

Banking deregulation: Allocational consequences of relaxing entry barriers*

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We present an equilibrium analysis to predict the long-run allocational consequences and risk implications of banking deregulation. Loan demand and deposit supply functions are derived from primitive assumptions about the preferences of individuals, and banks are viewed as (differentiated) competitors in a spatial context. We find that a relaxation of entry barriers into banking improves the welfare of borrowers and savers at the expense of bank stockholders. Equilibrium loan interest rates fall and equilibrium deposit interest rates rise as banking becomes more competitive. Despite this, the equilibrium debt–equity ratios of banks increase as entry barriers are relaxed. We also examine the implications of capital standards and find that an increase in the minimum capital requirement benefits borrowers but hurts depositors.

1. Introduction

This paper presents a theoretical model analyzing the allocation consequences of lowering entry barriers into banking.¹ With the recent wave of deregulation in banking has come a relaxation in bank charter granting policies. Prior to 1981, concern over the safety of existing banks made it difficult for a new bank to gain a charter to enter the US banking market. Since 1981, however, the focus has shifted to the virtue of increased

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Many papers have examined bank regulation issues [e.g. Benston (1983), Bhattacharya (1982), Chan and Mak (1985), Edwards and Scott (1979), Kahane (1977), Kareken and Wallace (1978)]. Williamson (1987) explores the allocational consequences of increased competition, but addresses issues different from those we focus on. Chan et al. (1992) explore the implications of increased competition (as represented by lowered bank charter values) for the implementability of incentive compatible risk-sensitive deposit insurance pricing

competition and has resulted in an encouragement of entry. We seek to assess how borrowers, savers and bank shareholders are affected by the increased competition in banking that has resulted from this regulatory regime shift in the US. Our analysis is also applicable to banking industries in various other countries such as Canada (65 banks), Japan (150 banks) and Great Britain (550 banks) which have industry structures that can be closely approximated by the oligopoly assumption.

To study this issue, we construct a spatial model in which the location and product attributes of a bank distinguish it from its competitors. This modeling approach is motivated by two considerations. First, banking regulation is driven in part the assessments of its impact on the convenience and needs of the community the bank operates in. For example, in light of the landmark Supreme Court decision in 1963 that rejected the proposed merger of Philadelphia National Bank and Girard Corn Exchange Bank and Trust Company, the Justice Department issued guidelines in 1968 to banking authorities to indicate which types of bank mergers would be challenged on anticompetitive grounds. The key element in this analysis is the effect on competition in the bank market area. The market area is that area where customers can conveniently bank. Among the factors to be considered are distances between merger partners, distances from the nearest competitors, and commuting and shopping patterns.² A second motivating consideration is the interesting recent evidence provided by Hannan (1989), Allen, et al. (1991) and others which suggests that the prices of bank products and services are significantly influenced by industry structure as measured by the concentration of banks in a given area. That is, spatial considerations seem to be important in determining bank pricing.

In our spatial model, banks are differentiated from each other on both the loan and deposit sides. This differentiation creates 'frictions' in the deposit and loan markets and makes the equilibria in these markets depend on the number of banks. We study the effects of **the** number of banks on the nature of these equilibria. Our main results are as follows. Loan interest rates decline with increasing competition, and deposit interest rates increase with increasing competition. Moreover, increased competition makes the bank's shareholders worse off but makes borrowers and depositors better off. This suggests that there are economic incentives for banks to wish to consolidate, implying that there will be fewer banks in the US in the future. Strikingly, the cost of reserve requirements is borne by the bank's depositors and **shareholders**, rather than the borrowers. Perhaps our most significant result is that an increase in the minimum capital requirement benefits borrowers and hurts depositors. We argue that, from a 'cause-and-effect' standpoint,

²See, for example, Lash (1987)

this implies that raising the capital standard is virtually isomorphic to reimposing Reg Q **ceilings** on deposit interest rates.

Our overall conclusion is that increased competition benefits savers and borrowers. A key assumption in our analysis is that banks' investment opportunity sets do not change with deregulation and increasing competition. If asset **proscriptions** are lifted at the same time that chartering policy is relaxed, then it is possible that banks may switch to riskier assets.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 analyzes the equilibrium and presents comparative **statics** results. Section 4 concludes. All proofs are in the appendix.

2. The **model**

La. General *formulation*

Consider an economy consisting of three classes of agents – entrepreneurs, households and bank shareholders. The economy lasts for a single period and all activity is concentrated at two dates – the beginning of the period (date zero) and the end of the period (date one).

At date zero an entrepreneur invests in a risky project. Entrepreneurs have limited initial endowments and must finance the risky project by borrowing. (Hereafter we refer to entrepreneurs as 'borrowers'.) For simplicity, suppose there are two types of borrowers – low quality and high quality – indexed by i , $i = 1, 2$. There are N_i borrowers of type i . For any investment $I \in [0, \infty)$, a borrower obtains a date-one return $R(I)$ with probability $\delta_i \in (0, 1)$ and a return of zero with probability $1 - \delta_i$, where $\delta_2 > \delta_1$. The production function $R(I)$ is assumed to be twice-differentiable, increasing, and strictly concave in I , with $R(0) = 0$. Each borrower's payoff attributes are common knowledge.

Banks are assumed to have access to a monitoring technology which makes the return on a borrower's project observable. This monitoring advantage makes banks 'special' relative to other sources of credit. Banks compete for borrowers by offering loan contracts specifying a repayment obligation a and a loan amount I .³ The interest factor (one plus the interest rate) on loans is thus $\beta_i \equiv \alpha_i / I_i$. We assume banks can distinguish among borrowers ex ante, so each type i borrower receives a distinct loan contract (α_i, I_i) . When a borrower's project is successful, the bank collects the borrower's repayment obligation a_i . When a borrower's project is unsuccessful, the bank collects nothing.⁴

³See Allen (1990), Boyd and Prescott (1985), Millon and Thakor (1985) and Ramakrishnan and Thakor (1984) for papers that rationalize financial intermediary existence based on *precontract* private information considerations.

⁴The analysis in this paper pertains to *unsecured lending*. The basic insights of the *lull-information* analysis would not change if borrowers could post collateral. However, the asymmetric-information equilibrium results are likely to be affected if collateral were available. [See, for example, Besanko and Thakor (1987)].

Unlike entrepreneurs households are assumed to be homogeneous. Deposit contracts specify an interest factor $r \geq 1$. (Hereafter deposit interest factors will be referred to as deposit rates.) Deposit insurance is assumed to be complete, so r is guaranteed to the depositor no matter what the performance of borrowers turns out to be. A depositor is assumed to prefer investing in bank deposits. everything else the same, because deposits provide a liquidity benefit originating from depositors' ability to make *interim* (between dates zero and one) withdrawals. To focus exclusively on *credit* risk. we assume that intraperiod withdrawals are very small and accompanied quickly by offsetting redeposits of funds.⁵ Banks are assumed to specialize in liquidity services and can thus provide them at a cost lower than their value to depositors.

