PRIVATE INFORMATION, DEPOSIT INTEREST RATES,
AND THE "STABILITY" OF THE BANKING SYSTEM

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Abstract

"Summary of Recommendations: . . . Repeal present control
by the System over interest rates that member banks may
pay on time deposits and present prohibition of interest
payments by member banks on demand deposits."

Milton Friedman (1960, p. 100)

"I conclude that the over-all monetary effects of ceiling
regulations are small and easy to neutralize by tradi-
tional monetary controls. The allocative and distribu-
tive effects are, however, unfortunate. The root of the
policy was an exaggerated and largely unnecessary concern
for the technical solvency of savings and loan associa-
tions."

James Tobin (1970, p. 5)

The regulation of deposit interest rates has received little support
from economists. The same is true for the original rationale for such regula-
tion: that bank competition for deposits generates inherent "instability" in
the banking system. This paper develops an "adverse selection" model of
banking in which this rationale is correct. Moreover, in this model instabil-
ity in the banking system can arise despite the presence of a "lender of last
resort," and despite the absence of any need for "deposit insurance." How-
ever, in the world described, the regulation of deposit interest rates is
shown to be an appropriate response to "instability" in the banking system.
Finally, it is argued that "adverse selection" models of deposit interest rate
determination can confront a number of observed phenomena that are not readily
explained in other contexts.

The Banking Acts of 1933 and 1935 empowered the Federal Reserve System to regulate rates of interest paid on bank deposits. The rationale for this regulation was that competitive banking was, in some sense, "unstable."[1/] In particular, the supporters of deposit rate regulation argued that bank "competition" for deposits would bid up deposit rates of interest. This, in turn, would induce banks to hold "excessively risky" portfolios, with consequent adverse implications for the stability of the banking system. Moreover, this view was far from a new one at the time. The banking panics of 1857, 1873, and 1884 had been attributed to the practice of paying interest on deposits by both contemporary observers, and by subsequent students of banking. However, as the quotations above indicate, economists who agree on very little else have almost uniformly agreed that this view is incorrect.

The reason for this agreement would seem to be that no theory of banking has predicted that increases in deposit interest rates will adversely affect the security of bank portfolios, and empirical evidence has also failed to find such a connection. In fact, at a theoretical level Kareken and Wallace (1978) have argued that the portfolios of unregulated banks will be completely safe if there is a complete set of contingent claims markets. Similarly, Fama (1980, 1983) suggests that unregulated banks would offer a menu of deposits backed by portfolios with varying degrees of risk which depositors could choose among in such a world. Thus there appears to be some degree of consensus on this issue. Moreover, empirical evidence is supportive of such claims. Rolnick and Weber (1982, 1983), for instance, find in their examination of "laissez-faire banking" that "free banks" historically held quite safe portfolios (on average). Sprague (1910) also suggests that in the panics of 1873, 1884, 1893, and 1907 depositor losses were minor at best. Thus theoretical and empirical evidence for unregulated banks suggests that

bank portfolio choices are not a source of "instability."[2] Empirical evidence for regulated banks (Benston (1964)) does not suggest differently.

It would seem, then, that the level of risk associated with bank portfolios will not explain the "instability" of unregulated banking systems. In contrast to the volume of literature on bank portfolio choices, however, the literature on the effect of competition among banks for deposits is surprisingly small. In view of the pre-1935 concern with such competition, it would seem that some attention should be devoted to whether competition among banks for deposits can be "destabilizing" in and of itself. This is the subject of this study. It will be argued here that a cogent economic rationale for deposit interest rate regulation can be constructed based on the problems created by competition for deposits alone. In addition, it will be argued that in the presence of these problems, it is irrelevant for the argument whether or not higher deposit interest rates affect bank portfolio decisions. Thus, the analysis here differs from virtually all existing analyses of bank stability in that it focuses strictly on competition for deposits, essentially to the exclusion of any consideration of bank portfolios (i.e., banks face a trivial portfolio choice in the model). In the presence of stability problems created by this competition, the regulation of deposit interest rates will be shown to be an appropriate policy response. Moreover, it will be seen that these stability problems cannot be rectified by other conventional means, i.e., they arise even in the presence of a "lender of the last resort," and even though "deposit insurance" is unnecessary in the model. Thus it is clear that competition for deposits, and not bank portfolio decisions, fractional reserves, demand for loans or withdrawals, or other commonly cited factors are responsible for instability here. These latter features are therefore dispensed with in the analysis.

The results cited are obtained in the following setting. Banks "compete" for the deposits of a heterogeneous group of agents. These agents value consumption streams similarly, but vary in terms of their probability distributions over date of withdrawal from their respective banks. In addition, while each agent knows his own probability distribution, this distribution is private information ex ante. This method of introducing private information corresponds closely to the rationale for bank regulation suggested by Simons (1936).

Bank competition, then, takes place not only to attract deposits, but in order to attract depositors with certain characteristics. It is bank competition for depositors of particular types (withdrawal probabilities), coupled with private information which is the source of potential problems in the banking industry. These problems constitute a rationale for deposit interest rate regulation. Moreover, as will be seen, the model presented provides a simple framework which is capable of analyzing not just deposit rate regulation, but a wide variety of other financial regulations as well.

Finally, it will be argued that the model can confront a wide range of observations on banking behavior. Specifically, the empirical implications of the model can be broken down into two categories. In the first, a stable equilibrium exists for the banking industry. In this case, the model suggests that banks will offer both true demand and time deposits, with penalties for early withdrawal on time deposits. Such arrangements, it is argued, are not readily explained outside of a private information framework. Moreover, they coincide with observed arrangements for unregulated banking systems, such as Canada's, providing some empirical validation for this as a model of deposit interest rate determination.

In the second category are implications of the model suggesting when competition for deposits will lead to problems of "instability." One such implication is that certain types of adverse changes in the probability distribution of withdrawals increase the likelihood that "instability" of the banking system will be observed. We will see below that such an implication accords well with experiences during the bank panics of the second half of the 19th century.

The model presented here is, of course, not the only existing model of bank instability based on private information. In particular, Bhattacharya (1982) and Diamond and Dybvig (1983) provide models which argue that factors related to private information can be destabilizing. Their arguments rest on the nature of bank portfolios, however. In light of the evidence cited above (Rolnick and Weber (1982, 1983), Sprague (1910), Benston (1964)), the implications of these models seem to be at variance with existing evidence regarding the structure of these portfolios. In contrast, the observations discussed above are supportive of the model put forth below. Thus, this seems to be the first model of bank instability based on private information which provides implications which accord well with the experiences of (relatively) unregulated banking systems.

The scheme of the paper is as follows. Section I sets forth a full-information version of the model as a means of introducing the economic setting in a simple way, and of expositing the formal role of certain assumptions. This section also makes clear the economic incentives which lead to the existence of intermediaries. Section II introduces private information into the model, and details the nature of bank competition for deposits in the presence of informational frictions. Section III considers an equilibrium for the banking industry under private information. It is argued that the conven-

tional interpretation of banking system "instability" can be equated with the failure of a Nash equilibrium to exist in this setting. It will be seen that no equilibrium need exist, and that when no equilibrium does exist, the imposition of deposit rate ceilings results in existence of a Nash equilibrium. Thus these ceilings may correct for the "destabilizing" influence of competition for deposits. Finally, it will be demonstrated that regulation is required only if a Pareto optimum is not attainable as a Nash equilibrium. Section IV argues that the model delivers predictions in accordance with historical experience, and with the experiences of modern unregulated banking systems. It also argues that models not based on private information cannot do this. Lastly, it is shown that the model provides a framework for analyzing in a simple way a relatively complex mixture of policy measure. Section VI concludes.

I. The Model with Full Information

A. The Model Under Autarky

We wish to consider the simplest possible economy which permits an illustration of the points of interest. (This is consistent with showing that bank competition for deposits, along with private information, are the only aspects of the model required to generate instability.) To this end, we focus on an economy in which agents (depositors) are of two types, indexed by i = 1, 2. (Heterogeneity of these agents plays no role in section I. Obviously it will be important when private information is introduced below, however.) These agents face essentially similar economic circumstances. In the model's initial time period (t=0) each depositor has one unit of real resources to "store" for future consumption purposes. There are two future time periods (t=1,2). Let C_t denote consumption in period t. Then all agents have identical preferences over nonnegative consumption streams denoted by

$V(C_0, C_1, C_2)$. For simplicity, we assume that these preferences take the very special form $V(C_0, C_1, C_2) = U(C_1 + C_2)$; $U' > 0$, $U'' < 0$.[3/] Thus agents do not consume at $t = 0$ (the planning period), and are otherwise indifferent regarding the timing of consumption. However, we assume that agents of type i face a probability p_i $(p_2 > p_1)$ of being forced to consume at $t = 1$, e.g., with probability p_i an agent of type i "dies" before period 2, in which case $C_2 \equiv 0$.

Since agents do not value period zero consumption, all agents will store their initial endowment for future consumption. The storage technology for this economy, to which all agents have access, is quite simple. A unit stored one period produces $Q_1 \geqslant 1$ units of the good if withdrawn from storage at $t = 1$, and $Q_2 > Q_1$ units if withdrawn at $t = 2$. Hence longer-term "investments" are more productive than shorter-term ones here.

