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Market Structure and Risk Taking in the Banking Industry

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Abstract

This study demonstrates that the common view according to which an increase in competition leads banks to increased risk taking fails to hold in an environment where risk averse consumers can choose in which bank to make a deposit based on their knowledge of the riskiness incorporated in the banks' outstanding loan portfolios. With an exclusive focus on market imperfections generated by imperfect competition we find that banks' incentives for risk taking are invariant to a change in the banking market structure from duopoly to monopoly. Finally, we show that deposit insurance would eliminate the gains bank competition when banks use asset quality as a strategic instrument.

Keywords: Risk Taking in Banking, Market structure, Bank Competition, Deposit Insurance

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1. Introduction

A traditional and widespread view postulates that competition for depositors will induce banks to engage in excessive risk taking. Such a view has motivated extensive regulation of the banking industry with the most noticeable one being the establishment of the deposit insurance institution. The idea of competition generating financial fragility also seems to underly the commonly used government policy of supporting mergers of failing banks into healthy ones as a measure to increase the stability of banking markets. Also in the literature we can find support for a positive link between competition and risk taking in the banking industry. For example, in Keeley (1990) market power in either the loan or deposit market (or both) creates positive bank charter values. Positive bank charter values imply an additional cost of bankruptcy, which mitigates the incentives of bank owners to increase risk.

In this paper we formally investigate the structural relationship between competition for depositors and credit market fragility within the framework of a model where risk taking is made an operational strategic decision of the banks. We demonstrate that the common view according to which an increase in competition leads banks to invest in more risky asset portfolios fails to hold in an environment where risk averse depositors can choose in which bank to make their deposits based on their knowledge of the risk included in the banks' portfolios in addition to deposit rate comparisons. With our attention exclusively restricted to market imperfections generated by imperfect competition we show that market structure alone will not change the incentives for risk taking in banking markets. We present a fairly robust finding according to which the banks' incentives for risk taking are invariant to a change in the banking market structure from duopoly to monopoly. Thus, our analysis has unambiguous welfare implications: introduction of competition into the banking industry can only improve social welfare.

In general, the way whereby banks construct their lending portfolios will affect the risk inferences drawn by depositors (or, more generally, suppliers of capital to banks) and these inferences will affect the deposit rate demanded by these depositors. In fact, the choice of riskiness in the outstanding lending portfolios constitutes an important strategic instrument

with respect to the competition taking place among banks. In this respect each bank faces a number of central strategic decisions: Should the bank concentrate its lending activities to a few industries or a few geographical regions (countries) so as to exploit gains from specialization based on economies of scale with respect to, for example, monitoring as a way to create a competitive advantage for itself? Or, should the bank invest in a portfolio as to minimize the risk of its asset portfolio, thereby attracting risk averse depositors who will accept a minimal deposit rate?

In the present paper we build a formal model of strategic competition between banks for the purpose of analyzing the tradeoff between risky and less risky investments. In order to capture the tradeoff between high interest paid on deposits and low risk, our model makes it possible to provide answers for the following question: Will introduction of competition between banks generate lending portfolios which are more risky than those offered by a banks facing no threat of competition? Further, we investigate how the consequences of credit market competition are related to the regulatory environment in the form of the widely-used deposit insurance policy.

Existing research has identified a number of mechanisms justifying the view that competition tends to destabilize credit markets by increasing the equilibrium bankruptcy risk. One branch of the literature has focused on how the consequences of adverse selection, generated by the inability to observe the characteristics of borrowers, are linked to the market structure in the lending industry. Riordan (1993) applied auction theory to the bank loan market and demonstrated how more intense market competition may damage market performance. Broecker (1990) introduced exogenous credit testing in a model recognizing the fundamental property that competition in lending rates tends to reduce the average quality of loans. Shaffer (1998) has extended the analysis of winner's curse problems in lending and, in particular, he has reported empirical evidence regarding the nature and magnitude of such effects. In models exploring the relationship between the incentives of banks for costly information acquisition based on ex ante project monitoring and the market structure of the banking industry, Kanniainen and Stenbacka (1998) as well as Gehrig (1999) find that competition

between banks will typically undermine the incentives of banks to avoid classification errors. Thus, these analyses identify a tradeoff between the degree of lending competition and the incentives of banks to acquire information. Dell'Ariccia, Friedman and Marquez (1999) have investigated the consequences of adverse selection on the market structure of the lending industry. These authors demonstrate how asymmetric information can constitute a barrier to entry into the banking market and they characterize how this barrier is endogenously determined by the nature of competition. Caminal and Matutes (1997) have analyzed the welfare consequences of increased concentration in the lending industry in a model where banks choose between credit rationing and monitoring in order to alleviate an underlying moral hazard problem. They show that an increase in market power will induce banks to raise their lending rate while at the same time also strengthening the bank's incentives for project-specific monitoring. These effects typically operate in opposite directions implying that there need not be a monotonic relationship between lending industry concentration and social welfare.

The relationship between the market structure of the lending industry and the riskiness of banks' loan portfolios has been investigated using a number of approaches. Matutes and Vives (2000) have examined the consequences of imperfect competition for deposits on the risk-taking incentives of banks. Their model characterizes in detail the roles played by limited liability, deposit insurance, deposit market competition, and observability of banks' asset portfolios in determining the risk-taking incentives of banks. In particular, they demonstrate that the welfare performance of the banking industry and the efficiency of alternative regulatory measures depend on the degree of rivalry between the banks, on the extent to which banks internalize social costs of bank failures as well as on the deposit insurance regime.

In a related paper, Matutes and Vives (1996) demonstrate how the welfare implications of deposit insurance are linked to the banking market structure. In that model, the possibility of a bank failure allows for the emergence of vertical differentiation through the formation of expectations by depositors, and this is a central mechanism of the competition taking place in their model. Winton (1997) focuses on the question of how investors' beliefs interact with

bank competition, entry, and regulation to influence the resulting market structure in the banking industry. His analysis centers around the link between bank size and diversification of a bank's loan portfolio as well as on the implication of this link on how a customer's choice of bank will create an adoption externality such that investors' beliefs are self-fulfilling in a rational expectations equilibrium. Hellwig (1998) investigates the incentives of financial intermediaries to underdiversify under different types of financing contracts and under various assumptions about project technologies. Finally, Winton (1999) analyzes additional aspects of the tradeoff between diversification and specialization in lending. As the adoption externality based on the link between bank size and diversification of banks' asset portfolios is fairly well understood from the research contributions cited above, the present paper focuses on a model where the portfolio risk is a crucial and explicit operational strategic decision variable of all banks.

