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On the relationship between market power and bank risk taking

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Abstract We analyze risk taking behavior of banks in the context of spatial competition. Banks mobilize unsecured deposits by offering deposit rates, which they invest either in a prudent or a gambling asset. Limited liability along with high return of a successful gamble induce moral hazard at the bank level. We show that when the market power that the banks enjoyed in the deposit market is low, banks invest in the gambling asset. On the other hand, for sufficiently high levels of market power, all banks choose the prudent asset to invest in. We further show that a merger of two neighboring banks increases the likelihood of prudent behavior. Also, introduction of a deposit insurance scheme exacerbates banks' moral hazard problem if the insurance premium is sufficiently low. Finally, we introduce a loan market where the borrowers of the banks choose the investment strategy prior to the deposit contracts. We show that as the market power that the banks enjoy in the loan market increases the borrowers tend to take more risk.

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1 Introduction

Competition in banking sectors is often conducive to banks being involved in high-risk activities. Keeley (1990), Hellmann et al. (2000) and Repullo (2004), among many others, argue that high competition in the deposit market reduces a bank's incentives for prudent behavior through the reduction of a bank's expected profits. A plethora of measures thus have been adopted by the prudential regulators to promote safety of the banking systems in the developed and emerging economies. Following the recommendations of Basel Committee on Banking Supervision, different forms of minimum capital requirement and deposit rate ceiling, or a combination of both (Hellmann et al. 2000; Repullo 2004) are applied in order to curb banks' incentives for risk taking. On the other hand, deposit insurance is in use to enhance depositors' confidence and prevent systemic financial crises (Diamond and Dybvig 1983).

The main purposes of this paper are to analyze the nature of the association between market power and bank risk taking when banks compete in a monopolistically competitive deposit market, and then exploit such association to study the effects of bank mergers and deposit insurance on the risk taking behavior. To this end, we analyze a model of locational competition à la (Salop 1979). Banks collect deposits from the potential depositors by offering deposit rates and invest their total funds (deposits plus equity capital) either in a prudent or a gambling asset, and the depositors incur a per unit transport cost to travel to a bank in order to deposit their funds.[1] No bank can commit to the choice of the degree of investment risk (safe or risky) since this decision is taken after the depositors have deposited their funds. In our model, risk neutral banks are subject to limited liability. The gambling asset offers an expected return lower than that of the prudent asset, but has a higher return if it succeeds. The above characteristics of the assets make the banks prone to choose a risky investment which creates a moral hazard problem at the bank level.

We show that in equilibrium there is a negative association between market power and bank risk taking. The intermediation margin of the banks is increasing in the ratio of the transport cost to the number of banks. Hence, as in Salop (1979), we use the transport cost relative to the number of banks as the measure of market power. For very low levels of market power, an equilibrium emerges in which all banks invest in the gambling asset offering a high deposit rate. If market power is very high, then a *gambling equilibrium* ceases to exist, and the banks invest in the prudent asset and offer a lower deposit rate, which is referred to as a *prudent equilibrium*. For an intermediate level of market power, both of the aforesaid equilibria exist. We also analyze the effect of bank merger on the equilibrium risk taking. Merger between

[1] This should not literally be interpreted as the cost (or time) a depositor spends in traveling to a bank. Banks could be differentiated because of differences in ATM facilities, availability in various geographic areas, internet banking services, etc. This is part of the transaction costs incurred by the depositors.

banks increases banks' intermediation margin and makes gambling less likely. In other words, merger can be viewed as a substitute for prudential regulation that aims at guaranteeing financial stability. Finally, we study the effect of the introduction of a deposit insurance scheme on the equilibrium of the banking sector.[2] Diamond and Dybvig (1983) argue that deposit insurance serves to protect the depositors in face of bank failure and to enhance depositors' confidence that prevents bank runs. We show that, when per unit insurance premium is low, such a scheme exacerbate the risk-enhancing moral hazard problem by making gambling by the banks more likely which conforms to a number of empirical findings.

The negative association between market power and bank risk taking has been established, among many others, by Matutes and Vives (1996) and Repullo (2004). Our work is similar to that of Repullo who considers a dynamic model of banking based on spatial competition à la Salop (1979) with insured depositors to show that for very low level of market power, low intermediation margins reduce banks' franchise value and induce banks invest only in the gambling asset. Our model differs from Repullo (2004) in the following aspects. We consider a model of static bank competition. We believe this to be adequate in order to analyze the effects of market power since, in the long run, free entry washes away monopoly rents that the banks enjoy in the short run. Hellmann et al. (2000) consider a model of bank competition to argue that a minimum capital requirement alone cannot serve as an effective prudential regulatory instrument, and this has to be combined with a deposit rate ceiling in order that efficiency can be achieved. Repullo (2004) shows that a risk-based capital requirement can undermine banks' incentive for risk taking and promote safety. Our model also retains similarity with the work of Matutes and Vives (1996), which considers a model of bank competition where depositors have beliefs about the probability of failure of the banks, and banks can choose to invest in different assets with different degrees of riskiness that depends on the market share of each bank. It is the presence of depositors' beliefs what generates consistency requirements that should be fulfilled in any equilibrium. Our model also imposes similar consistency requirements on the equilibria. Since we avoid the complexity added by the existence of such beliefs, these requirements boil down to a no gambling condition requiring that if a bank makes its clients believe that it is going to invest in the prudent asset, in equilibrium it indeed does so.

In a seminal paper, Boyd and De Nicolo (2005) suggest that the above mentioned negative relationship between market power and risk taking can be reversed if one considers simultaneous interaction between the deposit and the loan markets in which the borrowers, rather than the banks, choose the riskiness of a bank's investment. In an extension of the basic model we also introduce a loan market where the borrowers choose the investment strategy. The main difference of our model with that of Boyd and De Nicolo (2005) is that these authors consider homogeneous competition in both the deposit and the loan markets, whereas in the present context competition in these markets are heterogeneous. We show that higher market power of the banks in the loan

[2] A fairly priced deposit insurance can be viewed as a real option. See Greenbaum and Thakor (2007) for a detailed discussion on deposit insurance as an instrument of prudential regulation.

markets induces more risk taking, but this behaviour does not depend on the market power the banks enjoy in the deposit market.

The paper proceeds as follows. In Sect. 2 we describe the basic model with uninsured deposits. The following section describes and characterizes the equilibrium of the banking sector, and studies the effect of market power on social welfare. Section 4 analyses the effects of bank merger and deposit insurance on the banks' risk taking behavior. Finally, in Sect. 5 we analyze the effects of loan contracts on risk taking. The paper concludes in Sect. 6. Proofs of our main results are presented in the appendices.

2 The model

Consider a banking sector with n risk neutral banks located uniformly on a unit circle. Banks compete in deposit rates in order to mobilize deposits. Let $r = (r_1, \ldots, r_n)$ be the deposit rates offered by the banks with $r_i > 1$ for each i. The total supply of deposits at bank i's is given by $D_i(r_i, r_{-i})$, where r_{-i} is the vector of rates offered by the other banks.

There is a continuum of risk-neutral depositors, also uniformly distributed on the unit circle, with a unit of fund apiece. A depositor can deposit her fund in a bank which pays off a deposit rate in the next period. Deposits are assumed not to be insured.[3] Each depositor incurs a per unit transport cost t in order to travel to a bank.

Each bank i faces a minimum capital requirement of k. Thus a bank with total supply of deposits D_i invests $(1 + k)D_i$ either in a prudent or a gambling asset.[4] The asset return is in general stochastic with a given probability distribution, and is equal to $\tilde{y}$. In case of the prudent asset, $\tilde{y} = \alpha > r_i$ for all $i = 1, \ldots, n$ with probability 1, i.e., the return on the prudent asset is constant. For the gambling asset, on the other hand, we have $\tilde{y} = \gamma > \alpha$ with a given probability θ and $\tilde{y} = 0$ with probability $1-\theta$. We assume that the success or failure of the gamble is independent across banks, and the prudent asset has an expected return higher than that of the gambling asset, i.e., $\alpha > \theta\gamma$. We also assume that $\alpha < (2-\theta)\theta\gamma$ so that the return from the prudent asset is not too high, otherwise the banks do not have incentives to invest in the gambling asset, and the moral hazard problem becomes trivial.[5] A bank i's intermediation margin is given by $\mu = E[\tilde{y} - r_1]$, where $E[\,.\,]$ represents the expected value of the random variable. Each bank is subject to limited liability, i.e., in case a bank's project fails its depositors are not paid back.

[3] In Sect. 4 we analyse the effects of the introduction of a deposit insurance scheme.

[4] A bank might invest a fraction of its total fund in each asset. It is easy to show that, under limited liability, optimality would imply that banks choose only one asset to invest in.

[5] The moral hazard problem of the banks becomes important under limited liability which implies that whenever gambling fails, the banks do not have to repay the promised deposit rates. Without limited liability, the moral hazard problem of the banks with respect to asset choice is trivial. Under unlimited liability it would always be possible to implement the choice of the prudent asset. Often banks offer different types of deposits: in some the repayment obligation is unavoidable, and in others it is state-contingent. If the banks must invest a part of their deposits in a safe asset, e.g. in the money market, then certainly the incentive problem would be less stringent.

