BANK RESERVE REQUIREMENTS AS AN IMPEDIMENT TO SIGNALING

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Effective legal reserve requirements may hamper the private capital market's ability to price bank deposits. In the model developed here, the market has less information about bank assets than the banks have, and a bank can therefore signal its superior information through its choice of excess reserves. Mandatory reserves can inhibit such signaling and therefore result in inefficient deposit pricing.

I. INTRODUCTION

Although the basics of fractional reserve banking were explained by Edgeworth [1888], the rationale for legal reserve requirements. as well as the details of their design, have continued to evolve. and the impetus for reform has been gathering momentum in recent years. The time-honored liquidity motivation. as well as the more contemporary monelary control consideration, have been widely debated: and while the latter remains popular. increasing skepticism has been expressed by Benston [1978], Greenbaum and Kanatas [1982], Laurent [1979; 19811, Robertson and Phillips [1974] and Starleaf [1975], among others.

Like many of these papers, this one questions the benefits of reserve requirements. Whereas most dispute their value as a monetary policy instrument. however. a new argument presented here shows that reserve requirements may subvert efficient deposit pricing and thereby aggravate asset quality and bank solvency problems. The argument relates to the recent proposal that the private capital markets should play an expanded role in monitoring the exposure of banks. We examine the potential of a commercial bank's excess reserves to signal asset quality in an environment without deposit insurance (the results apply so long as deposit insurance remains incomplete] and where the risk of each bank's assets is a priori unknown to all except the bank. In such a setting, the efficient pricing of deposits depends on a depositor's ability to ascertain the risk characteristics of the bank's assets. It is sbown that excess reserves can signal the unknown risk and thus resolve the informational asymmetry. The ability to signal using excess reserves varies inversely. however, with reserve requirements. Thus, reserve re-

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quirements may impede the ability of excess reserves lo inform market participants. Reserve requirements are likely to impede signaling when (i) loan rates and reserve requirements are high, or (ii) reserve requirements are low but a bank's deposit base is large. Reserve requirements are unlikely to impede signaling when banks are similar in their asset characteristics. The underlying intuition is discussed in section III.

Excess-reserves-based signaling may be important because of its potential in facilitating the private sector's monitoring of banks. We show that any effort to expand the private market's monitoring of bank asset quality through more accurate deposit pricing presupposes an appropriate regulatory milieu. Exposing large depositors to losses may be a precondition for expanding the role of the private capital markets. but this analysis indicates that reserve requirements and/or inappropriate discount window pricing can subvert such efforts. The potential for conflict between the Federal Reserve. focusing on monetary policy, and the deposit insurers, seeking to mitigate their monitoring burden and exposure. is palpable. Thus. the model clarifies the conditions necessary to engage the private market in monitoring hank asset quality through deposit pricing. These requirements are formidable and the interdependence of regulatory conslraints used for monetary policy and bank soundness purposes could frustrate programs based on piecemeal reform.

The model posits a risk-neutral two-period economy where each bank issues deposits and makes risky loans at the outset. Although asset quality varies across banks, the choice of assets is not endogenous. This is an important simplification since, in general. a bank's asset choice will impinge on the posited signaling problem. Loans may default or be repaid at the end of the first period. or they may be extended for a second period at the borrower's option and then be repaid or default. Thus. from the lender's perspective loans have both default risk and duration uncertainty. The duration of deposits is likewise uncertain because of withdrawals that may occur at the end of the first period. Deposits are assumed to be exogenous. Endogenous deposits complicate the model unnecessarily since we address neither bank runs nor the manner in which the bank's asset choice is influenced by the sensitivity of deposit supply to that choice.

If deposits are withdrawn. the bank will repay principal and interest provided loans have either been repaid, or if repayment at the end of the second period is anticipated. In the latter case, deposit withdrawals will be financed with the bank's reserves together with borrowings at the discount window. If deposits are retained, they will be redeemed with interest at the end of the second period provided loans are repaid. The second period payoffs are random for both the bank and the depositors because of loan defaults. The bank alone knows the probability distribution associated with the terminal payoff of its loans: the depositors are a priori uninformed. Since depositon are uninsured, however. they are concerned about the loan payoff distribution.

The bank is required to maintain a specified fraction of its deposits in the form of noninterest-bearing cash assets. It is free. of course. to hold reserves in excess of requirements. The motivation for holding excess reserves— apart from the informational asymmetry—is to avoid borrowing at the Federal Reserve discount window at a possibly punitive interest rate.

The discount window interest rate is determined by a pricing policy that maximizes a welfare function (a weighted average of consumer welfare and expected bank profits), and generates a nonnegative expected profit for each bank. This reflects an attempt to capture regulator behavior. Thus. the regulator's problem is modeled as that of designing an optimal discount-window pricing policy. taking reserve requirements as given. There are two ways of viewing this. One is as a short-run optimization problem for the regulator, taking as given the practice of fixing reserve requirements for protracted periods. The other views reserve requirements as a regulatory tax without monetary policy purpose.