In the present study we construct a model of a differentiated banking industry in which banks are engaged in two-stage competition with two strategic variables: (i) how much risk to incorporate in their loan portfolios, and (ii) how much interest to offer for deposits. Our study demonstrates that the common view according to which an increase in competition leads banks to increased risk taking fails to hold in an environment where consumers can choose in which bank to make a deposit based on their knowledge of the riskiness incorporated in the banks' outstanding loan portfolios. We present a crucial relationship between banking market competition, the nature of portfolio equilibria and the depositors' attitude towards risk. In particular, we demonstrate that the banks' incentives for risk taking are invariant to a change in the banking market structure from duopoly to monopoly. In light of the risk-taking incentives being invariant to the market structure we can conclude that introduction of competition into the banking industry can only improve social welfare as it will generate higher deposit rates. Further, we analyse a semicollusive banking duopoly and show how such an industry will find it profitable to differentiate its banks by having one bank investing in a high-risk portfolio whereas the rival bank in low-risk portfolio. Finally, we show that deposit insurance would eliminate all incentives for banks to lower the risk of their portfolios.

The paper is organized as follows. Section 2 introduces a model of a differentiated banking industry with no deposit insurance where risk averse consumers gain utility from interest paid on demand deposits and saving accounts, whereas their utility declines with an increase in the risk taken by their chosen bank. Section 3 solves for the equilibrium deposit rates as well as the banks' subgame perfect portfolio selection choices under competition. In Section 4 we study a pure monopoly owning two bank branches as well as the optimal risk taking of a semicollusive banking industry. Section 5 briefly explores the consequences of deposit insurance. Section 6 presents a generalization of portfolio selection offering important insights regarding the robustness of our results. Concluding comments are included in Section 7.

2. A Model of the Banking Industry

Consider an economy with two profit-maximizing banks, called bank 1 and bank 2. There is a continuum of investors, each with one unit of currency (say \$1) to deposit into an interest-bearing account at one (and only one) of the banks.

2.1 Banks

Banks compete for investors by paying interest to each consumer who makes a deposit. We denote by r_i the deposit rate offered by bank $i, i = 1, 2$. Banks subsequently lend the acquired funds to risky business projects. In the long run the banks make decisions regarding the riskiness of their asset portfolios.

It seems reasonable to view the bank's portfolio decision as an irreversible commitment relative to the interest rate decisions There are three reasons for that:

(a) Portfolio assets are typically loan contracts for illiquid projects operating over a long period of time. Typically, there is a substantial cost of renegotiating such loan contracts and therefore the bank's asset portfolio cannot be changed very quickly.

(b) Banks will find it costly to increase the risk of their asset portfolios after consumers make their deposits since consumers can withdraw their funds at any time. This means that

banks which renege on their precommitment with respect to their announced investment policy will risk facing a wave of withdrawals.

(c) If one views a depositor-bank relationship as a repeated game, banks have incentives to maintain credibility regarding the risk they are taking.

When banks compete with respect to their choices of portfolio riskiness they must anticipate the effects of their portfolio choice on the resulting interest rate equilibrium. To capture such effects we apply subgame perfectness as the equilibrium concept. Furthermore, it is assumed that the riskiness incorporated in banks' outstanding asset portfolios is observable.

We capture the risk choice of banks within the framework of a very simple stylized model. Each bank can invest the funds it attracts into two types of portfolios consisting of entrepreneurial projects. It can either invest its assets into a high-risk portfolio, denoted by H, or a low-risk portfolio, denoted by L. The portfolio of type L can also have the interpretation of a more diversified portfolio yielding a lower expected return at a reduced risk. The investment return to the bank from each project is stochastic. Formally, the gross return, $\rho(s_i)$, on a portfolio of type $s_i \in \{H, L\}$, is given by

$$\rho(s_i) = \begin{cases} R(s_i) & \text{Probability } \theta(s_i) \\ 0 & \text{Probability } 1 - \theta(s_i) \ , \end{cases} \tag{1}$$

where $R(s_i) > 0$ and $0 < \theta(s_i) < 1$. We make the following assumption.

ASSUMPTION 1

(a) *Portfolio H has a lower probability of success so that $\theta(H) < \theta(L)$.*

(b) *Portfolio H yields a higher expected return so that $\theta(H)R(H) > \theta(L)R(L)$.*

Assumption 1 implies that $R(H)/R(L) > \theta(L)/\theta(H) > 1$ meaning that a 'good' realization of the risky portfolio, $R(H)$, should be sufficiently large to compensate for the lower probability of achieving such a return. If one interprets portfolio L as being more diversified, Assumption 1 captures the natural feature that diversification decreases the risk of a portfolio failure, but that this can be achieved only by sacrificing expected portfolio return. Such an assumption does not seem unreasonable in light of empirical evidence, see for example,

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Strahan (1995). Thus, we can define the benefit in terms of expected returns from selecting the risky portfolio by $\Delta \stackrel{\text{def}}{=} \theta(H)R(H) - \theta(L)R(L)$.

Let s_i ($s_i \in \{H, L\}$) denote the portfolio choice of bank i, $i = 1, 2$. Also, let n_i be the number of depositors (each depositing \$1) in bank i. Then, the profit of bank i is given by

$$\pi_i \equiv \begin{cases} \max\{n_i[R(s_i) - (1 + r_i)], 0\} & \text{Probability } \theta(s_i) \\ 0 & \text{Probability } 1 - \theta(s_i). \end{cases} \tag{2}$$

Notice that (2) shows that even if the portfolio realizes a strictly positive return there is still a possibility for bankruptcy if the bank commits itself to pay depositors a high interest, r_i. However, it is clear that a profit maximizing bank will never set such an interest rate, so this possibility will be ignored. That is, with no loss of generality we focus on the case where bankruptcy can occur only if the invested portfolio realizes zero return.

We are formally assuming that banks' costs of managing the loan portfolios are independent of the risk characteristics of its portfolio. Such an assumption can be seen as a normalization in light of the fact that the impact of these risk characteristics is incorporated into the assumptions regarding the portfolio revenues.

2.2 Depositors

We focus on a horizontally differentiated banking industry.[1] The depositors are assumed to be uniformly distributed on the unit interval in accordance to increased preference for bank 2 (alternatively, increased distance from bank 1). With uniform density we normalize the total mass of investors to equal one.[2]

The two competing banks are located at the endpoints of the unit interval segment: bank 1 is located at 0 whereas bank 2 is located at 1. Each depositor is endowed with one unit of funds and faces a linear transportation cost at rate of $\tau \geq 0$.

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[1]Recently, Villas-Boas and Schmidt-Mohr (1999) have employed a model of a horizontally differentiated banking industry for a different purpose. By identifying the intensity of competition with the degree of differentiation they have demonstrated how banks facing stronger competition may expose credit applicants to more precise screening in the presence of asymmetric information.