The banking market consists of n differentiated banks, each of which must keep a fraction $\xi \in (0, 1)$ of its deposits as reserves in a non-interest bearing account and must pay the FDIC a premium y per dollar of its deposits. The assumption that banks are differentiated means that borrowers do not view banks as perfect substitutes, even when they announce identical lending terms, and depositors do not view banks as perfect substitutes even when they announce identical deposit rates. The specific manner in which differentiation is introduced in this model is described in subsections b and c below.

The banking market evolves over time as follows. At date zero, banks are chartered and announce loan and deposit terms. Deposits are then received and loans granted under these terms. At date one, returns on borrower projects are realized and successful borrowers repay their loans. In addition, depositors withdraw their deposits plus interest. If loan repayments plus reserves exceed deposit claims plus the insurance premium, the balance is paid out to bank shareholders as a dividend. If loan repayments plus reserves are *insufficient* to cover deposit claims plus the insurance premium, the FDIC provides the difference and bank shareholders receive no dividend. Throughout the analysis, bank shareholders are assumed to be risk neutral and discount expected cash flows at the *riskless* interest factor r_f .

2.b. Loan demand

To develop a basis of bank differentiation, we will utilize a spatial **model**.⁶ Specifically, we assume that the N_i borrowers (of each type) are arranged along a circle of unit circumference according to a uniform distribution. Banks are also arranged along this circle and are assumed to be

⁵In effect, deposits take the form of checking accounts. An alternative interpretation of this assumption is that we abstract from the potential *illiquidity* of the bank's loan portfolio, which is the underlying reason why deposit withdrawal shocks create liquidity risk for the bank.

⁶The seminal paper on the subject of spatial models is Hotelling (1929). Subsequent research includes Eaton and Lipsey (1975), Prescott and Visscher (1977), Salop (1979), and Novshek (19801).

equidistant. The distance between each of the n banks is thus $1/n$. In obtaining a loan contract from a particular bank, a borrower incurs a 'transportation cost' t per unit of distance between his location and the bank's. Thus, a borrower located l units from a bank will incur a total transportation cost tl . To simplify, we assume that borrowers *will* obtain credit **from some** bank.

We do not mean to suggest that geography is the sole factor differentiating banks. The spatial model is an 'allegory' where 'geographical' space represents 'characteristics space'. Banks are differentiated because they have different geographic locations and they offer different combinations of ancillary services (financial advice, cash management services, credit cards, etc.) which prospective customers value in different ways. The transactions cost tl is thus a customer's disutility from consuming a less than ideal package of these ancillary services (the package include the bank's location).

An increase in the number n of banks in this model reduces the extent of bank differentiation. This seems consistent with actual experience. As more 'non-bank' financial firms offer traditional banking services, the distinctions between financial intermediaries have become increasingly blurred. Our model captures this feature in a simple way.

Prospective borrowers choose the bank offering a loan contract yielding the highest net expected utility. This expected utility for type i is $EU_i(\alpha_i, I_i) - tl$, where $EU_i(\alpha_i, I_i) \equiv \delta_i [R(I_i) + \alpha_i] r_i^{-1}$. A prospective borrower located l units from a bank offering a loan contract (I_i, α_i) and $n^{-1} - l$ units from neighboring banks on either side offering a loan contract $(\bar{I}_i, \bar{\alpha}_i)$, will choose the **first** bank if and only if

$$EU_i(\alpha_i, I_i) - tl \geq EU_i(\bar{\alpha}_i, \bar{I}_i) - t[n^{-1} - l]$$

The number of type- i borrowers 'captured' by the first bank is

$$b_i(I_i, \alpha_i, \bar{I}_i, \bar{\alpha}_i, n) \equiv [N/t] \{EU_i(\alpha_i, I_i) - EU_i(\bar{\alpha}_i, \bar{I}_i) + tn^{-1}\}.$$

It is straightforward to verify $\partial b_i / \partial \alpha_i < 0$, $\partial b_i / \partial I_i > 0$, $\partial b_i / \partial \bar{\alpha}_i > 0$, and $\partial b_i / \partial \bar{I}_i < 0$. Thus, as a bank makes its loan contract more favorable (lower α_i , higher I_i) or as a neighboring bank makes its loan contract less favorable, the bank attracts more borrowers. If all banks offer the same loan contract, the market is split evenly; i.e.,

$$b_i(I_i, \alpha_i, I_i, \alpha_i, n) = N_i/n$$

2.c. Deposit supply

Banks are also spatially differentiated on the deposit side. Specifically,

Table I
Properties of a bank's deposit supply function.

$s(r, r, n) = Ds(r)n^{-1}$
$s_1(r, \bar{r}, n) = D\tau^{-1}\{s'(r)[v(r) - v(\bar{r}) + n^{-1}] + s(r)v'(r)\} > 0$
$s_2(r, \bar{r}, n) = D\tau^{-1}s(r)v'(\bar{r}) > 0$
$s_3(r, \bar{r}, n) = -Ds(r)n^{-2} > 0$
$s_{12}(r, \bar{r}, n) = -D\tau^{-1}s'(r)v'(r) > 0$
$s_{13}(r, \bar{r}, n) = -Ds'(r)n^{-2} > 0$
$s_1(r, r, n) = D\{s'(r)n^{-1} + \tau^{-1}s(r)v'(r)\} > 0$
$s_2(r, r, n) = -D\tau^{-1}s(r)v'(r) > 0$
$s_{11}(r, r, n) = D\{s''(r)n^{-1} + 2s'(r)v'(r)^{-1} + s(r)v''(r)\tau^{-1}\}$

there are D identical households distributed uniformly around the unit circle. Each depositor faces a two-step decision problem. First, he must choose which bank to use. Second, he must decide how much to deposit. Working backwards, if a depositor chooses a bank offering a deposit rate r , the depositor will choose the deposit amount $s(r)$ to maximize the sum of an increasing and concave liquidity benefit $U(s)$ and the net present value of deposits $(rr_f^{-1} - 1)s$, i.e.,

$$s(r) = \underset{s}{\operatorname{argmax}} \{U(s) + (rr_f^{-1} - 1)s\}.$$

Because $U' > 0$ and $U'' < 0$, it follows that $s'(r) > 0$.

Let $v(r) \equiv U(s(r)) + (rr_f^{-1} - 1)s(r)$ represent the maximal utility a household obtains when facing a deposit rate r . By the envelope theorem, $v'(r) = r_f^{-1}s(r) > 0$, and $v''(r) = r_f^{-1}s'(r) > 0$. A household selects the bank that makes $v(r) - \tau l$ as large as possible, where τ is the disutility of traveling a unit of distance to a bank. By the same logic as in the previous section, the deposit supply function $s(r, \bar{r}, n)$ for a bank offering deposit rate r when neighboring banks are offering deposit rate \bar{r} , is given by

$$s(r, \bar{r}, n) = Ds(r)\tau^{-1}\{v(r) - v(\bar{r}) + \tau n^{-1}\}$$

Table I summarizes the key properties of $s(r, \bar{r}, n)$. (In the table, $s_j(r, \bar{r}, n)$ is the partial derivative of s with respect to its j th argument.) As one would expect, a bank's deposit supply is increasing in its own rate r , decreasing in its neighbors' rates \bar{r} , and decreasing in the number n of banks.