As already noted, agents are indifferent about the dating of consumption. Hence agents who do not face the constraint $C_2 \equiv 0$ will leave their unit in storage until $t = 2$ to realize a higher rate of return. In short, then, for agents of type i:

(1) $C_1 = Q_1$ with probability p_i

        $C_1 = 0$ with probability $1 - p_i$

(2) $C_2 = 0$ with probability p_i

        $C_2 = Q_2$ with probability $1 - p_i$.

Expected utility under such an arrangement for agents of type i is then given by

(3) $p_i U(Q_1) + (1-p_i) U(Q_2)$.

B. <u>Banking without a lender of last resort</u>

Suppose that agents are now allowed to enter freely into the activity of banking, i.e., accepting deposits and making investments on behalf of depositors. Agents who form banks have access to the storage technology just described which, of course, is available to all. It is now necessary, then, to describe the population of potential depositors, bank behavior, and to provide a notion of equilibrium for an economy with banks.

The population of depositors is as described above, with the additional specification that there are equal large numbers of depositors of type i; i = 1, 2. Bank behavior is also simple. Under the assumption of full-information banks may specify state contingent payoff vectors available to each type of depositor, denoted (R_j-P_j,R_j); j = 1, 2, where "states" here correspond to dates of withdrawal. R_j will henceforth denote the gross rate of return for type j agents to a unit stored for two periods, and P_j will denote a penalty paid by type j agents for "early withdrawal," i.e., $R_j - P_j$ is the gross return earned by type j agents for a deposit held one period. In addition, our assumption on bank behavior is that banks simply announce state contingent payoff vectors (R_j-P_j,R_j); j = 1, 2, and then obviously place all deposits obtained in storage. Henceforth the term deposit will generally be used both for the unit placed in storage at the bank, and for the state-contingent payoff vector to which it gives rise. In particular, we will often refer to deposits of type j; j = 1, 2.

Finally, a Nash equilibrium concept is imposed on the game in which banks announce (R_j-P_j,R_j) pairs; j = 1, 2. In particular, an equilibrium is a pair of deposits $(\hat{R}_j-\hat{P}_j,\hat{R}_j)$; j = 1, 2, such that no bank (or new entrant) can increase its profits by announcing an alternate (R_j-P_j,R_j) pair, given the announcements of all other banks. In light of the free entry assumption, of course, bank profits must be zero in equilibrium.

Equilibrium

It is quite simple to see what values $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ constitute a Nash equilibrium here. First, each bank must just break even (in expected terms) on each type of deposit. In light of the fact that the economy is large, banks face no uncertainty. Thus feasibility of the announced values $(\hat{R}_j - \hat{P}_j, \hat{P}_j)$ requires

$$(4) \qquad p_j(R_j - P_j) = Q_1 x_j; \quad j = 1, 2$$

$$(5) \qquad (1-p_j)R_j = Q_2(1-x_j); \quad j = 1, 2,$$

where x_j is the fraction of type j deposits removed from storage at $t = 1$. Eliminating x_j from (4) and (5), we obtain the resource constraint (equivalently, the zero profit condition) for type j deposits:

$$(6) \qquad R_j = \frac{Q_2}{1-p_j} - \left(\frac{Q_2}{Q_1}\right)\left(\frac{p_j}{1-p_j}\right)(R_j - P_j).$$

Given this resource constraint, it is easy to see that $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ must solve

$$(7) \qquad \max_{\{R_j, P_j\}} p_j U(R_j - P_j) + (1-p_j)U(R_j); \quad j = 1, 2,$$

subject to (6). In particular, given any other announced values $(R_j - P_j, R_j)$ which earn nonnegative profits, some bank could announce a preferred payoff vector, attract all type j agents, and increase its profits. Similarly, if all banks announce $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ values given by (7), no bank can announce deposits which depositors will prefer to those they currently hold, and which at least break even. Hence the posited $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ values do, in fact, constitute an equilibrium.

Finally, it will be noted that there are, in fact, both private and social incentives to establish financial intermediaries in this economy. In particular, in the absence of intermediaries agents' consumption streams are given by (1) and (2). These consumption streams are also feasible in the presence of intermediation (i.e., they satisfy (6)), but it is easy to check that they are not chosen. This is, of course, merely a statement of the fact that banks generate opportunities for depositors to share risk in this economy. This view of banks; that they constitute a risk-sharing arrangement for depositors, is a feature of several recent models of banking (e.g., Diamond and Dybvig (1983), King and Haubrich (1983)).

C. Banking with a lender of last resort

Now suppose that the banks just described have access to a lender of last resort, which behaves as follows. For each withdrawal at t = 1, the lender of last resort requires banks to take one unit out of storage. Beyond this, the lender will provide banks with funds at a zero net rate of interest between t = 1 and t = 2. The role of this assumption will be further discussed below, but at this point we may note that our subsequent analysis will give rise to bank instability despite the presence of a lender of last resort.

Given the presence of this new agent, banks now face a simpler resource constraint (zero profit condition). This is that the total amount paid out over the life of the bank cannot exceed the total return to storage. Since a unit must be removed from storage for each withdrawal at t = 1, this constraint is

(8) $\qquad p_j(R_j - P_j) + (1-p_j)R_j = p_jQ_1 + (1-p_j)Q_2; \quad j = 1, 2.$

Now, for the same reason as before, equilibrium values $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ must solve

$$(9) \qquad \max_{\{R_j, P_j\}} \; p_j U(R_j - P_j) + (1 - p_j) U(R_j); \quad j = 1, 2,$$

subject to (8). The first order conditions, which are necessary and sufficient for this maximization, can be manipulated to obtain

$$(10) \qquad \frac{p_j U'(R_j - P_j)}{(1 - p_j) U'(R_j)} = \frac{p_j}{1 - p_j}; \quad j = 1, 2.$$

Thus $U'(\hat{R}_j - \hat{P}_j) = U'(\hat{R}_j)$; $j = 1, 2$, or $\hat{P}_j = 0 \; \forall \; j$. Therefore, in the presence of a lender of last resort, banks provide complete insurance against being forced to withdraw early.

Having described bank behavior in the presence and absence of a lender of the last resort, it remains in this section to describe the role played by this institution. One has already been mentioned: we intend to show that deposit insurance and/or the presence of a lender of the last resort are insufficient to eliminate problems of bank stability under private information with bank competition for deposits. Thus it is necessary to have a lender of last resort. However, the presence of this institution also greatly simplifies the analysis in several respects. We now elaborate on these.

To begin, the resource constraints on deposits of type j are depicted in Figure 1. The heavier line depicts the resource constraint (zero profit condition) for banks without a lender of last resort, while the lighter line is that for a bank with access to the lender described. It is easy to check that the two loci intersect at $R_j - P_j = Q_1$. Since this corresponds to the autarky situation, for all $R_j - P_j > Q_1$ the presence of a lender of the last resort improves matters for all depositors. Also, introducing a lender of the last resort makes the slopes of the zero profit loci equal to

$-p_j(1-p_j)^{-1}$. As noted in (10), this results in complete insurance ($\hat{P}_j=0$) in equilibrium. The slopes of the zero profit loci absent a lender of last resort are $-(Q_2/Q_1)p_j(1-p_j)^{-1}$, so without a lender of last resort complete insurance is not provided. The fact that complete insurance is provided by banks in the presence of a lender of the last resort simplifies matters below. This simplification is also the reason for assuming that the lender of last resort charges no interest. We assume it requires that one unit be withdrawn from storage for each withdrawal largely for realism (i.e., this assumption plays no role in the analysis other than guaranteeing that the two loci depicted in Figure 1 intersect at $R - P = Q_1$).

Finally, the presence of a lender of last resort behaving as posited eliminates the possibility of certain perverse equilibria such as that analyzed by Diamond and Dybvig (1983). In particular, suppose that at time t = 1 all agents conjecture that all other agents are planning to make withdrawals. This situation gives rise to a "bank run" in Diamond-Dybvig (1983). However, in the presence of the lender of last resort, a run cannot occur. To see this notice that agents who find they can consume $C_2 > 0$ (finding this at t = 1) know that for each agent who does not make a withdrawal, a unit remains in storage until t = 2. This returns Q_2 units of the good. Since $\hat{P}_j = 0$; j = 1, 2, $\hat{R}_j < Q_2 \ \forall$ j. Therefore, if depositor claims take precedence over claims held by the lender of last resort, all depositor claims can be honored at t = 2. Hence there is no reason for depositors to be concerned with the withdrawal behavior of other depositors, and runs cannot occur. Then it will also be noted that (a) all claims held by the lender of last resort are always honored, and (b) there is no need for deposit insurance here (or in the analysis that follows). Thus the presence of a lender of last resort does eliminate the possibility of a "run" at t = 1, and does so in a way that retains "budget balance" for the lender of last resort.

II. The Model with Private Information

The economy with private information is identical to that described above, except for the following change. Henceforth each agent's type is private information, so that at t = 0 each agent knows his own probability of withdrawal at t = 1, whereas this is not directly observable to any other agent (or to any bank). However, each agent's portfolio is common knowledge, as are any side deals which an agent might make. Thus different types of depositors are indistinguishable unless they hold different types of deposits. It will be the attempt by banks to attract depositors of different types under private information which will result in "excessive competition for deposits" and in "bank instability" for this economy.