[2]Clearly, another way of modeling differentiated depositors would be by assuming that depositors have different degrees of risk aversion. Shy and Stenbacka (2002) apply such an approach in their analysis of diversification in the mutual funds industry. Section 7 elaborates on the implications of differentiating depositors according to risk rather than according to banks' attributes as captured by location.

Altogether, a depositor indexed by x, $x \in [0, 1]$, has a utility defined by

$$V_x \stackrel{\text{def}}{=} \begin{cases} u_1 - \tau x & \text{if he deposits with bank 1} \\ u_2 - \tau(1 - x) & \text{if he deposits with bank 2} \end{cases} \quad \text{where} \quad u_i \stackrel{\text{def}}{=} \begin{cases} r_i & \text{Prob. } \theta(s_i) \\ -\lambda & \text{Prob. } 1 - \theta(s_i). \end{cases} \tag{3}$$

Thus, a depositor who makes a deposit with bank i, bears the risk (with probability $1 - \theta(s_i)$) of losing his \$1 deposit as with this probability the bank is bankrupt due to zero return on its investment portfolio. In contrast, with probability $\theta(s_i)$ bank i is not bankrupt and is able to pay interest r_i to this depositor plus the initial \$1 deposit. The parameter $\lambda \geq 0$ needs an explanation as it will serve as a measure of the degree of risk aversion. First, note that if $\lambda = 1$, the depositor evaluates his loss to be exactly \$1. Therefore, we interpret $\lambda = 1$ as risk neutrality. In contrast, $\lambda > 1$ captures the idea that a risk-averse depositor evaluates the risk of losing his \$1 deposit as generating a disutility measured by the difference $\lambda - 1$ (in addition to his \$1 loss). Finally, $0 \leq \lambda \leq 1$ implies that the bank is able to return some (or all) of the amount deposited, say by deposit insurance. Formally, we will be using the following terminology.

DEFINITION 1

We say that a depositor's preferences exhibit: (i) risk aversion if $\lambda > 1$, (ii) risk neutrality if $\lambda = 1$, and (iii) risk loving if $0 \leq \lambda < 1$.

Alternatively, for $\lambda > 1$ we could make the interpretation that the difference $\lambda - 1$ denotes an individual default or bankruptcy cost. For instance, λ might be a representation of the idiosyncratic pain a bankruptcy inflicts on the investor. We assume that each depositor maximizes expected utility based on (3).

Finally, for a well-defined equilibrium to exist we assume

ASSUMPTION 2

$$\left| \frac{\theta(H)R(H) - \theta(L)R(L) + (\lambda - 1)[\theta(H) - \theta(L)]}{3} \right| \leq \tau \leq \theta(L)[R(L) - 1].$$

If the left-hand part of Assumption 2 is reversed, then in a situation where banks choose different portfolios, under risk aversion (risk loving) the bank investing in the more (less) risky

portfolio is able to pay a much higher interest which would drive the other bank out of the market. This possibility for undercutting under low degrees of differentiation would create discontinuities in the best-response functions and could lead to analytically cumbersome calculus without adding very much in terms of economic contents. The right-hand part of Assumption 2 is needed in order to ensure that in equilibrium banks pay nonnegative interest rates (see Table 2).

2.3 Sequence of events

There are three stages. In stage I, each bank i chooses between the high-risk portfolio $s_i = H$ and the low-risk portfolio $s_i = L$. In stage II each bank i, knowing the commitments made by both banks in stage I, chooses its interest rate, r_i. Finally, in stage III each depositor x chooses whether to deposit his \$1 in bank 1 or bank 2.

3. Equilibrium

We will be solving for a subgame-perfect portfolio equilibrium for this three-stage game.

3.1 Stage III: How do depositors choose their bank?

We denote by $\hat{x}$ the depositor who is indifferent between bank 1 and bank 2. The location of such a customer can be solved from $\mathrm{E}u_1 - \tau\hat{x} = \mathrm{E}u_2 - \tau(1 - \hat{x})$, hence

$$\theta(s_1)r_1 - [1 - \theta(s_1)]\lambda - \tau\hat{x} = \theta(s_2)r_2 - [1 - \theta(s_2)]\lambda - \tau(1 - \hat{x}).$$

Consequently,
$$\hat{x}(r_1, r_2, s_1, s_2) = \frac{\theta(s_1)(\lambda + r_1) - \theta(s_2)(\lambda + r_2) + \tau}{2\tau}, \tag{4}$$

therefore, the number of people who make a deposit with bank 1 is $n_1 = \hat{x}$, and the number of depositors selecting bank 2 is $n_2 = 1 - \hat{x}$.

3.2 Stage II: Interest rate competition between banks

In this subsection we characterize the Nash equilibrium for the subgame where competing banks select their deposit rates. Following the conventional approach, each bank i takes

the interest paid by the competing bank, r_j, and the portfolio selection of both banks, $s_1, s_2 \in \{H, L\}$, as given and chooses the interest r_i to maximize expected profit defined in (2). Hence, each bank solves

$$\max_{r_i} \mathrm{E}\pi_i = \theta(s_i)n_i\left[R(s_i) - (1 + r_i)\right], \tag{5}$$

where $n_1 = \hat{x}$, $n_2 = 1 - \hat{x}$ and $\hat{x}$ is defined in (4). This concave maximization problem yields a unique best-response function of bank i as a function of the interest rate paid by bank j

$$r_i(r_j) = \frac{\theta(s_i)[R(s_i) - 1] + \lambda[\theta(s_j) - \theta(s_i)] - \tau + \theta(s_j)r_j}{2\theta(s_i)}, \quad i, j = 1, 2, \ i \neq j. \tag{6}$$

Solving the system of equations defined by (6) yields the unique equilibrium interest rates

$$r_i = \frac{2\theta(s_i)[R(s_i) - 1] + \theta(s_j)[R(s_j) - 1] - 3\tau + \lambda[\theta(s_j) - \theta(s_i)]}{3\theta(s_i)}, \quad i, j = 1, 2, \ i \neq j. \tag{7}$$

Equation (7) reveals that

Proposition 1

The equilibrium interest paid to depositors in bank i

(a) increases with the return on the portfolio invested by bank i and the competing bank, bank j;

(b) decreases with an increase in the banks' differentiation parameter, τ;

(c) increases with depositors' degree of risk aversion if and only if the bankruptcy probability is higher than that of the rival bank (i.e., increases with λ if and only if $\theta(s_j) > \theta(s_i)$).