2.d. *Ex post* and *ex ante* bank profit

Because banks have limited liability, a bank's *ex post* cash flow depends on all possible realizations of the 'success-fail' random variables of borrowers. To make the model more tractable, we assume that *within* each

borrower class, returns are perfectly correlated. but that across risk **classes**, returns are independent. Thus, for example, the probability that both types of borrowers succeed is $\delta_1\delta_2$.

In the analysis below, we assume that a bank defaults only if both borrower types fail. Thus, the expected net present value of a bank's cash **flows** can be expressed as

$$r_t^{-1} \left\{ \sum_{i=1}^2 \delta_i \alpha_i b_i - [\delta_1 + \delta_2 - \delta_1 \delta_2] (r - \xi) s \right\} - E, \quad (1)$$

where the **bank's** equity E is given by

$$\sum_{i=1}^2 b_i I_i - s[1 - \xi - y - c],$$

and c is a bank's transactions cost per dollar of deposits. We assume that $\xi + y + c < 1$.

3. Banking market equilibrium

3.a. Equilibrium in the loan market

To characterize the equilibrium in the loan market, we consider the profit-maximization problem of a bank which contemplates 'deviating' from a 'candidate' equilibrium $(I_1^*, \alpha_1^*, I_2^*, \alpha_2^*, r^*)$. After substituting (2) into (1), that bank's profit-maximization problem can be stated as

$$\text{maximize } \pi \equiv \sum_{i=1}^2 \{ \delta_i \alpha_i - r_t I_i \} b_i + (1 - y - \xi - c)(r_t - a(r))s, \quad (3)$$

subject to:

$$\sum_{i=1}^2 b_i I_i - [1 - \xi - y - c]s \geq 0, \quad (4)$$

where

$$a(r) \equiv \frac{(\delta_1 + \delta_2 - \delta_1 \delta_2)(r - \xi)}{1 - y - \xi - c}$$

Constraint (4) is the requirement that equity be non-negative.

The **term** $a(r)$ is the net average cost per dollar of deposits.' Note that

'Since banks act as price setters in the deposit market, $a(r)$ is not the *marginal* cost of deposits. We discuss the marginal cost of deposits below.

$\alpha(r)$ is strictly increasing in the deposit rate r . The net cost $\alpha(r)$ embodies the benefits of deposits due to **their** option effect (depositors are repaid by the bank with probability $\delta_1 + \delta_1 - \delta_1 \delta_2 < 1$) and the costs of deposits due to the deposit insurance premium, the reserve requirement, and the transaction cost.⁸ The term $r_f - \alpha(r)$ is the difference between the average (and marginal) cost of equity r , and the average cost of deposits.

Using the expression for b_i in (3), the first-order conditions for α_i and I_i imply that at a symmetric equilibrium

$$\alpha_i^* = (r_f - \lambda) \delta_i^{-1} I_i^* + t n^{-1} \delta_i^{-1}, \quad i = 1, 2, \quad (6)$$

$$\delta_i R'(I_i^*) = (r_f - \lambda), \quad i = 1, 2. \quad (7)$$

where λ is the **Lagrange** multiplier for (4). As we shall see below, $r_f - \lambda$ can be interpreted as the marginal cost of loanable funds to the bank. Depending on parameter values, in equilibrium each bank may have a positive **equity-debt** ratio (in this case, $\lambda = 0$) or each may finance entirely with deposits (in this case, $\lambda > 0$). The case of a positive equity-debt ratio will be discussed in this section and the next, with the case of full deposit financing being deferred to section 3.c below.

To interpret conditions (6) and (7), consider the equilibrium in a perfectly competitive market. The bank will be indifferent between deposits and equity in this case. The perfectly competitive equilibrium loan contract (I_i^c, α_i^c) maximizes a type- i borrower's expected utility $EU_i(\alpha_i, I_i)$, subject to $\delta_i \alpha_i - r_f I_i = 0$. Thus,

$$\alpha_i^c = r_f \delta^{-1} I_i^c, \quad i = 1, 2. \quad (8)$$

$$\delta_i R'(I_i^c) = r_f, \quad i = 1, 2. \quad (9)$$

It is easy to see that $I_2^c > I_1^c$, implying that high-quality borrowers **receive** larger loans than low-quality borrowers. A comparison of (6) and (7) with (8) and (9) yields the following.

Proposition I When the equilibrium equity-debt **ratio** is positive:

- (i) The equilibrium loan size I_i^* for a type- i borrower is equal to the perfectly competitive loan size I_i^c .

⁸Note that in the absence of a reserve requirement d , deposit insurance y , transaction cost c , and loan risk (i.e. $\delta_1 = \delta_2 = 1$), the average cost of deposits is simply equal to the deposit rate r . The reserve requirement, deposit insurance premium and transaction cost work to increase the average cost of deposits, while the option effect of deposit insurance, which makes deposits more valuable the riskier is the loan portfolio, works to reduce the average cost of deposits.

(ii) *The equilibrium repayment obligation α_i^* of a type-i borrower is greater than the perfectly competitive repayment obligation a ;*

When loans are **financed** with debt and equity, the marginal cost of a dollar loaned is the **riskless** rate r_f , so credit contracts (l_i^*, α_i^*) are independent of the deposit insurance premium ξ and the reserve requirement y . The deposit insurance premium and the reserve requirement have an impact on deposit rates but do not affect the terms of lending. The result that the borrower's **loan** interest rate is higher than the perfectly competitive rate is intuitive; with differentiated banks, each bank possesses a *degree* of monopoly power with respect to each borrower, and this is reflected in the loan interest rate.

3.b. Equilibrium in the deposit market

To characterize the equilibrium deposit rate, let $\tilde{r}(\bar{r})$ denote a bank's reaction function, *i.e.*, the profit-maximizing deposit rate for an arbitrary deposit rate \bar{r} offered by other banks. The reaction function satisfies first- and second-order conditions given by:

$$r_f - \lambda = a(\tilde{r}) + \frac{a'(\tilde{r})s(\tilde{r}, \bar{r}, n)}{s_1(\tilde{r}, \bar{r}, n)}, \quad (10)$$

$$\text{SOC} \equiv [r_f - \lambda - a(\tilde{r})]s_{11}(\tilde{r}, \bar{r}, n) + 2s_1(\tilde{r}, \bar{r}, n)a'(\tilde{r}) < 0. \quad (11)$$

The left-hand side of (10) is the marginal cost of a dollar of equity. The right-hand side of (10) is the marginal cost of a dollar of deposits. Because each bank faces an upward sloping supply curve for deposits, this marginal cost exceeds the average cost $a(r)$. Note that, absent the option effect of deposit insurance and the costs of liquidity production, reserve requirements and the deposit insurance premium, $a(r)$ would be equal to r , the interest rate paid on deposits. In an equilibrium with a positive equity–debt ratio, each bank sets a deposit rate such that the marginal cost of equity equals the marginal cost of deposits. Thus, the marginal dollar of deposits has a zero net present value, while inframarginal deposits have a positive net present value since, from (10), $r_f - \lambda > a(r^*)$.

