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Capital Requirements, Monetary Policy, and Aggregate Bank Lending: Theory and Empirical Evidence

ANJAN V. THAKOR*

ABSTRACT

Capital requirements linked solely to credit risk are shown to increase equilibrium credit rationing and lower aggregate lending. The model predicts that the bank's decision to lend will cause an abnormal runup in the borrower's stock price and that this reaction will be greater the more capital-constrained the bank. I provide empirical support for this prediction. The model explains the recent inability of the Federal Reserve to stimulate bank lending by increasing the money supply. I show that increasing the money supply can either raise or lower lending when capital requirements are linked only to credit risk.

THE MOTIVATION OF THIS article is first to examine the impact of "risk-based" capital requirements—namely those that link mandatory capital-to-asset ratios for banks to their loans—on aggregate bank lending. These requirements, called the *Basle capital rules* (or BIS guidelines), went into effect in March 1989 for banks in the leading industrialized nations. These rules initially required banks to maintain capital equal to 7.25 percent of business and most consumer loans, with the requirement increasing to 8 percent by the end of 1992. Secondly, I wish to understand the link between monetary policy and aggregate bank credit in the presence of risk-based capital requirements.

My curiosity is sparked in part by two recent phenomena. One is the experience of the U.S. economy, which displayed sluggish growth during 1989–93 despite a monetary policy that attempted to spur bank lending and economic activity.[1] And the other is the striking decline in loans relative to security holdings (mostly government bonds) in the asset portfolios of U.S.

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[1] Cummins (1993) reports Mr. Greenspan's frustrations on this score.

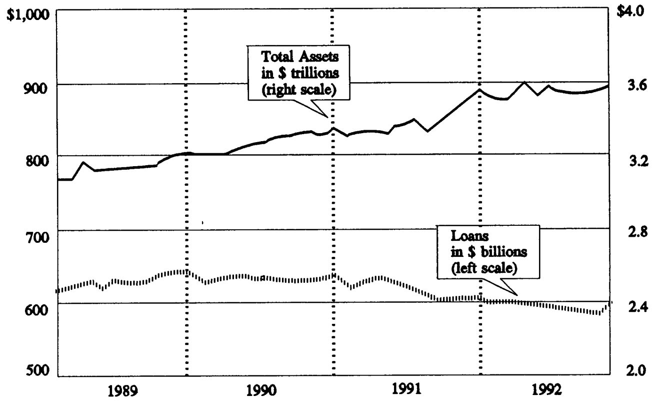

Figure 1. Behavior of bank assets and loans during 1989–92. This figure, based on data from the Securities and Exchange Commission, shows the time-series behavior of total bank assets and loans from 1989 through 1992.

banks. See Figure 1. These two phenomena have attracted considerable attention in the financial press.[2]

To explain these phenomena, I develop a model in which banks perform two key lending functions: prelending screening of loan applicants (credit analysis) and postlending monitoring (supervision of the borrower's management of the asset financed with the loan). Each borrower can simultaneously approach multiple banks, and there is unobservable heterogeneity in loan applicants' creditworthiness; some are creditworthy and some are not. Each bank knows how many other banks the borrower has approached, and based on that information the bank determines whether it will (noisily) screen the applicant and then whether it will extend a (monitored) loan. The model is set up so that a bank will not lend to a borrower it has not screened. The idea of screening is similar to that of creditworthiness testing in Broecker (1990).[3] In addition to lending, which must be supported with bank capital, banks can also invest in government securities that require no capital.

The assumption that loans must be supported with capital, whereas government securities need not, captures current U.S. regulatory rules. The BIS guidelines link capital requirements only to credit risk (loans) and not to interest rate risk (engendered by investments in securities). Although the

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[2] For example, *The Economist* reported, "Piece by piece, the ingredients of a sustained economic recovery are falling into place in America. But one oddity remains. Far from increasing their lending to businesses, banks are still cutting it." See Finance (1993). Other recent reports in trade publications also indicate that, while there has been some softening in credit demand, a lot of what has been going on can be explained by a tightening of credit standards and lending cutbacks by banks. See, for example, Goodwin (1993) and Klinkerman (1993). The viewpoint that recent credit crunches have been supply-induced is also presented in Wojnilower (1980).

[3] Broecker (1990) assumes that signals used in his creditworthiness tests are costless and that banks cannot react to each other. By contrast, the assumptions that signals are costly and that banks can react to each other play pivotal roles in my analysis.

Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991 required regulators to come up with rules to incorporate interest-rate risk in capital standards by June 1993, this initiative was delayed (see Rehm (1993)). Moreover, even when implemented, these rules will directly affect only midsized banks that account for roughly 10 percent of total U.S. banking assets. Thus, I assume capital requirements are linked only to risky lending, postponing until later a discussion of leverage ratios and capital requirements linked to a broader array of banking risks.

The model generates many results, three of which are central to the message of this article. First, a small increase in risk-based capital requirements for banks elevates the endogenously-determined probability of a borrower's being denied credit by the entire banking system, thus reducing aggregate lending. Second, a bank's agreement to lend will evoke an abnormally positive reaction in the borrower's stock price, and this reaction will be greater the more capital-constrained the bank. Third, with risk-based capital requirements, the effect of monetary policy on bank lending depends on its effect on the term structure of interest rates. If an increase in the money supply decreases short-term interest rates more than long-term rates, the probability of credit denial by banks will increase, leading to a reduction in aggregate lending induced by a greater money supply. If, on the other hand, a higher money supply leads to a greater reduction in long-term interest rates, then the probability of bank credit denial declines with an increase in the money supply.

To understand the intuition behind these results, we need to examine how rationing arises in the model, and this requires looking at the borrower's credit search problem. If the probability that a given bank will screen the borrower is unaffected by the number of banks the borrower approaches, then a creditworthy borrower will prefer applying to more banks than less because this enhances the probability that at least one bank will correctly identify the borrower as creditworthy;[4] thus, the probability of receiving credit increases. Moreover, approaching more banks also means that, on average, more banks will end up bidding for the borrower's business, and this means a lower loan interest rate.

However, approaching more banks is a double-edged sword for the borrower because banks adapt their behavior to the borrower's choice. The greater the number of banks the borrower approaches, the lower is the likelihood that a given bank will be able to obtain the borrower's business profitably and recover its screening cost. This means that as the borrower applies to more banks, each bank's expected profit from screening declines; this diminishes the probability with which it will wish to screen the borrower. Since unscreened borrowers are rationed, the borrower faces a higher rationing probability when it approaches more banks.[5] Thus, the borrower must now balance the earlier-mentioned benefits of approaching multiple banks against the cost of being rationed. In equilibrium each borrower approaches multiple banks and faces a positive probability of being rationed by each bank. Credit rationing therefore arises naturally from the screening costs banks incur.

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[4] My discussion focuses on creditworthy borrowers. It turns out that in equilibrium the borrowers who are not creditworthy prefer to mimic the strategy of their creditworthy cohorts.

[5] This discussion does not clarify why the rationing probability is not either zero or one. A more formal discussion of the intuition in Section II explains this.

A risk-based capital requirement can now be seen to affect the rationing probability. An increase in the risk-based capital requirement increases the bank's loan-funding cost. Since competition limits the bank's ability to pass this cost along to borrowers, the bank's expected profit from lending is diminished by an increase in the minimum capital requirement. This makes lending less attractive at the margin to the bank relative to investing in government securities; since these securities require no capital to be held against them, the higher capital requirement has no impact on the profitability of holding these securities.[6] Consequently, the bank lowers the screening probability, leading to a higher incidence of credit rationing in equilibrium. This result that higher risk-based capital requirements can exacerbate credit rationing is found neither in the extant literature on capital requirements (e.g., Besanko and Kanatas (1993), Boot and Greenbaum (1993), and Campbell, Chan, and Marino (1992)), nor in the literature on credit rationing. In Stiglitz and Weiss (1981), for example, the lack of distinction between capital and deposits renders vacuous any discussion of increasing capital requirements.[7]

The second result, namely the announcement effect of the bank's promise to lend, follows from the favorable signal about credit screening conveyed by the bank's decision to lend. Moreover, because the credit-granting probability is lower for more capital-constrained banks, the signal is stronger when credit is granted by a bank for which the capital-to-assets ratio is lower. I confront this prediction of the model with data on 161 loan commitments. The empirical results support the prediction.

I turn next to the monetary policy result. Suppose that the Central Bank increases the money supply in the hope of stimulating bank lending. There are two possible effects of this initiative. One is that short-term rates decline more than long-term rates, thereby widening the term premium. A bank that accepts short-maturity (or demand) deposits will therefore find investments in long-maturity government securities more profitable than before, implying an

[6] The BIS capital guidelines stipulate capital requirements against Treasury securities of sufficiently long maturity. Thus, when I introduce government securities, it should be understood that they are short-maturity securities against which no capital is required.

[7] Introducing capital requirements in Stiglitz and Weiss (1981) is not trivial. Because the deposit supply function there is *exogenously* given, the effect of capital requirements on credit rationing will depend on how these requirements impact deposit supply. Since the deposit interest rate is endogenously determined, given an exogenous upward-sloping function that links deposit supply to the expected *return* to depositors, it would be reasonable to posit a similar upward-sloping capital supply function to endogenously determine the cost of capital. With bank shareholders having a lower priority than depositors, a sensible equilibrium condition would be for the marginal cost of the (last) dollar of deposits to equal the marginal cost of the (first) dollar of capital. Inframarginal shareholders will earn more than inframarginal depositors, but the *total* availability of deposits plus equity to the bank will be the same as if there were no capital requirements, and the extent of equilibrium credit rationing would be unaffected.

increase in its reservation profit level for lending. Although the increased money supply also lowers the bank's cost of funding loans, this effect is weaker than the effect on its reservation-profit level. Consequently, each bank's expected net return from lending (relative to investing in securities) declines, elevating the rationing probability. This means that a higher money supply could perversely reduce bank lending. The other possibility is that long-term rates decline by more than short-term rates, narrowing the term premium. This causes the rationing probability to decline, and produces the traditional effect, namely a higher money supply leading to expanded lending.

An alternative story about how capital requirement increases could impact bank lending, one for which my screening model could be viewed as a metaphor, goes like this. Banks build relationships with firms that produce rents from lending and increase the availability of loans. Since an increase in bank capital requirements raises the bank's cost of lending without necessarily increasing its bargaining power, the bank earns lower rents when capital requirements go up. This reduces the supply of bank loans, especially for firms for which bank relationships are valuable. On the other hand, lending remains unchanged for large and well-known firms that operate in competitive credit markets. The price of loans does change for these firms, and this may cause them to substitute away from bank debt, but this is a demand-driven change rather than a supply-driven change (e.g., Thakor and Wilson (1995)).

Modeling this intuition would require endogenizing relationship rents, the dependence of these rents on the firm's other credit opportunities, and the dependence of the loan supply function on the *level* of these rents. Moreover, there would still remain the task of explaining announcement effects related to the bank's decision to grant credit, and the link between this announcement effect and the bank's capital (see Footnote 10). Nonetheless, this story and my noisy screening model share the broad intuition that when the lending profits of banks receive an exogenous shock, borrowers who are more bank-dependent are likely to experience a greater change in bank credit supply; see Kashyap, Lamont, and Stein (1994) and Kashyap, Stein, and Wilcox (1993) for empirical evidence.

In addition to the three main results, I also derive the following. Holding fixed the number of banks approached: i) the credit denial probability is lower for borrowers the bank can screen less noisily and also for more creditworthy borrowers, and ii) an increase in deposit-linked subsidies to banks stochastically lowers aggregate bank lending.

The rest is organized as follows. Section I develops the model. Section II contains the analysis and the results. Section III discusses the implications and Section IV the robustness of the model. Section V has the empirical results. Section VI concludes. An appendix contains the proofs.

I. The Model

The model discussion is organized into four subsections. The first describes the informational environment, the second presents the preferences and technology, the third describes the role of banks and the competitive and regulatory environment, and the fourth describes the formal game.

A. The Informational Environment

Consider a banking system with $\mathbf{N} > 0$ banks in which a borrower can choose the number of banks to approach for credit from $\mathscr{L} \equiv \{1, 2, \ldots, \mathbf{N}\}$, a subset of the integers. The borrower can be of one of two types: good (G) or lemon (L). The commonly known prior probability is $\gamma \in (0, 1)$ that a borrower is G and $1 - \gamma$ that it is L. Each borrower knows its own type at the outset, but all borrowers are a priori observationally identical to potential lenders. If a bank could discover a credit applicant's type, it would lend to it if it was G and deny credit if it was L.

B. Preferences and Technology

There is universal risk neutrality. G needs \$1 from a bank to invest in a project that will yield a publicly verifiable cash flow of R with probability $\delta \in (0, 1)$ and 0 with probability $1 - \delta$ one period hence. In addition to the verifiable stochastic cash flow, the project yields a nonverifiable, nonassignable, sure control rent of $R_c > 0$ to the borrower (see Diamond (1991) and O'Hara (1993)). L needs \$1 to invest in a project that yields no verifiable cash flow at the end of the period but yields a similar control rent of $R_c > 0$ to the borrower. Neither borrower has any assets in place or any investment opportunities other than the project in question. Moreover, bank financing has unique value to the borrower in that if no bank grants credit, the project is lost, and so is the control rent.

C. The Role of the Bank and the Competitive and Regulatory Environment

A bank has a special expertise in credit analysis, so it screens credit applicants more efficiently than others. Whereas an individual depositor can screen a credit applicant at a cost no lower than C', the bank can screen at a cost $C \in (O, C')$. This screening advantage can be justified either by intertemporal information reusability (e.g., Bhattacharya and Thakor (1993), and Chan, Greenbaum, and Thakor (1986)) or derived from more primitive assumptions about lower incentive costs in diversified intermediaries (e.g. Allen (1990), Millon and Thakor (1985), and Ramakrishnan and Thakor (1984)). Even with a single depositor, this creates a role for the bank, and the bank's advantage becomes greater as we increase the number of depositors needed to finance a \$1 loan (see Diamond (1984)).