It remains to describe bank behavior given that depositors' types are not directly observable, but that their trades are. As previously, each bank announces a set of deposits which it offers that are described by the pairs (R_j-P_j,R_j); j = 1, 2. As shown in Appendix A, it is not restrictive to assume that each agent holds only a single deposit. In announcing pairs (R_j-P_j,R_j), then, banks must consider the announcements of other banks, and whether or not they wish to induce depositors to self-select. In particular, without loss of generality, a bank may either attempt to induce type 1 and only type 1 agents to hold type 1 deposits, etc., or it may forego the opportunity to price discriminate. In the latter case by convention the bank announces $(R_1-P_1,R_1) = (R_2-P_2,R_2)$.

What is required, then, for a bank to induce self-selection? Clearly agents must be willing to hold the deposits designed for them. This requires that the following self-selection (or incentive compatibility) conditions hold:

(11) $p_1U(R_1-P_1) + (1-p_1)U(R_1) > p_1U(R_2-P_2) + (1-p_1)U(R_2)$

(12) $\qquad p_2 U(R_2-P_2) + (1-p_2)U(R_2) \geqslant p_2 U(R_1-P_1) + (1-p_2)U(R_1).$

If $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$, then (11) and (12) must hold. If $(R_1-P_1,R_1) = (R_2-P_2,R_2)$, then clearly (11) and (12) hold trivially.

III. Equilibrium

A. Equilibrium Conditions

As before, we impose a Nash equilibrium concept on the game played by firms. In addition, following Rothschild and Stiglitz (1976), we impose an additional restriction on banks: each announced deposit type must at least break even individually. This assumption serves to bring the analysis into line with that of Rothschild-Stiglitz (1976) and Wilson (1977), who study similar adverse selection settings, and might be justified by noting that real world banks face significant regulatory constraints on their ability to operate simultaneously in different markets.

Given this assumption and our notion of equilibrium, there are a number of "no-surplus" conditions which must be satisfied by an equilibrium set of announcements. These are easily exposited with reference to Figure 2, which depicts an equilibrium allocation with $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$ (a separating equilibrium). First, if different depositor types are distinguishable, type 2 agents must be offered the maximal (R_2-P_2,R_2) pair for them among the set of such pairs earning nonnegative profits when held by type 2 agents, i.e., (R_2-P_2,R_2) occurs at a tangency of a type 2 indifference curve with the relevant zero profit locus ($\pi_2 = 0$). If any other (R_2-P_2,R_2) pair were offered by all banks (i.e., if there were not such a tangency), then it would be possible for some bank to offer type 2 agents a preferred (R_2-P_2,R_2) pair below the $\pi_2 = 0$ locus, attracting all such agents and earning a profit. Second, if agents are distinguishable then (R_1-P_1,R_1) must be incentive com-

patible, and must earn zero profits. Hence (R_1-P_1,R_1) must lie along the zero profit locus $\pi_1 = 0$, and on or below the type 2 indifference curve through point B. As shown, the value of (R_1-P_1,R_1) given by the intersection of the relevant indifference curve with $\pi_1 = 0$ is preferred by type 1 agents to all other (R_1-P_1,R_1) pairs which are incentive compatible, and which at least break even. Hence if any pair other than this were offered, some bank could offer an incentive compatible (R_1-P_1,R_1) pair which would attract all type 1 agents, and hence earn a profit. Third, if $(R_1-P_1,R_1) = (R_2-P_2,R_2)$, then agents are not distinguishable. In this case banks must announce a common $(R-P,R)$ pair which is maximal for type 1 agents among the set of all such pairs which break even when deposits are held by type 1 and 2 agents in their population proportions. If any other (common) pair were announced by all banks, some bank could offer a preferred pair which attracts all type 1 agents and thus earns a profit.

In addition to these "no-surplus" conditions, equilibrium announcements (R_j-P_j,R_j) must satisfy (11) and (12). It is easily verified that (11) holds with equality in equilibrium only if $(R_1-P_1,R_1) = (R_2-P_2,R_2)$, and it is shown in Appendix B that (12) always holds with equality in equilibrium. Finally, of course, in a Nash equilibrium no firm can have an incentive to alter its announcements given the announcements of other firms, and in light of the free entry assumption, all banks must earn zero profits. It will also be recalled that we have employed the Rothschild-Stiglitz (1976) and Wilson (1977) assumption that each announcement (R_j-P_j,R_j) must at least break even individually. Thus formally

Definition. A Nash equilibrium is a set of nonnegative announced values $(\hat{R}_j-\hat{P}_j,\hat{R}_j)$; $j = 1, 2$, such that

(i) $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$; $j = 1, 2$, satisfy (11) and (12)

(ii)   if $(\hat{R}_1 - \hat{P}_1, \hat{R}_1) \neq (\hat{R}_2 - \hat{P}_2, \hat{R}_2)$, then $(\hat{R}_2 - \hat{P}_2, \hat{R}_2)$ solves

(13) $\max p_2 U(R_2 - P_2) + (1 - p_2) U(R_2)$

subject to

(14) $p_2 Q_1 + (1 - p_2) Q_2 = p_2 (R_2 - P_2) + (1 - p_2) R_2$

(iii)   if $(\hat{R}_1 - \hat{P}_1, \hat{R}_1) \neq (\hat{R}_2 - \hat{P}_2, \hat{R}_2)$, then $(\hat{R}_1 - \hat{P}_1, \hat{R}_1)$ solves (12) and

(15) $p_1 Q_1 + (1 - p_1) Q_2 = p_1 (R_1 - P_1) + (1 - p_1) R_1,$

where the values $(\hat{R}_2 - \hat{P}_2, \hat{R}_2)$ obtained from (13) and (14) are used in (12).

(iv)   if $(\hat{R}_1 - \hat{P}_1, \hat{R}_1) = (\hat{R}_2 - \hat{P}_2, \hat{R}_2)$, then the (common) values $(\hat{R} - \hat{P}, \hat{R})$ solve

(16) $\max p_1 U(R - P) + (1 - p_1) U(R)$

subject to

(17) $(p_1 + p_2) Q_1 + (2 - p_1 - p_2) Q_2 = \sum_{j=1}^{2} p_j (R_j - P_j) + \sum_{j=1}^{2} (1 - p_j) R_j.$

(v)   There is no alternate set of pairs $(R_j^* - P_j^*, R_j^*)$; $j = 1, 2$, such that any depositors will leave their current bank to obtain the state contingent payoff vector $(R_j^* - P_j^*, R_j^*)$; $j = 1, 2$, and such that each pair $(R_j^* - P_j^*, P_j^*)$ earns nonnegative profits given the agents it attracts (entry difference).

(vi) $(\hat{R}_j - \hat{P}_j, \hat{R}_j)$ satisfy the individual rationality conditions

(18) $p_j U(\hat{R}_j - \hat{P}_j) + (1 - p_j) U(\hat{R}_j) \geqslant p_j U(Q_1) + (1 - p_j) U(Q_2)$; $j = 1, 2.$

B. Underline Instability

Our interpretation of bank "instability" in this setting will be an equation of instability with the failure of a Nash equilibrium to exist. The justification for this interpretation is as follows. Obviously, it will generally be possible to find values (R_j-P_j,R_j); $j = 1, 2$, satisfying either (i), (ii), (iii), and (vi); or (i), (iv), and (vi). Thus the failure of an equilibrium to exist will be due to the inability of banks to find vectors (R_j-P_j,R_j) which prevent other banks from bidding away their depositors in a profitable manner, and causing them to fail. In short, when no Nash equilibrium exists this will be because any bank will fail with probability one due to the competition among banks for depositors.[4/] This interpretation seems to coincide with the rationale for the Banking Act (Golembe and Holland (1981)), and we proceed along these lines below.

C. Some Preliminary Results

Having defined an equilibrium, we now proceed by developing a pair of preliminary results. Section III D then considers issues concerning the existence of equilibrium. The preliminary propositions, which will be familiar from Rothschild and Stiglitz (1976) or Wilson (1977), amount to stating that any equilibrium deposit pair must induce self-selection of depositors. The first is

Proposition 1. Define the indifference curve of a type i agent to be the locus of $(R-P,R)$ pairs such that

$$p_i U(R-P) + (1-p_i)U(R) = k$$

(k constant). Then

$$\frac{\partial R}{\partial (R-P)}\bigg|_{dU_2=0} = \frac{-p_2 U'(R-P)}{(1-p_2)U'(R)} < \frac{-p_1 U'(R-P)}{(1-p_1)U'(R)} = \frac{\partial R}{\partial (R-P)}\bigg|_{dU_1=0}.$$

Proof: Obvious.

Proposition 1 states simply that the indifference curves of type 2 agents at any point in $(R-P,R)$ space are steeper than those of type 1 agents through the same point. This proposition permits us to establish

Proposition 2. Any equilibrium has $(\hat{R}_1-\hat{P}_1,\hat{R}_1) \neq (\hat{R}_2-\hat{P}_2,\hat{R}_2)$.