A symmetric equilibrium deposit rate r^* satisfies

$$\tilde{r}(r^*) = r^*, \quad (12)$$

i.e., r^* is the profit-maximizing deposit rate for a bank given that all other banks are setting a deposit rate equal to r^* . Comparative statics results on the equilibrium deposit rate can be obtained by analyzing (12).

We can now describe the interaction of the deposit market and the loan

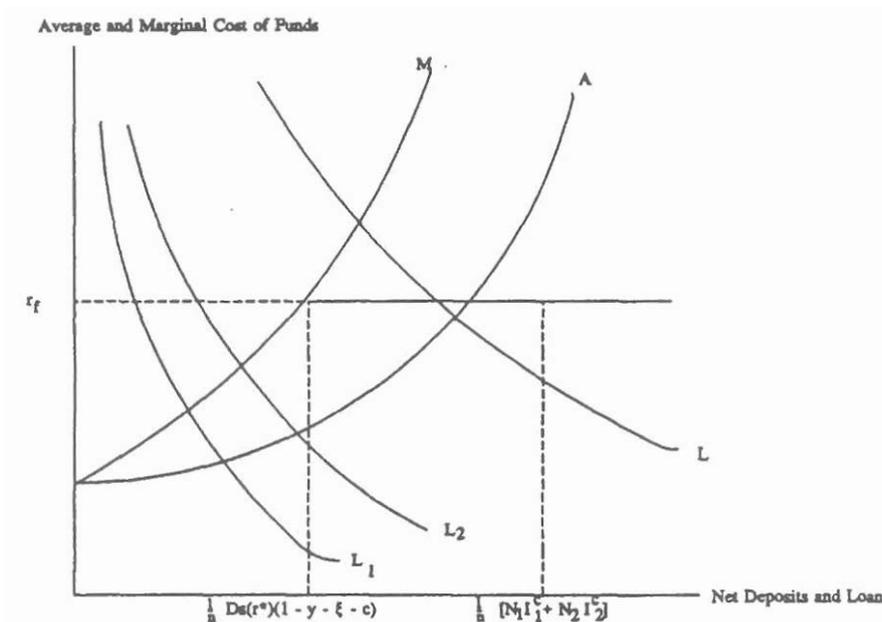


Fig. 1. Interaction of deposit and loan markets: Positive equity-debt ratio.

market. Fig. I displays a graph with *net* deposits, $s^{net} \equiv s(1 - y - \xi - c)$, on the horizontal axis and the bank's average and marginal costs of funds on the vertical axis. The curves *A* and *M* represent a bank's average and marginal costs of deposits, respectively, given that all other banks are offering the equilibrium deposit rate r^* . Note that the average cost schedule *A* is given by the graph of the function

$$a(r(1 - \xi - y - c)^{-1} s^{net}, r^*, n),$$

where (\bullet, r^*, n) is the inverse of the bank's deposit supply function $s(\bullet, r^*, n)$. The marginal cost schedule *M* is given by the graph of the function

$$d[a(r(1 - \xi - y - c)^{-1} s^{net}, r^*, n) s^{net}] / ds^{net},$$

which, for any $s^{net} > 0$, can be shown to exceed the average cost schedule. The bank's effective marginal cost of funds is the lower *envelope* of *M* and r_f . In an equilibrium with a positive **equity-debt** ratio, the level of the bank's equilibrium net deposits, $n^{-1} Ds(r^*)(1 - y - \xi - c)$, corresponds to the kink of the effective marginal cost schedule. At this point, the bank is indifferent between funding with a marginal dollar of equity and a marginal dollar of deposits, given that all other banks offer a deposit rate r^* .

Turning now to the loan side, the curve L represents the marginal profit of bank loans for a typical bank. This schedule is constructed as follows. From (7), the marginal profit of lending I dollars to a borrower of quality i is $\delta_i R'(I)$. The curves L , and L_2 show these marginal profit schedules. The curve L is the horizontal summation of $(1/n)N_1L_1$ and $(1/n)N_2L_2$, where $(1/n)N_i$ is the number of borrowers of type i that a typical bank attracts in equilibrium. The equilibrium in the deposit and loan markets is represented by the intersection of L and the marginal cost schedule. The case in which the equity–debt ratio is positive corresponds to the case in which L intersects the horizontal portion of the bank's marginal cost schedule, and the equilibrium amount of equity financing is the horizontal difference between this point of intersection and the kink in the effective marginal cost schedule. In this case, there is a 'separation' between the equilibrium terms of lending and the conditions in the deposit market. In particular, borrowers do not bear any portion of the costs of deposit insurance and the reserve requirements. Moreover, comparative statics changes that affect a bank's deposit supply function or the average cost of deposits $a(r)$ will not have an impact in the loan market, provided that the kink in the bank's marginal cost schedule (whose location would shift with parameter changes) remains to the left of the loan demand $(1/n)[N_1I_1^c + N_2I_2^c]$ that a bank would face in a perfectly competitive market.

It is important to emphasize that bank equity in our model is more than just a 'residual'. That is, a bank's equilibrium equity–debt ratio is the outcome of a profit-maximizing decision for the bank. Because deposits provide a liquidity service, deposit supply will generally be forthcoming at rates below the **riskless** rate r_f . Thus, starting from a situation in which a bank has zero deposits, the marginal cost of deposits will be less than the marginal cost of equity, and a bank will attempt to satisfy as much of its loan demand as possible from deposits. However, because the deposit market is imperfectly competitive, a bank must increase its deposit rate in order to attract more deposits. This is what leads to the rising average and marginal cost schedules, A and M . At some point, if equilibrium loan demand is **sufficiently** large, the bank will reach the point at which the marginal cost of deposits equals the marginal cost of equity, causing it to switch from deposit to equity financing. Therefore, in our model a bank **may** have an optimal interior capital structure. This is not due to tax consideration or agency problems, but rather to the imperfectly competitive conditions in the deposit market that lead each bank to perceive an upward sloping supply curve for deposits.

3.c. Comparative *statics*: Positive equity–debt ratio

We now investigate comparative statics in the loan and deposit markets,

maintaining the assumption of a positive **equity–debt** ratio throughout this subsection. We begin by investigating the effect of bank market structure on the equilibrium deposit and loan rates.