Screening is designed to weed out the lemons. Since these borrowers produce no verifiable cash flow, the bank always loses by lending to them. I assume, however, that such borrowers can be screened out only noisily. Screening produces a signal, ϕ, which tells the bank whether the borrower is G or L. I assume ("Pr" stands for "probability"):

$$\Pr(\phi = k \mid k) = \eta \in (0.5, 1), \quad \Pr(\phi = k \mid i \neq k) = 1 - \eta \quad \forall i, k \in \{\mathrm{G}, \mathrm{L}\}.$$

If screening were perfect, the lemons would never apply for credit, in which case banks would never screen, but then the lemons would apply, and so on! If multiple banks screen, then, conditional on the borrower's type, signals across different banks are independent and identically distributed. No bank knows the result of any other bank's screening. Both loan initiations and loan renewals are subject to screening, since I assume that information decays and displays only partial intertemporal reusability.

Screening subsumes all of the activities associated with credit analysis. This includes the cost of loan officers' time in contacting credit agencies, previous creditors, suppliers, and customers, as well as the cost of conducting a financial analysis of the borrower's repayment ability and credit risk in light of possible future shocks that are both borrower-specific as well as systematic. Although loan officers' wages are fixed over the immediate horizon, the resources devoted to screening one loan—which include but are not limited to loan officers' time— cannot be committed to screening another loan. Thus, screening has an opportunity cost, and screening costs are best thought of as being variable in nature. In addition to the empirical results in this paper, the empirical significance of bank screening has recently been reported in numerous papers. Billett, Flannery, and Garfinkel (1995) show that higher-quality banks elicit larger reactions in their borrowers' stock prices. Shockley and Thakor (1995) document abnormally positive stock price reactions when borrowers announce loan commitment purchases with usage fees. Berger and Udell (1994) find that lending relationships generate valuable private information.[8]

In addition to credit analysis, banks also perform postlending monitoring that may take the form of advice by the bank on efficient project management including tighter cost control and revenue enhancement procedures. I assume that C includes the cost of providing this monitoring as well, so that the bank does not have an additional monitoring decision to make after it has performed the initial screening. Following Allen (1993), I assume that the benefit of bank monitoring is increasing in the number of banks involved. This benefit is captured by assuming that R is an increasing function of j, the number of banks that lend to the borrower; this assumption is innocuous (see Section IV). That is, $R'(j) > 0$, with $R(1) \equiv R$ and $R(\mathbf{N}) \equiv \bar{R} < \infty$. The idea is that independent monitors have imperfectly correlated insights and that the value of aggregating these exceeds the distortions potentially introduced by free-riding. Given such a multiple-monitoring benefit, it turns out that the borrower prefers to split the loan up equally across all j banks that agree to lend.

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[8] Billett, Flannery, and Garfinkel (1995) use the lender's capital in their regressions but conclude that it is not an important determinant of lender quality. In general, a positive reaction in the borrower's stock price suggests that the bank loan has some value *and* that this loan was not completely anticipated by the stock market. While bank financing can have value for reasons other than screening—such as valuable ex post bank monitoring—none of these reasons by itself can generate an abnormal price reaction without new information being transmitted to the market. To see this, suppose that borrowers seek bank financing due to the perceived value of ex post bank monitoring. If there is no ex ante informational asymmetry, then it should be common knowledge that bank monitoring is valuable, and the valuation impact of the monitoring should be impounded in borrowers' stock prices even before monitoring occurs. The borrower's decision to acquire a bank loan should *not* elicit a price reaction, since in equilibrium the probability is one that such a borrower will borrow from a bank; eschewing a bank loan is an out-of-equilibrium event with probability zero. Of course, if the market is a priori unsure of whether the borrower will obtain a bank loan and thereby avail of bank monitoring, there will be an abnormal price reaction. But since the bank loan is known to be of value to this type of borrower, the equilibrium probability that the borrower will seek a bank loan is one, and the market's uncertainty can therefore arise only from uncertainty about whether the bank will agree to lend. To the extent that the bank's lending decision is not purely random (i.e., it is based on some sort of analysis), we return to the screening argument.

The **N** banks in the economy engage in unfettered competition. Bank regulation has two noteworthy aspects. First, there is a risk-based capital requirement against bank loans, which increases the bank's loan funding cost. Equity capital is thus assumed to be more costly than (insured) deposits.[9] The bank's cost of funding a loan will then be a weighted average of the costs of deposits and (equity) capital. Let this weighted average be r_{L}. That is, a bank needs a minimum expected payoff of $\$r_{\mathrm{L}} > 1$ one period hence in exchange for a \$1 loan today. Second, deposits are fully insured and carry with them a subsidy to banks. This subsidy could be either in the price of deposit insurance or in transactions privileges accorded bank deposits that are unavailable with competing transactions accounts.[10] The bank can thus acquire \$1 in deposits today in exchange for a sure promise to repay $\$r > 1$ one period hence. In addition to loans, the bank can invest in government securities or any asset that does not carry a capital requirement. For simplicity, I assume that a \$1 investment in these securities today yields a sure payoff of $\$r_M > \$r$ tomorrow; it makes no difference if r_M is the expected value of a random payoff. The net benefit of investing in these securities, due in part to the deposit-funding subsidy, can now be expressed as $\alpha \equiv r_M - r > 0$. Moreover, I assume $r_{\mathrm{L}} > r_M$.

D. The Formal Game

I wish to examine the unique Nash equilibrium in the credit market. The game proceeds as follows. First, a borrower, with knowledge of its own type (L or G) and all of the exogenous parameters of the model, approaches $N \leq \mathbf{N}$ banks for credit. Second, each bank that is approached knows N, but not the borrower's type.[11] Each bank then decides whether it will screen the borrower or not. Later I provide a sufficiency restriction on the exogenous parameters, which guarantees that the bank will never extend credit without screening. Thus, if a bank decides not to screen, it has effectively decided not to lend. Third, each bank discovers the result of its screening. A parametric restriction introduced later ensures that the signal is sufficiently informative, so that the bank offers credit if $\phi = \mathrm{G}$ and denies credit if $\phi = \mathrm{L}$. In offering credit, the bank irrevocably *commits to a range* of interest rates from which the bank will eventually choose a rate to lend, but the results of its screening remain private. Fourth, the borrower observes the number of offers, $\tilde{j} \leq N$, that it has received and communicates this information to the offering banks. Each bank now determines its optimal choice from the earlier-indicated price range. The $j \leq \tilde{j}$ banks bidding the lowest interest rate end up lending \$1/j each to the borrower, ensuring a verifiable terminal payoff of $R(j)$ with probability δ if the borrower is G.

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[9] This higher cost can be justified based on either adverse-selection grounds (see Myers and Majluf (1984)), or moral hazard considerations (e.g., Thakor (1990)).

[10] See Gorton and Pennacchi (1991) for a discussion of the advantages bank deposits enjoy over competing transactions accounts like money-market mutual funds.

[11] It is assumed that N can be costlessly communicated to each bank and therefore need not be inferred by these banks. See Section IV for further discussion.

II. The Analysis

The formal analysis proceeds in three steps. First, I analyze the outcome with a single monopoly bank (**N** = 1). Second, I consider multiple banks, define the equilibrium concept, and delineate the simplifying parametric restrictions. Finally, the key properties of the equilibrium are derived.

A. The Case of a Single Bank

As a preliminary step, I identify the condition sufficient to ensure that the monopoly bank will prefer to invest in government securities than to lend without screening. If it lends without screening, its expected profit is $\gamma[\delta R - r_L] + [1 - \gamma][-r_L]$, which should be less than α to make it unprofitable to lend. That is, we have the parametric restriction,

$$\gamma < [\alpha + r_L][\delta R]^{-1}. \tag{1}$$

This is intuitive. The prior probability of encountering G through random choice should be low enough to make the bank wish to avoid lending to unscreened borrowers. Note that, given equation (1), a bank will always deny credit to an applicant for whom $\phi = \text{L}$, since the signal is informative.

Another desirable condition is that ex ante the bank prefers to screen than to invest in securities, knowing that it will only lend to a borrower for whom the signal $\phi = \text{G}$. That is,

$$\{\Pr(\phi = \text{G} \mid \text{G})\Pr(\text{G})[\delta R - r_L] + \Pr(\phi = \text{G} \mid \text{L})\Pr(\text{L})[-r_L]\} \\ + \{[\Pr(\phi = \text{L} \mid \text{G})\Pr(\text{G}) + \Pr(\phi = \text{L} \mid \text{L})\Pr(\text{L})]\alpha\} - C > \alpha.$$

The first term in braces on the left-hand-side (LHS) of the inequality is the bank's expected profit on the loan, conditional on a $\phi = \text{G}$ signal. The second term represents the fact that the bank invests in securities when $\phi = \text{L}$ is the signal. Writing out the probabilities explicitly, we have

$$\eta\gamma[\delta R - r_L] + [1 - \eta][1 - \gamma][-r_L] + [1 - \eta\gamma - \{1 - \eta\}\{1 - \gamma\}]\alpha - C > \alpha.$$

Note that in writing the above inequality, I have used the fact that

$$\Pr(\phi = \text{G} \mid \text{G})\Pr(\text{G}) = \eta\gamma, \quad \Pr(\phi = \text{G} \mid \text{L})\Pr(\text{L}) = [1 - \eta][1 - \gamma],$$

and

$$\Pr(\phi = \mathrm{L}) = 1 - \eta\gamma - [1 - \eta][1 - \gamma].$$

Simplifying and rearranging gives us

$$\frac{C + [1 - \eta][1 - \gamma][r_{\mathrm{L}} + \alpha]}{\eta\gamma[\delta R - r_{\mathrm{L}} - \alpha]} < 1 \tag{2}$$

as the condition that guarantees the bank's ex ante preference for screening (prior to knowing the screening outcome) over investing in securities. In essence, equation (2) is a restriction that the screening cost not be too large, relative to the gain from screening.

With these restrictions, a monopoly bank will always screen a borrower applying for credit, provide credit if the screening reveals $\phi = \mathrm{G}$, and deny credit if the screen reveals $\phi = \mathrm{L}$. Investing in securities is a residual decision; the bank diverts loanable funds to securities only when $\phi = \mathrm{L}$. Note that equation (2) automatically guarantees the ex post condition that the bank prefers to lend rather than invest in securities when $\phi = \mathrm{G}$. An important feature of the monopoly outcome is that there is no credit rationing in the sense of *prescreening* credit refusal. Of course, a borrower on whom the bank receives a $\phi = \mathrm{L}$ signal is denied credit, but that is only because the borrower is judged to be not creditworthy.

B. Multiple Competing Banks

I now consider $\mathbf{N} \geq 2$. Recent empirical evidence indicates that even two competing banks may yield a competitive outcome (see Shaffer and DiSalvo (1994)). To examine this case, we first need a definition of equilibrium.

Definition 1: A (competitive) Nash Equilibrium (NE) is one in which the following conditions hold.

(i) Each borrower chooses the number of banks to approach for credit, $N(\leq\mathbf{N})$, so as to maximize its expected net terminal payoff, taking as given the equilibrium strategies of the banks.

(ii) Each bank decides whether or not to screen the borrower by a process of maximizing its own expected profit net of screening costs and taking as given the equilibrium strategies of borrowers and the other banks. The bank's decision also involves a determination of $1 - p$, the probability with which it will screen the borrower.

(iii) Conditional on the outcome of its screening, the bank maximizes its own expected profit in determining whether to lend and the interest rate at which to lend, again taking as given the equilibrium strategies of borrowers and the other banks. The interest rate can be specified in a range, with interest rate values within the range being made conditional on the number of banks offering credit to the borrower.

With multiple competing banks, no bank can be sure that it will be able to lend at a positive profit to a borrower it has screened. The outcome depends now on what the other banks do, and strategic interactions among banks play a key role. In the proposition below I state some important features of the equilibrium. It is assumed throughout that equations (1) and (2) hold.

PROPOSITION 1: *Suppose a type-*G *borrower optimally chooses* $N \geq 2$. *Then there exists a symmetric NE in which the type-*L *borrower chooses the same N, and each borrower faces a positive probability of being credit rationed by all banks.*[12]

The precise intuition behind rationing is as follows. Suppose that the probability that a bank will screen a given borrower is unaffected by the number of banks approached by the borrower. Then, the borrower perceives two benefits from applying to multiple banks. First, given noisy screening, it is less likely that G will be mistaken for L when there are more banks analyzing G. Second, the greater the number of banks approached, the larger is the expected number of banks that will bid for the borrower. This enhances both the probability of receiving credit and the probability of receiving it at a competitive price. Moreover, G will receive a larger payoff in the good state when there are more banks monitoring it. Now, as long as the expected net benefit to a bank from screening a borrower is positive, the bank will screen with probability one, so that a borrower can only gain by increasing the number of banks it approaches for credit. An equilibrium will be reached only when each bank the borrower has approached is willing to screen the borrower with a probability strictly between zero and one. This means that in equilibrium the borrower approaches enough banks to ensure that each bank is indifferent between screening and not screening the borrower.

This reasoning asserts that the bank's expected net benefit from screening depends on the number of banks approached by the borrower. This is because a bank can profit on a loan only if it is the borrower's sole lender. If two or more banks bid for the borrower, Bertrand competition ensures that each offers a breakeven price on the loan itself which fails to compensate for the *sunk* screening cost. Consequently, the bank recognizes that it will make money if it is a monopolist and lose money if it is a competitor. Since the probability of ending up as a competitor is increasing in the number of banks approached by the borrower, the bank's expected net benefit from screening declines as more banks are approached. Moreover, no bank prefers to lend to an unscreened borrower. Thus with multiple, noncolluding banks, an equilibrium must involve some probability of rationing for each borrower to ensure that each bank perceives some likelihood of being a monopolistic lender and earning sufficient profit in that state to overcome its expected losses when it is a competitor. The rationing probability is increasing in the number of banks approached, so that the borrower trades off the earlier-mentioned benefit of approaching multiple banks against the cost of being rationed. In the unique NE, the borrower approaches multiple banks and is rationed with a positive probability by each.

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[12] I will later prove that this NE is sequential and survives the Cho-Kreps (1987) Intuitive Criterion.

