-0.30) and significant, indicating that relatively richer countries have less concentrated banking systems. This is unsurprising: since GDP per capita can be viewed as a proxy for the size of the banking market, the larger is this market, the larger is the number of firms that can operate in it profitably. Remarkably, note that the U.S. sample exhibits an identical negative and significant correlation (-0.30) between median county per-capita income and HHI (Table 3).

As before, we present a set of regressions in which profits per bank, the Z-score and its components, and the loan to asset ratio are the dependent variables. We estimate versions of the following panel regression:

$$X_{ijt} = \sum \alpha_i^1 I_i + \sum \alpha_j^2 I_j + \beta HHI_{jt-1} + \gamma Y_{jt-1} + \delta Z_{ijt-1} + \varepsilon_{ijt}$$

where X_{ij} is bank profit, Z-score, the Z-score components and the loan-to-asset ratio of bank i in country j, I_i and I_j are bank i dummy and country j dummy respectively, HHI_j is a Hirschmann-Hirfendahl Index in county j, Y_j is a vector of country-specific controls, and Z_{ij} a vector of bank-specific controls. Two specifications are used. The first one is with country fixed effects, the second one is with individual fixed effects. Consistent with the two periods models, the HHI, the macro variables and bank specific variables are all lagged one year so as to capture variations in the dependent variable as a function of pre-determined past values of the dependent variable.[20]

Profit regressions

As noted earlier, an implication common to the models previously described is that the profits of the representative bank should decline as concentration declines at least for sufficiently large values of N. Since in reality firm heterogeneity, particularly in terms of size and cost, is important, we control for bank size and operating cost in our regressions.

[20] This is a fairly standard specification. See, for example, Demsetz and Strahan (1997).

Table 10 reports regressions with bank profits as the dependent variable. The independent variables are the three HHI measures (assets, loans and deposits), and we control for asset size and costs. As concentration increases, profits per bank increase with each HHI measure. Thus, the positive relationship between bank profits and concentration predicted by our models is not rejected by the data.

Z-score regressions

In Table 11 we present a set of regressions in which the Z-score is the dependent variable. Regressions 11.1 and 11.2 regress the Z-score against the HHI. In both cases, the coefficient of the HHI index is negative and highly significant.

Regressions 11.3 and 11.4 are the same as 11.1. and 11.2 except that they include GDP per capita, GDP growth and inflation. GDP growth enters with a positive and significant sign, indicating that bank insolvency risk is procyclical. By contrast, banks in countries with comparatively higher inflation exhibit higher insolvency risk. The addition of these country-specific control variables does not change the relationship between the Z-score and HHI, which remains negative and highly significant.

Regressions 11.5 and 11.6 are the same as 11.3 and 11.4, except that they include size (log asset) and the ratio of loans to total assets as additional control variables. Again, the HHI coefficient remains negative and highly significant. Indeed, such negative relationship is even stronger, since with the addition of all controls the coefficient associated with HHI increases in absolute value relative to the specification without controls (11.2).

Importantly, larger banks exhibit *higher* insolvency risk, as the coefficient associated with size is negative and highly significant[21]. This is the same result obtained for the U.S. sample in this paper, and for samples of U. S. and other industrialized country large banks obtained by De Nicolò (2000) for the 1988-1998 period. Thus, the negative relationship between bank size and risk of failure seems to have been a feature common to both developed and developing economies in the past 15 years. This also confirms the results in De Nicolò et al. (2004): during this period, size-related diversification benefits in banking may have been offset by banks' higher risk-taking.

The bottom panel of Table 11 reports the estimated coefficients of loans and deposits HHIs for each of the regressions described. While results are similar to those using the asset HHI, the negative effect on Z of changes in HHI are stronger when concentration is measured by deposits rather than loans. However, the fact that the coefficient of asset HHI is the largest and always highly significant suggests such a measure may better capture competitive effects related to *all* bank activities, rather than those related to deposit-taking and loan-making activities only.

Regressions of Z-score components

As done previously, Table 12 reports regressions of the components of the Z-score as dependent variables: returns on assets (ROAA), capitalization (EQTA) and volatility of earnings (Vol ROAA).

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[21] We also run the same regressions with the log of assets to GDP as a proxy measure of bank size *relative* to the size of the market, obtaining qualitatively identical results.

ROAA is *negatively* and significantly related to asset HHI as well as to bank size. Capitalization is *negatively* and significantly with concentration, as well as with bank size, while volatility of earnings is *positively* and significantly related to HHI and bank size. These results mean that larger HHIs contribute to move Z *in the same direction.* That is, as shown in Table 9, the sign of the correlation among these components *reinforce*, rather than offset, their effect on Z.

Taken together, these results show that relatively larger banks operating in more concentrated markets are less profitable, have a lower capitalization and larger volatility of earnings. These results are utterly at variance with the conjecture that efficiency gains associated with concentrated banking systems and/or large bank sizes translate into lower bank risk profiles.

Asset Composition Regressions

The relationship between concentration and asset composition is summarized in Table 13, which reports regressions with the ratio of loans to assets as the dependent variable. The coefficients associated with each measure of HHI are negative and highly significant in all specifications. Consistent with the prediction of both theories previously described under Nash competition, loan-to-asset ratios tends to be lower in more concentrated markets.