The derived optimal discount-window pricing policy has the desirable feature of inducing each bank to reveal its asset quality truthfully. Thus, the discount-window interest rate is a function of the bank's excess reserves, and this function is designed so that each bank's choice of excess reserves signals asset quality. There is. therefore, a discount rate for each bank, depending on its excess reserves. Banks with greater excess reserves are rewarded with lower discount rates. The intuition is as follows. Holding excess reserves—in the absence of signaling considerations—has two effects. One is the benefit of having a buffer stock of liquidity to satisfy an unexpected deposit withdrawal. The other is the opponunity cost of forgoing loan revenues. The latter cost of holding excess reserves is clearly greater for a bank with better asset quality. Moreover, such a bank is less averse to the higher discount rate that accompanies smaller excess reserves because it is less likely to require discount-window financing. Thus. the optimal discount-window pricing policy induces better quality banks lo choose lower excess reserves. Consequently, each bank reveals its private information through its choice of excess reserves, thereby facilitating the pricing of uninsured deposits.

In this environment required reserves convey no information since they are not an object of bank choice, except in a trivial sense. They may. however. subvert the informational role of excess reserves. Reserve requirements have three distinct effects on the signaling capability of excess reserves. The primary effect is a constriction of the values over which excess reserves can be varied. Thus. some banks may be powerless to signal, and these are shown lo be the lower-quality banks. There are. however, two other countervailing effects. First, increased reserve requirements desensitize the signaling schedule to cross-sectional variations in the unknown asset-quality parameter. Thus, excess reserves (as a signal) change less with bank quality. and signaling for the entire cross-section of banks may be possible even with truncated feasible excess reserve values. In addition, increased reserve requirements reduce bank profitability and may therefore obviate the need to signal among banks at the lower end of the quality continuum. Thns. a smaller set of feasible excess reserve values may not be constraining because there is a smaller cross-sectional variation in the underlying quality parameter. In section III, the conditions are identified under which the fist (direct) effect dominates the other two with the consequence that required reserves impede signaling.

Thns, reserve requirements may impair the capital market's ability to discipline the risk-taking proclivities of hanks—hy making them pay a risk-sensitized price for their liabilities-at a time when public regulators are seeking to increase the private sector's role in monitoring bank asset quality. Although the Federal Reserve's 119801 discount-window pricing policy embodies nonlinearities as required by this model, it is difficult to say how similar the existing pricing schedule is lo the derived (optimal) schedule. Moreover. sincc alternative signaling instruments (such as the bank's financial structure) are not examined. it is not clear that excess reserves is the optimal instrument for signaling bank asset quality. The limited objective is to clarify a substantially ignored information-related cost associated with reserve requircmcnts. At a more fundamental level. the paper illustrates the theory of second best. as in Lipsey and Lancaster [1956].

The remainder is in three sections. Section II develops the model. Section III examines implications, and section IV concludes. (Formal proofs are in an appendix available from the authors upon request.)

II. THE MODEL

Consider an economy in which all are risk neutral, and there are two time periods. The fist begins at $I = 0$ and ends at $r = 1$, and the second begins at $t = 1$ and ends at $t = 2$. The economy consists of banks. borrowers. depositors and a governmental regulator. Depositors entrust their funds to banks. and banks purchase risky loans from borrowers. For convenience. it is assumed that there is no deposit insurance. and that banks have no capital. financial or otherwise.[1] The regulator controls two policy variables. It instructs banks at $I = 0$ to retain at minimum a fraclion, $s \in [0,1]$, of its deposits as legal reserves, and it establishes the interest factor (one plus the interest rate), ω, at which banks can borrow at the discount window. Although the results are unaffected if excess reserves earn interest at a rate less than that expected on loans, reserves are assumed to earn no interest. The fraction of deposits a bank holds as excess reserves is $\delta \in [0, 1-s]$.

The decision sequence follows. At $t = 0$, each bank obtains a fixed amount of deposits, D. It thereupon allocates required reserves of sD and ex-

1. The model can accommodate financial capital without altering the basic results

cess reserves of 6D. It invests the remainder, $(1-s-\delta)D$, in two-period loans of which some unknown fraction will be prepaid at $t = 1$ without penalty to the borrower. At $t = 0$, neither the bank nor the borrower knows whether the loan will be prepaid at $t = 1$, repaid at $t = 2$, or defaulted at either $t =$ 1 or 2. The loan will have a one-period maturity with probability 9 ε [0,1] and a two-period maturity with probability $(1 - \theta)$. At $t = 1$, the borrower discovers whether it has a one-period or a two-period loan. One-period borrowers default with probability 1 – q, e [0,1], and two-period borrowers default with probability $1 - q_2 \; \varepsilon \; [0,1]$. The haok is assumed lo know as much as the borrowers at t = 1. 2, so that borrowers are unable to misrepresent their default attributes in the hope of securing better terms.

The duration of deposits is likewise uncertain. With probability a ε [0,1] all dcposits will be withdrawn at $t = 1$, and with probability (I – a) all deposits will remain with the bank until I = 2. If deposits are withdrawn and all loans are prepaid, the process terminates at $t = 1$ with depositors receiving $r_D D$, where r_D is the one-period deposit interest factor. If loans are prepaid without a deposit withdrawal, excess reserves and loan receipts are reinvested at the riskless one-period interest rate. R – 1. (The term structure of interest rates is assumed to be flat and nonstochastic, so that R^2 is the two-period riskless interest factor.) The process then terminates at I = 2 and two-period depositors receive $R_D D$.