The timing of events is as follows. Banks simultaneously offer deposit rates. Depositors then choose the bank in which to deposit their funds. The deposit mobilization is followed by the portfolio choice of the banks. Finally, project outputs are realized and the depositors are paid off. This timing is crucial in characterizing the equilibrium risk taking behavior. Since the investment decision is taken after the depositors have deposited their funds, a bank is unable to commit to a particular investment strategy. Thus the assumption that $\gamma > \alpha$ along with limited liability imply that the banks find it more attractive to invest in the gambling asset, which gives rise to a potential moral hazard problem at the bank level. We focus on two types of symmetric equilibria. A prudent equilibrium where all banks choose to invest in the prudent asset, and a gambling equilibrium in which all banks invest in the gambling asset.

3 The equilibrium of the deposit market

3.1 Description

In this section we characterize the symmetric equilibria of the banking sector where banks compete in the deposit market by offering deposit rates and choose a prudent asset or a gambling asset to invest in, and each depositor chooses a bank to place her fund. We look for the subgame perfect equilibria of the stage game.

If a bank i chooses to invest in the prudent asset and the gambling asset, its expected profits are respectively given by

$$\pi^P(r_i, r_{-i}) = [\alpha k + (\alpha - r_i)]D_i(r_i, r_{-i}), \tag{1}$$
$$\pi^G(r_i, r_{-i}) = \theta[\gamma(1+k) - r_i]D_i(r_i, r_{-i}). \tag{2}$$

We solve the stage game by backward induction. Each bank i would choose to invest in the prudent asset if the expected profits from doing so exceed the expected profits from the gambling asset, i.e., $\pi_i^P \geq \pi_i^G$. This occurs if the total deposits of a bank satisfies the following *no gambling condition* (henceforth, NGC).

$$r_i \leq \frac{(\alpha - \theta\gamma)(1+k)}{1-\theta} \equiv \bar{r}. \tag{NGC$_i$}$$

If the above inequality is reversed, i.e., a *gambling condition* (henceforth, GC) holds, then a bank would invest in the gambling asset. The condition (NGC$_i$) is a Nash incentive compatibility condition which guarantees that each bank i behaves prudently given the behavior of the depositors, and that the rival banks have chosen to invest in the prudent asset. If the depositors preferred their banks to invest in the safe asset and if the banks could commit to be prudent, then it would not be necessary to impose an NGC. Note that if the minimum capital requirement is tighter, i.e., each bank must invest a higher fraction k of its own equity capital, the NGC is more likely to be satisfied for each bank, and hence all banks are more likely to behave prudently. The opposite holds for low values of k , this condition is less likely to be satisfied.[6]

In the second stage, a depositor takes the decision whether to place her fund in a bank. Because we focus on symmetric equilibria, we can assume directly that consumers only contemplate depositing their funds in the nearest bank. Consider a particular bank i and a depositor at a distance x from such bank. Suppose that she anticipates that the bank will invest in the prudent asset. Then she would deposit her unit fund if the following *participation condition* holds.

$$r_i - 1 \geq tx. \tag{3}$$

In case the depositor expects the bank to gamble, the above condition turns out to be

$$\theta r_i - 1 \geq tx. \tag{4}$$

If one of the above two conditions is satisfied for each of the depositors, then no one leaves her fund idle. In other words, all the depositors in the economy are served by at least one bank. In this case a *covered market* is said to emerge. If one of the above conditions does not hold for at least one depositor located between two neighboring banks, then an *uncovered market* emerges. In the subsequent sections we only analyze the symmetric equilibria of a covered market.[7] It is worth noting that the depositors have no control over the portfolio choices of the banks. The above participation conditions imply that if a bank chooses to gamble instead of being prudent, then it must offer a higher deposit rate to its clients.

In the first stage of the game each bank sets the deposit rate in order to maximize its expected profits. In course of doing so, the banks must take into account the possible outcomes of the subgame that follows (stages 2 and 3). Hence, the aforesaid restrictions are imposed as constraints on the banks profit maximization problem. For example, when all banks maximize expected profits subject to (NGC_i) and (3), then a *prudent equilibrium* is said to arise. It is worth noting that the condition NGC or GC determines banks' portfolio choice that follows the decision taken by the depositors. If there is a small number of depositors who place their funds in a particular bank, then this bank is more likely to invest in the prudent asset (since the NGC is more likely to be satisfied). Hence, the conditions NGC and GC are endogenous rather than being exogenous constraints.

3.2 Characterisation

We analyze two types of symmetric equilibria (in deposit rates) of the stage game, namely a prudent equilibrium and a gambling equilibrium. Let r^P and r^G denote the equilibrium deposit rates offered by the banks when all of them respectively choose

6 A suitable combination of r_i and k can guarantee that the banks invest in the prudent asset. See Proposition 2 in Hellmann et al. (2000) for a discussion.

7 Details of the characterization of the equilibria of an uncovered market are available from the authors upon request.

the prudent asset and the gambling asset. A prudent equilibrium thus is a strategy profile in which all banks offer r^P and choose the prudent asset to invest in, and each depositor deposits her fund in a bank. On the other hand, a gambling equilibrium is a strategy profile in which all banks offer r^G and choose to gamble, and each depositor deposits her fund in a bank.[8] It is worth noting that we analyze only two extreme cases in one of which the NGC is satisfied for each bank [a prudent equilibrium], and in the other the NGC does not hold for any bank [a gambling equilibrium]. There might be equilibria where some banks behave prudently, and the rest gamble. Analysis of this type of equilibrium is ignored in the current paper.

The gambling equilibrium

In a symmetric gambling equilibrium, all banks offer the same deposit rate and invest in the gambling asset, and all depositors are served. When bank i promises a deposit rate r_i, a depositor in this bank gets (in expected terms) θr_i back. If the depositors anticipate that all banks are going to choose the gambling asset (i.e., for all banks condition GC holds), the deposit of bank i is given by

$$D_i(r_i, r) = \frac{1}{n} + \frac{\theta(r_i - r)}{t}. \tag{5}$$

Here, one should take two restrictions into account. First, all the banks must comply with the GC in order that the equilibrium is indeed a gambling equilibrium (stage 3 of the game). Second, there is no depositor who has incentive to keep her fund idle, i.e., the participation condition (4) must hold good. Hence, bank i's shareholders choose r_i to maximise, subject to GC and (4), the following expected profit

$$\pi^G(r_i, r) = \theta[\gamma(1+k) - r_i]\left[\frac{1}{n} + \frac{\theta(r_i - r)}{t}\right]. \tag{6}$$

The prudent equilibrium

In a symmetric prudent equilibrium, all banks offer the same deposit rate and invest in the prudent asset, and all depositors are served. When bank i offers r_i and all the rival banks offers r and if depositors anticipate that all banks are going to choose the prudent asset, then the deposit of bank i is given by:

$$D_i(r_i, r) = \frac{1}{n} + \frac{r_i - r}{t}. \tag{7}$$

All banks must comply with the NGC in order that the market structure that arises at equilibrium is indeed a prudent equilibrium. Second, there is no depositor who has an incentive to keep her fund idle, i.e., for any depositor and for any bank the participation condition (3) must hold good. Thus, bank i's shareholders choose r_i to maximise, subject to NGC and (3), the following expected profit following problem:

[8] The intermediation margins for each bank in a prudent and in a gambling equilibria are respectively given by $\mu^P = \alpha - r^P$ and $\mu^G = \theta(\gamma - r^G)$.

$$\pi^P(r_i, r) = [\alpha(1+k) - r_i]\left[\frac{1}{n} + \frac{r_i - r}{t}\right]. \tag{8}$$

In the following proposition we characterize the prudent and gambling symmetric equilibria of the deposit market. If the transportation cost increases relative to the number of banks, given the total number of depositors, then each bank has a higher margin which reflects a higher market power. In fact, it will be shown that, under both equilibria, the intermediation margins equal t/n. Hence for our economy, t/n is taken as a measure of market power. As in any monopolistically competitive model t/n also represents the degree of product differentiation. As $t/n \to 0$, the deposit competition becomes homogeneous.