IV. CONCLUSION

Our theoretical analysis considered two models: the CVH model, which is an extension of the work of Allen and Gale (2000, 2003), and the BDN model, which is an extension of our work (Boyd and De Nicolo, 2005). We showed that the predictions of the CVH model are similar to the original Allen and Gale (2000, 2004) model in one key respect: under a standard Nash equilibrium concept, risk shifting is strictly *increasing* in the number of firms. With the BDN model on the other hand, under the standard Nash equilibrium concept the risk predictions are exactly opposite: risk-shifting is strictly *decreasing* in the number of firms. With regard to asset allocations both models make roughly similar predictions under Nash competition. The equilibrium loan-to-asset ratio will be increasing in the number of firms when N becomes "sufficiently large". [22]

Our empirical tests were derived directly from the predictions of theory. They employed two different samples of banks with very different sample attributes. Our measure of profitability is accounting profits per bank, our risk measure is a Z-score, our asset allocation measure is the ratio of loans to assets, and our measure of competition is the HHI computed in a variety of ways. First, we examined the relationship between competition and profits per bank, which is generally predicted to be positive by both theory models. Here, we argued that employing the profits / assets ratio as the dependent variable is inappropriate in such tests (although this has been very frequently done) because, as shown in the theory section, the relationship between N and profits / assets is not necessarily even monotone. In essence, both profits and assets are decreasing in N but at different rates that depend on parameters.[23]

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[22] Under Pareto dominance, the CVH model gives completely different predictions: perfect competition leads to the first best (lowest) risk level, while the loan to asset ratio decreases as competition increases. By contrast, the BDN yield implications identical to those obtained under Nash competition for values of N not "too small".

[23] Indeed, we showed that even the relationship between N and profits per bank may not be a monotonic one.

With both samples, we found that the relationship between concentration and profits per bank is positive, statistically significant at high levels of confidence, and robust to a variety of specifications. Thus, the data support the predictions of both theory models. Next, we examined the relationship between competition and risk-taking. Here, we found that the relationship is negative, meaning that more competition (lower HHI) is *ceteris paribus* associated with a lower probability of failure (higher Z-score). This finding is consistent with the prediction of the BDN model, but inconsistent with the prediction of the CVH model. These results were obtained with both samples, are statistically significant at high confidence levels, and seemingly robust.

Finally, we examined the relationship between competition and asset composition, represented by the loan / asset ratio. Under Nash competition, both theoretical models predict that this relationship may be generally positive, and that is what we found in the empirical tests with both samples. As before, these results are statistically highly significant and robust to a variety of different specifications.

We draw two main conclusions from our investigation. First, there exist neither compelling theoretical arguments nor robust empirical evidence that banking stability decreases with the degree of competition in bank markets. On the contrary, using two large and very different bank samples, we found a positive relationship between bank stability, bank provision of finance (as captured by the loan to asset ratio) and competition. Many positive and normative analyses of regulation that depend on CVH-type models should be seriously re-examined in the context of contracting-type models of banking. Predictions of such models are simply not supported be the data.

Second, future modeling efforts should focus on extending contracting-type models of banking along several important dimensions. These include the issuance of bank equity claims and bank debt, and possibly doing that in a general equilibrium set-up. As we have shown, a seemingly trivial extension of two simple models has yielded important insights regarding the role of limited liability for incentives, as well as a novel set of implications regarding bank asset allocations. We believe that theory developed along the extensions outlined could lead to even more informative insights, sharper model implications, and better measurement.

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Table 1. Variable Definitions. Sample of U.S. Small Banks [24]

EA = Equity (book value) ÷ Total Assets, average over 3 years. Cox transform version = $Ln\left(\frac{(Equity / Asset)}{1-(Equity / Asset)}\right)$

HHI0 = Hirschmann-Herfindahl Index computed with banks only.

HHI100 = Hirschmann-Herfindahl Index computed with banks and savings and loan associations.

HHI-hat = Instrumental variables estimate of the Hirschman-Herfindahl Index. .Instrumental variables are farm, gini and lnlabor.

LA = Total Loans ÷ Total Assets, average over 3 years. Cox transform version = $Ln\left(\frac{(Loan / Asset)}{1-(Loan / Asset)}\right)$

PA = Total Profits ÷ Total Assets, average over 3 years

Profit = Quarterly average of net income over 3 years,. Transformed as ln(profit + 1500).

SDPA = Standard deviation of PA. This is computed with quarterly data for the twelve quarters up to and including June, 2003. Transformed as ln(SDPA).

Z = $\frac{(PA)+(EA)}{SDPA}$. Z is our fundamental risk-of-failure measure. (See discussion in body of text).

Control Variables

cti = Ratio of non-interest expense to interest income + non-interest income of banks, quarterly average over 3 years.

farm = Agricultural population ÷ Total population, 2003.

gini = Gini index, current income, 2003.

labgro = Percentage growth in labor force 1999 – 2003.

lnasset (asset) = Natural logarithm (dollar value) of total bank assets in 2003.

lnlabor (labor) = Natural logarithm of (number of people in) labor force, 2003.

Lnmedy (medy) = Natural logarithm (dollar value) of median income per capita, 2003.

unem = Unemployment rate, 2003.

[24] All balance sheet and income statement data are from the FDIC's *Call Reports* which are available at the FDIC website. Control variables are from various sources, mostly the Census Bureau website. All Control variables are at the county level.

Table 2.

Sample Statistics – U.S. Sample

Variable	Observation	Mean	Std. Dev.	Min	Max
asset	2,500	80,784.39	481,345.20	2,190	19,300,000
cti	2,500	0.4629737	0.9072113	0.0247162	29.12762
EA	2,500	0.1170843	0.0422184	0.0089886	0.7468389
farm	2,500	0.0705954	0.0563464	0	0.4085779
gini	2,500	0.52312	0.050812	0.15	0.69
HHi0	2,500	2,855.672	1,577.69	881.67	10,000
LA	2,500	0.571512	0.1465278	0	0.9556314
labgro	2,500	0.0062322	0.0671038	– 0.2419666	0.2717783
labor	2,500	13,752.79	13,875.65	365	232,227
medy	2,500	33,367.80	5,827.45	15,805	62,682
PA	2,500	0.0069673	0.0046641	– 0.0261662	0.0718267
Profit	2,500	740.4365	9,716.834	-1,089.5	409,816.2
SDPA	2,500	0.0041622	0.0028797	0	0.0448719
unem	2,500	5.82612	2.4746580	1.40	21.80
Z	2,496	35.58695	16.75539	3.091028	261.815