If the bank's loans are for one pcriod and it defaults. and if deposits are withdrawn, the process terminates at $t = 1$ with the depositors receiving the required and excess reserves. The bank is left with nothing. If deposits are not withdrawn, the bank invests its excess reserves at the riskless one-period interest rate for the second period: depositors then receive the required reserves plus R times the excess reserves at I = 2.

If loans are for two periods but deposits are withdrawn, the bank uses its reserves and borrows at the discount window in order to repay depositors. In this case, if the loans default at $t = 2$, the central bank will be unable to collect its discount-window advances. If loans are not prepaid and deposits are not withdrawn, borrowing at the discount window will be unnecessary and depositors recover their funds if and when loans are repaid. Figure 1 sketches the sequence. For simplicity, both partial withdrawal of deposits and partial default on loans have been ruled out. Thus, all loans and deposits are either for one period or for two, and all loans are either totally repaid or totally defaulted. These assumptions simplify the algebra without analytical effect.

Assume lhat banks differ only in their loan duration probability θ, which varies in the interval $(\underline{\theta}, \bar{\theta}) \subseteq (0.1)$. Later we will assume lhat $(\underline{\theta}, \hat{\theta})$ is the support of the regulator's prior density function over each bank's θ, This implies that banks are observationally identical from the regulator's viewpoint. so that the cross-sectional density function is also the regulator's prior density over each bank's θ. This assumption is unnecessarily restrictive. We can

FIGURE 1A
Initial Sequence of Events

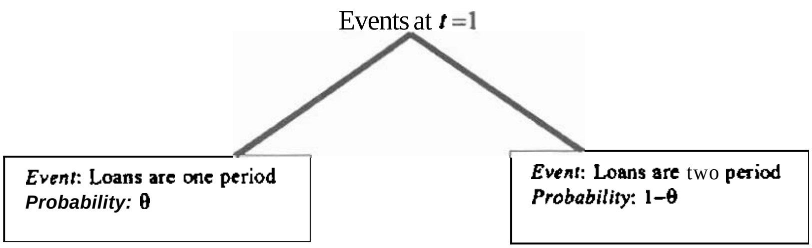


FIGURE 1B
Events Sequence for One-Period Loans

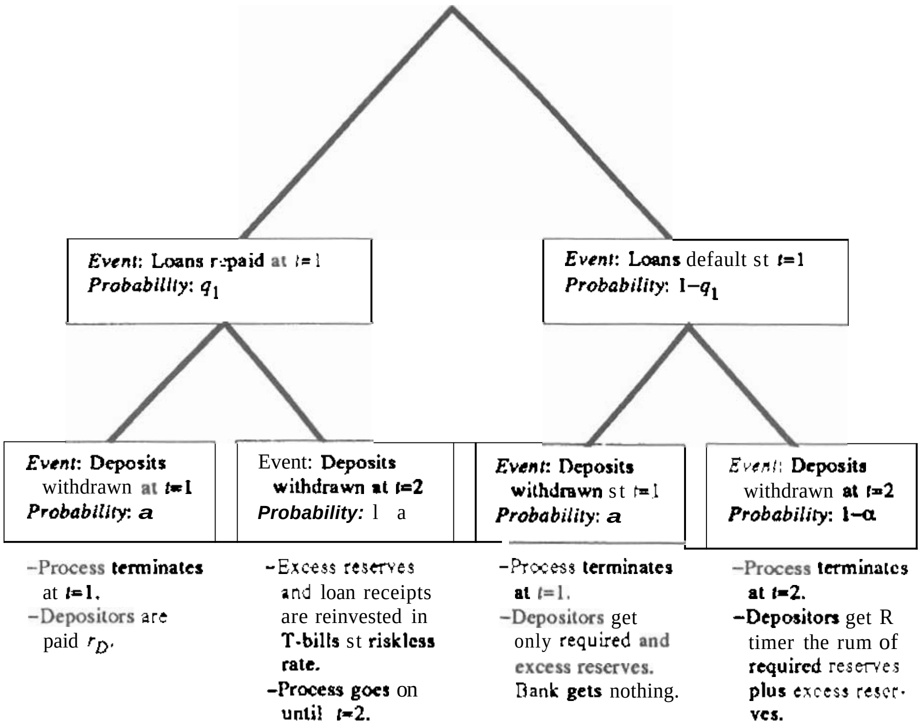
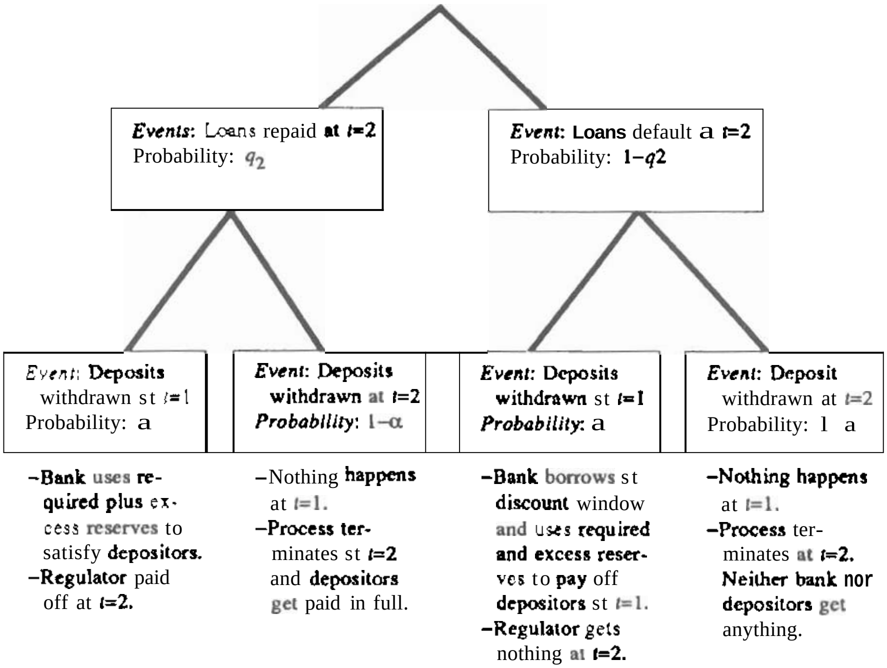