Proof: Suppose not. Then there is a single equilibrium pair $(\hat{R}-\hat{P},\hat{R})$. By condition (v), this pair offers no alternate bank an opportunity to attract some or all of a bank's depositors, and earn a nonnegative profit. In particular, there is no pair of positive values ε and δ such that

$$p_1 U(\hat{R}-\hat{P}-\varepsilon) + (1-p_1)U(\hat{R}+\delta) > p_1 U(\hat{R}-\hat{P}) + (1-p_1)U(\hat{R}),$$

and such that $(\hat{R}-\hat{P}-\varepsilon,\hat{R}+\delta)$ earns positive expected profits. However, select ε and δ such that (at $(\hat{R}-\hat{P},\hat{R})$)

$$\left. \frac{\partial R}{\partial(R-P)} \right|_{dU_1=0} > -\frac{\delta}{\varepsilon} > \left. \frac{\partial R}{\partial(R-P)} \right|_{dU_2=0}.$$

This is always possible by proposition 1. Then any bank offering a deposit $(\hat{R}-\hat{P}-\varepsilon,\hat{R}+\delta)$ attracts only type 1 depositors if ε and δ are selected sufficiently small. Moreover, for sufficiently small values of ε and δ, since only type 1 agents are attracted, $(\hat{R}-\hat{P}-\varepsilon,\hat{R}+\delta)$ earns positive profits. This contradicts the supposition, and establishes the proposition.

Proposition 2 states that any equilibrium has the feature that type 1 and 2 agents are distinguishable by banks. This means that equilibrium values of R_1 and P_1 will be determined by the necessity of inducing self-selection among depositors. With this in mind, we now consider the issue of when an equilibrium exists for this economy.

D.   Existence of Equilibrium

It should come as no surprise that the equilibrium defined above need not exist. Prior to discussing when it will exist, however, it may be useful to recall what nonexistence of an equilibrium means in this context. The nature of our equilibrium concept is such that nonexistence means that no bank can structure its deposits in a way that prevents other banks from attracting away its "best" depositors, and causing it to fail. This notion seems to coincide closely with that advanced by the congressional supporters of the Banking Act, so that when an equilibrium fails to exist, we will have the situation they envisioned.

In order to consider when an equilibrium will exist, it is useful to resort to a diagramatic exposition. Figure 2 depicts a situation in which an equilibrium exists. The interpretation of this figure is as follows. It will be recalled that the locus labeled $\pi_2 = 0$ is the locus of R and R-P values such that

$$p_2 Q_1 + (1-p_2)Q_2 = p_2(R_2-P_2) + (1-p_2)R_2,$$

or the locus along which banks earn zero profits by attracting type 2 depositors. $\pi_1 = 0$ is similarly the locus of $(R-P,R)$ values satisfying

$$p_1 Q_1 + (1-p_1)Q_2 = p_1(R_1-P_1) + (1-p_1)R_1.$$

The intermediate locus indicated by the broken line is the locus of $(R-P,R)$ values satisfying

$$(p_1+p_2)Q_1 + (2-p_1-p_2)Q_2 = (p_1+p_2)(R-P) + (2-p_1-p_2)R,$$

which is the zero profit locus for a bank where both types of agents hold the same deposits. The loci labeled $EU_i = k_i$ are indifference curves for type i agents, and in the Figure points labeled A and B are the equilibrium vectors of returns for type 1 and 2 agents, respectively.

In this figure, the self-selection constraint

$$p_2U(R_2-P_2) + (1-p_2)U(R_2) \geqslant p_2U(R_1-P_1) + (1-p_2)U(R_1)$$

hold with equality, and along with the zero profit condition, determines R_1 and P_1. How does one verify that A and B are in fact equilibrium points? Given that cross-subsidization is ruled out, it is clearly impossible to make type 2 agents better off unless they can mimic type 1 agents. Similarly, it is impossible for type 1 agents to be made better off in a profitable fashion without attracting type 2 agents. (Any point that lies on or below the $\pi_1 = 0$ locus, and on or above the $EU_1 = k_1$ locus, also lies above the $EU_2 = k_2$ locus.) Thus any attempt to attract depositors will involve having a single type of deposit, $(R-P,R)$. However, for this to be profitable, it must lie on or below the broken line. No such point can attract type 1 depositors, though, since the locus $EU_1 = k_1$ lies entirely outside this region. Therefore, there is no profitable single deposit which attracts both types of depositors, and A and B are equilibrium points.

Given this discussion, it is straightforward to indicate when an equilibrium will fail to exist. A situation where there is no equilibrium is depicted in Figure 3. As in Figure 2, points A and B are candidate equilibrium values. However, now consider a bank which offers a single type of deposit to both types of agents. Point C is one such possibility. This point attracts both types of depositors, and earns a nonnegative profit. Thus points A and B cannot be equilibrium points for this economy. Neither can any point such as C. While this has already been established as proposition 2, it is instructive to consider this in terms of the diagram.

With reference to Figure 4, then, consider point C. As shown in the diagram, any candidate equilibrium with $(R_1-P_1,R_1) = (R_2-P_2,R_2)$ must be opti-

mal for type 1 agents among the set of such deposit vectors earning nonnegative profits. Also, by proposition 1, the indifference curve of type 2 agents through point C is more steeply sloped than that of type 1 agents. Therefore, any bank offering a single type of deposit such as point D will attract type 1 agents, will not attract type 2 agents, and therefore will earn positive profits if D is selected sufficiently close to point C. Thus, if banks can offer rates of interest above R_c, point C cannot be an equilibrium. Then, in the economy of Figures 3 and 4, no bank can structure its deposits to prevent competitors attracting away its (best) depositors, and causing it to fail.

The exposition of this point has already suggested how nonexistence can be remedied. However, prior to considering regulatory intervention, we will briefly indicate precisely when an equilibrium will fail to exist.

The argument illustrated by Figures 3 and 4 was as follows. An equilibrium will not exist when there is a single type of deposit that can attract both types of depositors away from any pair of deposits satisfying the zero profit conditions, and the self-selection constraints (11) and (12). In terms of the diagrams, an equilibrium will not exist if the type 1 agent indifference curve through point A intersects the zero profit locus for deposits attracting both types of agents. More formally, define the following functions. $V_2: R^4 \rightarrow R_+^2$ maps the parameters of the economy into values (R_2-P_2, R_2) which are solutions to

$$\max_{\{R_2,P_2\}} p_2 U(R_2-P_2) + (1-p_2)U(R_2)$$

subject to

$$p_2(R_2-P_2) + (1-p_2)R_2 = p_2 Q_1 + (1-p_2)Q_2.$$

V_1: $R^4 \to R_+^2$ maps the same parameters into pairs (R_1-P_1,R_1) solving

$$p_1(R_1-P_1) + (1-p_1)R_1 = p_1Q_1 + (1-p_1)Q_2, \text{ and}$$

$$p_2U(R_1-P_1) + (1-p_2)U(R_1) = p_2U(R_2-P_2) + (1-p_2)U(R_2).$$

V: $R^4 \to R_+^2$ is a similar mapping defining a pair $(R-P,R)$ which solves

$$\max_{\{R,P\}} \; p_1U(R-P) + (1-p_1)U(R)$$

subject to

$$(p_1+p_2)(R-P) + (2-p_1-p_2)R = (p_1+p_2)Q_1 + (2-p_1-p_2)Q_2.$$

Given these definitions, an equilibrium will fail to exist iff

(19) $\quad p_jU[e_1 \cdot V_j(Q_1,Q_2,p_1,p_2)] + (1-p_j)U[e_2 \cdot V_j(Q_1,Q_2,p_1,p_2)] <$

$\quad\quad p_jU[e_1 \cdot V(Q_1,Q_2,p_1,p_2)] + (1-p_j)U[e_2 \cdot V(Q_1,Q_2,p_1,p_2)]; \; j = 1,2,$

where $e_1 = (1,0)$, and $e_2 = (0,1)$.

It will be noted that condition (19) is precisely that an arrangement with $(R_1-P_1,R_1) = (R_2-P_2,R_2)$ Pareto dominates any arrangement with $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$ satisfying the zero profit conditions and the self-selection constraints. But, by proposition 2, no such arrangement can be an equilibrium. Thus, if regulatory intervention permits an equilibrium to exist with $(R_1-P_1,R_1) = (R_2-P_2,R_2)$, there will be some association of this with positive welfare implications relative to interventions which might result in existence of an equilibrium, but which retain $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$. With this in mind, we now turn to a consideration of deposit interest rate regulation.

E. <u>Interest Rate Regulation</u>

The discussion of the previous sections indicated that no bank offering $(R_1-P_1,R_1) = (R_2-P_2,R_2)$ could keep its depositors. Thus, if no bank

offering $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$ can retain its depositors either, no equilibrium exists, and the situation described by the Banking Act supporters prevails. A natural question, then, is why no equilibrium exists under these circumstances? One way to phrase the answer is that whenever a bank offers $(R_1-P_1,R_1) = (R_2-P_2,R_2)$, some competing bank will attract away its profitable depositors by bidding up deposit interest rates. If banks are prevented from bidding up these rates, however, an equilibrium will exist under any circumstances. This is

Proposition 3. Consider an unregulated economy for which no equilibrium exists. An appropriately set interest rate ceiling results in existence of an equilibrium.

An informal "proof" of this proposition may be constructed by reference to Figure 4. Consider in this diagram an interest rate ceiling set at R_c (or more precisely, R_c-1). Given this legal ceiling, ask whether any competing bank can attract the depositors of a bank offering point C? Since any such bank is restricted to offering $(R-P,R)$ pairs with $R \leqslant R_c$, any such pair that attracts type 1 depositors also attracts type 2 depositors.[5] All such pairs also lie above the zero profit locus. Thus, since they attract both types of depositors, they earn negative profits and are not offered. Therefore, in the presence of an appropriate ceiling on deposit interest rates, an equilibrium always exists.