Table 3.
Simple Correlations – U.S. Sample

	Asset	cti	ea	farm	Gini	hhi0	la	labgro	labor	medy	pa	profit	sdpa	unem
asset	1													
cti	-0.0109	1												
ea	-0.0046	-0.0057	1											
farm	-0.0646	-0.0855	0.031	1										
gini	-0.0852	-0.108	0.0317	**0.3196**	1									
hhi0	**0.1032**	-0.0274	0.0019	**0.1174**	**0.1228**	1								
la	0.0499	-0.083	**-0.4194**	0.0522	-0.0728	-0.0952	1							
labgro	0.0252	0.0724	-0.0713	-0.0903	**-0.2466**	-0.045	0.0789	1						
labor	**0.1247**	**0.1224**	-0.0434	**-0.4333**	**-0.4663**	**-0.3142**	**0.1016**	**0.2058**	1					
medy	0.0473	0.0519	-0.0039	0.0005	**-0.5923**	**-0.2997**	**0.1656**	0.185	**0.3762**	1				
pa	0.0829	**-0.2945**	**0.1733**	0.0728	0.0587	0.0814	-0.0242	-0.0265	**-0.1138**	-0.0534	1			
profit	**0.9943**	-0.0109	0.0115	-0.0396	-0.0636	**0.1015**	0.0406	0.0205	**0.1004**	0.038	0.094	1		
sdpa	0.0562	**0.2465**	0.21	-0.0839	**-0.1072**	0.0237	0.0103	0.0684	0.0686	0.0234	0.0143	0.0295	1	
unem	-0.0185	-0.0036	-0.0188	**-0.3727**	**0.1886**	0.0204	-0.0566	**-0.1746**	0.0011	**-0.3164**	-0.0659	0.0024	0.029	1
z	-0.052	-0.0827	**0.4617**	0.0919	**0.1017**	-0.0686	**-0.3018**	**-0.1032**	-0.0432	0.0003	**-0.1219**	**-0.1663**	**-0.5013**	-0.0336

Notes: Coefficients significant at 5% confidence level or lower are reported in **boldface**.

Table 4. Dependent Variable: Profit

Profit. Natural logarithm of bank profits, average over 3 years. Before taking logs, each bank's profits are increased by a constant, 1500, so as to avoid logarithms of negative numbers.

HHI0 is the Hirschmann-Herfindahl Index computed with banks only. HHI100 is the Hirschmann-Herfindahl Index computed with banks and savings and loan associations. HHI-hat is an instrumental variables estimate of the Hirschman-Herfindahl Index, when HHI0 is regressed on lnlabor, farm and gini. lnmedy = natural logarithm of median income per capita, 2003. labgro is the percentage growth in labor force 1999 – 2003. unem is the unemployment rate, 2003. gini is a GINI index computed with current household income, 2003. farm is the ratio, agricultural population / total population in 2003. lnasset = Natural logarithm of bank assets. cti = ratio of non-interest expense to interest income + non-interest income of banks, quarterly average over 3 years.

Columns 4.1 and 4.2: OLS, Robust. Column 4.3: OLS with State Clusters. Column 4.4: Instrumental Variable estimation with instruments farm, gini and lnlabor.

Equation:	4.1		4.2		4.3		4.4	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	7.528245	***653.36	5.461016	***17.81	4.800371	***8.41	4.800371	***9.46
HHI0	0.000011	***3.04	0.00000568	**2.21	0.0000102	*1.73		
HHIhat							0.0000102	*1.85
Lnmedy			-0.0586852	**-2.04	0.0051075	0.15	0.0051075	0.16
Labgro			-0.155465	***-2.63	-0.0668677	-1.18	-0.0668677	-1.36
Unem			-0.0025441	-1.36	-0.0063289	***-2.92	-0.0063289	***-4.06
Farm			0.041932	0.48	0.1484463	1.57	0.1484463	**2.41
Lnasset			0.2516723	***51.33	0.2516453	***10.66	0.2516453	***13.12
Cti			-0.0343095	***-8.08	-0.0371975	**-2.14	-0.0371975	**-2.24
R-squared / NOBS	0.1637	2500	0.6215	2500	0.5649	2500	0.5649	2500
F-test / p-value	F(45, 2453)	***9.872	F(45, 2447)	***8.127				
RMSE / Categories (States)	0.25621	46	0.17259	46	0.18336	46	0.18336	
Regression With:								
HHI100	0.00000983	***2.68	0.000006	**2.28	0.0000101	1.59	0.0000101	*1.76

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Table 5. Dependent Variable: Z

Z = (PA + EA) / SDPA. This is our fundamental risk-of-failure measure. It is an estimate of the number of standard deviations below the mean by which profits would have to fall so as to extinguish equity. (See discussion in body of text).

HHI0 is the Hirschmann-Herfindahl Index computed with banks only. HHI-hat is an instrumental variables estimate of the Hirschman-Herfindahl Index, when HHI0 is regressed on lnlabor, farm and gini. lnmedy = natural logarithm of median income per capita, 2003. HHI100 is the Hirschman-Herfindal Index when both banks and savings and loans are included. labgro is the percentage growth in labor force 1999 – 2003. unem is the unemployment rate, 2003. lnasset = Natural logarithm of bank assets. farm is the ratio, agricultural population / total population in 2003. cti = ratio of non-interest expense to interest income + non-interest income of banks, quarterly average over 3 years.

Columns 5.1 and 5.2: OLS, Robust. Column 5.3: OLS with State Clusters. Column 5.4: Instrumental Variable estimation with instruments farm, gini and lnlabor.