The first part of Proposition 1 demonstrates that an increase in the average return of a bank's portfolio will increase the deposit rates in equilibrium. The second part of Proposition 1 demonstrates how the degree of competition affects the equilibrium interest rates. When competition is intense (τ is low), banks must pay higher interest rates. The third part of Proposition 1 highlights the effect of risk aversion on banks' profit maximizing interest rates. A bank with a higher probability of bankruptcy (lower θ) must 'compensate' its depositors by paying a higher interest.

We define

$$\psi_i(s_i, s_j) \overset{\text{def}}{=} \theta(s_i)[R(s_i) - 1] - \theta(s_j)[R(s_j) - 1] + \lambda[\theta(s_i) - \theta(s_j)]. \tag{8}$$

We note that (i) $\psi_i = 0$ if $s_i = s_j$, that is, if both banks choose the same portfolio. Further, we can directly observe the general property (ii) $\psi_i(s_i, s_j) = -\psi_j(s_j, s_i)$. The function $\psi_i(s_i, s_j)$ can be viewed as a measure which depositors use in comparing the portfolios of the two banks. As (9) indicates, this measure directly affects the "location" of the indifferent depositor and thereby the market shares of the banks.

Substituting (7) and (8) into (4) shows that the location of the indifferent consumer is given by

$$\hat{x} = \frac{1}{2} + \frac{\psi_1}{6\tau}, \tag{9}$$

which is less than 1 by Assumption 2, and could be greater than or less than $1/2$ depending on the relative returns of the portfolios invested by the banks and on depositors' degree of risk aversion.

Substituting (7) and (9) into (5) yields the equilibrium profit levels as functions of the portfolios chosen by both firms. Hence, the profit function associated with equilibrium in the deposit rates is given by

$$\pi_i(s_i, s_j) = \frac{\tau}{2} + \frac{\psi_i(s_i, s_j)}{18\tau} \left[\psi_i(s_i, s_j) + 6\tau \right]. \tag{10}$$

3.3 Stage I: How do banks choose their portfolios?

In the first stage, each bank i selects either the high-risk portfolio ($s_i = H$), or the low-risk portfolio ($s_i = L$). Substituting these portfolio selections into (10) yield

$$\pi_i(H, L) = \pi_j(L, H) = \frac{\tau}{2} + \frac{\psi_i(H, L)}{18\tau} [\psi_i(H, L) + 6\tau] \tag{11}$$

and

$$\pi_i(L, H) = \pi_j(H, L) = \frac{\tau}{2} + \frac{\psi_i(L, H)}{18\tau} [\psi_i(L, H) + 6\tau]. \tag{12}$$

The profit of each firm under each outcome is displayed in Table 1.

Table 1 provides all the crucial information needed for our analysis. We make the following definition.

Bank 2

		H (High-risk)		L (Low-risk)	
Bank 1	H	$\frac{\tau}{2}$	$\frac{\tau}{2}$	$\frac{\tau}{2} + \psi_1(H,L)$	$\frac{\tau}{2} + \psi_2(L,H)$
	L	$\frac{\tau}{2} + \psi_1(L,H)$	$\frac{\tau}{2} + \psi_2(H,L)$	$\frac{\tau}{2}$	$\frac{\tau}{2}$

Table 1: Equilibrium profit levels for all portfolio choice outcomes

DEFINITION 2

Let

$$\hat{\lambda} \overset{\text{def}}{=} 1 + \frac{\theta(H)R(H) - \theta(L)R(L)}{\theta(L) - \theta(H)}. \tag{13}$$

*Then, we say that depositors' preferences exhibit **strong risk aversion** if $\lambda > \hat{\lambda}$, **weak risk aversion** if $1 < \lambda < \hat{\lambda}$, and **risk neutrality** if $\lambda = 1$.*

Note that $\hat{\lambda} > 1$ since $\theta(H)R(H) - \theta(L)R(L) > 0$ by Assumption 1, which implies risk aversion by Definition 1.

Definition 2 implies that depositors are (i) strongly risk averse if $\psi_i(H,L) = -\psi_i(L,H) < 0$, (ii) weakly risk averse if $\psi_i(H,L) = -\psi_i(L,H) > 0$, (iii) risk neutral if $\psi_i(H,L) = -\psi_i(L,H) = 0$.

Direct comparisons of the profit levels exhibited in Table 1 show that bank 1 will *not* deviate from (H,H) if $\pi_1(L,H) < \pi_1(H,H)$, hence if $\lambda < \hat{\lambda}$. Also, Table 1 reveals that bank 1 will *not* deviate from (L,L) if $\pi_1(H,L) < \pi_1(L,L)$, hence if $\lambda > \hat{\lambda}$. This proves the following crucial proposition.

Proposition 2

Under competition between banks, in a subgame-perfect equilibrium the portfolio investments by the banks will exhibit

(a) low risk when depositors are strongly risk averse ($\lambda > \hat{\lambda}$),

(b) high risk when depositors are weakly risk averse or risk neutral ($\lambda < \hat{\lambda}$).

Proposition 2 highlights an important relationship between the banking market competition, the nature of portfolio equilibria, and depositors' attitude towards risk. The main finding in

Proposition 2 is that strong risk aversion among depositors and the lack of deposit insurance causes competitive banks to invest in low-risk portfolios in order to reduce their risk of bankruptcy.

As Proposition 2 makes clear, the portfolio equilibrium shifts from high risk to low risk as the risk attitudes shift from weak to strong risk aversion. The cutoff level, $\hat{\lambda}$, in terms of the critical degree of risk aversion depends on portfolio parameters in an interesting way. We can directly see that $\hat{\lambda}$ increases proportionally to $\Delta = \theta(H)R(H) - \theta(L)R(L)$ which is the benefit in terms of expected return from selecting a risky portfolio. The rate of the increase in $\hat{\lambda}$ is inversely related to the risk differential $\theta(L) - \theta(H)$. Thus, Proposition 2 implies the prediction that the depositor's threshold degree of risk aversion where competing banks shift to low-risk portfolios is proportional to the expected benefit from a high-risk portfolio selection with the factor of proportionality being the inverse of the risk differential. The extent to which this prediction can form a basis of empirically testable relationships depends on how well we have access to estimates on banks' portfolio riskiness and the degree of risk aversion prevailing among the population of depositors.