Consider the implications of proposition 3 in light of the arguments made in support of the Banking Act then. Absent deposit interest rate regulation no bank can protect its sources of deposits. Interest rate ceilings, however, prevent "excessive competition," and permit any bank to offer deposits which result in its earning a nonnegative profit. In short, the argument

above replicates that offered by congressional adherents of deposit rate
regulation. Moreover, it indicates that regulation of <u>deposit</u> rates of inter-
est is an appropriate response. In contrast to the views expressed by Benston
(1964), Friedman (1960, 1970), Golembe and Holland (1981), and Tobin (1970),
then, these arguments do have a cogent basis in economic theory.

IV. <u>Empirical Implications of the Model</u>

The model of the previous sections has a number of implications
which can be matched against observations to verify that it has predictive
power as a model of bank behavior. These implications can roughly be divided
into two categories. First, when a stable Nash equilibrium does exist (in the
absence of regulation) the model delivers a number of predictions regarding
the structure of deposit interest rates and withdrawal penalties which will
emerge. In this section we enumerate these, and compare them with observa-
tions on Canadian banking, which is largely free from regulation on the kinds
of deposits which banks can offer. We then argue that these features cannot
be explained (for an unregulated system such as Canada's) by a model in which
elements of private information are absent. As the Canadian experience sup-
ports the model, together these observations suggest that it has some claim to
to be taken seriously as a model of deposit interest rate determination.

Second, the model also delivers some predictions about when problems
with bank instability are more or less likely to be observed. This section
examines one such prediction, and contrasts it with observations from the
banking panic of 1907. This panic is a particularly interesting one, as
monetary policy was unusually accommodative, and as banks in general were in a
particularly strong position prior to the panic. We argue below that the
implications of the model here are consistent with observations from 1907,
whereas other more standard explanations of bank panics are not.

A. Implications for the Structure of Payoffs on Deposits

To begin, recall that in any unregulated equilibrium (which we now assume exists for the purposes of this section), $(R_1-P_1,R_1) \neq (R_2-P_2,R_2)$, and (12) holds with equality. Therefore, (R_1-P_1,R_1) is determined by conditions (i), (ii), and (iii). These conditions, in turn, imply that in equilibrium bank deposits will display the following features:

1) There will be both time and demand deposits. In particular, there will be deposits (demand deposits) where the amount of interest earned is independent of how long a deposit is held in the bank. There will be other deposits (time deposits) where the longer a deposit is held, the more the depositor earns.

2) Demand deposits have no penalties for early withdrawal.

3) Deposits bearing high rates of interest have positive penalties for early withdrawal.

In order to state these results formally, we begin with

Proposition 4. $P_2 = 0$ in an unregulated equilibrium.

Proof: As an equilibrium reveals withdrawal probabilities, (R_2-P_2,R_2) must be optimal for type 2 agents among the set of deposits earning zero profits when held by type 2 agents. Such optimality implies equality of the slope of the zero profit locus and the equilibrium indifference curve for type 2 agents. The indifference curve has slope

$$\frac{-p_2 U'(R_2-P_2)}{(1-p_2)U'(R_2)} \, ,$$

and the zero profit locus has slope $-p_2/(1-p_2)$. Equality implies

$$\frac{-p_2 U'(R_2-P_2)}{(1-p_2)U'(R_2)} = \frac{-p_2}{1-p_2} \, ,$$

or $R_2 - P_2 = R_2$, which establishes the proposition.

Proposition 4 has two implications. The first is that the payoff in early withdrawal states is the same as that in late withdrawal states. This is the distinguishing feature of a demand deposit. The second is that there are no penalties for early withdrawal on demand deposits. Thus, a prohibition of such penalties on demand deposits is not a binding restriction.

Our second result is

Proposition 5. $P_1 > 0$.

Proof: Obvious from Figure 2, along with the fact that (12) must hold with equality in equilibrium.

Together with proposition 4, this result indicates that deposits with low interest rates have no penalty for early withdrawal, while deposits with high interest rates do have such penalties.

Clearly, the presence of demand as well as time deposits accords with actual experience. Similarly, the fact that early withdrawal penalties are charged on certain types of deposits is in accordance with experience. However, in the U.S. many would argue that this is a consequence of regulation. Therefore, in order to examine the model's implications for withdrawal penalties, it is useful to consider the features of deposits offered by Canadian banks, which are basically unregulated in this regard.

In Canada, banks typically use penalties for early withdrawal in order to avoid excessive "mismatching of maturities" in their assets and liabilities. For instance, the Bank of Canada Review (1981) states that[6/]

With the introduction in 1980 of substantially heavier
penalties for early encashment the banks averted a recur-
rence of a similar run-off of longer term deposits.

This indicates the role that penalties for early withdrawal play in matching
various types of depositors with particular accounts.

In addition, these penalties are an important choice variable for
Canadian banks. To see this, it is sufficient to examine how they vary in
response to changing economic circumstances. In mid-1979, average penalties
for early withdrawal in Canada were 0.5% on deposits of one- to two-year
maturity. By mid-1980, the average penalty was 2%, and by mid-1981 was nearly
7%. Clearly, then, unregulated banks view withdrawal penalties as an instru-
ment for matching depositors with deposits, and the penalties charged may be
very substantial. Thus Canadian experience tends to bear out the predictions
of the model.

This is, of course, significant only if these features are difficult
to explain. In fact, they are not readily explained outside of an "adverse
selection" setting, such as the one presented here. In order to see this,
consider the economy of Section I in which depositors' types are public infor-
mation. Suppose that in such a world, $P_1 > 0$. If this were the case, some
banks could offer type 1 agents a deposit paying $(1-p_1)R_1 + p_1(R_1-P_1)$ with
certainty, and earn zero expected profits. Type 1 agents would obtain identi-
cal expected returns on both types of deposits, but would face reduced un-
certainty in the second case. Therefore, such deposits would be preferred (by
risk averse individuals), and presumably deposits with $P_1 > 0$ would be driven
from the market.[7] Thus penalties for early withdrawal are anomalies in the
absence of self-selection constraints. When these constraints are present,
however, penalties for early withdrawal perform the obvious role of deterring
type 2 agents from holding type 1 deposits. In short, it seems that some form

of self-selection problem is a necessary adjunct to any explanation of struc-
tures of deposit rates and withdrawal penalties such as those observed in
Canada.

B. Implications for Bank Stability

The model also delivers predictions regarding circumstances which
are likely to lead to bank instability. In this section we develop one such
implication, and argue that the model confronts observations from the banking
panic of 1907. It is also argued that this panic presents problems for other
theories of bank instability.

The implication we have chosen to develop is the effect on existence
of equilibrium of changes in the probability of early withdrawal, p_1. This
choice is dictated by the events preceding the panic of 1907 (described be-
low). Since it is extremely tedious to demonstrate the general implications
of a change in p_1 for the existence of an equilibrium (even for specific
simple formulations of preferences), we proceed by presenting an illustrative
example. This example serves the purpose of demonstrating that increases in
p_1 can lead to nonexistence of equilibrium (where an equilibrium did exist
initially).

Example 1. Let $U(C) = \ln C$, and let $p_2 = 1/2$, $Q_1 = 1$, and $Q_2 = 2$. Then
(proposition 4) $\hat{R}_2 = p_2 Q_1 + (1-p_2)Q_2 = 1.5$, and $(\hat{R}_1 - \hat{P}_1, \hat{R}_1)$ solves the pair of
equations

(20) $p_1(R_1 - P_1) + (1-p_1)R_1 = p_1 Q_1 + (1-p_1)Q_2$

(21) $p_2 \ln(R_1 - P_1) + (1-p_2)\ln R_1 = (1/2)\ln(R_1 - P_1) + (1/2)\ln R_1 = \ln(1.5)$.

(a) Let $p_1 = 1/4$. Then (20) becomes

$$(1/4)(R_1 - P_1) + (3/4)R_1 = 1.75,$$

and (21) can be rewritten as $R_1(R_1 - P_1) = (1.5)^2 = 2.25$. Solving these equations, we obtain $(\hat{R}_1 - \hat{P}_1, \hat{R}_1) = (1.155, 1.948)$, which generates expected utility for type 1 agents of $p_1 U(1.155) + (1-p_1)U(1.948) = (1/4)\ln(8.538)$.

Now consider the optimal (for type 1 agents) pooling allocation, which solves

$$\max \; (1/4)\ln(R-P) + (3/4)\ln R$$

subject to

$$(p_1 + p_2)Q_1 + (2 - p_1 - p_2)Q_2 = (p_1 + p_2)(R-P) + (2 - p_1 - p_2)R.$$

Using our assumed parameter values, the constraint becomes

$$(3/4)(R-P) + (5/4)R = 3.25.$$

Then the solution has $(\hat{R} - \hat{P}, \hat{R}) = (1.083, 1.950)$, which generates expected utility (for type 1 agents) $p_1 U(1.083) + (1-p_1)U(1.95) = (1/4)\ln(8.030)$. Thus $p_1 U(\hat{R}_1 - \hat{P}_1) + (1-p_1)U(\hat{R}_1) > p_1 U(\hat{R} - \hat{P}) + (1-p_1)U(\hat{R})$, and an equilibrium exists.