Equation:	5.1		5.2		5.3		5.4	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	36.43258	***49.19	114.5409	***4.00	78.49964	**2.63	78.49964	***3.72
HHI0	-0.0002962	-1.27	-0.0004233	*-1.77	-0.0006652	***-3.07		
							-0.0006652	***-3.46
HHIhat								
Lnasset			-4.282122	***-9.36	-3.994285	***-4.7	-3.994285	***-6.75
cti			-1.851448	***-4.28	-1.932756	***-3.21	-1.932756	***-3.21
Lnmedy			-2.734607	-1.02	0.3729289	0.14	0.3729289	0.19
Labgro			-11.68179	**-2.12	-22.76262	***-3.77	-22.76262	***-4.92
Unem			-0.4346776	**-2.5	-0.163795	-1.35	-0.163795	-1.14
Farm			6.3417	0.77	3.925396	0.58	3.925396	0.59
R-squared / NOBS	0.0531	2496	0.0995	2496	0.0621	2496	0.0621	2496
F-test / p-value	F(45, 2449)	***2.779	F(45, 2443)	***2.254				
RMSE / Categories (States)	16.457	46	16.068	46	16.25	46	16.25	
Regression With:								
HHI100	-0.0002484	-1.05	-0.0004149	*-1.69	-0.0006608	***-3.27	-0.0006608	***-3.25

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Table 6. Dependent Variables: PA, EA, SDPA

EA = equity / total assets. PA = total profits / total assets. SDPA = standard deviation of PA. This is computed with quarterly data for the twelve quarters up to and including June, 2003.
HHI0 is the Hirschmann-Herfindahl Index computed with banks only. HHI-hat is an instrumental variables estimate of the Hirschman-Herfindahl Index, when HHI0 is regressed on farm, gini and lnlabor. labgro is the percentage growth in labor force 1999 – 2003. unem is the unemployment rate, 2003. lnmedy is the natural logarithm of median income, 2003. lnasset = Natural logarithm of bank assets, 2003. farm is the ratio, agricultural population / total population in 2003. cti = ratio of non-interest expense to interest income + non-interest income of banks, quarterly average over 3 years.

Columns 6.1, 6.2, 6.5, 6.6, 6.10, 6.11: OLS, Robust. Columns 6.8, OLS, Robust with Cox transformation of the dependent variable. Columns 6.3 and 6.7: OLS with State Clusters. Columns 6.4 6.9 and 6.13: Instrumental Variable estimation with instruments farm, gini and lnlabor.

Equation:	6.1		6.2		6.3		6.4		6.5	
Dependent Variable:	PA		PA		PA		PA		EA	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	0.0062899	***31.04	0.0233475	***3.06	0.0134014	1.46	0.0134014	**2.13	0.1160196	***61.91
HHI0	0.0000002	***3.73	0.0000001	*1.92	0.0000001	1.53			0.0000004	0.63
HHIhat							0.0000001	**1.99		
Lnasset			0.0011483	***9.42	0.0010108	***6.13	0.0010108	***7.78		
cti_m			-0.001139	***-10.79	-0.001302	***-3.00	-0.001302	***-3.08		
Lnmedy			-0.002714	***-3.8	-0.001599	-1.67	-0.001599	**-2.53		
Labgro			-0.002816	*-1.92	-0.001183	-0.73	-0.001183	-0.94		
Unem			-0.000083	*-1.8	-0.000145	*-2.53	-0.000145	***-3.42		
Farm			0.0016409	0.75	0.0062666	***3.00	0.0062666	***3.47		
R-squared / NOBS	0.0841	2500	0.171	2500	0.1194	2500	0.1194	2500	0.0436	2500
F-test / p-value	F(45, 2453)	***4.612	F(45, 2447)	***3.385					F(45, 2453)	***2.487
RMSE / Categories (States)	0.00451	46	0.00429	46	0.00438	46	0.00438		0.04167	46

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Table 7. Dependent Variables: PA, EA, SDPA (continued)

Equation:	6.6		6.7		6.8		6.9		6.10	
Dependent Variable:	EA		EA		EA Cox		EA		SDPA	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	0.1965448	***2.7	0.1985825	***3.44	-1.04316	*-1.72	0.1985825	***3.22	-5.620775	***-287
HHI0	0.0000006	1.04	0.0000005	0.99	0.0000046	0.89			0.0000088	1.43
HHIhat							0.0000005	0.94		
Lnasset	-0.010685	***-9.2	-0.010082	***-4.64	-0.079601	***-8.19	-0.010082	***-5.6		
cti_m	-0.001916	-1.91	-0.001869	-1.67	-0.017625	**-2.09	-0.001869	*-1.73		
Lnmedy	0.0041578	0.61	0.0031523	0.58	-0.009878	-0.17	0.0031523	0.48		
Labgro	-0.040997	***-2.93	-0.044820	***-3.61	-0.441135	***-3.77	-0.044820	***-3.65		
Unem	-0.000998	**-2.26	-0.000515	-1.28	-0.009805	***-2.65	-0.000515	-1.37		
Farm	-0.028736	-1.38	-0.037825	**-1.87	-0.098923	-0.57	-0.037824	**-2.06		
R-squared / NOBS	0.0813	2500	0.0396	2500	0.0874	2500	0.0396	2500	0.0682	2496
F-test / p-value	F(45, 2447)	***2.469			F(45, 2447)	***2.934			F(45, 2449)	***3.685
RMSE / Categories (States)	0.04089	46	0.04143	46	0.34222	46	0.04143		0.43491	46

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Equation:	6.11		6.12		6.13	
Dependent Variable:	SDPA		SDPA		SDPA	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	-6.986309	***-9.11	-5.645029	***-6.64	-5.645029	***-9.03
HHI0	0.0000148	**2.31	0.0000222	***3.92		
HHIhat					0.0000222	***4.01
Lnasset	0.0267904	**2.19	0.0234214	*1.96	0.0234214	*1.89
cti_m	0.0736823	***6.36	0.083961	***2.89	0.083961	***2.8
Lnmedy	0.0981416	1.37	-0.0267917	-0.33	-0.0267917	-0.45
Labgro	0.0477146	0.32	0.3470395	**2.04	0.3470395	***2.61
Unem	0.0054713	1.18	0.0004327	0.1	0.0004327	0.1
Farm	-0.391701	*-1.78	-0.446612	**-2.6	-0.446612	***-2.6
R-squared / NOBS	0.0892	2496	0.0401	2496	0.0401	2496
F-test / p-value	F(45, 2443)	***2.928				
RMSE / Categories (States)	0.43052	46	0.43796	46	0.43796	

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Table 7. Dependent Variables: LA

LA = total loans ÷ total assets, average over 3 years. HHI0 is the Hirschmann-Herfindahl Index computed with banks only. HHI-hat is an instrumental variables estimate of the Hirschman-Herfindahl Index, when HHI0 is regressed on farm, gini and lnlabor.HHI100 is the Hirschman-Herfindahl Index when both banks and savings and loans are included. lnmedy = natural logarithm of median income per capita, 2003. labgro is the percentage growth in labor force 1999 – 2003. unem is the unemployment rate, 2003. farm is the ratio, agricultural population / total population in 2003. lnasset = natural logarithm of bank assets, 2003. cti = ratio of non-interest expense to interest income + non-interest income of banks, quarterly average over 3 years.