Two points are noteworthy. First, there is the issue of the borrower approaching multiple banks. Even though the theory accommodates any $N \leq \mathbf{N}$, most constellations of exogenous parameter values yield $N = 2$ or 3; the expected number of banks actually lending to the borrower is, of course, lower. Second, rationing in my model is the bank's decision to deny credit without screening. This should be interpreted as credit denial based on "prescreening" and underwriting standards. Banks routinely specify various criteria that borrowers must meet before their loan applications are considered seriously (screened at a cost). Checking compliance with these criteria can be viewed as relatively costless prescreening to ensure that underwriting standards can be met. Thus, an increase in the rationing probability should be viewed as the adoption of more stringent prescreening criteria and hence a greater likelihood that a loan applicant will be rejected before costly screening is undertaken. The next proposition shows that even though the rationing probability is identical across borrowers, the credit denial probability is not. The reason is that screening is informative, so that L always faces a greater likelihood of being turned down than G does.

PROPOSITION 2: *The probability that* L *will be denied credit is higher than the probability that* G *will be denied credit.*

This result is novel in the rationing literature. In Stiglitz and Weiss (1981), for example, *all* borrowers face the same probability of being rationed, regardless of their relative creditworthiness. In Besanko and Thakor (1987b), it is the more creditworthy borrowers who face a higher rationing probability than their observationally indistinguishable, but less creditworthy, cohorts. Moreover, because I *explicitly* model interactions among multiple competing banks, I can distinguish between credit denial by an individual bank and credit denial by the entire banking industry, in contrast to much of the existing rationing literature (e.g., Besanko and Thakor (1987a,b), Bester (1985), and Stiglitz and Weiss (1981, 1983)). Thakor and Callaway (1983) is an exception, but it does not endogenize the borrower's choice of how many banks to approach. I now derive p (the rationing probability) for a given N, and the borrower's optimal N.

PROPOSITION 3: *Suppose $N \geq 2$ is the borrower's optimal choice. Then, in a NE the probability that a bank will ration credit is the solution to*

$$\begin{aligned}&\{\eta\gamma[1-\eta[1-p]]^{N-1}[\delta R - r_{\mathrm{L}} - \alpha]\}\\ &\qquad - \{[1-\eta][1-\gamma][1-[1-p][1-\eta]]^{N-1}[r_{\mathrm{L}}+\alpha]\} = C. \qquad (3)\end{aligned}$$

Moreover, $p = p(N) \in (0, 1)$ in the above equation.

The intuition behind (3) is straightforward. The first pair of braces on the LHS of (3) represents the bank's expected profit from being a monopolist. The term $\eta\gamma$ is the probability that the bank will offer credit to G and the term $[1 - \eta[1 - p]]^{N-1}$ is the probability that such a borrower will be denied credit by all the other banks it has approached; $[\delta R - r_{\mathrm{L}} - \alpha]$ is the bank's net expected profit from being the sole lender to G, relative to investing in securities. The second pair of braces represents the bank's total expected loss when it is not a monopolist. The entire LHS of equation (3) then represents the bank's expected profit from lending (assessed prior to screening), conditional on having decided to screen. This should equal the bank's screening cost (the RHS of equation (3)) in a competitive equilibrium.

Consider now the borrower's optimization, given that it recognizes that an individual bank's p, as a function of N, is determined by equation (3). The following proposition tells us how the optimal N is determined. As a preliminary step, note that a borrower approaching N banks and receiving credit from $j > 2$ banks has a repayment obligation $i(j,N)$, which is

$$i(j, N) = \frac{\alpha + r_{\mathrm{L}}}{\delta \Pr(\mathrm{G} \mid \Omega(j, N))}. \tag{4}$$

Note that equation (4) is derived from each bank's participation constraint holding tightly at the optimum, conditional on all of the information available at the time of setting $i(j, N)$. Here $\Pr(G \mid \Omega(j, N))$ is the (posterior) probability assessment of banks that the borrower is G, conditional on the event $\Omega(j, N)$ that j banks out of N are offering credit. Note that

$$\Pr(\mathrm{G} \mid \Omega(j, N)) = \frac{\Pr(\Omega(j, N) \mid \mathrm{G})\Pr(\mathrm{G})}{\{\Pr(\Omega(j, N) \mid \mathrm{G})\Pr(\mathrm{G}) + \Pr(\Omega(j, N \mid \mathrm{L})\Pr(\mathrm{L})} \tag{5}$$

where

$$\Pr(\Omega(j, N) \mid \mathrm{G}) = \binom{N}{j}\{[1 - p]\eta\}^{j}\{1 - [1 - p]\eta\}^{N-j}, \tag{6}$$

$$\Pr(\Omega(j, N) \mid \mathrm{L}) = \binom{N}{j}\{[1 - p][1 - \eta]\}^{j}\{1 - [1 - p][1 - \eta]\}^{N-j}, \tag{7}$$

$$\Pr(\mathrm{G}) = \gamma, \quad \text{and} \quad \Pr(\mathrm{L}) = 1 - \gamma.$$

Proposition 4: *There exists $R_c > 0$ small enough such that* G*'s optimal choice of N, say N^*, satisfies*

$$N^* \in \operatorname*{argmax}_{N \in \mathcal{L}} [1 - \{1 - \eta[1 - p]\}^{N}]R_c + \sum_{j=2}^{N} \Pr(\Omega(j, N) \mid \mathrm{G})\delta[R(j) - i(j, N)], \tag{8}$$

with the convention that if the argmax set is not unique, N^* is the minimal element of that set. In this case, the NE involves G *approaching two or more banks for credit and being rationed by all banks with a positive probability. This NE involves* L *approaching the same number of banks as* G*. When* *augmented by the out-of-equilibrium belief on the part of banks that* Pr *(borrower is* L$|N \neq N^*$*) = 1 and each bank's strategy of denying such a borrower credit with probability 1, this NE is a sequential equilibrium which passes the Intuitive Criterion. Moreover,* N^* *is nondecreasing in* $R'(j)$*.*

Note that equation (8) describes the borrower's maximand, conditional on $N^* \geq 2$. This is because $\{1 - \eta[1 - p]\}^N$ is the probability that the borrower will be denied credit by all banks it approaches when $N \geq 2$. Thus, $1 - \{1 - \eta[1 - p]\}^N$ is the probability that at least one bank will grant credit, and in this case G is assured of receiving the control rent R_c. If only one bank extends credit, then G is charged a monopolistic price and R_c is all it gets. But if two or more banks offer credit, then the borrower receives a competitive price. If N banks are approached, then $\Pr(\Omega(j, N) | \text{G}) = (N/j)\{[1 - p]\eta\}^j \{1 - [1 - p]\eta\}^{N-j}$ is the probability that j of them will offer credit, and $\delta R(j) - i(j, N)$ is G's expected payoff given that j banks offer credit. Thus, equation (8) describes the function G maximizes when it knows that $N^* \geq 2$.

C. The Limiting Case as the Screening Noise Goes to Zero

What would happen if the noise in each bank's screening vanished asymptotically? Of course, noise cannot vanish altogether because the lemons would not then have a strict preference for applying for credit, and no bank would need to screen and, as argued previously, that cannot be a NE either. It is instructive nonetheless to examine the limiting case with $\eta \rightarrow 1$ because the equilibrium solution is much more transparent in that case than with $\eta \in (0.5, 1)$.

PROPOSITION 5:

$$\lim_{\eta \to 1} p \equiv p_1 = \left[\frac{C}{\gamma[\delta R - r_{\text{L}} - \alpha]}\right]^{1/N-1}. \tag{9}$$

Moreover, p_1 *is increasing in* r_{L} *and* α*.*

In the limiting case, an increase in the bank's cost of funding loans or an increase in deposit-linked subsidies will cause each bank to raise its rationing probability. These are useful properties to keep in mind while considering the implications of the analysis, which I do in the next section.

III. Implications of the Analysis

A. Implications of Risk-Based Capital Requirements and Regulatory Subsidies

To examine the policy implications of the equilibrium, consider first the impact of a small increase in the risk-based capital requirement.

PROPOSITION 6: *Suppose N^* is unique. Then, a small increase in the risk-based capital requirement will increase the probability that any borrower will be rationed by all banks, and hence will stochastically lower aggregate bank lending.*

The precise intuition is as follows. An increase in the risk-based capital requirement increases the bank's loan-funding cost, but it lowers the bank's expected profit on the loan *only* when it erroneously lends to L or when it is the sole bidder for G. When the bank lends to L, it never gets repaid, so it suffers a loss that increases with the loan-funding cost and hence with the risk-based capital requirement. When the bank is one of many bidders, the loan price is competitive, so the entire incremental funding cost created by the capital requirement is absorbed by the *borrower* if it is G; the bank simply earns its reservation return, given the cost of funding the loan. In the state in which the bank is the sole bidder, however, the loan price is monopolistic. Hence, it depends on the borrower's project payoff rather than the bank's loan-funding cost, conditional on the borrower being G. The bank's expected net return then depends on the difference between the loan price and the loan-funding cost, so this return decreases as the capital requirement increases and drives up the loan-funding cost. The diminution of the bank's expected net return on lending increases the probability that the borrower will be rationed by the bank. Since this holds for all the banks approached by the borrower, the probability that the borrower will be rationed by all of them also increases with the risk-based capital requirement.

Numerical simulations are used to characterize the behavior of the equilibrium as r_L increases by more than small amounts, thereby possibly altering N^*. In all of the simulations, I use the following exogenous parameter values: $R = 5$, $\delta = 0.6$, $R_c = 1$, and $R(j) = j^2R$ for $j \leq 10$ and $R(j) = 100R + (j - 10)R$ for $j > 10$ to reflect the diminishing marginal usefulness of approaching more banks beyond a certain number. Figure 2 graphs the results of the simulations. The rationing probability and the credit denial probability both increase in r_{L} as long as N^* remains unchanged. Thus, at least small increases in risk-based capital requirements stochastically lower bank lending. This provides a possible equilibrium explanation for the decline in bank lending in the United States after (and in anticipation of) the adoption of the BIS capital rules. For larger increases in r_{L}, the borrower adapts by reducing the number of banks it approaches, and this initially reduces the credit denial probability.

Next, I examine the implications of the analysis for announcement effects related to the borrower's stock price. Before the bank announces that it has agreed to lend to the borrower, the stock market believes that the firm is good with probability γ. Using the law of iterated expectations, we see that the market value of each firm's equity is $\gamma[\delta R - \{\alpha + r_{\mathrm{L}}\}/\gamma]$. Now, if the borrower is offered credit by j of the N banks it applies to, the market value of the borrower's equity becomes $\Pr(\mathrm{G} \mid \langle \phi = \mathrm{G} \rangle_j, \langle \phi = \mathrm{L} \rangle_{N-j})\delta R - \alpha - r_{\mathrm{L}}$. It is transparent that the market value of the firm's equity is higher after the

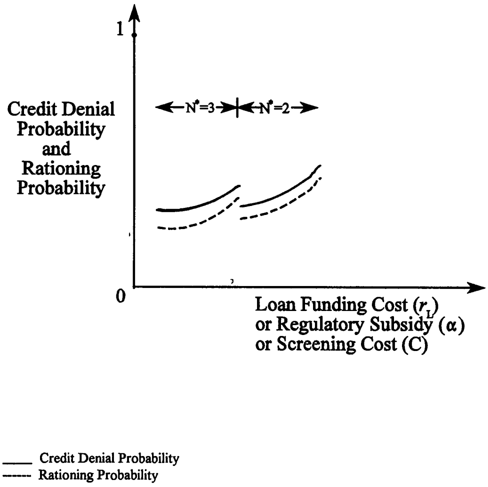

Figure 2. Behavior of equilibrium with respect to changes in the bank's loan funding cost or regulatory subsidies or screening cost. This figure shows how the equilibrium credit denial probability and the rationing probability change as one increases the loan funding cost, the regulatory subsidy, or the screening cost. The behaviors of the two probabilities are depicted for two values of the equilibrium number of banks approached for credit, $N^* = 2$ and $N^* = 3$. There are discontinuities in both graphs as the borrower optimally switches from three to two banks.

market learns the firm has been offered credit than before. Thus, the granting of bank credit should be accompanied by a positive announcement effect.

By Proposition 6, we know that ex ante, probability of rationing is higher for a more capital-constrained bank. Thus, $\Pr(G|\langle\phi = G\rangle_j, \langle\phi = L\rangle_{N-j})$ will be higher for a fixed j, which means that the market value of the borrower's equity will experience a greater appreciation when j banks agree to lend to it. This leads to the following corollary to Proposition 6.

COROLLARY 1: *When the borrower announces that it has received offers of credit from $j \geq 2$ banks, there is an abnormal appreciation in the price of the borrower's equity. The more capital-constrained the lenders, the greater the price appreciation of the borrower's equity.*

This corollary provides testable predictions that neatly distinguish the model empirically from other theories of credit rationing, such as Jaffee and Russell (1976), Stiglitz and Weiss (1981, 1983) or Besanko and Thakor (1987b). These predictions will be confronted with the data in a later section.

Consider next deposit-linked regulatory subsidies. These have long existed, and could be strategic instruments of bank regulation (see Buser, Chen, and Kane (1981) and Chan, Greenbaum, and Thakor (1992)). Subsidies can arise from underpriced deposit insurance, interest rate controls, and restrictions on competing transactions accounts like mutual funds, and so on. An increase in these subsidies lowers r, while leaving r_M unaffected. Thus, α is increased, and we have the following:

COROLLARY 2: *Suppose N^* is unique. Then, a small increase in deposit-linked regulatory subsidies (and hence in α) increases the probability that any borrower will be rationed by all banks, and hence will stochastically lower aggregate lending.*

As in the case of r_L, one can numerically evaluate the impact of small as well as large increases in α. Although the numerical values of the equilibrium parameters are different for this simulation than for the one involving changes in r_L, the qualitative aspects of the impact of α on the behavior of the rationing and credit denial probabilities are similar. Thus, the results of this simulation are also shown in Figure 2. As one can see, increasing α elevates the probability that a borrower will be denied credit by all banks, holding fixed N^*. Thus, somewhat counterintuitively I find that *as banks are provided access to cheaper funds, they lend less*. The intuition is that even though deposits are getting cheaper, equity capital is not, so that the cost of a given mix of deposits and equity is declining at a rate slower than the cost of deposits. As long as there are assets that do not require bank capital to be allocated to them, the bank's net return from investing in those assets (acquired solely with deposits) will rise *relative to its net return* from investing in loans, as the cost of deposits is lowered. Consequently, banks lend less as deposits become cheaper. Of course, as in the case of the other comparative statics, as α increases sufficiently, the borrower adapts by lowering N^* and initially reducing the credit denial probability.