FIGURE 1C
Events Sequence for Two-Period Loans



assume observable differences between banks so long as a bank knows more about its own θ than the regulator. For example, we could assume that the regulator believes that bank i's θ lies in $(\underline{\theta}_i, \bar{\theta}_i)$ and intervals vary across i's. Subscripts are dispensed with, however, because the results are unchanged under the more general specification. q_2 is assumed to be sufficiently smaller than q_1 so that one-period loans are preferred to two-period loans. Thus, a larger θ indicates better asset quality as well as shorter expected duration. For each loan dollar, the debtor is obligated to repay r_L (principal plus interest) if repayment occurs at $t = 1$, and $R_L > r_L$ if repayment occurs at $t = 2$. Although one-period loans dominate those for two periods, a bank would not be in position to increase its expected profit by simply writing all loan contracts for one period, even if asset choice were endogenous. Recall that at $t = 0$, neither the bank nor the borrower knows whether the latter will require a loan for one period or for two. Thus, even if the bank were to write a one-period contract, a two-period borrower would be unable to repay at $t = 1$.

An informational asymmetry is introduced by assuming that each bank knows its own θ, but depositors and the regulator do not. In general, r_L and R_L will be functions of θ, q,, and q_2. Thus. if r_L and R, are publicly observable and the market for loans is perfectly competitive, the risk-neutrality assumption would permit a bank's private information to be inferred by inverting the loan interest rates using a zero expected profit condition for the bank. Such inference would not necessarily be possible. however, if banks enjoyed some monopoly power in the loan market. Therefore. it is assumed that r_L and R_L exceed their competitive values and tbis premium is not known by depositors or the regulator. Although both interest rate factors will vary across banks, noisy inference may be possible. Thus. the regulator's prior about bank i's private information parameter, 0,. will be that it lies in some interval. $(\underset{\sim}{\theta}_i, \bar{\theta}_i)$, and these intervals vary across banks. This means that the problem under study should be viewed as applying to a specific bank. with the regulator solving such a problem for each baok.[2] It is also possible. however. to think of groups of observationally distinct banks. with observationally identical members within each group.

Depositors are risk neutral and deposits are competitively priced. Thus both r_D and R_D will exceed R since bank assets are risky and deposits are uninsured. Moreover. because R_D represents a two-period interest factor and r_D a one-period factor. R, $>$ r_D. Since D. r_L and R_L are exogenous, the bank need only choose δ, fixing its excess reserves and loan volume. Although also assumed to be fixed. the effects of varying the reserve requirement ratio, s, will be examined later. The regulator's task is to choose the discount rate factor, ω. Since the signaling potential of excess reserves is of interest. the regulator's decision is described as being contingent on the bank's choice of 6. The regulator, tberefore. must precommit to a schedule. $\omega(\delta)$, and then allow the bank to choose δ. The regulator chooses this schedule to maximize a welfare function described later.

The bank's choice of δ will depend on its θ, since excess reserves are diverted from loans. Thus, the bank sacrifices lending opportunities for liquidity and this tradeoff depends on the profitability of the bank's lending opportunities as indexed by 0. The regulator's policy schedule therefore can be written as $\omega(\delta(\theta))$. Alternatively, the regulator can be viewed as asking each bank to disclose its 0, whereupon it awards the bank $[\delta(\theta), \omega(\theta)]$, based on the reported 8. This is the approach followed here. It is equivalent to interpreting δ as a signal with ω king based on δ. Modeling the regulator's problem in this way is consonant with the revelation principle described by Mycrson [1979] which implies that the regulator can restrict itself to those policies that require the bank to report its θ without incentive to misrepresent.

2. The regulator's priors arc assumed to be "correct" in the sense that each bank's θ belongs to the appropriate interval.

Note that θ cannot be verified ex post by the regulator. all that the regulator knows is the bank's report. This precludes (costless) contingent contract equilibria of the type analyzed in Bhattacharya [1980]. Of course. allocational distortions resulting from private information may be reduced by repeating the game between the regulator and the hank. Since θ is a probability distribution parameter. however, it will never be noiselessly revealed in any finite horizon, repeated game. Distortions will, therefore, persist.