3.4   Analysis of equilibrium interest rates and market shares

We now characterize the deposit rates generated through the portfolio equilibria. Table 2 displays the deposit rates generated by the symmetric portfolio equilibria (H, H) and (L, L), which are calculated directly from (7). Further, substituting the asymmetric portfolio selection outcomes into (7) yields

$$r_1(H, L) = r_2(L, H) = \frac{\theta(H)[2R(H) - \lambda - 2] + \theta(L)[R(L) + \lambda - 1] - 3\tau}{3\theta(H)}, \qquad (14)$$

and

$$r_1(L, H) = r_2(H, L) = \frac{\theta(L)[2R(L) - \lambda - 1] + \theta(H)[R(H) + \lambda - 1] - 3\tau}{3\theta(L)}. \qquad (15)$$

The interest rates charged at each outcome is displayed in Table 2. Table 2 reveals the following proposition which is proved in Appendix A.

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<table>
<tbody>
<tr><td colspan="5" align="center">**Bank 2**</td></tr>
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		H (high-risk)		L (low-risk)	
1	H	$R(H)-1-\frac{\tau}{\theta(H)}$	$R(H)-1-\frac{\tau}{\theta(H)}$	eq.(14)	eq.(15)
	L	eq.(15)	eq.(14)	$R(L)-1-\frac{\tau}{\theta(L)}$	$R(L)-1-\frac{\tau}{\theta(L)}$

Table 2: Equilibrium interest rates for all portfolio choice outcomes

Proposition 3

The equilibrium interest paid when both banks invest in low-risk portfolios is lower than the interest rate paid to depositors when both banks invest in high-risk portfolios. Formally, $r_i(L,L) < r_i(H,H)$, $i = 1, 2$.

This proposition indicates that competition between the banks is intensified when both banks invest in risky portfolios, thereby pushing them to raise the interest paid to their customers.

3.5 Numerical examples

It is instructive to end our analysis of competition with a numerical example which illustrates the general conclusions drawn earlier in this section. Table 3 is drawn under the assumptions that $R(H) = 10 > 5 = R(L)$, $\theta(H) = 0.5 < 0.9 = \theta(L)$, $\tau = 3$, and $\lambda \in [0, 5]$. Note that in this case, $\hat{\lambda} = 2.25$ where $\hat{\lambda}$ is defined in (13). In Table 3, lines 10 and 11 confirm the first part of Proposition 2 showing that bank 1 will not deviate from (L, L) when $\lambda > \hat{\lambda} = 2.25$. Lines 9 and 12 confirm the second part of Proposition 2 showing that bank 2 will not deviate from (H, H) when $\lambda < \hat{\lambda} = 2.25$. When $\lambda = \hat{\lambda}$, all four outcomes yields the same profit to both banks, hence all outcomes constitute equilibria.

Lines 1 and 2 in Table 3 confirm Proposition 3 showing that banks pay higher interest to depositors when both banks invest in risky portfolios since in this case competition is most intense, or alternatively, banks complements high interest to high bankruptcy probability. Lines 14 and 15 show that the high interest rate associated with risky portfolios generates a higher expected (net-of-transportation- cost) utility to depositors when depositors are not strongly risk averse, and lower expected utility when depositors are strongly risk averse; where $\mathrm{E}u_i(\cdot)$ is the expected utility derived from (3).

λ :		0.00	0.50	1.00	2.00	2.25	3.00	4.00	5.00
	Risk Aversion:	RL	RL	RN	WRA	$\hat{\lambda}$	SRA	SRA	SRA
1.	$r_i(H,H)$	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
2.	$r_i(L,L)$	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
3.	$r_1(H,L)$	2.40	2.53	2.67	2.93	3.00	3.20	3.47	3.73
4.	$r_2(H,L)$	1.00	0.93	0.85	0.70	0.67	0.56	0.41	0.26
5.	$\hat{x}(H,H)$	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
6.	$\hat{x}(L,L)$	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
7.	$\hat{x}(H,L)$	0.55	0.54	0.53	0.51	0.50	0.48	0.46	0.44
8.	$\hat{x}(L,H)$	0.45	0.46	0.47	0.49	0.50	0.52	0.54	0.56
9.	$\pi_i(H,H)$	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.	$\pi_i(L,L)$	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
11.	$\pi_1(H,L)$	1.82	1.74	1.67	1.53	1.50	1.40	1.28	1.16
12.	$\pi_2(H,L)$	1.22	1.28	1.34	1.47	1.50	1.60	1.74	1.89
13.	$\pi_1(H,L) + \pi_2(H,L)$	3.03	3.02	3.01	3.00	3.00	3.00	3.02	3.04
14.	$\mathrm{E}u_i(H,H)$	1.50	1.25	1.00	0.50	0.38	0.00	-0.5	-1.0
15.	$\mathrm{E}u_i(L,L)$	0.60	0.55	0.50	0.40	0.38	0.30	0.20	0.10
16.	$\mathrm{E}u_1(H,L)$	1.20	1.02	0.83	0.47	0.38	0.10	-0.3	-0.6
17.	$\mathrm{E}u_2(H,L)$	0.90	0.78	0.67	0.43	0.38	0.20	-0.0	-0.3

Table 3: Numerical example of competitive banking industry. RL=risk loving; RN=risk neutrality; WRA=weak risk aversion; SRA=strong risk aversion.

Lines 7 and 8 in Table 3 show that in the nonequilibrium (asymmetric) outcomes, the bank which invests in a low-risk portfolio has a higher market share if and only if depositors are strongly risk averse. This demonstrates the role which depositors' degree of risk aversion plays in interbank competition, in the sense that more potential depositors are attracted to banks by considering the risk of bankruptcy and not only the magnitude of the interest rate paid to depositors.

4. Monopoly Banking Industry

Proposition 2 has demonstrated that when depositors have strong risk aversion, competition will induce banks to lower the risk of their portfolios. The effect of market structures on the risks taken by banks depends on what we mean by a monopoly bank in a differentiated banking environment. We will therefore concentrate our analysis on two types of a collusive banking industry: the pure monopoly and semicollusive banking industries.

4.1 Pure monopoly owning two branches

In order to focus exclusively on the relationship between market structure and the market-determined risk incentives we regard a monopoly as a bank that owns two branches named branch 1 and branch 2 analyzed in section 2. In what follows, we solve for the interest rate and the portfolio choice of this monopoly bank.

Let $U^{\min}$ denote the reservation utility of each depositor. This is the utility each consumer can gain if he does not use the services of the monopoly bank (e.g., investing the money in different types of financial institutions, buying government bonds, and so on).

Let s ($s \in \{H, L\}$) be the monopoly's portfolio choice (for both branches); and let r be the uniform interest rate paid to all customers. Further, let $r(s)$ denote the interest rate given that the bank chooses portfolio s.