Proposition 1 *For a given minimum capital requirement k, there exist threshold values of market power ϕ^P, ϕ^G and ϕ^α with $\phi^P < \phi^G < \phi^\alpha$ such that*

(a) *if $\frac{t}{n} \in [0, \phi^P]$ (low market power), then only the gambling equilibrium exists with each bank offering the deposit rate $r^G = \gamma(1+k) - \frac{t}{\theta n}$;*
(b) *if $\frac{t}{n} \in [\phi^P, \phi^G]$ (intermediate market power), then both the gambling and the prudent equilibria exist with each bank offering the deposit rates $r^G = \gamma(1+k) - \frac{t}{\theta n}$ and $r^P = \bar{r}$;*
(c) *if $\frac{t}{n} \in [\phi^G, \phi^\alpha]$ (high market power), then only the prudent equilibrium exists with each bank offering the deposit rate $r^P = \min\{\bar{r}, \alpha(1+k) - \frac{t}{n}\}$.*

The proofs of the above and the subsequent propositions are relegated to the appendix. The intuition behind the above proposition is fairly simple. When the market power is very low, competition erodes banks' profit, thus leaving little incentive for them to invest in the prudent asset. Therefore, all banks choose the gambling assets to invest in. On the other hand, for very high market power, banks earn quasi-monopoly rent, and hence the banks' incentives for investment in the gambling asset disappear, and only the prudent equilibrium exists. For the intermediate values of market power there are multiple equilibria in the sense that both the gambling and the prudent equilibria co-exist.[9] Notice also that as market power increases the equilibrium deposit rates decrease implying that when the banks move to the prudent equilibrium, they lower the deposit rates by exercising greater market power.

Similar results have been obtained by Repullo (2004), and many other authors. It is worth noting the difference between the characterization of the equilibrium deposit rates in the present model and that in the aforementioned paper. In our model, the timing of events is crucial. Notice that in the three stage game, first the banks post the rates, then the depositors decide whether to deposit their funds which determines the supply function of deposits of each bank, and finally, the banks decide on their investment strategies. The deposit rates and investment strategies characterized in the

[9] For even a higher values of t/n, the market may become uncovered, i.e., banks offer even lower deposit rate which is not conducive to attract the depositors located at a longer distance. Also, we only consider the interior solutions to the banks' maximization problem. There is an equilibrium with a corner solution,namely, $r^P = \alpha(1+k) - \bar{r}$. We do not consider the above equilibrium rate in order to avoid discontinuities in our analysis. We also omit the analysis of an uncovered market that emerges for $t/n > \phi^\alpha$ in which only a prudent equilibrium exists.

above proposition constitute a subgame perfect equilibrium, and hence one should check the unilateral deviation of a given bank in two different nodes of the game.[10] Suppose we analyze a gambling equilibrium with the symmetric deposit rate r^G. A possible deviation by bank i from its equilibrium strategy is at stage 1 bank i deviates with a deposit rate which would make it behave prudently. Since the depositors are not insured, such a deviation would change the supply function of deposits in the next stage. In a model with deposit insurance as in Repullo (2004), the supply function remains the same irrespective of whether a bank chooses a prudent or a gambling asset to invest in. In such models the depositors do not change their behavior as a response to any deviations on behalf of the banks. Thus in our model, the determination of equilibrium deposit rates is more complicated, and hence is quantitatively different than those in a model with deposit insurance.

4 Extensions

In this section we study a few important extensions of the model presented in the previous section. The first is the effect of an increase in the market concentration due to a merger between two neighboring banks on the circle. Next, we analyze how the introduction of a deposit insurance scheme exacerbates the moral hazard problem of the banks.

4.1 Bank merger

It is obvious that merger between banks enhances market concentration. Keeping in mind the anti-competitive issues, merger is often viewed as welfare-decreasing because of its adverse effects on the consumers surplus. In the current set up, following the analysis of the previous sections, merger among banks has an additional effect on the welfare because of its implications for risk taking. In particular merger, via increased market concentration, might enhance the incentives for prudent behavior of the banks. In reality the competition authorities in most of the countries would not have the implications of a merger for risk taking in mind while scrutinizing a possible merger. This calls for a policy coordination between the antitrust authority and the prudential regulator in the context of a bank merger, the case that is quite different from a merger between two firms. In practice, a bank merger policy needs to provide substantial protection but, obviously, the policy should take into account also the long-term cumulative effects of the merger movement.[11] In this sense, a good deal of the debate on competition effects from bank consolidation has been phrased in terms of the conflict between two competing hypotheses or paradigms (i) mergers imply reductions in competition and increases in market power through

[10] See Appendix A for details.

[11] For instance, in the USA each merger must be approved by a federal banking agency (the Office of the Comptroller of the Currency, the Federal Reserve Board and the Federal Deposit Insurance Corporation) after an evaluation of its competitive effects. Approvals are subject to antitrust challenges by the Department of Justice.

firm growth and market concentration and (ii) a more competitive environment reduces rents and makes the risk-taking option more attractive. Having this motivation in mind, an immediate extension of our baseline model is the analysis of the implications of a horizontal merger between several banks for the equilibrium in our model. In order to analyze the effect of a merger on the risk taking behavior of the banks, we make the following assumption. When two neighboring banks merge, the merged entity does not shut down the operation of one of the two offices. In other words, a merged bank can be viewed as a multi-plant firm, operating the pre-merger banks as "plants". The effects of mergers in spatial competition models are studied, among others, by Levy and Reitzes (1992) and Brito (2003). In these papers, it is shown that mergers generally lead to a price increase. Nonetheless, these models do not consider merger under investment uncertainty. In this subsection, we focus on the implications of a merger on the risk taking behavior of the banks by considering the case of a bilateral merger between any pair of neighboring banks. Since Brito (2003) shows that, in a circular city model, closing one of the locations is not profitable for the merged entity, we also assume that the merged bank continues to operate from both of the pre-merger locations. This can be justified by the existence of a sufficiently high relocation cost. In addition, we assume for simplicity that no efficiency gains result in from a merger. Suppose that the timing of the events described in Sect. 2 includes an initial stage where a pair of neighboring banks merge.[12] When such merger takes place, a symmetry argument cannot be applied to solve the game since the impact of the merger on rival banks depends on their location. Without loss of generality, let the merged entity be composed of banks i and $i+1$. Let $\Pi^P_{i,i+1}$ and $\Pi^G_{i,i+1}$ be the expected profits of the merged entity under prudent and gambling strategies respectively. The profit maximization problem for the merged bank can be expressed as

$$\max_{r_i,\, r_{i+1}} \Pi^P_{i,i+1} \equiv \pi^P_i \left(r_i,\, r_{-i}\right) + \pi^P_{i+1} \left(r_{i+1},\, r_{-(i+1)}\right),$$
$$\max_{r_i,\, r_{i+1}} \Pi^G_{i,i+1} \equiv \pi^G_i \left(r_i,\, r_{-i}\right) + \pi^G_{i+1} \left(r_{i+1},\, r_{-(i+1)}\right).$$

A merger between a pair of neighbouring firms in the circular city model has been analysed by Levy and Reitzes (1993) when transport costs are linear, who show that a merger of a pair of neighboring firms increases the price. Following them, it is easy to show that after merger takes place each bank offers a lower deposit rate and that the deposit rate offered by a bank j ($j \neq i,\ i+1$) is decreasing in the distance between this bank and banks i and $i+1$. Hence, it is immediate to see that the equilibrium deposit rates r^P and r^G decrease for all banks $i = 1, \ldots, n$ and that the NGC is more easily satisfied. We summarize this result in the following proposition.

Proposition 2 *For each bank in the deposit market, the likelihood of prudent behavior increases following a pair of neighboring banks merge.*

12 We do not discuss merger profitability since a merger of any pair of neighboring banks is always profitable in the circular city model (see Brito 2003). It is also well-known that mergers are generally profitable when reaction functions are upward sloping (see Deneckere and Davidson 1985).

The above proposition suggests that a merger in the banking sector increases the likelihood that the banks choose to invest in the prudent asset. The intuition behind is as follows. Prior to the merger each bank has independently maximized its expected profit. In the post-merger stage, merged banks realize that lowering the deposit rate in one location increases the expected profit in the other. Consequently, the merged entity lowers the deposit rate, and this induces other banks to lower the deposit rate as well. Hence, both the expected profits of investing in the prudent and the gambling assets increase for all banks. A lower deposit rate makes the NGC more likely to be satisfied, thereby increasing the likelihood of prudent behavior. One may think that the above intuition is only true if the merging banks are neighbors, since a bank can affect only its neighbor's profits. However, according to Levy and Reitzes (1992), a merger between non-neighboring banks in the circular city model also leads to a fall in the deposit rate. Thus, our results would not substantively change if we had allowed two non-neighboring banks to merge. An additional interpretation of Proposition 2 is that a merger policy might also become an incentive structure to discourage speculative banking. In other words, a more competition-oriented merger control seems to point towards the standard adverse effects on prices of increased concentration in banking but may leave out the effects of the merger on the risk taking behavior of banks. In practice, banking regulators often allow mergers and a possible explanation is that outright bank closures may destroy informational capital on borrowers. But it is also possible that central bankers, which are often in charge of banking supervision as well, may implicitly prefer stability (or the liquidation of all trouble banks) over competition. In this sense, a related result to ours can be found in Perotti and Suárez (2002). They obtain that merger between banks occur as failed banks are promoted to be taken by solvent institutions and this provides additional incentives for banks to prefer prudent lending to risky lending. Our model, however, differs from theirs in important respects since they basically consider mergers to monopoly in a duopoly with fully insured deposits.