(b) Now let $p_1 = .45$. Repeating the steps above we obtain $(\hat{R}_1 - \hat{P}_1, \hat{R}_1) = (1.2574, 1.7894)$ and $(\hat{R} - \hat{P}, \hat{R}) = (1.4447, 1.5976)$. Thus $p_1 U(\hat{R}_1 - \hat{P}_1) + (1-p_1)U(\hat{R}_1) = .4231 < p_1 U(\hat{R} - \hat{P}) + (1-p_1)U(\hat{R}) = .4232$. Hence there exists a pooling allocation which type 1 agents prefer to any feasible, incentive compatible separating allocation. Therefore no equilibrium exists with this larger value of p_1.

Thus, for the example, increases in p_1 of sufficient magnitude lead to instability of the banking system. We now contrast this with the events surrounding the panic of 1907.

The Panic of 1907

The panic of 1907 is a difficult one for most models of bank failure. First, monetary policy before and during the panic was unusually accommodative and expansionary, and there were large injections of bank reserves by the federal government (Sprague (1910), p. 216, 315). Second, banks held historically high levels of reserves immediately before the panic, and loan quality was unusually high (Sprague, p. 216-220). Third, it is clear that the panic is not to be explained by usual devices which make use of some illiquidity of bank portfolios, as the New York banks at the center of the crisis had their reserves reduced by only 10 percent during the panic (Sprague, p. 264, 304), and they increased rather than called in loans (Sprague, p. 300-301). Finally, devices such as that of Diamond-Dybvig (1983) which make use of self-fulfilling expectations of bank runs do not seem to be consistent with observations, as some financial institutions survived runs of as much as two weeks' duration (Sprague, p. 254), and as the extent of bank failures was quite limited (Sprague, p. 306). Hence existing models of bank failures seem inconsistent with the events of 1907.

Using example 1, however, the model developed here can confront these events. The salient change in the banking environment between 1897 and 1907 was the increasing importance of state banks and of trust companies. These institutions held minimal reserves, but kept deposits with larger reserve agents (Sprague, p. 226, 236). This can be considered in the context of the model as an increase in the probability of early withdrawal for type 1 agents.[8] As the model is consistent with the notion that such changes make

bank instability more likely, it seems the model developed here can confront the anomalous events of 1907.

Other Implications

The model also delivers a range of other implications, one of which is of interest at this point. As has just been noted, in 1907 banks in general were in a particularly strong position as regards the value of their assets. Nevertheless, this did not help in averting the panic of 1907. We now show that, in general, increases in the value of bank assets do not lead to enhanced stability of the banking system. In particular, we show that increases in Q_1 can lead to nonexistence of equilibrium (where an equilibrium did exist initially). This is especially interesting, as increases in Q_1 both increase the returns to bank investments in general, and reduce $Q_2 - Q_1$ (which could be interpreted as making these investments more liquid).

Proposition 6. If

(a) $$U'(Q_1) < (\frac{p_1 + p_2}{2p_1})U'(Q_2),$$

then a "small" increase in Q_1 makes existence of an equilibrium "less likely,"

where "less likely" means there are parameter values such that a Nash equilibrium exists, but such that small increases in Q_1 lead to nonexistence. Prior to proving proposition 6, it is worthwhile to discuss the issues involved in the proof. First, increasing Q_1 increases $\hat{R}_2 = p_2 Q_1 + (1-p_2)Q_2$, and hence increases $U(\hat{R}_2)$. Also, such increases relax the zero profit condition facing type 1 agents. Hence $p_1 U(\hat{R}_1 - \hat{P}_1) + (1-p_1)U(\hat{R}_1)$ rises with an increase in Q_1. Similarly, $p_1 U(\hat{R} - \hat{P}) + (1-p_1)U(\hat{R})$ rises (where $(\hat{R} - \hat{P}, \hat{R})$ is the maximal pooling allocation for type 1 agents). If (a) holds, we show that $p_1 U(\hat{R} - \hat{P}) + (1-p_1)U(\hat{R})$ increases by more than does $p_1 U(\hat{R}_1 - \hat{P}_1) + (1-p_1)U(\hat{R}_1)$. Since we

know that existence issues center on how type 1 agents rank $(\hat{R}_1 - \hat{P}_1, \hat{R}_1)$ and $(\hat{R} - \hat{P}, \hat{R})$, all we need show is that there are parameter values such that this ranking is reversed when Q_1 increases. We now turn to this.

Proof of Proposition 6. We know that $\hat{P}_2 = 0$, so that $\hat{R}_2 = p_2 Q_1 + (1-p_2)Q_2$. Therefore

$$\frac{\partial \hat{R}_2}{\partial Q_1} = p_2,$$

and the increase in type 2 utility resulting from a change in Q_1 is given by $U'(\hat{R}_2)p_2$.

Now we also know that $(\hat{R}_1 - \hat{P}_1, \hat{R}_1)$ solves

(22) $\max \ p_1 U(R_1 - P_1) + (1-p_1)U(R_1)$

subject to

(λ) $p_2 U(R_1 - P_1) + (1-p_2)U(R_1) = U(\hat{R}_2)$

(μ) $p_1(R_1 - P_1) + (1-p_1)R_1 = p_1 Q_1 + (1-p_1)Q_2,$

where λ and μ are nonnegative Lagrange multipliers. Let $W(p_1, p_2, Q_1, Q_2)$ denote the maximized value of expected type 1 utility. Then, as is well-known,

(23) $\frac{\partial W}{\partial Q_1} = \lambda U'(\hat{R}_2)p_2 + \mu p_1.$

Now one first order condition for the problem (22) has

(24) $(p_1 - \lambda p_2)U'(\hat{R}_1 - \hat{P}_1) = \mu p_1.$

Using (24) in (23) we have

(25) $\quad \frac{\partial W}{\partial Q_1} = \lambda U'(\hat{R}_2)p_2 + p_1 U'(\hat{R}_1 - \hat{P}_1) - \lambda p_2 U'(\hat{R}_1 - \hat{P}_1) < \lambda U'(\hat{R}_1 - \hat{P}_1)p_2$

$\quad\quad\quad + U'(\hat{R}_1 - \hat{P}_1)[p_1 - \lambda p_2] = p_1 U'(\hat{R}_1 - \hat{P}_1),$

where the inequality follows from the fact that $\hat{R}_1 - \hat{P}_1 < \hat{R}_2$ (figure 2).

Finally, let $\overline{W}(p_1, p_2, Q_1, Q_2) \equiv p_1 U(\hat{R} - \hat{P}) + (1 - p_1)U(\hat{R})$. Clearly, as Q_1 increases $\overline{W}$ will rise by at least as much as if both $\hat{R} - \hat{P}$ and $\hat{R}$ increase by $(1/2)(p_1 + p_2)\Delta Q_1$ (since this change in $(\hat{R} - \hat{P}, \hat{R})$ is feasible). Therefore,

(26) $\quad \frac{\partial \overline{W}}{\partial Q_1} > (1/2)[p_1 U'(\hat{R} - \hat{P}) + (1 - p_1)U'(\hat{R})](p_1 + p_2)$

$\quad\quad\quad > (1/2)[p_1 U'(\hat{R}) + (1 - p_1)U'(\hat{R})](p_1 + p_2) = (1/2)U'(\hat{R})(p_1 + p_2),$

where the second inequality follows from the (easily established) fact that $\hat{R} > \hat{R} - \hat{P}.$

To complete the proof, notice that $Q_2 > \hat{R}$ and $Q_1 < \hat{R}_1 - \hat{P}_1$. Therefore, from (25),

$\quad \frac{\partial W}{\partial Q_1} < p_1 U'(\hat{R}_1 - \hat{P}_1) < p_1 U'(Q_1),$

and from (26),

$\quad \frac{\partial \overline{W}}{\partial Q_1} > \left(\frac{p_1 + p_2}{2}\right)U'(\hat{R}) > \left(\frac{p_1 + p_2}{2}\right)U'(Q_2)$

Then, since from (a) $\left(\frac{p_1 + p_2}{2}\right)U'(Q_2) \geq p_1 U'(Q_1)$, it follows that

$\quad \frac{\partial \overline{W}}{\partial Q_1} > \frac{\partial W}{\partial Q_1}.$

Therefore, if (for instance) $p_1 U(\hat{R}_1 - \hat{P}_1) + (1 - p_1)U(\hat{R}_1) = p_1 U(\hat{R} - \hat{P}) + (1 - p_1)U(\hat{R})$ initially, an increase in Q_1 leads to nonexistence. This establishes the proposition.

Hence changes which both increase the value of bank assets and improve their liquidity need not enhance bank stability. This result also may help to account for the observations surrounding the panic of 1907.

V. Policy Implications

In addition to providing predictions about the nature of an un-regulated banking system which accord with experience, it is also the case that self-selection models provide a rich framework for policy analysis. In order to demonstrate this, we now provide both a positive and a normative analysis of a relatively complex government intervention. In particular, consider any unregulated equilibrium. Then suppose that the government im-plements the following mix of policies

a) $P_2 \geqslant 0$ by regulation,

b)   deposit interest payments (payments on the gross rate of interest) are taxed at rate t; payment of penalties is <u>not</u> subsidized, and

c)   all tax proceeds are returned as a lump sum to agents in amount equal to their tax liability.

While this combination of policies is fairly complex, our model provides quite easily that its effect will be to leave R_2 and P_2 unchanged, and to reduce R_1. It is also easy to demonstrate that it results in a Pareto improvement.