My result about the perverse effect of deposit subsidies on credit rationing has no counterpart in the literature. Indeed, articles like those of Stiglitz and Weiss (1981) and Williamson (1987) would predict the exact opposite if subsidies were introduced there. Interbank competition in those models would result in the subsidies being captured by depositors, leading to a higher deposit supply and lower rationing.

B. Implications for Monetary Policy

There is an interesting monetary policy implication of Corollary 2. A standard approach to increasing bank lending is to expand the money supply. The impact of this on bank lending depends on its effect on the term structure of interest rates. There are two possible effects. One is to lower *short-term* interest rates by more than long-term rates, possibly because long rates tend to be affected by other factors such as investor risk aversion, and governmental budget deficits; this widens the term premium.[13] We can view r as a short-term rate since it is the cost of retail (insured) deposits. As the expanded money supply lowers short-term rates relative to long-term rates, the bank can skew a greater proportion of its investments in government securities toward long-maturity securities.[14] In other words, r_M can be increased relative to r as the expanded money supply lowers r. Hence, α increases as r is lowered. Note also that the cost of equity capital is likely to not be affected greatly; if it declines, the decline will be less than in r. This means that a lowering of r is likely to increase α without reducing r_L much. Once again, banks ration credit with a higher probability, and aggregate bank lending stochastically declines as banks shift from lending to security holdings. This may explain why monetary policy initiatives to spur bank lending were ineffective in the U.S. during 1989–93, and why U.S. banks earned more from security holdings than lending for the first time in U.S. banking history in 1991.[15]

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[13] Our model-related discussion is in risk-adjusted real terms. Note that the empirical observation about the widening of the term premium refers not just to the nominal but to the real, risk-adjusted term premium. In my model, however, any increase in the nominal term premium on the riskless asset implies an increase in the risk-adjusted real term premium, as long as money supply changes do not affect the spreads between nominal and real riskless rates for different maturities. To see this, suppose $r_f(\tau)$ is one plus the real riskless rate on a bond of maturity τ, and $\beta(\tau)$ is the inflation premium, so that the nominal equivalent is $r_f(\tau)\,[1 + \beta(\tau)]$. Suppose $\delta \in (0, 1)$ is the probability that a risky loan of any maturity will repay. Then, the risk-adjusted real rate is

The other possibility is that long-term rates are lowered more than short-term rates. Now, α declines as the money supply expands, making loans more attractive relative to securities. Banks consequently reduce the rationing probability, and aggregate bank lending stochastically increases.

My conclusion about the link between the money supply and credit rationing in the presence of risk-based capital requirements is novel. Despite the emphasis of the "macro" credit rationing literature on the importance of considering both monetary *and* credit aggregates in studying the efficacy of monetary policy (see Bernanke (1988) and Blinder and Stiglitz (1983)), rationing models are silent about why changes in bank lending were not positively correlated with money supply changes during 1989–93.[16] This phenomenon is particularly perplexing in the context of the Stiglitz and Weiss (1981, 1983) models which would predict lower rationing and *more* lending by banks faced with a higher supply of loanable funds! Thus, while my model predicts that a higher money supply could either increase or decrease bank lending, the standard rationing model predicts *only* increased lending. This difference is mainly because the term structure of interest rates is the propagation mechanism by

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$r_f(\tau)/\delta$ and the risk-adjusted nominal rate is $r_f(\tau)[1 + \beta(\tau)]/\delta$ and the difference is $r_f(\tau)\beta(\tau)/\delta$. Consider now a short maturity τ_s and a long maturity τ_l, with $\tau_l > \tau_s$. We assume that the difference in nominal rates $r_f(\tau_1)[1 + \beta(\tau_1)] - r_f(\tau_s)[1 + \beta(\tau_s)]$ increases as the money supply increases. This implies, however, that $r_f(\tau_1) - r_f(\tau_s)$ increases, since $\beta(\tau_1)$ and $\beta(\tau_s)$ are assumed to be unaffected. Hence, $[r_f(\tau_1)/\delta] - [r_f(\tau_s)/\delta]$, the risk-adjusted real spread, increases with the money supply. Of course, this ignores the impact of monetary policy and inflation on borrowers' incentives to develop credit reputations and signal types (Smith (1994)).

[14] The usual approach to expanding the money supply is for the Fed to buy government securities. At first blush, this would seem to drain security holdings from the banking sector, thereby freeing up deposits for lending (the traditional argument). However, the Fed can be thought of as purchasing short-maturity government paper to expand the money supply, and banks as increasing their holdings of long-maturity government paper.

[15] Keeton (1994) documents the surge in security holdings at U.S. banks and notes that over half of it cannot be explained by the "usual" factors such as the business cycle.

[16] Other models of interest are Rajan (1994), where a theory of fluctuations in bank credit policy is developed, and Morgan (1993) and Keeton (1993), whose work supports the traditional argument that an easier monetary policy leads to more lending.

which money supply shocks are transmitted to bank lending in my model; I assume that individual banks are *price takers* with access to elastically supplied deposits. By contrast, Stiglitz and Weiss (1981, 1983) assume an upward sloping deposit supply function for individual banks, so that the money supply directly affects the quantity of loanable funds available to banks; a greater money supply then *necessarily* means more bank loans.

These potential effects of capital requirements on rationing may be absent if the requirements were truly risk-based. With a capital requirement against interest rate risk, an increase in the bank's holding of government securities would necessitate an increase in capital as well. That is, α would decline when r_L increases. If the risk weights are chosen "correctly," a change in the capital requirement should not increase the marginal benefit of holding securities relative to the marginal benefit from screening and lending. Thus, changes in capital requirements may have no impact on credit rationing. Note, however, that issues of detail—such as the choice of risk weights and the measurement of interest rate risk—become important. Inappropriately calibrated capital requirements will result in either greater credit rationing or excessive bank lending relative to the case with risk-insensitive capital requirements.

In the near future, U.S. banks will have to set aside capital to cover interest rate risk; this was mandated by FDICIA. But this new capital rule is likely to have an immediate and perceptible impact only on medium-sized banks which control just 10 percent of U.S. banking assets. About 8400 small banks, accounting for approximately 30 percent of U.S. banking assets, will be exempt from allocating capital for interest rate risk, except under special circumstances.[17] Moreover, the 50 largest banks, which control 60 percent of U.S. banking assets, will be allowed to compute their own interest rate risk exposure and thus effectively have discretion over how much capital to allocate for this exposure. Such discretion is absent when it comes to the capital set aside to cover credit risk. Thus, a significant fraction of the banking industry will be only loosely covered by capital requirements against interest rate risk, but all banks will be rigidly required to post capital against credit risk, implying that the relationship between credit rationing and risk-based capital requirements derived here may persist.

My analysis has not explicitly considered the "leverage ratio," an important constraint on banks. It mandates that banks maintain a minimum ratio of the book value of equity to the book value of assets. This ratio, which applies to U.S. banks, is not required by the Basle capital rules, and is also not adjusted for any of the bank's risks (see Parry (1993)). This ratio constrains the bank to support an asset expansion with capital, even if that expansion were achieved through increased security holdings. However, this would also be true for asset expansions achieved through higher lending. And since the Basle ratios do not apply to security holdings, loans still require more capital at the margin than do securities. Consequently, the leverage ratio does not qualitatively change my results.

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[17] For example, if the value of the bank's off-balance sheet interest rate swaps exceeds 10 percent of its total assets, or 15 percent of the bank's fixed- and floating-rate loans and securities with maturities of 5 years or more exceeds 30 percent of total capital.

This exposes a weakness in the traditional way of thinking about monetary policy. In the standard macro model of the relationship between the money supply and bank lending, the binding constraint on banks is taken as the level of reserves needed to support a given deposit base; the capital constraint is assumed to be slack. In this case, an increase in the reserves available to banks always produces greater lending. What I show is that this is no longer true when the capital constraint is binding. In this case, an increase in reserves permits banks to accept more deposits and increase asset size, but it does not necessarily mean more lending. This is apparently what has happened in the United States during 1989–93.

It is interesting to compare my results with those in recent research on the effect of monetary policy on bank lending. Kashyap and Stein (1995) find evidence that business lending may respond to monetary policy tightening in that when policy is tightened, both total loans and business loans at small banks fall, while loans at large banks are unaffected. Morgan (1993) finds empirical evidence that monetary policy has asymmetric effects; tight monetary policy slows the economy more than easy monetary policy accelerates it. By contrast, my work shows that an easy monetary policy *could* have perverse effects. This also contrasts with Keeton's (1993) theoretical finding that banks' ability to hold securities may facilitate the spurring of bank lending through an easy monetary policy. In Keeton's analysis, easy monetary policy lowers open-market rates, thereby lowering banks' cost of funding loans through security sales or large CDs. While this effect is also present in my analysis (r is lowered), I show that an explicit consideration of equilibrium credit rationing with interbank competition for loans leads to the result that a greater money supply could reduce or increase bank lending. Some empirical support for my theory can be found in Morris and Sellon (1995), who find that a restrictive monetary policy does not seem to constrain business lending.

C. Implications of Other Comparative Statics

Numerical analysis is also helpful in determining the impact of changes in the other exogenous parameters of the model.

C.1. The Screening Cost

Figure 2 shows how the equilibrium changes as one increases the screening cost C. As long as the increase in C does not affect N^*, p increases as C rises. This is intuitive. An increase in C lowers a bank's net expected return from screening and therefore increases the probability of rationing. However, the borrower alters its choice of N^* as C increases sufficiently. The optimal number of banks approached by the borrower declines sharply as C increases, and this causes each bank to initially lower the rationing probability. Consequently, the overall probability that a borrower will be denied credit by all banks also falls at the point at which the borrower switches to a lower N^*.

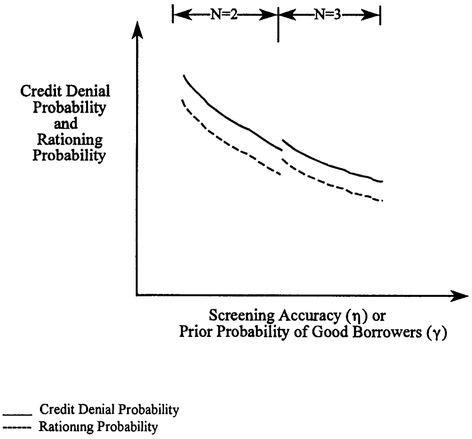

Figure 3. Behavior of equilibrium with respect to changes in screening accuracy (η) and the prior probability of good borrowers (γ). This figure shows how the equilibrium credit denial probability and the rationing probability change as one increases the screening accuracy or the prior probability of good borrowers. The behaviors of these two probabilities are depicted for two values of the number of banks approached for credit, $N^* = 2$ and $N^* = 3$. There are discontinuities in both graphs as the borrower optimally switches from two to three banks.

C.2. Noise in Screening

Screening becomes less noisy as η increases. Figure 3 indicates the impact of this on the equilibrium. As η increases, the rationing probability for an individual bank declines, holding fixed the number of banks approached. This is intuitive. An increase in η means a lower likelihood that the bank will inadvertently lend to L, and hence a greater marginal benefit from screening. As η increases sufficiently, the borrower adjusts by increasing N^*, even though this raises the probability of being rationed by a particular bank, as well as the probability of credit denial by all banks.

C.3. The Fraction of Creditworthy Borrowers

An increase in γ means that it is more likely that a randomly chosen borrower is creditworthy (G). Figure 3 shows how this affects the equilibrium. Initially, an increase in γ leaves N^* unchanged, but lowers each bank's rationing probability. This is intuitive. A greater likelihood of encountering G increases the bank's expected return from screening and hence reduces the rationing probability. Thus, the overall probability of being denied credit by the entire banking system also declines for the borrower as γ rises. As γ increases sufficiently, the borrower adjusts by approaching more banks. This causes the rationing probability to rise for each bank, and the overall probability of being rationed out of the whole banking system to rise as well.

D. Implications of International Cost of Capital Differences

Consider two countries with different costs of capital in banking, induced possibly by differences in government economic policy including bank regulation. Suppose country A (which could be the U.S.) has a higher cost of capital in banking than country B (which could be Germany or Japan). Then, the impact of an increase in risk-adjusted capital requirements will be greater in country A than in country B. That is, r_{L} in country A will increase more than that in country B when the risk-adjusted capital requirement is increased in both countries.[18] Consequently, there will be a greater stochastic decline in bank lending in country A. This points to the hazards in harmonizing bank capital regulation across countries with different costs of banking capital. More research is needed on this issue.

IV. Robustness of the Analysis

Next, I discuss numerous aspects of the robustness of my conclusions.

Demand Effects

An increase in the capital requirement attached to bank loans will increase the loan interest rate charged by a competitive bank. In my model, this causes no demand shifts because borrowers have no alternative credit sources. However, what if the loan demand curve is downward sloping? For instance, we can imagine that the G's have varying reservation prices for bank loans due to alternative sources with varying credit costs. In this case, a higher r_L will likely cause some Gs to drop out, but none of the Ls. The reason is that L never repays anything, so its demand is insensitive to the loan interest rate. Thus, an increase in r_{L} precipitates a decline in the average creditworthiness of the borrower pool, i.e., a decline in γ. The result is less bank lending. This is even true if L was not a lemon, but simply less creditworthy than G. Stiglitz and Weiss (1981) have shown that loan interest rate increases cause adverse selection in a fairly general setting. This means that if demand was sensitive to the loan price, my results are likely to be strengthened.

Credit Rationing Avoidance Mechanisms

Consider a borrower that approaches N banks and is rejected by all. One could think of many ways that the borrower could try to avoid rationing. One way is to offer to pay a higher rate. Such a borrower has an obvious incentive to offer to pay these banks a higher interest rate to obtain credit. Although the extensive form of the game I have studied does not permit that, it is easy to see that altering the extensive form to allow this would not change the economic intuition much. The reason is that each bank knows whether it screened and what it found if it did. A bank that did not screen must consider the information conveyed by the fact that $N - 1$ other banks denied credit. Thus, even if the borrower offers to pay r_L, the posterior beliefs of the bank about the borrower's type will be so heavily skewed toward L that the bank it may find it unprofitable to lend. All that this needs is an additional parametric restriction about the informativeness of multiple signals. Of course, if the bank screened and found $\phi = \mathrm{L}$, it will always refrain from lending. Thus, the additional complexity from permitting the borrower to react to the bank's credit decision does not appear warranted.