Proposition 2. *If the equilibrium equity–debt ratio is zero, an increase in the number of banks:*

(i) *has no effect on the equilibrium loan I_i^* for each class of borrower; i.e. $dI_i^*/dn=0$, $i=1,2$;*

(ii) *decreases the equilibrium interest rate on loans for each class of borrower: i.e., $d\beta_i/dn < 0$;*

(iii) *increase the equilibrium deposit rate r^* , given the regularity condition $s''(r)s(r) - [s'(r)]^2 \leq 0$ for all r : i.e., $dr^*/dn > 0$.*

Proposition 2 implies that, given a particular regularity condition, $s''(r)s(r) \leq [s'(r)]^2$, an increase in the number of banks increases the equilibrium deposit rate, when the equity–debt ratio is positive. A reduction in entry barriers is thus **beneficial** to depositors in this case. The regularity condition, $s''(r)s(r) \leq [s'(r)]^2$, is really quite weak: it is satisfied by a wide class of supply functions. We assume henceforth that this regularity condition holds.

Note that since the equilibrium involves a positive equity–debt ratio, the marginal cost of deposits to the bank is r_f , regardless of the number of banks in the economy. This is because the bank's equilibrium choice is to equate the marginal costs of deposits and equity. In view of this, it may seem surprising that the interest rate received by depositors goes up as the number of banks increases. The reason is that there is a **wedge between** the bank's marginal cost of deposits and the interest rate paid to depositors. The marginal cost of deposits to the bank, at any given level of deposits, is the additional cost the bank must incur to raise an extra unit of deposits beyond the given level, recognizing that the higher interest rate that is promised to attract that extra unit must be paid to **all** depositors, marginal as well as inframarginal? Given an imperfectly elastic deposit supply function, this marginal cost at any any given level of deposits is always higher than the interest rate **being** paid to depositors at **that** level of deposits. As we vary the deposit supply **function**, holding **fixed** the total deposit supply and the marginal costs of deposits, we also vary the interest rate paid on deposits which corresponds to that total deposit supply and that marginal cost of deposits to the bank. The effect of increasing the number of banks is to alter

⁹Suppose $r_f = 10\%$ and the bank needs to pay 7% interest on deposits to attract \$100 of deposits. Further, suppose that the interest rate must be raised to 7.019% to attract an additional dollar of deposits, i.e., to obtain a total of \$101 of deposits. Then, the marginal cost of deposits at \$100 is $(7.01 \times 101 - 7.00 \times 100)/1 = 8.01\%$, whereas the interest rate paid on deposits at \$100 is 7%.

the deposit supply function so that less deposits are forthcoming at any given deposit interest rate. Thus, even though the **equilibrium** marginal cost of deposits remains unchanged as π increases, the interest rate paid on deposits increases.

We can also perform comparative statics analysis for the deposit insurance premium y , the reserve requirement ξ , and the transactions cost of deposits c . Recall that these parameters do not affect the equilibrium lending terms when the equity–debt ratio is positive. However, these terms influence the equilibrium deposit rate through their impact on a bank's marginal cost of deposits.

Proposition 3. *If the equilibrium equity–debt ratio is positive;*

- (i) *An increase in the deposit insurance premium, y , decreases the equilibrium deposit rate r^* ; i.e., $dr^*/dy < 0$.*
- (ii) *An increase in the reserve requirement, ξ , decreases the equilibrium deposit rate r^* ; i.e., $dr^*/d\xi < 0$.*
- (iii) *An increase in the marginal transactions cost of deposits, c , decreases the equilibrium deposit rate; i.e., $dr^*/dc < 0$.*

The intuition underlying the proposition can be explained as follows. Holding the deposit rates of all other banks fixed at the initial equilibrium level, an increase in the reserve requirement, the deposit insurance premium, or the marginal transactions cost raises the marginal cost of deposits to a typical bank. As a result, the bank seeks fewer deposits, which is accomplished by lowering the interest rate on deposits. As all other banks lower **their** deposit rates, the bank's marginal cost of deposits decreases somewhat. However, these competitive effects are of a lower order of magnitude than the direct effect of the parameter change on the **bank's** marginal cost schedule. Thus, the net effect is a reduction in each bank's desired level of deposits and a corresponding decrease in the equilibrium deposit rate. An implication of Proposition 3 is that when the equilibrium equity–debt ratio is positive, the costs of deposit insurance and reserve requirements are partially shifted to depositors.

Our final comparative statics result of this section pertains to changes in the riskiness of the bank's loan portfolio, as measured by the success probabilities δ_i .

Proposition 4. *If the equilibrium equity–debt ratio is positive, and $\delta_i \in (0, 1)$ for $i = 1, 2$, then an increase in the success probability of either group of borrowers decreases the equilibrium deposit rate r^* : i.e., $dr^*/d\delta_i < 0$, for $i = 1, 2$.*

Proposition 4 implies that the equilibrium welfare of depositors increases with the riskiness of the bank's loan portfolio. This is because deposit

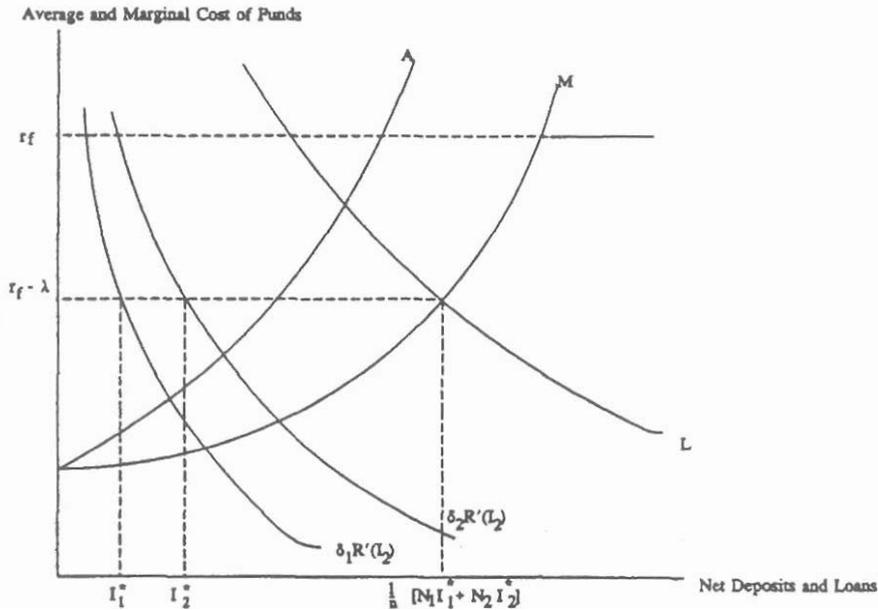


Fig. 2. Interaction of deposit and loan markets: Full deposit financing.

insurance is less valuable (and hence deposits less desirable), the less likely it is that borrowers will default.

3.d. Comparative srarics: Full deposit financing

We now turn to the case in which the equilibrium equity–debt ratio is zero. This case is illustrated in fig. 2. Here the bank's marginal profit of loans schedule L intersects the marginal cost of funds schedule on the upward sloping portion of the latter. From (7), the loan size I_i^* offered to a borrower of type i thus equates the marginal product $\delta_i R'(I)$ of investment to the marginal cost of deposits $r_f - \lambda$, i.e.,

$$\delta_i R'(I_i^*) = r_f - \lambda,$$

where λ is the **Lagrange** multiplier associated with the non-negativity of equity constraint (9). From fig. 2, one can see that the multiplier λ represents the difference between the marginal cost of equity and the marginal cost of deposits.