4.2 Deposit insurance

In this subsection we consider the introduction of a deposit insurance scheme that (partially) insures each depositor. Deposit insurance schemes are designed to prevent systemic confidence crises (Diamond and Dybvig 1983). In the current context the effect of such regulatory measure remains ambiguous for low deposit insurance. A little amount of deposit insurance increases a bank's deposit by compensating for the transport cost. On the other hand, deposit insurance induces banks to compete more fiercely and thus reduces bank's incentives to behave prudently by increasing the moral hazard at the bank level since they are protected by limited liability.

Under a deposit insurance scheme, even if a bank i fails while gambling, its depositors are paid back the promised deposit rate r_i. In this case, the expected prudent and gambling profits of bank i at a vector of deposit rates (r_i, r) are respectively given by:

$$\pi_i^P(r_i, r, \beta) = [\alpha(1+k) - r_i - \beta]\left[\frac{1}{n} + \frac{r_i - r}{t}\right], \tag{9}$$

$$\pi_i^G(r_i, r, \beta) = [\theta(\gamma(1+k) - r_i) - \beta]\left[\frac{1}{n} + \frac{r_i - r}{t}\right], \tag{10}$$

where β is the flat deposit insurance premium which is charged prior to the choice of the investment strategies of each bank. Notice that when the deposits are insured, the supply of deposits of bank i remains the same even if the bank choose to invest in the gambling asset. For simplicity, we focus only on the equilibria under the covered market. Further, notice that the no gambling condition of the banks does not change under the deposit insurance scheme since the expected profits (gross of the insurance premium) of the banks remain unchanged. The following proposition characterizes the equilibrium deposit rates under the deposit insurance scheme.

Proposition 3 *For a given minimum capital requirement k and per unit deposit insurance premium β, there exist threshold values of market power $\hat{\phi}^P$, $\hat{\phi}^G$ and $\hat{\phi}^\alpha$ with $\hat{\phi}^P < \hat{\phi}^G < \hat{\phi}^\alpha$ such that*

(a) *if $\frac{t}{n} \in [0, \hat{\phi}^P]$ (low market power), then only the gambling equilibrium exists with each bank offering the deposit rate $\hat{r}^G = \gamma(1+k) - \frac{t}{\theta n} - \frac{\beta}{\theta}$;*
(b) *if $\frac{t}{n} \in [\hat{\phi}^P, \hat{\phi}^G]$ (intermediate market power), then both the gambling and the prudent equilibria exist with each bank offering the deposit rates $\hat{r}^G = \gamma(1+k) - \frac{t}{\theta n} - \frac{\beta}{\theta}$ and $\hat{r}^P = \alpha(1+k) - \frac{t}{n} - \beta$;*
(c) *if $\frac{t}{n} \in [\hat{\phi}^G, \hat{\phi}^\alpha]$ (high market power), then only the prudent equilibrium exists with each bank offering the deposit rate $\hat{r}^P = \alpha(1+k) - \frac{t}{n} - \beta$.*

The intuition behind the above proposition is fairly simple, and is very similar to that of Proposition 1. It is worth noting that if the depositors are fully insured, then they do not react to any changes in the strategies of an individual bank.

Next, we show that deposit insurance exacerbates the moral hazard problem of the banks if the insurance premium is low enough, i.e., the gambling equilibrium exists over a higher range of the values of market power compared with the case of no insurance. In other words, under a regime of deposit insurance banks are more likely to gamble.

Proposition 4 *There exists $\hat{\beta} > 0$ such that whenever $\beta < \hat{\beta}$, the likelihood of gambling by all banks is higher than that under the no-insurance scheme.*

The fact that a high deposit insurance exacerbates banks' moral hazard problem is fairly intuitive. In general, since the banks are protected by limited liability in case the gamble fails, an insurance induces them to gamble. In this case, as the banks do not have to pay back their depositors, the underlying moral hazard has more bite on the risk taking behavior of the banks. Notice that, under a deposit insurance scheme, a bank's objective function under gambling changes (since it shifts out the total volume of deposits); whereas that under prudent behavior remains unchanged. This makes the gambling asset more attractive for the banks. Consequently, deposit insurance induces fiercer competition and leads to a situation where a gambling equilibrium is more likely to occur. In this context, the insurance authority behaves as a "lender of last resort" by partially guaranteeing the depositors the rate they have been promised by the banks.

We may also consider a partial deposit insurance scheme δ where the depositors of bank i are paid back only a fraction $\delta < 1$ of the promised deposit rate r_i, and $\delta = \theta$ corresponds to the case of no insurance. By the standard continuity argument, one can conclude that if δ is high enough the above proposition continues to hold. One implication of the Proposition 4 is that a high β is able to reduce the banks' incentive problem under the deposit insurance scheme, nevertheless it is not able to eliminate gambling completely.

What is then the effect of deposit insurance on welfare? Note that welfare does not change directly because of the introduction of deposit insurance. This is because, although the equilibrium deposit rates change, they are just transfers from the banks to the depositors. Hence following Proposition 4, the threshold value of market power ϕ^G (the upper limit of a gambling equilibrium) may shift to the right due to insured deposits. In other words, the range of the values of market power that supports both equilibria now may expand. Consequently, this measure may reduce welfare since there is a range for which only a prudent equilibrium emerged, but its introduction would now create the possibility of a gambling one.

5 Loan contracts and risk taking

In a seminal paper Boyd and De Nicolo (2005) show that if the banks are allowed to compete both in the deposit and credit markets, and if the banks do not have any control over the riskiness of the assets they invest in (which is decided by the banks' borrowers), then the established negative association between market power and risk taking can be reversed. In the current framework we can ask similar question by introducing a loan market.[13]

Let there be a continuum of identical risk neutral entrepreneurs or borrowers with a total measure 1, uniformly distributed on the unit circle, who own two projects risky and safe, apiece whose returns are as described in Sect. 2. For simplicity, we assume that the depositors and the borrowers are different individuals. To some extent this assumption is natural since the depositors cannot invest directly, and hence requires the banks or the financial intermediaries. Each project, prudent or gambling, requires an initial outlay of 1. The lending rate charged by bank i is $\rho_i > r_f$, where $r_f > 1$ is the opportunity cost of fund, which is the interest rate that prevails in the money market. As in Boyd and De Nicolo (2005) we assume that the banks do not have direct control over the nature of investment. For simplicity, we assume that the minimum capital requirement is set to $k = 0$. The timing of events is as follows. First, the banks simultaneously announce the deposit and loan rates. Then the depositors decide in which bank to deposit their funds, and the entrepreneurs decide from which bank to take loans. Finally, the entrepreneur simultaneously decide whether to invest in the prudent or the gambling asset.

All borrowers are risk neutral and identical, and are uniformly distributed along the unit circle. The per unit transportation cost for the borrowers is τ, which is in general different from t, the per unit transportation cost for the depositors. Thus, τ/n represents

[13] We thank an anonymous referee for encouraging us to analyze the effects of loan contracts on risk taking.

the market power of the banks in the loan market or the degree of differentiation of loan services. Since all the entrepreneur are risk neutral, they will either invest in the prudent asset or in the gambling asset. Therefore, we analyze two types of symmetric equilibria (in deposit and loan rates): the prudent equilibrium where all entrepreneurs invest in the prudent asset, and the gambling equilibrium where every borrower gambles. Now, consider a borrower who gets loan from bank i at an interest rate ρ_i. In the last stage of the game, this borrower invests in the prudent asset if and only if the following no *gambling condition* condition is satisfied:

$$\alpha - \rho_i \geq \theta(\gamma - \rho_i) \Longleftrightarrow \rho_i \leq \frac{\alpha - \theta\gamma}{1-\theta} \equiv \bar{\rho}. \tag{11}$$

We also assume that the sets of the depositors and the borrowers are mutually exclusive, and hence the deposit and loan contracts offered by the banks are independent. Such assumption may seem to be restrictive, but is quite natural. In general the depositors, who are endowed with funds to invest, do not have direct access to investment opportunities available in the economy, and hence the financial intermediaries exist.[14] For simplicity, we further assume that the deposit and loan rates are such that both the deposit and loan markets are covered, and hence we concentrate only on the interior equilibria.

In the prudent equilibrium, each bank i solves

$$\max_{\rho_i, r_i} (\rho_i - r_f)\left[\frac{1}{n} - \frac{\rho_i - \rho}{\tau}\right] - (r_i - r_f)\left[\frac{1}{n} + \frac{r_i - r}{t}\right]$$
$$\text{subject to } \rho_i \leq \bar{\rho}.$$

We assume that each bank finances its loans out of its deposits. If there is an excess demand for loans relative to the supply of deposits, then it borrows the additional amount from the money market at r_f. On the other hand, if the supply of deposits exceeds the demand for loans, then a bank can invest the extra fund in the money market at the same risk-free rate of return. Let ρ^P and r^P respectively denote the symmetric loan and deposit rates in the prudent equilibrium, which are given by:

$$\rho^P = r_f + \frac{\tau}{n},$$
$$r^P = r_f - \frac{t}{n}.$$

The above loan rate must adhere to the NGC, i.e.,

$$\frac{\tau}{n} \leq \bar{\rho} - r_f \equiv \psi^P.$$

In the gambling equilibrium, on the other hand, each bank i solves

$$\max_{\rho_i, r_i} (\theta\rho_i - r_f)\left[\frac{1}{n} - \frac{\theta(\rho_i - \rho)}{\tau}\right] - (\theta r_i - r_f)\left[\frac{1}{n} + \frac{\theta(r_i - r)}{t}\right]$$
$$\text{subject to } \rho_i \geq \bar{\rho}.$$

[14] See Chiappori et al. (1995) for interdependent deposit and loan contracts.