We assume that the reservation U_0 is sufficiently small so the bank serves the entire market (i.e., all customers $x \in [0, 1]$). Then, in order to serve the customer located at $x = 1/2$ (the customer with the highest transportation cost), it sets the minimal interest rate, r_s that satisfies

$$U^{\min} \leq V_{\frac{1}{2}} = \theta(s)r(s) - [1 - \theta(s)]\lambda - \tau/2, \tag{16}$$

where $V_{1/2}$ is defined in (3). Hence, when the bank chooses portfolio $s \in \{H, L\}$, the minimal interest rate it must pay customers in order to attract customer $x = 1/2$ and thereby all potential depositors to make a deposit is

$$r_s = \frac{2U^{\min} + \tau + 2\lambda[1 - \theta(s)]}{2\theta(s)}, \quad s \in \{H, L\}. \tag{17}$$

Appendix B establishes that a monopoly banking industry will always offer lower deposit rates than a duopoly banking industry —a result which should come as no surprise.

Assumption 1 and (17) imply that

Proposition 4

A monopoly bank choosing a risky portfolio must pay a higher interest rate to its customers compared with a monopoly choosing the less-risky portfolio. Formally, $r(H) > r(L)$.

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The intuition for why a monopoly bank choosing a more risky portfolio has to offer a higher interest rate does not seem to differ from the reason for why $r_i(H, H) > r_i(L, L)$ in the duopoly case, (Proposition 3). The bank must 'compensate' the indifferent customer for choosing the risky portfolio (higher bankruptcy probability) by increasing the expected interest paid.

Substituting $n = 1$ (population size) and (17) into (2) yields

$$\pi(s) = \frac{2\theta(s)R(s) - 2\lambda[1 - \theta(s)] - \tau - 2[u^{\min} + \theta(s)]}{2}, \quad s \in \{H, L\}. \tag{18}$$

Equation (18) reveals that

$$\pi(H) \geq \pi(L) \quad \text{if and only if} \quad 1 \leq \lambda \leq \hat{\lambda},$$

where $\hat{\lambda}$ is defined in Definition 2. Thus, if depositors are strongly risk averse, a monopoly banking industry will choose the investment portfolio with low risk. Otherwise, the monopoly will maintain high risk. Hence, in light of Proposition 2 we can conclude

Proposition 5

The incentives for taking risk are invariant to a change in the banking market structure from duopoly to monopoly.

Thus, we can conclude that the introduction of competition for risk-averse depositors will not affect the risk-taking of banks, despite the fact that a monopoly bank pays lower interest to depositors than banks facing competition (see Appendix B), thereby extracting more surplus from depositors. The mechanism for this striking result seems very much related to Swan's (1970a,b) findings that a monopoly firm and price-setting competitive industries will supply products of the same quality of goods. In Swan's environment a price setting monopoly will use the price system to extract more surplus while investing the same amount of resources into generating a supply of quality (or durability) identical to that of a competitive industry. In Swan's model, light bulbs will have the same durability regardless of whether they are produced by a monopoly or a competitive industry. In our model, a mechanism reminding of Swan's argument is developed to show that the risk taken by a monopoly bank is the same as that taken by an industry where banks compete with respect to deposit rates.

A result that the risk taking incentive of banks is invariant to the banking market structure can also be found in Matutes and Vives (2000). In their model, however, depositors are assumed to be risk neutral and the nature of their invariance result is very different as all feasible portfolios in their model exhibit the same average return. Thus, in the Matutes-Vives model portfolio risk is undetermined under all market structures reflecting the equilibrium feature that banks must compensate higher risk with higher deposit rates. The present manuscript offers a generalization of the Matutes-Vives model in two important respects. On the one hand, facing risk averse depositors banks need to overcompensate depositors for the portfolio risk they are exposed to. This aspect tends to favor minimum risk taking. On the other hand, minimal risk implies an expected reduction of Δ in portfolio return. These two counteracting effects are balanced at the threshold degree $\hat{\lambda}$ of risk aversion and, as Proposition 5 demonstrates, this threshold is invariant to market structure. Thus, Proposition 5 establishes that, in the absence of deposit insurance, depositors' risk aversion plays a key role in determining banks' portfolio risk and, most remarkably, that this role is invariant to market structure.

However, the Matutes–Vives model incorporates external effects according to which there are social costs of bank failures, such as instability of the payment system etc., which are born neither by the banking industry nor by the depositors. Our model includes no such externalities. Instead, our model assumes that the social costs of a bank failure are fully internalized by the agents via the rate of return that the depositors require. Of course, the invariance of the risk taking incentives of banks to market structure depends heavily on the absence of an interplay between banking market structure and the bankruptcy costs generated by bank failures. But, a priori we find it hard to come up with robust theoretical reasons in order to justify any particular direction of such a relationship between banking market structure and the bankruptcy costs of bank failures. In fact, for example in Keeley's (1990) model the bank charter values are related to the market structure and in his model this mechanism creates the relationship between the risk taking incentives and banking market structure.

Section 6 extends the model and demonstrates the robustness of the crucial invariance result of Proposition 5 by showing that the invariance result is robust relative to extensions where the banks have access to a *continuum of portfolios* differing with respect to their risk characteristics and expected return.

4.2 Semicollusion

We now turn our attention to a quasicompetitive banking industry. Instead of assuming that the two banks merge into a monopoly which sets a uniform interest rate paid to depositors, we now assume that the banks are required to maintain interest rate competition while being allowed to coordinate the risk taking incorporated in their portfolio decisions.

Thus, we now focus on an industry the operation of which we can understand in the following way. It could capture a banking industry where two separate banks operate under the same holding company. The owner of the holding company controls the investment strategies of the two banks, while delegating the interest rate decisions to its competing banks. Alternatively, it is a banking industry where risk taking is coordinated based on risk standards adopted on an industry level or based on regulation whereby the supervising authority coordinates the risk taking.[3] Line 13 in Table 3 illustrates in an example that joint industry profit is maximized when one bank invests in a low-risk portfolio whereas the other invests in a high-risk portfolio. Lines 16 and 17 illustrate that, ignoring transportation costs, the sum of utilities is lower than the sum of utilities under the symmetric outcomes when depositors have strong risk aversion.

Formally, comparing the sum of profits of the asymmetric outcomes to the sum of profits of the symmetric outcomes yields the following proposition (as illustrated in Table 1).

Proposition 6

A semicollusive banking industry will differentiate its banks by having one bank investing in a high-risk portfolio, and the other bank in a low-risk portfolio. Formally, $\pi_1(H,L) + \pi(L,H) > 2\pi_i(H,H) = 2\pi_i(L,L)$.

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[3]Within the framework of exploring the implications of semicollusion we are not in this context concerned with the issue of whether asymmetric credit standards would represent a plausible regulatory outcome.