When loans are financed with a combination of equity and debt the loan

market equilibrium does not depend on the equilibrium deposit rate. However, with full deposit financing, this 'separation' no longer holds because the marginal cost of a dollar loaned depends on the rate paid to depositors. The following proposition, which is a companion to Proposition 2, characterizes the impact of bank market structure on the equilibrium lending terms and deposit rate in this situation.

Proposition 5. *If the equilibrium equity–debt ratio is zero, an increase in the number n of banks:*

(i) *increases the equilibrium loan I_i^* for each class of borrower: i.e., $dI_i^*/dn > 0$, $i = 1, 2$;*

(ii) *decreases the equilibrium interest rate on loans for each class of borrower: i.e., $d\beta_i^*/dn < 0$, $i = 1, 2$; where $\beta_i \equiv \alpha_i^*/I_i^*$;*

(iii) *increases the equilibrium deposit rate r^* ; i.e., $dr^*/dn > 0$.*

Propositions 2 and 5 imply that deposit rates increase in n regardless of whether bank loans are financed by debt and equity or only by debt. By contrast, when bank loans are **financed** only by debt, loan size increases as n increases. but when bank loans are financed by debt and equity, loan size remains **fixed** as n changes. These results enable us to derive the relationship between the equilibrium equity–debt ratio of a bank and the structure of the banking market as represented by n . Denote the equilibrium equity–debt ratio by ε^* . If $N_1 I_1^c + N_2 I_2^c > [1 - \xi - y - c]Ds(r^*)$, the equilibrium debt–equity ratio must be positive, and is given by

$$\varepsilon^* = [N_1 I_1^c + N_2 I_2^c] \{ [1 - \xi - y - c] Ds(r^*) \}^{-1} - 1.$$

Because $s(r^*)$ **increases** in n , the equilibrium equity–debt ratio ε^* decreases in n . Thus we have:

Proposition 6. *The equilibrium equity–debt ratio ε^* decreases as the number of banks increases.*

It may seem counterintuitive that as the number of banks increases, the deposit rate **increases** and yet banks shift from equity to deposit financing. But recall that with price-setting banks, the equilibrium deposit rate r^* is set so that, at the margin, a bank is indifferent between deposits and equity. A bank then accepts all deposits forthcoming at the equilibrium rate. As more banks enter, equilibrium deposit rates increase, increasing the supply to deposits to the entire system. As a result, deposits fund a larger fraction of loans.

In the previous two sections we showed that with a positive equity–debt ratio, the reserve requirement, ξ , the deposit insurance premium, y , and the

deposit transaction cost, c , affected only the deposit market equilibrium. When the equilibrium involves full deposit financing, these parameters also have an impact on the equilibrium in the loan market.

Proposition 7. If the equilibrium equity–debt ratio is zero, an increase in the deposit insurance premium, y , reserve requirement ξ , or transactions cost, c

- (i) decreases the equilibrium loan for each class of borrowers: *i.e.*, $dI_i^*/dy < 0$, $dI_i^*/d\xi < 0$, and $dI_i^*/dc < 0$, $i = 1, 2$;
- (ii) increases *the* equilibrium *interest* rate for each class of borrowers: *i.e.*, $d\beta_i^*/dy > 0$, $d\beta_i^*/d\xi > 0$, $d\beta_i^*/dc > 0$, $i = 1, 2$;
- (iii) decreases the *equilibrium* deposit rate for each class of borrowers: *i.e.* $dr^*/dy < 0$, $dr^*/d\xi < 0$, and $dr^*/dc < 0$.

Part (iii) of Proposition 7 extends the results in Proposition 3 to the case of a zero equity–debt ratio. Parts (i) and (ii) indicate that part of the costs of the reserve requirement and the deposit insurance premium are shifted to borrowers. Increases in these parameters raise the marginal cost of deposit financing, and since a bank's loan portfolio is funded entirely by deposits in this case, the bank finds it optimal to reduce the amount loaned. Because banks are imperfectly competitive in the loan market, they have some monopoly power and thus pass along some of this higher cost to borrowers through higher interest rates.

This result highlights a regulatory tension between bank safety and monetary policy concerns (addressed in part by deposit insurance and reserve requirements respectively) on the one hand and economic growth objectives (partly reflected in the aggregate volume of bank lending) on the other hand. Although reserve requirements have experienced a secular and intertemporal decline in the US – caused by a growing disenchantment with their effectiveness as a monetary policy tool – there have recently been significant increases in the deposit insurance premium, with strong prospects for further increases. These increases have been necessitated by the large losses incurred by the bank deposit insurance fund, but our analysis indicates that the trend of increasing premia does not augur well for economic growth, to the extent that such growth is fueled by bank lending. Note that this conclusion is derived in the context of a banking industry which relies (almost) exclusively on deposit financing, a situation not unlike that existing for many US banks at present.

This has connotations for the international competitiveness of US banks as well. To the extent that higher deposit insurance premia lead to lower lending by banks, the recent increases in **FDIC** premia combined with the strong likelihood of significant future increases imply that US banks will experience slower growth than they have in the past. Since Japanese and

(particularly) European banks have not been subject to the same stresses. their growth in the international credit markets should continue at the expense of US banks, which would further accentuate the already noticeable international retrenchment of American banks.

3.e. Capital regulation

Our model can be extended to evaluate the impact of capital adequacy regulation on the deposit and loan markets. We model the capital standard as a constraint requiring that a bank's loan portfolio, $b_1 I_1 + b_2 I_2$, be financed with at least a fraction ϕ of equity E:

$$\frac{E}{b_1 I_1 + b_2 I_2} \geq \phi,$$

where $\phi \in [0, 1]$. This is equivalent to the constraint

$$(1 - \xi - y - c)s \leq (1 - \phi)[b_1 I_1 + b_2 I_2], \tag{13}$$

i.e., the ratio of net deposits to loans cannot exceed $(1 - \phi)$. Each bank chooses its lending terms and deposit rate, $\{\alpha_1, I_1, \alpha_2, I_2, r\}$, to maximize profit (3) subject to (13). Note that in the equilibrium characterized in the previous section, we considered the special case of (13) in which $\phi = 0$.