The above maximization problem yields the symmetric loan and deposit rates which are given by:

$$\theta\rho^G = r_f + \frac{\tau}{n},$$
$$\theta r^G = r_f - \frac{t}{n}.$$

Since at the above equilibrium loan rate, all entrepreneurs must choose the gambling asset to invest in, we require that

$$\frac{\tau}{n} \geq \theta\bar{\rho} - r_f \equiv \psi^G.$$

Clearly, $\psi^G < \psi^P$. The above findings are summarized in the following proposition.

Proposition 5 *There exist threshold values ψ^G and ψ^P of banks' market power τ/n in the loan market with $\psi^G < \psi^P$ such that*

(a) *if $\frac{\tau}{n} \in [0, \psi^G]$ (low market power), then only a prudent equilibrium exists with the banks offering loan rate $\rho^P = r_f + \frac{\tau}{n}$ and deposit rate $r^P = r_f - \frac{t}{n}$;*
(b) *if $\frac{\tau}{n} \in [\psi^G, \psi^P]$ (intermediate market power), then both prudent and gambling equilibria exist with the banks offering loan rates $\rho^P = r_f + \frac{\tau}{n}$ and $\rho^G = \frac{1}{\theta}(r_f + \frac{\tau}{n})$, and deposit rates $r^P = r_f - \frac{t}{n}$ and $r^G = \frac{1}{\theta}(r_f - \frac{t}{n})$;*
(c) *if $\frac{\tau}{n} \geq \psi^P$ (high market power), then only a gambling equilibrium exists with the banks offering loan rate $\rho^G = \frac{1}{\theta}(r_f + \frac{\tau}{n})$, and deposit rates $r^G = \frac{1}{\theta}(r_f - \frac{t}{n})$.*

We omit the proof of the above proposition which is similar to that of Proposition 1. Since the investment strategies are determined by the entrepreneurs neither the banks nor the depositors have any control over them. The banks are risk neutral, and hence they must be indifferent between the prudent and the gambling strategies chosen by the borrowers. As a consequence, expected loan rate in a gambling equilibrium must equal the loan rate in a prudent equilibrium, i.e., $\theta\rho^G = \rho^P = r_f + \tau/n$. On the other hand, since the depositors are also risk neutral, they are also indifferent between the prudent and the gambling assets, and hence $\theta r^G = r^P = r_f - t/n$. Note that the depositors receive a rate below the money market rate since we implicitly assume that only the banks can invest in the money market.

If the per unit transportation cost for the borrowers is high, then the banks set a high loan rate due to their increased market power. Then the best response of the borrowers is to choose a gambling strategy since if successful the gambling asset yields higher returns. This is due to the moral hazard problem of the entrepreneurs induced by limited liability. Although the banks and the borrowers are risk neutral, it is well known that limited liability induces the borrowers behave more like risk loving individuals, whereas the banks become more risk averse. Thus, the borrowers tend to take more risk as a response to a higher loan rate set by their lenders.

The equilibrium intermediation margin of each bank is given by:

$$\rho^P - r^P = \theta(\rho^G - r^G) = \frac{\tau + t}{n},$$

which now depends on the degrees of differentiation in both the deposit and the loan markets. If both the deposit and the loan services become homogeneous, i.e., $t/n \rightarrow 0$ and $\tau/n \rightarrow 0$, then one obtains the competitive outcomes with the equilibrium intermediation margin approaching zero. If the market power of the banks in one of the two markets increases, the equilibrium intermediation margin of the banks increases too. This implies that the may banks may increase both the loan and the deposit rates, and may still maintain a higher margin. In other words, the borrowers may cross subsidize the depositors even if the banks now enjoy higher market power in the deposit market. Alternatively, the banks may increase the intermediation margin by lowering both the rates in which case the depositors cross subsidize the borrowers. Such cross subsidization may occur because an increased market power of the banks allows them to compete in better terms in the other market.

Notice first that the equilibrium deposit rates now do not depend on the asset returns α and γ since the banks do not have control over the investment strategies of the entrepreneurs. Next, the symmetric loan rate in a gambling or a prudent equilibrium does not depend on the level of competition in the deposit market. This is because the depositors and the borrowers are treated as separate entities, and hence, the loan contracts are offered independently of the deposit contracts. Had the contracts been interdependent, the market power of the banks in the deposit market would have affected the equilibrium loan rates ρ^P and ρ^G. The equilibrium loan rates depend positively on the degree of product differentiation τ/n in the loan market, which implies that gambling increases with the degree of market concentration. Thus, the relationship between market power and risk taking, which has been established in Proposition 1, is reversed. At this juncture it is worth noting the main differences between the present model and that of Boyd and De Nicolo (2005). These authors consider homogeneous competition among banks in both the deposit and loan markets, and hence measure the intensity of competition of the banking sector by the total number of banks in the economy. Therefore, a change in the number of banks affect the level of competition both in the deposit and the loan markets. In our case, banks compete in differentiated deposit and loan services, and hence the intensity of competition is measured by the respective degrees of differentiation in the deposit and loan markets. Since the behavior of the entrepreneurs determines the nature of equilibrium (prudent or gambling), the risk taking behavior of the financial sector depends only on the characteristics of the loan market.

6 Conclusions

This paper uses a model of a banking sector based on spatial competition, and establishes a negative association between market power and risk taking by the banks. When the banks compete only in the deposit market, the reason that induces a negative association between market power and risk taking is fairly intuitive. A highly competitive banking sector leads to the erosion of the expected profits of the banks, and consequently diminishes a bank's incentives for prudent behavior as a successful gambling yields high return. Such logic has been established in the literature (as in our case) under the crucial assumption that banks can independently choose the level of asset risk. Boyd and De Nicolo (2005) show that if the banks are allowed to compete both in the deposit and credit markets, and if the banks do not have any control over the riskiness of the assets they invest in (which is decided by the banks' borrowers), then the established negative association between market power and risk taking can be reversed. We also draw a similar conclusion establishing a positive relationship between risk taking and the degree of differentiation of the loan services.

The results obtained in the previous sections must be carefully interpreted. With this paper we do not suggest any policy prescriptions as regard to optimal prudential regulation. We have made a very simplifying assumption that the realizations of the gambling asset are independent across banks. This simplification serves the purpose of the present paper. In general, banks are subject to aggregate as well as idiosyncratic shocks, and the design of optimal regulatory instruments heavily relies on the nature of aggregate macroeconomic shocks. Also, it is worth noting that aggregate shock would have generated some strategic interaction among the banks in the asset choice stage. We have also ignored the possibility that the depositors and the central banking authority may monitor the banks in order to mitigate the moral hazard problems in asset choice. Certainly, it might be prohibitively costly for the individual depositors to monitor the intermediaries which may not be the case for the prudential regulatory authority. Incorporation of monitoring would be an interesting extension of the present model, and is a part of a future research agenda. On the other hand, regulatory instruments such as minimum capital requirement and deposit insurance premium to some extent work as a substitute for such monitoring activities. Therefore, this aspect of prudential regulation has not completely been ignored in the current paper.

Unlike Hellmann et al. (2000) and Repullo (2004), our goal in this paper is also not to check the robustness of capital requirements and deposit rate ceiling as efficient policy instruments. Analyzing a simple model of monopolistic competition, we establish a negative association between market power and risk taking to show that bank mergers can induce prudent behavior. The reason is that a merger leads to increase in market power via increased intermediation margin. Mergers are often viewed as welfare-reducing because of their adverse anti-competitive effects on consumer surplus. But in the presence of systemic risk and uncertainty the welfare implications of merger may go in the other direction. Banal-Estañol and Ottaviani (2006) show that, when risk aversion is strong enough, mergers between Cournot firms reduce prices and improve social welfare. In the current context, a merger between two banks reduces the likelihood of gambling as it generates higher intermediation margin for each bank, although higher margins in both gambling and prudent equilibria imply lower consumer surplus. In a similar context as ours, Perotti and Suárez (2002) suggest that allowing solvent banks to acquire the failed ones is an effective regulatory instrument in promoting financial stability in the short run.