To see the above, consider Figure 5. In this figure, points A and B are pre-intervention equilibrium values, and solid lines are pre-tax indiffer-ence curves. It is straightforward to demonstrate that at point A, the tax scheme imposed results in a steeper indifference curve for type 2 agents. Then the dotted line represents their post-tax indifference curve. Given this indifference curve, the fact that $P_2 \geqslant 0$, and the fact that the self-selection constraint is binding in equilibrium, points A and C are the new equilibrium

payoff vectors. Since C has a lower value of R_1 associated with it than B does, R_1 falls. R_2 and P_2 are clearly unchanged. Finally, as all tax proceeds are returned as a lump sum, the consumption of type 2 agents is unaffected by this intervention. Point C is preferred to point B for the following reason: since the self-selection constraint binds initially, the intersection of the 45° line and the zero profit locus for type 1 agents must be in the interior of the upper contour set defined by $EU_1 = k_1$. Thus, all points along the zero profit locus, above the 45° line, and to the southeast of B, are strictly preferred to B. Thus, type 1 agents are made better off, establishing that the intervention is Pareto improving.

Despite the complicated nature of the intervention, then, its analysis was fairly simple. In short, the self-selection model of Section II provides a straightforward explanation of a wide range of observations, and a tractable format for the analysis of policy. The first feature also lends some credence to the model as providing a rationale for the regulation of deposit interest rates.

VI. Conclusions

Sprague (1910) asserts that the use of deposit interest rate payments to compete for deposits was the cause of the panics of 1857, 1873, and 1884. He also cites contemporary support for this assertion. Similarly, the original rationale for regulation of deposit interest rates in the 1930s was that "excessive competition" for deposits made it difficult for many banks to remain in business. While this argument may not have been quite correctly stated, there is a substantial economic basis for it. In fact, supporters of the Banking Act erred only in that they made their argument overly complex. In particular, they argued that competition for deposits would drive up deposit rates. This, in turn, would cause banks to make "riskier" loans to

cover higher costs. This additional riskiness was viewed as the cause of failures.

As we have demonstrated, the latter part of the argument is super-fluous. Not surprisingly, literature devoted to bank regulation has focused on banks' asset decisions. This literature[9] has found little merit in the notion that bank asset choices are either privately or socially "excessively risky" in the absence of regulation. However, the Banking Act supporters in fact could have made their argument with no reference whatsoever to bank portfolios. Omitting this part of the argument, the Banking Act rationale deserves more serious consideration on the part of economists.

It will be noted that this is true even though the model has been set up in a way which seems relatively favorable to the hypothesis of banking system stability. In particular, the absence of any uncertainty regarding the return on portfolios, the absence of any uncertainty about withdrawal demand (due to the large numbers of agents), and the presence of a "lender of the last resort" all seem conducive to such stability. However, even given these features of the model, competition among banks for depositors is sufficient to generate instability.

In closing, one might question whether some "special" assumptions are responsible for this result. In particular, the assumptions that there are two types of depositors, and that each bank has access to the same invest-ment opportunities might be questioned. In fact, neither assumption is neces-sary to the analysis. An arbitrary number of depositor types can be accom-modated at the expense of considerable additional complexity. The assumption that all banks have access to the same investment opportunities is also in-essential. Banks could have access to alternate investments and our argument would require only a conversion to a discussion of the profitability of banks

at the margin.   In short, then, in economies where depositors vary in their probabilities of early withdrawal in a way which is potentially unknown to banks, the role for deposit rate regulations is quite robust.   Moreover, the idea that the presence of uncertainty and private information about probability distributions over withdrawal dates gives rise to problems of bank stability is not a new one.   In particular, Simons (1936) made such a feature a cornerstone of his proposal for 100 percent reserve requirements.   Thus frictions of this type have been used previously as justifications for bank regulation, and as explanations for observed instability of the banking system.

Appendix A

In this appendix it is demonstrated that it is unrestrictive to view depositors as each holding a single type of deposit. Two assumptions of the model are crucial in the proof: (a) each agent observes all net trades of all other agents, and (b) banks may refuse to trade with any agent. The formal proof proceeds as follows, then. Suppose two types of deposits exists, that type i agents hold fraction θ_i of their resources in type 2 deposits, and that banks are willing to trade with all depositors. Also suppose that all banks call out deposit payoff vectors $(R_j - P_j, R_j)$; $j = 1, 2$. Then agents of type i receive expected utility

$$p_i U[\theta_i(R_2 - P_2) + (1 - \theta_i)(R_1 - P_1)] + (1 - p_i) U[\theta_i R_2 + (1 - \theta_i) R_1],$$

and the zero profit condition is

$$(p_1 \theta_1 + p_2 \theta_2)(R_2 - P_2) + [p_1(1 - \theta_1) + p_2(1 - \theta_2)](R_1 - P_1)$$

$$+ [(1 - p_1)\theta_1 + (1 - p_2)\theta_2]R_2 + [(1 - p_1)(1 - \theta_1)$$

$$+ (1 - p_2)(1 - \theta_2)]R_1 = (p_1 + p_2)Q_1 + (2 - p_1 - p_2)Q_2$$

if $\theta_1 = \theta_2$ (agent types are unobservable), and

$$p_i \theta_i(R_2 - P_2) + p_i(1 - \theta_i)(R_1 - P_1) + (1 - p_i)\theta_i R_2$$

$$+ (1 - p_i)(1 - \theta_i)R_1 = p_i Q_1 + (1 - p_i)Q_2; \ i = 1, 2,$$

if $\theta_1 \neq \theta_2$ (depositor types are distinguishable).

Now define

$$\hat{R}_i = \theta_i R_2 + (1-\theta_i)R_1$$

$$\hat{P}_i = \theta_i P_2 + (1-\theta_i)P_1; \quad i = 1, 2,$$

and suppose each bank calls out deposit payoff vectors $(\hat{R}_i - \hat{P}_i, \hat{R}_i)$; $i = 1, 2$. Clearly a deposit of one unit earning the state contingent payoff vector $(\hat{R}_i - \hat{P}_i, \hat{R}_i)$ delivers the same expected utility as a deposit of θ_i units earning $(R_2 - P_2, R_2)$, and a deposit of $1-\theta_i$ units earning $(R_1 - P_1, R_1)$. Thus if $(R_i - P_i, R_i)$; $i = 1, 2$, along with portfolio choice θ_i; $i = 1, 2$, constitute an equilibrium, this equilibrium can be replicated by having banks announce the constructed payoffs $(\hat{R}_i - \hat{P}_i, \hat{R}_i)$, and having each agent holding only a single deposit. The generalization of this to an arbitrary number of deposit types is obvious.

To see the role played by the two assumptions mentioned above, it is useful to refer to figure 2 and to consider the case where banks offer deposits with the payoffs denoted A and B. Clearly type 1 agents have no incentive to "diversify," i.e., to hold part of their wealth in deposits with the payoff denoted B. However, it is also clear that type 2 agents (since they are indifferent between points A and B) could increase their expected utility by attaining a payoff which is a convex combination of A and B.

Suppose these agents attempted to do so, then. Since A just breaks even when only type 1 agents hold type 1 deposits, the addition of type 2 agents holding part of their resources in the form of type 1 deposits would cause banks offering A to lose money. However, banks offering A can prevent this contingency, since all net trades are observable. In particular, they can refuse to offer type 1 deposits to anyone with a type 2 deposit. Hence type 2 agents cannot attain convex combinations of the points A and B, so that

it is actually not restrictive to assume that they can only hold one type of deposit.

The assumption that all net trades are observable is obviously a strong one. However, it is not readily replaced with any weaker assumption. Rothschild and Stiglitz (1976), Wilson (1977), Spence (1978), and Prescott and Townsend (1984) all make use of this assumption in the same way as we have here. Jaynes (1978) allows for unobservable trades, but exogenously imposes that a certain set of trades are observable and a certain set are not. Thus, in the context of adverse selection settings, assumptions of this form have not been dispensed with.[10]

Appendix B

In this appendix we prove that

$$p_2 U(R_2 - P_2) + (1 - p_2)U(R_2) \geqslant p_2 U(R_1 - P_1) + (1 - p_2)U(R_1)$$

holds with equality in any equilibrium. To see this fact, let us suppose the contrary. Then, since self-selection constraints are nonbinding in equilibrium, the free entry assumption implies that $(R_1 - P_1, R_1)$ solves

$$\max \ p_1 U(R_1 - P_1) + (1 - p_1)U(R_1)$$

subject to

$$p_1 Q_1 + (1 - p_1)Q_2 = p_1(R_1 - P_1) + (1 - p_1)R_1.$$

This maximization problem has associated with it the first order condition

$$\frac{p_1 U'(R_1 - P_1)}{(1 - p_1)U'(R_1)} = \frac{p_1}{1 - p_1} \ ,$$

which implies $P_1 = 0$. This fact, plus the zero profit condition, implies

$$p_1 Q_1 + (1 - p_1)Q_2 = R_1.$$

But from proposition 4, $P_2 = 0$, so the zero profit condition for type 2 depositors implies

$$p_2 Q_1 + (1 - p_2)Q_2 = R_2.$$

Together, these imply $R_1 > R_2$. But then $(R_1 - P_1, R_1) > (R_2 - P_2, R_2)$, contradicting the hypothesis that

$$p_2 U(R_2 - P_2) + (1 - p_2)U(R_2) > p_2 U(R_1 - P_1) + (1 - p_2)U(R_1).$$

This contradiction establishes the desired result.