The expected profit of a bank that reports θ_i when its true attribute is θ_j is given by

$$\Pi(\theta_i \mid \theta_j) = D[\theta_j \phi(\theta_i) + (1 - \theta_j)\psi(\theta_i)] \tag{1}$$

where

$$\phi(\theta_i) \equiv q_1 \ \alpha R^{-1}\{r_L[1 - s - \delta(\theta_i)] - r_D(\theta_i) + s + \delta(\theta_i)\}$$

$$+ q_1(1-\alpha)R^{-2}\{r_L R[1 - s - \delta(\theta_i)] + s + R\delta(\theta_i) - R_D(\theta_i)\} \tag{2}$$

and

$$\psi(\theta_i) \equiv q_2 \ \alpha R^{-2}\{R_L[1 - s - \delta(\theta_i)] - r_D(\theta_i) - \delta(\theta_i) - s] \ \omega(\theta_i)\}$$

$$+ q_2(1-\alpha)R^{-2}\{R_L[1 - s - \delta(\theta_i)] + s + R\delta(\theta_i) - R_D(\theta_i)\}. \tag{3}$$

Recall that both r_D and R_D are market determined in response to the bank's reported θ, so that the depositor's expected single-period return per dollar of deposits is R. A bank that reports an attrihute of θ_i has an expected profit that is a multiple of its deposits. This multiple is the term in the square brackets in (1). Note that θ_j is the true probability that borrowers will prepay. The expression $\phi(\theta_i)$ is the bank's expected profit. conditional on loans being prepaid. This function depends only on the bank's reported type. The quantity $r_L[1 - s - \delta(\theta_i)] - r_D(\theta_i) + s + \delta(\theta_i)$ is the bank's net profit per dollar of deposits if one-period loans are repaid and if deposits are withdrawn. The expected present value of this profit is obtained by discounting with the one-period riskless interest factor R, and then multiplying with q,, the probability that the loans will he repaid. and a. the probability of a deposit withdrawal. The term $r_L R[1 - s - \delta(\theta_i)] + s + R\delta(\theta_i) - R_D(\theta_i)$ is the hank's net profit per dollar of deposits if one-period loans are repaid at t = 1 and deposits are not withdrawn. Multiplication of this profit by $q_1(1 - \alpha)R^{-2}$ produces an expected present value. The function $\psi(\theta_i)$ is the bank's expected profit conditional on the loans remaining outstanding for two periods. Equation (3) can be interpreted along the same lines as (2).[3]

The regulator measures the expected consumer welfare with

$$C(\theta) \equiv R^{-2}(1-\theta)\ \alpha D\ [r_D(\theta) - \delta(\theta) - s]\ [q_2\omega(\theta) - R] + W\{D[1-s-\delta(\theta)]\}. \quad (4)$$

The first term represents the expected net receipts (possibly negative) of the regulator. assuming that discount-window borrowings are financed at the riskless interest rate. The second is a measure of welfare produced by bank lending; $W(\cdot)$ is a strictly concave and strictly increasing function of bank loans.[4]

Although this formulation excludes a Fed Funds market. accommodating one is not difficult. If banks can borrow without limit at a Fed funds rate below the discount rate, then there would be no purpose for either excess reserves or the discounl window, an uninteresting case. If banks can borrow or lend Fed funds at $t = 1$, a must be reinterpreted as the joint probability that deposits are withdrawn at $t = 1$, and that the Fed funds rate exceeds the discount rate. More interesting is the possibility of Fed funds transactions at $t = 0$. If each bank has unlimited lending opportunities at its given 0, then the bank with the largest θ will borrow the loanable funds of all the other banks at a risk-adjusted rate that is no less than what other banks could earn on their loans, but is still low enough lo produce positive profits for the borrowing bank. This will result in all direct lending being done by one bank. With a finite upper bound on each bank's lending, possibly resulting from a capital constraint or some other scale restriction. however, there will be a continuum of banks distinguished by their respective θ's, even with Fed funds trading at $t = 0$.

Although the regulator does not know each bank's θ, it has a prior density function, $f(\theta)$, which is strictly positive over the interval $(\underline{\theta}, \bar{\theta})$ and zero elsewhere. As discussed earlier, the prior density function could be $f_i(\theta)$, defined over $(\underline{\theta}_i, \bar{\theta}_i)$ to denote the regulator's bank-specific priors. Given $f(\theta)$ for a particular bank, the regulator chooses the vector of functioos. $[\delta(\theta), \omega(\theta)]$, so as to maximize (for a fixed weighting scalar λ)

$$\int_{\underline{\theta}}^{\bar{\theta}} [C(\theta) + \lambda\Pi(\theta)] f(\theta) d\theta;\ \lambda\ \varepsilon\ [0,1]$$

3. We could enrich the regulator's decision by allowing it also to choose a probability with which to permit the bank lo operate, given a report. However. there would be no interaction between the licensing probability and the other policy variables. In equilibrium, the licensing probability would be a step function with a license granted with probability one if the bank's reported θ exceeds some critical level, and not otherwise. Therefore we simply assume that every bank's reported θ indicates a nonnegative expected profit, given the regulatory allocation contingent upon its report.