The equilibrium conditions in the loan and deposit markets are analogous to (6), (7), and (10):

$$\alpha_i^* = (r_t - \lambda)\delta_i^{-1} I_i^* + t n^{-1} \delta_i^{-1}, \tag{14}$$

$$\delta_i R'(I_i^*) = r_t - \lambda, \tag{15}$$

$$r_t - \lambda = \alpha(r^*) + \frac{\alpha'(r^*)s(r^*, r^*, n)}{s_1(r^*, r^*, n)}, \tag{16}$$

where $\lambda \geq 0$ is the **Lagrange** multiplier for the capital requirement (13). As before, \mathbf{I} represents the difference between the marginal cost of equity and the marginal cost of deposits in equilibrium. When the capital requirement is not binding, we have $\lambda = 0$. It is straightforward to establish that the earlier comparative statics relationships established in Propositions 2 through 5 continue to hold when there is a capital requirement. In particular, the effects of increased bank competition characterized in Propositions 2 and 5 are not dependent on the absence of a capital standard.

To examine the **allocative** effects of capital regulation of this type, we assume that the standard is binding and consider the impact of an increase in the required ratio ϕ of equity to loans. The results of this comparative statics exercise are summarized in Proposition 8:

Proposition 8. *An increase in the capital requirement ϕ :*

- (i) *increases the equilibrium loan I_i^* for each class of borrowers; i.e., $dI_i^*/d\phi > 0$;*
- (ii) *decreases the equilibrium interest rate on loans for each class of borrowers; i.e. $d\beta_i^*/d\phi < 0$;*
- (iii) *decreases the equilibrium deposit rate; i.e., $dr^*/d\phi$.*

Proposition 8 implies that borrowers benefit from stricter capital regulation while depositors are hurt. A higher capital standard reduces the extent to which banks can rely on deposit financing. Banks thus compete less aggressively for deposits, reducing the equilibrium deposit rate. Because the capital requirement is binding, in equilibrium the marginal cost of deposits is less than the cost of equity. The amount lent is thus based on the marginal cost of deposits, as indicated by (15). The decrease in the deposit rate causes a decrease in the marginal cost of deposits, which makes it attractive for a bank to increase the amount it lends.

This result has significant implications for the current debate on **risk-abatement** regulatory measures. It is well known that a bank's incentive to heighten the value of the deposit insurance put option through the undetected pursuit of higher asset risk becomes stronger with a decline in its equity capital. This is frequently pointed out as a root cause of the demise of the US savings and loan industry, and has played no small part in the adoption of uniform capital guidelines by the twelve leading industrial nations under the Bank of International Settlements (**BIS**) accord. By 1993, banks in the US and other participating nations will be subject to the same *minimum* capital standards for a broadly defined category of on-balance-sheet and off-balance-sheet items. The common perception appears to be that this will reduce welfare distortions created by deposit insurance. While higher capital requirements *may* prove effective in inducing banks to choose safer assets, what our analysis shows is that they could hurt depositors. One can view this as a 'tax' on depositors that is aimed at curbing *bank* risk taking. In a sense, this was previously achieved by Regulation Q ceilings which kept deposit interest rates pegged at artificially low levels. The putative rationale for Reg Q was that, in its absence, banks would engage in 'reckless' competition for deposits that would drive deposit interest rates up and cause banks to seek 'excessively' risky assets to pay for costlier deposits. Although **the** removal of Reg Q ceilings was beneficial to depositors, the adoption of more stringent capital standards has effects similar to the reimposition of

Reg Q ceilings both in terms of depositor welfare (as implied by our model) and bank risk taking.

5. Concluding remarks

Deregulation has been a dominant theme in banking over the last few years. It is reflected in the Depository Institutions Deregulation and Monetary Control Act of 1980, the subsequent Garn–St. Germain Depository Institutions Act of 1982, CEBA and FIRREA as well as more recent developments, embodied in the Treasury Proposal (1991) for banking reform, that include the increased scope of non-bank financial firms in offering traditional banking services as well as the muchdebated weakening of Glass–Steagall proscriptions on banks. As a result, numerous questions have been raised over the future consequences of these profound developments, particularly as they relate to **allocational** and distributive effects across various groups of agents in the economy. In this paper, we have examined the effects of one specific aspect of deregulation, namely the lowering of entry barriers into banking. Our analysis captures competitive interactions among banks, so that the impact of (lowering) entry barriers can be explicitly and directly assessed.

Future research could focus on exploring the implications of altering the nature of capital requirements, reducing reserve requirements, and easing Glass–Steagall portfolio restrictions. The spatial model we have utilized for examining the impact of easing entry restrictions may provide a useful framework for analyzing these other regulatory issues.

Appendix

Proof of Proposition 2

Parts (i) and (ii) of the Proposition follow immediately from (6) and (7). To prove part (iii), let $\hat{r}(\hat{r}, n)$ denote a bank's reaction function when there are n banks. Differentiating each side of (18) with respect to n yields

$$dr^*/dn = \frac{\hat{r}_2}{\{1 - \hat{r}_1\}} \Big|_{\hat{r} = r^*},$$

where \hat{r}_j is the partial derivative of r with respect to its j th argument. Totally differentiating (10) with respect to n and \hat{r} , and utilizing the expression for SOC in (11) and the expressions in table 1, yields

$$\hat{r}_1 \Big|_{\hat{r}=r^*} = \frac{s(r^*)^4 \tau^{-2} r_f^{-2}}{s(r^*)^4 \tau^{-2} r_f^{-2} + \theta}, \quad (\text{A.1})$$

$$\hat{r}_2 \Big|_{\hat{r}=r^*} = \frac{-[D^2 s(r^*)^3 \tau^{-1} n^{-2} r_f^{-1}] a'(r^*)}{\text{SOC} \cdot s_1(r^*, r^*, n)} \quad (\text{A.2})$$

where

$$\theta \equiv \{s(r)^4 r_f^{-2} \tau^{-2} + [s'(r^*)^2 - s(r^*)s''(r^*)]n^{-2} + s'(r^*)^2 n^{-2} + s'(r^*)s(r^*)^2 \tau^{-1} n^{-1} r_f^{-1}\}.$$

Because $s''(r)s(r) \leq [s'(r)]^2$, it follows that $\theta > 0$, and $\hat{r}_1 < 1$. Thus, $dr^*/dn > 0$. \square

Proof of Proposition 3

Let ρ be a parameter that increases $a(r)$ and (possibly) $a'(r)$, and let $\hat{r}(\bar{r}, n, \rho)$ denote a bank's reaction function given this parameter. Totally differentiating the bank's first-order condition (10) yields

$$\frac{\partial \hat{r}}{\partial \rho} = \left\{ \frac{\partial a}{\partial \rho} s_1(r, \bar{r}, n) + \frac{\partial a'}{\partial \rho} s(r, \bar{r}, n) \right\} / \text{SOC} < 0$$

Now, differentiating each side of the equilibrium condition (12) gives

$$dr^*/d\rho = \frac{\partial \hat{r}/\partial \rho}{\{1 - \hat{r}_1\}} \Big|_{\hat{r}=r^*} < 0, \quad (\text{A.3})$$

because when $s''(r)s(r) \leq [s'(r)]^2$, the denominator in (A.3) is positive. Thus, any parameter change that shifts up $a(r)$ and $a'(r)$ will decrease the equilibrium deposit rate. Noting that $r^* \geq 1$ (since r is an interest factor) and $\xi < 1$, it is straightforward to prove that $a(r)$ and $a'(r)$ are strictly increasing in y , c , and ξ . Thus $\partial \hat{r}/\partial \rho < 0$ when $\rho = y$, c , or ξ . From (A.3) then, it follows that dr^*/dy , $dr^*/d\xi$, and dr^*/dc are negative. \square