As opposed to the positive effect of bank mergers on risk taking, a deposit insurance scheme may increases the likelihood of gambling. Deposit insurance is a popular regulatory measure that is sought to protect depositors from the expected loss due to excessive speculation by banks. Such measure is adopted in almost all the countries with a few exceptions. We have argued that small amount of deposit insurance has ambiguous effect on risk taking, whereas high insurance is conducive to more gambling by exacerbating banks' moral hazard problem, and it may even reduce social welfare by making gambling more likely. At this juncture it is worth noting that a removal of deposit insurance is not able to completely eliminate gambling since a gambling equilibrium exists even with uninsured deposits. This is because the bank moral hazard problem emerges from the high return of a successful gamble and limited liability, which is shown to be aggravated by high deposit insurance. Our result is in conformity with the empirical findings of Baer and Brewer (1986), Demirgüç-Kunt and Detragiache (1998), and Demirguc-Kunt and Huizinga (1998), among many others, who assert that explicit deposit insurance may provoke financial instability by exacerbating bank's risk-enhancing moral hazard problem. In other words, high deposit insurance causes a significant reduction in market discipline on bank risk taking, thereby increasing the banks' incentives to gamble.

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Appendix

Appendix A: Proof of Proposition 1

In order to characterize the equilibrium deposit we first have to describe the candidates for subgame perfect equilibria, and then check if there exist any profitable unilateral deviations on behalf of a given bank i. Notice that each bank i takes decision in the first stage of the game (by announcing the deposit rate) as well as in the final stage where it chooses its investment strategy. Therefore, a deviation in which a bank changes its deposit rate subsequently alters the supply function of deposit with the bank. For example, suppose we want to check whether all banks posting r and choosing the gambling asset constitute a subgame perfect equilibrium. There are potentially many possible unilateral deviations. Suppose that bank i deviates to a deposit rate r_i and chooses the prudent asset. Then the supply function of deposits with this bank becomes

$$\frac{1}{n} + \frac{r_i - \theta r}{t}.$$

Notice that we are assuming that the rest of banks maintain their portfolio choice after the deviation. This is the case because if a bank deviates it must be in order to behave prudently (it is already best responding under gambling). That implies a lower interest rate, which in turn increases the deposit of the other banks, so the GC still holds for them.[15] We will denote by $\pi_i^{G\to P}(r_i, r)$ the expected profits of bank i generated by this deviation. Similarly, $\pi_i^{P\to G}(r_i, r)$ will denote the expected profits of bank i generated by a deviation in which bank i switches to a deposit rate r_i and chooses the gambling asset while the rival banks maintain the symmetric deposit rate r and continue choosing the gambling asset.

15 We thank an anonymous referee for pointing this out.

The gambling equilibrium

In a symmetric gambling equilibrium, each bank i solves the following maximization problem:

$$\max_{r_i} \theta[\gamma(1+k)-r_i]\left[\frac{1}{n}+\frac{\theta(r_i-r)}{t}\right]$$
$$\text{subject to } \ r_i \geq \bar{r},$$
$$\theta r_i \geq 1+\frac{t}{2n},$$

which yields the candidates for gambling equilibria deposit rates. Let $r_i = r = r^G$ be the candidates which are given by:

$$r^G = \begin{cases} \gamma(1+k)-\frac{t}{\theta n} & \text{if } \ \frac{t}{n} \leq \phi, \\ \bar{r} & \text{if } \ \phi \leq \frac{t}{n} \leq \phi^{\gamma}, \\ \frac{1}{\theta}\left(1+\frac{t}{2n}\right) & \text{if } \ \frac{t}{n} \geq \phi^{\gamma}. \end{cases}$$

where

$$\phi \equiv \theta[\gamma(1+k)-\bar{r}] = \alpha(1+k)-\bar{r}$$
$$\phi^{\gamma} \equiv \frac{2}{3}[\theta\gamma(1+k)-1].$$

For simplicity we assume that $\theta\gamma(1+k)+2 < 3\theta\bar{r}$ which implies that $\phi < \phi^{\gamma}$. Now we check under what conditions the above candidate deposit rates survive as equilibrium rates. Let bank i deviates to the prudent asset by posting a deposit rate r_i while the rival banks continue to gamble with deposit rate r. The expected profits of bank i from a deviation is given by:

$$\pi_i^{G\to P}(r_i, r) = [\alpha(1+k)-r_i]\left[\frac{1}{n}+\frac{r_i-\theta r}{t}\right].$$

The deposit rate that maximizes the above expression, and the maximum expected profit from deviation are respectively given by:

$$r_i(r) = \frac{1}{2}\left[\alpha(1+k)+\theta r-\frac{t}{n}\right] = \frac{1}{2}\left[\bar{r}+\phi-\frac{t}{n}+\theta r\right], \tag{12}$$

$$\pi_i^{G\to P}(r_i(r), r) = \frac{1}{4t}\left[\frac{t}{n}+\bar{r}+\phi-\theta r\right]^2. \tag{13}$$

First consider the candidate $r = r^G = \gamma(1+k)-\frac{t}{\theta n} = (1/\theta)[\theta\bar{r}+\phi-t/n]$ for the gambling equilibrium which generates the equilibrium expected profits $\pi^G(r^G, r^G) =$

$\frac{t}{n^2}$ for each bank. Now the best deviation and the corresponding maximized expected profits are respectively given by:

$$r_i^{'} := r_i(r^G) = \frac{1}{2}(1+\theta)\bar{r} + \phi - \frac{t}{n},$$
$$\pi_i^{G\to P}(r_i^{'}, r^G) = \frac{1}{t}\left[\frac{t}{n} + \frac{1}{2}(1-\theta)\bar{r}\right]^2.$$

The above deviation is clearly profitable since the last expression in always greater than t/n^2. However, such deviation must also be credible, i.e., we must have $r_i^{'} \leq \bar{r}$, otherwise the NGC would be not satisfied and bank i would choose the gambling asset instead. This imposes the restriction that

$$\frac{t}{n} \geq \phi - \frac{1}{2}(1-\theta)\bar{r}.$$

If t/n is below the above threshold, then $r_i^{'}$ is not a credible deviation, and the only possible deviation is to switch to the prudent asset with a the deposit rate $\bar{r}$ under which we have

$$\pi_i^{G\to P}(\bar{r}, r^G) = \frac{\phi}{t}\left[\frac{2t}{n} - (\phi - (1-\theta)\bar{r})\right].$$

Thus, the above deviation is profitable for bank i if and only if

$$\frac{\phi}{t}\left[\frac{2t}{n} - (\phi - (1-\theta)\bar{r})\right] \geq \frac{t}{n^2}$$
$$\iff \left(\frac{t}{n}\right)^2 - 2\phi\left(\frac{t}{n}\right) + \phi[\phi - (1-\theta)\bar{r}] \leq 0$$
$$\iff \left(\frac{t}{n} - [\phi + \sqrt{\phi(1-\theta)\bar{r}}]\right)\left(\frac{t}{n} - [\phi - \sqrt{\phi(1-\theta)\bar{r}}]\right) \leq 0. \quad (14)$$

Notice that

$$\phi - \sqrt{\phi(1-\theta)\bar{r}} < \phi - \frac{1}{2}(1-\theta)\bar{r} < \phi + \sqrt{\phi(1-\theta)\bar{r}}.$$

Therefore, the above deviation is profitable for bank i only if

$$\phi - \sqrt{\phi(1-\theta)\bar{r}} \leq \frac{t}{n} \leq \phi - \frac{1}{2}(1-\theta)\bar{r}.$$

Thus, from the above we can conclude that the candidate deposit rate $r^G = \gamma(1+k) - t/\theta n$ is indeed a gambling equilibrium if and only if

$$0 \leq \frac{t}{n} \leq \phi - \sqrt{\phi(1-\theta)\bar{r}} \equiv \phi^G.$$

Next, consider the candidate solution $r^G = \bar{r}$. In that case the best possible deviation of bank i, and maximum expected profit from the deviation are given by:

$$r_i(\bar{r}) = \frac{1}{2}\left[\phi + \frac{1}{2}(1-\theta)\bar{r} - \frac{t}{n}\right],$$
$$\pi_i^{G\to P}(r_i(\bar{r}), \bar{r}) = \frac{1}{4t}\left[\frac{t}{n} + \phi + (1-\theta)\bar{r}\right]^2.$$

The above deviation is credible, i.e., $r_i(\bar{r}) \le \bar{r}$ only if

$$\frac{t}{n} \ge \phi - (1+\theta)\bar{r}.$$

On the other hand, the above deviation is always profitable since

$$\frac{1}{4t}\left[\frac{t}{n} + \phi + (1-\theta)\bar{r}\right]^2 \ge \frac{\phi}{n} = \pi^G(\bar{r}, \bar{r}).$$

Since $r^G = \bar{r}$ is a candidate solution for $t/n \ge \phi \ge \phi - (1+\theta)\bar{r}$, it never survives as gambling equilibrium rate. Finally, consider the candidate $r^G = (1/\theta)(1 + \frac{t}{2n})$. It is easy to see that a bank i can profitably deviate by posting a deposit rate $1 + (t/2n)$ and choosing the prudent asset to invest in. Therefore, this candidate does not survive as an equilibrium either. Therefore, to summarize, a symmetric gambling equilibrium exists if and only if $t/n \le \phi^G$ with each bank setting the deposit rate $r^G = \gamma(1+k) - t/(\theta n)$.