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[18] To see this, suppose r_E^A is the cost of bank equity capital in country A and r_E^B is the cost of bank equity capital in country B. Let the capital requirement mandate that a dollar of loans must be financed with at least $\$\beta$ of bank capital. Then, $r_{\mathrm{L}}^i = \beta r_E^i + [1 - \beta]r$, $i \in \{A,B\}$, and $\partial r_{\mathrm{L}}^A / \partial \beta = r_E^A$, $\partial r_{\mathrm{L}}^B / \partial \beta = r_E^B$, so that $r_E^A > r_E^B$ implies that $\partial r_{\mathrm{L}}^A / \partial \beta > \partial r_{\mathrm{L}}^B / \partial \beta$.

Another possibility is for the borrower to offer to pay banks in advance (at the time of applying) for screening. A problem is that the borrower may lack the liquidity to do this; note that more than one bank will have to be paid for there to be a positive probability that the borrower will receive a competitive price. To circumvent this, the borrower could precommit to an interest rate with the bank, conditional on the bank lending, that embeds the cost of screening. This would enable the bank to recoup the screening cost in the competitive state, so as to reduce the rationing probability. Since we have assumed that the bank can precommit to a rate schedule, conditional on lending, symmetry in precommitments suggests that we should permit the borrower to precommit to a rate schedule, *conditional* on borrowing. This schedule would be designed to compensate the bank for C. However, since the borrower cannot be bound to borrow—just like the bank cannot be bound to lend—interbank competition will unravel this scheme because a borrower faced with multiple banks willing to lend will wish to invite them to bid. Since the borrower must abide by the precommited rate schedule only if it borrows from the bank, the borrower can coax the bank to renegotiate by threatening to borrow from a competitor. Thus, the initial precommitment is not subgame perfect, and lacks ex ante credibility.

Sequential Credit Application

The effect of this is similar to that discussed above. Any bank approached by the borrower after it is initially rejected by a group of banks must take into account the information conveyed by N credit denials. This information is likely to be sufficiently adverse to discourage lending by any bank.

Effect of Bank Monitoring on Borrower Returns

I have assumed that the borrower's project return in the successful state, R, is increasing in the number of lenders. There are two reasonable ways to alter this assumption. One is to assume instead that R is independent of the number of monitoring banks. The only effect this has on the results is that the borrower now optimally chooses to apply to only two banks. Moreover, there would be no benefit to splitting the loan across these two banks, should they both decide to lend. Thus, randomizing with equal probabilities across the two lenders would be equivalent to splitting the loan fifty-fifty. All of the principal results are qualitatively unchanged. The advantage of assuming that R is increasing in N is that it leaves open the possibility of each borrower approaching more than two banks. The other way to alter this assumption is to assume that δ is increasing in the number of monitoring banks. This reduces the rationing probability ceteris paribus, as the number of lenders increases. This effect opposes the upward pressure on the rationing probability due to the competition effect. Consequently, the rationing probability will be lower and the borrower will approach more banks than in our present model. However, my main results will be qualitatively sustained.

Continuum of Types

Instead of two types of borrowers, suppose that we have a continuum of types.[19] That is, suppose the success probabilities of the G borrowers lie in a continuum $[\delta^-, \delta^+] \subset (0, 1)$ such that even a borrower with $\delta = \delta^-$ is creditworthy. Suppose that, regardless of the borrower's δ, the signal ϕ still tells the bank only whether the borrower is G or L, and

$$\Pr(\phi = \mathrm{G} \mid \mathrm{G} \text{ of type } \delta) = \eta(\delta) \in (0.5, 1), \quad \delta \in [\delta^-, \delta^+] \quad \text{with} \quad \partial\eta/\partial\delta > 0.$$

Then, $\Pr(\phi = \mathrm{G} \mid \mathrm{G}) \equiv \bar{\eta} = \int_{\delta^-}^{\delta^+} \eta(\delta) F(d\delta)$, where $F(\cdot)$ is the cumulative distribution function over possible δ's. We can then write

$$\Pr(\phi = \mathrm{L} \mid \mathrm{G} \text{ of type } \delta) = 1 - \eta(\delta)$$

and

$$\Pr(\phi = \mathrm{L} \mid \mathrm{G}) = \Pr(\phi = \mathrm{G} \mid \mathrm{L}) = 1 - \bar{\eta}.$$

Now higher δ types will face a lower probability of rationing, but all borrowers granted credit by the same number of banks will face identical interest rates. The other results will be qualitatively sustained as well (with the conjecture that all borrowers will choose the same N^*).

What will happen with sequential credit applications? Since the credit denial probability is higher for lower δ types, it will still be true that any bank approached by a borrower rejected by N banks will account for the adverse information conveyed by N credit denials and deny credit.

Observability of Number of Banks Approached

A seemingly strong informational assumption I make is that each bank approached by the borrower knows the number of other banks the borrower has approached as well as the number of banks that have agreed to lend to it. Why can the borrower not take this evidence and present it to other banks (even those that have not screened the borrower) and convince them to lend?

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[19] I thank René Stulz for suggesting that I examine this aspect of the robustness of the model, and the referee and René Stulz for suggestions regarding the empirical tests reported later.

The answer is that the borrower has an obvious incentive to exaggerate the number of banks willing to lend to it. For credibility, it will need to obtain certification from the banks that agree to lend, and these banks have no incentive to certify.

But suppose that credible certification was possible. Ironically, this worsens the problem for the borrower. The reason is that all the banks initially approached by the borrower will *anticipate* that *other* banks will free-ride on their costly screening of the borrower, and since the borrower can approach an arbitrarily large number of these other banks, the screening banks are very likely to lose the borrower's business. Consequently, no bank will screen, and the borrower will be rationed almost surely.

A possible solution is to permit banks to observe N only noisily. However, this makes the problem worse for the borrower than if N were noiselessly observed. The reason is that the noise in N reduces each bank's expected return from screening and therefore increases the rationing probability.[20]

V. Empirical Analysis

In this section I examine the empirical relevance of my results. I draw on the existing empirical evidence as well as provide new evidence.

A. Existing Empirical Evidence

Multiple Banks and Credit Rationing

My result that the borrower approaches multiple banks ($N = 2$ or 3 mostly) is consistent with Hellwig's (1990) observation that borrowers typically deal with multiple banks and with the Petersen and Rajan (1994) evidence that small firms borrow from 1.3 to 1.4 banks on average. Moreover, my result that the rationing probability increases with the number of lenders approached is supported by the Petersen - Rajan finding that firms with more lenders are more likely to be rationed, although they interpret their evidence differently.

Capital Rationing and Capital Requirements

Proposition 6 asserts that higher capital requirements lead to more rationing. There is considerable empirical support for this result. For example, a survey by Arthur Anderson Enterprise Group and National Small Business United found that the percentage of small business loan applicants who reported "problems obtaining bank loans" was higher for April 1992–April 1993 than for April 1991–April 1992; the figure was 68 percent in the 1993 survey and 52 percent in the 1992 survey. A more careful study by Jacklin

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[20] I suspect that in practice this issue is resolved by the fact that the borrower develops relationships with a group of banks that it approaches routinely for credit. This number—which is 7 to 8 banks on average for Fortune 500 U.S. companies—is well known, and these banks then compete with each other for the borrower's business.

Table I

Average Shares of Bank Credit in Selected Quarters (in Percent)

This table is constructed from data in Hancock, Laing and Wilcox (1994). It shows the percentage of total credit in each of five different categories that was accounted for by banks during different quarters in 1986, 1989, and 1993.

Bank Credit	1986:Q1	1989:Q3	1993:Q3
Commercial and industrial (C&I) loans	21.6	19.7	15.0
Single-family real estate loans	12.1	14.9	17.5
Commercial real estate loans	12.5	16.4	16.3
Consumer loans	16.7	15.7	13.9
Other loans	9.7	6.6	4.8

(1993) explicitly attempted to sort out whether the reduced lending reflected lower credit demand or curtailed credit supply, and concluded in favor of the latter. For the 1990–92 period it found a reduction in banks' investments in assets requiring risk-based capital. For the 1989–92 period it found tentative support for the hypothesis that banks have been increasing their interest rate exposure. Moreover, Bauhmol (1993) reports that while commercial and industrial (C&I) loans at banks declined by $30 billion during 1989–92 (see Figure 1), lending by non-bank lenders—who were not subject to the risk-based capital requirements facing banks—grew. For example, loans by life insurance companies increased by $50 billion between 1990 and 1992.

Screening Accuracy and Credit Rationing

In Section III *C*, I discussed the implication of screening noise for credit rationing. A reduction in screening noise (or improvement in screening accuracy) lowers the rationing probability, so it follows that when banks contract their lending—say due to an increase in risk-based capital requirements—the borrowers more likely to be rationed are those for whom credit screening is more noisy. Since screening is typically more noisy for more information-sensitive assets, the prediction is that banks' holdings of these assets will decline more than their holdings of other assets, even if risk-based capital requirements increase identically for assets of different information sensitivities. A recent empirical study by Hancock, Laing, and Wilcox (1994) supports this prediction; see Table I. C&I and consumer loans, which are information-sensitive and involve noisy screening, experienced a decline between 1986 and 1993, whereas real estate loans, which are "commodity products," experienced an increase during the same time period. Moreover, small banks, which typically lend to small firms, cut their lending the most during the last recession (see also Kashyap and Stein (1995)). Since small firms are likely to be less well known and more difficult to evaluate, this evidence is also consistent with the model's prediction that noisier screening leads to higher rationing.

B. New Empirical Evidence

The Predictions to be Tested

I confront two of the predictions of my theory with the data. The first is that the announcement that a lender has agreed to lend to a borrower should evoke an abnormally positive reaction in the borrower's stock price, and the second is that this reaction should be greater the more capital-constrained the lender (Corollary 1).

The Sample

The U.S. Securities and Exchange Commission (SEC) requires publicly-traded firms to disclose all financing agreements in their 10K and 10Q filings if the financing amounts to more than 10 percent of the firm's capitalization. Loan commitments are considered material information to investors and are thus treated as any other financing arrangement, even when undrawn.[21] Moreover, banks are required to post capital against commitments with maturities exceeding one year. Of course, even for commitments of shorter maturity, the bank must *plan* to allocate capital against the contingency that the borrower may take down the commitment. I focus on loan commitments because over 80 percent of all commercial lending in the United States is done via loan commitments.

An initial sample consisting of 2,307 new loan commitment contracts is assembled from the 1989 and 1990 SEC filings of all firms with common equity traded on the New York Stock Exchange (NYSE), the American Stock Exchange (AMEX), and the National Association of Securities Dealers Automated Quotations system (Nasdaq). Since 10K reports are due 90 days after the close of the fiscal year, the sample includes several commitments acquired in the final quarter of 1988 but not filed with SEC until 1989; for the same reason, some commitments purchased in the last quarter of 1990 may be excluded. Nevertheless, this sample represents substantially all loan commitment contracts purchased by these firms over the two-year period.

Moody's Bank and Finance Manual is used to obtain information regarding the Tier-1 capital and total assets for the end of the year in which the loan commitment purchase was announced. Data from the Center for Research in Security Prices (CRSP) are used to obtain the size of each firm in the sample, the equally-weighted market index return, and the stock return for each firm.

The restrictions imposed on the sample are that: i) an event date for the commitment— defined as the earlier of the day of the first news story listed in *Lotus One Source CD/Corporate* or the day of the filing of an 8K report disclosing the commitment contract—could be determined, ii) the borrower's common stock was listed 200 trading days prior to the event date and remains listed throughout the period ending 30 trading days after the event date, iii) there were no capital structure or asset structure changes within a two-day window around the event, iv) the contract filed with the SEC represents an increase in the amount of loans available to the particular firm under commitment, so that the firms in the sample are increasing their borrowing rather than simply renegotiating old commitments, and v) capital and asset information about the financial intermediary providing the loan commitment could be obtained from *Moody's Bank and Finance Manual.*

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[21] Bhattacharya and Thakor (1993) review the loan commitment literature. Houston and Venkataraman (1994) model the borrower's choice between loan commitments and other debt; Shockley (1995) provides empirical evidence.

This yields a final sample of 161 firms. The firms in the sample range in size (equity market value one month prior to announcement) from \$2,693,910 to \$36,892,008,000.

Methodology

A market-model event study methodology is used. The ordinary-least-squares coefficients of the market-model regression are estimated over the period $t = -200$ days to $t = -60$ days. The daily abnormal stock return, calculated for each firm i, is averaged for the M firms to obtain the following average abnormal return on day t

$$AR_t = \frac{1}{M} \sum_{i=1}^{M} [R_{it} - \hat{a}_i - \hat{b}_i R_{mt}] \tag{10}$$

where R_{it} is the return for the common stock of firm i on day t, R_{mt} is the return for the CRSP equally-weighted marked index on day t, and $\hat{a}_i$ and $\hat{b}_i$ are the ordinary-least-squares estimates of the market-model parameters. This procedure is followed for a 2-day period, $t = -1$ days to $t = 0$ day (where $t = 0$ denotes the announcement day), to determine the cumulative average abnormal return (CAR).

Further, to deal with heteroskedasticity problems, the average abnormal return for each firm is standardized to obtain the *Average Standardized Abnormal Return* (ASAR)

$$\text{ASAR}_{it} = \frac{R_{it} - \hat{a}_i - \hat{b}_i R_{mt}}{S_{it}} \tag{11}$$

where

$$S_{it} = \left[S_i^2 \left[1 + \frac{1}{\text{L}} + \frac{(R_{mt} - \bar{R}_m)^2}{\sum_{k=1}^{L} (R_{mk} - \bar{R}_m)^2} \right] \right]^{1/2}. \tag{12}$$

S_i^2 is the residual variance for firm i from the market-model regression, L is the number of observations during the estimation period, R_{mk} is the return on the market portfolio for the kth day of the estimation period, R_{mt} is the return on the market portfolio for day t, and $\bar{R}_m$ is the average return of the market portfolio for the estimation period. Next the ASAR_{it} is summed for a 2-day period, $t = -1$ to $t = 0$, to determine the *Average Standardized Cumulative Abnormal Return* (ASCAR):

$$\text{ASCAR}_{(-1,0)i} = \sum_{t=-1}^{t=0} \text{ASAR}_{it} \tag{13}$$

which is used in the cross-sectional regressions. To test the prediction that a commitment by an intermediary to lend should evoke an abnormal price appreciation in the borrower's equity, I examine whether the ASCAR in equation (13) is statistically significantly different from zero.