Proof of Proposition 4

It is straightforward to show that $a(r)$ and $a'(r)$ are strictly increasing in δ_i . By the same logic as in the proof of Proposition 3, this establishes the result. \square

Proof of Proposition 5

The equilibrium conditions for I_i^* , β_i^* , r^* and λ can be stated as follows:

$$\delta_i R'(I_i^*) = r_f - \lambda, \quad i = 1, 2, \quad (\text{A.4})$$

$$\beta_i^* = (r_f - \lambda) \delta_i^{-1} + \delta_i (n I_i^*)^{-1}, \quad i = 1, 2, \quad (\text{A.5})$$

$$\dot{r}(r^*, n, \lambda) = r^*, \quad (\text{A.6})$$

$$N_1 I_1^* + N_2 I_2^* = Ds(r^*)(1 - \xi - y - c), \quad (\text{A.7})$$

where $\hat{r}(\bar{r}, n, \lambda)$ is the solution to (10), for a fixed value of λ . It is straightforward to show that $\hat{r}_3 \equiv \partial \hat{r} / \partial \lambda < 0$ at a symmetric equilibrium.

As a first step, differentiate each side of (A.5) to obtain

$$dI_i^*/dn = -Q_i(d\lambda/dn), \quad i = 1, 2, \quad (\text{A.8})$$

where

$$Q_i = [\delta_i R''(I_i^*)]^{-1} < 0.$$

As a next step, differentiate each side of (A.7) with respect to n and use (A.8) to obtain

$$d\lambda/dn = P(dr^*/dn), \quad (\text{A.9})$$

where

$$P \equiv -Ds'(r^*)[1 - \xi - y - c]\{N_1 Q_1 + N_2 Q_2\}^{-1} > 0.$$

Now, differentiate each side of (A.6) with respect to n and use (A.9) to obtain

$$(dr^*/dn)\{\hat{r}_1 - 1\} + \hat{r}_3 P = -\hat{r}_2. \quad (\text{A.10})$$

Given our assumption that $s''(r)s(r) \leq [s'(r)]^2$, it follows that $\hat{r}_1 < 1$. Moreover, at a symmetric equilibrium, $\hat{r}_2 > 0$ and $\hat{r}_3 < 0$. This implies $dr^*/dn > 0$. Conditions (A.8) and (A.9) then imply $d\lambda/dn > 0$; $dI_i^*/dn > 0$, $i = 1, 2$. Finally, because β_i^* decreases in λ and nI_i^* , it follows that

$$d\beta_i/dn < 0, \quad i = 1, 2. \quad \square$$

Proof of Proposition 7

Let the parameter p equal ξ , y , or c . The equilibrium conditions are given

in (A.4)–(A.7), where we now note that the deposit reaction function is parameterized by p ; i.e. (A.3) can be written

$$\hat{r}(r^*, n, \lambda, \rho) = r^*. \quad (\text{A.6'})$$

Also recall from the proof of Proposition 3 that $\partial \hat{r} / \partial \rho < 0$.

Differentiating each side of (A.4) yields

$$dI_i^*/d\rho = -Q_i(d\lambda/d\rho), \quad i = 1, 2, \quad (\text{A.11})$$

where $Q_i < 0$ is as defined in the proof of Proposition 5. As a next step, differentiate each side of (A.4) with respect to p and rearrange terms to obtain

$$dr^*/d\rho = T + U d\lambda/d\rho, \quad (\text{A.12})$$

where:

$$T = s(r^*)[s'(r^*)(1 - \xi - y - c)]^{-1} > 0.$$

$$U = -[Ds'(r^*)(1 - \xi - y - c)]^{-1}[N_1Q_1 + N_2Q_2] > 0.$$

Now, differentiate each side of (A.6') and utilize (A.12) to get

$$[(\hat{r}_1 - 1)U + \hat{r}_3](d\lambda/d\rho) = -\hat{r}_4 + (1 - \hat{r}_1)T, \quad (\text{A.13})$$

where $\hat{r}_4 \equiv \partial \hat{r} / \partial \rho$. Since $\hat{r}_1 < 1$, $\hat{r}_3 < 0$, $\hat{r}_4 < 0$, $U > 0$, and $T > 0$, (A.13) implies that $d\lambda/d\rho < 0$. From (A.12) and (A.11), it immediately follows that $dr^*/d\rho < 0$ and $dI_i^*/d\rho < 0$ for $i = 1, 2$. Finally, from (A.5) and the result that $dI_i^*/d\rho < 0$, we have $d\beta_i^*/d\rho > 0$. \square

Proof of Proposition 8

The equilibrium condition for β_i^* , r^* , and λ can be stated as follows:

$$\delta_i R'(I_i^*) = r_f - \lambda, \quad i = 1, 2, \quad (\text{A.14})$$

$$\beta_i^* = (r_f - \lambda)\delta_i^{-1} + \delta_i(nI_i^*)^{-1}, \quad i = 1, 2, \quad (\text{A.15})$$

$$\hat{r}(r^*, n, \lambda) = r^*, \quad (\text{A.16})$$

$$(1 - \phi)[N_1I_1^* + N_2I_2^*] = Ds(r^*)(1 - \xi - y - c). \quad (\text{A.17})$$

First, differentiating each side of (A.14) with respect to λ yields:

$$dI_i^*/d\phi = -Q_i d\lambda/d\phi, \quad i=1, 2, \quad (\text{A.18})$$

where $Q_i < 0$ is as defined in the proof of Proposition 5. Next, differentiating each side of (A.16) with respect to ϕ yields:

$$dr^*/d\phi = W(d\lambda/d\phi), \quad (\text{A.19})$$

where $W \equiv \hat{r}_3/(1 - \hat{r}_1)$. Recalling from the proof of Proposition 5 that $\hat{r}_3 < 0$ and $\hat{r}_1 < 1$, it follows that $W < 0$. Now, differentiating each side of (A.17) and using (A.18) and (A.19) yields:

$$\begin{aligned} -[N_1 I_1^* + N_2 I_2^*] &= \{(1 - \phi)[N_1 Q_1 + N_2 Q_2] \\ &+ Ds'(1 - \xi - y - c)W\}(d\lambda/d\phi). \end{aligned} \quad (\text{A.20})$$

The term in curly brackets on the right-hand side of (A.20) is strictly negative, implying $d\lambda/d\phi > 0$. From (A.18) and (A.19), it immediately follows that $dI_i^*/d\phi > 0$ and $dr^*/d\phi < 0$. Finally, from (A.15) and the result that $dI_i^*/d\phi > 0$, it follows that $d\beta_i^*/d\phi < 0$. \square

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