Columns 7.1 and 7.2: OLS, Robust. Column 7.3: OLS, Robust with Cox transformation of the dependent variable LA. Column 7.4: OLS with State Clusters. Column 7.5: Instrumental Variable estimation with instruments farm, gini and lnlabor.

Equation:	7.1		7.2		7.3		7.4		7.5	
Variable	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	0.5886069	***95.98	-0.429506	*-1.81	-4.088853	***-3.82	-0.981633	**-2.42	-0.981633	***-4.96
HHI0	-0.000006	***-3.11	-0.000005	**-2.55	-0.000022	**-2.48	-0.000007	*-1.96		
HHIhat									-0.000007	***-3.57
Lnasset			0.0277701	***7.31	0.1264053	***7.37	0.0340005	***7.35	0.0340005	***8.11
Cti			-0.014769	***-4.49	-0.068701	***-4.63	-0.014373	***-3.07	-0.014373	***-3.28
Lnmedy			0.0685398	***3.08	0.2973801	***2.96	0.1132189	***2.98	0.1132189	***6.05
Labgro			0.0926573	**2.03	0.3878734	*1.88	0.1352681	**2.17	0.1352681	***3.09
Unem			0.0004181	0.29	0.0010898	0.17	0.0018983	0.78	0.0018983	1.39
Farm			0.0890876	1.3	0.3478967	1.13	0.3328125	***2.92	0.3328125	***5.68
R-squared / NOBS	0.1498	2500	0.1848	2500	0.1826	2498	0.0802	2500	0.0802	2500
F-test / p-value	F(45, 2453)	***9.018	F(45, 2447)	***6.982	F(45, 2445)	***6.837				
RMSE / Categories (States)	0.13637	46	0.13369	46	0.60282	46	0.14073	46	0.14073	
Regression With:										
HHI100	-0.000006	***-3.24	-0.000005	***-2.64	-0.000023	***-2.58	-0.000007	**-2.06	-0.000007	***-3.51

Notes: RMSE is the root mean squared error of regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. F-test/p-value is for the block of 47 state variables.

Table 8. Sample Statistics - International Sample

	Mean	Median	Minimum	Maximum
Bank variables				
HHI (Assets)	2651	1918	391	10,000
Log Asset	12.9	12.5	3.8	20.4
Z-score (time series)	44.2	19.1	-40.5	497.6
Return on Average Asset	1.36	1.21	-24.5	15.9
Equity to Asset Ratio	14.4	10.8	0.05	64.3
Loan to asset ratio	0.47	0.48	0.05	0.92
Macroeconomic variables				
GDP (PPP) per capita (in thousands of US$)	6021	5930	440	21,460
Annual Real GDP growth	3.85	2.97	-12.6	12.8
Annual Inflation	33.1	8.4	-11.5	527.2

Table 9. Correlations – International Sample

	HHI (Assets)	GDP (PPP) per capita	Real GDP growth	Inflation	Z-score (time series)	ROAA	Equity to Asset
HHI (Assets)	1.00						
GDP (PPP) per capita	**-0.30**	1.00					
Real GDP growth	-0.01	-0.07	1.00				
Inflation	0.07	-0.03	-0.08	1.00			
Z-score (time series)	-0.04	0.02	0.08	-0.04	1.00		
ROAA	**-0.14**	0.07	-0.08	-0.08	0.07	1.00	
Equity to Asset	0.01	0.09	-0.07	0.01	**0.11**	**0.16**	1.00
ROAA Volatility	0.03	0.03	**-0.18**	0.01	**-0.33**	**-0.26**	**0.19**

Notes: Coefficients significant at 5% confidence level or lower are reported in **boldface**.

Table 10. Dependent Variable: Bank Profits
International Sample

Equation:	10.1		10.2		10.3		10.4		10.5		10.6	
Independent Variables (t-1) #	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
HHI (Asset)	1.838	**2.30	2.535	**1.98								
HHI (Loans)					2.062	***2.8	2.541	*1.89				
HHI (Deposits)									2.149	***3.3	2.793	**2.12
GDP per capita	0.001	***3.80	0.001	***7.57	0.001	***3.8	0.001	***7.58	0.001	***3.8	0.001	***7.55
GDP Growth	7.343	1.46	0.121	***3.80	0.074	1.5	0.120	***3.80	0.07	1.4	0.114	***3.68
Inflation	0.001	0.184	0.001	1.27	0.001	0.9	0.001	1.27	0.001	0.05	0.001	1.20
Log Asset	1.654	***10.38	-0.036	-0.13	1.655	***10.4	-0.032	-0.12	1.655	***10.4	-0.026	-0.12
Cost to Income	-1.056	***-3.9	-1.428	-1.13	-0.105	***-3.9	-1.419	-1.13	-1.058	***-3.9	-1.411	-1.12
R2/ Adjusted R2	0.076	0.067	0.449	0.331	0.077	0.067	0.448	0.331	0.077	0.068	0.449	0.331
NOBS/ Reg. Type	13090	A	13090	B	13090	A	13090	B	13090	A	13082	B

Notes: Regression types: (A) country fixed effects.; (B) individual fixed effects. T-statistics (robust standard errors) reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. #: coefficients are all multiplied by 1,000.