Intuitively, since these semicolluding banks must engage in interest-rate competition, the only way in which they can facilitate some degree of collusion is to introduce a new dimension of differentiation between the bank branches. Risk differentiation serves such a purpose even though it is less efficient than the interest rate mechanism as an instrument of exploiting market power relative to depositors. By making one bank risky and the other relatively safe, the banks can further differentiate themselves by offering some depositors high return bundled with high risk, whereas others low expected return with lower degree of bankruptcy. Thus, under semicollusion the risk-invariance result of Proposition 5 is not maintained. More precisely, comparing Propositions 6 with 2 yields the following.

Proposition 7

(a) When depositors are strongly risk averse, a fully-competitive banking industry is less risky than a semicollusive industry.

(b) When depositors are weakly risk averse, or when they are risk lovers, a fully-competitive banking industry is more risky than a semicollusive industry.

Consequently, Proposition 7 establishes that the degree of risk aversion in the population of depositors plays a key role when evaluating the impact of coordination of risk taking activities in the banking industry. Proposition 7 implies that coordination of risk taking activities will lead to increased risks compared to a fully-competitive banking industry when depositors are strongly risk averse. Thus, in the presence of strongly risk averse depositors industrywide coordination of banks' risk taking would prevent the economy from exploiting the risk-reducing potential of competition with respect to risk taking.

5. Deposit Insurance

So far, our analysis was based on the assumption that there is no deposit insurance. Deposit insurance systems, no matter whether they are federally or privately established, have the ultimate goal of securing funds to depositors upon realizing such states of nature where uninsured banks would be unable to fulfill their liabilities to depositors.

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It is not the purpose of this paper to exhaustively evaluate the benefits or the distortions introduced by instituting a deposit insurance system. Neither is it our purpose to offer a detailed study of different types of regulatory instruments.[4] Instead, we merely point out that, as expected, instituting deposit insurance reduces the incentives of banks to invest in low-risk portfolios.

To see this, the easiest way to introduce deposit insurance into the model is to reinterpret the utility function (3) for the case where $\lambda < 1$. When $0 \leq \lambda < 1$, depositors don't lose their entire deposits upon bankruptcy of their banks. Formally, we interpret $\lambda = 0$ as a *complete* deposit insurance, where the insurer is obligated to reimburse each depositor his \$1 upon bankruptcy.[5] We interpret $0 < \lambda < 1$ as an *incomplete* deposit insurance, in which a depositor loses only a fraction of λ of his deposit upon bankruptcy.

Using this interpretation, since we confine the analysis to the range where $\lambda < 1 < \hat{\lambda}$, Propositions 2 and 4 yield the expected result where

Proposition 8

The introduction of deposit insurance eliminates all incentives for banks to invest in low-risk portfolios.

In light of Proposition 8 it might be tempting to jump to policy conclusions regarding deposit insurance. Our model, however, needs to be complemented with a number of features in order to serve as a well-founded basis for a welfare analysis evaluating deposit insurance as a policy tool. A rigorous assessment of deposit insurance should take place within more structured models making it possible to address many additional issues. These issues include, for example, the depositors' incentives to acquire information regarding the risk characteristics of banks' loan portfolios as well as assessments of the external effects from bank failures. A number of important features for such a welfare evaluation of deposit insurance systems can be found in Besanko and Thakor (1993).

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[4]For such a study see Matutes and Vives (2000).

[5]For example, in the U.S. deposit insurance covers both principal and accrued interest, in which case $\lambda = -r_i$. It can directly be seen that arguments can generalized to incorporate such a modification of deposit insurance incorporating accrued interest without any change whatsoever in the qualitative conclusions.

6.   Extension: Continuum of Portfolio Choices

The purpose of this section is to demonstrate the robustness of our market structure invariance result (Proposition 5) by extending the model so as to fully endogenize the risk-taking decisions of banks. Suppose now that banks face a full spectrum of portfolios varying by their degree of risk. More precisely, each bank can choose one portfolio, s_i satisfying $s_i \in [L, H] \subset \mathbb{R}$. Thus, a high value of s_i indicates that the bank chooses a risky portfolio, whereas $s_i = L$ means that the bank chooses the portfolio with the lowest possible risk.

Similar to (1), let $R(s) > 0$ be the gross return on portfolio s achieved with probability $\theta(s)$, $s \in [L, H]$. Under this extension, a straightforward generalization transforms Assumption 1 into

ASSUMPTION 3

(a) $\theta'(s) < 0$ and $\theta''(s) > 0$, meaning that the portfolio risk increases the probability of a failure at an increasing rate.

(b) $R'(s) > 0$ and $R''(s) < 0$, meaning that expected return increases with risk but at a declining rate.

(c) $\theta'(s)R(s) + \theta(s)R'(s) > 0$, meaning that the expected portfolio return is a strictly increasing function of the portfolio's risk.

In order to find out how the market structure affects the risk taking we compare a banking duopoly with that of a monopoly.

6.1   Duopoly equilibrium

We look for a Nash equilibrium in a portfolio-choices $\langle s_1, s_2 \rangle$. Partially differentiating (10) with respect to s_i yields the first-order condition (for an interior maximum)

$$\frac{1}{18\tau} \frac{\partial \psi_i}{\partial s_i} \left[2\psi_i(s_i, s_j) + 6\tau\right] = 0 \quad \text{implying that} \quad \frac{\partial \psi_i}{\partial s_i} = 0$$

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in a symmetric equilibrium, since under symmetry $\psi(s,s) = 0$. Thus, for every bank i, in a symmetric equilibrium Assumption 3 implies that

$$\frac{\partial \psi_i}{\partial s_i} = \theta'(s_i)R(s_i) + \theta(s_i)R'(s_i) + (\lambda - 1)\theta'(s_i) \geq 0 \quad \text{for } \lambda \leq 1. \tag{19}$$

Clearly, by Assumption 3 banks choose the portfolio with maximal risk $s_i = H$ if $\lambda < 1$ (depositors are risk lovers according to Definition 1). Therefore, in what follows we confine our analysis to the case of risk aversion and assume that $\lambda > 1$. Then, (19) implies that in a symmetric portfolio equilibrium $s_1 = s_2 = \hat{s}$ is implicitly determined implicitly from

$$\theta'(\hat{s})\left[R(\hat{s}) + \lambda - 1\right] + \theta(\hat{s})R'(\hat{s}) = 0. \tag{20}$$

6.2 Monopoly equilibrium

In order to find out the optimal portfolio for a banking monopoly we start from the objective function (18). Differentiating (18) with respect to s yields

$$\pi'(s) = \theta'(s)R(s) + \theta(s)R'(s) + (\lambda - 1)\theta'(s) = 0,$$

from which we can conclude that the monopoly's profit maximizing choice of portfolio s^M is implicitly determined implicitly from

$$\theta'(s^M)\left[R(s^M) + \lambda - 1\right] + \theta(s^M)R'(s^M) = 0. \tag{21}$$

Comparing (20) with (21) yields the analog of Proposition 5.