4. Alternatively, the welfare assessment might be thought to depend on the likelihood of default. in which case $W(\cdot)$ would be replaced by its expected value. This alteration leaves the results unaffected, however.

subject to

$$\Pi(\theta) \geq 0 \tag{6}$$

$$r_D(\theta) \equiv \{R - \theta(1 - q_1)\,[s + \delta(\theta)]\}\,[\theta q_1 + (1 - \theta)]^{-1}. \tag{7}$$

$$R_D(\theta) \equiv [R^2 - \theta A_1(\theta) - (1 - \theta)A_2(\theta)][\theta q_1 + (1 - \theta)q_2]^{-1} \tag{8}$$

where

$$A_1(\theta) \equiv (1 - q_1)\,[s + \delta(\theta)R] \tag{9A}$$

$$A_2(\theta) \equiv (1 - q_2)\,[s + \delta(\theta)R] \tag{9B}$$

$$\Pi(\theta) = D[\theta\,\phi(\theta) + (1 - \theta)\,\psi(\theta)] \tag{10}$$

$$\Pi(\theta_j) \geq \Pi(\theta_i \mid \theta_j)\ \forall\ \theta_i, \theta_j \in (\underline{\theta}, \bar{\theta}). \tag{11}$$

$$\delta(\theta) \in (0, 1-s)\ \forall\ \theta \in (\underline{\theta}, \bar{\theta}) \tag{12}$$

$$\max_{\theta}\ \omega(\theta)[r_D(\theta) - \delta(\theta) - s]\,[1 - s - \delta(\theta)]^{-1} < R, \tag{13}$$

$$q_1/q_2 > \max_{\theta}\ \{\beta_1(\theta)[\beta_2(\theta)]^{-1} \vee \beta_3(\theta)[\beta_4(\theta)]^{-1}\}, \tag{14}$$

and where "$\vee$" is the max operator, and

$$\beta_1(\theta) \equiv R_L - \omega(\theta)r_D(\theta) - [s + \delta(\theta)]\,[R_L - \omega(\theta)]$$

$$\beta_2(\theta) \equiv r_L - r_D(\theta) - [s + \delta(\theta)]\,[r_L - 1]$$

$$\beta_3(\theta) \equiv R_L[1 - s - \delta(\theta)] + R\,s + \delta(\theta) - R_D(\theta)$$

$$\beta_4(\theta) \equiv r_L R[1 - s - \delta(\theta)] + R\,s + \delta(\theta) - R_D(\theta).$$

Constraint (6) reflects that a bank cannot be compelled to operate with negative expected profit. In this game, the regulator posts $[\delta(\theta), \omega(\theta)]$, the bank reports θ, and the regulator awards an allocation contingent on the report. The bank then operates with that allocation. Banks with sufficiently low θ's are awarded allocations that result in zero expected profits. in which case these banks suspend operations.

Expressions (7) and (8) define $r_D(\theta)$ and $R_D(\theta)$. Because depositors are risk neutral and deposits are priced in a perfectly competitive market, both $r_D(\theta)$ and $R_D(\theta)$ are determined so that the depositors' expected payoff discounted at the risk-free interest rate equals the initial deposit.[5] Equation (10) is another definition, and (11) is an incentive compatibility constraint indicating that under the optimal regulatory policy no bank should wish to misrepresent. Constraint (12) limits the range of $\delta(\theta)$ according to the reserve requirements. and constraint (13) restricts the discount rate; if the discount rate exceeds the interest rate on bank loans, the discount facility will never he used. Finally. (14) ensures that banks' expected profits can be ordered with higher θ denoting higher expected profit. Thus. a bank is never worse off with one-period than with two-period loans after it has discovered the borrowers' types at $t = 1$. It is assumed that R_L is sufficiently high and q_1 is sufficiently greater than q_2 so that (13) and (14) do not impose binding restrictions on the domains of $\delta(\theta)$, $\omega(\theta)$, $r_D(\theta)$ and $R_D(\theta)$, which are endogenously determined.[6]

The reader may wonder if a simpler model might suffice. To see why that is unlikely, let us recapitulate. Since excess reserves are commonly justified as a buffer against liquidity needs stemming from stochastic deposit withdrawals, a model is needed with at least two periods and uncertain deposit withdrawals. Since we wish to examine the ability of excess reserves to convey information about bank asset quality, at least two types of earning assets are required. Moreover, the two assets must vary in maturity because if all loans are for one period, the bank would be able lo terminate at the end of the first period without concern for liquidity. If loans were known to be for two periods. then either there is no liquidity problem accompanying an unanticipated deposit withdrawal at the end of the first period (because first period deposit withdrawals could be financed by discount window borrowing, or elsewhere). or the liquidity problem would be so severe as to force the suspension of operation. In either case, the bank's liquidity problem would be unrelated to asset quality. Therefore. a model is needed in which liquidity and asset quality are linked, so that excess reserves that provide liquidity also have the potential to signal asset quality. Note too that

5. To see this more clearly, rewrite (7) as

$$\theta\{q_1 r_D(\theta) + (1 - q_1)[s + \delta(\theta)]\} + (1 - \theta) r_D(\theta) = R.$$

At $t = 0$, depositors require an expected payoff of R, conditional on their withdrawing their funds at $t = 1$. The term within braces is the depositor's expected payoff if loans are prepaid, which is multiplied by the probability that loans will be prepaid. Note that with probability q_1 these one-period loans are prepaid and the depositors receive $r_D(\theta)$; with probability $1-q_1$, one-period loans default and the depositors get only required and excess reserves, $s + \delta(\theta)$. If the bank discovers it has two-period loans, however, withdrawing depositors receive $r_D(\theta)$.