Table 11. Dependent Variable: Z-score(t)
International Sample

Equation:	11.1		11.2		11.3		11.4		11.5		11.6	
Independent Variables (t-1)	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
HHI (Asset)	-14.72	***-4.4	-11.17	***-3.0	-12.64	***-3.5	-13.61	***-3.1	-14.72	***-2.6	-14.24	**-2.0
GDP per capita					0.001	1.5	-0.001	-0.8	0.001	1.55	-0.001	-1.3
GDP Growth					0.233	*1.8	-0.072	-0.5	0.364	**2.5	0.104	0.6
Inflation					-0.004	***-2.6	-0.001	-0.3	-0.004	**-2.0	-0.0001	-0.1
Log Asset									-1.014	***-2.4	-2.759	*1.7
Loans/Assets									3.023	0.9	-6.024	-1.0
R2/ Adjusted R2	0.055	0.048	0.405	0.266	0.054	0.047	0.406	0.260	0.059	0.049	0.414	0.232
NOBS/ Reg. Type	17334	A	17334	B	15591	A	15591	B	12493	A	12493	B
Regressions with:												
HHI (Loans)	-11.40	***-3.5	-5.665	-1.5	-7.27	**-2.1	-6.602	-1.6	-2.94	-0.5	0.362	0.1
HHI (Deposits)	-11.80	***-3.5	-9.102	**-2.4	-9.83	***-2.7	-11.27	***-2.7	-11.44	**2.1	-7.482	-1.1

Notes: Regression types: (A) country fixed effects.; (B) individual fixed effects. T-statistics (robust standard errors) reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 12. Dependent Variables: Components of the Z-score
International Sample

Equation:	12.1		12.2		12.3		12.4		12.3		12.4	
Dependent Variable (t)	ROAA		ROAA		EQTA*		EQTA*		Vol ROAA		Vol ROAA	
Independent Variables (t-1)	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
HHI (Asset)	-0.95	*-1.6	-1.874	**-2.0	-1.44	***-3.6	-2.465	***-4.3	0.40	***3.8	0.1882	1.1
GDP per capita	-0.001	-0.3	0.0001	***3.1	-0.0001	***-9.9	-0.0001	0.4	-0.0002	-1.3	0.0001	*1.9
GDP Growth	0.051	***2.5	0.032	1.4	-0.043	***-3.1	-0.0325	**-2.3	-0.032	***-8.7	-0.0370	***-8.5
Inflation	0.001	1.5	0.0011	*1.9	0.0001	0.1	-0.0001	-0.3	0.0001	0.1	-0.0002	-1.5
Log (Asset)			-1.876	***-8.8			-2.427	***-18.3			-0.2566	***-6.3
Loans/Assets			-0.916	-1.1			-3.074	***-6.1			0.0366	0.2
R2/ Adjusted R2	0.369	0.216	0.341	0.145	0.789	0.738	0.834	0.784	0.528	0.412	0.549	0.413
NOBS/ Reg. Type	17498	B	13642	B	16659	B	13167	B	17143	B	13415	B
Regressions with:												
HHI (Loans)	1.39	**2.3	2.585	***2.7	-1.21	***-3.0	-3.149	***-5.4	0.15	1.4	-0.237	-1.3
HHI (Deposits)	0.82	1.4	1.450	1.5	-1.57	***-3.9	-2.707	***-4.7	0.22	**2.1	-0.227	-1.3

Notes: Regression type: (B) individual fixed effects. T-statistics (robust standard errors) reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. * Identical results are obtained when the Cox transformation Ln(X/(1-X)) is used instead.

Table 13. Dependent Variable: Loan to Asset Ratio (t)*

Equation:	13.1		13.2		13.3		13.4		13.5		13.6	
Independent Variables (t-1)	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
HHI (Asset)	-0.06	***-6.4	-0.06	***-9.5	-0.05	***-4.9	-0.05	***-6.6	-0.102	***-6.3	-0.05	***-4.6
GDP per capita					-0.0003	-1.6	0.0002	1.6	-5.729	**-2.4	-8.086	***-4.5
GDP Growth					0.0006	***14.3	0.0004	***18.6	6.256	***13.4	4.522	***16.6
Inflation					0.0011	-1.5	0.0003	0.7	-5.993	-0.5	1.421	**2.0
Log (Asset)									-2.932	**-2.4	0.0312	***12.7
R2/ Adjusted R2	0.210	0.204	0.801	0.755	0.222	0.216	0.800	0.752	0.232	0.225	0.833	0.784
NOBS/ Reg. Type	18952	A	18952	B	16998	A	16998	B	13865	A	13865	B
Regressions with:												
HHI (Loans)	-0.063	***-6.1	-0.060	***-9.0	-0.059	***-4.9	-0.047	***-6.4	-0.104	***-6.3	-0.058	***-5.3
HHI (Deposits)	-0.040	***-3.9	-0.041	***_6.1	-0.037	***-3.4	-0.029	***-4.0	-0.068	***-4.2	-0.009	-0.9

Notes: Regression types: (A) country fixed effects.; (B) individual fixed effects. T-statistics (robust standard errors) reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.
* Identical results are obtained when the Cox transformation Ln(X/(1-X)) is used instead