The next issue is to test the prediction that the two-day ASCAR is greater the more capital-constrained the lender. In my model, all loans are of the same size, so a lender's capital ratio adequately represents its existing capital-constraint. However, loan commitment sizes vary greatly in my sample, so that I need to account for the fact that a loan commitment that is large relative to a lender's capital may, ceteris paribus, cause the lender to feel more capital-constrained than a smaller commitment would. Thus, I need to deal with capital constraints along two dimensions—the ratio of capital to total assets and the ratio of the loan commitment size to capital.

To do this, I partition firms into two groups, those with loan commitments from the most capital-constrained lenders and those commitments from the least-capital-constrained lenders, where a higher *capital ratio* (tier-1 capital/total assets) represents a lesser capital constraint. Next, I partition firms into quartiles based on the *commitment-size* ratio, which is the ratio of loan commitment size to tier-1 capital.[22] Once these divisions are done, dummy variables are created for the commitment-size ratio quartiles, and stepwise regressions are run for both capital ratio groups. The ASCAR from equation (13) is then used in the following regression:

$$\text{ASCAR}_{(-1,0)i} = \beta_1 L_i + \beta_2 M_i + \beta_3 U_i + \beta_4 H_i + \beta_5 \text{LSize}_i + \epsilon_i \tag{14}$$

where the βs are regression coefficients, ϵ_i is a mean-zero error term, L_i is 1 if the firm's commitment-size-ratio is in the lowest 25 percent and 0 otherwise, M_i is 1 if the firm's commitment-size ratio is in the second-lowest 25 percent and 0 otherwise, U_i is 1 if the firm's commitment-size ratio is in the second-highest 25 percent and 0 otherwise, H_i is 1 if the firm's commitment-size ratio is in the highest 25 percent and 0 otherwise, and LSize_i is the residual error from the regression of the log of firm size on the commitment-size ratio. I use borrower firm size to capture possible size effects; the residual error from the regression of the log of firm size versus the commitment-size ratio is used to avoid multicollinearity problems arising from the correlation between log firm size and loan commitment size. Note that I have not used a proxy for firm

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[22] I use tier-1 capital because it approximates the definition of capital in my model more closely than total capital does. See Greenbaum and Thakor (1995) for capital definitions.

Table II

Two-Day Average Standardized Abnormal Returns (ASARs) and Average Standardized Cumulative Abnormal Returns (ASCARs) for Loan Commitments

This table provides the two-day ASARs and ASCARs for firms that purchased loan commitments. Day −1 is the day immediately prior to the announcement day and Day 0 is the announcement day. Under each ASAR and ASCAR is the *z*-statistic for that abnormal return, along with its significance.

Day	ASAR	ASCAR
−1	0.007	0.007
	[2.692***]	[2.692***]
0	0.012	0.019
	[6.687***]	[6.626***]

*** Significant at the 1 percent level.

quality in the above regression. My choices were to use either the commitment interest rate or the firm's bond rating. Unfortunately, the commitment interest rate is an inappropriate proxy because commitments tend to have a multidimensional pricing structure (see Shockley and Thakor (1995)), and bond ratings are unavailable for 106 firms in my sample; therefore, using ratings would have severely restricted my sample size.

The Results

In Table II, I present the ASARs and ASCARs for the two-day time window represented by the day before the announcement and the day of the announcement. *Z* statistics are in brackets below the abnormal returns. As is apparent, both the ASARs and the ASCARs are statistically significantly different from zero at the 99 percent confidence level.

To provide a perspective on what happens during a longer time window around the announcement date, in Figure 4 I have provided graphs of the 21-day ASARs and ASCARs. This longer time window starts 10 days prior to the announcement date and ends 10 days after. As is transparent, the largest movement is around the announcement date.

Next, I partition firms into two groups, those that purchased loan commitments from the most-capital-constrained lenders and those that purchased loan commitments from the least-capital-constrained lenders. The cutoff is such that the most-capital-constrained lenders had capital ratios below 4.7984 percent and the least-capital-constrained lenders had capital ratios above 4.7984 percent. Table III provides information about the average commitment-size ratio for each of quartiles based on this ratio for both groups of firms.

In Table IV, I report the results from my estimation of the regression equation (14). In addition, I also divide firms into three groups based on the commitment-size ratio and estimate the corresponding version of equation (14)

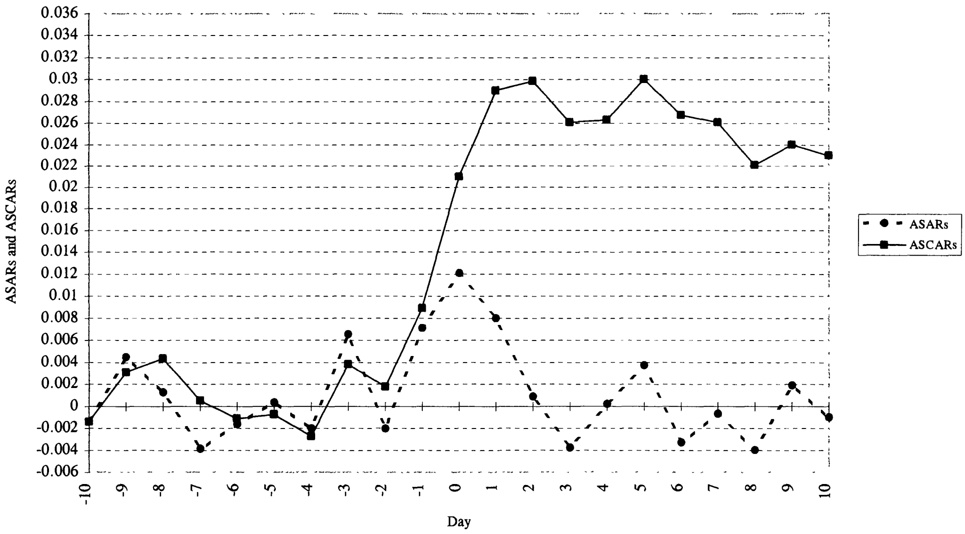

Figure 4. 21-day average standardized abnormal returns (ASARs) and average standardized cumulative abnormal returns (ASCARs) of loan commitments. This figure shows how the ASARs and ASCARs change through time for the firms that purchased loan commitments. Day 0 is the day of the loan commitment purchase announcement. Thus, the time window in this graph starts 10 days prior to the announcement and ends 10 days after. For days close to the announcement day, both the ASARs and the ASCARs are statistically significantly different from zero (data on significance of each abnormal return available from the author upon request).

for the most- and least-capital-constrained lenders, where the three groups are the bottom 25 percent, the middle 50 percent, and the top 25 percent. These results are reported in Table V. In both tables the regression coefficients (βs) associated with the dummy variables represent the mean ASCARs for the firms in the different groups.

Consider Table V first. Consistent with the theory, the ASCARs are increasing in the commitment-size ratio for firms that purchased their commitments from the most-capital-constrained lenders. Somewhat surprisingly, the ASCARs are positively related to firm size; however, this relationship is not statistically significant. The results are not as strong for firms that purchased their loan commitments from the least-capital-constrained lenders. There is no longer a monotonic relationship between the ASCARs and the commitment-size ratio. Although the size variable has the expected sign—the announcement effect is larger for the smaller firms—it is not statistically significant.

Now consider Table IV. For the firms that purchased their loan commitments from the most-capital-constrained banks, the ASCARs are positively dependent on the commitment-size ratio except for the U group. For the firms that purchased their loan commitments from the least-capital-constrained banks, there is no discernible monotonicity. The signs and statistical significance of the size variable are similar to those in Table V.

Table III

Commitment-Size Ratios

This table provides information about commitment-size ratios, defined as the average ratio of loan commitment size purchased by the borrower to the tier-1 capital of the commitment seller. Panel A of the table presents this information for firms that purchased commitments from the most-capital-constrained lenders, and Panel B presents this information for firms that purchased commitments from the least-capital-constrained lenders.

Quartile	Average Ratio of Loan Commitment Size to Tier-1 Capital	Range of Ratios
Panel A. Firms With Most-Capital-Constrained Lenders		
Lowest 25%	0.003919	[0.003919, 0.008513]
Lower middle 25%	0.018889	[0.008716, 0.037163]
Upper middle 25%	0.065276	[0.038595, 0.100722]
Highest 25%	0.755199	[0.103827, 6.682705]
Panel B. Firms With Least-Capital-Constrained Lenders		
Lowest 25%	0.005849	[0.000661, 0.012133]
Lower middle 25%	0.026278	[0.012433, 0.041854]
Upper middle 25%	0.08451	[0.043048, 0.1327]
Highest 25%	0.904714	[0.134807, 11.01322]

I tentatively conclude from Tables IV and V that the ASCARs are positively related to the commitment-size ratio for firms that borrow from the most-capital-constrained lenders, although for firms *within* the middle 50 percent based on the commitment-size ratio, the monotonicity does not appear to hold. It is difficult to say much about firms that purchase commitments from the least-capital-constrained lenders. This is consistent with the theory. Only if the lender is sufficiently capital-constrained as measured by the capital ratio is the ASCAR positively related to the commitment-size ratio. That is, *both* the capital ratio and the commitment-size ratio appear to affect the lender's capital constraint.

A more precise test would be to examine whether the ASCARs in the different commitment-size ratio quartiles are statistically significantly greater for the firms purchasing commitments from the most-capital-constrained lenders than for the firms purchasing them from the least-capital-constrained lenders. The results of these one-tailed tests are reported in Tables VI and VII. In each table, the bolded numbers represent the ASCAR pairs for which the theory has an unambiguous prediction. Consider the bolded numbers in Table VII first. Except for the two pairs in the middle column, the differences in ASCARs across the most- and least-capital-constrained lenders are positive and statistically significant as the theory predicts. Moreover, the theory also predicts that the largest difference in ASCARs should be between the firms purchasing the largest loan commitments (the highest 25 percent based on the commitment-size ratio) from the most-capital-constrained lenders, and those

Table IV

Estimation of Average Standardized Cumulative Abnormal Returns (ASCARs) by Quartiles Based on the Commitment Size Ratio

This part of the table presents results from the regression of the ASCARs for firms with loan commitments from the most-capital-constrained lenders on LSize (the residual error from the regression of the log of firm size on the commitment-size ratio) and dummy variables for the quartiles based on the commitment-size ratio. The regression equation is:

$$\text{ASCAR}_{(-1,0)} = \beta_1 \text{L} + \beta_2 M + \beta_3 U + \beta_4 H + \beta_5 \text{LSize} + \epsilon$$

where $L = 1$ if firm's ratio of loan commitment to Tier-1 capital is in the lowest quartile (0%–25%) and $L = 0$ otherwise,
$M = 1$ if firm's ratio of loan commitment to Tier-1 capital is in the next quartile (25%–50%) and $M = 0$ otherwise,
$U = 1$ if firm's ratio of loan commitment to Tier-1 capital is in the next quartile (50%–75%) and $U = 0$ otherwise,
$H = 1$ if firm's ratio of loan commitment to Tier-1 capital is in the highest quartile (75%–100%) and $H = 0$ otherwise,
and the β_is are regression coefficients and ε is a mean-zero error term.

Variable	Parameter Estimate	t-stat	Prob > $\|T\|$	R^2	N
L	0.6278	0.9170	0.3621	0.1643	79
M	1.3477	2.0000	0.0491		
U	0.0788	0.1240	0.9019		
H	1.8557	2.9210	0.0046		
Lsize	0.0744	0.3570	0.7223		

This part of the table presents results from the regression of the ASCARs for firms with loan commitments from the least-capital-constrained lenders on LSize (the residual error from the regression of the log of firm size on the commitment-size ratio) and dummy variables for the quartiles based on the commitment-size ratio. The regression equation is:

$$\text{ASCAR}_{(-1,0)} = \beta_1 \text{L} + \beta_2 M + \beta_3 U + \beta_4 H + \beta_5 \text{LSize} + \epsilon$$

where the L, M, and H dummies, the β_is, and ε are as defined above.

Variable	Parameter Estimate	t-stat	Prob > $\|T\|$	R^2	N
L	−0.2764	−0.5100	0.6117	0.1194	82
M	0.8779	1.6810	0.0968		
U	1.5950	2.7850	0.0067		
H	0.2448	0.4170	0.6777		
Lsize	−0.1781	−1.0940	0.2772		

purchasing the smallest loan commitments (the lowest 25 percent based on the commitment size ratio) from the least-capital-constrained lenders. Table VII shows that this is indeed true. Along the same lines, the theory predicts that the difference between the ASCARs of firms purchasing the largest loan commitments from the most-capital-constrained lenders and those purchasing the smallest loan commitments from the least-capital-constrained lenders should be greater than the difference between the ASCARs of firms purchasing the largest and smallest loan commitments from the least-capital-constrained lenders. As Table VII notes, this is true as well. The results in Table VI are

Table V

Estimation of Average Standardized Cumulative Abnormal Returns (ASCARs) by Firms Divided Into Three Groups Based on the Commitment Size Ratio

This part of the table presents results from the regression of the ASCARs for firms with loan commitments from the most-capital-constrained lenders on LSize (the residual error from the log of firm size on the commitment-size ratio) and dummy variables for the groups based on the commitment-size ratio (lowest 25%, middle 50%, and highest 25%). The regression equation is:

$$\text{ASCAR}_{(-1,0)} = \beta_1 L + \beta_2 M + \beta_3 H + \beta_4 \text{LSize} + \epsilon$$

where $L = 1$ if firm's ratio of loan commitment to Tier 1 capital is in the lowest quartile (0%–25%) and $L = 0$ otherwise,
$M = 1$ if firm's ratio of loan commitment to Tier 1 capital is in the middle 50% (25%–75%) and $M = 0$ otherwise,
$H = 1$ if firm's ratio of loan commitment to Tier 1 capital is in the highest quartile (75%–100%) and $H = 0$ otherwise,
and the β_is are regression coefficients and ϵ is a mean-zero error term.