6. But R_L should not be so high relative lo r_L that θ cannot be used to rank loan qualities. Intuitively, this is why we want $q_1 >> q_2$. Because $R_L > r_L$ and $r_D(\theta)$ is possibly nonmonotonic in θ, two-period borrowers may be preferred by the bank if q_1 is not substantially larger than q_2.

we want signaling along a continuum, which is the reason for choosing the probability of having a one-period loan as the private information parameter. The alternative of assuming that a bank knows its loan duration and quality at $t = 0$—but the regulator does not—leads to comer solutions. Moreover. such private information is not particularly interesting in this context because it is verifiable ex post.

This formulation assumes lhat the regulator desires to have the market correctly price deposits, and it prices discount borrowings accordingly. Since the regulator seeks to maximize social welfare, however. such a policy will be pursued only if signaling is welfare improving. We therefore need to know the costs of deposit pricing according to "average quality" that could be expected in the absence of signaling. This analysis implicitly assumes that there are potential entrants into banking who are "lemons." Without ex ante signaling of asset quality. these new lenders would enter and depositors with rational expectations would price deposits to reflect their presence. With a sufficient density of lemons, average deposit yields would be so high that lending by even the better-quality banks would be impeded. In extremis, the allocational distortion would lead to market failure. The next section shows that with signaling, it is optimal for poorer quality banks to withdraw from the market leading to a welfare improvement.[7] Public statements by Federal Deposit Insurance Corporation (FDIC) and Federal Home Loan Bank Board (FHLBB) officials relating to risk-sensitive insurance premia, modified payouts and brokered deposits, particularly those preceding the May 1984 crisis at Continental Illinois National Bank. would seem to support the idea of encouraging banks to signal their asset quality through a self-selection process.

III. RESULTS

In this section. properties of the solution lo the constrained maximization problem described by expressions (5) through (14) are examined. The first result serves to simplify the later analysis. It indicates that the global incentive compatibility constraint, (11), can be replaced by a local representation.

LEMMA. Any regulatory policy is feasible if and only if it satisfies (6). (7), (8), (9A), (9B), (10), (12), (13), (14)

and

$$\Pi(\theta) = \Pi(\underline{\theta}) + \int_{\underline{\theta}}^{\theta} D[\phi(\theta) - \psi(\theta)]\, d\theta. \qquad (15)$$

7. This is equivalent to assuming that the social cost of mispricing deposits is arbitrarily high. But even this don not rule out the possibility that the measure of $(\underline{\theta}, \bar{\theta})$ is so small, a r_L and R_L are so large that even the bank with $\theta = \bar{\theta}$ finds it optimal not to signal $[\delta(\bar{\theta}) = 0]$. The bank then prefers lo accept deposits at a cost commensurate with the mean $\bar{\theta}$, and the discount window will be unused. Thus. once again there must be some lemons, ie., banks with θ's so low that it becomes attractive f a the better quality banks to identify themselves.

Moreover, $\Pi''(\theta) \geq 0$ wherever $\Pi'(\theta)$ exists. (16)

Satisfaction of (14) also guarantees that $\Pi'(\theta) > 0$ wherever it exists. Thus, the lemma says that the regulatory policy must assure that the hank's expected profit will increase with its reported 8. Moreover. the marginal rate of increase should not decrease in 8.

It is assumed that $[1 - F(\theta)]/f(\theta)$ is nonincreasing in θ. This assumption guarantees monotonicity of the social welfare function in the relevant policy variables. It is more or less standard in models of this type and it is satisfied by the Uniform. Logistic. Pareto, Exponential and other distributions.[8] The next result establishes the existence of a solution to the regulator's problem.

PROPOSITION 1. There exists a solution to the optimization program expressed in (5) to (14).

The properties of the optimal (denoted by asterisks) regulatory policy are considered next.

PROPOSITION 2. $\delta^*(\theta)$ is decreasing in 8.

As indicated earlier, banks with better asset quality hold less excess reserves.

PROPOSITION 3. An $\omega(\theta)$ that is increasing in θ is always incentive compatible; and if banks earn sufficient rents in the loan market, the set of incentive-compatible regulatory policies will contain only those $\omega(\theta)$ schedules that are strictly increasing in θ.

An $\omega(\theta)$ that is increasing in θ is incentive compatible because $\delta^*(\theta)$ is decreasing in θ, and an $\omega(\theta)$ that moves in the opposite direction encourages low θ banks to keep high excess reserves. However, even an $\omega(\theta)$ that is nonincreasing may be incentive compatible. This could happen if R_L and r_L are sufficiently low so that variations in δ do not decisively affect the bank's expected profit. Because $r_D(\theta)$ need not be monotonic in θ (see equation (7)). a bank may choose to keep abundant excess reserves and pay a higher discount rate if it gains sufficienlly from a lower $r_D(\theta)$. But if R_L and r_L are high, a bank that keeps large excess reserves forgoes profits and must be rewarded with a discount rate that is decisively lower than that of a borrower with a low F.