Fig. 1

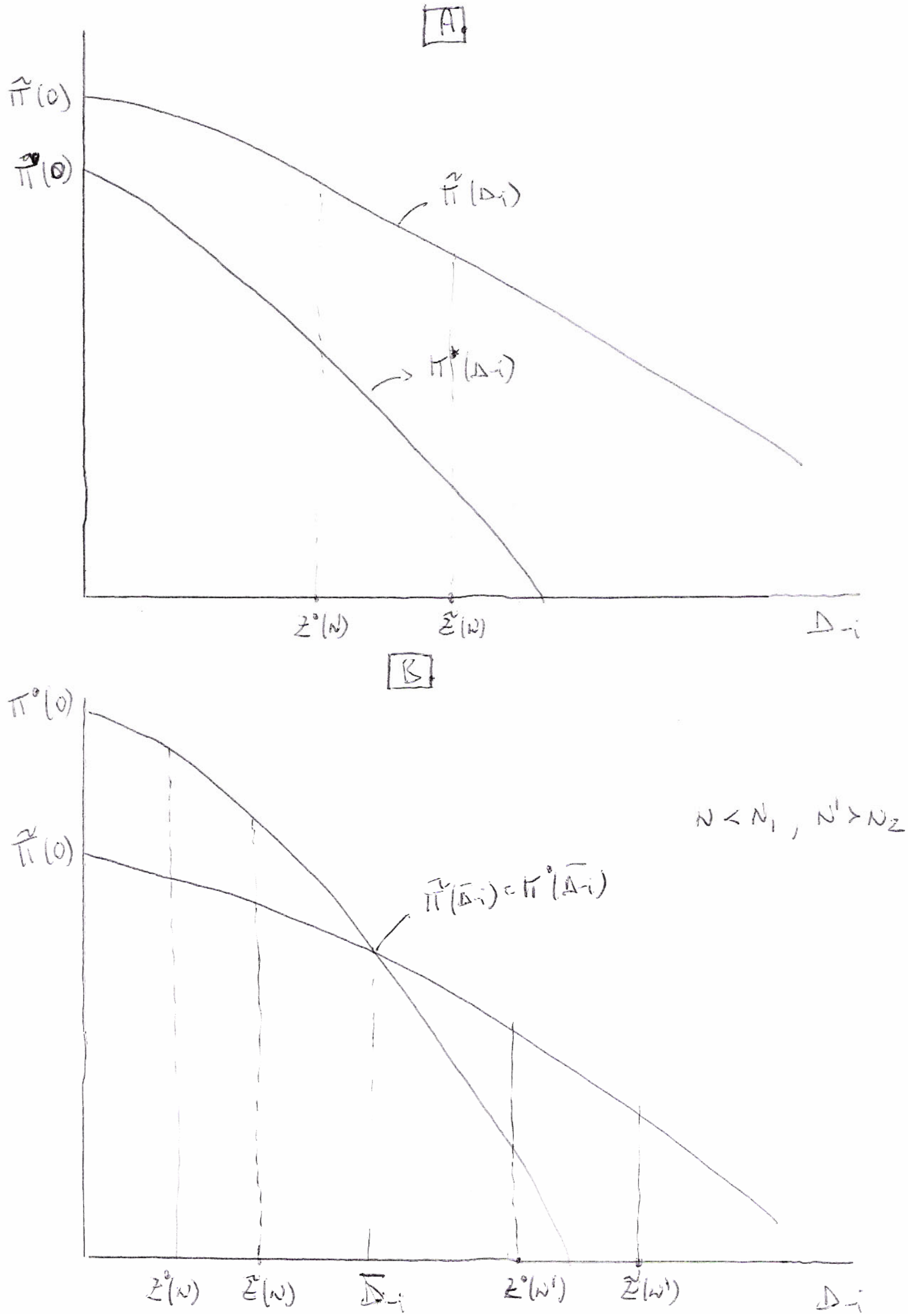

A
$\tilde{\pi}(0)$
$\pi^*(0)$
$\tilde{\pi}(\Delta_{-i})$
$\pi^*(\Delta_{-i})$
$z^*(N)$
$\tilde{z}(N)$
Δ_{-i}
B
$\pi^*(0)$
$\tilde{\pi}(0)$
$N < N_1$, $N' > N_2$
$\tilde{\pi}(\bar{\Delta}_{-i}) = \pi^*(\bar{\Delta}_{-i})$
$z^*(N)$
$\tilde{z}(N)$
$\bar{\Delta}_{-i}$
$z^*(N')$
$\tilde{z}(N')$
Δ_{-i}

Fig. 2. CVH model (A=0.1, beta=1, r =1.1)

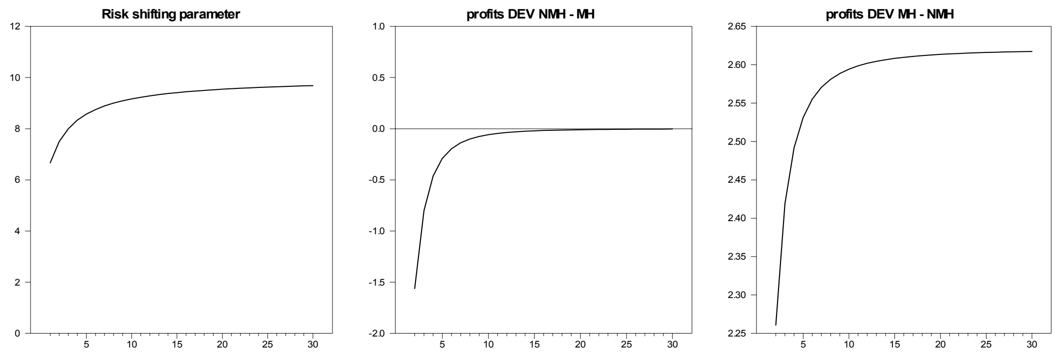


Fig. 3. CVH model (A=0.1, beta=5, r =1.1)

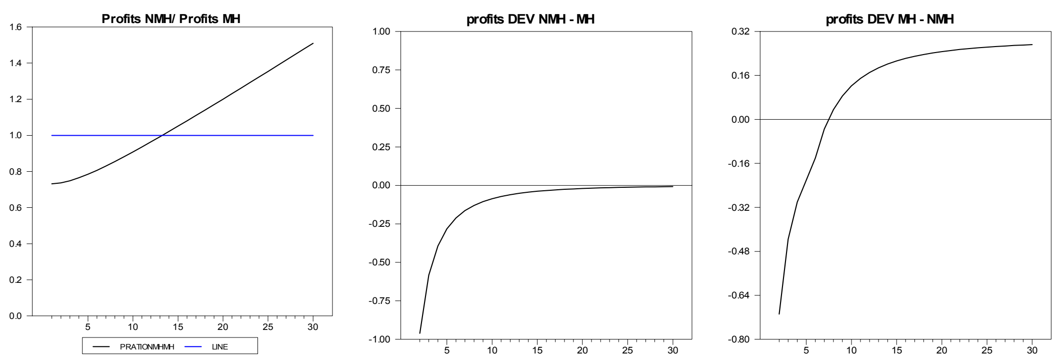


Fig. 4. CVH model (A=0.1, beta=5, r =1.1)