Proposition 9

In the extended model, where banks can choose from a continuum of portfolios varying in their degree of risk and expected returns, the market structure has no effect on the portfolio equilibrium.

It should be pointed out that the market structure invariance result is obtained within the framework of a model which is restricted to the *deposit market* only. In this respect our model is particularly relevant to situations where banks enjoy more substantial market power in the deposit market than in the loan market. Such an emphasis need not, however, be a

bad characterization of, for example, the European banking industry in light of the evidence presented in Neven and Röller (1999) according to which there is empirical support for the hypothesis that the corporate market is more competitive than the household market. Like most papers in this field our analysis covers cases where the banks' investment opportunity set exhibits constant returns to scale meaning that the efficient frontier in terms of risk and average return is invariant to the level of investment. Similarly, we formally assume that banks' costs of managing the loan portfolios is independent of the risk characteristics of their portfolio. Such an assumption can be seen as a normalization in light of the fact that the impact of these risk characteristics is incorporated into the assumptions regarding the portfolio returns. Consequently, our prediction is that our market structure invariance result may not hold if we incorporate either banks' functioning in loan markets or economies of scale with respect to the investment opportunities available to banks.

7. Concluding Remarks

With only a few exceptions most countries in the world have selected to maintain a mandatory system of deposit insurance (New Zealand being one such exception). Given the distortions associated with explicit deposit insurance policies or implicit policies of the "Too Big To Fail"-type, it is impossible to infer from our observations of actual bank behavior how the banks' incentives to reduce the risk of their loan portfolios are related to the market structure of the banking industry. In particular, as our analysis has made clear, deposit insurance will induce banks to invest in risky portfolios by eliminating the strategic incentives banks have to present low-risk portfolio to their customers. For these reasons, and in light of the rapidly ongoing consolidation of the banking industry both in North America and in Europe, it is extremely important to investigate the effects of the market structure in the banking industry on the investment behavior of banks. Initially, such studies have to be carried out in the framework of banking industries operating in the absence of deposit insurance, because only such an intermediate step makes it possible to adequately address the fundamental policy issues associated with welfare evaluations of deposit insurance systems.

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A major finding of our analysis consists of the demonstration of how banks' incentives for risk taking are invariant to a change in the banking market structure from duopoly to monopoly. Irrespectively of whether a bank meets threats from competition or not, the bank will find it worthwhile to sacrifice the higher expected portfolio returns from risky specialization in favor of lower portfolio riskiness as soon as it faces sufficiently risk averse depositors. Essentially, the market structure invariance result is a consequence of the feature that the interest rate mechanism is more efficient than risk shifting as an instrument for banks to exploit market power in deposit markets. If, however, the opportunities for coordinating the interest rate decisions is eliminated the banking industry will have incentives to exploit the less efficient instrument of risk coordination as our section on a semicollusive banking industry showed. In such a case the market structure invariance result will break down. Similarly, other types of market imperfections, like asymmetric information, will break our invariance result if these imperfections interact with market structure. Finally, we found that introduction of deposit insurance would eliminate all incentives for reducing risk as the actors in the deposit market could then dump all the risk on the government.

Throughout our analysis the hypothesis that depositors can observe the riskiness included in banks' outstanding asset portfolios is crucial. Of course, the practical relevance of such an assumption could be questioned, in particular if it is very costly for depositors to acquire such information. However, the publicly cited credit ratings of banks could very well serve as a reasonable empirical proxy of the riskiness of bank portfolios. Thus, the changes in risk premia in response to changes in the credit ratings of banks offering uninsured deposit opportunities could offer a valuable source for empirical verification of the effects predicted by our model. In this respect Strahan's (1995) empirical analysis offers at least a partly relevant piece of evidence. In addition our analysis has assumed that the bankruptcy costs of a bank failure are fully internalized by the banks and the depositors via the rate of return that depositors requires. Such an assumption seems reasonable since the nature of external effects like social costs of bank runs or bank charter values would have to refer to particular regulatory environments, which are not introduced at the generality of the present model.

Finally, in this paper we chose to differentiate depositors according to their preferences for bank-specific attributes, as formulated by the Hotelling-type location model. However, we would like to point out that depositors could also be differentiated according to their attitude towards risk. It is well known that models incorporating two types of consumer differentiation are hard to solve for, and in many cases do not have equilibria in pure strategies. More importantly, however, if we would focus on vertical (risk-aversion) differentiation rather than horizontal (bank attribute-type) differentiation the model would generate market segmentation with respect to risk. This means that one bank would serve depositors with high risk aversion, whereas the rival bank would serve depositors with low risk aversion. Of course, such a configuration would mean that our market structure invariance result would break down. However, we do not observe deposit markets where banks are differentiated into low-risk and high-risk banks. Instead, differentiation with respect to the risk dimension is offered by risky investment instruments other than deposits.

Appendix A.   Proof of Proposition 3

Table 2 implies that $r_i(L, L) < r_i(H, H)$ if

$$\tau < \frac{\theta(H)\theta(L)[R(H) - R(L)]}{\theta(L) - \theta(H)}.$$

Assumption 2 implies that $\tau \leq \theta(L)[R(L) - 1]$. Hence, it is sufficient to prove that

$$\theta(L)[R(L) - 1] < \frac{\theta(H)\theta(L)[R(H) - R(L)]}{\theta(L) - \theta(H)}.$$

After some manipulations, this inequality can be written as

$$-[\theta(L) - \theta(H)] < 0 < \theta(H)R(H) - \theta(L)R(L),$$

which holds by Assumption 1. $\qquad \square$

Appendix B.   Demonstrating That a Monopoly Bank Pays Lower Interest Than Competitive Banks

Comparing (17) with the symmetric profit levels in Table 1 reveals that a banks in a duopoly market structure pay a higher interest compared with a monopoly bank if

$$U^{\min} < (\theta(s_i))^2(R(s_i) - 1) - \lambda(1 - \theta(s_i)) - \frac{3\tau}{2}. \tag{22}$$

Under duopoly interest competition, the utility of a depositor located at $x = 1/2$ is found by substituting the interest rates under symmetric outcomes given in Table 2 into (3). Hence,

$$V_{\frac{1}{2}} = (\theta(s_i))^2(R(s_i) - 1) - \lambda(1 - \theta(s_i)) - \frac{3\tau}{2},$$

which is greater than $U^{\min}$ if and only if (22) holds.

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