The final result addresses the adverse impact of reserve requirements.

PROPOSITION 4. Depending on the distribution of 8, some banks with low θ's may be unable to differentiate themselves from other banks with still

8. Other papers that use this assumption include Baron [1982], Baron and Besanko [1984], and Shah and Thakor [1988]. Baron and Myerson [1982] suggest a way lo characterize optimal solutions in such problems without imposing restrictions on the distribution of θ.

lower θ's. Moreover. the higher the legal reserve requirement, the larger may be the set of θ's for which differentiation is precluded.

For this proposition to be true, $f(\theta)$ must have a large support and be sufficiently dispersed. Reserve requirements affect excess-reserve based signaling in three distinct ways. First and most obviously. an increase in s constricts the range over which excess reserves can be varied. This impedes the ability of lowerquality banks to signal. Second, higher reserve requirements desensitize the signaling schedule. $\delta^*(\theta)$, to changes in θ. Thus. $\delta^*(\theta)$ increases more slowly with decreases in θ and this tends to reduce the direct effect of the constricted range of variation in δ; i.e., a smaller set of bank types at the lower end of the quality spectrum may be inhibited from signaling. Finally, an increase in reserve requirements reduces aggregate lending. bank profits and consumer welfare? Consequently. fewer banks will seek or be granted charters and a less disparate set of θ's needs lo be signaled.

Reserve requirements are likely to impede signaling in two situations. If loan rates (r_L and R_L) and reserve requirements are high. further increases in s are likely to interfere with signaling. With high loan rates. banks will differ in their preferences for combinations of excess reserves. the discount rate, and the single- and two-period deposit rates. Thus. $\delta^*(\theta)$ will be relatively sensitive, even for high values of s, and will approach the upper bound. $1-s$, relatively rapidly.[10] But since $1-s$ is reduced by the increase in s, $\delta^*(\theta)$ could reach its upper bound at a high value of 0.

Signaling also may be impeded when s is small, hut D is large. In this case, the bank's profit in the good state is large even though the loan interest rates may not be high. Thus. variations in θ induce large changes in expected profits. This means that the preferences of banks with different θ's for different combinations of signals and payoffs are more sharply delineated. This again sensitizes $\delta^*(\theta)$ and hence increases the likelihood of attaining the upper bound of $1-s$ at a high value of θ. An increase in reserve requirements also could make additional low θ banks unprofitable and thereby reduce the range of θ's over which signaling occurs.

Reserve requirements are unlikely to impede signaling when banks arc similar. For example, when $f(\theta)$ contains just two closely-spaced mass points, two possibilities emerge. One is that distinguishing among banks is uneconomic in that the costs of signaling exceed the potential benefits and

9. The tax effect of an increased reserve requirement can be offset, of course, in a variety of ways, including a reduction h the tax on bank income.

10. One may wonder why a bank that can invest in loans with very high interest rates would want to keep excess reserves that approach the upper bound. $1-s$. However. note that the information environment is asymmetric. When all banks are earning high loan interest rates, all will want to keep low excess reserves in the first-best (symmetric information) case. Under asymmetric information, however, excess reserves signal asset quality and the signaling schedule becomes a very steep function of the private information parameter when loan rates are high. This causes banks with poorer asset qualities to choose relatively high excess reserves. They are enticed to do so because they ean thereby avail themselves of lower discount rates.

therefore mispricing of deposits is preferable to signaling. Alternatively, signaling may be worthwhile. but the range of variation in $\delta^*(\theta)$ may be so small that reserve requirements pose little threat to the viability of signaling.

When reserve requirements impede signaling, banks may be priced according lo average quality, in which case those with hetter-quality assets subsidize poorer-quality banks. as in Akerlof [1970]. The importance of this market failure will, of course, depend on the initial dissimilarity of banks and the associated costs of cross-subsidization. Alternatively. banks may seek other signaling instruments. If. however. excess reserves are the least costly instrument. then alternatives imply losses and mandatory reserves increase the cost of financial intermediation.

IV. CONCLUSION

With the surcharge on Federal Reserve discount window borrowing linked to a bank's excess reserves. the latter may transmit information that would facilitate risk-based deposit pricing by the private capital market. This might reduce the burden currently sustained by deposit insurers and other public regulatory bodies. However. legal reserve requirements can impede any such enhancement of the capital market's role.

Many have noted the less than striking success of legal reserve requirements in fostering their two traditional objectives, the provision of liquidity and the facilitation of monetary control. This paper provides yet another argument favoring reserve requirement reform. By restricting the range over which banks are permitted to vary their excess reserves, reserve requirements may inhibit the transmission of asset quality information by banks to their depositors. The frustration of informational exchange may undermine the private capital market's ability to price bank liabilities and may therefore impede any effort to expand the mle of these markets in monitoring and disciplining the risk-taking proclivities of banks. The results also illustrate the potential for conflict between regulatory agencies that share the same instrument of regulation, but do not share identical objectives. More concretely, the Federal Reserve's desire to use reserve requirements to enhance monetary control may subvert the deposit insurer's desire to have the market's pricing of bank deposits reflect bank asset quality.

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