Pareto dominant equilibrium

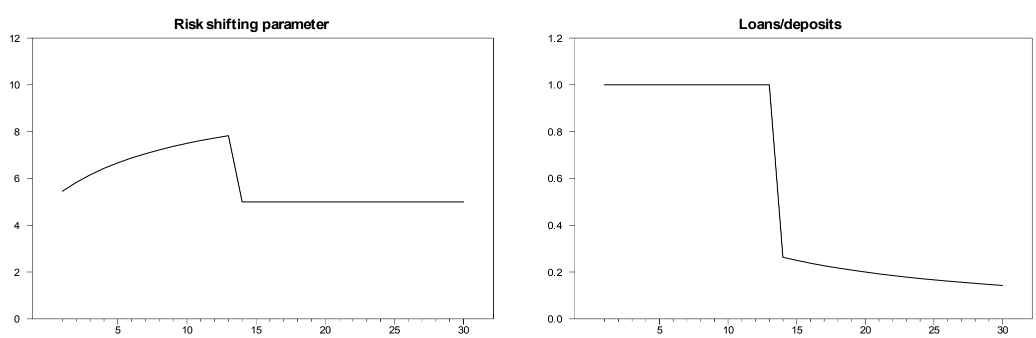
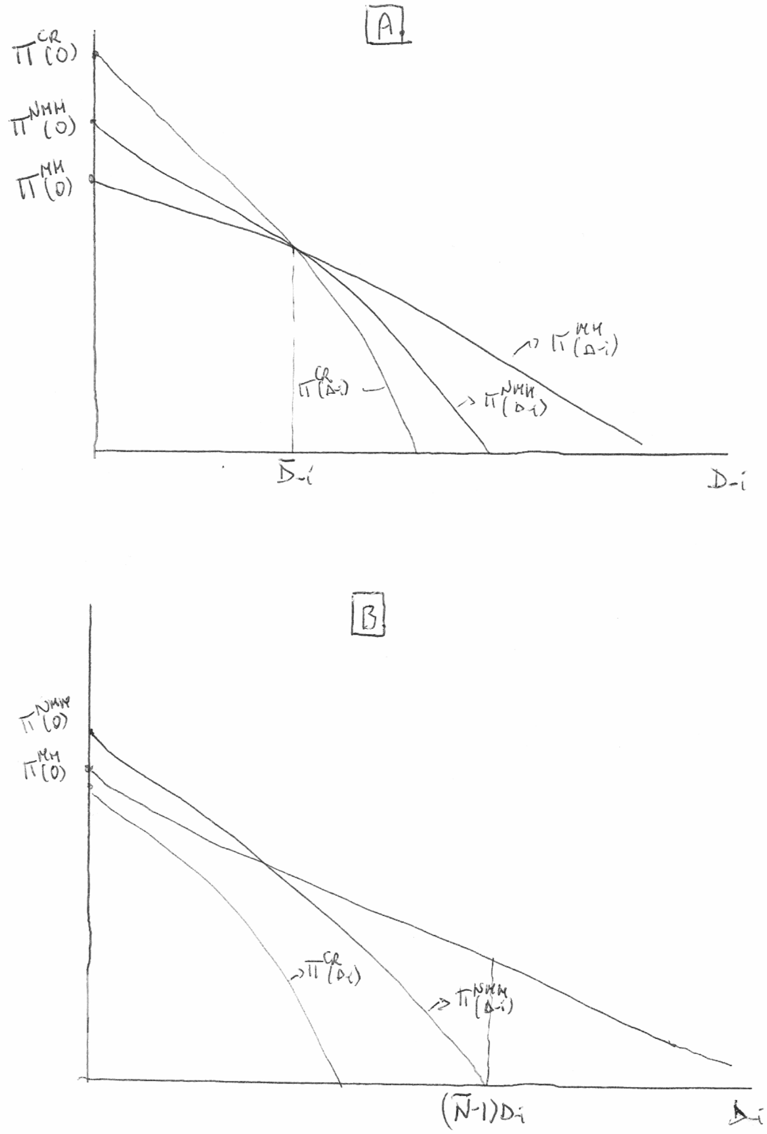


FIG. 5



A
Π^CR (0)
Π^NMH (0)
Π^MH (0)
Π^MH (D-i)
Π^CR (D-i)
Π^NMH (D-i)
D̄-i
D-i
B
Π^NMH (0)
Π^MH (0)
Π^CR (D-i)
Π^NMH (D-i)
(N̄-1)D-i
D-i

Fig. 6. BDN model (A=0.1, alpha=0.5, beta=2, r =1.1)

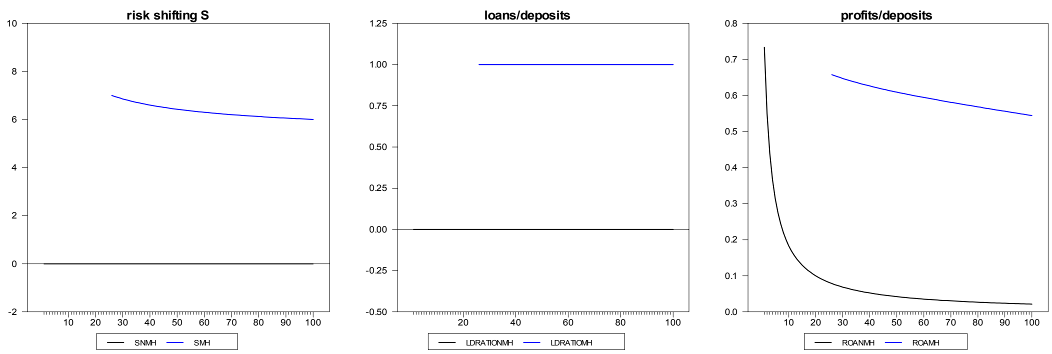


Fig. 7. BDN model (A=0.1, alpha=0.5, beta=2, r =1.1)

Pareto-dominant equilibrium