Variable	Parameter Estimate	t-stat	Prob > $\|T\|$	R^2	N
L	0.5353	0.7810	0.4374	0.1422	79
M	0.6758	1.4210	0.1596		
H	1.9029	2.9810	0.0039		
Lsize	0.0094	0.0460	0.9635		

This part of the table presents results from the regression of the ASCARs for firms with loan commitments from the least-capital-constrained lenders on LSize (the residual error from the log of firm size on the commitment-size ratio) and dummy variables for the groups based on the commitment-size ratio (lowest 25%, middle 50%, and highest 25%). The regression equation is:

$$\text{ASCAR}_{(-1,0)} = \beta_1 L + \beta_2 M + \beta_3 H + \beta_4 \text{LSize} + \epsilon$$

where the L, M, and H dummies, the β_is and ϵ are as defined above.

Variable	Parameter Estimate	t-stat	Prob > $\|T\|$	R^2	N
L	−0.2288	−0.4240	0.6726	0.1094	82
M	1.2027	3.0850	0.0028		
H	0.1706	0.2940	0.7698		
Lsize	−0.1367	−0.8740	0.3849		

comparable to those in Table VII. Once again, firms borrowing from the least-capital-constrained lenders that are in the middle 50 percent of firms based on the commitment-size ratio fall in a group where the results are not strong.

My overall conclusion is that these tests provide support for the theory in the following ways:

(i) There is a statistically significant positive abnormal return for the borrowing firm associated with the announcement of a loan commitment purchase.

Table VI

Market Model 2-Day Average Standardized Cumulative Abnormal Return (ASCAR) Difference of Means Comparisons Between the Most- and Least-Capital-Constrained Lenders for the Four Quartiles Based on the Commitment Size Ratio

This table presents results on whether the mean ASCARs of firms that purchase commitments from the most-capital-constrained lenders are higher than the mean ASCARs of firms that purchase commitments from the least-capital-constrained lenders, and whether this difference is larger as one increases the commitment-size ratio of firms linked with the most-capital-constrained lenders and decreases it for firms linked with the least-capital-constrained lenders. *t*-statistics are in parentheses. Tests are one-tailed, i.e., they test whether the most-capital-constrained means are larger than the least-capital-constrained means. As an example of how to read this table, note that the fourth number in the first column indicates that 2.1321 percent is the difference between the mean ASCAR of the highest 25 percent commitment-size ratio firms that borrowed from the most-capital-constrained lenders and the mean ASCAR of the lowest 25 percent commitment-size ratio firms that borrowed from the least-capital-constrained firms. The theory predicts that the bolded numbers should be positive. I also test whether the difference in mean ASCARs between the highest-commitment-size ratio firms in the most-capital-constrained group and the lowest-commitment-size ratio firms in the least-capital-constrained group is significantly different from the difference between the highest- and lowest-commitment-size ratio firms in the least-capital-constrained group. This difference between ASCAR differences = 2.6534 (2.67***).

		Least-Capital-Constrained			
		Lowest 25%	Next 25% (25%–50%)	Next 25% (50%–75%)	Highest 25%
Most-Capital-Contrained	Lowest 25%	**0.9042**	−0.2501	−0.9673	0.3830
		(2.24)**	(0.35)	(−1.33)	(0.93)
	Next 25% (25%–50%)	**−0.5080**	**1.6241**	0.4699	−0.2473
		(−2.60)	**(0.55)**	(−0.28)	(−1.75)
	Next 50% (50%–75%)	**0.3552**	**−0.7991**	**−1.5163**	−0.1660
		(0.83)	**(−1.09)**	**(−2.05)**	(−0.38)
	Highest 25%	**2.1321**	**0.9779**	**0.2607**	**1.6109**
		(2.14)**	**(0.84)**	**(0.22)**	**(1.61*)**

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

(ii) This announcement effect is the strongest for the largest loan commitments sold by the most-capital-constrained lenders. Generally, both the size of the loan commitment and the Tier-1 capital of the lender appear to be important determinants of the lender's capital constraint. The empirical relationship between the announcement effect for the borrower and the capital constraint of the lender seems to be the strongest when comparing firms whose loan commitment sizes are sufficiently different and who purchase these commitments from lenders with sufficiently low capital ratios.

Table VII

Market Model 2-Day Average Standardized Cumulative Abnormal Return (ASCAR) Difference of Means Comparisons Between the Most- and Least-Capital-Constrained Banks for the Three Groups (Lowest 25%, Middle 50%, and Highest 25%) Based on the Commitment-Size Ratio

This table presents results on whether the mean ASCARs of firms that purchase commitments from the most-capital-constrained lenders are higher than the mean ASCARs of firms that purchase commitments from the least-capital-constrained lenders, and whether this difference is larger as one increases the commitment-size ratio of firms linked with the most-capital-constrained lenders and decreases it for firms linked with the least-capital-constrained lenders. t-statistics are in parentheses. Tests are one-tailed, i.e., they test whether the most-capital-constrained means are larger than the least-capital-constrained means. This table should be read in the same way as Table VI. The theory predicts that the bolded numbers should be positive. I also test whether the difference in mean ASCARs between the highest-commitment-size ratio firms in the most-capital-constrained group and the lowest-commitment-size ratio in the least-capital-constrained group is significantly different from the difference between the highest- and lowest-commitment-size ratio firms in the least-capital-constrained group. This difference between ASCAR differences = 2.5312 (2.54**).

		Least-Capital-Constrained		
		Lowest 25%	Middle 50% (25%–75%)	Highest 25%
Most-Capital-Constrained	Lowest 25%	**0.7642**	−0.6674	0.3648
		(1.87)**	(−1.2)	(0.89)
	Middle 50% (25%–75%)	**0.9046**	**−0.5269**	0.5052
		(2.05)**	**(−0.90)**	(1.14)
	Highest 25%	**2.1318**	**0.7002**	**1.7324**
		(2.13)**	**(0.66)**	**(1.73**)**

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

VI. Conclusion

I have explored the impact of risk-based capital-requirements on credit rationing with multiple competing banks, emphasizing the roles of the bank as a prelending screening agent and a postlending monitor. The analysis permits me to distinguish between credit rationing by an individual bank and that by the entire banking system, and focus on the link between the announcement effects associated with a borrower acquiring a promise of credit and the lender's capital constraint.

The main results are as follows. Every borrower approaches multiple banks for credit and stands a chance of being rationed by the entire banking system. Increases in risk-based capital requirements and regulatory subsidies stochastically reduce aggregate bank lending, and banking systems with higher costs of capital lend less and are more affected by increases in risk-based capital requirements. This does not say whether risk-based capital requirements are good or bad, since I have not considered why they are adopted in the first place. However, the results here may be useful to keep in mind as regulators attempt to achieve greater international harmonization of regulatory mandates for banks.

Two important testable predictions of the model are that the stock price of a borrower should experience an abnormal increase when it is announced that a bank has agreed to lend to it, and this increase should be greater the more capital-constrained the bank. These predictions are confronted with data on 161 loan commitments. The empirical results support these predictions.

The analysis also has implications for monetary policy and banking system design. In particular, it shows that when the capital requirement, rather than the reserve requirement, is the binding constraint for banks, an increased money supply could either increase bank lending or perversely reduce it, depending on the effect of the money supply increase on the term structure. Moreover, since these effects of capital requirements depend on the cost of capital in banking, it is important to grasp the differences between alternative banking systems that lead to cost-of-capital differences, as one contemplates the optimal design of banking systems in the former Communist-bloc countries.

Appendix

Proof of Proposition 1

Since all competing banks are identical, I will focus on a symmetric NE. Given that G chooses $N \geq 2$, L's equilibrium choice must be the same if any deviation from that N is met with credit denial by every bank. I will stipulate this as each bank's strategy. It costs no generality since G's choice is exogenously specified in this proposition.

It must be the case that, given that both G and L apply for credit and each borrower chooses $N \geq 2$, the equilibrium cannot involve each borrower being screened with probability 1. To see why, suppose counterfactually that every bank that a borrower approaches screens with probability 1. Then each bank that is screening the borrower knows that it will (almost) surely end up in a competitive bidding situation on the borrower. In this case, the standard Bertrand undercutting argument implies that the interest factor (one plus the loan interest rate), i, on the loan will be bid down to the level that leaves the bank indifferent between making the loan and investing in government securities. All banks that bid will eventually offer the borrower the same rate. This is the only competitive bidding outcome possible, given that banks initially quote only price ranges and the borrower returns to the banks to let them know how many banks agreed to extend credit and permit them each to quote a single interest factor conditional on that knowledge. Before deriving i explicitly, note that (1) ensures that a bank that observes $\phi = \mathrm{L}$ will not bid even if it needs to only specify a price range initially. This is because of a standard "winner's curse" argument. The bank's own signal is the best predictor of the signals other banks will receive, so that bidding on a borrower whose signal is $\phi = \mathrm{L}$ will impose expected losses on the bank; other banks are likely not to bid, so that it is likely that the bidding bank will end up with the borrower's business and consequently lose money. Thus, even in the multiple bank case, the borrower will receive bids only from banks that have observed $\phi = \mathrm{G}$. We now see that i solves

$$\Pr(\mathrm{G} \mid \langle \phi = \mathrm{G} \rangle_j,\ \langle \phi = \mathrm{L} \rangle_{N-j})[i\delta - r_{\mathrm{L}}] + \Pr(\mathrm{L} \mid \langle \phi = \mathrm{G} \rangle_j,\ \langle \phi = \mathrm{L} \rangle_{N-j})\,[-r_{\mathrm{L}}] = \alpha, \tag{A-1}$$

where $\langle \phi = \mathrm{G} \rangle_{\mathrm{j}}$ means that the signal $\phi = \mathrm{G}$ was recorded by j banks, i.e., there are j banks bidding. Similarly, $\langle \phi = \mathrm{L} \rangle_{\mathrm{N-j}}$ means that the signal $\phi = \mathrm{L}$ was recorded by $N - j$ banks. The first term on the LHS of equation (A-1) is the expected profit of the lending syndicate (I assume that every bank that bids i ends up making $1/j$ of the loan) if the borrower is G, multiplied by the conditional probability that the borrower is G. The second term on the LHS of (A-1) is the conditional probability that the borrower is L multiplied by the bank's loss of r_{L} on a lemon. Note that the conditioning is on the information conveyed by the fact that j out of N banks bid and the remaining banks did not. Thus,

$$i\,(j,\,N) = \frac{\alpha + r_{\mathrm{L}}}{\delta \Pr(\mathrm{G} \mid \langle \phi = \mathrm{G} \rangle_j,\ \langle \phi = \mathrm{L} \rangle_{N-j})}. \tag{A-2}$$

A bank's ex ante expected profit from screening can now be written as

$$\Pr(\phi = \mathrm{G})\left\{ E_{j-1}\left[\begin{array}{l} \Pr(\mathrm{G} \mid \phi = \mathrm{G},\ \langle \phi = \mathrm{G} \rangle_{j-1},\ \langle \phi = \mathrm{L} \rangle_{N-j})[\delta i\,(j) - r_{\mathrm{L}}] \\ \quad + \Pr(\mathrm{L} \mid \phi = \mathrm{G},\ \langle \phi = \mathrm{G} \rangle_{j-1},\ \langle \phi = \mathrm{L} \rangle_{N-j})[\,-\,r_{\mathrm{L}}] \end{array}\right]\right\} \tag{A-3}$$
$$+ \Pr(\phi = \mathrm{L})\alpha - C,$$

where $E_{j-1}(\cdot)$ is the expectation with respect to the random variable $j - 1$ representing the number of banks besides that in question which record $\phi = \mathrm{G}$ on the borrower. Note that equation (A-3) is not written to explicitly reflect the fact that the bank makes a loan of only \$$1/j$. This does not matter, however, since the bank earns an expected return of α on the loan, which is exactly what it earns on securities. Hence, the bank's rule for allocating its loanable funds across securities and loans is irrelevant when it is lending competitively. Also $\Pr(\mathrm{G} \mid \phi = \mathrm{G},\ \langle \phi = \mathrm{G} \rangle_{j-1},\ \langle \phi = \mathrm{L} \rangle_{N-j}) = \Pr(\mathrm{G} \mid \langle \phi = \mathrm{G} \rangle_j,\ \langle \phi = \mathrm{L} \rangle_{N-j})$. Using (A-1) and simplifying we can write (A-3) as

$$\Pr(\phi = \mathrm{G})\alpha + \Pr(\phi = \mathrm{L})\alpha - C = \alpha - C < \alpha.$$

Thus, no bank's expected profit from screening is as great as that from investing in securities, and no bank will screen. This contradicts our initial supposition that all banks will screen with probability 1.

It is also easy to see that the equilibrium cannot involve all banks always refusing to screen any borrower. If this were the case, one bank could break away and profitably screen the borrower because it would be assured of being a monopolistic lender.