The prudent equilibrium

Next, we analyze the symmetric prudent equilibrium in which all banks invest in the prudent asset by setting the same deposit rate. In the symmetric prudent equilibrium, each bank i solves the following maximization problem:

$$\max_{r_i} [\alpha(1+k) - r_i]\left[\frac{1}{n} + \frac{r_i - r}{t}\right]$$
$$\text{subject to } \; r_i \le \bar{r},$$
$$r_i \ge 1 + \frac{t}{2n},$$

which yields the candidates for gambling equilibria deposit rates. Let $r_i = r = r^P$ be the candidates which are given by:

$$r^P = \begin{cases} \bar{r} & \text{if } \; \frac{t}{n} \le \phi, \\ \alpha(1+k) - \frac{t}{n} & \text{if } \; \phi \le \frac{t}{n} \le \phi^\alpha, \\ 1 + \frac{t}{2n} & \text{if } \; \frac{t}{n} \ge \phi^\alpha. \end{cases}$$

where

$$\phi^\alpha \equiv \frac{2}{3}[\alpha(1+k) - 1].$$

Consider any candidate r for the symmetric prudent equilibrium, and consider a deviation r_i which induces bank i to gamble. This deviation generates expected profits for bank i which is given by:

$$\pi_i^{P\to G}(r_i, r) = \theta[\gamma(1+k) - r_i] = \left[\frac{1}{n} + \frac{\theta r_i - r}{t}\right].$$

Note that we are again assuming that the rival banks maintain their asset choice after the deviation. Now if bank i deviates to the gambling asset, its deposit rate must raise, thus decreasing the deposit of the other banks, and hence they still satisfy the NGC. Maximization of the above expression yields:

$$r_i^{'} := r_i(r) = \frac{1}{2\theta}\left[\theta\bar{r} + \phi - \frac{t}{n} + r\right],$$
$$\pi_i^{P\to G}(r_i^{'}, r) = \frac{1}{4t}\left[\frac{t}{n} + \theta\bar{r} + \phi - r\right]^2.$$

First, consider the candidate $r^P = \bar{r}$. Then

$$r_i(\bar{r}) = \frac{1}{2\theta}\left[(1+\theta)\bar{r} + \phi - \frac{t}{n}\right],$$
$$\pi_i^{P\to G}(r_i(\bar{r}), \bar{r}) = \frac{1}{4t}\left[\frac{t}{n} + \phi - (1-\theta)\bar{r}\right]^2.$$

Straightforward calculations show that the above deviation is credible but not profitable if and only if

$$\frac{t}{n} \geq \phi^G + (1-\theta)\bar{r} - \sqrt{\phi(1-\theta)\bar{r}} \equiv \phi^P.$$

Therefore, this candidate is indeed an equilibrium if

$$\phi^P \leq \frac{t}{n} \leq \phi. \tag{15}$$

The assumption $2(1-\theta)\theta\gamma > \alpha$ implies that $\theta\gamma(1+k) > \bar{r}$, which in turn implies $\phi^P < \phi^G$.

Next, consider the interior solution $r^P = \alpha(1+k) - \frac{t}{n} = \bar{r} + \phi - \frac{t}{n}$. In this case the best deviation of bank i and the maximized profit from the deviation are respectively given by:

$$r_i^{'} := r_i\left(\alpha(1+k) - \frac{t}{n}\right) = \frac{1}{2\theta}\left[2\phi + (1+\theta)\bar{r} - \frac{2t}{n}\right],$$
$$pi_i^{P\to G}(r_i^{'}, r^P) = \frac{1}{t}\left[\frac{t}{n} - \frac{1}{2}(1-\theta)\bar{r}\right]^2.$$

The above expected profit is clearly lower than the profits of bank i under the equilibrium candidate, i.e., t/n^2. Hence, the interior solution is indeed an equilibrium whenever

$$\phi \leq \frac{t}{n} \leq \phi^{\alpha}. \tag{16}$$

Finally, consider the candidate solution $r^P = 1 + (t/2n)$. It is clear that a bank will not deviate to a prudent deposit rate under an uncovered market. It will not get a deposit greater than $1/n$, and will have to pay a higher deposit rate. Then, the only alternative is to deviate to a gambling deposit rate in which case the best possible deviation of bank i is given by:

$$r_i^{'} = \frac{\theta\gamma(1+k)+1}{2\theta} - \frac{t}{4\theta n}.$$

But it is easy to check that with this deposit rate the market is still uncovered. For a depositor at a distance $\frac{1}{2n}$, her payoff from depositing her fund in bank i is

$$\theta r_i^{'} - \frac{t}{2n} = \frac{\theta\gamma(1+k)+1}{2} - \frac{3t}{4n} < 1.$$

The last inequality holds because in this case we have $\frac{t}{n} \geq \phi^{\alpha}$. Therefore, from the inequalities in (15) and (16) it follows that the symmetric prudent equilibrium exists if and only if

$$\phi^P \leq \frac{t}{n} \leq \phi^{\alpha}$$

with the equilibrium deposit rates $r^P = \min\{\bar{r}, \alpha(1+k) - \frac{t}{n}\}$. This completes the proof of the proposition. □

Appendix B: Proof of Proposition 3

The proof of this proposition is very similar to that of Proposition 1. Therefore, we omit several details.

The gambling equilibrium

The candidate deposit rates for the gambling equilibrium is given by:

$$\hat{r}^G = \begin{cases} \gamma(1+k) - \frac{t}{n} - \frac{\beta}{\theta} & \text{if } \frac{t}{n} \leq \hat{\phi}, \\ \bar{r} & \text{if } \hat{\phi} \leq \frac{t}{n} \leq \hat{\phi}^{\gamma}, \\ 1 + \frac{t}{2n} & \text{if } \frac{t}{n} \geq \hat{\phi}^{\gamma}. \end{cases}$$

where

$$\hat{\phi} \equiv \frac{1}{\theta}[\phi - \beta],$$
$$\hat{\phi}^{\gamma} \equiv \frac{1}{\theta}\left[\phi^{\gamma} + \frac{2}{3}(1-\theta-\beta)\right].$$

The assumption that $\theta\gamma(1+k)+2 < 3\theta\bar{r}$ implies that $\hat{\phi} < \hat{\phi}^{\gamma}$.

Let bank i unilaterally deviate to the prudent asset by posting a deposit rate r_i, whereas the rival banks continue to choose the gambling asset with deposit rate r. This deviation generates an expected profit to bank i which is given by:

$$\pi_i^{G\to P}(r_i, r) = [\alpha(1+k) - r_i - \beta]\left[\frac{1}{n} + \frac{r_i - r}{t}\right].$$

Let $r_i(r)$ be the deposit rate that maximizes the above expected profit from deviation, which is given by:

$$r_i(r) = \frac{1}{2}\left[\alpha(1+k) - \frac{t}{n} - \beta\right] + \frac{1}{2}r = \frac{1}{2}\left[\bar{r} + \theta\hat{\phi} - \frac{t}{n}\right] + \frac{1}{2}r. \tag{17}$$

The above expression follows from the facts that $\phi \equiv \alpha(1+k) - \bar{r}$ and $\theta\hat{\phi} = \phi - \beta$. This deviation generates a maximum expected profit to bank i which is given by:

$$\pi_i^{G\to P}(r_i(r), r) = \frac{1}{4t}\left[\frac{t}{n} + \bar{r} + \theta\hat{\phi} - r\right]^2. \tag{18}$$

Now consider the candidate deposit rate $\hat{r}^G = \gamma(1+k) - \frac{\beta}{\theta} - \frac{t}{n} = \bar{r} + \hat{\phi} - \frac{t}{n}$. The last expression follows from the facts that $\phi \equiv \theta[\gamma(1+k) - \bar{r}] = \alpha(1+k) - \bar{r}$ and $\theta\hat{\phi} = \phi - \beta$. Then,

$$r_i^{'} := r_i(\hat{r}^G) = \bar{r} + \frac{\hat{\phi}}{2}(1+\theta) - \frac{t}{n},$$
$$\pi_i^{G\to P}(r_i^{'}, \hat{r}^G) = \frac{1}{t}\left[\frac{t}{n} - \frac{\hat{\phi}}{2}(1-\theta)\right]^2.$$

The above deviation $r_i^{'}$ must be credible, i.e.,

$$r_i^{'} \leq \bar{r} \iff \frac{t}{n} \geq \frac{\hat{\phi}}{2}(1+\theta). \tag{19}$$

On the other hand, the above deviation is profitable if and only if

$$\frac{1}{t}\left[\frac{t}{n}-\frac{\hat{\phi}}{2}(1-\theta)\right]^2 \geq \frac{\theta t}{n^2}=\pi^G(\hat{r}^G,\hat{r}^G) \tag{20}$$
$$\Longleftrightarrow \left[\frac{t}{n}-\frac{\hat{\phi}}{2}(1+\sqrt{\theta})\right]\left[\frac{t}{n}-\frac{\hat{\phi}}{2}(1-\sqrt{\theta})\right] \geq 0.$$