Footnotes

$\underline{1/}$As stated by Golembe and Holland (1981, p. 65)

>   Interest rate controls came into being because
> the payment of excessive interest on deposits was one
> widely accepted explanation of the banking troubles
> characterizing the 1920s and the crisis and the financial
> panic that followed. Proponents of this explanation
> maintained that unhealthy competition among banks devel-
> oped in many parts of the country as these institutions
> sought to attract funds by bidding up the rate of inter-
> est paid to depositors. To cover the cost of these
> funds, it was argued, the banks in turn had to invest
> their resources on terms which sacrificed asset quality
> for yield.

$\underline{2/}$Bhattacharya (1982) suggests otherwise, based on considerations of moral hazard. However, his paper does not fully specify the environment in which banks operate, so that it is unclear whether this is sufficient to overturn the Kareken-Wallace (1978) result.

$\underline{3/}$Preferences of a similar form have also been employed by Diamond and Dybvig (1983) and King and Haubrich (1983) in models of banking with private information.

$\underline{4/}$It would be easy to allow banks to differ in their investment opportunities. Then failure of an equilibrium to exist would be due to the fact that any bank at the margin would fail with probability one because of competition for deposits. In other words, the extreme notion of instability in the text--that any bank fails with probability one--is not necessary to the analysis, but merely a simplification.

$\underline{5/}$Any such pair lying on or above $EU_1 = k_1$ also lies above $EU_2 = k_2$.

$\underline{6/}$Page 18.

$\underline{7/}$This is, of course, just a restatement of our earlier result that $\hat{P}_j = 0$; $j = 1, 2$, under full information.

- 2 -

$\underline{8/}$The reason this should be regarded as in increase in p_1 rather than p_2 is that Sprague attributes 19th century banking panics to competition among banks which were reserve agents for the deposits of smaller financial institutions. These, of course, included state banks and trust companies. In the model, it is the deposits of type 1 agents which banks find relatively attractive. Hence it seems appropriate to regard smaller financial institutions as "type 1 agents" here.

$\underline{9/}$E.g., Kareken and Wallace (1978), Rolnick and Weber (1982, 1983), and Benston (1964).

$\underline{10/}$Of course in all of the literature cited above firms are engaged in price discrimination. This is also the case for banks here. Hence ability to subdivide the relevant market must be assumed at some level. The assumption in the text is probably no more objectionable than any other that permits price discrimination to take place.

References

Bank of Canada Review, April 1981.

Benston, G., "Interest Payments on Demand Deposits and Bank Investment Behavior," Journal of Political Economy, 1964.

Bhattacharya, S., "Aspects of Monetary and Banking Theory and Moral Hazard," Journal of Finance, 1982.

Bryant, J., and N. Wallace, "Open Market Operations in a Model of Regulated, Insured Intermediaries," Journal of Political Economy, 1980.

Diamond, D., and P. Dybvig, "Bank Runs, Deposit Insurance, and Liquidity," Journal of Political Economy, 1983.

Friedman, M., A Program for Monetary Stability, Fordham Univ. Press, New York, 1960.

_____, "Controls on Interest Rates Paid by Banks," Journal of Money, Credit, and Banking, 1970.

Golembe, C., and D. Holland, Federal Regulation of Banking, Golembe Associates, Washington, D.C., 1981.

Jaynes, G., "Equilibria in Monopolistically Competitive Insurance Markets," Journal of Economic Theory, 1978.

Kareken, J., and N. Wallace, "Deposit Insurance and Bank Regulation: A Partial Equilibrium Exposition," Journal of Business, 1978.
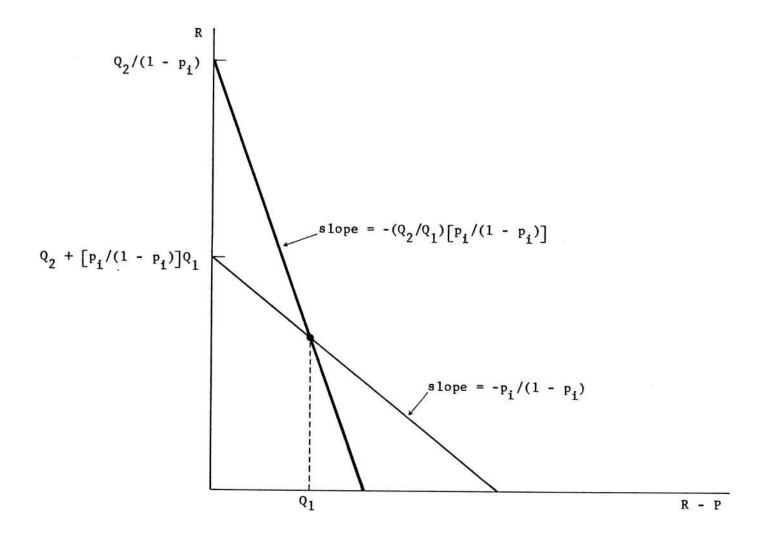
King, R., and J. Haubrich, "Banking and Insurance," unpublished, 1983.

Prescott, E., and R. Townsend, "Pareto Optima and Competitive Equilibria with Adverse Selection and Moral Hazard," Econometrica, 1984.

Rolnick, A., and W. Weber, "The Free Banking Era: Some Evidence on Laissez-Faire Banking," American Economic Review, 1983.
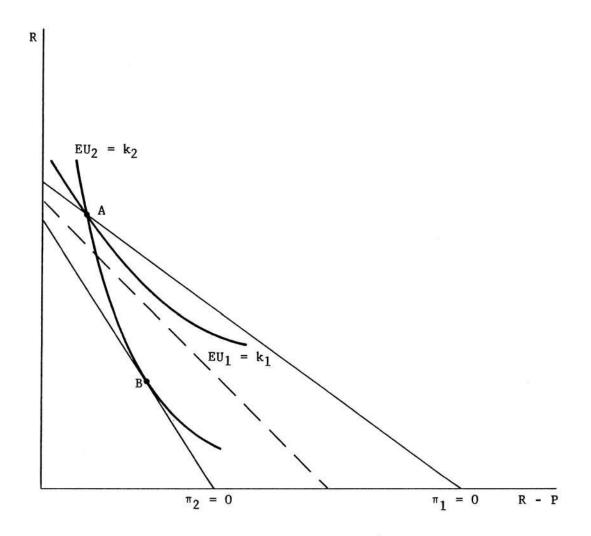
_____, "A Theory of Free Bank Failures: Tests and Implications," unpublished, 1982.

Rothschild, M., and J. Stiglitz, "Equilibrium in Competitive Insurance Markets: the Economics of Incomplete Information," Quarterly Journal of Economics, 1976.

Simons, H., "The Requisites of Free Competition," American Economic Review (Papers and Proceedings), 1936.

Spence, M., "Product Differentiation and Performance in Insurance Markets," Journal of Public Economics, 1978.

Sprague, O. M. W., History of Crises Under the National Banking System, Washington, D.C., Government Printing Office, 1910.

Tobin, J., "Deposit Interest Ceilings as a Monetary Control," Journal of Money, Credit, and Banking, 1970.

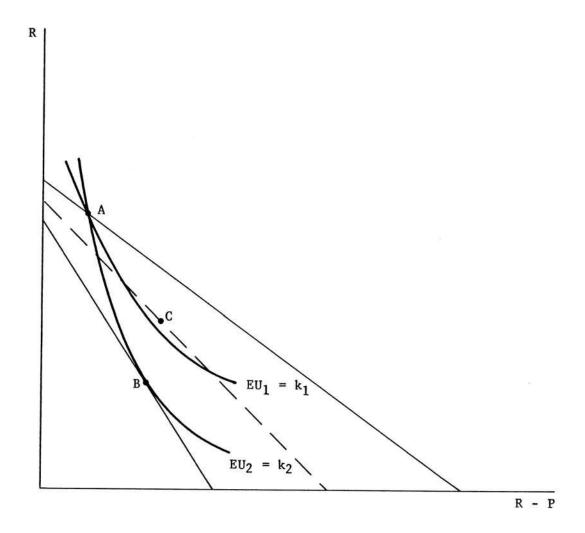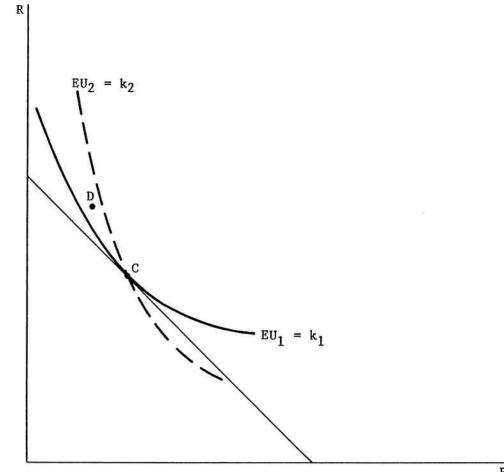Wilson, C., "A Model of Insurance Markets with Incomplete Information," Journal of Economic Theory, 1977.

Figure 1

Figure 2

Figure 3

R

A

C

B

$EU_1 = k_1$

$EU_2 = k_2$

R - P

Figure 4

Figure 5