The only remaining possibility is that each bank in a symmetric NE screens the borrower with some probability $1 - p \in (0,1)$, where p is the probability that the representative bank does *not* screen. To ensure $p \in (0,1)$, each bank must be indifferent between screening and not screening. The existence of a NE hinges on whether there exists such a p for any $N \geq 2$. To see that a p always exists, recall that the bank's expected profit on the loan (before netting out the screening cost) is α if the bank bids competitively and greater than $\alpha + C$ if it is a monopolist. With multiple banks, the relevant possibilities at the post-screening stage can be classified in two groups: (i) the bank will record $\phi = \text{G}$ on the borrower and be the only bank bidding for the borrower, and (ii) the bank will record $\phi = \text{G}$ and compete with at least one other bank that has also recorded $\phi = \text{G}$, or the bank will record $\phi = \text{L}$. With (i) the bank is a monopolist, and with (ii) it is a competitor. Hence, with multiple banks, the bank's expected profit is a weighted average of its monopoly and perfect competition expected profits. Let $\Psi(p(N))$ be the probability of (i) and $1 - \Psi(p(N))$ the probability of (ii), where $\Psi(\cdot)$ is a function of p, which in turn depends on N. For the equilibrium to exist, we must have

$$\Psi(p(N))\, b[\alpha + C] + [1 - \Psi(p(N))]\alpha = \alpha + C, \tag{A-4}$$

where b is some number greater than 1. It is transparent from (A-4) that $\Psi(p(N)) \in (0, 1)$, which in turn requires that $p(N) \in (0, 1)$. Moreover, it is always possible to find a $\Psi(p(N))$ for every N such that (A-4) is satisfied. Thus, a NE exists. □

Proof of Proposition 2

The probability that a borrower will be given credit is the probability that it will be screened multiplied by the probability that the screen will reveal $\phi = \text{G}$. The probability that G will be offered credit is thus $[1 - \text{p}]\eta$, and the probability that L will be offered credit is $[1 - p][1 - \eta]$. The result now follows from the informativeness of the signal, i.e., $\eta > 1 - \eta$. □

Proof of Proposition 3

As indicated in the Proof of Proposition 1, every bank approached by the borrower must be indifferent between screening and not screening in equilibrium. We thus need to compute the expected profit of a bank, *conditional* on having decided to screen, but prior to performing the screening. The bank (henceforth referred to as "my bank") recognizes that there are two possible outcomes of its screening: $\phi = \text{G}$ or $\phi = \text{L}$. The probabilities are

$$\Pr(\phi = \text{G}) = \Pr(\phi = \text{G} \mid \text{G})\Pr(\text{G}) + \Pr(\phi = \text{G} \mid \text{L})\Pr(\text{L}) = \eta\gamma + [1 - \eta][1 - \gamma] \tag{A-5}$$

and

$$\Pr(\phi = \mathrm{L}) = 1 - \eta\gamma - [1 - \eta][1 - \gamma]. \tag{A-6}$$

Now, my bank offers credit if $\phi = \mathrm{G}$ and declines if $\phi = \mathrm{L}$ (see the Proof of Proposition 1). In the latter case my bank invests in securities, so we can focus initially on $\phi = \mathrm{G}$. With $\phi = \mathrm{G}$, there are again two possibilities. One is that no other bank extends credit, which can happen either because no other bank screened the borrower or because no bank recorded $\phi = \mathrm{G}$, even though some of them screened. In this case my bank will be a monopolist. The other possibility is that one or more other banks offer credit, so that all banks price competitively.

Let $\Omega(\mathrm{G}, j, N)$ represent the event that j *other* banks offer credit when my bank has screened and recorded $\phi = \mathrm{G}$, and the borrower has approached N banks. Thus, $\Pr(\Omega(\mathrm{G}, j, N)) = \Pr(\phi = \mathrm{G}$ for my bank and j other banks out of the N approached offer credit). In each of the two cases indicated above (my bank is a monopolist and my bank is a competitor), there are two possibilities: the borrower is G or L. Thus, there are four possibilities associated with my bank recording $\phi = \mathrm{G}$, and the bank's expected profit from screening is:

$$\begin{aligned}
&\Pr(\Omega(\mathrm{G}, 0, N))\Pr(\mathrm{G} \mid \Omega(\mathrm{G}, 0, N))\,[\delta R - r_{\mathrm{L}}] \\
&\quad + \Pr(\Omega(\mathrm{G}, 0, N))\Pr(\mathrm{L} \mid \Omega(\mathrm{G}, 0, N))[-r_{\mathrm{L}}] \\
&\quad + \sum_{j=1}^{N-1} \Pr(\Omega(\mathrm{G}, j, N))\{\Pr(\mathrm{G} \mid \Omega(\mathrm{G}, j, N))[\delta i(j+1, N) - r_{\mathrm{L}}] \\
&\qquad\qquad + \Pr(\mathrm{L} \mid \Omega(\mathrm{G}, j, N))[-r_{\mathrm{L}}]\} \\
&\quad + \Pr(\phi = \mathrm{L})\alpha - C.
\end{aligned} \tag{A-7}$$

Note that the first two terms and the two terms within the summation from j = 1 to $N - 1$ in equation (A-7) represent the four possible outcomes when my bank records $\phi = \mathrm{G}$. The fifth term in equation (A-7) represents the outcome when my bank records $\phi = \mathrm{L}$. I define $i(j + 1, N)$ in a manner similar to equation (4), i.e.,

$$i(j + 1, N) = \frac{\alpha + r_{\mathrm{L}}}{\delta \Pr(\mathrm{G} \mid \Omega(\mathrm{G}, j, N))} \tag{A-8}$$

for each j. Observe now that equation (A-8) implies that for every j

$$\Pr(\mathrm{G} \mid \Omega(\mathrm{G}, j, N))[\delta i(j + 1, N) - r_{\mathrm{L}}] + \Pr(\mathrm{L} \mid \Omega(\mathrm{G}, j, N))[-r_{\mathrm{L}}] = \alpha. \tag{A-9}$$

Thus,

$$\sum_{j=1}^{N-1} \Pr(\Omega(G, j, N))\{\Pr(G \mid \Omega(G, j, N))[\delta i(j+1, N) - r_L] + \Pr(L \mid \Omega(G, j, N))[-r_L]\} = \sum_{j=1}^{N-1} \Pr(\Omega(G, j, N))\alpha. \tag{A-10}$$

Substituting equation (A-10) in (A-7) yields the bank's expected profit from screening as

$$\begin{aligned}&\Pr(\Omega(G, 0, N))\Pr(G \mid \Omega(G, 0, N))[\delta R - r_L] \\ &\quad + \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))[-r_L] + \sum_{j=1}^{N-1} \Pr(\Omega(G, j, N))\alpha \\ &\quad + \Pr(\phi = L)\alpha - C = \Pr(\Omega(G, 0, N))\Pr(G \mid \Omega(G, 0, N))[\delta R - r_L] \\ &\quad + \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))[-r_L] + \sum_{j=0}^{N-1} \Pr(\Omega(G, j, N))\alpha \\ &\qquad - \Pr(\Omega(G, 0, N))\alpha + \Pr(\phi = L)\alpha - C.\end{aligned} \tag{A-11}$$

Now,

$$\begin{aligned}&\sum_{j=0}^{N-1} \Pr(\Omega(G, j, N))\alpha - \Pr(\Omega(G, 0, N))\alpha + \Pr(\phi = L)\alpha \\ &\quad = \Pr(\phi = G)\alpha - \Pr(\Omega(G, 0, N))\alpha + \Pr(\phi = L)\alpha \\ &\quad = \alpha - \Pr(\Omega(G, 0, N))\alpha.\end{aligned} \tag{A-12}$$

Substituting equation (A-12) in (A-11) gives the bank's expected profit from screening as

$$\begin{aligned}&\Pr(\Omega(G, 0, N))\Pr(G \mid \Omega(G, 0, N))[\delta R - r_L] \\ &\quad - \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))r_L - \Pr(\Omega(G, 0, N))\alpha + \alpha - C \\ &= \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))[\delta R - r_L] \\ &\quad - \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))r_L \\ &\quad - [\Pr(\Omega(G, 0, N))\Pr(G \mid \Omega(G, 0, N)) \\ &\qquad + \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))]\alpha + \alpha - C \\ &= \Pr(\Omega(G, 0, N))\Pr(G \mid \Omega(G, 0, N))[\delta R - r_L - \alpha] \\ &\quad - \Pr(\Omega(G, 0, N))\Pr(L \mid \Omega(G, 0, N))[r_L + \alpha] + \alpha - C.\end{aligned} \tag{A-13}$$

Now, using Bayes rule

$$
\begin{aligned}
&\Pr(\Omega(\mathrm{G}, 0, N))\Pr(\mathrm{G} \mid \Omega(\mathrm{G}, 0, N)) \\
&\quad = \Pr(\Omega(\mathrm{G}, 0, N))\left[\frac{\Pr(\Omega(G, 0, N) \mid \mathrm{G})\Pr(\mathrm{G})}{\Pr(\Omega(\mathrm{G}, 0, N))}\right] \\
&\quad = \Pr(\Omega(\mathrm{G}, 0, N) \mid \mathrm{G})\Pr(\mathrm{G}) \\
&\quad = \eta\{1 - \eta[1 - p]\}^{N-1}\gamma.
\end{aligned}
\tag{A-14}
$$

Similarly,

$$
\begin{aligned}
\Pr(\Omega(\mathrm{G}, 0, N))\Pr(\mathrm{L} \mid \Omega(\mathrm{G}, 0, N)) &= \Pr(\Omega(\mathrm{G}, 0, N) \mid \mathrm{L})\Pr(\mathrm{L}) \\
&= [1 - \eta]\{1 - [1 - p][1 - \eta]\}^{N-1}[1 - \gamma].
\end{aligned}
\tag{A-15}
$$

For my bank to be indifferent between screening and not screening, the expression in equation (A-13) should be equal to α. Substituting equations (A-14) and (A-15) in (A-13) and equating to α gives the following equilibrium condition that determines p for every N:

$$
\begin{aligned}
&\eta\gamma\{1 - \eta[1 - p]\}^{N-1}[\delta R - r_{\mathrm{L}} - \alpha] \\
&\qquad - [1 - \eta][1 - \gamma]\{1 - [1 - p][1 - \eta]\}^{N-1}[r_{\mathrm{L}} + \alpha] = C.
\end{aligned}
$$

Given equation (2), it is easy to verify that the p that solves the above equation is in (0, 1). □

Proof of Proposition 4

Now, a sufficient condition for obtaining $N^* \geq 2$ is that G's expected net payoff be higher with $N = 2$ than with $N = 1$. That is, equation (8) with $N = 2$ should exceed R_c (the borrower's net payoff if it approaches only one bank). This means that we must have

$$
\{[1 - p]\eta\}^2[\delta R(2) - i(2, 2)] > \{1 - \eta[1 - p]\}^2 R_c.
$$

Since $R(2) > i(2, 2)$, the LHS of the above inequality is strictly positive. Moreover, the LHS does not contain R_c. Hence, this inequality will hold for R_c small enough. Clearly, in this case G will optimally approach two or more banks, and from Proposition 3 we know that $p \in (0, 1)$ for every bank, so that there is a positive probability that the borrower will be rationed out of the whole banking system.

I will now verify that L must choose the same number of banks as G to approach in equilibrium. In the proof of Proposition 1, it was asserted that any deviation from N^* (G's optimal choice of N) will be met with credit denial by every bank. I will prove now that such a response meets the requirement of a sequential equilibrium (Kreps and Wilson (1982)). This means there exists at least one belief and an associated best response by banks such that no borrower deviates from the equilibrium. Note first that if banks *believe* with probability 1 that the borrower is L, then credit denial without screening is a best response, and no borrower chooses $N \neq N^*$. Moreover, one can show also that beliefs and strategies form a "consistent assessment" in the sense of Kreps and Wilson (1982). Hence, the NE is sequential. It also passes the Cho and Kreps (1987) Intuitive Criterion test. To see this, suppose a borrower defects from the equilibrium with $N < N^*$. The first step in the Intuitive Criterion test is to see if either G or L can be ruled out as a potential defector regardless of the beliefs held by banks. Now, if a bank believes with probability 1 that the defector is G, then its best response is to extend credit without screening. Moreover, given the *lexicographic consistency* requirement of a sequential equilibrium, it is common knowledge that all banks share this belief and hence all will offer credit without screening. Given this best response, there are two possibilities. One is that both L and G defect and hence neither can be ruled out as a defector. In this case, the sequential equilibrium (trivially) passes the Intuitive Criterion. The other possibility is that only L defects; this would be the case, for example, if $N^* = 2$ and the defection therefore occurs with $N = 1$, so that G would prefer to stay with the equilibrium rather than defect and receive a monopolistic price. That is, G would not defect with $N < N^*$, regardless of banks' beliefs since it does not defect with the most favorable beliefs. Hence, G can be pruned as a potential defector in the first step. The second step of the Intuitive Criterion is to see if there is any type from the set of types remaining after the pruning in the first step that would choose to defect, regardless of the banks' best response with beliefs concentrated on the set of remaining types. In other words, would L defect when banks believe with probability 1 that L is the defector? The answer is no since each bank's best response is to deny credit with probability 1. Hence, the sequential equilibrium survives the Intuitive Criterion with $N < N^*$.

Consider now $N > N^*$. If banks believe with probability 1 that the defector is G, then once again their best response is to offer credit with probability 1 without screening. Actually, with multiple banks, each bank is indifferent between offering credit or not, since it recognizes that credit will have to be competitively priced. But in this case, *both* L and G wish to defect. L wishes to defect because it increases the probability of receiving credit, and G wishes to defect for that reason as well as because it enhances its payoff in the successful state by receiving credit from a larger number of banks. Neither type can therefore be pruned in the first step, and the sequential equilibrium survives the Intuitive Criterion. Finally, note that a greater $R'(\cdot)$ increases the second term in equation (8). From equation (3) we also see that p is unaffected by $R'(\cdot)$. Hence, an increase in $R'(\cdot)$ increases G's gain from approaching more banks, without affecting the rationing probability. This implies that N^* is nondecreasing in $R'(\cdot)$. $\square$

Proof of Proposition 5

Taking the limit with $\eta \to 1$ in equation (3) yields equation (9). Differentiating p_1 partially yields $\partial p_1/\partial r_L > 0$ and $\partial p_1/\partial \alpha > 0$. ☐

Proof of Proposition 6

An increase in the risk-based capital requirement, no matter how small, will increase r_L since capital is more costly than deposits. It can be seen from equation (3) that $\partial p/\partial r_L > 0$ for any N. Now, if N^* is unique, then the borrower's expected payoff at N^* is strictly higher than for any $N \neq N^*$. A sufficiently small increase in r_L will increase p a little, but will not change N^* because N^* is chosen from a subset of the positive integers, i.e., N is not a continuous variable. Thus, the probability that the borrower will be rationed (not screened) by all banks, p^{N^*}, will increase with r_L. ☐

Proof of Corollary 1

Obvious. ☐

Proof of Corollary 2

Since α enters the relevant equilibrium conditions in the same manner as r_L, the proof is the same as that of Proposition 5. ☐

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