Notice that

$$\frac{\hat{\phi}}{2}(1-\sqrt{\theta}) < \frac{\hat{\phi}}{2}(1+\theta) < \frac{\hat{\phi}}{2}(1+\sqrt{\theta}) < \hat{\phi}.$$

Conditions (19) and (20) together imply that switching to the prudent asset with a deposit rate $r_i^{'}$ while the rival banks maintain $\hat{r}^G=\gamma(1+k)-\frac{\beta}{\theta}-\frac{t}{n}$ is a credible and profitable deviation for bank i if

$$\frac{t}{n} \geq \frac{\hat{\phi}}{2}(1+\sqrt{\theta}) \equiv \hat{\phi}^G. \tag{21}$$

If $t/n < (\hat{\phi}/2)(1+\theta)$, then the only credible deviation for bank i is $\bar{r}$ which yields an expected profit equal to

$$\pi_i^{G\rightarrow P}(\bar{r},\hat{r}^G)=\frac{\theta\hat{\phi}}{t}\left[\frac{2t}{n}-\hat{\phi}\right],$$

which is easily shown to be lower than $\theta t/n^2$, the gambling equilibrium expected profit for each bank at the interior deposit rate, and hence the deviation to the prudent asset with $\bar{r}$ is never profitable for bank i. Therefore, the deposit rate $\hat{r}^G=\gamma(1+k)-\frac{\beta}{\theta}-\frac{t}{n}$ is indeed a gambling equilibrium for $t/n \leq \hat{\phi}^G$.

Next, consider the candidate deposit rate $\hat{r}^G=\bar{r}$. Then, the best deviation and the corresponding maximum expected profit for bank i are respectively given by:

$$r_i^{'} := r_i(\bar{r})=\bar{r}+\frac{\theta\hat{\phi}}{2}-\frac{t}{2n},$$
$$\pi_i^{G\rightarrow P}(r_i^{'},\bar{r})=\frac{1}{4t}\left[\frac{t}{n}+\theta\hat{\phi}\right]^2.$$

The above deviation profit can easily shown to be higher than $\theta\hat{\phi}/n=\pi^G(\bar{r},\bar{r},)$, and hence $\hat{r}^G=\bar{r}$ is never a gambling equilibrium. Finally, consider the candidate solution $\hat{r}^G=1+t/2n$. A logic similar to the one in the proof of Proposition 1 shows that this candidate is neither a gambling equilibrium deposit rate.

The prudent equilibrium

The candidate deposit rates for the prudent equilibrium are given by:

$$\hat{r}^P = \begin{cases} \bar{r} & \text{if } \frac{t}{n} \leq \theta\hat{\phi}, \\ \alpha(1+k) - \frac{t}{n} - \beta & \text{if } \theta\hat{\phi} \leq \frac{t}{n} \leq \hat{\phi}^\alpha, \\ 1 + \frac{t}{2n} & \text{if } \frac{t}{n} \geq \hat{\phi}^\alpha. \end{cases}$$

where

$$\hat{\phi}^\alpha \equiv \phi^\alpha - \frac{2\beta}{3}.$$

Let bank i unilaterally deviates to the gambling asset by posting a deposit rate r_i, whereas the rival banks continue to choose the prudent asset with deposit rate r. This deviation generates an expected profit to bank i which is given by:

$$\pi_i^{P\to G}(r_i, r) = [\theta(\gamma(1+k) - r_i) - \beta]\left[\frac{1}{n} + \frac{r_i - r}{t}\right].$$

Let $r_i(r)$ be the deposit rate that maximizes the above expected profit from deviation, which is given by:

$$r_i(r) = \frac{1}{2}\left[\gamma(1+k) - \frac{t}{n} - \frac{\beta}{\theta}\right] + \frac{1}{2}r = \frac{1}{2}\left[\bar{r} + \hat{\phi} - \frac{t}{n}\right] + \frac{1}{2}r. \qquad (22)$$

This deviation generates a maximum expected profit to bank i which is given by:

$$\pi_i^{P\to G}(r_i(r), r) = \frac{\theta}{4t}\left[\frac{t}{n} + \bar{r} + \hat{\phi} - r\right]^2. \qquad (23)$$

First, consider the candidate deposit rate $\hat{r}^P = \bar{r}$. Then,

$$r_i(\bar{r}) = \bar{r} + \frac{\hat{\phi}}{2} - \frac{t}{2n},$$
$$\pi_i^{P\to G}(r_i(\bar{r}), \bar{r}) = \frac{\theta}{4t}\left[\frac{t}{n} + \hat{\phi}\right]^2.$$

The above expression is easily shown to be higher than $\theta\hat{\phi}/n = \pi^P(\bar{r}, \bar{r})$, and hence $\hat{r}^P = \bar{r}$ is never a prudent equilibrium.

Next, consider the candidate deposit rate $\hat{r}^P = \alpha(1+k) - \beta - \frac{t}{n} = \bar{r} + \theta\hat{\phi} - \frac{t}{n}$. Then,

$$r_i' := r_i(\hat{r}^P) = \bar{r} + \frac{\hat{\phi}}{2}(1+\theta) - \frac{t}{n},$$
$$\pi_i^{P\to G}(r_i', \hat{r}^P) = \frac{\theta}{4t}\left[\frac{2t}{n} + (1-\theta)\hat{\phi}\right]^2.$$

The above deviation $r_i^{'}$ must be credible, i.e.,

$$r_i^{'} \geq \bar{r} \Longleftrightarrow \frac{t}{n} \leq \frac{\hat{\phi}}{2}(1+\theta). \tag{24}$$

On the other hand, the above deviation is profitable if and only if

$$\begin{aligned} \frac{\theta}{4t}\left[\frac{2t}{n}+(1-\theta)\hat{\phi}\right]^2 \quad &\geq \quad \frac{t}{n^2}=\pi^P(\hat{r}^P,\hat{r}^P) \\ &\Longleftrightarrow \left[\frac{t}{n}-\frac{\hat{\phi}}{2}(\theta+\sqrt{\theta})\right]\left[\frac{t}{n}-\frac{\hat{\phi}}{2}(\theta-\sqrt{\theta})\right]\leq 0. \end{aligned} \tag{25}$$

Notice that

$$\frac{\hat{\phi}}{2}(\theta-\sqrt{\theta}) < 0,$$

given that $\theta < 1$, and

$$\frac{\hat{\phi}}{2}(\theta+\sqrt{\theta}) < \frac{\hat{\phi}}{2}(1+\theta).$$

Therefore, conditions (24) and (25) together imply that switching to the gambling asset with a deposit rate $r_i^{'}$ while the rival banks maintain $\hat{r}^P = \alpha(1+k)-\beta-\frac{t}{n}$ is a credible and profitable deviation for bank i if

$$\frac{t}{n} \leq \frac{\hat{\phi}}{2}(\theta+\sqrt{\theta}) \equiv \hat{\phi}^P. \tag{26}$$

If $t/n > (\hat{\phi}/2)(1+\theta)$, then the only credible deviation for bank i is $\bar{r}$ which yields an expected profit equal to

$$\pi_i^{P\to G}(\bar{r},\hat{r}^P) = \frac{\theta\hat{\phi}}{t}\left[\frac{2t}{n}-\theta\hat{\phi}\right],$$

which is easily shown to be lower than t/n^2, the prudent equilibrium expected profit for each bank at the interior deposit rate, and hence the deviation to the gambling asset with $\bar{r}$ is never profitable for bank i. Therefore, the deposit rate $\hat{r}^P = \alpha(1+k)-\beta-\frac{t}{n}$ is indeed a prudent equilibrium for $\hat{\phi}^P \leq t/n \leq \hat{\phi}^\alpha$. This completes the proof of the proposition. □

Appendix C: Proof of Proposition 4

Recall that $\phi^G = \phi - \sqrt{(1-\theta)\phi\bar{r}}$ which is the upper bound on gambling under no deposit insurance. On the other hand,

$$\hat{\phi}^G = \frac{\hat{\phi}}{2}(1+\theta) = \frac{(1+\theta)(\phi-\beta)}{2\theta}$$

which is the upper bound on gambling under full deposit insurance. Therefore, deposit insurance increases the likelihood of gambling relative to no insurance if and only if

$$\begin{aligned}\phi^G &\leq \hat{\phi}^G \\ &\Longleftrightarrow \phi - \sqrt{(1-\theta)\phi\bar{r}} \leq \frac{(1+\theta)(\phi-\beta)}{2\theta} \\ &\Longleftrightarrow \beta \leq \frac{(1-\theta)\phi + 2\theta\sqrt{(1-\theta)\phi\bar{r}}}{1+\theta} \equiv \bar{\beta} > 0.\end{aligned}$$

The above completes the proof of the proposition. □

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